Final Report

Lower Shoalhaven River Flood Study

59918099

Prepared for
Shoalhaven City Council

09 November 2022

Cardno now Stantec

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Document Information

Prepared for	Shoalhaven City Council
Project Name	Lower Shoalhaven River Flood Study
File Reference	59918099_R005_RevFinal_LShoal_FloodStudy.docx
Job Reference	59918099
Date	09 November 2022
Version Number	Final

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Effective Date 9/11/2022

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Date Approved 9/11/2022

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
Rev A	27/09/2021	Draft for Client Review	Sharni Lemaire	David Whyte
Rev B	12/11/2021	Final Draft	David Whyte	David Whyte
Rev C	25/11/2021	Updated Final Draft	David Whyte	David Whyte
Rev D	10/12/2021	Updated Final Draft	David Whyte	David Whyte
Rev E	24/02/2022	Updated Final Draft	David Whyte	David Whyte
Rev F	27/05/2022	Updated Final Draft	David Whyte/ David Stone	David Stone
Final	09/11/2022	Updated Final Draft	Frank Guo/ Alireza Pouya	Shefali Chakrabarty

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Executive Summary

Background

The floodplain for the Lower Shoalhaven River area was formed by the infilling of an old coastal lagoon and flood behaviour in the area has been extensively modified since European settlement. The southern part of the floodplain is drained by the Crookhaven River, which rises near Nowra, while the northern section is drained by Broughton Creek, which rises upstream of Berry. The present river channel is characterised by a number of flood mitigation works including drainage channels, floodgates, constructed levee embankments and bank stabilisation works.

Two hundred years ago the main entrance and the natural mouth of the river was at Shoalhaven Heads. In approximately 1822 Alexander Berry had a narrow channel excavated between the Shoalhaven River and the Crookhaven River to the west of what is now Comerong Island. This was undertaken to provide a safer access for boats entering the river from the ocean, as there was a dangerous sand bar at Shoalhaven Heads, whilst the Crookhaven River has a deeper, safer, more protected and permanent entrance due to the shelter of the headland. Following the construction of the Berry's Canal the Shoalhaven Heads entrance is now intermittent and is opened by the occurrences of floods and subject to closure by natural onshore oceanic process. The Shoalhaven Heads entrance is artificially opened in accordance with the Shoalhaven River Entrance Management Plan for flood mitigation. Normal flows presently reach the ocean at Crookhaven Heads, via the man-made channel 'Berry's Canal'.

Shoalhaven City Council engaged Cardno to assist with the preparation of the Lower Shoalhaven River Flood Study. The purpose of this Flood Study is to define flood behaviour and flood risk in the Lower Shoalhaven River catchment which will be subsequently used in the Risk Management Study and Plan to identify and recommend appropriate actions to manage flood risks in the Lower Shoalhaven River catchment. This Flood Study report details:

- Data collection and review;
- Community consultation and stakeholder consultation to collect flood information;
- Hydrology model setup;
- Hydraulic model setup;
- Model calibration and validation;
- Design event flood estimation;
- Flood modelling of design events, parameter sensitivity testing and climate change;
- Flood model results and mapping; and
- Flood damages, flood planning and emergency response considerations.

Study Area

The Shoalhaven River has a catchment of approximately 7,250 km^2 and is the sixth largest coastal catchment in NSW. The river rises some 50 kilometres inland of Moruya and follows a generally northerly direction for some 170 kilometres to Tallowa Dam where it is joined by the Kangaroo River from the north. The river then flows east past Nowra for a further 90 kilometres and is joined by Nowra and Browns Creeks, Bomaderry Creek and Broughton Creek in its lower reaches. The Shoalhaven River flows into the Tasman Sea along with the Crookhaven River at Crookhaven Heads and through an intermittently open and closed entrance at Shoalhaven Heads. The Shoalhaven River has a length of around 332 kilometres from its headwaters to the mouth. The Study Area is shown on **Figure 2-1**.

The Shoalhaven River valley can be broadly categorised into the following three regions:

- Upstream of Welcome Reef where the catchment is generally a rolling plateau;
- Between Welcome Reef and Nowra, including Kangaroo Valley, where the catchment consists of steep forested country with the main streams entrenched in deep gorges; and
- Downstream of Nowra, the Lower Shoalhaven River coastal estuary and floodplain which consists of approximately 120 square kilometres of primarily rural land.

The major towns that are located around the Shoalhaven River are Nowra, Bomaderry, Berry, Terara, Greenwell Point, Culburra Beach, Orient Point and Shoalhaven Heads.

History of Flooding

Historical flood records are available since 1860, with the largest floods recorded in 1870, 1873, 1925, 1860, 1978, 1916 and 1891 (in order of magnitude). There is still debate about the exact magnitude of these events. The flood of April 1870 is estimated to have been greater than a 0.5% Annual Exceedance Probability (AEP) event. It inundated the Terara Township by over a metre, and swept away approximately one third of the village. Five lives were lost in rural areas along the Shoalhaven River.

According to some accounts, the earlier 1860 flood was even more devastating and carried away over 50 buildings. Several lives were lost as well as some 79 acres (32 hectares) of land. More recent significant floods occurred in August 1974, June 1975, October 1976 and March 1978. The 1870 flood was 1.2 m higher than the March 1978 event. In the recent past, the Lower Shoalhaven River catchment was flooded in June 2013, August 2015, June 2016 and most recently again in February 2020 and August 2020. Minor flooding also occurred in March 2021 and May 2021.

Data Collection and Review

All available previous flood studies and floodplain risk management study reports and associated models have been reviewed. Available rainfall, water level, ocean tide gauge data and topographic/bathymetric data have been collected along with collection of additional bathymetric and structure surveys to inform the models.

Community consultation was undertaken in the form of a questionnaire to obtain information from the community about historical flood observations and relevant stakeholder agencies have been corresponded with to obtain relevant data and flood information for use in the study.

Model Setup

An XP-RAFTS hydrologic model was established to represent the entire Shoalhaven River and Kangaroo River catchments including the Tallowa Dam and Danjera Dam. A TUFLOW 2-dimensional hydraulic model was setup to represent the waterways within the study area including the Shoalhaven River downstream of Grassy Gully, Crookhaven River, Broughton Creek from Berry along with all the tributaries and all floodplain areas. The model consist of a 15m grid 2D domain and uses ground survey and Aerial Laser Survey data to define the topography/bathymetry of the study area and includes bridges and culverts under roads, flood mitigation drains and floodgates. The model extends to the ocean where suitable entrance conditions and ocean tidal boundaries have been applied.

Model Calibration and Validation

The hydrologic and hydraulic models have been calibrated through the investigation of combinations of model parameters to ensure they provide an accurate representation of the historical flood events. The August 2015 historical flood event was chosen for calibration and June 2013, June 2016 and March 1978 storm events were selected for validation. There are seven water level gauges within the hydraulic model extent available to calibrate parameters to match the stage and flow hydrographs in the Shoalhaven River and tributaries.

For the 2015 calibration event, the overall response of the hydrological model at the seven flow gauges and four instantaneous flow gauges shows a good correlation with gauged data with peak flows slightly lower than gauged at Burrier, which is the main Shoalhaven River inflow to the hydraulic model. Some gauges show a lesser correlation, however, this is explained through the unknowns of the accuracy of rainfall depths and temporal patterns of rainfall throughout the catchment due to its size and limitations of available rainfall to fully describe the rain event. The accuracy of rating curves for developing flows at these gauges is also unknow and has not been reviewed.

The hydraulic model peak water level results are within +/- 100 mm at most water level gauge locations, excluding Gradys Caravan Park where the model is estimating levels approximately 300mm higher than recorded. A good correlation of peak levels is achieved at the surveyed flood marks and levels/depths reported by the community with almost all having a less than +/-100mm difference, excluding some outliers.

Both the hydrological and hydraulic models in combination have been able to adequately represent the August 2015 flood event hydraulic behaviour and the models are considered to be adequately calibrated for use in design flood estimation.

For the June 2013 validation event, the overall hydrologic model flow comparison shows the previously calibrated parameters of the August 2015 calibration event provide a reasonable match with the recorded data. A good correlation is seen at Tallowa Dam, although flows appear to be underestimated at Burrier.

This resulted in hydraulic model peak flood levels lower than recorded. The underestimated levels are also likely explained by the opening at Shoalhaven Heads being modelled as larger than what occurred in this event leading to lower levels in the estuary.

For the June 2016 validation event, the calibrated hydrologic model parameters produced modelled peak flows that were significantly higher than that recorded for this event. A higher continuing loss needed to be applied throughout the catchments upstream of Tallowa Dam. Despite applying these much higher loss rates, the overall peak flows at each gauge are still higher than recorded. Within the hydraulic model the higher inflows are also represented in the flood levels, with all gauges' peak levels higher than recorded.

Validation against the March 1978 event was undertaken in the hydrology model only to demonstrate that an appropriate match to flows at Grassy Gully could be achieved for a larger flow event. The results showed that with the previously calibrated parameters of the August 2015 Calibration Event, a reasonable match with the recorded data is achieved for the March 1978 event. However, continuing losses needed to be reduced to achieve the observed peak flows.

Design Floods

The hydrologic modelling of the Shoalhaven River catchment for determining design flood event flows has been undertaken using the calibrated XP-RAFTS hydrologic model in accordance with the current industry standard Australian Rainfall and Runoff 2019 (ARR2019) Guidelines. The ARR2019 Guidelines includes updated Intensity-Frequency-Duration (IFD) data, areal reduction factors (ARFs), storm loss parameters, pre-burst rainfall and has introduced ensemble modelling methods to account for the variability in rainfall temporal patterns. Data specific to the catchment has been obtained from the ARR Data Hub and Bureau of Meteorology (BoM).

The data was input to the hydrologic model to simulate a range of design events and durations to define flow inputs to the hydraulic model. The design events modelled for the Flood Study include the:

- 20% AEP event
- 10% AEP event;
- 5% AEP event;
- 2% AEP event;
- 1% AEP event;
- 0.2% AEP event; and,
- Probable Maximum Flood (PMF).

For this study the Probable Maximum Flood event is estimated using the Probable Maximum Precipitation (PMP) and rainfall and flows have been derived for both the Generalised Short Duration Method (GSDM) for shorter storm durations relevant to the tributaries and the Generalised Southeast Australia Method (GSAM) for longer duration storms relevant to the mainstream Shoalhaven River and floodplains.

A Flood Frequency Analysis (FFA) was undertaken to determine the design event expected flows at Grassy Gully II gauge (215216) which is the main inflow to study area hydraulic model.

The ARR2019 design flow estimates calculated by the hydrology model (XP-RAFTS/StormInjector) compare well with the FFA expected flows across the range of events up to the 1% AEP.

The flows derived from the XP-RAFTS model are used as inflow locations in the TUFLOW hydraulic model and suitable ocean boundary conditions for each design event were established in accordance with DPE guidelines.

Flood Behaviour

Flooding within the Lower Shoalhaven floodplain can result from any or all of the following:

- Flow from the Shoalhaven River catchment;
- Backwater flooding from the floodplain (e.g. Worrigee Swamp) which initially occurs as a result of local runoff but in larger events is augmented by flow over the river bank elsewhere;
- Overbank flooding from Broughton Creek;
- Contributing flows from Nowra/Browns Creek, Bomaderry Creek and Crookhaven River:
- Local flooding at the Bomaderry, Terara, Shoalhaven Heads, Greenwell Point, Culburra and Orient Point townships; and
- Ocean storm surge and or waves penetrating through the two entrances (Shoalhaven Heads and Crookhaven Heads).

Flooding within the Lower Shoalhaven River area begins with small tributaries and overland flow filling both the Broughton Creek floodplain and the Crookhaven Creek swamp areas. As the flows increase in events up to the 1% AEP, the Shoalhaven River rises and a backwater from the Crookhaven River is seen to start filling back up into the Pyree, Brundee and Numbaa areas before the Terara levees are overtopped and then flows break out of the Shoalhaven River and flow across the Crookhaven Creek/Crookhaven River floodplain towards Crookhaven Heads. The Broughton Creek floodplain outlet is constrained by the topography/bathymetry of the Broughton Creek channel outlet to Shoalhaven River, with higher ground along the banks of Broughton Creek and the Shoalhaven River, and is further constrained by the Shoalhaven River levels preventing flow from discharging from the floodplain. As levels rise sufficiently, spilling begins to occur from the Shoalhaven River to Broughton Creek north of Pig Island.

In the PMF, the same behaviour is observed and with increased flows, the breakout of the Shoalhaven River channel is more pronounced with deeper depths and with more spilling from the Shoalhaven River into the Broughton Creek floodplain.

While the system is tidal for a large extent upstream past Gradys Caravan Park, riverine flood flows are dominant in determining water levels during floods within the Shoalhaven River upstream of Nowra, with entrance conditions, ocean conditions and sea level rise impacting areas up to approximately Pig Island. The Broughton Creek floodplain is relatively uninfluenced by ocean conditions, and is mainly controlled by the constrained outlet to the Shoalhaven River.

Summary of Results

For more frequent events up to the 20% AEP, flooding is largely contained within the channel banks of the Shoalhaven River and tributaries, including Bomaderry Creek. Flooding in these frequent events largely affects the following areas:

- Broughton Creek floodplain (with depths of 1.5m or more) including Jaspers Brush, Bolong, Back Forest Far Meadow and Berry. Bolong Road is affected at the lower end of Broughton Creek;
- Upper Bomaderry Creek and the lower reach of Bomaderry Creek near Shoalhaven River, affecting Bolong Road;
- Swamp area to the east of Nowra between Marriott Park and Millbank Road (with depths generally up to 1.5m), including urban areas around Haigh Avenue and Morton Parade;
- Generally shallow depths (0.5 - 1m) in the swamp area in the north of Brundee;
- Numbaa and Pyree areas including tributaries of Berry's Canal and the Lower Crookhaven River (including Ryans Creek, Macdonald and Salt Pan Creeks) which affect Comerong Island Road and Greenwell Point Road;
- Generally shallow depths (0.5 - 1m) around the Worrigee, Brundee Swamp and Saltwater Swamp areas;
- Low-lying foreshore areas around Shoalhaven Heads (Hay Ave and Jerry Bailey Rd), Coolangatta (affecting Bolong Road), Comerong Island and Culburra Beach; and
- Tributary flows affect properties in Berry, Bomaderry, East Nowra and South Nowra.

For the 10% AEP, flood results show similar affected areas but with greater flood depths and increased flood extents. Properties in low-lying foreshore areas become more flood affected particularly around Culburra Beach, Shoalhaven Heads and Greenwell Point. Protection is afforded to Terara from the Terara levees up to approximately the 10% AEP event, however, overtopping is observed south of Pig Island. Flooding to the west of Millbank Road increases as the swamp areas begin to fill with greater depths. Greenwell Point will begin to become isolated with depths on Greenwell Point Road becoming unsafe for vehicles.

For events larger than the 5% AEP event:

- Flooding is widespread throughout the Shoalhaven and Crookhaven River floodplain with depths becoming greater, commonly exceeding 2m with the various tributaries becoming interconnected to a combined floodplain;
- Depths within the Broughton Creek floodplain are greater than 3m over large areas. The Broughton Creek floodplain becomes connected to the Shoalhaven River;
- Terara Levees are overtopped south of Pig Island;
- More properties around the foreshore areas become inundated including:
  - Shoalhaven Heads - Jerry Bailey Road and Shoalhaven Heads Road.
  - Greenwell Point – widespread flooding of low-lying streets including Adelaide St, Comarong St, West St, South St, Hasler Rd, Keith Ave, Leonore Ave, Fraser Ave, Greens Rd, Bailey Ave, Crookhaven Drive.
  - Orient Point – Orama Crescent.
  - Culburra Beach – Orient Point Rd, Addison Rd, Whistler St and Brighton Parade with sections of Prince Edward Ave becoming submerged.

The 2% AEP event has similar flood extents to the 5% AEP with greater flood depths with some newly flooded areas around East Nowra and near Moorhouse Park/Scenic Drive to the west of Nowra Bridge.

The 1% AEP again has greater depths and extents, particularly around the lower Crookhaven and Greenwell Point and Culburra Beach.

In the 0.2% AEP event, almost the entire floodplain now has depths exceeding 3m. Greenwell Point and Culburra Beach becoming significantly affected along with East Nowra and Terara.

The PMF affects large areas of the Broughton Creek, Lower Shoalhaven and Crookhaven River floodplain as well as the tributaries and overland flow areas. Depths are greater with the backwater affecting parts of Nowra, Bomaderry and Berry as well as more severe flooding of the foreshore areas in the lower reaches.

Compared to the previous 1990 Shoalhaven River Flood Study, it is noted that water levels are typically lower than the previous flood study results. It is observed that:

- Water levels are 300mm to 500mm lower at Nowra Bridge than the 1990 flood study for the 20% AEP and 5% AEP events;
- Water levels are generally significantly lower by 900mm than the previous flood study at Nowra Bridge in the 1% AEP, due to the lower flows calculated in the current study; and
- The PMF event yields water levels that are very close (50mm lower than) the previous Lower Shoalhaven River Flood Study (Public Works, 1990) Extreme event at Nowra Bridge.

It is also noted that different methodologies are used in these two studies, i.e. different hydrology, up-to-date data, modelling software and methods, and different tailwater boundary and entrance conditions.

However, comparison of the levels of each AEP event with the estimated AEP of historical events shows that the current study correlates well with observed data, generally within 100mm of the expected flood level for the equivalent return period.

Sea Level Rise

Projected Sea Level Rise predominantly affects the lower reaches of the system towards the entrances, the low-lying areas around the foreshore (Shoalhaven Heads, Comerong Island, Greenwell Point, Orient Point and Culburra Beach) and within the Crookhaven River floodplain areas. The following statements are made for each sea level rise scenario:

- The SCC projected 2050 sea level rise of +0.23m results in typically less than 150mm of water level increase and no impacts upstream of the Broughton Creek confluence;

- The SCC projected 2100 sea level rise of +0.36m results in typically less than 200mm of water level increase and no impacts upstream of the Broughton Creek confluence; and
- The NSW 2100 sea level rise of +0.90m results in typically less than 550mm of water level increase locally near the entrances and within the Crookhaven River decreasing moving upstream into the swamp areas to the west. Minor increases of up to 50mm are observed in the Broughton Creek floodplain while in the Shoalhaven River, no impacts are observed upstream of Terara.

Climate Change

The study also assessed the potential impacts of both Climate Change induced rainfall increases and sea level rise using current recommended ARR2019 values based on global climate modelling. Increased rainfall due to climate change has the biggest impact in the Shoalhaven River upstream of Nowra Bridge due to the increased flows and the incised valley. The increased flow dominates changes in expected flood levels to approximately Terara, with sea level rise having impacts in the Shoalhaven River downstream of Terara and in the Crookhaven River/Crookhaven Creek floodplain. Only minor increases in flood level are observed in the Broughton Creek floodplain.

For the 1% AEP, with rainfall increases of 16.3% due to Climate Change, associated increased flows may result in increases in flood levels in the Shoalhaven River upstream of Nowra by up to almost 1.4m at Grassy Gully and 1.1m at Gradys Caravan Park reducing to 200mm at Nowra Bridge. Increases in the lower floodplain areas are generally less than 150mm for all scenarios up to 7.6% rainfall increase with increases typically 150 – 250 mm for the 16.3% (2090 RCP 8.5) rainfall increase.

In combination with Sea Level Rise a further increase in water levels may be expected around low-lying foreshore areas and up to 400mm total water level increases near the Shoalhaven and Crookhaven River entrances.

Conclusion

The results of this Flood Study show that both the hydrological and hydraulic models have been successfully calibrated; with a combined calibration/validation to four historical events. Design flood estimates have been validated against a Flood Frequency Analysis of observed annual peak flood levels and flows to provide confidence in the design flow estimates. The models are considered to provide a good representation of flood behaviour in the catchment and can be used with confidence in assessing design flood behaviour.

The study uses the current industry standard methods and guidelines in flood estimation using Australian Rainfall and Runoff 2019 and a series of DPE floodplain management guidelines to define flood behaviour in the Lower Shoalhaven River area for a range of representative design flood events.

The design event flood estimates were validated to a Flood Frequency Analysis of observed annual peak flood levels. As part of this analysis, the Grassy Gully II gauge (215216) level-flow relationship (rating curve) was reviewed and updated using the hydraulic model to inform the extrapolation to higher flows beyond the gauging data. The modelling approach, model setup, parameters, FFA, calibration and design flow estimates have been peer reviewed by an independent consultant on behalf of Council.

The 1% AEP design flood levels in the current Flood Study are lower than those derived from the previous 1990 flood study modelling that Council has adopted. This is due to the design flow estimates being lower using updated data and methods along with differences in model setup and more up-to-date survey and catchment conditions.

The models have been run for the 50%, 20%, 10%, 5%, 2%, 1%, 0.2% AEP storms and Probable Maximum Flood (PMF) event for the existing, Projected 2050 and Projected 2100 scenarios and flood levels, depths and velocities mapped. Provisional hazard, hazard, hydraulic categories and combined hazard and hydraulic categories have also been mapped.

Assessment of the impacts of rainfall increases and sea level rise due to climate change was undertaken along with assessment of tidal inundation and sensitivity to various model parameters.

The report also provides guidance on the adoption of Flood Planning Levels and Emergency Response parameters for use in planning and by the NSW SES.

The study will be used by Council and various stakeholders to inform flood planning and emergency management in the Study Area. The outputs of the Flood Study will provide information on current and future flood risk which is important for increasing community awareness and for building resilience.

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Tables

Figures

Abbreviations

AEP	Annual Exceedance Probability
ALS	Aerial Laser Survey
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR87	Australian Rainfall and Runoff 1987 edition
ARR2019	Australian Rainfall and Runoff 2019 edition
BoM	Bureau of Meteorology
DCP	Development Control Plan
DPE	Department of Planning and Environment
FDM	Floodplain Development Manual
FFA	Flood Frequency Analysis
FPL	Flood Planning Level
FRMC	Floodplain Risk Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
ha	Hectare
IFD	Intensity Frequency Duration
km	Kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	Metre
m^2	Square metre
m^3	Cubic metre
m^3/s	Cubic metres per second (flow)
mAHD	Metres to Australian Height Datum
mm	Millimetre
m/s	Metres per second (velocity)
NSW	New South Wales
OEH (now DPE)	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service
SCC	Shoalhaven City Council

Glossary

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to have a 1% AEP flood immunity while other roads may be designed to be overtopped in the 20 year ARI or 5% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.

Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.

Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Overland Flow	The flow of water over the ground surface either along formal flowpaths such as roads and formed channels, or informal flowpaths along topographic low points and through properties and open space areas. The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Terminology in this Glossary have been derived or adapted from the NSW Government Floodplain Development Manual, 2005, where available.

1 Introduction

Shoalhaven City Council (Council) engaged Cardno to assist with the preparation of the Lower Shoalhaven River Flood Study. The purpose of this Flood Study is to define flood behaviour and flood risk in the Lower Shoalhaven River catchment which will subsequently be used in the Floodplain Risk Management Study and Plan to identify and recommend appropriate actions to manage flood risks. This Flood Study report details:

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> Flood damages, flood planning and emergency response considerations.

1.1 Study Context

The Floodplain Management process progresses through 6 stages in an iterative process:

> Stage 1 - Formation of a Floodplain Management Committee;
> Stage 2 - Data Collection;
> Stage 3 - Flood Study;
> Stage 4 - Floodplain Risk Management Study (FRMS);
> Stage 5 - Floodplain Risk Management Plan (FRMP); and
> Stage 6 - Implementation of the Floodplain Risk Management Plan.

This project covers Stages 2 to 5 of the Floodplain Management process. This Flood Study report addresses Stage 2 and Stage 3 of the Floodplain Management process.

1.2 Objectives

The objectives of Flood Study are to:

> Collate and review available flood information for the catchment;
> Develop updated hydrologic and hydraulic models using recent information and software, calibrated and validated to historical events;
> Derive design flood event flows, water levels and other hydraulic parameters through hydraulic modelling;
> Define and document flood risk in the catchment including mapping; and
> Determine impacts of flooding on the community, flood planning levels, flood damages and emergency response considerations.

The completed Flood Study will form the basis of the FRMS&P, which will include identification and analysis of flood risk and the floodplain risk management options assessment.

2 Study Area

2.1 Overview

The floodplain for the Lower Shoalhaven River area was formed by the infilling of an old coastal lagoon and flood behaviour in the area has been extensively modified since European settlement. The southern part of the floodplain is drained by the Crookhaven River, which rises near Nowra, while the northern section is drained by Broughton Creek, which rises upstream of Berry. The present river channel is characterised by a number of flood mitigation works including drainage channels, floodgates, constructed levee embankments and bank stabilisation works.

Two hundred years ago the main entrance and the natural mouth of the river was at Shoalhaven Heads. In approximately 1822 Alexander Berry had a narrow channel excavated between the Shoalhaven River and the Crookhaven River to the west of what is now Comerong Island. This was undertaken to provide a safer access for boats entering the river from the ocean, as there was a dangerous sand bar at Shoalhaven Heads, whilst the Crookhaven River has a deeper, safer, more protected and permanent entrance due to the shelter of the headland. Following the construction of the Berry's Canal the Shoalhaven Heads entrance is now intermittent and is opened by the occurrences of floods and subject to closure by natural onshore oceanic process. The Shoalhaven Heads entrance is artificially opened in accordance with the Shoalhaven River Entrance Management Plan for flood mitigation. Normal flows presently reach the ocean at Crookhaven Heads, via the man-made channel 'Berry's Canal'.

2.2 Catchment Description

The Shoalhaven River has a catchment of approximately 7,250 km^2 and is the sixth largest coastal catchment in NSW. The river rises some 50 kilometres inland of Moruya and follows a generally northerly direction for some 170 kilometres to Tallowa Dam where it is joined by the Kangaroo River from the north. The river then flows east past Nowra to the ocean and is joined by the Ettrema/Yalwal Creeks catchment downstream of Tallowa Dam and Nowra and Browns Creeks, Bomaderry Creek and Broughton Creek in its lower reaches. The Shoalhaven River flows into the Tasman Sea along with the Crookhaven River at Crookhaven Heads and through an intermittently open and closed entrance at Shoalhaven Heads. The Shoalhaven River has a length of around 383 kilometres from its headwaters to the mouth. The Study Area is shown on **Figure 2-1**.

The Shoalhaven River valley can be broadly categorised into the following three regions:

> Upstream of Welcome Reef where the catchment is generally a rolling plateau;

> Between Welcome Reef and Nowra, including Kangaroo Valley, where the catchment consists of steep forested country with the main streams entrenched in deep gorges; and

> Downstream of Nowra, the Lower Shoalhaven River coastal estuary and floodplain which consists of approximately 120 square kilometres of primarily rural land.

The major towns that are located around the Shoalhaven River are Nowra, Bomaderry, Berry, Terara, Greenwell Point, Culburra Beach, Orient Point and Shoalhaven Heads. The 2016 census indicated that the population of these significant urban areas was 51,661 people.

2.3 Description of Flood Behaviour

Flooding within the Lower Shoalhaven floodplain can result from any or all of the following:

> Flow from the Shoalhaven River catchment;

> Backwater flooding from the floodplain (e.g. Worrigee Swamp) which initially occurs as a result of local runoff but in larger events is augmented by flow over the river bank elsewhere;

> Overbank flooding from Broughton Creek;

> Contributing flows from Nowra/Browns Creek, Bomaderry Creek and Crookhaven River:

> Local flooding at the Bomaderry, Terara, Shoalhaven Heads, Greenwell Point, Culburra and Orient Point townships; and

> Ocean storm surge and or waves penetrating through the two entrances (Shoalhaven Heads and Crookhaven Heads).

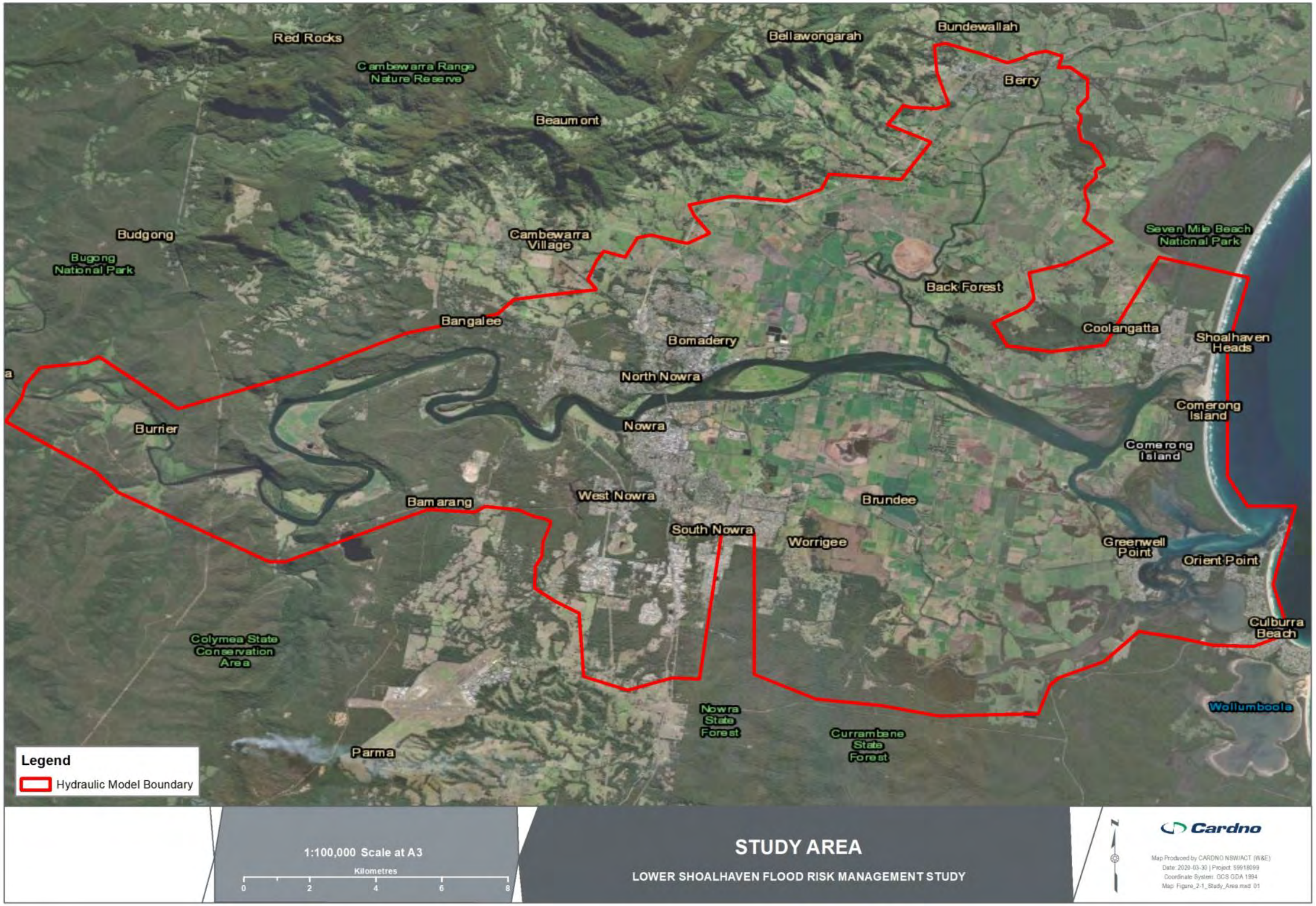

Figure 2-1 Lower Shoalhaven River Study Area

3 Review of Available Data

3.1 Previous Reports and Studies

A number of previous studies have been conducted within and around the study area. These studies have been reviewed as part of this study and relevant information incorporated.

Previous studies are summarised in **Table 3-1**.

Table 3-1 Summary of Previous Studies and Report

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Shoalhaven River Entrance Management (Public Works Department (PWD) NSW, 1984)	This study included an assessment of entrance morphology, accretion levels and breakout dynamics. The outcome of the report developed a range of entrance management options. This document has since been superseded.	This study assists with the understanding of the entrance conditions at Shoalhaven Heads.
Shoalhaven River Entrance Study (Water Research Laboratory, 1986)	This study included an assessment of entrance morphology, accretion levels and breakout dynamics. The outcome of the report came up with entrance management options. This document is superseded.	This study assists with the understanding of the entrance conditions at Shoalhaven Heads.
Lower Shoalhaven River Flood Study (Public Works Department (PWD) NSW, 1990)	The Flood Study for the region was undertaken in 1990 using a WBNM hydrological model, and a CELLS hydraulic model. The models were calibrated to yearly historical floods from 1974 – 1979 and the 1988 flood event. Results were provided for downstream conditions at Shoalhaven Heads for the 5%, 2%, 1% AEP and PMF events. Various design levels were determined depending on whether the heads were open or closed. The report states that the hydrologic model was calibrated with an initial loss of 30 mm but continuing loss varied for each historical event ranging from 1.5mm/hr to 2.5mm/hr. The study adopted an initial loss of 30 mm and continuing loss of 2 mm/hr for design storm events.	This Flood Study establishes a hydraulic model for the Lower Shoalhaven River which is further refined in the 2008 Flood Risk Management Study. Losses adopted in this study can be used in validating the current study.
Shoalhaven River Revised Design Flood Properties – Burrier to Nowra (Department of Land and Water Conservation, 1995)	This assessment was an extension of the Lower Shoalhaven River Flood Study (1990) and defined peak flood levels for the 2%, 1% AEP and PMF events for the River between Burrier and Nowra. Hydrological modelling was undertaken using WBNM with hydraulic modelling undertaken in MIKE-11. Peak flood levels were recorded for major flood events in 1974, 1975 and 1978 and were used to calibrate the MIKE-11 model. This study was an extension to the 1990 Flood Study and provides peak flood levels at the confluence of Nowra Creek and Shoalhaven River which assists in setting downstream tailwater conditions.	The applied model variables will assist in the validation of the current study.

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Riverview Road Area Nowra Floodplain Management Study and Plan (Webb, McKeown & Associates Pty Ltd, now WMAwater, 2002)	The primary objectives of the Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development. Examples of mitigation measures proposed include: > Flood mitigation dams; > Catchment treatment; > River improvement works; > Shoalhaven Heads entrance works; > Levees; > Flood proofing; and > Flood Evacuation planning, upgrades to Council's Flood Policy on Further Residential Development.	This study reviews all feasible flood mitigation options within the Riverview Road area. It identifies the existing problem, the preferred options, their benefits, drawbacks and recommendations to Council. This study provides information on feasible flood mitigation options in the Lower Shoalhaven River catchment.
Terara Village Floodplain Management Study and Plan (WMAwater, 2002)	The primary objectives of the Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development. Examples of mitigation measures proposed include: > Flood mitigation dams; > Catchment treatment; > River improvement works; > Shoalhaven head entrance works; > Levees; > Flood proofing; and > Flood Evacuation planning, upgrades to Council's Flood Policy on Further Residential Development.	This study reviews all feasible flood mitigation options within the Terara Village. It identifies existing problem, the preferred options, their benefits, drawbacks and recommendation to Council. This study provides information on feasible flood mitigation options in the Lower Shoalhaven River catchment.
Terara Levee – Final Design Report (SKM, now Jacobs, 2005)	The Terara Levee Final Design Report forms the basis of the Levee design and brings together the findings and recommendations of previous studies, including the proposed bank and levee works divided into two sections. This final design process ensured that the final levee design met the requirements for flood protection and geotechnical stability as well as minimising impacts on the environment. The objective of the design process was to design a levee and bank protection for the: > 5% AEP event flood level plus 300 mm freeboard from Bryant Street to Nobblers Lane; > 5% AEP event flood level plus 100 mm freeboard for L.R McCulloch and Lot 3 N.D & J Wooley Properties; and > 6.66 % AEP (15 year ARI) event flood level plus zero freeboard west of Lot 3 N.D & J Wooley Properties.	This report helps to define the Terara levee levels in the 2D hydraulic model of this study.

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Lower Shoalhaven River Floodplain Risk Management Study (WMAwater, 2008)	The study built on the initial 1990 study, further investigating key flooding issues and possible solutions. The model incorporated the scenario of Shoalhaven Heads closed but scouring out as the flood progressed. Key issues identified included blockage at Shoalhaven Heads, evacuation access, urban development and expansion. An economic analysis was undertaken which estimated Average Annual Damage at $1.8m with 734 properties affected in the 1% AEP event. A variety of management measures were discussed including flood modifications (basins, levees), property modifications (house raising, voluntary purchase) and response modifications (evacuation planning). Property and emergency response initiatives were considered to be more applicable.	This study provides information on feasible flood mitigation options in the Lower Shoalhaven River catchment. These options will be re-visited to review their feasibility for application to the current study.
Lower Shoalhaven River Floodplain Risk Management Plan (WMAwater, 2008)	The plan outlines the preferred mitigation options, their benefits and how Council may implement these mitigation options. Examples of the mitigation measures proposed include: > Development a post-flood evaluation and review program to further refine models; > Implementation of stormwater management plan for local drainage flooding issues; > Finalise and implement Council's Shoalhaven River Entrance Management Plan for Flood Mitigation (EMPFM); and > Update flood polices such as FPL's property set-backs and improve resident flood awareness.	This plan presents the preferred flood mitigation options within the Lower Shoalhaven River catchment, their benefits and how Council may implement these programs. This information will be used to inform the identification of mitigation options.
Caravan Parks Flood Safety Study (Bewsher Consulting, 2008)	The study was undertaken to: > Assess the flood risk of, and prepare emergency plans for, 30 caravan parks in the Shoalhaven LGA; and > Prepare a revised flood risk management policy for caravan parks and manufactured homes estates in the Shoalhaven LGA. A draft policy was prepared for Council which was to be applied to all caravan parks within the LGA. This policy includes the following performance criteria: > No increase in risk to life; > Safe evacuation of both residents and mobile homes; > No impacts on adjacent sites; and > Redevelopment of high risk zones where possible. > Long term sites should have no greater risk than allowed for residential developments; short term sites may adopt a higher risk.	This study provides information on flood risk and emergency plan for the Caravan Parks within the Lower Shoalhaven River catchment.

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Draft Coastal Zone Management Plan for the Shoalhaven Coastline (SMEC, 2009)	This draft Coastal Zone Management Plan for the Shoalhaven coastline is designed to manage coastal risk. It addresses immediate coastal hazards and longer-term coastal hazards for sea level rise that are based on 40 cm above 1990 levels by 2050 and 90 cm above 1990 levels by 2100. The plan aims to reduce known risk in five ways: > Avoid Risk; > Change the likelihood; > Change the Consequence; > Share the risk; and > Informed risk retention. The key actions include: > Managing access ways, preparing planting guides and reserve vegetation plans with local communities; > To consider ecological processes; > Safety; and > Views and access.	This plan reviews the management plan for the Shoalhaven Heads and Culburra Beach within the Lower Shoalhaven River catchment. It identifies the preferred options, their benefits and how Council may implement these programs.
Kangaroo River Flood Study (SMEC, 2009)	This study undertook hydrologic and hydraulic modelling to define flood behaviour in the Kangaroo Valley, including mapping of various flood parameters.	This study is superseded as the flood study models were updated by Cardno as part of the Kangaroo Valley Floodplain Risk Management Study and Plan (Cardno, 2016)
Lower Shoalhaven River Floodplain Risk Management Study and Plan - Climate Change Assessment (WMAwater, 2011)	This study comprised an amendment to the 2008 study to incorporate the predicted impacts of climate change. The study adopted NSW Government sea level rise estimates of 0.4 m by 2050 and 0.9 m by 2100, and increases in precipitation of 10%, 20% and 30% in line with DPE Guidelines. Based on these values, the findings of the previous 2008 study were updated including planning levels, flood damages, flood mitigation options and evacuation procedures.	This study provides information on climate change impacts.
Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2011)	The study (including the amended study to include the diversion of Berry Town Creek due to highway upgrades) was undertaken to define the existing flooding behaviour and associated hazards of the study area, and to investigate possible mitigation options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure that community concerns were addressed. The top three structural options identified by the multi-criteria analysis were: > Town Creek Vegetation Clearing; > North St Diversion Swale; and > Railway Culvert Upgrade. The Plan outlines implementation strategies based upon both their likely benefit and the funding available for Council from the State Government.	This study provides hydrological model and data for hydraulic the model. The information on feasible flood mitigation options will be considered for the Lower Shoalhaven River catchment.

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Shoalhaven River Flood Study (WMAwater, 2013)	This study was undertaken for the Manildra Group to develop a hydraulic model of the Shoalhaven River and adjoining floodplain to be used to evaluate the hydraulic impact of Shoalhaven Starches Plant expansion at Bomaderry, Nowra. This study used contemporary modelling methods compared with the previous April 1990 Lower Shoalhaven River Flood Study by PWD, in particular the use of a 2d TUFLOW model and updated data.	This study identified existing flooding behaviour within the catchment and developed a TUFLOW hydraulic model. This study provides the base data for hydraulic model development for the current Flood Study.
Lower Shoalhaven River Drainage Remediation Action Plan (Water Research Laboratory, UNSW, 2014)	This report describes landscape management issues and remediation options associated with acid sulphate soils in flood mitigation drains of Broughton Creek and Crookhaven River. The study details short-term and long-term strategies that could be used to improve water quality in the flood mitigation drains. Remediation action plans were presented for a total of 39 drainage areas on the Lower Shoalhaven River floodplain. Broughton Creek was identified as the worst affected area, containing the top 13 acid affected drains. Short-term remediation options: > Groundwater manipulation; > Tidal/saline Manipulation; > Acid Neutralisation (Liming); and > Permeable Reactive Barriers. Long-term remediation options: > Wet Pasture; > Drain Infilling and Reshaping; > Land Raising; and > Reversal to Saltmarsh or Wetland. The study found that one-way floodgates aggravate environmental problems associated with acid sulfate soil. The study also assessed the impact of climate change and sea level rise.	This study provides information on flood mitigation drains and remediation action plan. Data on some floodgates able to be extracted from this model. This would be helpful for flood mitigation options in the Lower Shoalhaven River catchment.
Greenwell Point, Shoalhaven Floodplain Management Options Feasibility Study (WMAwater, 2014)	This study provides an initial feasibility study into three flood modification management options for Greenwell Point previously identified by Council for further investigation: construction of levees, raising of Greenwell Point Road and House raising. It also provides alternative options to manage flood risk which includes: > Flood mitigation and control dams; > Retarding basins; > Bypass floodways; > Channel modifications and improvements; > Flood gates; > Pump improvements; and > Culvert and drainage structure improvements.	This study provides information on feasible flood mitigation options in the Lower Shoalhaven River catchment.
South Coast Regional Sea Level Rise Policy and Planning Response Framework (Whitehead & Assoc, Coastal Environment, 2014)	Eurobodalla Shire Council (ESC) and Shoalhaven City Council (SCC) engaged Whitehead and Associates Environmental Consultants (W&A), in consultation with Coastal Environment (CE), to develop a Regional Sea-level Rise Planning and Policy Response Framework that will inform coastal planning within the two Local Government Areas (LGAs). This study report outlines the context, methodology and outcomes of the current study.	This study will provide the framework for the climate change and sea-level rise sensitivity assessment.

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Shoalhaven August 2015 Post Flood Survey Report (Haskoning Australia Pty Ltd, 2015)	The post flood survey captured the flood mark levels in the catchments of Shoalhaven River, St Georges Basin, Sussex Inlet and Lake Conjola where flooding was experienced due to over 400mm rainfall on the 24th and 25th August 2015.	The flood level information was used to calibrate and validate the flood model results for Lower Shoalhaven River catchment for the 2015 event.
Lower Shoalhaven Levee Audit Report (Haskoning Australia Pty Ltd, 2015)	This report outlines the findings of an Audit of the Lower Shoalhaven River flood mitigation levees in March 2015. The scope of the Levee Audit was to record the location, nature and condition of each of the eight earthen levees owned by Council.	This report helps identify the levee condition for the 2D hydraulic model.
Management options for Improving Flows of the Shoalhaven River at Shoalhaven Heads (WRL-UNSW, 2015)	The study details community feedback, identified concerns and potential engineered management options for increasing flow circulation at Shoalhaven Heads. This study recommends to review the 1990 Flood Study and update to incorporate modern computational methods. This study recommended that the 1990 Shoalhaven River Flood Study could be improved to address following: > Refined entrance design levels, opening dynamics and dredging effects; > The role of Berry's Canal as the preferential flowpath during moderate to large floods in light of the expansion of the canal and the implications to discharge at the Shoalhaven Heads entrance; > Implications of Broughton Creek flooding levels and alternative triggers for localised floods; > Concerns with vegetation encroachment at the entrance and infilling dynamics of the bay; and > Climate change implications.	The recommendations in this study can be used to update the flood model and mitigation options in the Lower Shoalhaven River catchment.
Kangaroo Valley Floodplain Risk Management Study and Plan (Cardno, 2016)	This study included a review and update to the Kangaroo Valley Flood Study hydrology and hydraulic models and identified flood behaviour, risk and management measures for the Kangaroo Valley.	The calibrated XP-RAFTS model forms part of the catchment and is able to be used for catchment areas and parameters for this portion of the catchment. Proposed mitigation measures are not relevant to this study as the Kangaroo Valley is not in the Lower Shoalhaven study area.
Bomaderry Creek Floodplain Risk Management Study and Plan (Cardno, 2016)	The study built on the Bomaderry Creek Flood Study (BMT, WBM 2010) which defined flood behaviour in the catchment. This study investigated what could be done to reduce or manage the effects of flooding in the catchment, and recommended a mix of strategies to manage the risks of flooding. The top three structural options identified by the multi-criteria analysis were: > Maleen Street and Briniwarr Street Levee; > Birriley Street Raising and Culvert Upgrade; and > Tarawal Street Levee.	This study provides a hydrological model and data that was used to inform this study. The information on feasible flood mitigation options will be considered for the Lower Shoalhaven River catchment.

Study / Report	Description	Implications for Lower Shoalhaven River Flood Study
Nowra/Browns Creek Floodplain Risk Management Study and Plan (Cardno, 2016)	The study investigated the options to reduce or mange the effects of flooding and recommendations were developed to manage risk and how Council may implement these programs. The top three structural options identified by the multi-criteria analysis were: > Vegetation Management; > Industrial precinct drainage with upstream basins; and > Upstream Basins.	This study provides a hydrologic model and data that was used to inform this study. The information on feasible flood mitigation options will be considered for the Lower Shoalhaven River catchment.
Shoalhaven Coastal Hazard Mapping Review (Advisian, 2016)	This study presented an updated coastal hazard assessment at the beaches in the Shoalhaven. It describes the coastal process affecting the beaches and the impact of these processes on the areas where property is at risk. This study has adopted sea-level rise of: > 100 mm for 2030; > 230 mm for 2050; and > 350 mm for 2100.	This study provides information on boundary conditions at Shoalhaven Heads and Culburra Beach during sea-level rise scenarios.
Nowra Bridge Project – Review of Environmental Factors – Flooding and Hydrology Assessment (RMS, 2018)	Transport for NSW (TfNSW)(formerly RMS) prepared an REF for of a new bridge on the A1 Princes Highway over the Shoalhaven River at Nowra. A flooding and hydrologic assessment was prepared by Arup Pty Ltd. The assessment concluded that the proposed bridge design and intersection upgrade at Bridge Road and Illaroo Road achieves flood immunity for the up to 1% AEP flood event. However, the proposed design increases peak flood levels at a limited number of properties near Moorhouse Park by about 0.2 m for the 2% and 1% AEP event.	This study is superseded by the detailed design.
Nowra Bridge Project – Detailed Design and flood model (Cardno, 2020)	The Nowra Bridge Project includes detailed design of the Nowra Bridge duplication, Bomaderry Creek bridge widening and Princes Highway road upgrades and associated flood modelling. The flood model findings were consistent with the REF impacts as part of the requirements of the project.	At the time of this Flood Study, the Nowra Bridge Duplication was under construction. The approved bridge and road design has been incorporated into the modelling completed for this Flood Study.

3.2 Review of Policies and Planning

The Lower Shoalhaven River catchment is located in the Shoalhaven Local Government Area (LGA) where development is controlled through the Shoalhaven Local Environment Plan (LEP) and various Development Control Plans (DCPs). The LEP is a planning instrument which designates land use and development in the LGA, while DCPs regulate development with specific guidelines and parameters.

Other policies and plans which will be reviewed in detail and discussed in later stages of the study include:

> Shoalhaven City Council Engineering Design Specifications
> Nowra-Bomaderry Structure Plan
> SCC community engagement policy and SCC Community Strategic Plan
> Emergency management plans – DISPLAN and Shoalhaven City Local Flood Plan Draft
> Growth Management Strategy
> Illawarra Regional plan

3.3 Survey Information

3.3.1 Terrain

Various sources of the terrain information were available around the study area for use in developing the model Digital Elevation Model (DEM), including:

> LiDAR data 2010 (LPI);

> 10m Contours (LPI); and

> DEM product of 1 second Shuttle Radar Topography Mission (SRTM) data, sourced from Geoscience Australia.

A review has been undertaken to ensure appropriate data was adopted in the study. The results are summarised in **Table 3-2.**

Table 3-2 DEM Source Review

Data	Source	Coverage	Accuracy	Comments
LiDAR data	LPI LiDAR Data 2010 (Nowra), 2011 (Kiama) and 2015 (Moss Vale)	Full coverage in the study area (Lower Shoalhaven)	Horizontal: 0.8m Vertical: 0.3m	Will be used in hydrologic and hydraulic modelling
10m Contour	NSW Digital Topographic Database (DTDB), with multiple sources, e.g. Registered Image Trace, Engineering Design File (CAD), Scanned Map Image Trace, Survey Controlled, etc.	Full Catchment-wide coverage	5m	Used in upper catchment areas where 1m data not available for catchment delineation.
1 SEC SRTM	National elevation data products derived from the Shuttle Radar Topography Mission (SRTM) data.	Full Catchment-wide coverage	3.75m ±1.99	Poor resolution in grid size (~30m), suitable for catchment delineation in the absence of LiDAR

The Digital Terrain Model (DEM) was developed from the LiDAR data available at Cardno GeoHub supplied from NSW Government – Land and Property Information (LPI) from 2010 (Nowra), 2011 (Kiama) and 2015 (Moss Vale) with a 1m cell size. The **Figure 3-1** shows the extent of Lidar data and 2D hydraulic model extent.

The bathymetry data was provided by Council from DPE Bathymetric Survey database (56228) collected between Sept 2005 and Nov-2006 and was used in the WMAwater 2013 Flood Study.

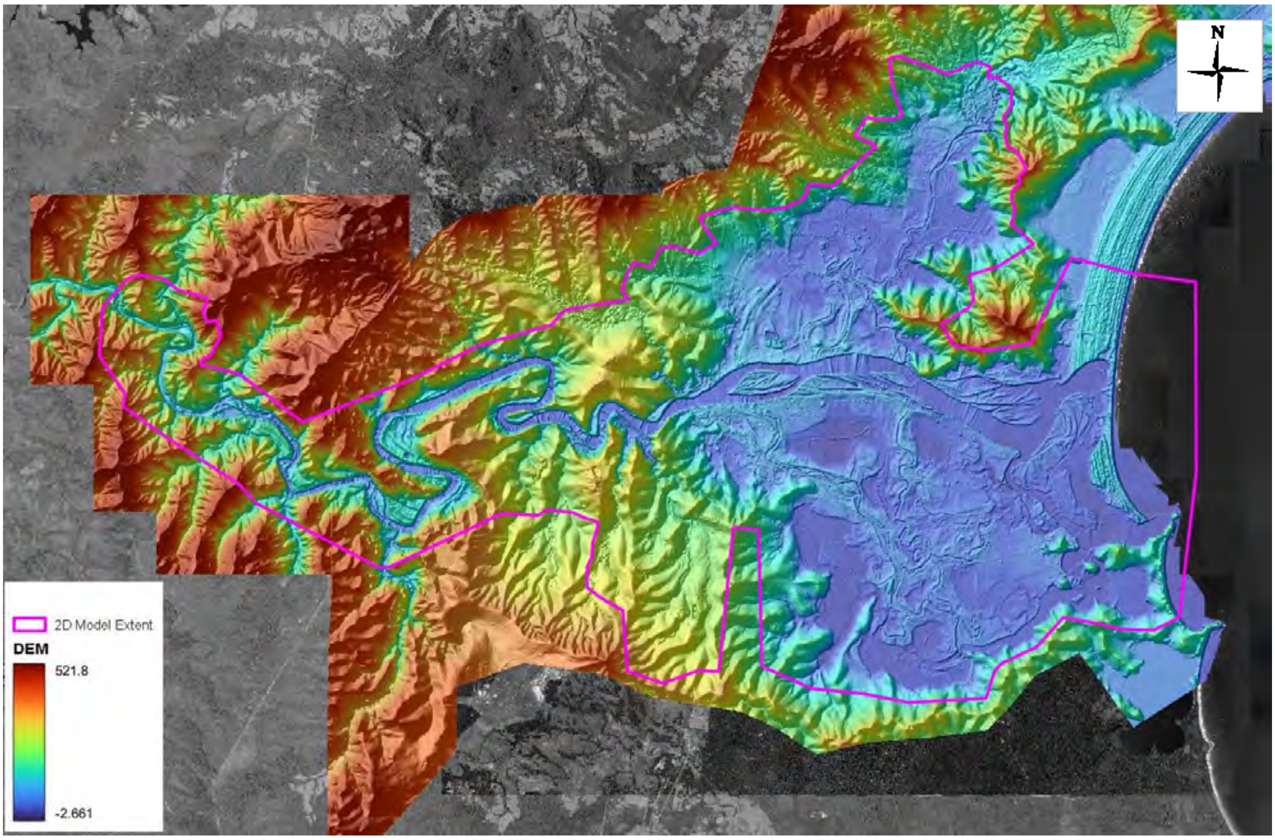

Figure 3-1 LiDAR Data Coverage and Hydraulic Model Extent

3.3.2 Hydraulic Structures

The Lower Shoalhaven River floodplain has numerous structures within waterways that may influence hydraulic behaviour. These structures, including bridges and culverts, are generally located along the Princes Highway and railway, as well as other crossings at Greenwell Point Road, Albatross Road, Bolong Road and Yalwal Road along with other smaller structures within agricultural drainage channels.

Hydraulic structure data (including location, type, inverts and dimensions) was available from the below sources:

- GIS data supplied by Council, and supplemented with details from as-built drawings, Council information/intelligence, or other available survey data;
- Detailed survey of 53 hydraulic structures, collected by Allen Price & Scarratts Pty Ltd (2018/2019) (**Figure 3-2**);
- 35 hydraulic structures identified from the Council GIS drainage layer (**Figure 3-3**) which contained culvert dimensions but no invert levels. Survey of these structures was not required, with Cardno interpolating the inverts from the DEM for the purpose of modelling. Council supported this approach for these structures as they were less significant structures;
- Levees, floodgates and flood mitigation channels identified from the Council GIS data (**Figure 3-3**);
- Detailed design drawings and models for Nowra Bridge Project and Berry to Bomaderry Bypass; and
- The stormwater structures from the Broughton Creek Floodplain Risk Management Study & Plan (Cardno, 2012), Nowra and Browns Creek Floodplain Risk Management Study & Plan (Cardno, 2016) and Bomaderry Creek Floodplain Risk Management Study & Plan (Cardno, 2016) were included in the model.

Note: at the time of survey, there were 5 hydraulic structures under construction as part of the TfNSW Berry to Bomaderry Bypass. Details of these structures were not required for the calibration and validation events, however, details were provided by TfNSW for use in the design event flood modelling.

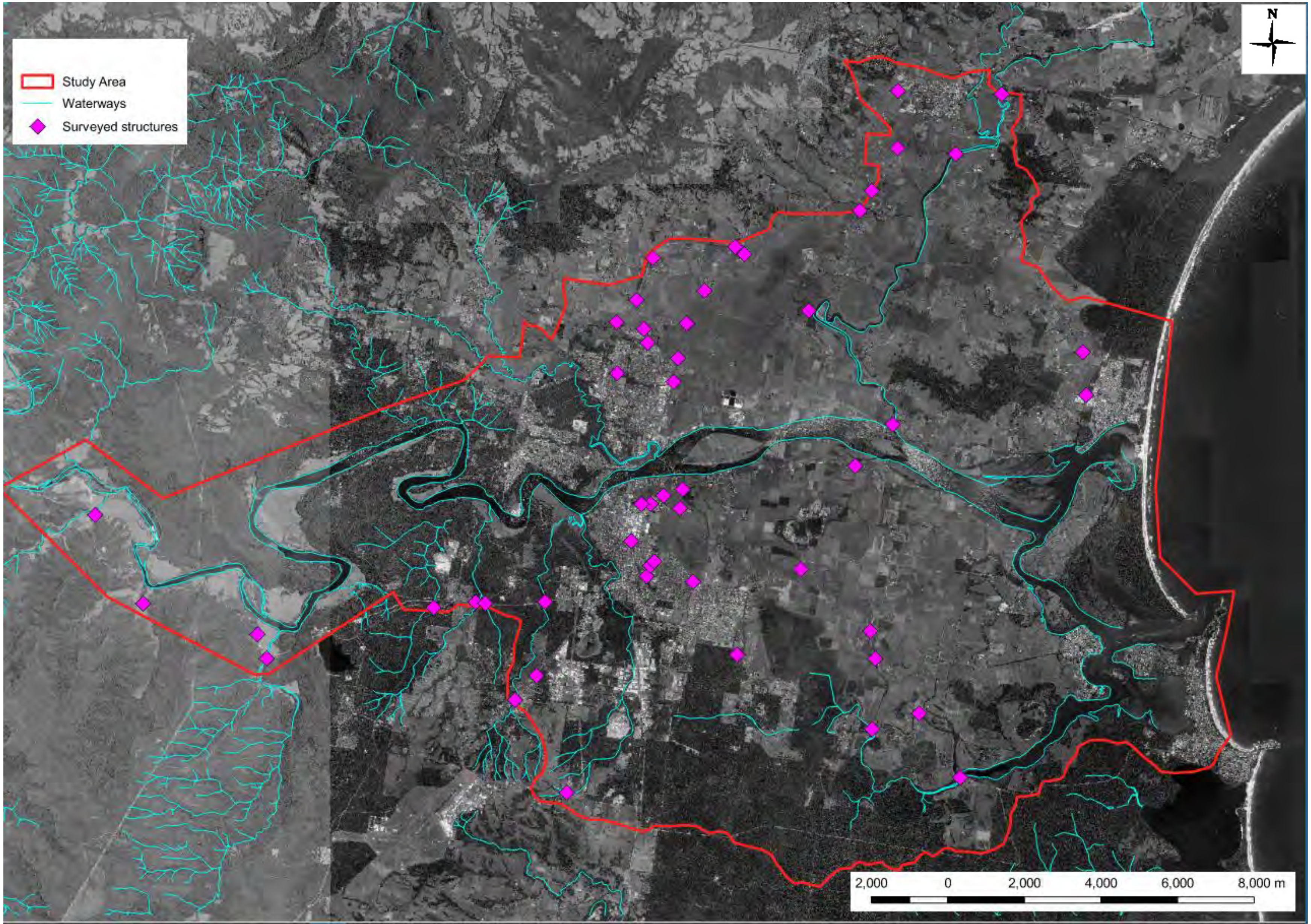

Figure 3-2 Surveyed Structures Reference Location (Surveyed by Allen Price & Scarratts, 2018/2019)

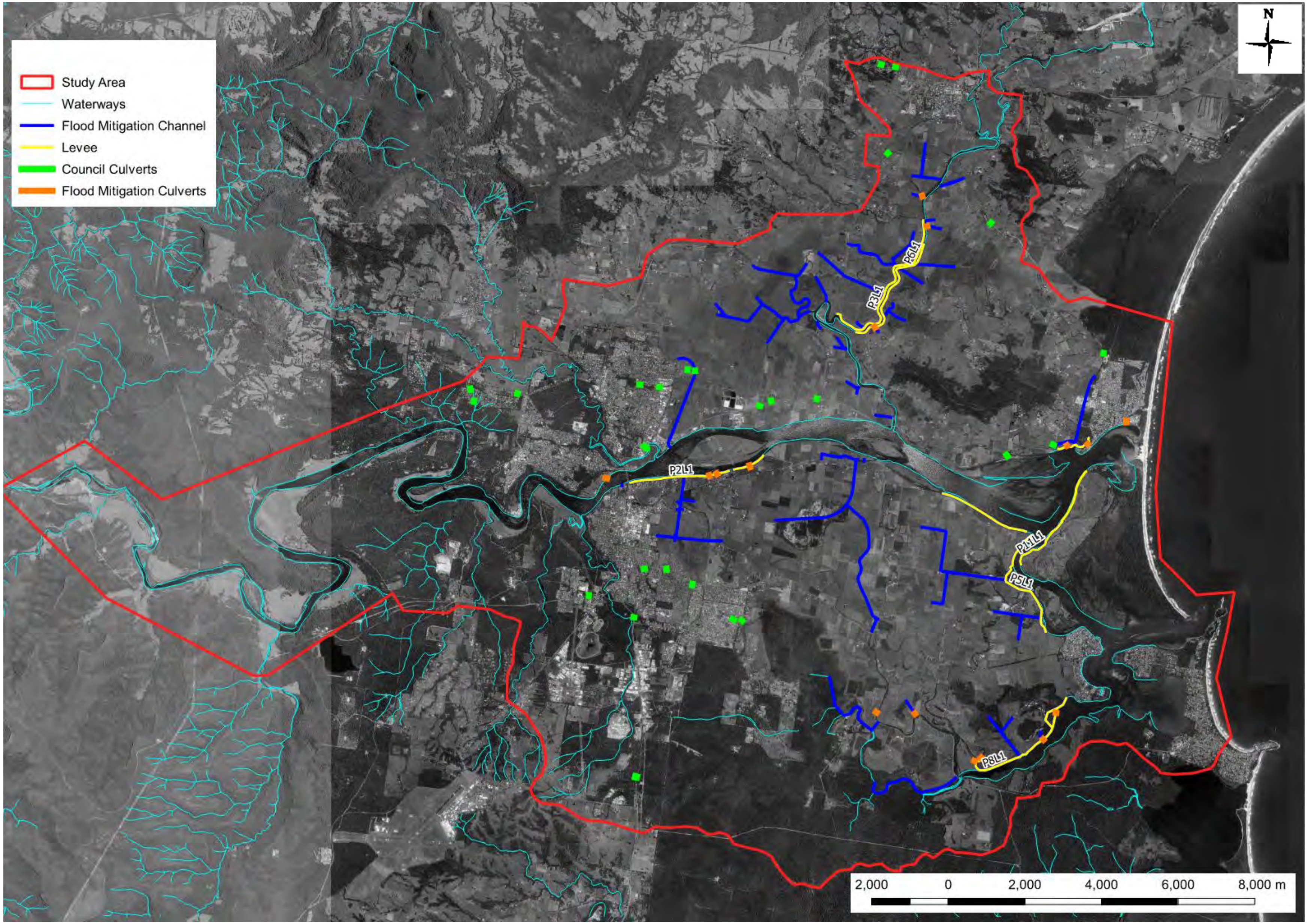

Figure 3-3 Hydraulic Structures from Council GIS Layer and previous studies

3.3.3 Shoalhaven Heads River Mouth Survey

Survey of the Shoalhaven Heads river mouth and coastal berm at various stages between March 2017 and March 2018 was provided by Council in DWG format. These surveys were reviewed and incorporated in the hydraulic model for the baseline closed state of Shoalhaven Heads.

Shoalhaven Heads survey was also provided for April, September and October 2015, which allowed assessment of the bathymetry pre- and post the August 2015 event when the entrance was breached.

3.3.4 Flood Levee Survey

A DWG file of the levee survey undertaken in 2017 was provided by Council. The following surveys were incorporated in the hydraulic model:

> P1L1 and P1L2 Terara levee - along south bank of Shoalhaven River near Terara Road;

> P2L1 – along south bank of Shoalhaven River near west of Numbaa Cemetery; and

> P5L1 – along south bank of Shoalhaven River near Regatta Creek confluence.

Survey was not available for the other levees shown in **Figure 3-3**, however, these are represented well by the ALS data.

3.3.5 GIS Data

The following Geographic Information System (GIS) data was provided by Council as part of the study:

> Acid Sulphate Soils

> Air Photo

> Cadastre;

> Drainage;

> Endangered Ecological Communities;

> Estuarine Macrophytes;

> Floodgates;

> Flood Mitigation Channels;

> Levees;

> SEPP14;

> SLEP2014;

> Vegetation;

> Wastewater;

> Water and Water Catchment; and

> Waterways.

3.4 Historical Data

3.4.1 Historical Flood Data

Historical flood records are available since 1860, with the largest floods recorded in 1870, 1873, 1925, 1860, 1978, 1916 and 1891 (in order of magnitude). There is still debate about the exact magnitude of these events. The flood of April 1870 is estimated to have been rarer than a 1 in 200 (0.5%) Annual Exceedance Probability (AEP) event. It inundated the Terara Township by over a metre, and swept away approximately one third of the village. Five lives were lost in rural areas along the Shoalhaven River.

According to some accounts, the earlier 1860 flood was even more devastating and carried away over 50 buildings. Several lives were lost as well as some 79 acres (32 hectares) of land. More recent significant floods occurred in August 1974, June 1975, October 1976 and March 1978. The 1870 flood was 1.2 m higher than the March 1978 event. **Table 3-3** lists the month and year of the historical floods at Nowra up to the year 2020. In the recent past, the Lower Shoalhaven River catchment was flooded in June 2013, August 2015, June 2016 and most recently again in February 2020 and August 2020. Minor flooding also occurred in March 2021 and May 2021. **Table 3-4** provides the recorded flood levels from the recent flooding at five key locations.

Table 3-3 Historical Floods at Nowra (Source: Lower Shoalhaven RFT, Shoalhaven City Council, 2017)

Month	Year	Month	Year
February	1860	June	1951
June	1864	May	1955
April	1867	February	1956
June	1867	July	1956
March	1870	October	1959
April	1870	March	1961
May	1871	November	1961
February	1873	June	1964
June	1891	September	1967
February	1898	August	1974
July	1899	June	1975
July	1900	October	1976
July	1904	March	1978
January	1911	April	1988
October	1916	August	1990
December	1920	June	1991
July	1922	8th August	1998
11th May	1925	19th August	1998
27th May	1925	October	1999
April	1927	November	2000
January	1934	June	2013
February	1934	August	2015
September	1938	June	2016
April	1945	February	2020
May	1948	August	2020
June	1949		

Table 3-4 Recorded Levels (m AHD) of Recent Flooding of the Lower Shoalhaven River

Event	Recorded Level (mAHD) at Gauge Location				
	Grassy Gully II Gauge 215216	Grady's Caravan Park MHL Gauge 215430	Nowra Bridge MHL Gauge 215411	Terara MHL Gauge 215420	Shoalhaven Heads MHL Gauge 215470
March 1978	n/a	n/a	5.25	3.6	2.1
June 2013	17.22	11.35	3.76	3.48	2.26
August 2015	17.63	11.94	3.97	3.54	2.22
June 2016	8.68*	10.96	3.4	3.1	2.0
February 2020	9.43*	12.08	3.6	3.4	1.9
August 2020	17.90	13.57	4.17	3.89	1.97

* Quality of data during this event is unclear. Possible instrument failure

3.4.2 Flood Photographs

A number of flood photographs were available from Council. This information is valuable to provide a qualitative description of flooding but is normally of less value for providing peak flood levels as the photographs may not be taken at the time of peak.

3.4.3 Rainfall, Water Level and Streamflow Data

Within the immediate catchment area there are a number of gauges including:

> Seven rainfall pluviometer gauges;

> 50 daily read rainfall gauges within and surrounding the catchment;

> Ten water level and stream flow gauges; and

> Seven water level gauges in the tidal areas.

A summary of the available rainfall data is presented in **Table 3-5** and **Table 3-6**. Details of the streamflow and water level gauges used for calibration are shown in **Table 3-7** to **Table 3-9.** The locations of the available rainfall, streamflow and water level gauges is shown in **Figure 3-4** and **Figure 3-5.**

Council has also provided Cardno with release data for Tallowa Dam from Shoalhaven Water, which includes recorded flows at Hampden Bridge, Fossickers Flat and Burrier as well as the flow and level over the spillway of Tallowa Dam. These locations are shown in **Figure 3-5** and details of the data provided is shown in **Table 3-9.**

This data is limited as it only provides a single instantaneous reading at 8am each morning. As such, the exact flow behaviour between 8am each day is unknown.

Table 3-5 Rainfall 1 Minute Gauge Stations available for the Specified Events in the Catchment Area

Station ID	Station name	Type	Period of Record	Source
68072	Nowra AWS	Rainfall (1 min)	Nov 2011 - Current	BOM
68239	Moss Vale AWS	Rainfall (1 min)	Sep 2010 - Current	BOM
68242	Kiama AWS	Rainfall (1 min)	Sep 2010 - Current	BOM
69128	Nerriga AWS	Rainfall (1 min)	June 2013 - Current	BOM
69132	Braidwood Racecourse AWS	Rainfall (1 min)	Sep 2010 - Current	BOM
69148	Moruya AWS	Rainfall (1 min)	Sep 2010 - Current	BOM
70351	Canberra AWS	Rainfall (1 min)	Apr 2009 - Current	BOM

Table 3-6 Rainfall Daily Gauge Stations available for the Specified Events in the Catchment Area

Station ID	Station name	Type	Period of Record	Source
68003	Berry Masonic Village	Daily	Jan 1886 - Current	BOM
68008	Bundanoon (Ballymena)	Daily	Jan 2002 - Current	BOM
68009	Burrawang (Range Street)	Daily	Jan 1891 - 2016	BOM
68029	Kangaroo Valley (Budgong)	Daily	Dec 1999 - Current	BOM
68036	Kangaroo Valley (Main Rd)	Daily	Jan 2014 - Current	BOM
68048	Nowra Treatment Works	Daily	Jan 1896 - Current	BOM
68080	Greenwell point bowling club	Daily	Jan 1960 - Current	BOM
68083	Culburra treatment works	Daily	Jan 1962 - Current	BOM
68085	Nerriga (Tolwong)	Daily	Jan 1961 - Current	BOM
68175	Toolijooa (Nyora)	Daily	Jan 1967 - 2015	BOM
68181	Hampden bridge (Kangaroo River)	Daily	Jan 1966 - Current	BOM
68190	Wattamolla (Tamol)	Daily	Jan 1970 - 2018	BOM
68197	Foxground road	Daily	Jan 1972 - Current	BOM
68202	Robertson (Pearsons Lane)	Daily	Apr 1997 - Current	BOM
68213	Nowra boat shed (Shoalhaven River)	Daily	Jan 1860 - Current	BOM
68217	Barrengarry (the old school house)	Daily	Jan 1982 - Current	BOM
68218	Wattamolla (Griffiths)	Daily	Nov 1982 - Current	BOM
68224	Robertson (The Pie Shop)	Daily	Jan 1985 - Current	BOM
68233	Grassy Gully (Shoalhaven River)	Daily	Jan 1991 - Current	BOM
68244	Pyree (Le Warnetre)	Daily	Jan 1901 - 2017	BOM
68245	Callala Treatment Plant	Daily	May 1901 - Current	BOM
68247	Beaumont (The Cedars)	Daily	Jan 1993 - Current	BOM
68249	Touga	Daily	Aug 2002 - Current	BOM
69010	Braidwood (Wallace Street)	Daily	Jan 1887 - Current	BOM
69041	Charleyong	Daily	Jan 1951 - Current	BOM
69062	Snowball	Daily	Jan 1896 - Current	BOM
69150	Braidwood (Mongarlowe (Leweston))	Daily	April 1998 Current	BOM
70012	Bungonia (Inverary Park)	Daily	Jan 1883 - Current	BOM
70036	Lake Bathurst (Somerton)	Daily	Jan 1931 - 2018	BOM
70057	Braidwood (Krawarree)	Daily	Jan 1898 - Current	BOM
70060	Lower Boro (Calderwood)	Daily	Jan 2003 - Current	BOM
70061	Majors Creek (The Old School)	Daily	Jan 1898 - Current	BOM
70063	Marulan (George St)	Daily	Jan 1894 - Current	BOM
70105	Mount Fairy (Merigan)	Daily	Jan 1899 - 2016	BOM
70174	Windellama (Pindaroo)	Daily	Dec 1999 - 2017	BOM
70261	Jerrabattgulla (Gilston)	Daily	Jan 1971 - 2017	BOM
70334	Nerriga (Timberlight)	Daily	Jan 1992 - Current	BOM

Station ID	Station name	Type	Period of Record	Source
70335	Hillview (Shoalhaven River)	Daily	Jan 1991 - Current	BOM
70342	Lower Boro (Annwyn)	Daily	May 2002 - Current	BOM
70354	Bungendore (Lockhart)	Daily	May 2006 - Current	BOM
68035	Jamberoo (The Ridge)	Daily	Jan 1992 - Current	BOM
68209	Jamberoo (Druewalla)	Daily	Jan 1963 - 2016	BOM
68243	Burrawang (Spurfield)	Daily	Jan 1961 - Current	BOM
69127	Araluen Lower (Araluen Rd)	Daily	Jan 1980 - Current	BOM
70016	Captains Flat (Foxlow St)	Daily	Jan 1898 - Current	BOM
70035	Bungendore (Gidleigh)	Daily	Jan 1886 - 2016	BOM
70077	Goulburn (Springfield)	Daily	Jan 1930 - Current	BOM
70214	Parkers Gap	Daily	Apr 2001 - Current	BOM
70269	Marulan (Johnniefelds)	Daily	Jan 1972 - Current	BOM
68248	Fitzroy Falls	Daily	Nov 2002 - Current	BOM

Table 3-7 Stream Flow Gauge Stations available for the Specified Events and within the Catchment.

Station ID	Station name	Type	Period of Record	Source
215002	Shoalhaven River at Warri	Discharge (15 min)	Sep 1914 - Current	BOM
215007	Mongarlowe River at Monga	Discharge (15 min)	Jan 2003 - Jan 2006	BOM
215008	Shoalhaven River at Kadoona	Discharge (15 min)	Aug 1850 - Current	BOM
215014	Bungonia Creek at Bungonia	Discharge (15 min)	Apr 1981 - Current	BOM
215016	Bomaderry Creek at Bomaderry	Discharge (15 min)	July 2003 - Oct 2010	BOM
215018	Broughton Creek at Broughton Vale	Discharge (15 min)	May 2008 - Current	BOM
215019	Jaspers Brush Creek at Jaspers Brush	Discharge (15 min)	Feb 2011 - Current	BOM
215216	Grassy Gully II	Discharge (15 min)	Mar 1987 - Current	WaterNSW
568159	Danjera Dam (Danjera Creek)	Water Level (15 min)	Jun-2002 - Current	Council
568196	Danjera Creek	Water Level (15 min)	Oct-2004 - Current	Council

Table 3-8 Water Level Gauge Stations available for the Specified Events and within the Study Area.

Station ID	Station name	Type	Period of Record	Source
215216	Grassy Gully II	Water Level (15 min)	Mar 1987 - Current	WaterNSW
215430	Gradys Caravan Park	Water Level (15 min)	Oct 2010 - Current	MHL
215411	Nowra Bridge	Water Level (15 min)	Aug 1990 - Current	MHL
215420	Terara	Water Level (15 min)	Aug 2001 - Current	MHL
215415	Hay Street	Water Level (15 min)	Jan 2002 - Current	MHL
215470	Shoalhaven Heads	Water Level (15 min)	Feb 1991 - Current	MHL
215417	Greenwell Point	Water Level (15 min)	Dec 1988 - Current	MHL
215408	Crookhaven Heads*	Ocean Tide (15 min)	Mar 1992 - Current	MHL
216470	Jervis Bay*	Ocean Tide (15 min)	Sep 1989 - Current	MHL

* NB: The Crookhaven Heads tidal gauge is influenced by freshwater flows and is not suitable for use as an ocean boundary during flood events. Jervis Bay is outside the study are but used instead of Crookhaven Heads for tidal boundary

Table 3-9 Tallowa Dam Release Data Details

Location	Data Type	Date from	Date to
Tallowa Dam Level Above Spillway (m)	Instantaneous Level at 8am	16/07/2009	15/10/2018
Tallowa Dam Flow (ML/day)	24hr Volume to 8am	16/07/2009	15/10/2018
Hampden Bridge Flow (m^3/s)	Instantaneous Flow at 8am	18/11/2003	15/10/2018
Fossickers Flat Flow (m^3/s)	Instantaneous Flow at 8am	18/11/2003	15/10/2018
Burrier Flow (m^3/s)	Instantaneous Flow at 8am	18/11/2003	15/10/2018

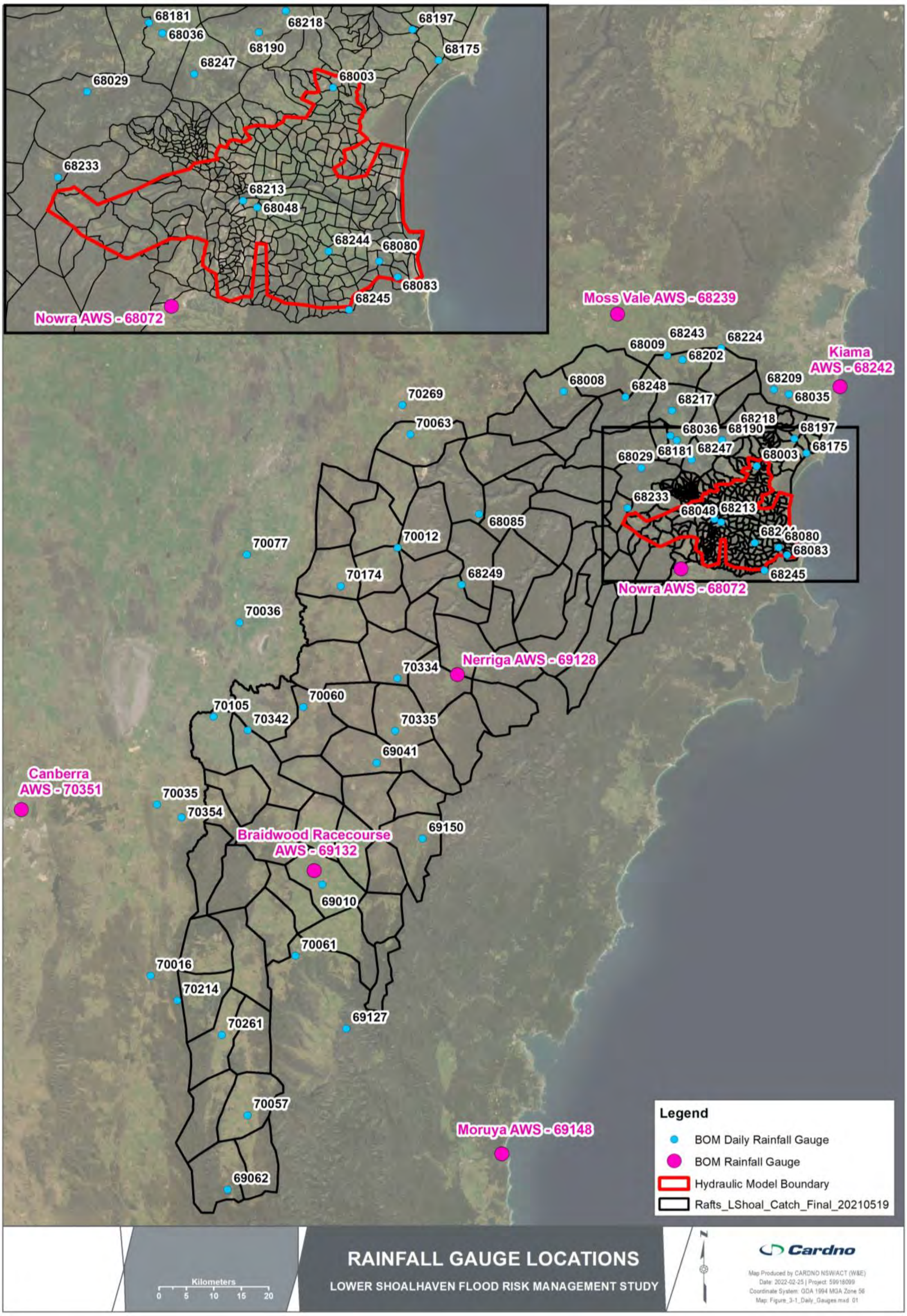

Figure 3-4 BOM Rainfall Gauge Locations

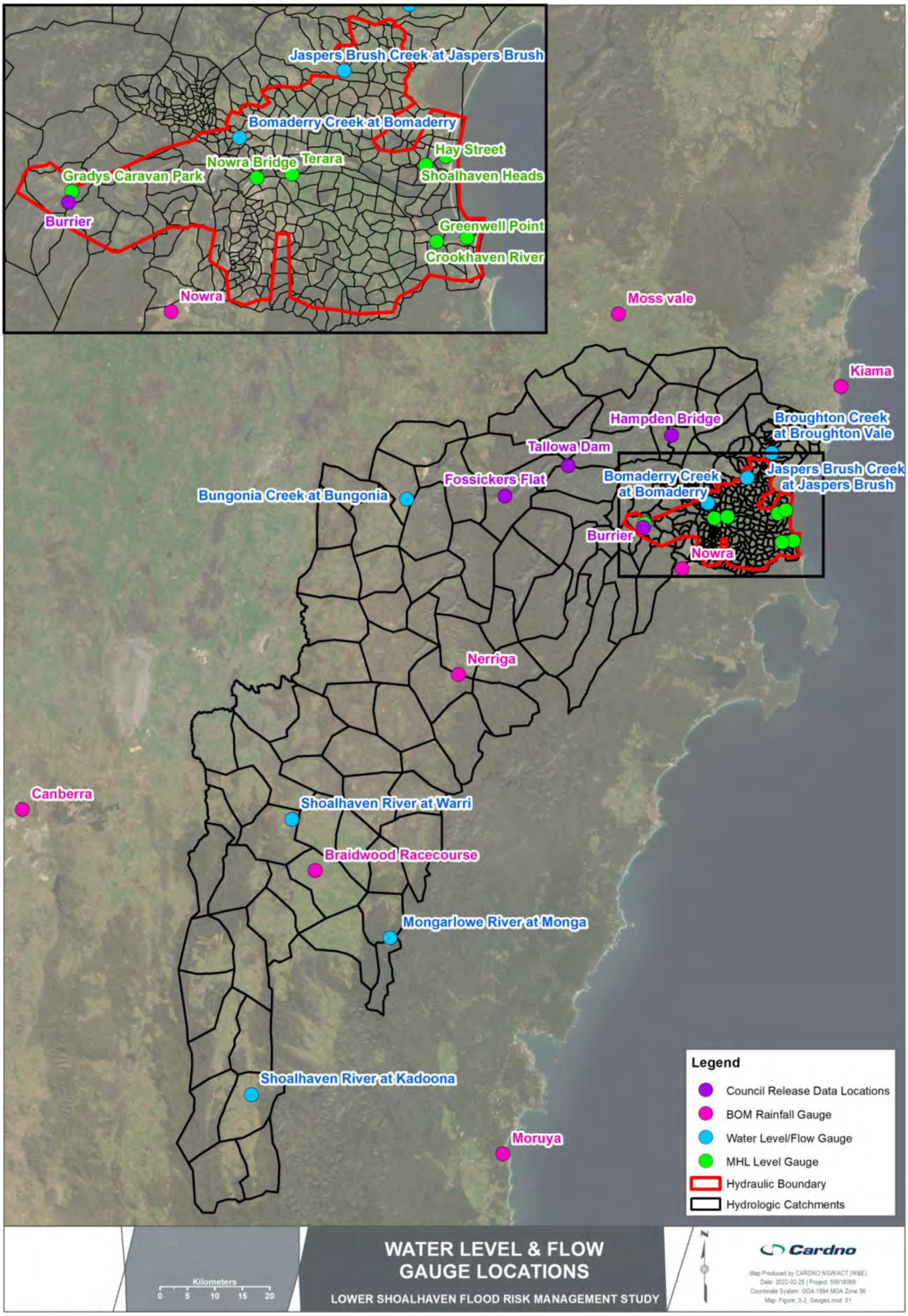

Figure 3-5 Rainfall, WaterNSW Level and Discharge, Shoalhaven Water gauges and MHL Level Gauge Locations used for Model Calibration

3.4.4 Previous Hydrological Modelling

Hydrology files in Boyd format (old version of the Watershed Bounded Network Model (WBNM) software package) was used to estimate catchment runoff as part of the Lower Shoalhaven River Flood Study (PWD, 1990). The 1990 hydrology model is not executable by current WBNM software. As such, only information on catchment areas were able to be retrieved from the 1990 hydrology model. The catchment areas were translated to GIS format from *Figure 8 – Catchment Subdivision* of the 1990 study. Information on runoff-routing, link and lag time, roughness, losses and impervious percentages were not able to be extracted from the model.

From the review of previous studies, it was found that Kangaroo Valley Flood Study Floodplain Risk Management Study and Plan (Cardno, 2016), Broughton Creek Floodplain Risk Management Study & Plan (Cardno, 2012), Nowra and Browns Creek Floodplain Risk Management Study & Plan (Cardno, 2016) and Bomaderry Creek Floodplain Risk Management Study & Plan (Cardno, 2016) are based on XP-RAFTS hydrology. During the data review stage, these XP-RAFTS hydrology models were reviewed and found to be suitable for the purposes of this study.

Given the existing XP-RAFTS models, the change in hydrology modelling methodology as part of ARR2019 guidelines and compatibility issues with the 1990 Boyd model to current WBNM software, it was determined that the hydrology model had to be recreated and revised.

Hence, the hydrologic model was re-built in XP-RAFTS software for the Lower Shoalhaven River Flood Study.

3.4.5 Previous Hydraulic Modelling

The previous hydraulic model was prepared for Lower Shoalhaven Flood Study (PWD, 1990) using CELLS. The CELLS model of the Shoalhaven River represented the channel and floodplain as a series of interconnected cells, termed either river or floodplain cells. The river cells were connected by cross sections and the floodplain cells connected by weirs.

In the 30 years since this model was developed, significant advances have been made in hydraulic modelling packages and methodologies.

One of the objectives of this study is to develop a 2D hydraulic model for the study area to replace the existing CELLS model. WMAwater undertook a flood assessment for the Shoalhaven River in 2013 for the Manildra Group, and within this Study established a TUFLOW hydraulic model of the Shoalhaven River Floodplain. As such, the dynamic hydraulic modelling system TUFLOW will be applied for the Lower Shoalhaven River Study.

3.4.6 Calibration and Validation Event Data

Calibration and validation of the hydrologic and hydraulic models (**Section 6**) is a key component of the Flood Study, as it ensures the models (developed as described in **Section 4** and **Section 5**) can reasonably reproduce observed flood behaviour in the catchment being investigated. The Shoalhaven River has a long history of flooding and a network of rainfall and stream flow and level gauges from which to gather calibration data.

The selection of storm events for calibration and validation was based on the availability of high resolution rainfall data and stream flow gauge data, as well as events for which the catchment conditions (e.g. development, vegetation, hydraulic structures) can be appropriately estimated and represented in the model.

The August 2015 event was selected for calibration due to having the best availability of data (including Council-surveyed flood debris levels) against which to compare modelled flood levels. In addition, the August 2015 event was the largest recent event (prior to the August 2020 event) in terms of flood levels in the Lower Shoalhaven River. Selection of the August 2015 calibration event was agreed upon in consultation with Council. Validation of the model ensures the model can accurately represent a variety of events, and for this study validation was undertaken for the June 2013 and June 2016 events. Total rainfall at each AWS gauge for each calibration and validation event is shown in **Table 3-10**, and the cumulative rainfall over the course of each event is shown in **Figure 3-6** to **Figure 3-8**.

A detailed description of the calibration data and methodology is provided in **Section 6.1**, and the calibration/validation events in **Section 6.3, 6.4,** and **6.5** and **6.6** for the August 2015, June 2013 and June 2016 events, respectively.

Table 3-10 Total Rainfall for Historical Rainfall Events

Station Name	Total Rainfall for the Event (mm)		
	June 2013 Event (23rd - 26th)	August 2015 Event (23rd - 27th)	June 2016 Event (3rd - 6th)
Kiama (68242)	183.8	263.8	257.6
Moruya (69148)	114.0	173.4	243.4
Nerriga (69128)	162.6	117.4	196.2
Nowra (68072)	271.0	420.2	352.6
Moss Vale (68239)	134.6	166.2	280.0
Braidwood (69132)	113.4	85.2	165.2

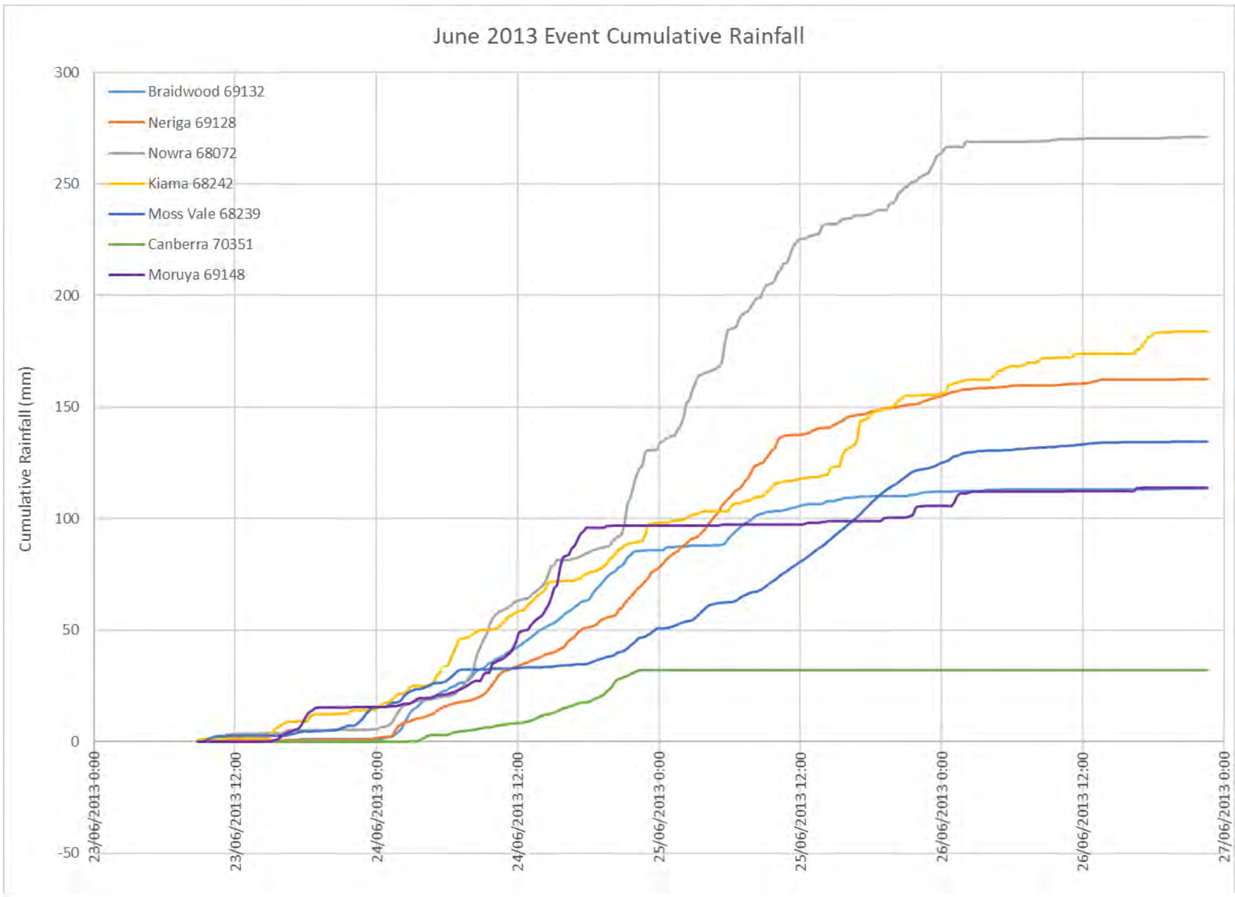

Figure 3-6 Cumulative Rainfall for the June 2013 Event

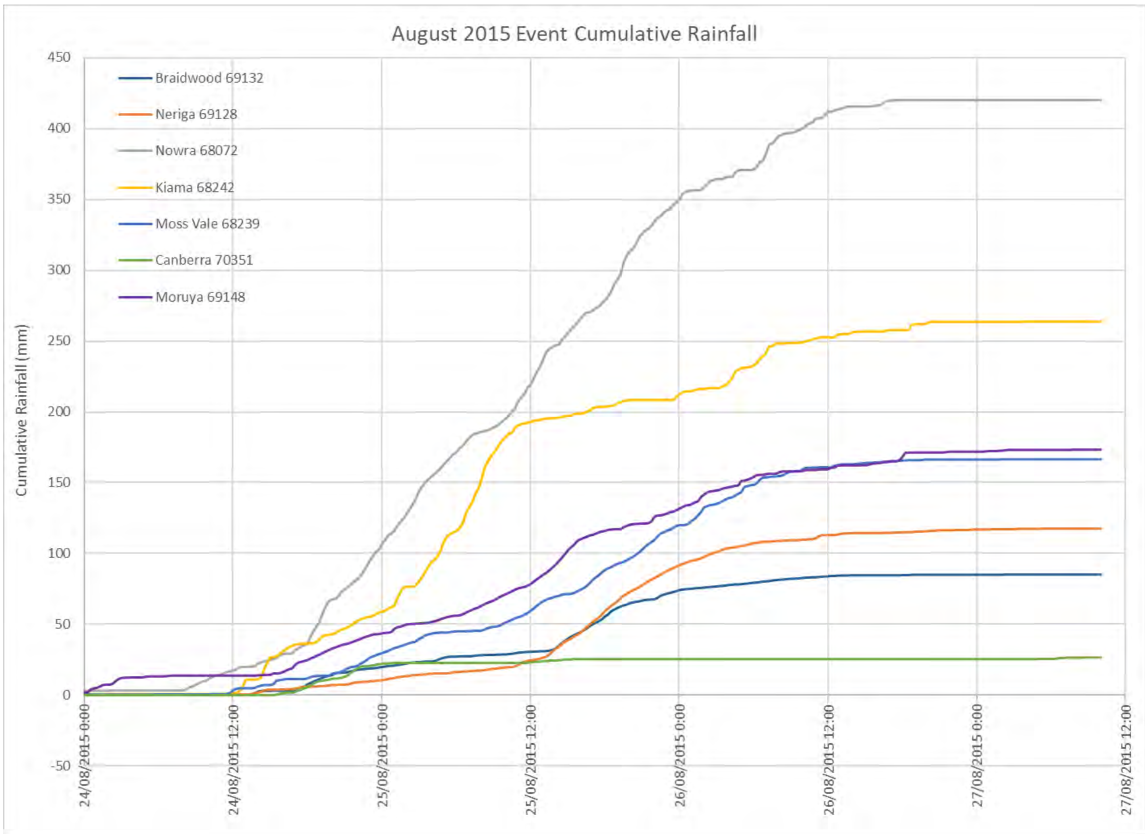

Figure 3-7 Cumulative Rainfall for the August 2015 Event

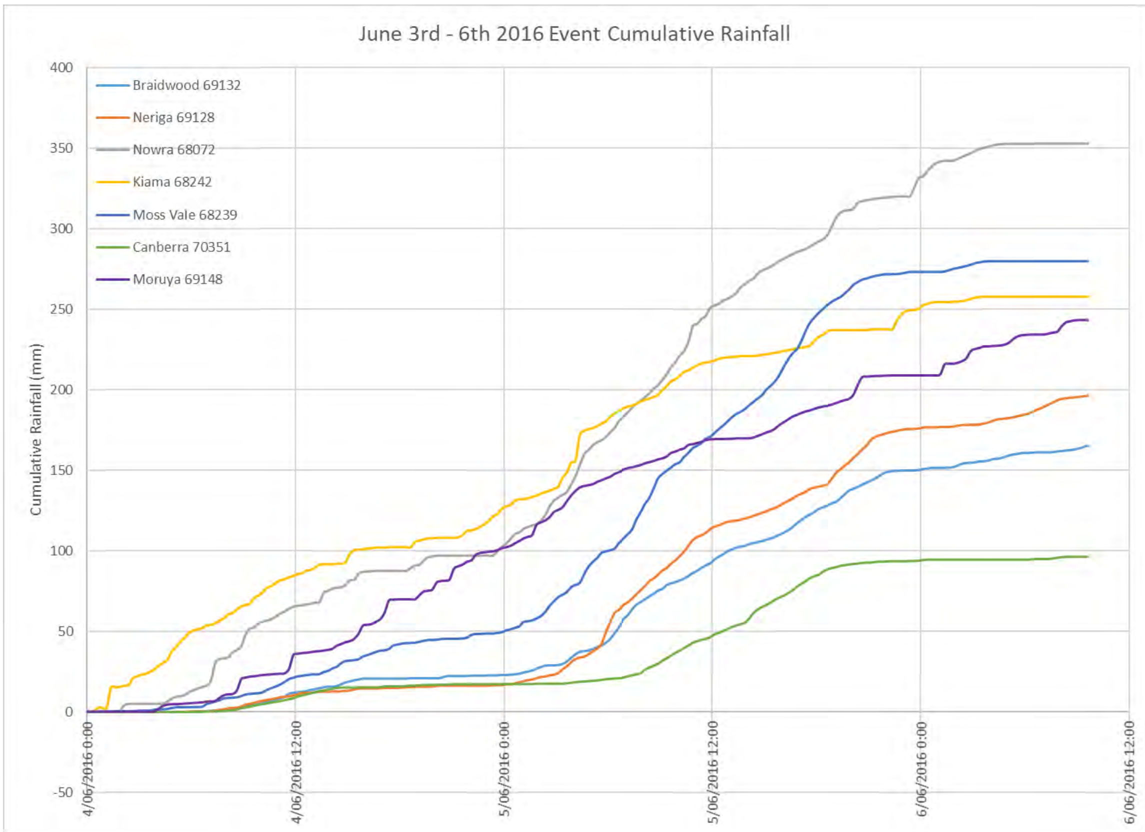

Figure 3-8 Cumulative Rainfall for the June 2016 Event

3.4.6.2 *February 2020 and August 2020 Flood Events*

The February 2020 event, which reached 12.08 m AHD at Shoalhaven River at Gradys Caravan Park (Gauge 215430) on the 10th February 2020, was similar in magnitude to the August 2015 event, which reached 11.94 m AHD at the same location.

The August 2020 Event reached 13.57m AHD at Gradys Caravan Park (Gauge 215430) on the 8th August 2020 and peaked at 4.17 m AHD at Nowra Bridge was the largest event since 1990.

The February 2020 and August 2020 events were not used for the model calibration as they occurred after the analysis had been completed.

3.4.6.3 *Flood Events in the 1970s*

It is noted also that flood events from the 1970s have previously been used as calibration events, including, for example, the Shoalhaven River Flood Study (PWD, 1990), the Lower Shoalhaven River FRMS&P (WMAwater, 2008), and the Shoalhaven River Flood Study completed by WMAwater in 2013 for the Manildra Group. The March 1978 event is the seventh largest flood on record following construction of Tallowa Dam in 1976. For context, peak flood levels at key locations for this event have been provided in **Table 3-4**.

A detailed description of the March 1978 validation event is provided in **Section 6.6**.

3.5 Community Consultation

Consultation with the community and stakeholders is an important component in the development of a Floodplain Risk Management Study and Plan. Consultation provides an opportunity to collect information from observed flood events, feedback and observations from the community on problem areas and potential floodplain management measures. It also provides a mechanism to inform the community about the current study and flood risk within the study area and seeks to improve their awareness and readiness for dealing with flooding.

The details and outcomes of Cardno's community engagement activities to date are provided in **Appendix D**.

4 Hydrology Model Development

Previous design flow estimates for the catchment were determined as part of the Lower Shoalhaven River Flood Study (1990). These design flows were derived using methods and data from Australian Rainfall and Runoff (ARR) 1987 and used catchment parameters representative of the catchment at that time.

Due to the changes made in the development of hydrological models with the implementation of ARR2019 (http://arr.ga.gov.au/arr-guideline) along with changes to the catchment through development, this has the potential to impact a number of results previously provided. In order to provide an accurate representation of the newly defined guidelines, an update to the hydrological model for the Shoalhaven River catchment was required.

In order to provide updated design inflows within the TUFLOW hydraulic model an XP-RAFTS hydrological model was developed based on previous studies, with the updating of areas to be compatible with ARR2019, using data from the ARR Data Hub website.

4.1 Model Selection

For the hydrological model of the Lower Shoalhaven Catchment, XP-RAFTS was selected as the most appropriate for the update of the 1990 flood study. This software was considered as the most suitable due to:

> The availability of previous XP-RAFTS models within the hydrological catchment that can be directly incorporated;

> The ability to simulate storage within sub-catchments (Tallowa Dam);

> Compatible with application of ARR2019 methodologies;

> The ability to account for spatial and temporal variations in storm rainfalls across a catchment;

> The ability to accommodate variations in catchment characteristics;

> The ability to estimate discharge hydrographs at any location within a catchment; and

> It has been widely used across eastern NSW and therefore, where suitable calibration data is not available, the results from modelling of other similar catchments can be used as a guide in the determination of model parameters.

4.2 Shoalhaven River XP-RAFTS Model

4.2.1 Catchment Delineation

The Shoalhaven River hydrological model covers a total catchment area of 7,250 km^2 and was divided into 495 Sub-catchments using 1m Digital Terrain Model (DEM) and upstream of the hydraulic model extent boundary the available 5m data was used. Both were developed from the LiDAR data available at Cardno GeoHub supplied from NSW Government – Land and Property Information.

The sub-catchment delineation is based on the following:

> Consistent with the 1990 Flood Study for Upper Shoalhaven River, upstream of Burrier;

> Consistent with Broughton Creek (Cardno, 2012), Nowra and Browns Creek (Cardno, 2016), Bomaderry Creek (Cardno, 2016) studies and Kangaroo Valley (SMEC, 2009); and

> In any areas not covered within previous studies, catchment delineation was undertaken with consideration to ensure that its outputs would be reliable for use in the TUFLOW hydraulic model. Sub-catchment boundaries in the vicinity of hydraulic structures were aligned, ensuring the accuracy of flows through hydraulic structures in the hydraulic model.

The consolidated XP-RAFTS model consists of a total of 614 nodes. This includes nodes representing sub-catchments as well as dummy nodes to combine the flow hydrographs where multiple nodes discharge into a single location.

The catchment area was compared against the BoM Australian Hydrological Geospatial Fabric (Geofabric) drainage divisions and river region boundaries and this identified that a sufficiently good match was obtained.

The XP-RAFTS sub-catchment delineation is shown in **Figure 4-1** and **Figure 4-2.**

4.2.2 Catchment Storage Coefficient

Catchment storage coefficient (B) is calculated based on catchment area, slope and degree of imperviousness. This value is further influenced by the catchment roughness depending on the chosen PERN parameter. Due to the large size of the Lower Shoalhaven River catchment and differing topography and land use, different parameters of PERN were applied to different areas within the catchment. It was found through the calibration runs (**Section 6.1.2**) that a catchment Storage Coefficient Multiplication Factor (BX) value of 1.2 was appropriate to achieve a good correlation with the catchment response.

4.2.3 Impervious Areas

The proportion (as a percentage) of impervious surfaces within each sub-catchment within the hydraulic model extent was calculated using the provided cadastre and digitised materials layer. Previously calibrated catchments impervious areas were applied, this includes:

- Bomaderry Creek;
- Nowra and Browns Creek; and
- Broughton Creek.

All other sub-catchments within the hydraulic model boundary were calculated from the Cadastre and materials layer, with Urban areas calculated to be 70% Impervious. Outside of the hydraulic boundary visible townships were calculated to be 70% impervious while for catchments with no visible townships a 1% imperviousness of the total catchment area is applied.

4.2.4 PERN - Land Use/Catchment Roughness

The PERN parameter within XP-RAFTS is a unit-less empirical parameter used to describe the roughness value of individual catchment areas, and can be considered somewhat similar to the Manning's 'n' value.

Land use throughout the catchment varies greatly, covering heavily forested mountains and valleys, rural flats, urban areas and farmland floodplains in the lower reaches. In order to represent these differences in catchment roughness, different PERN values have been applied within the hydrological model. This is shown in **Table 4-1** below. These values were arrived at through varying the PERN range as part of the calibration described in **Section 6.1.1**.

Table 4-1 PERN values within the Hydrological Model.

Description	PERN Value
Impervious	0.02
Pervious Forested Areas	0.08
Pervious Floodplain/Urban	0.045
Pervious Inland Grassed Areas	0.06

4.2.5 Sub-catchment Slope

The sub-catchment slope was calculated as the vectored slope. The slope is approximated using the averaged slope over the sub-catchment along the longest flowpath. The sub-catchments varied greatly in slope from 0.01% - 36%. This large range is due to the catchment including very flat floodplains at the downstream area, as well as much higher slopes in the escarpments bordering the catchment.

4.2.6 Lag Time

The XP-RAFTS model has been setup using link lagging to route flows from one catchment to the next. Throughout the catchment a stream velocity of 1m/s was assumed in the calculation of the lag time applied to model links. Through the calibration process (**Section 6.1.3**) it was found that between west of Nerriga and Fossickers Flat, the Shoalhaven River channel gradient steepens and a stream velocity of 2m/s was adopted and lag times shortened to suit. This resulted in better timing of the peak flow at the Fossickers Flat Gauge. Downstream of Tallowa Dam, the stream velocity of 2.5m/s was adopted using the hydraulic model results for velocities near Gradys Caravan Park as a guide. This assisted the timing of the peak in the Lower Shoalhaven River within the hydraulic model study area.

A peer review of the XP-RAFTS model was later undertaken by WMAwater in 2021.The peer review concluded that the approach adopted in the XP-RAFTS model, which is not the Muskingum-Cunge stream routing, has impacted the model behaviour in extreme events. The peer review suggested that the lag time values in the XP-RAFTS may be too high for the PMF event resulting in underestimation of PMF flows. This would occur since a constant lag time value is applied to each link over various AEP events in the XP-RAFTS model.

WMAwater was also engaged by Council to undertake a conversion of the current XP-RAFTS hydrologic model to a Watershed Bounded Network Model (WBNM) hydrologic model. It is noted that WBNM lag is a function of flow which means it would be able to give lower lag time values for rare and extreme events. In consultation with Council, lag time values in the XP-RAFTS model for the PMF event were calibrated such that it would be able to produce PMF peak flow similar to the WBNM model. Based on the results of the calibration, 52% of the lag time value was applied to each link for the PMF event.

4.2.7 Losses

For the Shoalhaven River catchment hydrology, the Initial Loss - Continuing Loss method was adopted. This is to keep consistency with the previous models within the catchment, excluding the Kangaroo Valley Updated FRMSP which used the Australian Representative Basin Model (ARBM) loss method.

The losses used within previous models and those extracted from the ARR Data Hub are shown in **Table 4-2**. It should be noted that the Data Hub for ARR2016 has been updated to ARR2019 causing changes to the losses provided.

The most recent ARR2019 guidance also provides a probability neutral burst loss and also recommends using a factor of 0.4 for the reported ARR2019 Data Hub continuing loss value.

Table 4-2 Previous Models Initial and Continuing Loss

Study / Report	Adopted Losses
Lower Shoalhaven River Flood Study (PWD, 1990)	IL = 30 mm CL = 2 mm/hr
Broughton Creek Floodplain Risk Management Study & Plan (Cardno, 2012)	IL = 25 mm CL = 2.5 mm/hr
Nowra and Browns Creek Floodplain Risk Management Study & Plan (Cardno, 2016)	IL = 10 mm CL = 2 mm/hr
Bomaderry Creek Floodplain Risk Management Study & Plan (Cardno, 2016)	IL = 10 mm CL = 2.5 mm/hr
ARR2019 – Data Hub Update (May 2019) Note: Taken from centroid not IFD Catchment, no 0.4 factor applied.	<u>Entire Shoalhaven River Catchment Centroid</u> IL = 28 mm CL = 4.8 mm/hr <u>Lower Shoalhaven River Study Area Centroid</u> IL = 37 mm CL = 4.0 mm/hr

The adopted losses were determined through the calibration process (**Section 6.1.4**) by varying the continuing loss and initial loss for a range of values guided by adopted losses in previous studies and ARR Data Hub values. Calibration and validation showed that adopting a single set of continuing loss values may not be able to represent the full range of events. The applied continuing losses were varied across the design events to generate flows to match the expected flow from the FFA as shown in **Table 8-5**.

Table 4-3 Adopted Rainfall Losses for Design Events

Location	Initial Loss (mm)	Continuing Loss (mm/hr)
Upstream (U/S) of Warri	37	Varies with AEP
Kangaroo Valley	51	Varies with AEP
U/S of Hydraulic Boundary Excluding U/S of Warri and Kangaroo Valley	29	Varies with AEP
Within Hydraulic Model Extent	29	Varies with AEP

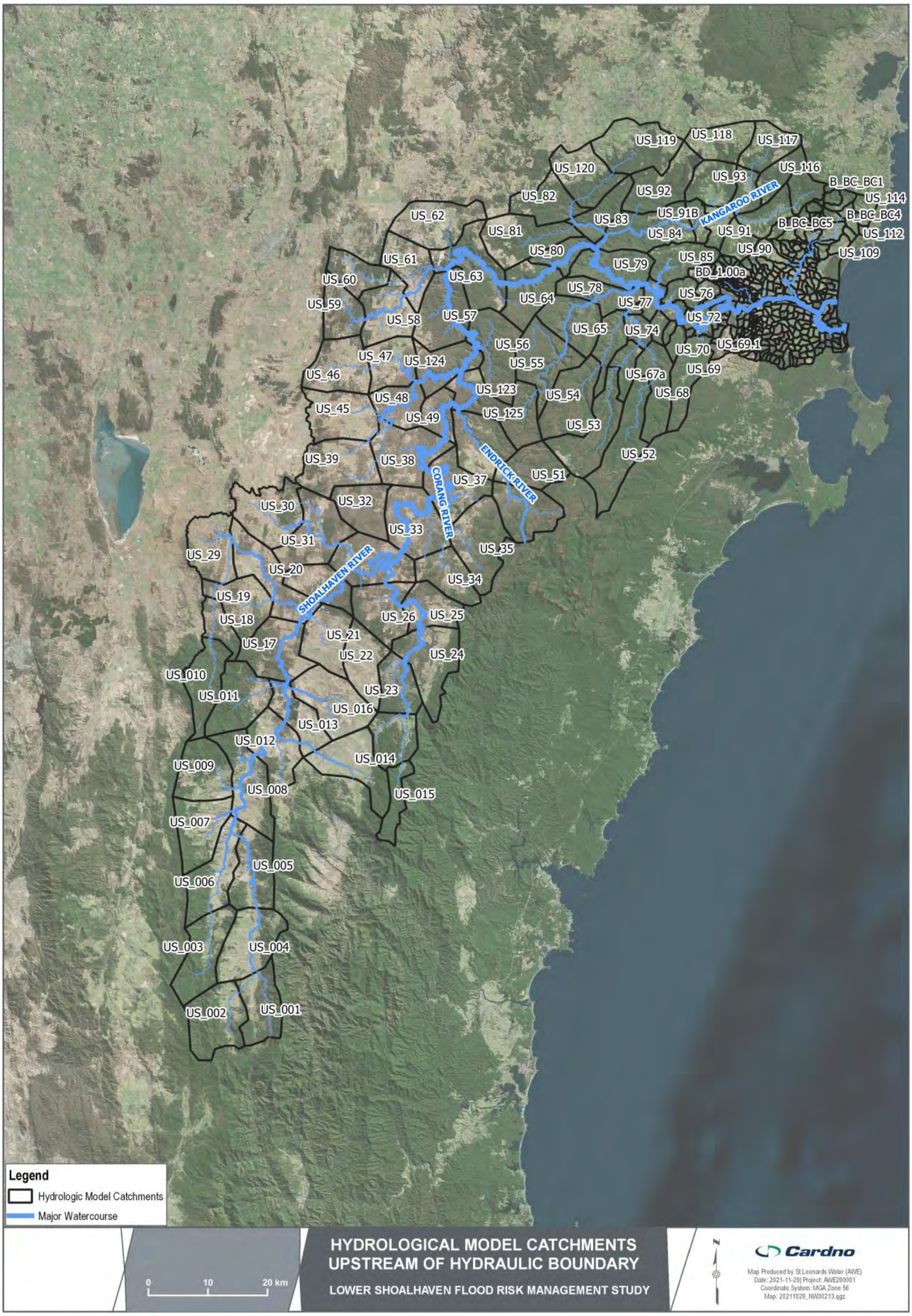

Figure 4-1 Hydrologic model sub-catchments upstream of the hydraulic model boundary

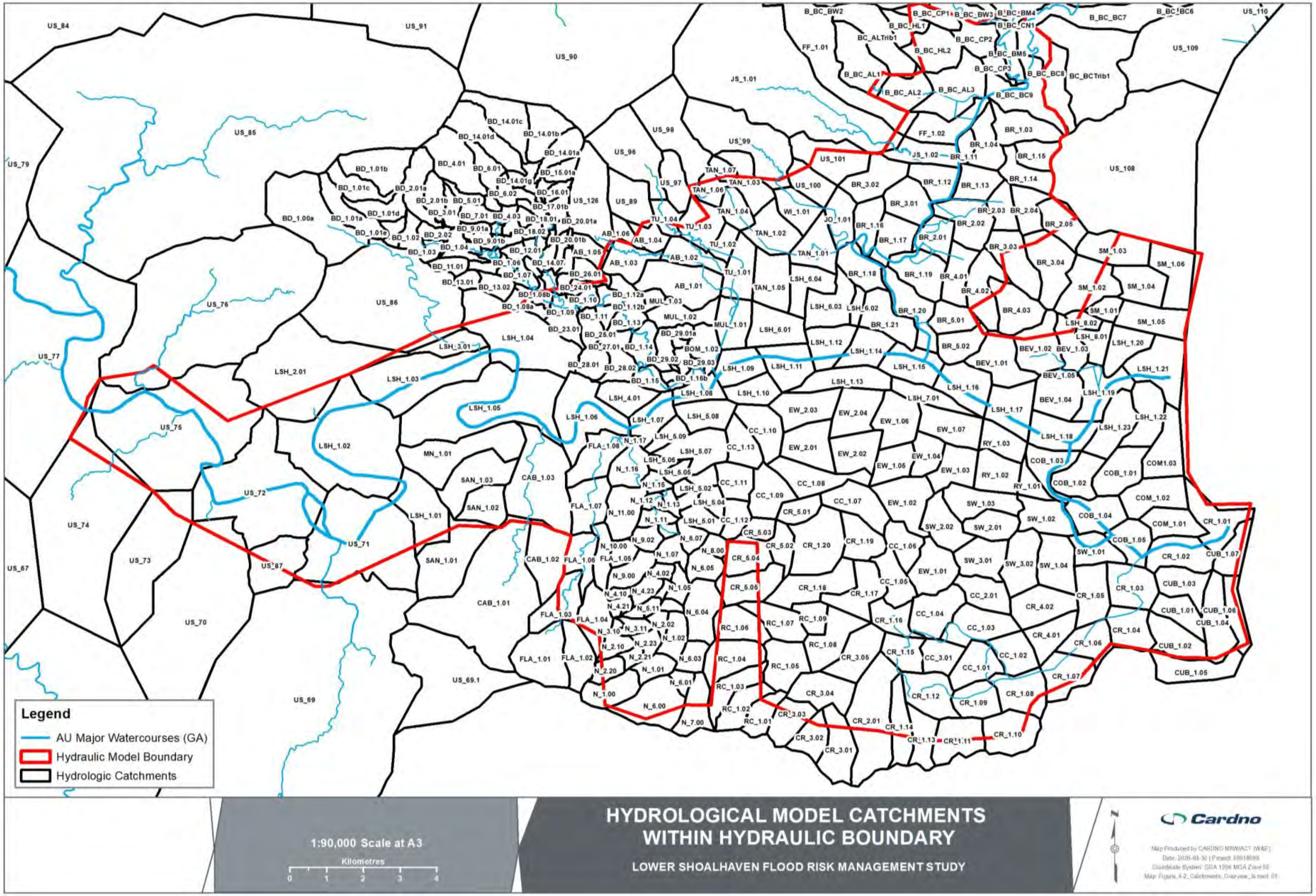

Figure 4-2 Hydrologic Model sub-catchment boundaries within the hydraulic model extent

4.2.8 Tallowa Dam

Tallowa Dam is a concrete dam completed in 1976 which forms the impoundment known as Lake Yarrunga located at the confluence of the Kangaroo River and Shoalhaven River. The dam collects runoff from a catchment area of approximately 6,243 square kilometres. Tallowa Dam acts as a backup for the Warragamba and Upper Nepean Dams' water supply to Sydney Water. When Sydney's dam levels drop to a level below 75% water is fed from Tallowa Dam into the Warragamba system.

The Tallowa Dam, which is outside the hydraulic model extent (approximately 20 km upstream of the hydraulic model boundary), was modelled within XP-RAFTS. The Reservoir Stage-Storage relationship and Spillway Stage-Discharge relationship details were provided by Council from Shoalhaven Water as part of the assessment. These are shown in **Figure 4-3** and **Figure 4-4** below.

The Spillway level was taken as 56.34 m AHD, taken from the Kangaroo Valley Flood Study (SMEC 2009). For historical events, the initial water level was equal to the water level value at 8am level of the first day of the event provided within Council's release data, adopted levels are provided in **Table 4-4**. For design events, the dam is assumed to be full, with an initial water level of 56.34 m AHD.

Table 4-4 Calibration and validation events initial water levels (Provided by Council)

Event	Initial Water Level (m AHD) at 8am in Tallowa Dam
June 2013	56.35
August 2015	56.29
June 2016	56.01

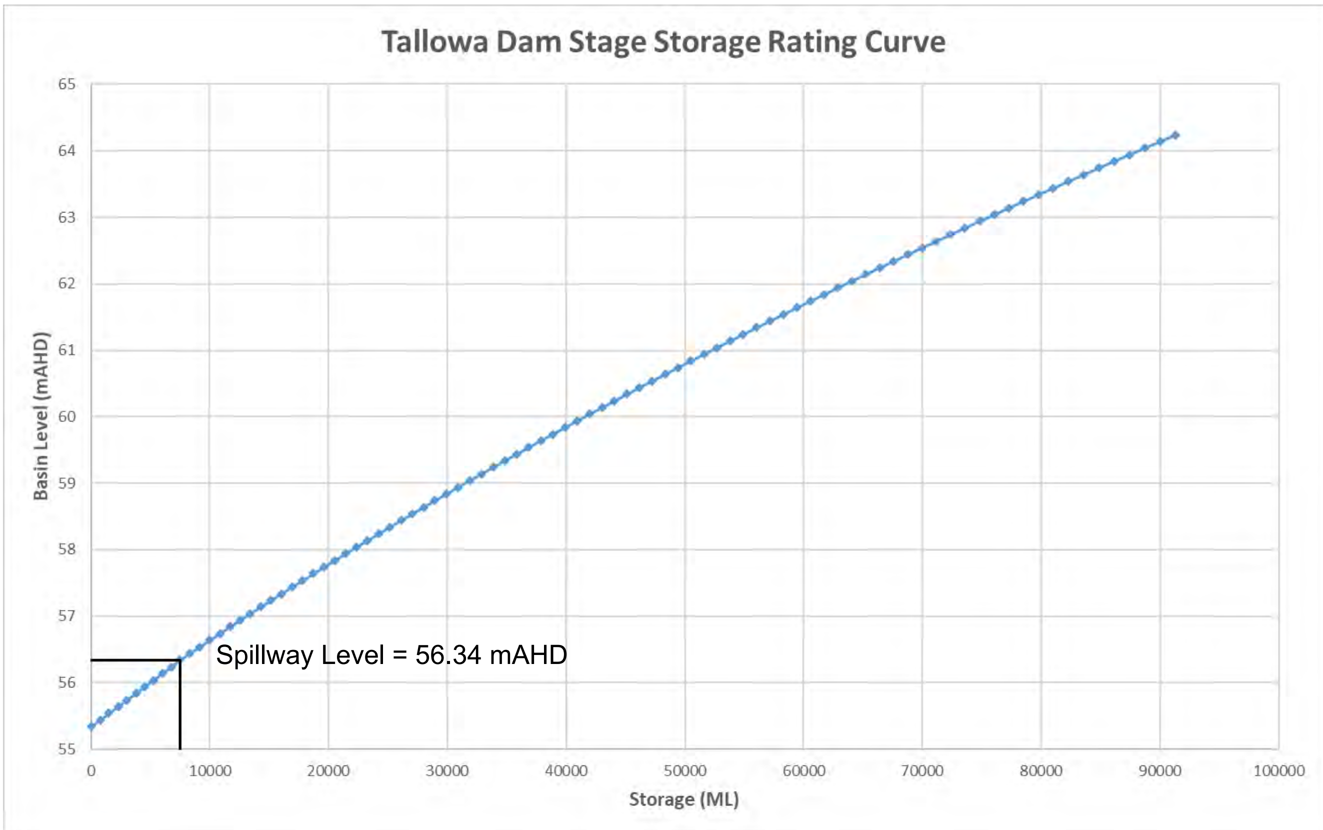

Figure 4-3 Tallowa Dam Adopted Stage-Storage Rating Curve

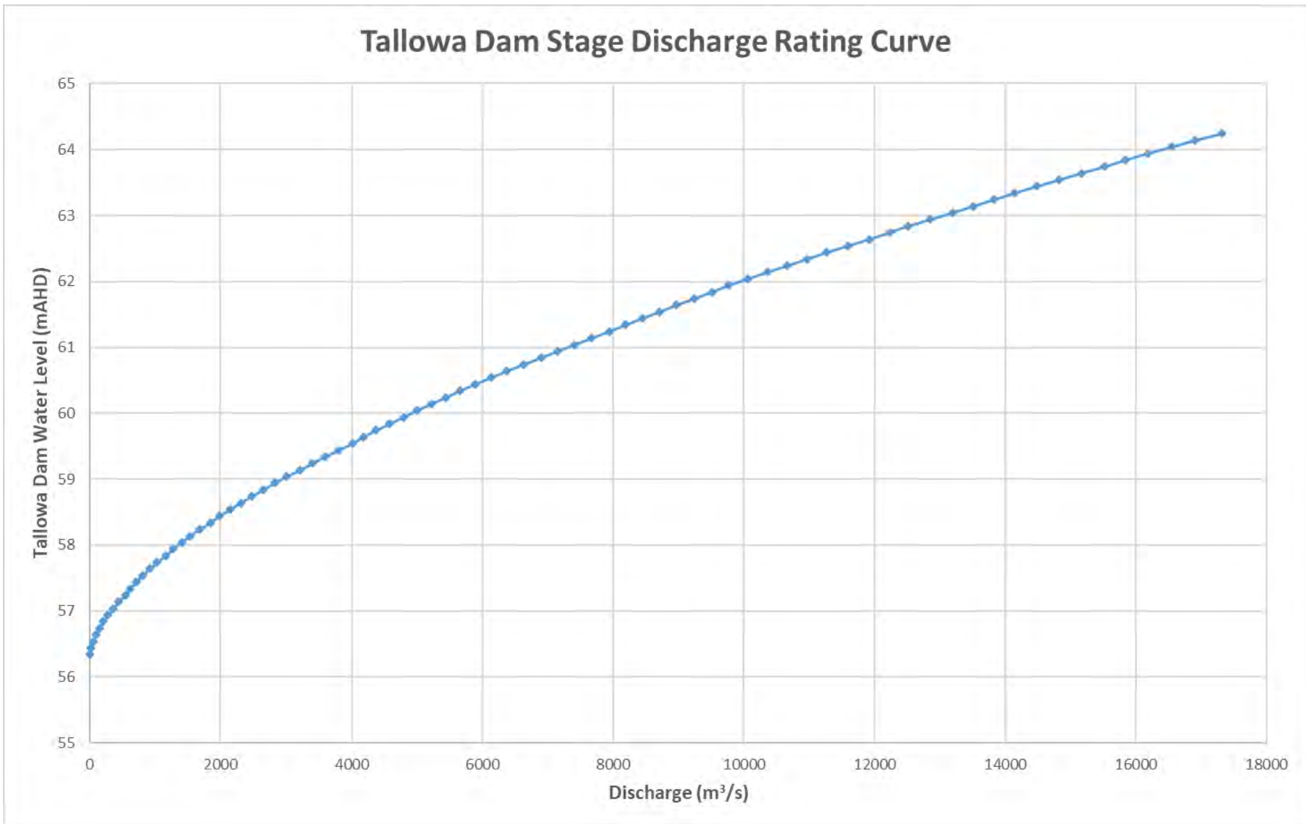

Figure 4-4 Tallowa Dam Adopted Stage-Discharge Rating Curve

4.2.9 Danjera Dam

Danjera Dam is a earthfill embankment and concrete mass mattress wall dam completed in 1971 which forms an impoundment on Danjera Creek just upstream of the confluence with Yalwal Creek some 15km upstream of the Shoalhaven River. The dam collects runoff from a catchment area of approximately 114 square kilometres. Danjera Dam is owned by Shoalhaven Water and used to form part of the water supply system, however is now a recreational reservoir.

The Danjera Dam, which is outside the hydraulic model extent (approximately 20 km upstream of the hydraulic model boundary), was modelled within XP-RAFTS. The Reservoir Stage-Storage relationship and Spillway Stage-Discharge details were provided by Council as part of the assessment. These are shown in **Figure 4-5** and **Figure 4-6** below.

The Spillway level was taken as 73.76 m AHD, taken from the Danjera Dam Safety Emergency Plan (Shoalhaven Water, 2001). For historical events, the initial water level was equal to the water level value at the time of the start of each event provided within Council's data, adopted levels are provided in Table 4-5. For design events, the dam is assumed to be full, with an initial water level of 73.76 m AHD.

Table 4-5 Calibration and validation events initial water levels (Provided by Council)

Event	Initial Water Level (m AHD) in Danjera Dam
June 2013	73.76
August 2015	<71.36*
June 2016	71.30

*data was only received from 28th August after the event when the dam level was 71.36 m AHD.

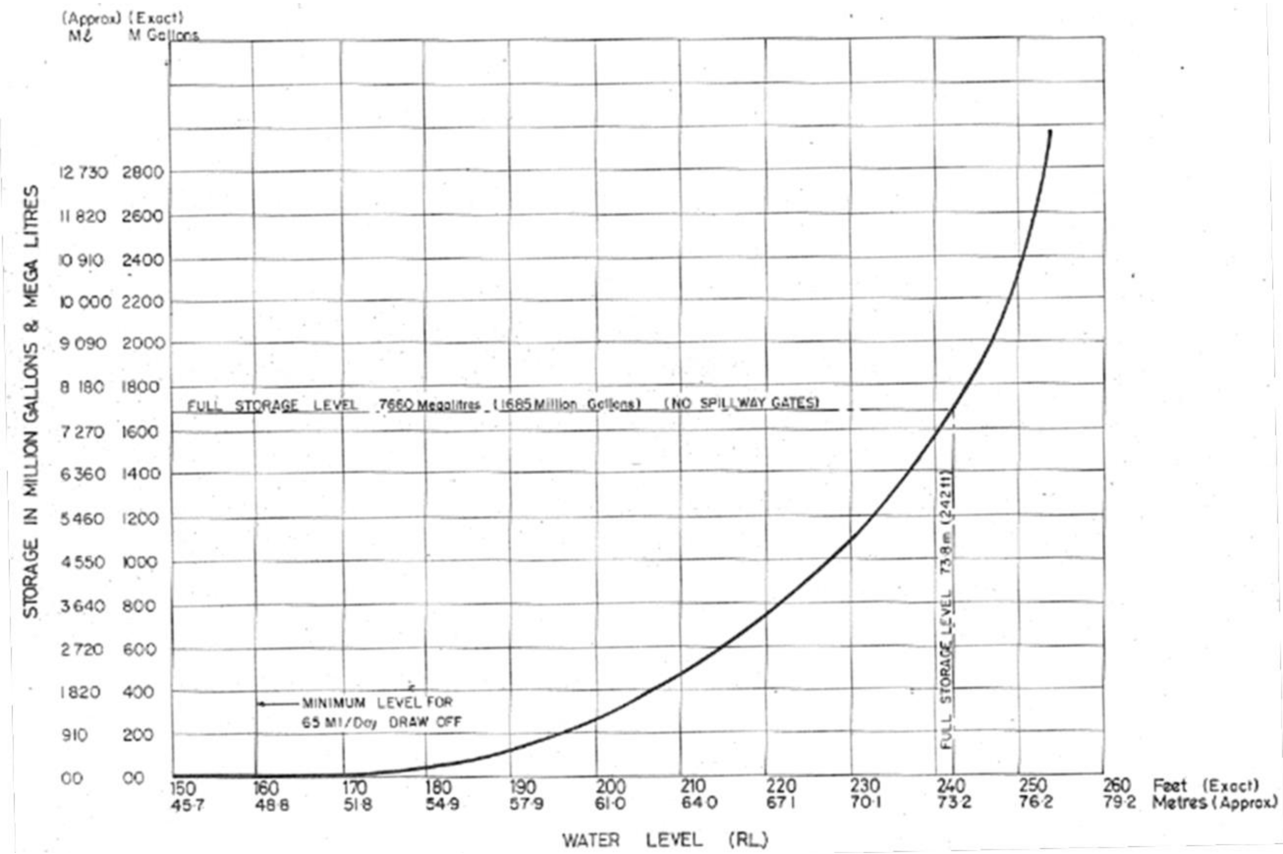

Figure 4-5 Danjera Dam Stage-Storage Rating Curve (Danjera Dam DSEP, 2001)

PRELIMINARY DANJERA DAM ELEVATION - STORAGE - DISCHARGE DATA		
ELEVATION m RL	**STORAGE** ML	**SPILLWAY DISCHARGE** m^3/s
73.76	7728	0
74.07	8021	41
74.37	8315	112
74.68	8683	207
74.98	9051	316
75.29	9319	444
75.59	9588	581
75.90	10035	735
76.20	10483	895
76.50	11113	1065
76.81	11742	1245
77.11	12806	1440
77.42	13870	1640
77.72	14870	1760
77.76	14999	1780
78.01	15805	1860
78.26	16706	1930
78.51	17594	1990
78.56	17770	2015
78.76	19143	2050
79.00	19845	2159
79.25	20997	2247
79.50	22212	2339
79.75	23493	2435
80.00	24843	2533
80.25	26267	2636
80.50	27768	2742

Assumes: Infinitely High Embankment.

Source: Danjera Dam – Interim Probable Maximum Flood Study (DPWS, 1998)

Figure 4-6 Danjera Dam Adopted Stage-Discharge Rating Table

5 Hydraulic Model Development

5.1 Model Selection

One of the objectives of this study is to develop a 2D hydraulic model for the study area to replace the existing CELLS model prepared for Lower Shoalhaven Flood Study (PWD, 1990). The CELLS model of the Shoalhaven River represented the channel and floodplain as a series of interconnected cells, termed either river or floodplain cells. The river cells were connected by cross sections and the floodplain cells connected by weirs.

In the more than 30 years since this model was developed, significant advances have been made in hydraulic modelling packages and methodologies.

WMAwater established a TUFLOW hydraulic model of the Lower Shoalhaven River Floodplain as part of a Shoalhaven River Flood Study in 2013 for Manildra Group and this model was provided for this study. The TUFLOW model has been adopted as the basis for the current Lower Shoalhaven River Flood Study and has been reviewed, extended and updated to reflect the recent data.

Using the provided model and additional and recent data, a one and two dimensional (1D/2D) dynamically linked TUFLOW hydraulic model was developed for the study area.

TUFLOW is a grid based 2D hydrodynamic free-surface flow solver. The engines are suited for simulating flood, tide, storm tide, tsunamis and coastal hydraulics. TUFLOW incorporates world leading 1D/2D dynamic links to an advanced 1D scheme.

TUFLOW HPC (Heavily Parallelised Compute) is a second order explicit grid based solver. TUFLOW HPC can run a simulation using multiple CPU cores, or alternately GPU hardware for high speed execution (requiring the add-on GPU Hardware module). TUFLOW HPC includes the full functionality of the ESTRY 1D network or quasi-2D modelling system based on the full one-dimensional (1D) free-surface St Venant flow equations.

TUFLOW HPC (Version 2020-10-AA-iSP-w64) on GPU hardware was used, to take advantage of the significantly faster solution scheme, which has distinct advantages for the study area with adopting appropriate grid cell size.

5.2 Model Setup

5.2.1 Model Extents

The hydraulic model extents cover the Lower Shoalhaven River from upstream of Burrier to the Tasman Sea outside Shoalhaven Heads and Crookhaven Heads. The model includes the main Shoalhaven and Crookhaven River channels, their floodplains and the lower reaches of the major tributaries including Nowra and Browns Creeks, Bomaderry Creek and Broughton Creek.

The model extents cover the Nowra, Bomaderry, Terara, Berry, Greenwell Point, Orient Point, Shoalhaven Heads and part of the Culburra Beach townships.

The TUFLOW model extents are shown in **Figure 5-1**.

5.2.2 Model Grid Size

In the adoption of an appropriate grid cell size, it is important to consider both the level of refinement of the model results, together with the overall run times. While a high level of refinement may be preferred in some cases, a model that takes a significantly long time to run can create issues in the calibration phase as well as in later phases in the assessment of mitigation options. Therefore, it is important to achieve a balance.

A 15m x 15m grid cell size has been adopted to allow faster model run times to test adjustment of model parameters. A 15m grid model was also chosen to achieve a reasonable balance among an appropriate grid resolution for results, overall run times and resolution of the input data given the size of the overall model extent.

It is noted that the Wu equation has been included in the latest version of TUFLOW by the software developer as it was found that the traditionally used Smagorinsky method is not independent of grid size, particularly where the depth is much greater than the grid size, and hence, different results are achieved using different grid sizes. As a result, a sensitivity was undertaken to examine the impacts of changing the grid size. This showed that with the Wu viscosity formulation, grid size has minimal effect on the flood levels which converge to a similar value with either a 10m or 15m grid.

5.2.3 Topography

The Digital Terrain Model (DEM) was developed from the LiDAR data available at Cardno GeoHub supplied from NSW Government – Land and Property Information (LPI) from 2010 (Nowra), 2011 (Kiama) and 2015 (Moss Vale) with a 1m cell size. The **Figure 3-1** shows the extent of Lidar data and 2D hydraulic model extent.

The bathymetry data was provided by Council from DPE Bathymetric Survey database (56228) collected between Sept 2005 and Nov-2006 and was used in the WMAwater 2013 Flood Study.

Parts of the topography of the Lower Shoalhaven River floodplain has changed due to new developments and rehabilitation of the Terara levee (in 2005). As such, model setup incorporating these topographical changes are relevant to recent flooding information used to calibrate and validate the models.

For Design Event modelling terrain modifications were made to include major infrastructure projects under construction at the time of the study i.e. Berry to Bomaderry Bypass and Nowra Bridge duplication road design finished levels based on the approved designs which were provided by TfNSW.

These were not included in calibration/validation event modelling.

5.2.4 Drainage Channels

Within the Lower Shoalhaven River catchment there are numerous flood mitigation drains, agricultural drain and small creeks along the floodplain. For some of these watercourses, the LiDAR data does not appropriately define the channel as the LiDAR data has been altered by heavy vegetation and other obstructions picked up within the LiDAR.

For any major flowpaths, these water courses have been modelled to remove these obstructions to allow for a continuous channel and represent more realistic flows through these areas. This has been digitised with channels cut into the terrain guidance using recent aerial imagery and the upstream and downstream LiDAR and bathymetry data. Many of these channels have a bridge or culvert at the outlet through a road or levee with a floodgate installed. These have been modelled as appropriate described in the following section.

For Bomaderry Creek, the channel bathymetry information used in the Bomaderry FRMSP Model (Cardno, 2013) have been applied.

5.2.5 Bridges, Culverts and Levees

The Lower Shoalhaven River floodplain has numerous structures within waterways that may influence the hydraulic behaviour. These structures are mainly along the Princes Highway and the railway corridor, although various other crossings are present including at Greenwell Point Road, Albatross Road, Bolong Road and Yalwal Road along with other smaller structures within agricultural drainage channels.

Structures described in Section 3.3.2 and 3.3.4 have been included in the model, including bridges and culverts – either surveyed or based on Council GIS information, flood mitigation channels, levees and floodgates.

Where available levees have been included based on survey, else the ALS has been checked to ensure that the levees are represented. Z-lines with elevation for the top of levee have been used to reinforce the levee in the model grid for the Riverview Road and Terara Levees.

As detailed information about floodgate type and discharge rating curves were not available, it was agreed with Council to model these structures as unidirectional flow culverts such that flow is only allowed to flow out of these structures from the floodplain areas and does not allow tidal flows to flow back through these structures.

In addition, for design event simulations, major infrastructure projects under construction at the time of the study were also included in the models:

- Berry to Bomaderry Princes Highway upgrade - The road formation and hydraulic structures including bridges and culverts have been included in the model based on the approved design which was provided by TfNSW; and
- Nowra Bridge Duplication - While under construction at the time of this study, this highway upgrade has been included in the model based on the approved design which was provided by TfNSW. This includes the road formation and Nowra Bridge duplication and Bomaderry Creek bridge widening

The stormwater infrastructure is included as 1D elements within the hydraulic model. The 1D elements are connected directly to the 2D domain allowing for flows to interact with the modelled structures. Details of the source of hydraulic structure information is provided in **Section 3.3.2** and **3.3.4.**

Figure 5-1 below shows the location of the structures included in the TUFLOW hydraulic model.

5.2.6 Roughness

The roughness applied within the Hydraulic model extents have been determined based on the previous studies (previously applied in the Lower Shoalhaven Flood Study) and Aerial Imagery. The applied Manning's roughness values for different land types are shown in **Table 5-1** below. The roughness map is shown in **Figure 5-2**.

Table 5-1 Manning 'n' Roughness values applied to each land type in the TUFLOW model

Land Type	Manning's "n" Roughness Value
Roads and Railway Lines	0.02
Water Courses	0.02
Vegetated Waterways, Sand Banks and Grass Islands	0.03
Floodplain - Low Grass	0.035
Parks and Gardens	0.04
Swamp Land	0.06
Industrial Developments	0.07
Urban Development	0.08
Dense Vegetation	0.09

5.2.7 Tidal Boundary

For the calibration and validation events, tidal hydrograph data was obtained from MHL for the Jervis Bay gauge (Station No. 216470). This water level time series data was applied to the Shoalhaven Heads and Crookhaven Heads ocean boundaries as the downstream boundary condition.

In comparing the Crookhaven Heads Gauge and Jervis Bay Gauge it is clear that the Crookhaven Gauge is influenced by the freshwater flows and would not provide an accurate ocean boundary representation. However, data from the Jervis Bay Gauge was only available for the June 2013 and August 2015 events, so the tidal boundary for the June 2016 event was adopted based on level data at Crookhaven Heads.

5.2.8 Inflow Boundaries

Inflow hydrographs derived from the hydrological model are applied at the upstream model extents along the Shoalhaven River upstream of Grassy Gully, and at the boundary along each of the tributaries. Inflow hydrographs derived from the hydrological model are also applied as an internal boundary condition at each sub-catchment outlet within the TUFLOW model extent.

The XP-RAFTS sub-catchment characteristics used within the model is shown in **Appendix A**.

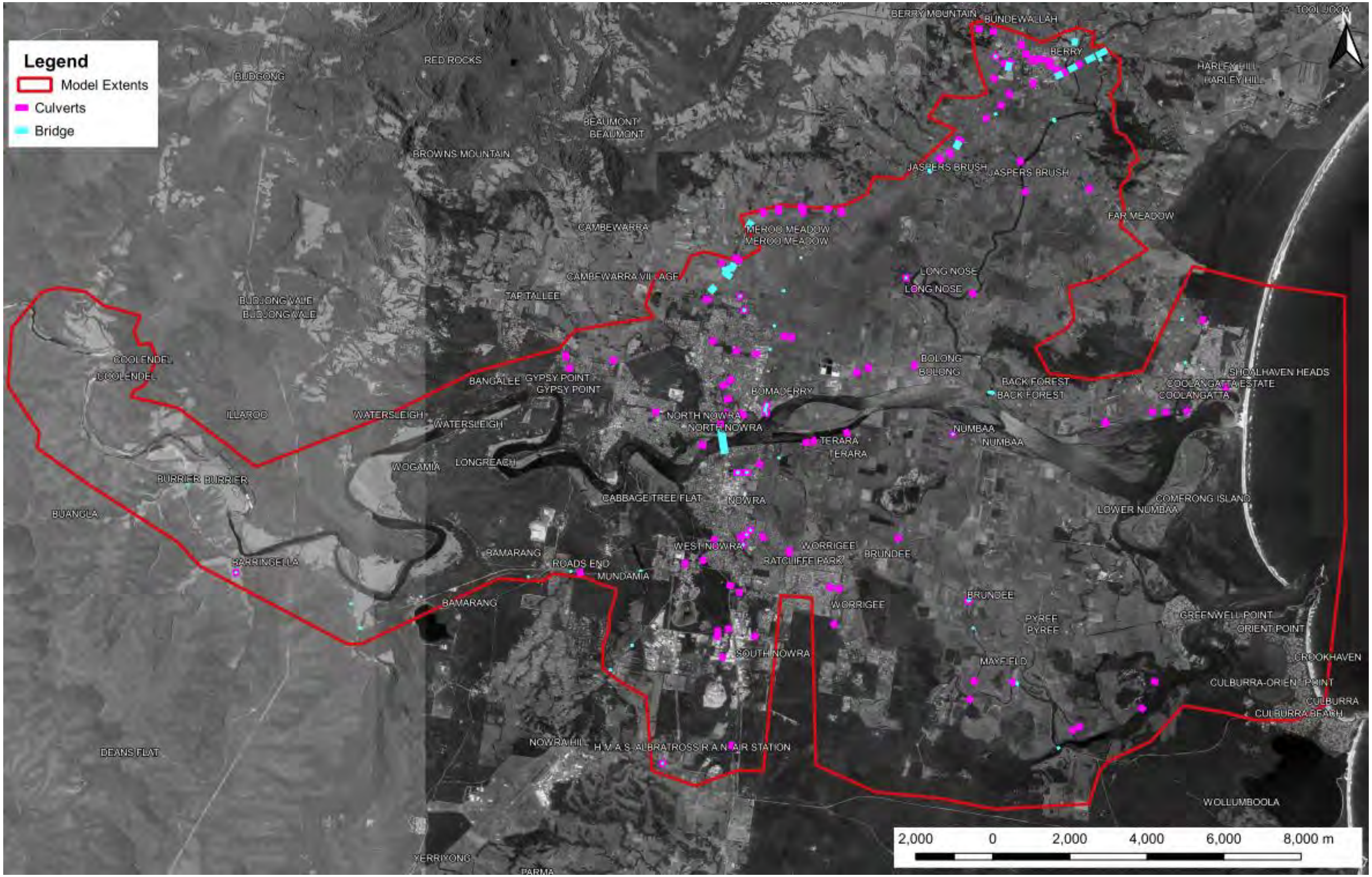

Figure 5-1 Location of Bridge and Culvert Structures Modelled within TUFLOW

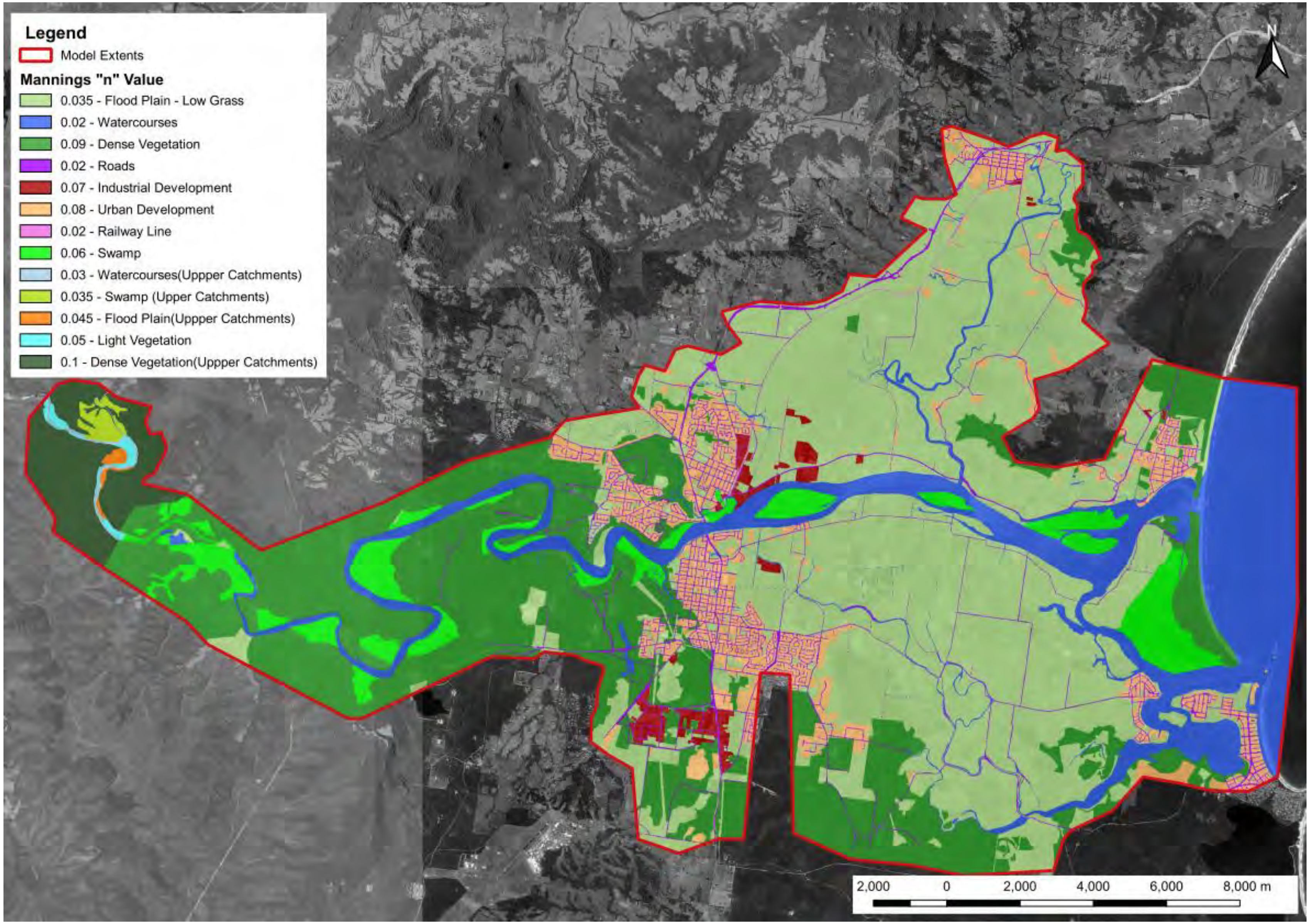

Figure 5-2 Applied Roughness Zones within the Hydraulic TUFLOW Model

5.3 Shoalhaven Heads Breach Modelling

Flood flows in the Lower Shoalhaven River system outlet to the ocean through Crookhaven Heads (via Berrys Canal) and through Shoalhaven Heads. Crookhaven heads is a permanently open trained entrance, while Shoalhaven Heads is a dynamic entrance which is typically closed with a coastal beach and berm with a berm height at around 2m AHD. During flood events, the berm and the entrance shoals will scour and the entrance opens to a width to accommodate the flows for the relevant event. The entrance will then subsequently enter a closing cycle where sediment is again deposited in the entrance through coastal tide and wave action which creates the flood tide delta which eventually closes the entrance and re-establishes the berm. The state of the entrance will influence water levels inside the entrance, particularly for smaller events, and it is important to be able to model the distribution of flows between Crookhaven Heads and Shoalhaven Heads during an event. Further, Council have an entrance management policy under which Council will cut a 1m deep (4m wide) notch in the berm when the water level at Nowra Bridge reaches (or is expected to reach) 3.0m AHD or water level reaches (or is expected to reach) 2.0m AHD at Shoalhaven Heads, to allow the flood flows to begin the breach development of berm to open the Shoalhaven River entrance at Shoalhaven Heads.

The TUFLOW hydraulic model being used for this study uses a fixed bed/bathymetry which means it does not incorporate a movable bed model to allow the dynamic nature of the entrance sediments to be modelled. However, it is important to understand the entrance dynamics and opening dimensions achieved under various flows to allow this to be represented in the model.

A breach development study was undertaken to quantify the breach development at the Shoalhaven River entrance at Shoalhaven Heads during flood events. A Delft3D model was developed in order to simulate the breach formation using a sediment transport model and the model was calibrated to the August 2015 flood event. The model allowed for the distribution of flows between Crookhaven Heads and the Shoalhaven Heads as the breach developed for a range of design flood event inflows. The model was used to approximate the breach development for the 1%, 5%, 20% AEP and PMF flows. A technical report on the development of this model is provided in **Appendix K**.

The resulting output of the breach modelling provided a relationship between breach width and Shoalhaven River flows (**Figure 5-3**). This relevant breach width for each event (**Table 5-2**) was incorporated into the TUFLOW model as a bathymetry surface of the final breach width and depth.

Figure 5-3 Relationship between flow at Nowra Bridge and Shoalhaven Heads breach opening width

Table 5-2 Shoalhaven Heads calculated breach widths

Flow Event	Post-breach channel width @0mAHD
20% AEP	70
10% AEP	280
5% AEP	320
2% AEP	345
1% AEP	400
0.2% AEP	490
PMF	600

Sensitivity runs were undertaken in TUFLOW to allow a breach development as determined from the Delft3D model through a time varying bathymetry grid at the entrance developing to the full width over 30 hours following a trigger level of 3m AHD at Nowra Bridge as per the Shoalhaven Heads Entrance Management Plan. The model was also run with the final bathymetry of the peak developed opening width and depth. This showed that using a fixed open entrance from the start of the simulation had no influence on the peak flood levels obtained, with changes to the flood levels only occurring during the rising limb of the flow hydrograph (**Figure 5-4**).

As such, for the design event modelling, the Shoalhaven River entrance at Shoalhaven Heads were modelled as open with the bathymetry representing the final breach width and depth associated with each flow rate. Sensitivity to a closed Shoalhaven Heads has also been assessed and is discussed in **Section 10.7.4**.

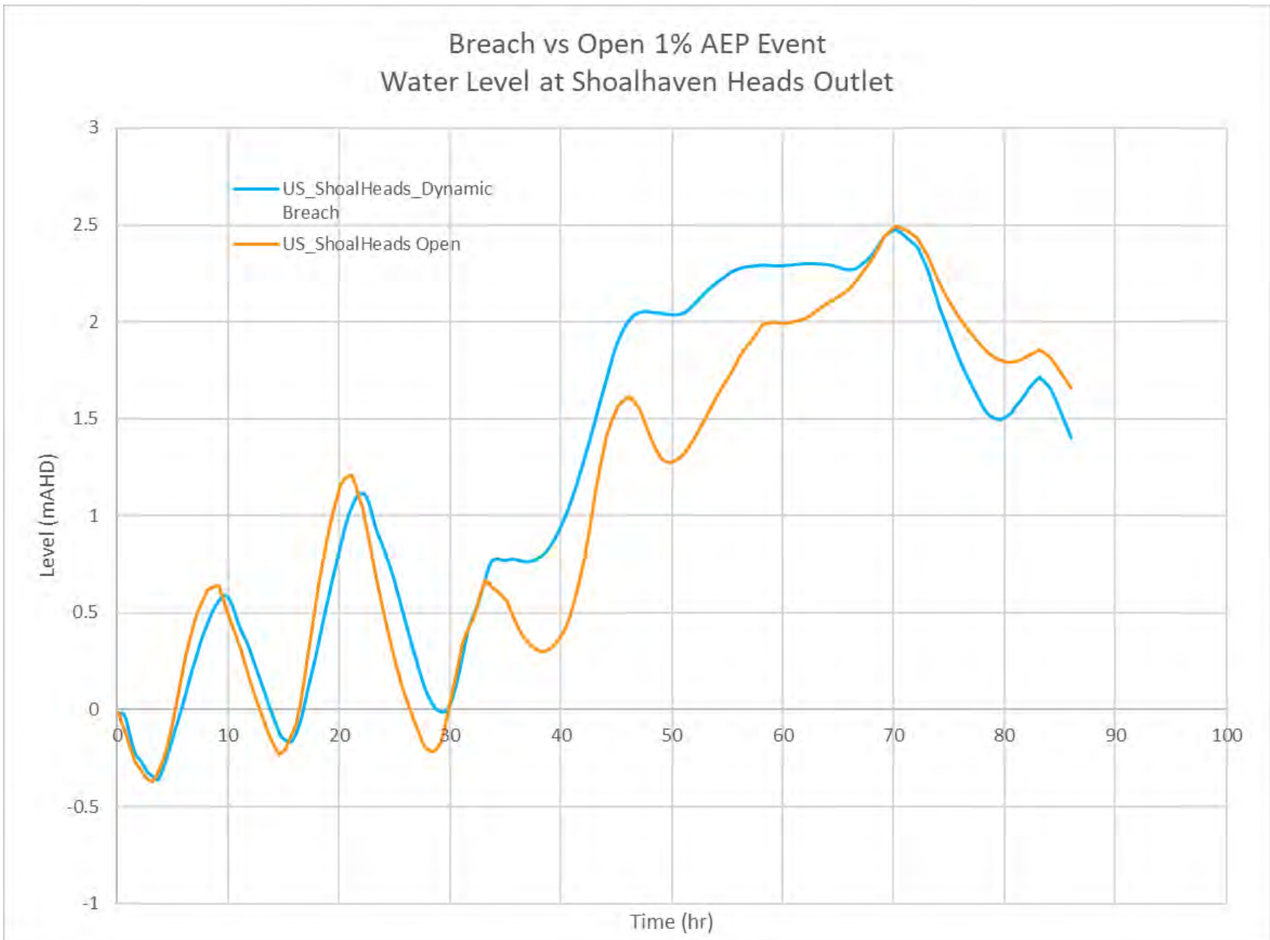

Figure 5-4 TUFLOW water level sensitivity at Shoalhaven Heads using a dynamic breach opening vs fully open entrance

Note: the earlier adopted PMF result was used to approximate the breach development. Following adoption of higher PMF flows, a sensitivity test was undertaken to assess possible impacts of the higher PMF (leading to a wider opening) on water levels. The sensitivity test showed that the higher PMF would have a limited impact on flood levels. Hence, no updates were undertaken as part of this flood study. However, the entrance breach model could be revised and updated during the FRMS&P phase.

6 Model Calibration and Validation

The model calibration and validation was undertaken in two steps, hydrological model calibration and hydraulic model calibration.

The selected storm events considered for calibration and validation are described in **Section 3.4.6**, and include:

> August 2015;
> June 2013;
> June 2016; and
> March 1978.

For the purposes of this study, the August 2015 flood event was chosen as the calibration event as it had the greatest availability of reliable data, including gauged flow and level data and surveyed flood marks provided from Council. Of the three selected storm events, the August 2015 event is the largest recent event (prior to the August 2020 flood event) in terms of flood levels in the Lower Shoalhaven River area. Validation of the model was undertaken using the June 2013 and June 2016 events comparing model results against gauged flow and water level data. The March 1978 event was modelled in the hydrology model to validate that the behaviour and flows would be appropriate for a larger event.

6.1 Hydrological Model Calibration

The calibration of the XP-RAFTS rainfall-runoff model is a vital part of the flood study update process as it establishes that the modelled conditions represent as accurately as possible the catchment's response during a flooding event.

The aim of the calibration is to determine the different model parameters that best represent the catchment's response in order to produce representative design flows for the hydraulic model. The XP-RAFTS model was calibrated and validated through the use of eight (8) available streamflow gauges within the catchment. The location of these stream flow gauges is provided in **Figure 3-5**.

The storm events that were used for the calibration and validation are June 2013, August 2015 and June 2016. The initial water level in Tallowa Dam for each event is noted in **Table 4-4**. Less information is available for the March 1978 event and rainfall and flow gauge information was obtained from the 1990 Flood Study. Tallowa Dam was assumed to be full at the start of the event.

The hydrological modelling was undertaken to develop catchment runoff hydrographs for the sub-catchment areas for the four historical storms. These hydrographs were then used as inflow boundaries for calibration of the hydraulic modelling.

Steps in the calibration and validation process for the Lower Shoalhaven River catchment included:

> Establishing the hydrological Model within XP-RAFTS;
> Include already calibrated catchments from previous flood studies;
> Extract one-minute rainfall data from BOM for gauges within the catchment (due to the length of the three specified events, the 1-minute data was converted into 15 minute intervals);
> Undertake a suite of hydrological model runs adjusting PERN, initial losses, continuing losses, rainfall allocation and catchment storage factor to match to the 8 available flow gauges within the catchment, focusing on calibration to the August 2015 event and validating the model set up through the June 2013 and June 2016 event;
> Developing design hydrographs from the calibrated model and running 0.5%, 1%, 2%, 5%, 20%, 50% and 63.2% AEP Events using the XP-RAFTS model using the ARR2019 rainfall, temporal patterns and areal reduction factors available on the ARR Data Hub utilising Storm Injector software;
> Compare modelled flood design discharges to design flood discharges derived from flood frequency analysis (FFA) at the Shoalhaven River at Grassy Gully (**Section 7**); and
> Adjust losses within the hydrologic model to arrive at a flow within the FFA constraints.

In order to arrive at the best possible fit to the gauge data, multiple calibration runs were undertaken testing the sensitivity and range from different model constraints.

In order to provide an appropriate calibration, the following model parameters were modified to determine the best fit of model behaviour to the gauge data.

6.1.1 PERN - Land Use

Due to the difference of land use and topography within the catchment, different values of PERN were applied within the pervious hydrological catchments upstream of the hydraulic boundary.

The following PERN values were tested for pervious sub-catchments, with the best PERN value chosen based on land use in different areas of the catchment as well as correlation with the streamflow hydrograph gauge data:

- 0.045;
- 0.06; and
- 0.08.

The adopted PERN values were applied consistently to the August 2015 Calibration event, and the June 2013, June 2016 and March 1978 validation events. The adopted PERN values are shown in **Table 4-1.**

6.1.2 Catchment Storage Coefficient

Catchment storage coefficient (B) is calculated based on catchment area, slope and degree of imperviousness. This value is further influenced by the catchment roughness depending on the chosen PERN parameter. Due to the large size of the Shoalhaven River catchment and differing topography and land use, different values of PERN had to be applied to different areas within the catchment.

The shape of the hydrograph can be globally modified by changing the Catchment Storage Coefficient Multiplication Factor (Bx). Bx values of 0.8, 1.0 and 1.2 were tested to assess the catchment response. It was found through the calibration runs that a Catchment Storage Coefficient Multiplication Factor (Bx) value of 1.2 was appropriate to achieve a good correlation with the catchment response.

6.1.3 Lag Time

Throughout the catchment a stream velocity of 1m/s was assumed in the calculation of the lag time applied.

Through the calibration process, sensitivity was undertaken by varying the lag times globally. Lag times scenarios tested were:

- 0.5 x lag time;
- 1.5 x lag time; and
- 2.0 x lag time.

In general, it was found that shorter lag times provided a fast catchment response with a peak flow that was too high, while longer lag times had a peak that was too low.

Results of the hydraulic modelling showed a lag in the timing of the peak flows in the Lower Shoalhaven estuary indicating that the inflow hydrographs were delayed by around 6-12hours. With closer inspection of the topography, it was found that the Shoalhaven River channel gradient steepens between west of Nerriga and Fossickers Flat, and a stream velocity of 2 m/s was adopted. This resulted in better timing of the peak flow at the Fossickers Flat Gauge. Downstream of Tallowa Dam, the stream velocity of 2.5 m/s was adopted using the hydraulic model results for velocities near Gradys Caravan Park as a guide. This assisted the timing of the peak in the Lower Shoalhaven River within the hydraulic model study area.

Furthermore, based on the results of the calibration of the XP-RAFTS model with the converted WBNM model, 52% of the lag time value was applied to each link for the PMP event to ensure the PMF flows were not underestimated.

6.1.4 Rainfall Losses

Different initial loss (IL) and continuing loss (CL) values were applied in order to provide the best match with the flow gauge data for each event. The best fit for each of the 3 calibration/validation events is shown in **Table 6-1** below.

Cardno tested a range of IL and CL values within XP-RAFTS to check the sensitivity of flow results to loss parameters. The values tested were determined using losses applied in previous studies and ARR2019 recommended values and guidance.

Initial losses tested include:

> 10 mm;
> 15 mm;
> 29 mm;
> 37 mm; and
> 51 mm.

It was found that the model was sensitive to changes of CL, affecting the peak in the catchments corresponding with gauge locations. A number of different losses were applied, including:

> 2 mm/hr;
> 2.5 mm/hr;
> 3 mm/hr;
> 3.5 mm/hr;
> 3.8 mm/hr;
> 4.2 mm/hr; and
> 4.5 mm/hr.

Due to the large size of the catchment different losses were applied to different areas of the catchment based on the results from the calibration scenarios and guidance from ARR Data Hub. The losses that provided the best match within the 3 calibration/validation events are shown in **Table 6-1 below.**

Table 6-1 Adopted Rainfall Losses for August 2015 and June 2013 Event

Location	Initial Loss (mm)	Continuing Loss (mm/hr)
U/S of Warri gauge	37	2.5
Kangaroo Valley	51	2
All other areas U/S of Hydraulic Model Boundary	29	2
Lower Shoalhaven - Within Hydraulic Model Boundary	29	2

Table 6-2 Adopted Rainfall Losses for the June 2016 Event

Location	Initial Loss (mm)	Continuing Loss (mm/hr)
U/S of Warri	37	4.5
Kangaroo Valley	51	2
All other areas U/S of Hydraulic Model Boundary	29	4
Lower Shoalhaven - Within Hydraulic Model Boundary	29	4

6.1.5 Rainfall

To apply the gauged rainfall to the hydrological model for the calibration event, Thiessen Polygons were originally developed using the 6 available AWS gauges to determine the nearest gauge to be applied to each catchment. However, due to the size of the catchment, the relatively sparse distribution of AWS rainfall gauges and the variability of the catchment characteristics, using only the AWS gauges did not provide an accurate calibration with the flow gauges.

To improve the calibration, daily read gauge data was sourced from BOM for the three events, to determine the spatial variability of rainfall over the catchment. Of the 50 daily read gauges within the catchment, 23 gauges were chosen to represent the rainfall volumes throughout the catchment. Gauges were filtered to reduce the number where the adjacent gauges had similar rainfall and having multiple gauges would not add value to the calibration. The greatest variability of rainfall between closer gauges/catchments was found to be within the Kangaroo Valley and Lower Shoalhaven River areas, and hence more daily read gauges were used in these areas.

To best cover the full hydrology of the catchment, a total of 28 rainfall gauges were used, including 5 available AWS 1 minute data gauges and 23 daily read gauges, representing the rainfall distribution over the large catchment for each of the specified historic events. The gauges used for temporal patterns is shown in **Table 6-3** and daily read gauges and their allocation to catchments is shown in **Figure 6-1**.

Inspection of available BOM rain radar data was undertaken to analyse the rainfall patterns over the course of each calibration/validation event. There are 2 radar loops that cover the Shoalhaven River Catchment, BOM Wollongong Radar Loop (IDR033) and BOM Canberra Radar Loop (IDR403). The distribution of rainfall totals for each day of the event was also assessed at each gauge to compare with the AWS temporal patterns. This allowed inspection of which AWS gauge most closely represented the temporal pattern in each area of the catchment.

The daily read gauge data was converted to 15 minute rainfall inputs by distributing the total event rainfall at the daily read gauge using the temporal pattern of the closest or most appropriate AWS gauge over the duration of the event. Thiessen Polygons were then used to determine the closest rainfall gauge to be applied to each catchment.

The gauges used and temporal pattern allocation is shown on **Figure 6-1** below. **Figure 6-8, Figure 6-9** and **Figure 6-13** each indicate the total rainfall depth applied at each location for the August 2015, June 2013 and June 2016 events respectively.

Table 6-3 Rainfall AWS Gauge Data used for Calibration Events Temporal patterns throughout the catchment

Station ID	Station name	Type	Period of Record	Source
69132	Braidwood Racecourse	Rainfall (1 min)	Sep 2010 - Current	BOM
70351	Canberra	Rainfall (1 min)	Apr 2009 - Current	BOM
68242	Kiama	Rainfall (1 min)	Sep 2010 - Current	BOM
69128	Nerriga	Rainfall (1 min)	June 2013 - Current	BOM
68072	Nowra	Rainfall (1 min)	Nov 2011 - Current	BOM
68239	Moss Vale	Rainfall (1 min)	Sep 2010 - Current	BOM

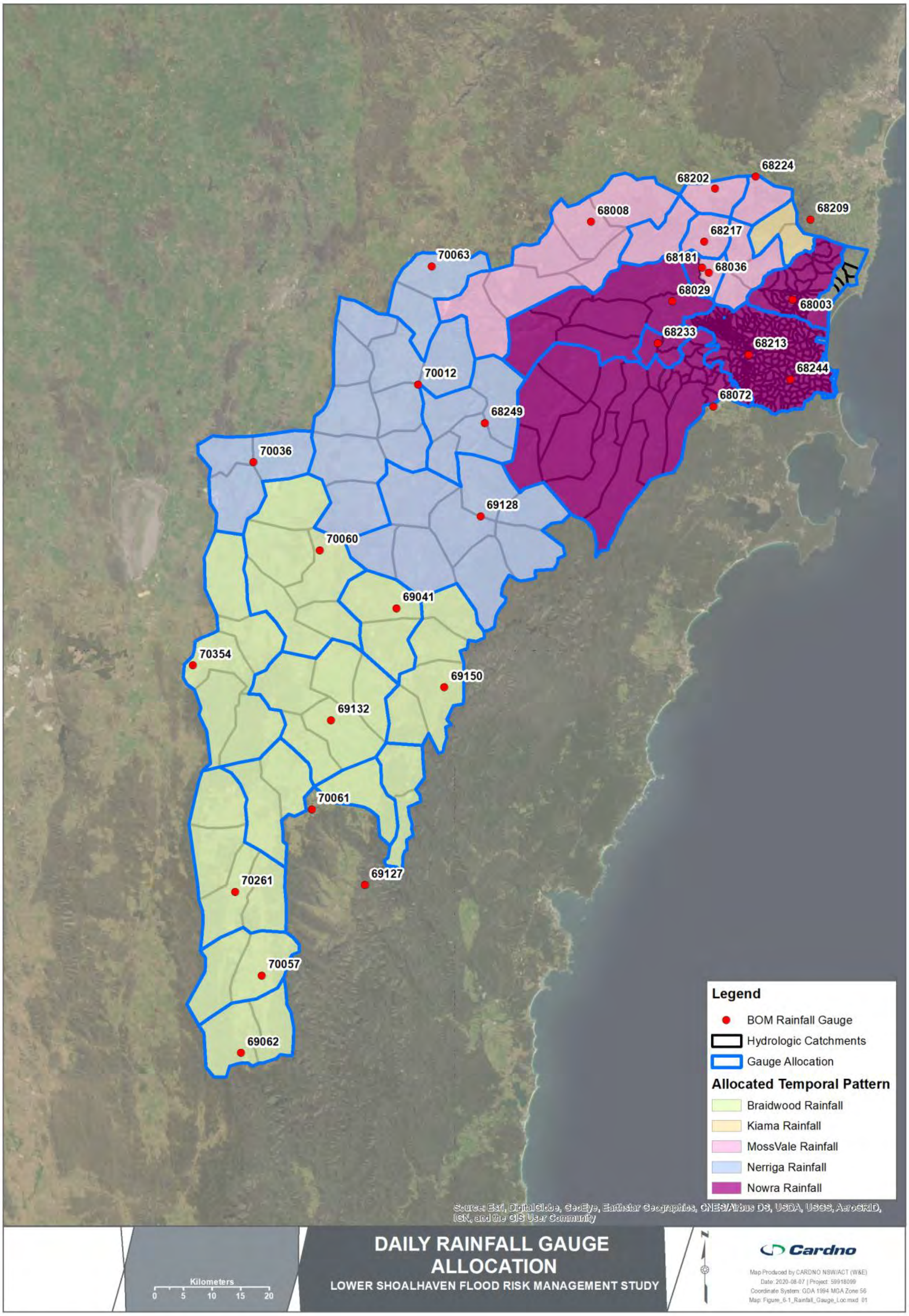

Figure 6-1 Allocation of Rainfall Gauges used within the 2013, 2015 and 2016 Event Hydrological Models

6.2 Hydraulic Model Calibration and Validation Approach

The TUFLOW model was calibrated using the August 2015 flood event and validated with the June 2013 and June 2016 flood events. The approach and methodology are described below.

Model parameters were initially chosen based on literature, observation of land use, vegetation, field inspection and data from previous models and studies. The model was run for the calibration event and model parameters adjusted until a good comparison of modelled water levels and gauged water levels was achieved at each of the 5 water level gauge locations.

A further 28 surveyed water level locations were available for comparison for the August 2015 event.

Calibration was achieved through adjustment of Manning's n roughness values, and adjustment of the assumed Shoalhaven Heads entrance bathymetry to allow a good match to the tidal response before and after the flood flows, as well as the peak of the flood flows.

6.2.1 Manning's n Roughness Values

As part of the hydraulic calibration, the value of Manning's 'n' assigned to the main watercourses in the hydraulic model was varied to assess the effect on modelled results. The Manning's n values tested included:

> 0.02;

> 0.025; and

> 0.03.

It was found the Manning's 'n' value of 0.02 provided the most accurate comparison with the available water level gauge data. The sensitivity of modelled design flood levels to out-of-bank roughness has also been assessed for design flood events as discussed in **Section 10.7.2**.

6.2.2 Shoalhaven Heads Entrance Conditions

Shoalhaven Heads survey collected in 2015 was provided to Cardno by Council and represents a closed Shoalhaven Heads scenario. However, there is no survey or information available on the entrance conditions immediately before, during, and immediately after each event. As such, it is not possible to simulate the dynamic entrance conditions present during each calibration and validation event using an entrance breach or scour model. Instead, observation of aerial photographs before and after the three calibration events was undertaken to determine the appropriate entrance condition assumptions for each event. This showed:

> June 2013 (**Figure 6-2**) – Photo from 5 July 2013 (just after the June 2013 event) shows an entrance channel of approximately 100m width with significant scouring of the alluvial shoals inside the entrance. The entrance channel width is assumed to have peaked at around 175 m using adjacent dune vegetation as a guide.

> August 2015 (**Figure 6-3**) – Photo from 10 August 2015 (just before the August 2015 event) shows a closed entrance with a low berm which looks to be overtopped in a high tide and significant shoals inside the entrance. The entrance low berm width is estimated to be approximately 100-140m. The entrance channel width is assumed to have peaked at around 200-250 m during the event using adjacent dune vegetation from the photo on 4 March 2016 as a guide.

> June 2016 (**Figure 6-4**) - Photo from 29 May 2016 (just before the June 2016 event) shows a closed entrance with a low berm which looks to be overtopped in a high tide and significant shoals inside the entrance with deeper channels through the shoals. The entrance low berm width is estimated to be approximately 100-120 m. Entrance channel width is assumed to have peaked at around 350 m during the event using adjacent dune vegetation from photo on 1 May 2017 as a guide. The shoals inside the entrance appear to be smaller when compared with before the June 2016 event possibly indicating significant scour of these shoals. However, it is noted that this photo is almost a year after the event.

Figure 6-2 Aerial Photographs before (17 July 2012) and after (5 July 2013) the June 2013 Event

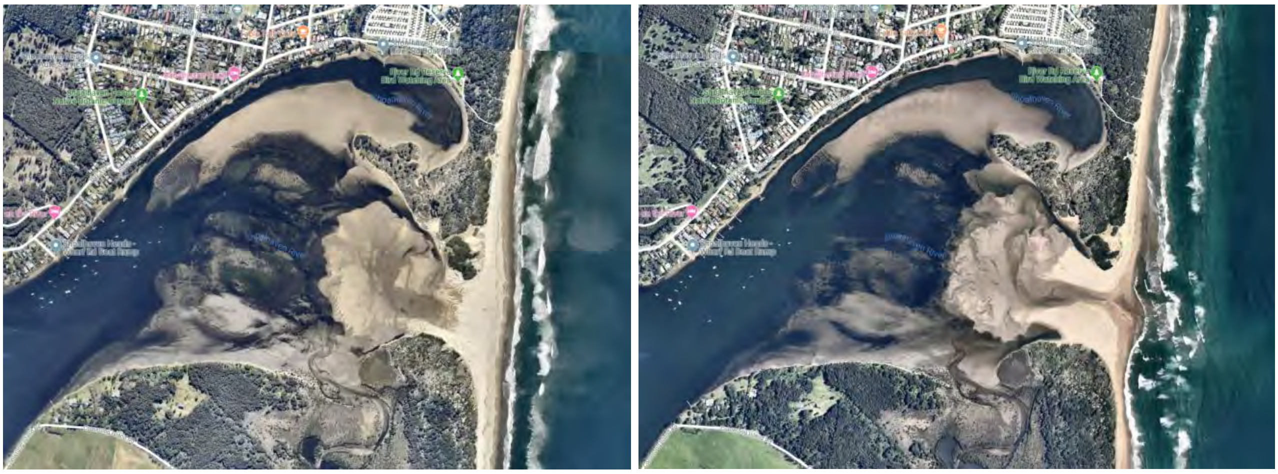

Figure 6-3 Aerial Photographs before (10 August 2015) and after (4 March 2016) the August 2015 Event

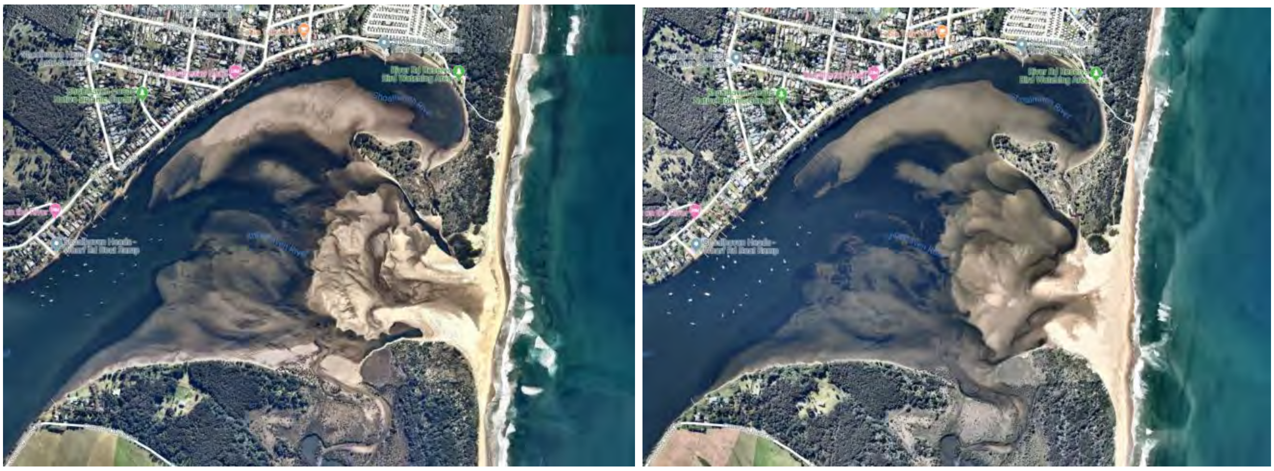

Figure 6-4 Aerial Photographs before (29 May 2016) and after (1 May 2017) the June 2016 Event

To determine the effect of the entrance condition on tidal response and flood flow peak water levels, the August 2015 event was simulated with the closed entrance berm and two different assumed entrance channel widths.

The options assessed included:

> Option A – The heads were modelled using the provided Shoalhaven Heads survey data, which is a closed entrance scenario;

> Option B – To connect the estuary to the ocean, the bed was lowered and widened at the entrance and extended through the shoaled area behind the berm. The entrance channel was opened to approximately 350m wide, with scouring of the shoals and the bed level interpolated from the river bed level of approximate RL -0.5m to the ocean bed RL of -1.0m; and

> Option C – As for Option B, except the entrance channel was opened to approximately 200m wide, with the bed level interpolated from the shoal height of approximate RL 0.5m to the ocean bed RL of -1.0m.

The open entrance scenarios provided a closer match to the tidal response and flood flow behaviour through the entrance compared with the surveyed berm scenario. Option C provided the best representation of the tidal signal and gauged peak levels for the August 2015 calibration event and was adopted for the model calibration. This entrance scenario was also assumed to apply to the other two validation events.

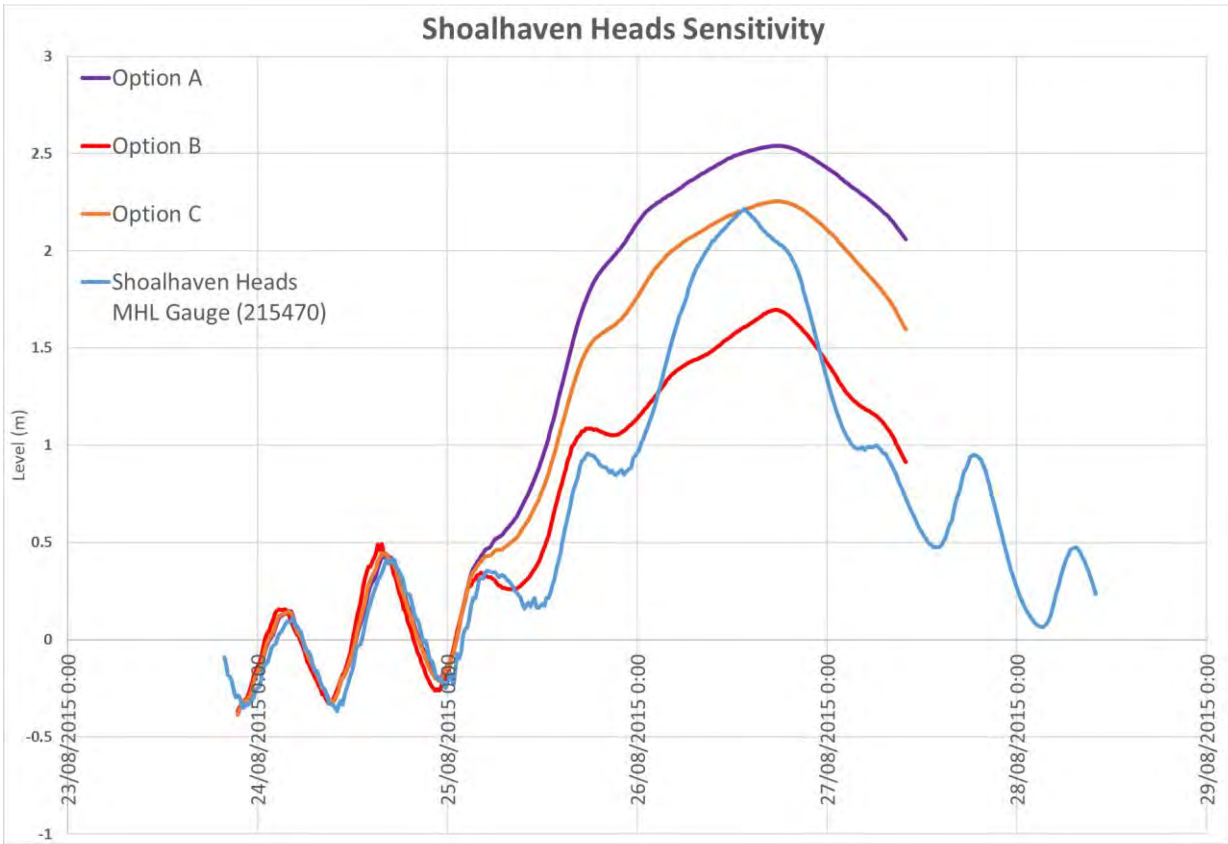

Figure 6-5 Shoalhaven Heads Opening Sensitivity

6.2.3 Surveyed Flood Levels

For the August 2015 event, Council provided Cardno with surveyed flood level observations at certain locations within the Lower Shoalhaven River Catchment. The points are located near the Shoalhaven River at Nowra, Bomaderry, Shoalhaven Heads and the Crookhaven River at Greenwell Point. The point locations are shown in **Figure 6-6**. The surveyed points were used to cross-check results of the August 2015 calibration event, as described in **Section 6.3.5**.

6.2.4 Community Consultation

From the Community Consultation a total of 61 responses were provided through the Survey Monkey Consultation questionnaire. Of the 61 respondents 41 indicated that their property had been affected by flooding and 14 respondents provided estimated flood levels for the 3 calibration events. The location of these responses is shown in **Figure 6-7**. The observed points were used to cross-check results of the August 2015 calibration event and June 2013 and June 2016 validation events, as described in **Section 6.3.7, Section 6.4.6** and **Section 6.5.6** respectively.

Figure 6-6 August 2015 Event Flood Level Survey Locations

Figure 6-7 Community Consultation Response Location

6.3 August 2015 Calibration Event

6.3.1 Description

The August 2015 event is the largest of the recently recorded flood events within the Lower Shoalhaven River Catchment. For this event, the available data includes flow gauge data, water level gauge data, surveyed peak water levels and community observed peak flood levels/depths.

6.3.2 Rainfall Losses

For the August 2015 event the global losses as described in **Table 6-1** were applied.

6.3.3 Rainfall

The allocation of rainfall gauges for the August 2015 event is shown in **Figure 6-8.**

This rainfall application provided the best representation of the volume of rainfall within each catchment and utilising the best matched temporal pattern from the available AWS gauges.

6.3.4 Flow Calibration

Graphs showing the comparison of the modelled flow behaviour during the event at each of the 7 flow gauges and 4 instantaneous flow gauges are presented in **Appendix B.** Note that for the 4 gauges with instantaneous gauge readings at 8am each day, the actual flow behaviour in between each reading is unknown, hence the shape of the hydrograph and the actual peak flow is unknown. Hence, the calibration seeks to have modelled flows which pass through or close to the instantaneous values.

Overall, the modelled catchment response and peak flows show an adequate correlation with the available gauge data, particularly around Tallowa Dam and Burrier, albeit with peak flows slightly lower than gauged values. The following observations are made at each gauge:

> A good correlation with the timing (catchment response) and peak flow is observed at Warri, Bungonia, Tallowa Dam and Burrier gauges:

> Warri – The calibrated flow hydrograph at Warri is a good match with the peak flow, although the volume captured at this gauge was not represented in the available rainfall gauge data;

> Tallowa Dam – Tallowa Dam modelled data compares quite closely to the provided instantaneous flows at the times provided showing an accurate representation of the stage storage and stage discharge relationship within the XP-RAFTS model;

> Bungonia – The modelled flow provided a slightly lower peak but accurate timing with the gauged data;

> Burrier – Compares well with the peak flows, but timing does not match on the rising or falling limb of the hydrograph. Note that there is a large volume of flow occurring earlier than what was recorded, which is caused by the local catchments using the Nowra AWS temporal pattern which shows rainfall occurring during this period. If a local temporal pattern was available, this may show a larger volume of rainfall occurring later, and this would change the timing and peak of the event and model results would provide a better correlation. This is also observed to a lesser degree at Fossickers Flat and Tallowa Dam which is likely due to Nerriga AWS temporal patterns being used:

> Hampden Bridge and Fossickers Flat show a reasonable correlation for timing, with peak flows slightly lower than observed. – This is likely due to differences in the local temporal patterns and the applied temporal patterns as there is a significant gap of AWS stations for catchments within this area to understand the local rainfall pattern. Temporal patterns from Moss Vale and Nerriga have been applied to these catchments. It is expected that local temporal patterns and even localised rainfall burst depths may have been different from available gauges and hence some of the multiple peaks combined with the right timing would boost these peak flows to a closer correlation. This would then have a flow on effect to Tallowa Dam outflows and Burrier peak flows.

> Kadoona – The available rainfall data at this gauge for this event could not give an appropriate flow hydrograph. Different temporal patterns were tested at this gauge, with the daily rainfall volume applied from within the catchment although, no temporal pattern could match the shape and flattened peak represented in the gauged data. This could also be due to a catchment characteristic not being represented within the XP-RAFTS model. Further calibration of the gauge was not undertaken due to

it only representing 3 of the uppermost sub-catchments of the Shoalhaven River and therefore having minimal effect on the hydraulic model inputs;

> Monga – The Mongarlowe River at Monga is representative of one catchment proving difficult to provide accurate timing due to there being no representative temporal pattern for this catchment. Using the daily rainfall gauge closest to this catchment a close peak flow and volume was achieved although timing occurred earlier due to the application of the available temporal patterns; and

> Broughton Creek, Jaspers Brush and Bomaderry Creek all show a reasonable correlation with similar timing of multiple peaks but with different timing - peak flows which are sometimes higher and sometimes lower than the observed peaks. However, overall the modelled volumes compared to gauged volumes are reasonable. For each of these locations, there is only one or two sub-catchments upstream of the reporting location and hence the model results are very sensitive to the temporal pattern for catchment response. The modelled temporal pattern is different to that of the catchments but is the best representation of the available data.

6.3.5 Peak Water Level Calibration

Modelled water levels were compared with gauged water levels at the seven water level gauges within the Lower Shoalhaven/Crookhaven estuary and the results are graphed in **Appendix C**. **Table 6-4** below shows the peak water level comparison at each gauge location.

Table 6-4 August 2015 Event – Peak Water Level Model versus Gauge Comparison

MHL Station No.	Gauge Location	Gauge Data Peak Level (mAHD)	Calibration Run Peak Water Level (mAHD)	Difference Calibration Less Gauged (m)
215216	Grassy Gully II	17.62	18.27	0.65
215430	Grady's Caravan Park	11.94	12.23	0.29
215411	Nowra Bridge	3.89	3.92	0.03
215420	Terara	3.63	3.62	-0.01
215415	Hay Street	2.23	2.25	0.02
215470	Shoalhaven Heads	2.22	2.24	0.02
215417	Greenwell Point	1.30	1.31	0.01
215408	Crookhaven River	1.03	1.11	0.08

The table above demonstrates that the model provides a good correlation with gauged flood levels to within +/- 100mm at most locations. This excludes Grady's Caravan Park which is within 300mm of the gauged peak, which could be due to the supplied bathymetry not reaching to the full upstream extent of the model and therefore affecting the levels at this gauge. Just downstream of the gauge, there are some shoaled areas and a bypass flowpath which may have scoured out during the high flow event, which would lower levels at the gauge in the model. It is therefore deemed an accurate representation of flood behaviour at the gauge locations, which is the most accurate data for calibration.

Observation of the water level comparison plots in **Appendix C** show that the model is able to accurately represent the tidal response before the flood flows begin.

6.3.6 Surveyed Flood Levels

For the August 2015 event Council has provided Cardno with surveyed peak flood levels at certain locations within the Lower Shoalhaven River Catchment. The points are located near the Shoalhaven River at Nowra, Bomaderry, Shoalhaven Heads and the Crookhaven River at Greenwell Point. The point locations are shown below in **Figure 6-6**.

The below **Table 6-5** shows a comparison for the August 2015 event with the hydraulic model showing the difference in the observed and modelled results.

The modelled water levels compare well with surveyed flood marks, to generally within +/- 50mm to 100mm, with the exception of surveyed points around Greenwell Point and within Bomaderry Creek where modelled levels are some 0.5m and 1.3m higher, respectively. At these locations the surveyed levels are assumed to be in error given that gauged water levels downstream of these points are much higher than the surveyed level and gauged levels match with the model results.

6.3.7 Community Consultation Observations

Of the 61 respondents to the community consultation questionnaire, 41 indicated that their property had been affected by flooding and, of these, 8 respondents provided levels for the August 2015 event. The location of these responses is shown in **Figure 6-7**.

The table below shows the comparison of the estimated depths provided by the community and the modelled results.

In general, the model compares well with the community observations. It is noted that there is some variability in the results for depths at properties. This can be explained through inaccuracies in the observed estimated flood depth or differences in the ALS data used in the model and the actual ground levels at the observation location.

6.3.8 Conclusion

The overall response of the hydrological model at the 7 flow gauges and 4 instantaneous flow gauges shows a good correlation with gauged data with peak flows slightly lower than gauged at Burrier, which is the main Shoalhaven River inflow to the hydraulic model. Some gauges show a lesser correlation, however, this is explained through the unknowns of the accuracy of rainfall depths and temporal patterns of rainfall throughout the catchment due to its size and limitations of available rainfall to fully describe the rain event. The accuracy of rating curves for developing flows at these gauges is also unknown and has not been reviewed.

It is considered that the hydrological model is well calibrated and is suitable for use in developing design event hydrographs.

The hydraulic model peak water level results are within +/- 100 mm at most water level gauge locations, excluding Gradys Caravan Park where the model is estimating levels approximately 300mm higher than recorded. A good correlation of peak levels is achieved at the surveyed flood marks and levels/depths reported by the community with almost all having a less than +/-100mm difference, excluding some outliers commented on previously.

Both the hydrological and hydraulic models in combination have been able to adequately represent the August 2015 flood event hydraulic behaviour and the models are considered to be adequately calibrated for use in design flood estimation.

Table 6-5 August 2015 Event Surveyed Peak Water Level versus Modelled Peak Water Level

Point ID	Quality +or- (m)	Surveyed RL (mAHD)	Modelled Peak Water Level (mAHD)	Difference (Modelled less Surveyed) (m)	Comment
2	0.053	2.269	2.251	-0.018	Within Quality Tolerance
5	0.029	2.276	2.243	-0.033	< 5mm of Quality Tolerance
8	0.047	2.238	2.243	0.005	Within Quality Tolerance
10	0.043	2.319	2.25	-0.069	< 30mm of Quality Tolerance
11	0.02	2.279	2.244	-0.035	< 15mm of Quality Tolerance
13	0.027	2.241	2.247	0.006	Within Quality Tolerance
14	0.03	2.26	2.247	-0.013	Within Quality Tolerance
16	0.026	2.259	2.247	-0.012	Within Quality Tolerance
17	0.025	2.27	2.242	-0.028	Within Quality Tolerance
18	0.022	2.277	2.242	-0.035	< 15mm of Quality Tolerance
19	0.017	2.234	2.242	0.008	Within Quality Tolerance
20	0.019	2.281	2.244	-0.037	< 30mm of Quality Tolerance
24	0.022	2.248	2.254	0.006	Within Quality Tolerance
25	0.021	2.27	2.254	-0.016	Within Quality Tolerance
26	0.025	2.343	2.254	-0.089	< 100mm of Quality Tolerance
28	0.014	2.401	3.761	1.36	Surveyed level deemed unreliable due to the backwater from the Shoalhaven River with a gauged peak level of 3.891 mAHD. Surveyed flood mark cannot be lower than the downstream water level.
30	0.021	3.843	3.786	-0.057	< 35mm of Quality Tolerance
31	0.016	3.996	3.79	-0.206	Taken Close to Nowra Bridge
33	0.015	4.002	3.979	-0.023	< 10mm of Quality Tolerance
34	0.015	3.889	4.225	0.336	Modelled levels are higher than surveyed. There is not accurate bathymetry of the Bomaderry Creek U/S of the Princes Hwy Bridge. Channel assumptions used from Bomaderry FRMSP (Cardno, 2016). Representation of hydraulics through the bridge may not be accurate with a 15m grid scale.
35	0.016	0.831	1.31	0.479	Located near Greenwell Point Gauge, Surveyed level appears low compared to nearby surveyed levels and the Greenwell Point gauge peak level of 1.30 m AHD.
36	0.026	1.34	1.321	-0.019	Within Quality Tolerance
38	0.019	1.38	1.325	-0.055	< 40mm of Quality Tolerance
39	0.01	1.36	1.396	0.036	< 30mm of Quality Tolerance
40	0.015	0.985	1.482	0.497	Off Shaws Creek, Surveyed level appears low compared to Greenwell Point gauge peak level of 1.30 m AHD.
43	0.016	0.918	1.481	0.563	Off Shaws Creek, Surveyed level appears low compared to Greenwell Point gauge peak level of 1.30 m AHD.
44	0.017	0.911	1.486	0.575	Off Shaws Creek, surveyed level appears low compared to Greenwell Point gauge peak level of 1.30 m AHD.
GIN IN POST	0.017	2.283	2.254	-0.029	< 20mm of Quality Tolerance

Table 6-6 Calibration to information received for the August 2015 Event through Community Consultation

Respondent ID	Location	Estimated Depth (m)	Modelled Depth (m)	Difference (m)	Comments
2	Shoalhaven Heads	0.47	0.629	-0.159	Within appropriate range
8	Shoalhaven Heads	1.0	0.924	0.076	Within appropriate range
28	Shoalhaven Heads	1.1	1.283	-0.183	Within appropriate range, levels vary throughout the property up to approx. 1.29m depth, from surrounding survey points the estimated depth looks to be slightly lower than surveyed
31	Shoalhaven Heads	1.2	1.051	0.149	Within appropriate range, surrounding surveyed points indicate this value is slightly higher than surveyed
34	Shoalhaven Heads	knee high within the house ~600 mm	0.623	-0.023	Within appropriate range based on assumed levels from the community member
37	Shoalhaven Heads	0.3-0.7	0.259	0.041	Within appropriate range
48	Shoalhaven Heads	0.3	0.377	-0.077	Within appropriate range, surrounding survey points indicate this value is slightly lower than surveyed
52	Shoalhaven Heads	0.25	0.338	-0.088	Within appropriate range, within 0.03 m of surrounding survey point

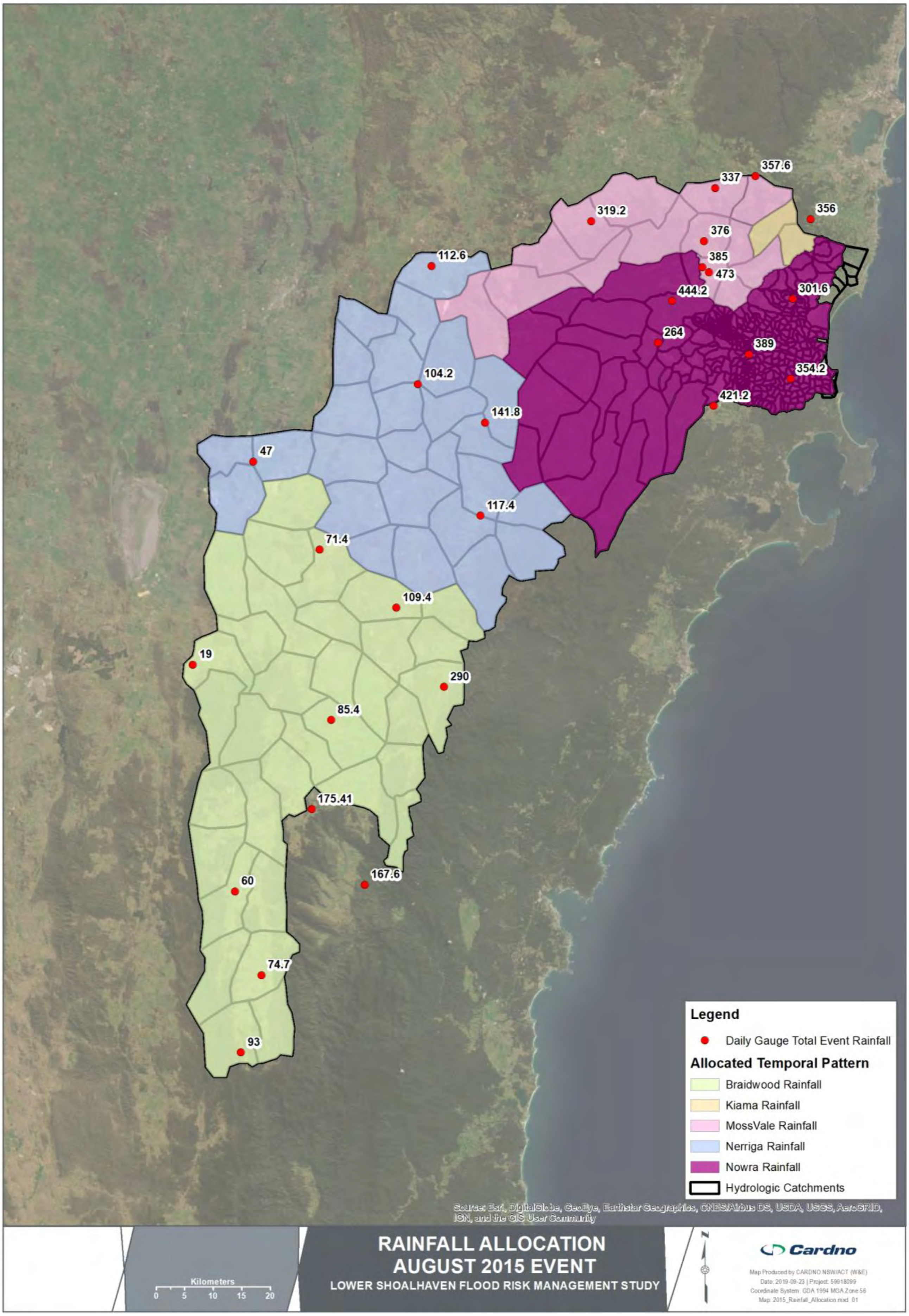

Figure 6-8 Assignment of Gauged Rainfall for Calibration of the August 2015 Event.

6.4 June 2013 Validation Event

6.4.1 Description

The June 2013 Event has the highest peak flood levels of the two validation events in the Lower Shoalhaven River. For this event the available data includes flow gauge data, water level Gauge data and Community observed peak flood depths.

6.4.2 Rainfall Losses

In order to provide higher flows within the Kangaroo Valley catchment a sensitivity to the continuing loss within the catchments upstream of Tallowa Dam along the Kangaroo River was undertaken.

The different loss rates applied include:

> 0 mm/hr;

> 0.5 mm/hr; and

> 2.5 mm/hr.

It was shown that despite lowering the rainfall losses, the volume of rainfall applied was not representative of the event at the Hampden Bridge, Tallowa Dam and Burrier Gauges.

Therefore, for the June 2013 event the global losses as described in **Table 6-1** were applied.

6.4.3 Rainfall

The rainfall allocation to sub-catchments was kept the same as what was applied in the August 2015 event, although two of the daily gauges did not have data for this event. Both gauges, 70354 and 70061 were close to the Braidwood (68132) gauge and therefore it was used for this event.

The Kiama AWS gauge as opposed to the Nowra AWS gauge temporal pattern showed a better response at the Broughton Creek and Jaspers Creek flow gauges and therefore was applied to the upper section of the Broughton Creek catchment.

The rainfall allocation for the June 2013 Event is shown in **Figure 6-9.**

6.4.4 Flow Validation

Graphs showing the comparison of the modelled flow behaviour during the event at each of the 7 flow gauges and 4 instantaneous flow gauges are presented in **Appendix B.** Note that for the 4 gauges with instantaneous gauge readings at 8am each day, the actual flow behaviour in between each reading is unknown, hence the shape of the hydrograph and the actual peak flow is unknown.

Overall, the modelled catchment response and peak flows show adequate correlation with the gauge data, particularly around Tallowa Dam and Burrier, however, peak flows are lower than gauged values. The following observations are made:

> The upper Shoalhaven River gauges (Kadoona, Warri, Monga and Bungonia) all show a reasonable correlation with timing, however, tend to overestimate the peak gauged flow and volume;

> Hampden Bridge and Tallowa Dam show a good correlation with the instantaneous gauged data, while at Fossickers Flat, the modelled peak occurs earlier than recorded;

> At Burrier, the modelled peak flows occur earlier and are lower than the gauged peak; and

> Bomaderry Creek, Broughton Creek and Jaspers Brush all show a good correlation to gauged flow data with differences due to the sensitivity of the modelled catchment to local rainfall amounts and patterns which are not well defined by gauged rainfall.

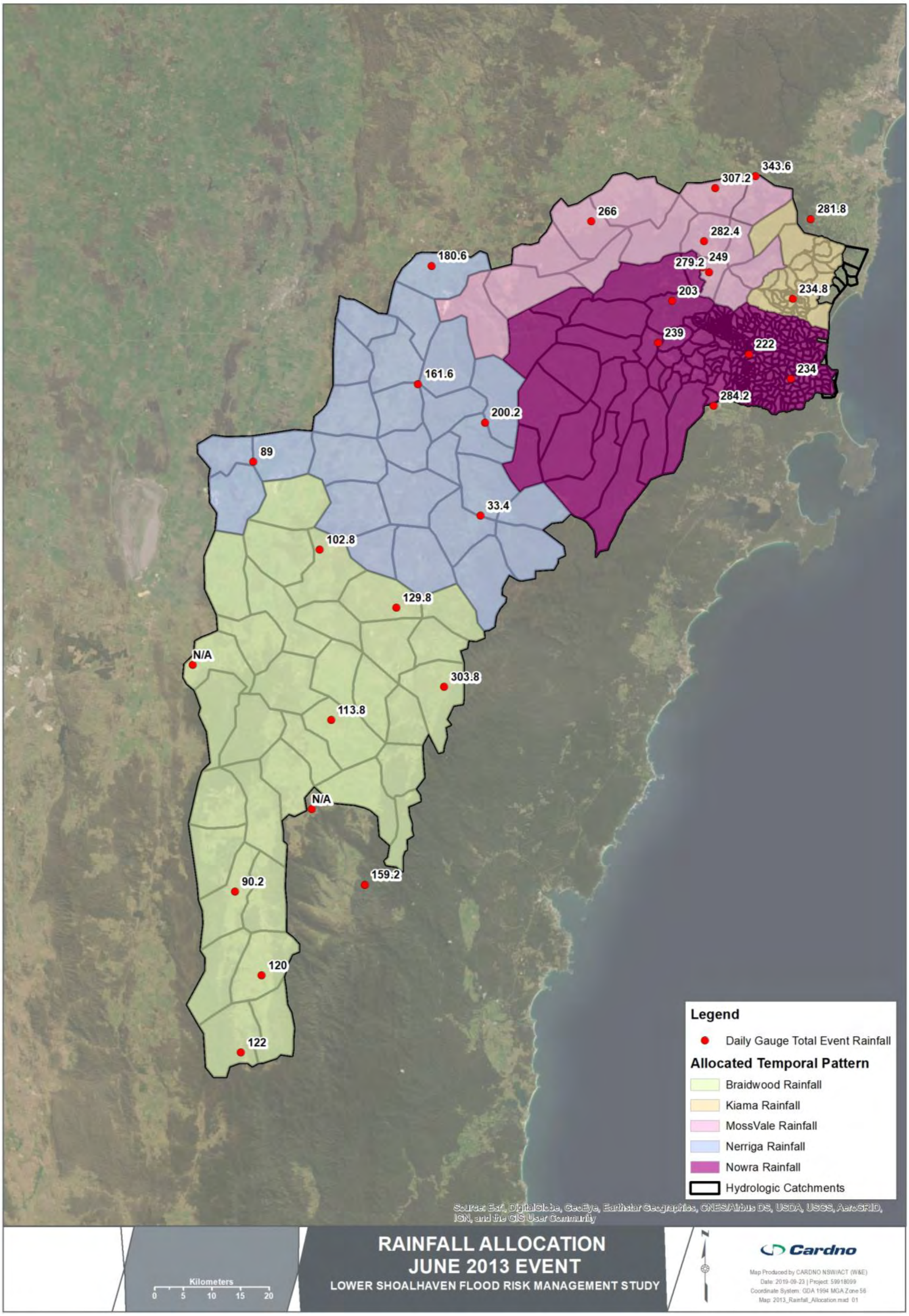

Figure 6-9 Assignment of Gauged Rainfall for model Validation with the June 2013 Event.

6.4.5 Peak Water Level

Modelled water levels were compared with gauged water levels at the seven water level gauges within the Lower Shoalhaven/Crookhaven estuary and the results are graphed in **Appendix C**. **Table 6-7** below shows the peak water level comparison at each gauge location.

Table 6-7 June 2013 Event – Peak Water Level Model versus Gauge Comparison

MHL Station No.	Gauge Location	Gauge Data Peak Level (mAHD)	Modelled Peak Water Level (mAHD)	Difference Modelled Less Gauged (m)
215430	Grady's Caravan Park	11.35	11.23	-0.12
215411	Nowra Bridge	3.76	3.46	-0.30
215420	Terara	3.48	3.22	-0.26
215415	Hay Street	2.27	2.00	-0.27
215470	Shoalhaven Heads	2.26	1.99	-0.27
215417	Greenwell Point	1.54	1.32	-0.22
215408	Crookhaven River	1.34	1.23	-0.11

The table above demonstrates that the model provides a good correlation with gauged flood levels to within +/- 300mm at all locations. It is therefore deemed an accurate representation of flood behaviour and suitable use in simulating design flood events.

6.4.6 Community Consultation

From the Community Consultation flood levels were provided by five respondents for the June 2013 event. The location of these responses is shown in **Figure 6-7**.

Table 6-8 below shows the comparison of the levels provided and the modelled results.

Table 6-8 Calibration to information received for the 2013 Event through Community Consultation

Respondent ID	Location	Provided Depth (m)	Modelled Depth (m)	Difference (m)	Comments
2	Shoalhaven Heads	0.53	0.527	-0.003	Level taken within front yard of property/onto the road, flood event was described as "Access to the property was cut off"
20	Comerong Island	1.0	1.019	0.019	Highest level recorded on property is 1.2m, comments specified "Yard/surrounding property flooded"
28	Shoalhaven Heads	1.1	1.033	-0.067	Highest level recorded on property near the shed, comments specified "Yard/Surrounding property flooded" and "Access to the property was cut off"
48	Shoalhaven Heads	0.3	0.31	0.01	Within appropriate range
52	Shoalhaven Heads	0.3	0.273	-0.027	Within appropriate range

All model results correlate closely with the reported depths, generally to within 30mm with a maximum of 70mm difference for a reported 1.1m depth. This demonstrates that the model is representing the behaviour during this event which closely matches what the community experienced.

6.4.7 Conclusion

The overall hydrological modelled flow comparison shows the previously calibrated parameters of the August 2015 calibration event provide a reasonable match with the recorded data. The temporal patterns applied at the uppermost catchments, Kadoona, Mongarlowe, Bungonia and Mongarlowe provide the closest representation to the timing of the flows, although, the peak flow modelled is higher than that recorded. A good correlation is seen at Tallowa Dam, although flows appear to be underestimated at Burrier.

The hydraulic model's representation of the June 2013 validation event shows that overall, modelled peak flood levels are lower than recorded. This is likely explained by the opening at Shoalhaven Heads being modelled as larger than what occurred in this event leading to lower levels in the estuary. Lower levels may also be due to underestimation of flows at the Burrier gauge. From previous sensitivity analysis of the heads in the August 2015 event it can be seen that opening the heads has a small effect of the upper most gauge, Grady's Caravan Park which is providing the closest peak match. For all other gauges within the hydraulic model, the peak water level would be increased by closing the heads. This demonstrates that for the June 2013 event a smaller entrance opening should be applied.

6.5 June 2016 Validation Event

6.5.1 Description

The June 2016 event has the highest flows at Burrier, however, is the lowest of the validation events in terms of water levels in the Lower Shoalhaven River. For this event the available data includes flow gauge data, water level gauge data and Community observed peak flood depths.

6.5.2 Rainfall Losses

For the June 2016 event the global losses as described in **Table 6-1** were applied.

6.5.2.1 *Sensitivity of continuing losses*

Use of the calibrated loss parameters for the June 2016 event provided significant overestimation of flows at the gauge locations. In order to provide a better representation of flows within the June 2016 event, a sensitivity of the continuing loss was undertaken. This was focused mainly on the flow gauges at Kadoona, Warri and Fossickers Flat. Kangaroo Valley was unchanged as it was providing a good match to the gauged data. The continuing losses applied are shown in **Table 6-9** below, with the effect at the 3 main gauges upstream of Tallowa Dam shown in **Figure 6-10**, **Figure 6-11** and **Figure 6-12**.

The continuing loss upstream of Warri was maintained as 2.5 mm/hr as this provided a better correlation with the calibration and other validation events.

Table 6-9 Continuing Loss Sensitivity (mm/hour) for the June 2016 Event

Scenario	Upstream of Warri Gauge	From Warri to Fossickers Flat Gauge
A	2.5	2
B	3	2.5
C	3.5	3
D	4.5	4

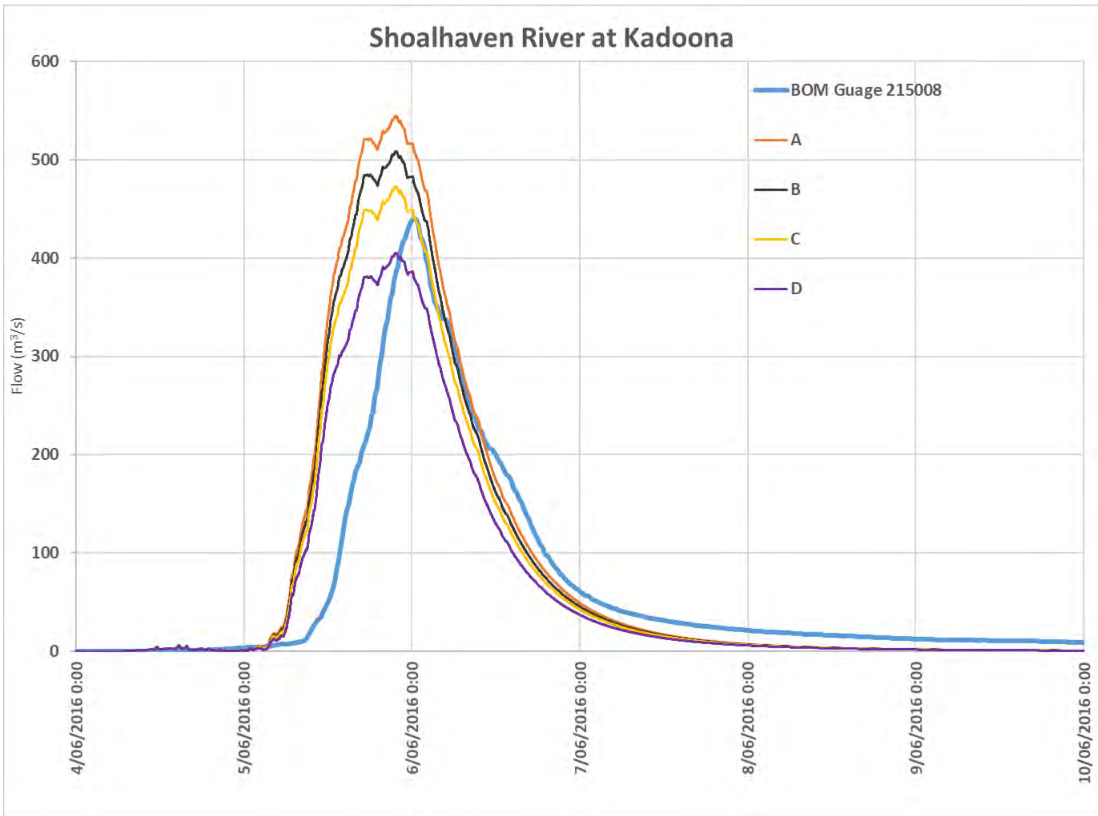

Figure 6-10 Continuing Loss Sensitivity for June 2016 Event at Kadoona BOM Gauge

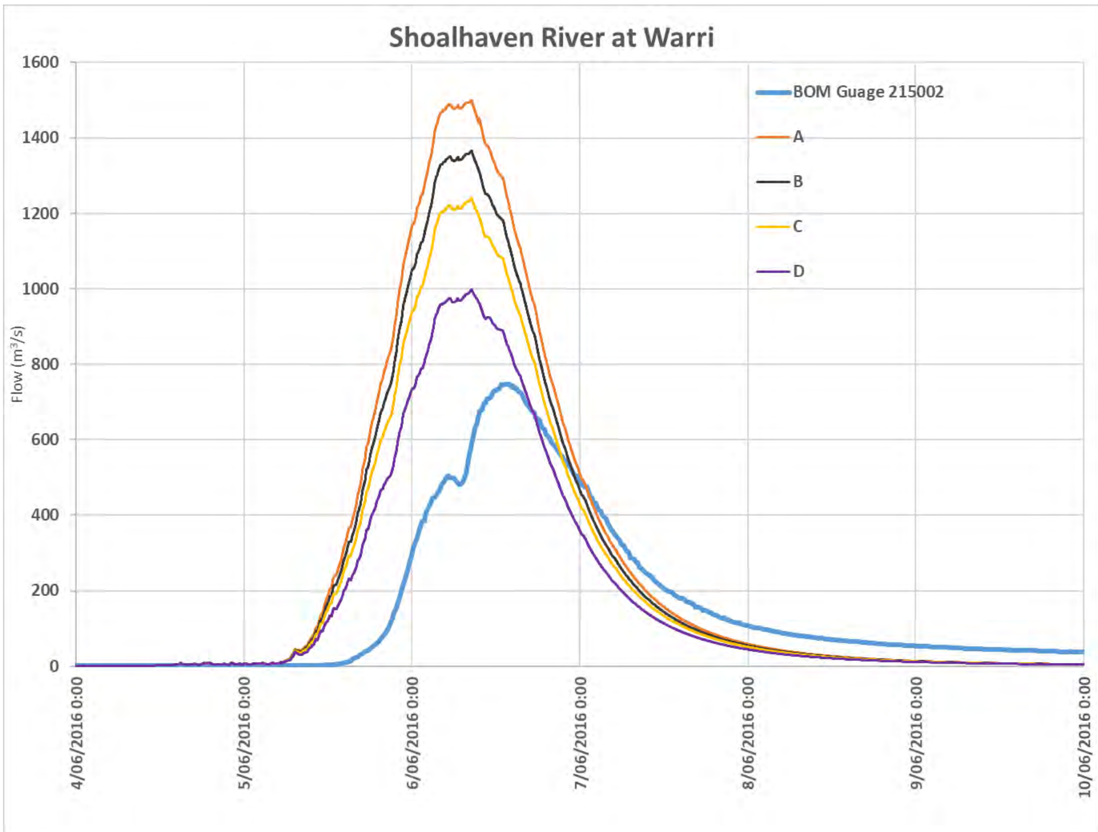

Figure 6-11 Continuing Loss Sensitivity for June 2016 Event at Warri BOM Gauge

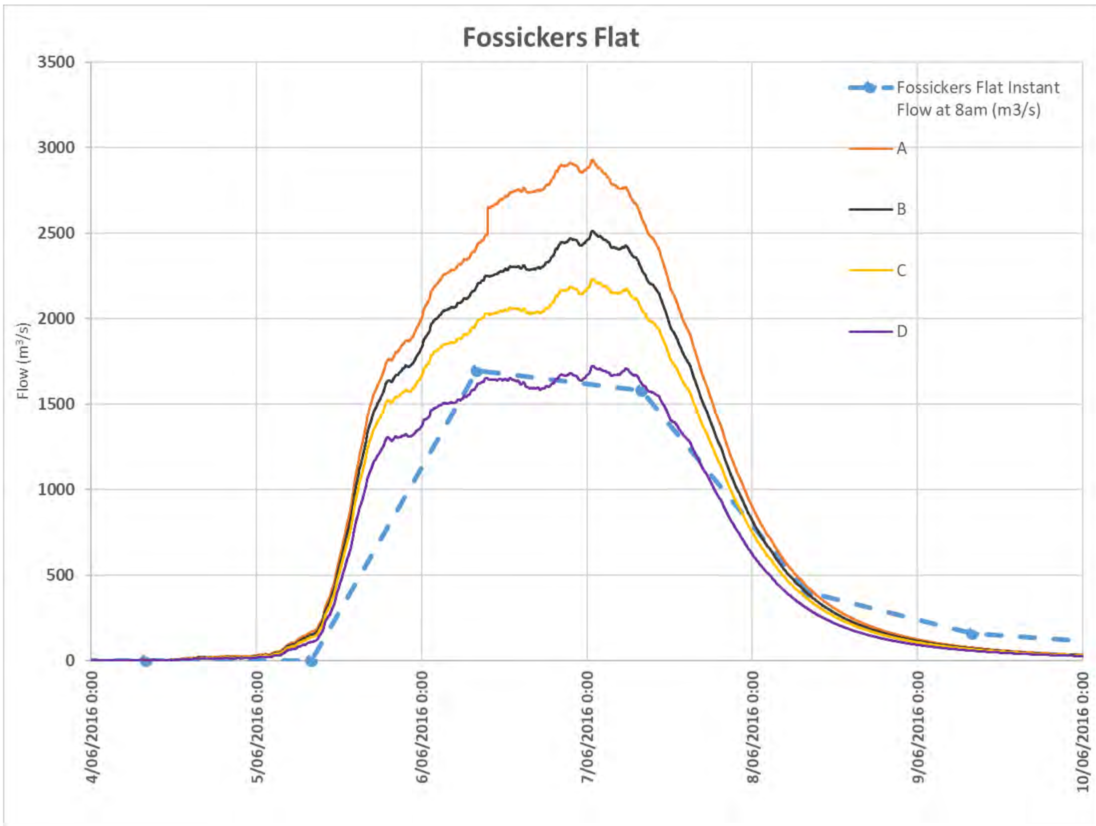

Figure 6-12 Continuing Loss Sensitivity for June 2016 Event at Fossickers Flat Instantaneous Flow Gauge

6.5.3 Rainfall

The rainfall allocation for the June 2016 event is shown in **Figure 6-13.**

This rainfall application provided the best representation of the volume of rainfall within each catchment and utilising the best matched temporal pattern from the available AWS gauges.

6.5.4 Flow Validation

Graphs showing the comparison of the modelled flow behaviour during the event at each of the 7 flow gauges and 4 instantaneous flow gauges are presented in **Appendix B.** Note that for the 4 gauges with instantaneous gauge readings at 8am each day, the actual flow behaviour in between each reading is unknown, hence the shape of the hydrograph and the actual peak flow is unknown.

Overall, the modelled catchment response and peak flows show adequate correlation with the available gauge data, particularly around Tallowa Dam and Burrier, however, peak flows are lower than gauged values. The following observations are made:

- The upper Shoalhaven River gauges (Kadoona, Warri, Monga and Bungonia) show a reasonable correlation with timing, however, peak flows are mismatched with peak gauged flow and volume, despite continuing loss parameter adjustments. This demonstrates that these catchments are sensitive to localised catchment rainfall and temporal patterns which are not well represented by the available rainfall gauge information;
- Hampden Bridge, Fossickers Flat, Tallowa Dam and Burrier all show a good correlation with the instantaneous gauged data, with a small amount of additional flow on the receding limb of the hydrograph for Tallowa Dam and Burrier. Flows may be slightly overestimated at Burrier, however, the data is insufficient to fully understand this;
- At Burrier, the modelled peak flows occur earlier and are lower than the gauged peak;
- Bomaderry Creek and Jaspers Brush show a good correlation to gauged flow data with timing of peaks, however, the volume of rainfall is underestimated at Jaspers Brush and overestimated at Bomaderry; and
- Broughton Creek appears to have either not received much local rainfall or there was an issue with the flow gauge during the event.

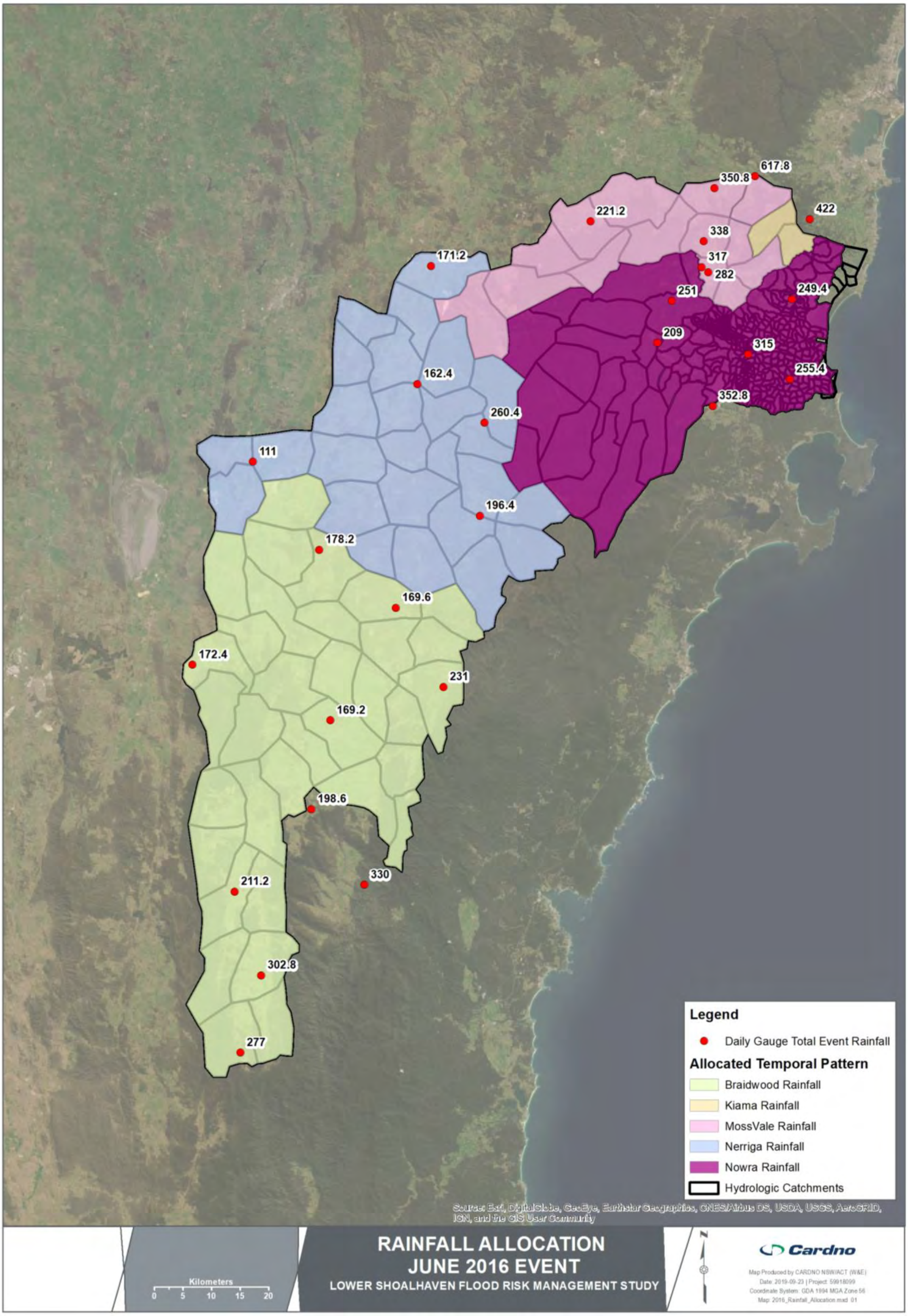

Figure 6-13 Assignment of Gauged Rainfall for Model Validation with the June 2016 Event.

6.5.5 Peak Water Level

Modelled water levels were compared with gauged water levels at the seven water level gauges within the Lower Shoalhaven/Crookhaven estuary and the results are graphed in **Appendix C**. **Table 6-10** below shows the peak water level comparison at each gauge location.

Table 6-10 June 2016 Event – Peak Water Level Model versus Gauge Comparison

MHL Station No.	Gauge Location	Gauge Data Peak Level (mAHD)	Modelled Peak Water Level (mAHD)	Difference Modelled Less Gauged (m)
215216	Grassy Gully	17.62	18.27	0.64
215430	Grady's Caravan Park	10.96	11.82	0.86
215411	Nowra Bridge	3.42	3.69	0.27
215420	Terara	3.15	3.42	0.27
215415	Hay Street	2.00	2.12	0.12
215470	Shoalhaven Heads	2.04	2.10	0.06
215417	Greenwell Point	1.66	1.68	0.02
215408	Crookhaven River	1.65	1.68	0.03

The table above demonstrates that the model provides a good correlation with gauged flood levels to within +/- 300mm at most locations. As for the August 2015 calibration event, it is likely that the shoaled areas downstream of Gradys Caravan Park are scoured during high flow events, creating a greater flow area which is not represented in the model and therefore affecting the levels at this gauge. It is therefore deemed an accurate representation of flood behaviour and suitable use in simulating design flood events.

6.5.6 Community Consultation

Flood levels were provided by eight respondents for the June 2016 event. The location of these responses is shown in **Figure 6-7**.

Table 6-11 below shows the comparison of the levels provided and the modelled results.

Table 6-11 Calibration to information received for the June 2016 Event through Community Consultation

Respondent ID	Location	Reported Depth (m)	Modelled Depth (m)	Difference (m)	Comments
1	Greenwell Point	0.2	0.2 - 0.44	0.215	Flooding was specified as "Yard/surrounding property flooded". Observation lies within modelled depth range.
2	Shoalhaven Heads	0.25	0.34 - 0.57	0.09 - 0.32	Model estimates slightly higher than observed estimated depth
28	Shoalhaven Heads	0.8	0.45 - 1.15	0.35	Majority of property flooded to approximately 0.7m, observation lies within modelled depth range
34	Shoalhaven Heads	1.0	0.75	-0.253	Largest depth on property recorded on driveway.
37	Shoalhaven Heads	0.3-0.7	0.32	0.02	Modelled depth within estimated depth range. Large depths (0.7 m) occurring in the parkland behind property, approx. 0.1-0.3m in backyard
48	Shoalhaven Heads	0.3	0.34	0.04	Within appropriate range
52	Shoalhaven Heads	0.2	0.21	0.01	Modelled depth similar to observation
56	Greenwell Point	0.3	0.34	0.04	Within appropriate range

6.5.7 Conclusion

The overall hydrological modelled flow comparison shows the previously calibrated parameters of the August 2015 calibration event provide a relatively close match with the recorded data, excluding that of the continuing losses. A sensitivity of the continuing losses was undertaken as the modelled peak flows were significantly higher than that recorded for this event.

From this sensitivity it was found for the hydrological model a higher continuing loss rate was to be applied throughout the catchments upstream of Tallowa Dam as discussed in **Section 6.5.2.1**. Despite applying these much higher loss rates, the overall peak flows at each gauge are still higher than recorded.

Within the hydraulic model the higher hydrological inputs are also represented in the flood levels, with all gauges' peak levels higher than recorded.

6.6 March 1978 Validation Event

6.6.1 Description

The March 1978 event was the largest event for which there is data available from the 1990 Flood Study.

It is considered good practice to include a range of event sizes in calibration/validation activities to better inform the selection of model parameters. For the 1978 event available rainfall data at a number of gauges in the catchment, and flow data at Grassy Gully has been obtained from the 1990 Flood Study data.

Validation of the March 1978 event has been limited to the XP-RAFTS hydrology model and has not been simulated with the hydraulic model.

6.6.2 Rainfall and Losses

Rainfall obtained from the 1990 Flood Study from five pluviograph stations was used: Oranmeir, Durra, Bungonia, Colyers Creek and Toorooroo Plateau as shown in **Figure 6-14**.

For the March 1978 event the global losses as described in **Table 6-1** were applied to check the validation.

6.6.3 Flow Validation

Use of the calibrated loss parameters for the March 1978 event resulted in an underestimation of flows at the gauge locations. In order to provide a better representation of flows for the March 1978 event, a sensitivity of the continuing loss was undertaken to obtain a better match. These were applied universally to all catchments. The continuing losses applied are shown in **Table 6-12** below, with the effect on the flow hydrograph at Grassy Gully shown in **Figure 6-15** versus measured flow at Grassy Gully.

It is seen that a reasonable match with the observed flows was achieved, with the actual peak flow lying between the modelled peaks achieved with a continuing loss of between 1.5mm/hr and 1.0 mm/hr.

Table 6-12 Continuing Loss Sensitivity (mm/hour) for the March 1978 Event

Scenario	Continuing Loss
A	2.0
B	1.5
C	1.0

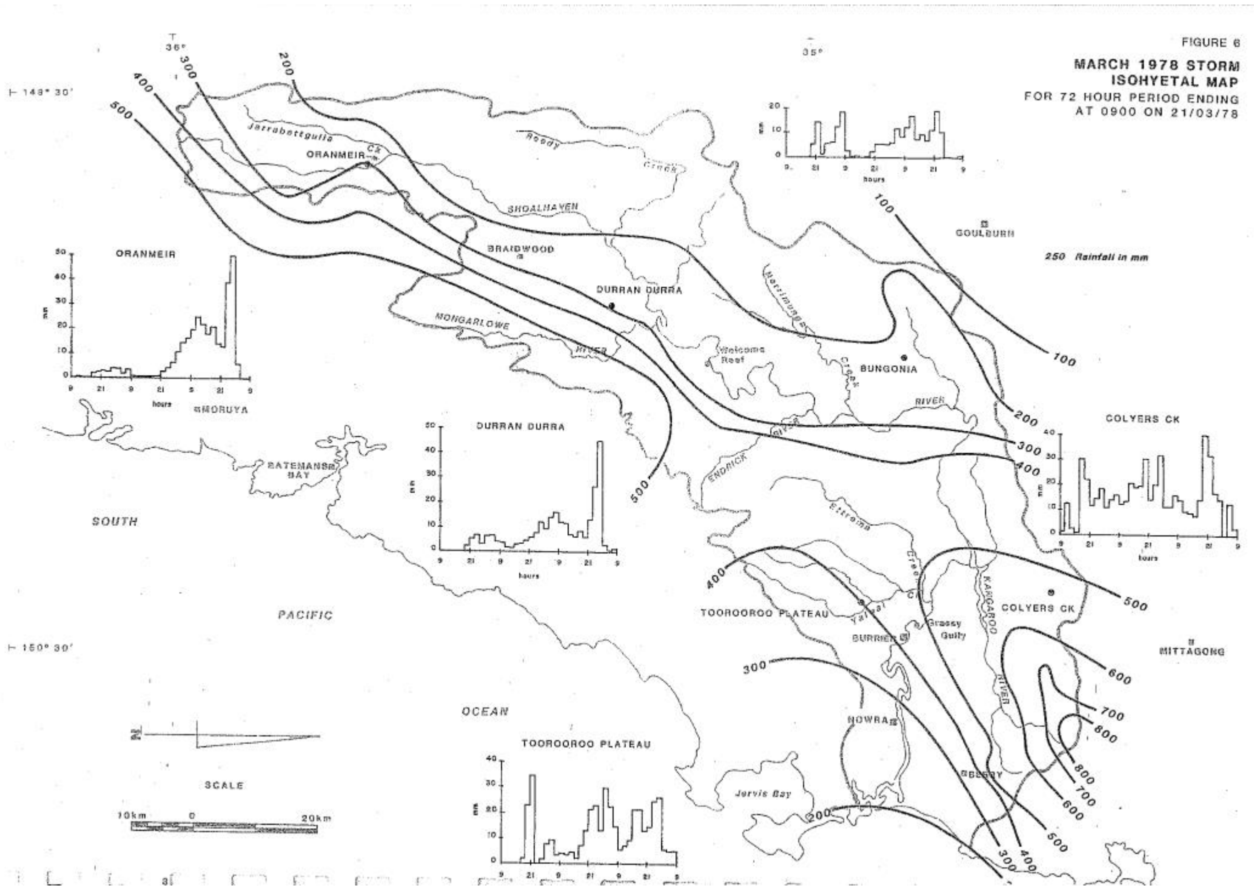

Figure 6-14 Rainfall Isohyetal Map for March 1978 Event (source:1990 Flood Study, PWD, 1990)

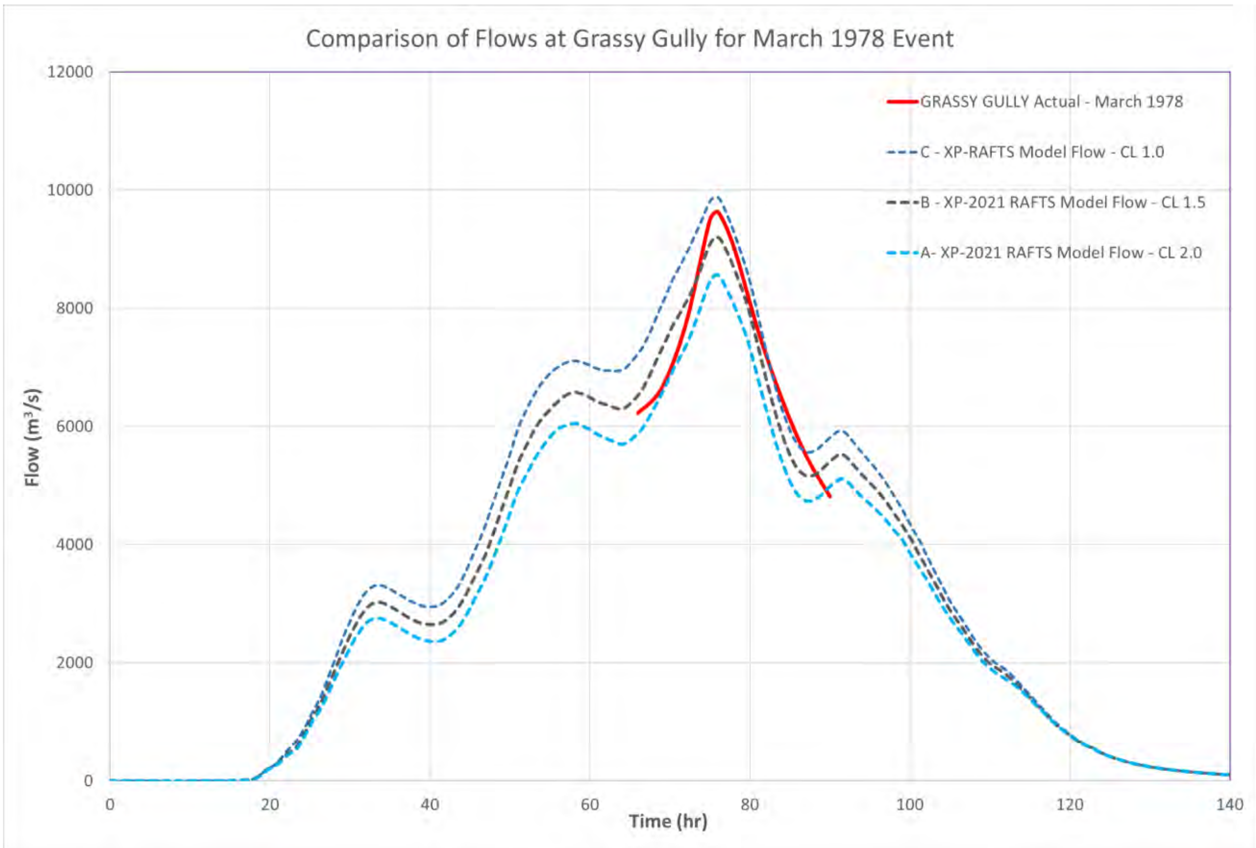

Figure 6-15 Continuing Loss Sensitivity for March 1978 Event at Grassy Gully

7 Flood Frequency Analysis

At-Site Flood Frequency Analysis (FFA) of historical events is used to validate the modelled design flood event flow estimates. An FFA at gauges with long periods of record is a robust method of estimating the probability of flooding. A full description of the statistics of FFAs and methods is provided in Australian Rainfall and Runoff Book 3 Chapter 2 (Ball et al., 2019). The FFA uses an Annual Maximum Series (AMS) of historical gauged peak flood flows to develop design flood estimates for various return periods.

The AMS is formed by extracting the maximum discharge in each year at a gauge location. It is important the AMS represents a homogenous record of flows at the gauge. Adjustment to the flow record may be needed if:

i) there have been changes to hydraulic controls near the gauge (such as a new bridge or culvert) that would affect the gauged water level for a given flow; or,

ii) there have been changes in the catchment (such as construction of a detention basin) that have affected the flow that would be experienced at the gauge for a given rainfall event.

The values in the homogeneous AMS are ranked and they are assigned a plotting position depending on the length of the record. A probability distribution is then fitted to the data to provide the expected quantile for flow for an Annual Exceedance Probability (AEP) - the probability that maximum flood discharge in a year exceeds a particular magnitude.

Design flood event discharge calculated using the hydrology model can then be compared against the estimated AEP flows derived from the FFA to ensure that the hydrology model is producing design event flows that align with historical observations at a particular location.

In the Shoalhaven River catchment, there are three gauge locations (shown on **Figure 7-1**) with long enough records suitable to undertake a FFA to improve confidence in the estimation of design flood behaviour in the Lower Shoalhaven River:

> Shoalhaven River at Grassy Gully II (215216)

> Shoalhaven River at Warri (215002)

> Kangaroo River at Hampden Bridge (215220)

A description of the rating curve review and flood frequency analysis undertaken at each gauge is provided in **Appendix E**.

Flood Frequency analyses were undertaken for all three gauges. The resulting FFA at both the Shoalhaven River at Warri and Kangaroo River at Hampden Bridge gauges did not provide a good fit to historical events at the right hand tail (for rare event AEPs) and FFA estimates appear conservatively high. However, the ARR2019 design event flows do plot well with the historical event AEP plotting positions. It was considered that further effort to review and revise the rating curves or extend the AMS record at these two gauges was not warranted. As this study is concerned with the Lower Shoalhaven River and due to the long records available at Nowra Bridge, effort was focussed on assessment of flows at Shoalhaven River at Grassy Gully II gauge described in the following sections.

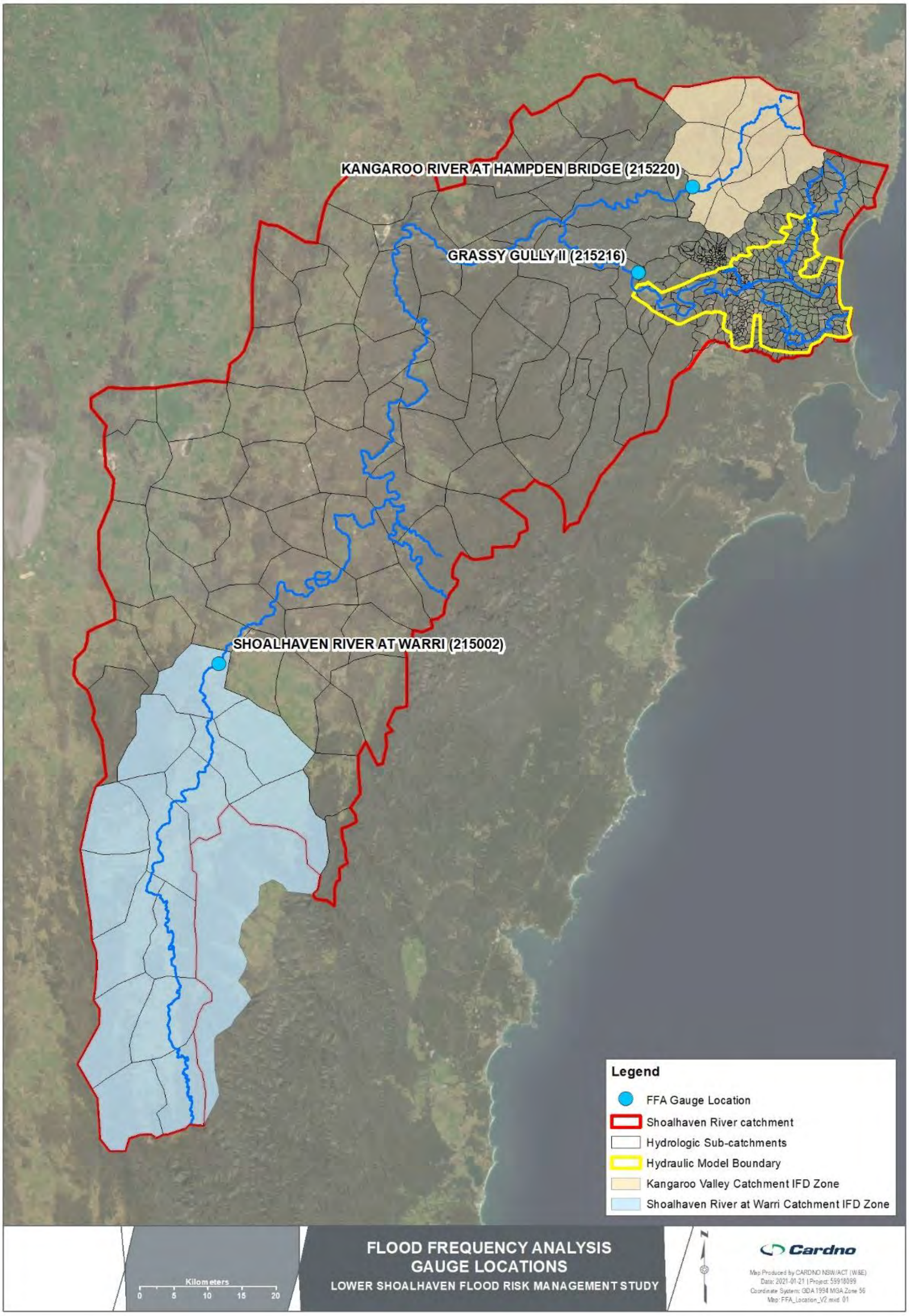

Figure 7-1 Flood Frequency Analysis Gauge Locations

7.1 Shoalhaven River at Grassy Gully II (215216)

7.1.1 Available Data

The Grassy Gully II gauge is located on the Shoalhaven River approximately 38 km upstream of Nowra Bridge. This is a valuable location to undertake a flood frequency analysis, as it is sufficiently downstream to capture inflows from the majority of the catchment, and sufficiently upstream to not be tidally influenced (unlike Nowra Bridge), while still being close to the area of interest in the Lower Shoalhaven River.

The Grassy Gully II gauge (215216) was opened on the 20th October 1982, however, has only been recording water levels since 1987 with continuous level and flow data available from this date to present. Prior to this gauge opening, Grassy Gully I was located approximately 500 m downstream of Grassy Gully II. Flow data at this gauge was requested from WaterNSW but was unable to be obtained. It is noted also that according to the 1990 Lower Shoalhaven River Flood Study (PWD,1990), the recorder at Grassy Gully failed during the 1974 and 1975 floods.

7.1.2 Review of Rating Table

A rating curve review at the Grassy Gully II gauge (215216) was undertaken to assess its suitability for use in the FFA. The gauging record was provided by WaterNSW (via Council), along with the current rating table (from 2013). Using the Annual Maximum Stage data, the provided rating table was used to convert recorded stage data into flows, to compare with the WaterNSW-provided flow data. These are plotted on **Figure 7-2.**

As can be seen in **Figure 7-2**, there is a discrepancy between provided and calculated flow values using the latest rating curve, which created uncertainties around the annual peak flow values. Investigation through the PINEENA database revealed a number of rating curve changes over time, with a recent more notable change that appears to place more confidence in recent gaugings from the 2013 event using ADCP than other manual gauging methods used to define previous rating tables.

There was considered to be sufficient uncertainty in the relationship between stage and flow at Grassy Gully II to warrant further investigation. Confirmation of the rating curve through hydraulic modelling was used to improve confidence in the AMS for use in the FFA to develop design flow estimates that were robust for use in the flood study. The rating curve was validated by establishing a TUFLOW two-dimensional hydraulic model of the river reach at Grassy Gully. The model used available LiDAR and bathymetry data, and selection of hydraulic roughness parameters (Manning's 'n') was based on land use and vegetation cover. The model was run for an extreme event inflow hydrograph to develop a relationship between stage and flow at the Grassy Gully II (215216) gauge location over a full range of flows.

The sensitivity of the model results to the assigned Manning's 'n' was tested as part of the rating curve development.

The resulting TUFLOW derived rating curve is shown in **Figure 7-3** compared with the latest WaterNSW rating curve (from 2013-present) and the previously adopted rating curve (2007-2013).

It was found that the hydraulic model rating plots well through the majority of gauging points for low flows and compares well with the WaterNSW 2007-2013 rating curve. This allows effective extrapolation of the rating relationship for larger flows beyond the field gaugings using the TUFLOW derived rating curve. The rating relationship is based on the hydraulic characteristics of the channel reach as assessed by the model, rather than an extrapolation from lower values.

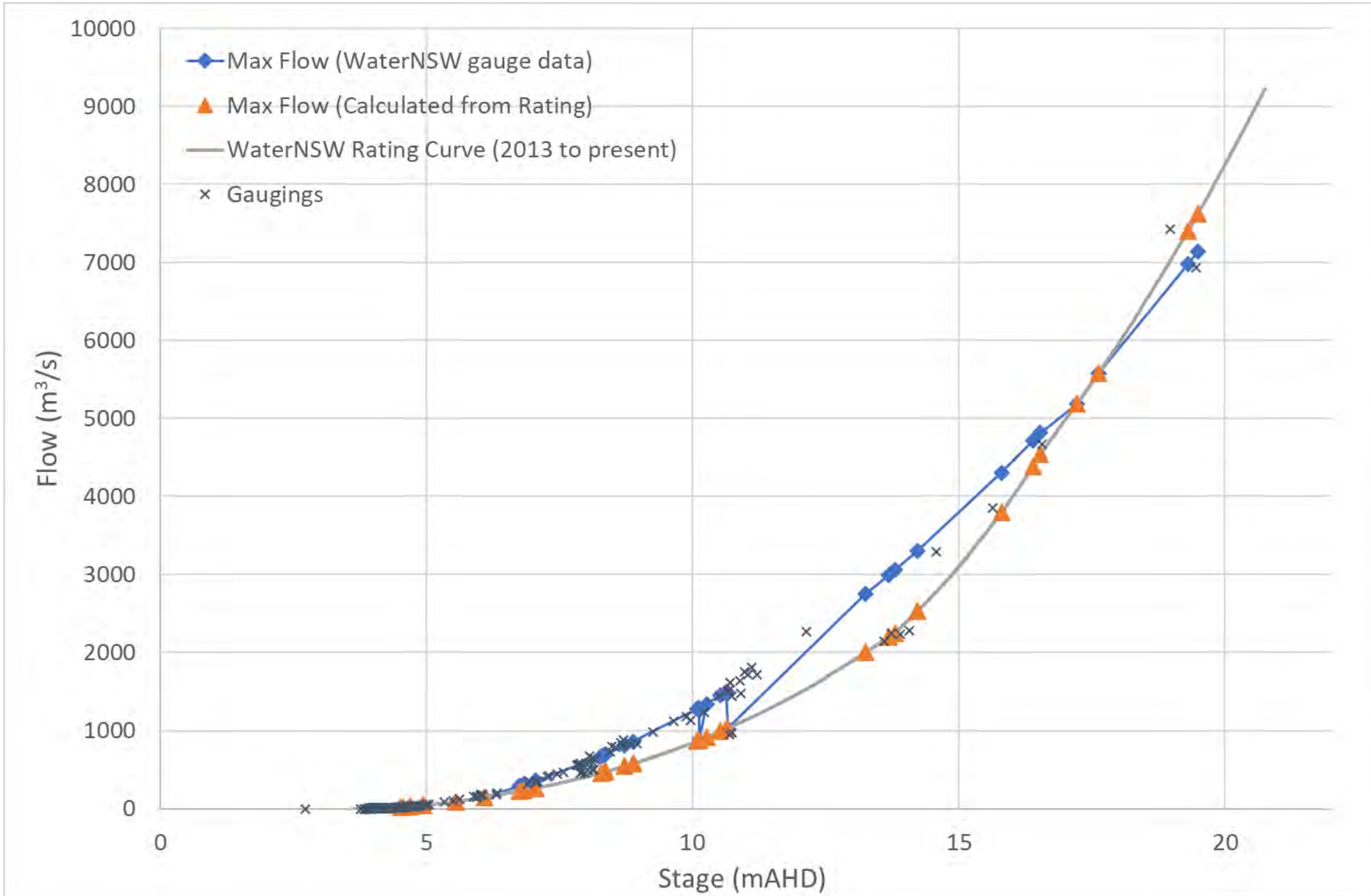

Figure 7-2 Shoalhaven River at Grassy Gully II (215216) – Gaugings, Annual Maximum Series and rating table converted flows

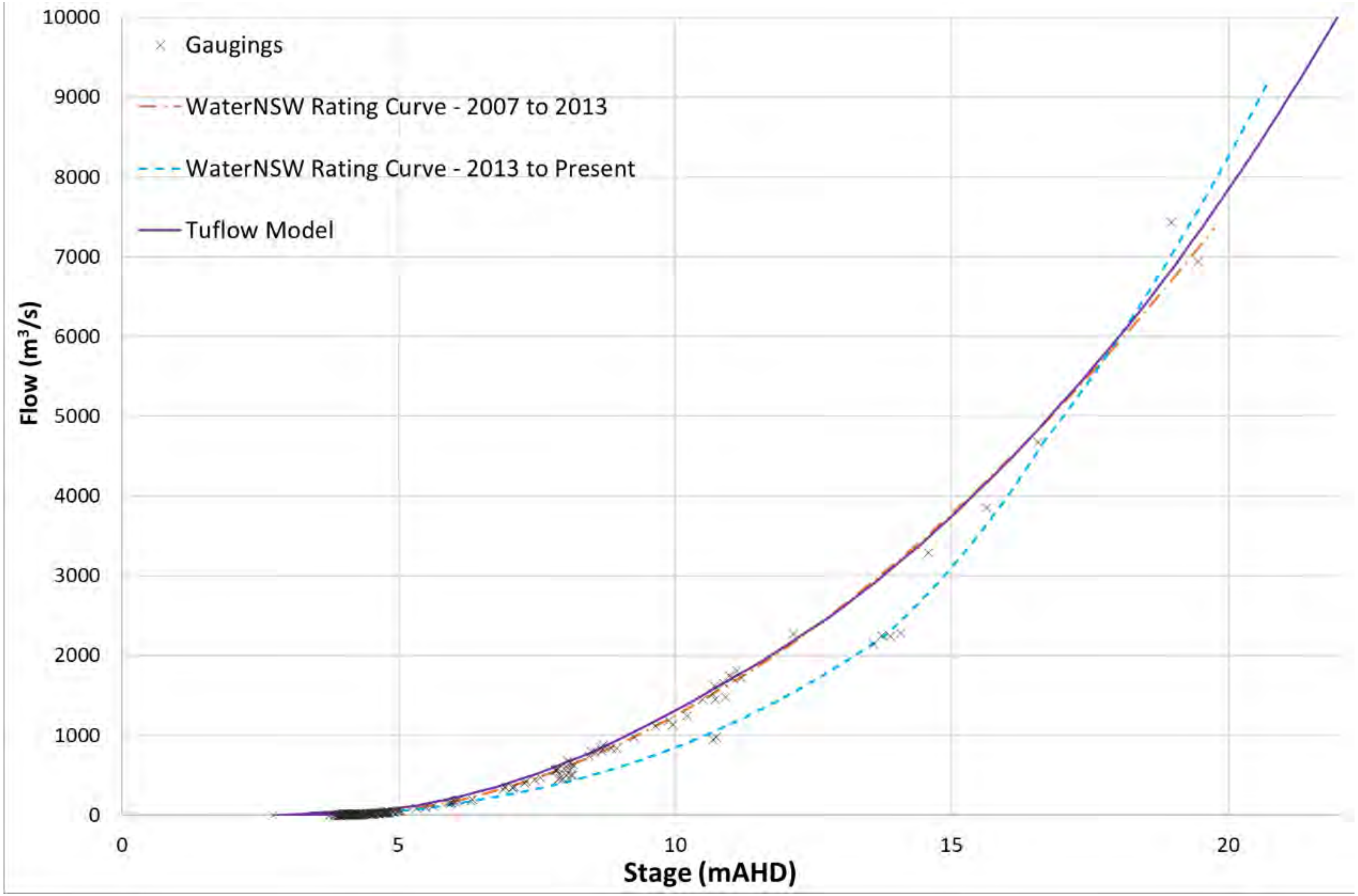

Figure 7-3 Shoalhaven River at Grassy Gully II (215216) – TUFLOW derived rating curve.

7.1.3 Annual Maximum Series

Using the TUFLOW derived rating table described above, recorded stage data at Grassy Gully II (215216) was converted into an annual maximum series (AMS) of flows for use in the Flood Frequency Analysis. This provided an annual maximum flow record of 34 years, which is considered a short record. To improve confidence in the estimate of rarer events it is beneficial to extend the record period as much as possible.

Observed peak flood levels at Nowra Bridge are available from as early as 1860 from the Shoalhaven River Flood History 'compendium', presented in **Figure 7-4** (Condon, 1986). This is in addition to continuous records at Nowra Bridge gauge (215411) since August 1990, however, there is no stage-discharge relationship available for Nowra Bridge to determine the peak flood flows associated with each event.

APPENDIX 4.

ANNUAL SERIES

		STANDARD DATUM	
April	1842	--	Same as 1852
March	1857	--	
February	1860	5.7	4 floods
June	1864	5.2	April/June 1865
April	1867	5.1	March 1870 5.5
April	1870	6.5	
May	1871	4.7	
February	1873	6.2	
June	1891	5.3	
February	1898	5.0	May 1838 Page 114 ("Shoalhaven")
July	1899	2.7	
July	1900	4.4	
July	1904	3.7	
January	1911	3.6	
October	1916	5.3	
December	1920	4.2	
July	1922	4.4	
11 May	1925	5.4	
April	1927	2.5	
January	1934	--	
September	1938	--	
April	1945	--	
May	1948	3.0	
June	1949	4.0	
June	1951	3.0	
May	1955	3.2	
February	1956	4.6	
July	1958	3.0	
October	1959	4.7	
March	1961	4.2	
June	1964	3.5	
September	1967	3.2	
August	1974	4.9	
June	1975	4.9	
October	1976	4.1	
March	1978	5.3	

Figure 7-4 Annual Series (developed by J Condon), included in the Shoalhaven River Flood History document.

There is some uncertainty around location of observation, floodplain conditions (e.g. vegetation, changes in topography and bathymetry over time), influence of tides and entrance conditions at the time of each event.

There have been a number of changes in the catchment over time that may influence the homogeneity of the water level record at Nowra Bridge, i.e. for a given flow, the water level that was experienced at the time of the event may be different if the same rainfall event was experienced under 'present day' conditions.

Some notable changes in the catchment that would have an influence on flood levels at Nowra Bridge include:

> Hydraulic Structures:

- Original Nowra Bridge (now southbound carriageway) – 1881
- Terara Levees – approx. 1974 and 1978 and repair in 2005
- Nowra Bridge duplication (northbound carriageway) - 1981

> Dams in the catchment:

- Danjera Dam – completed 1971
- Fitzroy Falls Reservoir – completed 1974
- Tallowa Dam – completed 1976

Based on the above, it can be seen that historical water levels cannot be converted to flows using the rating curve at Nowra Bridge for ‘present day’ catchment conditions. The flow associated with the reported historical flood level needs to be determined using a rating curve for the catchment conditions that prevailed at the time of each event.

It is then necessary to (as best as possible) estimate the magnitude of historic event flows if they had occurred under ‘present day’ conditions, so that a homogeneous AMS record can be established for use in the Flood Frequency Analysis.

Using the available hydrologic and hydraulic modelling tools, the available historical flood level information at Nowra Bridge has been used by converting it to flows at Grassy Gully II under current catchment conditions using a series of adjustments involving the following steps:

> Convert recorded stage levels in m (Standard Datum) to mAHD;

> Investigate the sensitivity of levels at Nowra Bridge to tailwater conditions;

- this showed that beyond a gauge height of approximately 2.5 m AHD there was little to no tidal influence on the stage-discharge relationship even using Highest Astronomical Tide (HAT) level as the boundary condition.

> Convert levels at Nowra Bridge to flows under prevailing catchment conditions at the time of each event;

- this required running the TUFLOW model for different scenarios to consider the influence on construction of Nowra Bridge and downstream Terara levees on flood levels to develop rating curves for three different representative periods.

> Convert flows at Nowra Bridge to flows at Grassy Gully II (215216);

- the hydraulic model was used to derive a relationship of flows between the two gauges which indicated flows are around 5% higher at Nowra Bridge.

> Investigate the effect of Tallowa Dam on peak flows at Grassy Gully II and make adjustments to flows to “present day” catchment conditions;

- The hydrology model was run with and without Tallowa Dam for a series of events to examine the change in flow hydrographs. It was found that Tallowa Dam does have an attenuation effect on flows and flows pre 1976 had to be adjusted to account for the expected flow today.

> Develop a homogeneous annual maximum series of flow at Grassy Gully II for use in the FFA.

The resulting AMS is presented in **Table 7-1**. Peak flow estimates for historical events at Grassy Gully II presented in **Table 7-2**.

Table 7-1 Annual Maximum Series at Grassy Gully II (215216)

Year	Maximum Flow (m^3/s)	Year	Maximum Flow (m^3/s)
1987	55	2004	82
1988	7,332	2005	1,355
1989	2,960	2006	81
1990	7,150	2007	862
1991	4,818	2008	745
1992	3,267	2009	56
1993	365	2010	1,550
1994	915	2011	1,505
1995	1,406	2012	3,025
1996	1,339	2013	5,340
1997	2,720	2014	1,560
1998	4,283	2015	5,667
1999	4,713	2016	~4,200*
2000	414	2017	1,355
2001	754	2018	150
2002	728	2019	63
2003	346	2020	5,893

*Level data at Grassy Gully during this event is poor. Estimated from Burrier gauge.

Table 7-2 Historic Levels at Nowra Bridge and Corresponding Flows at Grassy Gully

Catchment Conditions	Month	Year	Flood Level at Nowra Bridge (m standard datum)	Flow at Grassy Gully (m^3/s)
Pre 1881	April	1842		
	March	1857		
	February	1860	5.7	11,350
	June	1864	5.2	8,939
	April	1867	5.1	8,536
	April	1870	6.5	15,195
	May	1871	4.7	7,223
	February	1873	6.2	13,861
1881-1974	June	1891	5.3	9,173
	February	1898	5	8,039
	July	1899	2.7	3,065
	July	1900	4.4	6,337
	July	1904	3.7	4,791
	January	1911	3.6	4,603
	October	1916	5.3	9,173
	December	1920	4.2	5,867
	July	1922	4.4	6,337
	May	1925	5.4	9,608
	April	1927	2.5	2,765
	January	1934	-	-
	September	1938	-	-
	April	1945	-	-
	May	1948	3	3,534
	June	1949	4	5,398
	June	1951	3	3,534
	May	1955	3.2	3,888
	February	1956	4.6	6,852
	July	1958	3	3,534
	October	1959	4.7	7,118
	March	1961	4.2	5,867
	June	1964	3.5	4,426
	September	1967	3.2	3,888
"Current"	August	1974	4.9	7,516*
	June	1975	4.9	7,516*
	October	1976	4.1	5,863*
	March	1978	5.3	9,232*

*The 1970s peak flows at Grassy Gully that have been 'back-calculated' from levels at Nowra Bridge differ notably from corresponding flows reporting in the 1990 Flood Study (PWD). Without level information for these events at Grassy Gully II, it is not possible to confirm the appropriate flows. For consistency, the 'back calculated' 1970s peak flows (in **Table 7-2**) have been used in the Grassy Gully II FFA.

7.2 Flood Frequency Analysis

Following the above process, the 'best possible' homogenous record of flows was produced at Grassy Gully II (215216). An FFA was undertaken using the resulting Annual Maximum Series (AMS) of flows and the most current techniques in ARR2019 (Ball et al, 2019).

Where the extended record has missing years, these are considered by including the number of years with flow above or below threshold flow values. This allows the number of values to be extended to cover the full period and the plotting positions are adjusted accordingly to provide a better fit to the data. For the Nowra Bridge record, it was identified that the lowest flow noted as a flood pre-1900 was around 7,000m^3/s, while the period between 1900 to 1987, floods greater than approximately 2,700m^3/s are documented. These two values have been used as the thresholds to add the missing years as censored values. A multiple Grubbs-Beck test for censoring potentially influential low discharges was also applied.

Years with no data (96 records) were assigned a peak flow of 0 m^3/s, and excluded from the record using the "Block Exclude" function in TUFLOW FLIKE. Using the "Censored Values" function, it was assumed that 31 values are below 7,000m^3/s, with 65 records below 2,700 m^3/s. The multiple Grubbs-Beck censoring identified a further 22 records below 2,450m^3/s and these values were excluded.

The resulting FFA is shown in **Figure 7-5** and the design event flood quantiles shown in **Table 7-3**.

It is noted that with an estimated flow of 15,195 m^3/s, the 1870 event and largest on record, is expected to have a recurrence interval around 1 in 269 AEP, with the 1873 event being a 1 in 100 AEP event. This is considered realistic given the available record, and provides greater confidence in the FFA outputs at Grassy Gully II.

Table 7-3 FFA derived expected design event flows at Grassy Gully II Gauge (215216)

AEP Event	FFA Expected Flow (m^3/s)
50%	1,202
20%	4,140
10%	6,623
5%	9,017
2%	11,832
1%	13,641

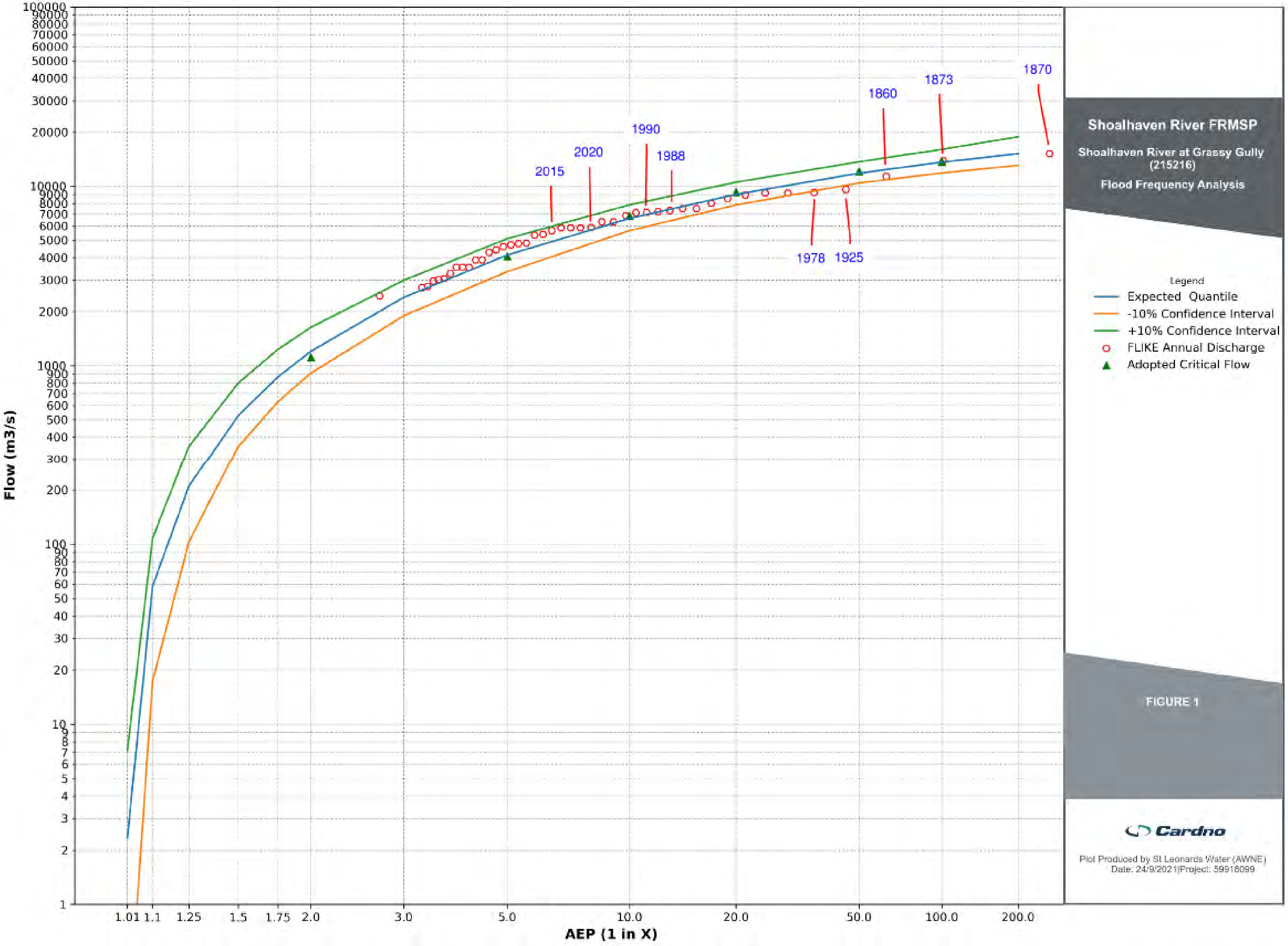

Figure 7-5 Flood Frequency Analysis – Shoalhaven River at Grassy Gully II gauge (215216)

8 Hydrology – Design Flood Estimation

8.1 Hydrology – ARR2019 Update

The hydrology modelling of the Shoalhaven River catchment for determining design flood event flows has been undertaken in accordance with the new Australian Rainfall and Runoff 2019 (ARR2019) Guidelines. The new ARR2019 Guidelines includes updated Intensity-Frequency-Duration (IFD) data, areal reduction factors (ARFs), storm loss parameters, pre-burst rainfall and has introduced ensemble modelling methods to account for the variability in rainfall temporal patterns.

Data specific for the catchment has been obtained from the ARR Data Hub and Bureau of Meteorology and is provided in **Appendix F**.

8.1.1 Intensity-Frequency-Duration Data

Due to the large size of the Shoalhaven River catchment different IFD Zones were defined to reflect the rainfall variation over the catchment. The variation in rainfall depth for the 1% AEP event across the catchment is significant. In general, rainfall intensities and depths increase from south to the north across the catchment and lower rainfall in the western highland areas compared with the eastern coastal areas. The highest intensity is in the Kangaroo Valley region, which is significantly larger than the majority of the total catchment. For example, in the 1% AEP 24 hr storm, design rainfall depths range from 151 mm in the central western section of the catchment near Bungonia, compared to 580 mm in the northern parts of Kangaroo Valley.

As such, it was deemed appropriate to develop a suite of IFD ‘zones’ to aggregate sub-catchments in different regions and apply rainfall depths more appropriately. The IFD zones were derived using the 2 hr, 6 hr, 12 hr and 48 hr gridded rainfall distribution. A grid showing the 1% AEP 48hr duration storm and derived IFD Zones are shown in **Figure 8-1.** Each IFD Zone was developed to be representative of the distribution of rainfall across the zone, with the centroid of the zone best representing the average of the catchment within +/-5% of the rainfall depth at the centroid of the sub-catchments within that zone. The IFD data is provided in the attached ARR Data hub outputs in **Appendix F**.

The method of delineating IFD Zones was based on grouping sub-catchments (in the XP-RAFTS model). The aim was to develop groupings where the IFD at the centroid of that group was within 5% of the average of the corresponding IFD for each sub-catchment’s centroid.

Table 8-1 below indicates (for each storm duration in the 1% AEP event) this difference. Values in bold text are over the 5% threshold and indicate that further delineation of IFD zones may be warranted. However, when looking at the 18-hour event (which was critical for the 1% AEP event) – we can see that the assigned IFD zones are within, or close to, the 5% margin. For this reason, it is not expected that changes to the IFD zone delineation would materially influence peak design flows in the Lower Shoalhaven River.

Table 8-1 IFD Zone Percentage variation

1% AEP Event Percentage difference IFD Zone to sub-catchment average							
Duration	**IFD Zone 1**	**IFD Zone 2**	**IFD Zone 3**	**IFD Zone 4**	**IFD Zone 5**	**IFD Zone 6**	**IFD Zone 7**
5 min	0.7	-1.7	-0.2	1.3	**-8.1**	-4.4	1.1
10 min	1.0	-1.6	-0.4	0.0	**-9.0**	-3.8	0.8
15 min	1.0	-1.5	-0.4	-0.3	**-9.3**	-3.7	0.8
30 min	0.8	-0.8	-0.3	0.0	**-9.0**	-4.2	0.9
1 hour	0.5	-1.5	0.0	1.3	**-8.0**	-4.9	1.2
2 hour	0.4	-1.3	1.1	2.9	**-8.2**	**-5.3**	1.8
3 hour	0.2	-1.4	1.8	3.7	-4.6	**-5.3**	2.2
6 hour	-2.6	-1.7	1.8	4.4	-1.5	-4.5	2.7
12 hour	**-5.9**	1.6	-1.1	3.9	0.4	-2.7	3.3
24 hour	**-9.0**	-0.7	-3.1	2.4	0.8	-3.2	4.3
48 hour	**-9.5**	3.3	-3.9	0.2	1.0	-3.4	**5.0**
72 hour	**-10.2**	**5.0**	-4.9	-0.8	1.1	-3.4	**5.6**
96 hour	**-10.8**	**5.7**	**-5.5**	-1.1	1.1	-3.5	**5.5**
120 hour	**-11.2**	**5.9**	**-5.4**	-1.0	1.1	-3.4	**5.2**
144 hour	**-11.5**	**5.7**	**-5.0**	-0.6	1.3	-3.4	**5.1**
168 hour	**-11.7**	**5.3**	**-5.0**	0.0	1.5	-3.3	**5.0**
Note: Percentage difference in IFD Zone is calculated as the difference between the depth at the IFD Zone Centroid and the average depth of all sub-catchments within that zone.							

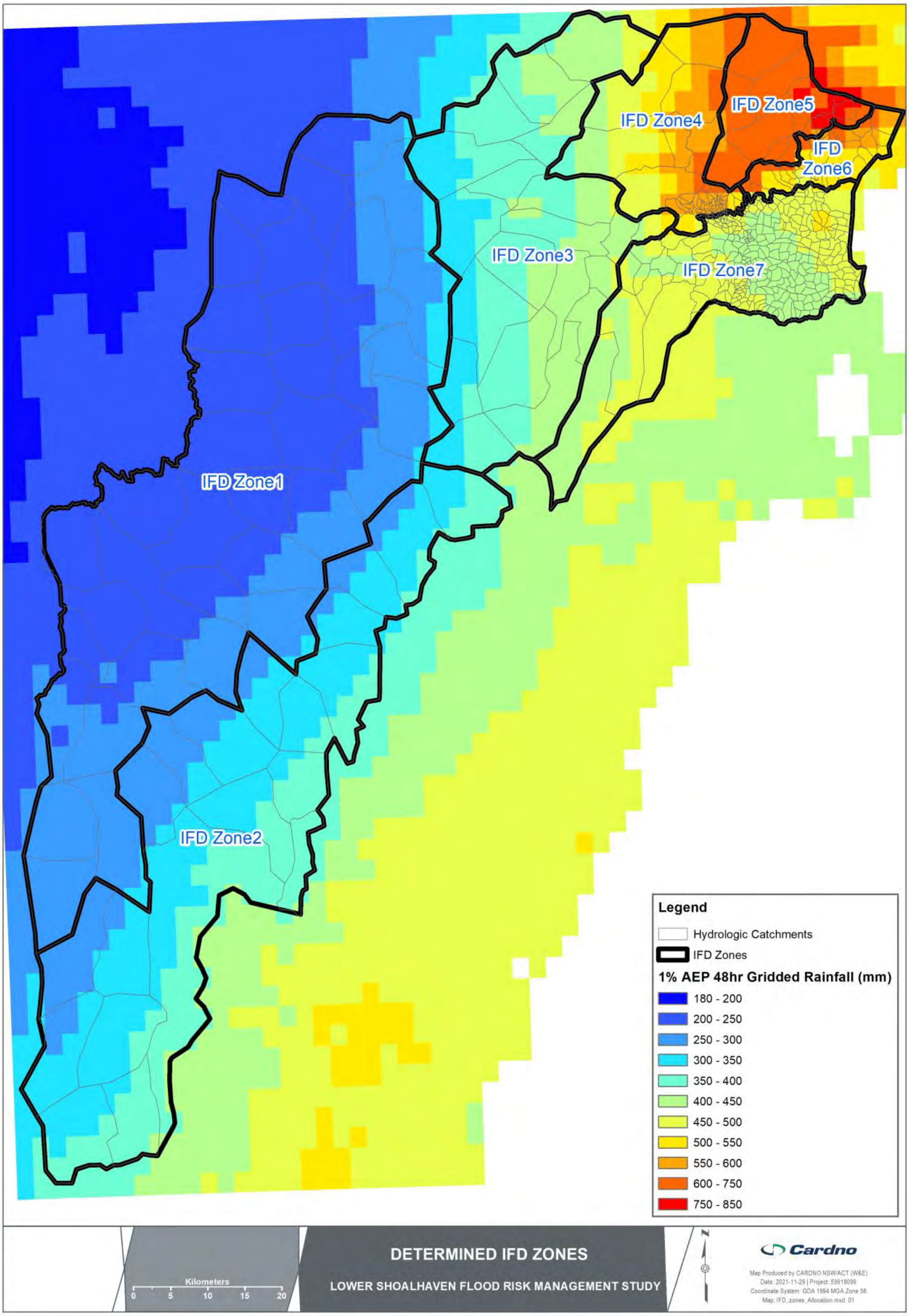

Figure 8-1 IFD Zones for the Shoalhaven River catchment

8.1.2 At-Site IFD

When the ARR2019 design flood estimates do not provide a good correlation with the FFA, it is possible that the rainfall IFD obtained from the BoM is not representative of the catchment depending on the rainfall gauges being used to derive the IFD. In such cases, an at-site IFD can be generated to compare with the BoM IFD and utilised if deemed more representative.

For the Shoalhaven River catchment, there is insufficient pluviometer gauges, both spatially, and with a sufficient length of continuous record to provide a good record for at-site IFD generation. There is a large number of daily read gauges which can be used for comparison, however, this can only be used in 24 hour duration intervals and is only for 9am to 9am periods. Hence, these daily records could also miss the peak 24 hour rainfall if it occurred from 6pm to 6pm for example. As such, this was not examined further and the BoM IFD is considered to be the most suitable to use for the catchment.

8.1.3 Temporal Pattern Data

Ensemble modelling methods are employed in accordance with the ARR2019 Guidelines. Ensemble modelling involves modelling a set of 10 different temporal patterns for each design event and storm duration. The Shoalhaven River catchment is within the *Southern Slopes Mainland* zone for selecting temporal patterns from the ARR Data Hub. Design storms are sorted into three temporal pattern bins as shown in **Figure 8-2**. A different set of 10 temporal patterns are associated with each temporal pattern bin. The 1% AEP event, for example, falls within the 'Rare' temporal pattern bin.

An ensemble of ten temporal patterns for each storm duration were run using StormInjector. In accordance with ARR 2019 guidelines, areal temporal patterns are used for catchment areas >75km^2 and for durations longer than 12 hours. The 5,000km^2 aerial temporal patterns were applied for all events as the total catchment area falls below 7,500km^2. Point temporal patterns have also been used for smaller tributaries with shorter critical durations. The adopted critical duration for each event was the duration which had the highest mean flow, with the adopted temporal pattern being the one closest to the mean flow, with a bias to the temporal pattern above the mean.

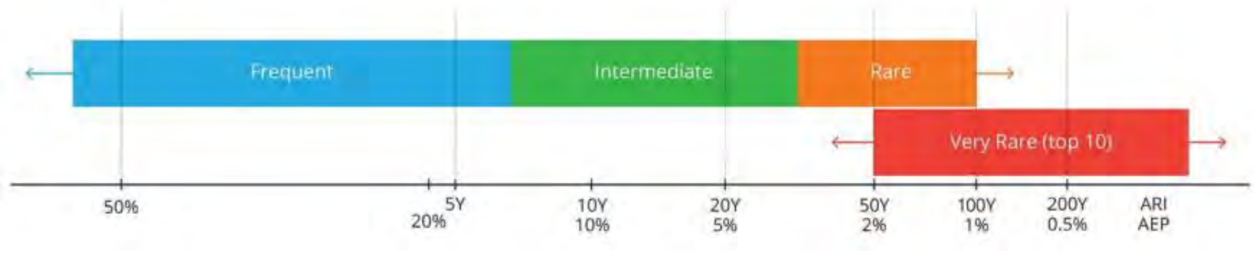

Figure 8-2 Bins for temporal patterns versus AEP (source: ARR Figure 2.5.12)

8.1.4 Areal Reduction Factors (ARFs)

In accordance with ARR2019, Areal Reduction Factors are required for catchments that are sufficiently large. Design rainfall intensities at a point are not representative of the areal average rainfall intensity across the catchment. The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and Annual Exceedance Probability (AEP), is called the Areal Reduction Factor (ARF). This allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.

It should be noted that the ARF provides a correction factor between the catchment rainfall depth (for a given combination of AEP and duration) and the mean of the point rainfall depths across a catchment (for the same AEP and duration combination). Applying an ARF is a necessary input to computation of design flood estimates from a catchment model that preserves a probability neutral transition between the design rainfall and the design flood characteristics. The ARF merely influences the average depth of rainfall across the catchment, it does not account for variability in the spatial and/or space-time patterns of its occurrence over the catchment.

Based on the size of the Lower Shoalhaven River catchment (7,250km^2), areal reduction factors are required to provide an accurate representation of rainfall intensity across the catchments. ARFs are determined based on a formula relating to catchment area, AEP event and duration. In large catchments however, there is a risk that applying one ARF across the total area would artificially reduce the total effective rainfall, and underestimate peak flows.

To examine the effect of this in the Shoalhaven River catchment, three scenarios were tested to determine the appropriate application of ARFs. The scenarios were run for the 1% AEP event only, and included:

> S1 - Standard ARR 2019 Guidelines (single ARF applied to the whole catchment based on total catchment area of 7,500km^2);

> S2 - Application of an ARF over a sub-region, the area of IFD Zones 3-7 (Refer to **Figure 8-1**); and

> S3 - Application of individual ARFs for catchment area of each IFD zone (shown in **Figure 8-1**).

These results were discussed with DPE and Council, and it was resolved to proceed with Scenario 3 – applying an IFD zone specific ARF to each zone calculated based on ARFs from the ARR Data Hub which uses relationship between ARF, catchment area of each IFD zone and event duration. This was applied directly to the IFD depths overwriting the exported IFD Depths from ARR DataHub.

8.1.5 Pre-burst Application

Pre-burst depths were obtained from the ARR Data Hub and applied to the design storms. The ARR Data Hub provides the 10%, 25%, Median, 75% and 90% pre-burst depths and ratios.

The influence of the application of pre-burst on peak flows was investigated by comparing results generated using the 90th percentile pre-burst and median pre-burst. At locations in the upper catchment (Warri and Hampden Bridge), the percentage difference is greatest in the more frequent events, however, has less impact at the 2% and 1% AEP event. However, lower in the catchment at Grassy Gully II, the selection of pre-burst makes 10-18% difference across the suite of design events.

From this sensitivity it was found that an application of 90% Pre-burst was needed to match the estimated design event flows from the Flood Frequency Analysis and therefore was adopted for all design event scenarios.

For shorter duration events, pre-burst has been applied using Jordan (2005) temporal patterns over 7 hours, while for durations of 12 hours or more, the GSAM coastal temporal pattern has been used for the pre-burst over 36 hours.

8.1.6 Initial and Continuing Losses

Consideration of the effect of initial and continuing losses throughout the Shoalhaven River Catchment was undertaken.

Preliminary design event estimates applying the calibrated losses provided lower flows than expected compared with the FFA expected flows. It was found that it was not possible to validate design flows to the FFA using a uniform set of loss parameters derived from calibration across the design events. In order to increase the flow an envelope of continuing losses were applied in order to determine the effect. The losses applied were 0 mm/hr, 1 mm/hr and 5 mm/hr. This showed that it was necessary to vary continuing losses across the design events to generate flows to match the expected quantile from the FFA. This is supported by the varying losses required to be applied for the different calibration and validation events to achieve a good correlation. The resulting applied losses are shown in **Table 8-2**. A summary of corresponding peak design flows is presented in **Section 8.2**.

Table 8-2 Initial and Continuing loss application for Design Events

AEP Event	Initial Loss Applied (mm)	Continuing Loss Applied (mm/hr)
50%	Calibrated 2015 Event Initial Losses	3.5
20%	Calibrated 2015 Event Initial Losses	2
10%	Calibrated 2015 Event Initial Losses	1
5%	Calibrated 2015 Event Initial Losses	0.5
2%	Calibrated 2015 Event Initial Losses	0
1%	Calibrated 2015 Event Initial Losses	0

8.1.7 Probable Maximum Precipitation (PMP) Estimation

The Generalised Southeast Australia Method (GSAM) (BoM, 2006) was used to estimate the rainfall intensity of the Probable Maximum Precipitation (PMP) for the Shoalhaven River catchment. The GSAM is appropriate for durations of 12 hours to a maximum of 120 hours depending on the location and catchment area, where as the GSDM (Generalised Short-Duration Method, BoM, 2003) is only appropriate up to durations of 6 hrs and catchments less than 1,000 km^2 (**Figure 8-3**). Due to the Lower Shoalhaven having a longer critical duration and a catchment area of approx. 7,250 km^2 the GSAM method is considered appropriate.

The GSAM PMP flows were calculated in XP-RAFTS using the ARR87 PMP calculator. The centroid of the catchment (-35.131S, 150.024E) was determined and appropriate factors were applied to produce the rainfall for the 12 hr to 96 hr durations. An area of 5,000 km^2 has been utilised as the total catchment area falls between the 5,000 km^2 and 10,000 km^2 specifications.

For the calculation of the PMP an initial loss of 1mm and continuing loss of 0 mm/hr was applied.

Table 8-3 PMP Rainfall depths applied

Duration (hours)	Summer PMP (mm)		Autumn PMP (mm)		Final PMP Depths (mm)
	Initial Depth	PMP Estimate	Initial Depth	PMP Estimate	
24	457	572	396	454	570
36	532	665	494	566	670
48	586	732	580	666	730
72	669	836	713	818	840
96	739	923	782	897	920

PMP Applied Catchment Factors: Catchment average TAF = 1.47, Annual depth=68.96896, Autumn depth =55.24666

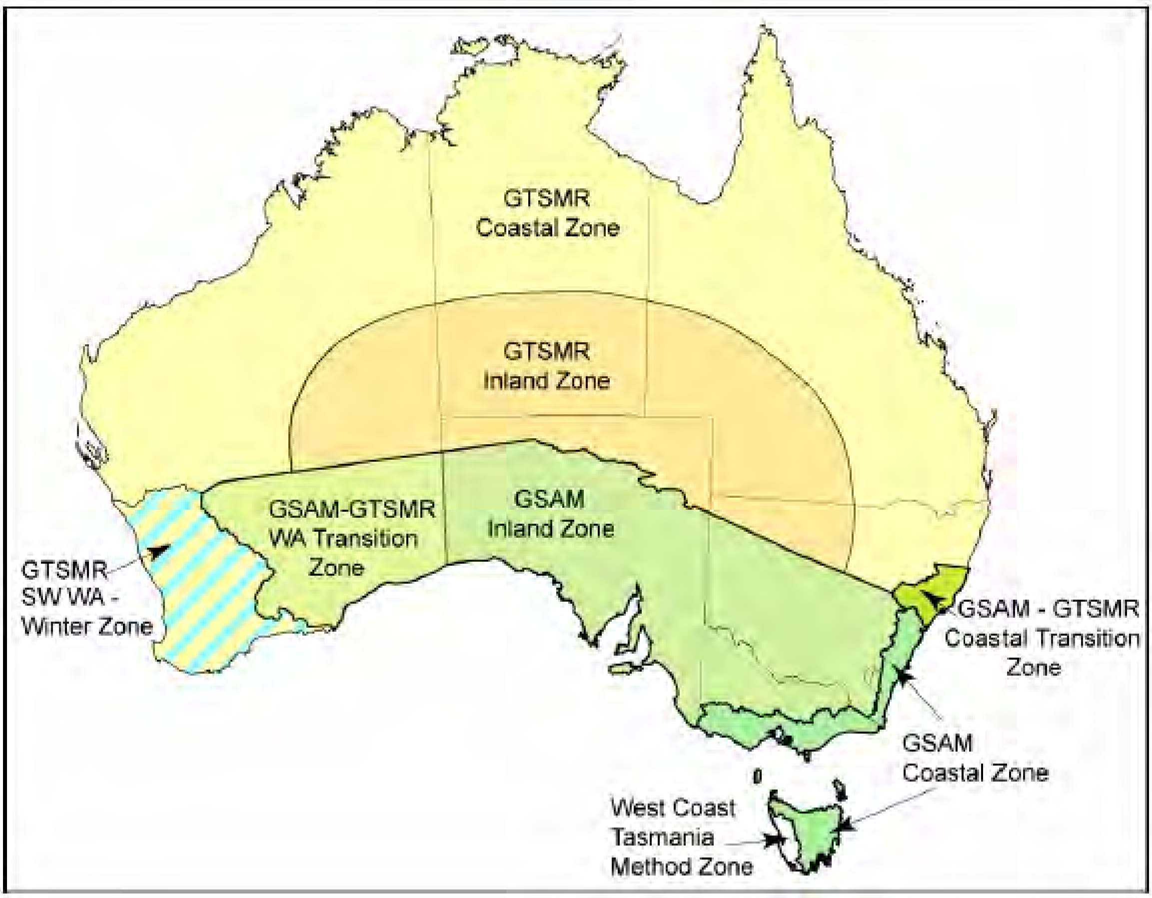

Figure 8-3 Generalised PMP method Zones (BoM, 2006)

8.2 Design Flood Event Durations and Flows

Table 8-4 shows design event flows calculated in the XP-RAFTS hydrology model at key locations within the model Study Area (**Figure 8-4**).

The focus of this study is the Lower Shoalhaven River mainstream flooding and the critical durations for the main model inflow at Grassy Gully at the upstream of the model and at Nowra Bridge are the governing storm events. Flows at reporting locations in tributaries were assessed to ensure that other durations that could produce peak flood levels across the model were captured. There are some noted anomalies in the critical duration flows, particularly for the 5% AEP, which are related to the application of ARR2019 and adopted parameters relevant to the mainstream flooding. It is noted that full validation of the ARR2019 flows has not been undertaken for the tributaries as they are not the focus of this flood study and it is likely that Council will adopt flood levels for Bomaderry Creek, Broughton Creek and Nowra and Browns Creek based on the corresponding local catchment flood studies which are more detailed in these areas.

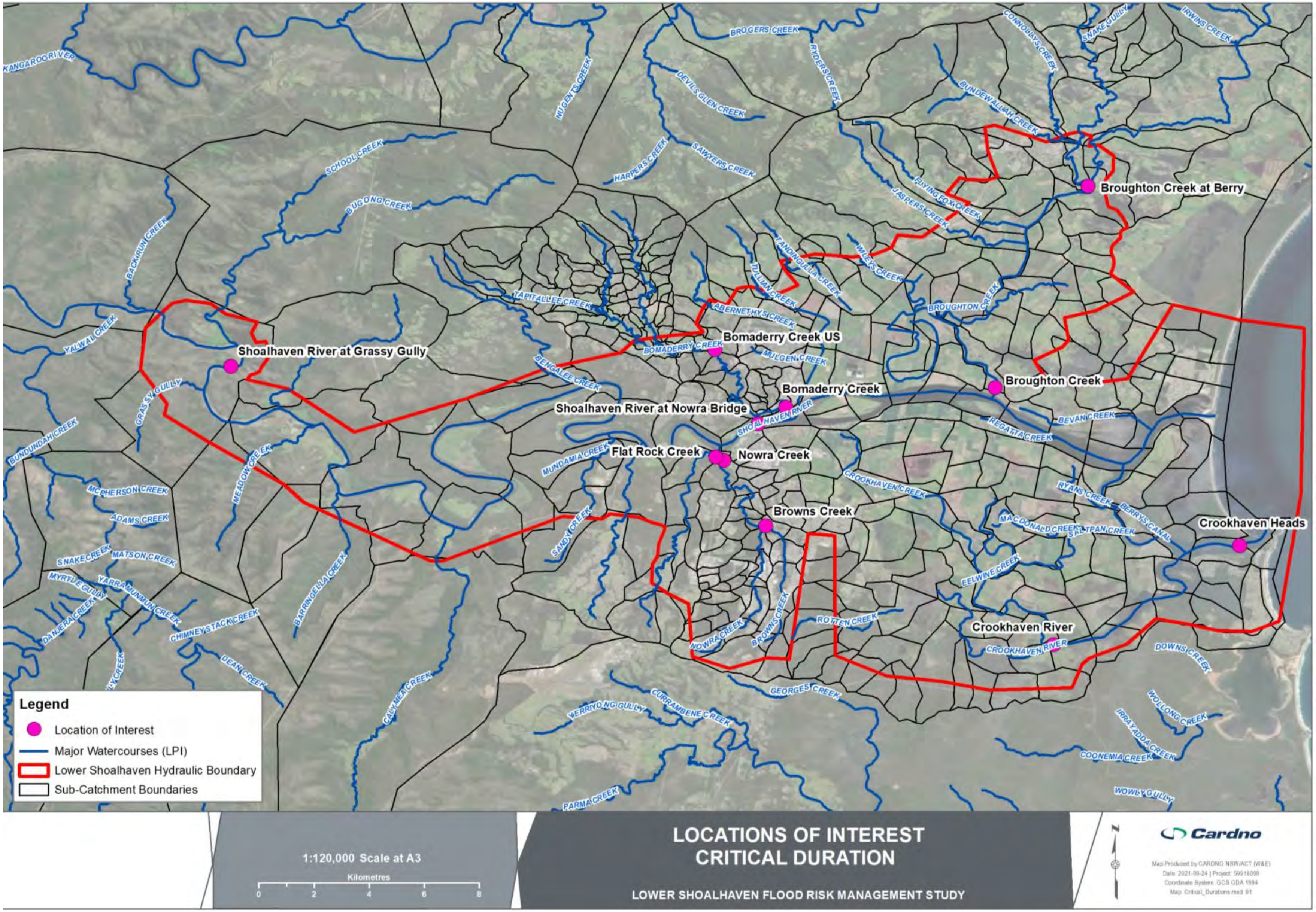

Figure 8-4 Locations for determining critical duration flows

Table 8-4 Critical Durations, Flow and Temporal Patterns at key locations from hydrology model

Event	Location	Grassy Gully II	Nowra Bridge	Bomaderry Creek	Broughton Creek at Berry	Broughton Creek	Browns Creek	Nowra & Flat Rock Creek	Crookhaven River
	XP-RAFTS Model Node	US_77	LSH_1.07	BD_1.16b	DUM_12	BR_1.20	N_6.07	N_1.17	DUM_87
50% AEP	Critical Duration	18hr	18hr	6hr	6hr	6hr	6hr	6hr	6hr
	TP	6387	6387	6150	6149	6149	6152	6149	6149
	Flow (m^3/s)	**1,113**	**1,143**	**243**	**663**	**881**	**65**	**177**	**180**
20% AEP	Critical Duration	18hr	18hr	6hr	90min	90min	6hr	90min	90min
	TP	6387	6385	6150	6019	6025	6152	6021	6020
	Flow (m^3/s)	**4,084**	**4,082**	**395**	**1,182**	**1,564**	**100**	**280**	**311**
10% AEP	Critical Duration	18hr	18hr	3hr	90min	90min	90min	90min	90min
	TP	6385	6385	6071	6012	6015	6011	6006	6013
	Flow (m^3/s)	**6,847**	**7,010**	**510**	**1,564**	**2,058**	**130**	**364**	**412**
5% AEP	Critical Duration	18hr	18hr	3hr	90min	90min	90min	3hr	3hr
	TP	6380	6385	6071	6011	6007	6009	6080	6078
	Flow (m^3/s)	**9,289**	**9,340**	**646**	**1,929**	**2,508**	**158**	**453**	**528**
2% AEP	Critical Duration	18hr	18hr	6hr	6hr	6hr	6hr	6hr	6hr
	TP	6380	6385	6132	6132	6132	6132	6132	6132
	Flow (m^3/s)	**12,102**	**12,200**	**632**	**1,844**	**2,451**	**157**	**442**	**530**
1% AEP	Critical Duration	18hr	18hr	6hr	6hr	6hr	6hr	6hr	6hr
	TP	6380	6385	6132	6132	6132	6132	6132	6132
	Flow (m^3/s)	**13,693**	**13,818**	**660**	**1,944**	**2,594**	**163**	**464**	**561**
0.2% AEP	Critical Duration	36hr	36hr	6hr	2hr	2hr	6hr	6hr	6hr
	TP	6558	6558	6132	6029	6029	6132	6132	6132
	Flow (m^3/s)	**17,996**	**18,587**	**714**	**2,379**	**3,358**	**174**	**533**	**660**
PMP*	Critical Duration	72hr	24hr	150min	150min	3hr	150min	3hr	4hr
	Method	GSAM	GSAM	GSDM	GSDM	GSDM	GSDM	GSDM	GSDM
	Flow (m^3/s)	**35,382**	**38,221**	**1,386**	**4,756**	**6,621**	**309**	**1,154**	**1,714**

* *Adoption of shorter lag time values in the XP-RAFTS model for the PMP event has been investigated for 24hr and 72hr critical durations. Flows for short critical durations (150min, 3hr and 4hr) can be further investigated during the FRMS&P phase if required..*

8.3 Comparison with FFA

Table 8-5 shows the comparison of the FFA design event expected flows at Grassy Gully II gauge (215216) with the ARR2019 design events flows calculated by the hydrology model (XP-RAFTS/StormInjector).

It is not possible to validate design flows to the FFA using a uniform set of loss parameters derived from calibration across the design events. As such, the applied continuing losses were varied across the design events to generate flows to match the expected quantile from the FFA. Using this method, the design flow estimates compare well with the FFA data across the range of events up to the 1% AEP (**Figure 7-5**).

Table 8-5 FFA derived expected design event flows at Grassy Gully II Gauge (215216)

AEP Event	FFA Expected Flow (m^3/s)	Design Flood Event Estimates		
		Peak Flow (m^3/s)	CL (mm/hr)	Pre-burst Application
50%	1,202	1,113	3.5	90% Pre-burst
20%	4,140	4,083	2	90% Pre-burst
10%	6,623	6,847	1	90% Pre-burst
5%	9,017	9,289	0.5	90% Pre-burst
2%	11,832	12,102	0	90% Pre-burst
1%	13,641	13,693	0	90% Pre-burst

8.4 ARR87 Design flood estimation

This section of the report describes the application of ARR1987 methodologies in the XP-RAFTS hydrologic model developed by Cardno. This assessment was undertaken for the purpose of comparing the ARR1987 1% AEP event peak flows from this study and previous studies in the Lower Shoalhaven River, and to compare the resulting 1% AEP peak flows generated by ARR1987 and ARR2019.

8.4.1 Design Input Parameters

8.4.1.1 *Design Rainfall*

IFD data was adopted from the Shoalhaven River Flood Study (WMAwater, 2013) provided by Council in the data handover at project commencement. The IFD has been provided in **Figure 8-5** for reference. It is noted also that the 2013 Flood Study adopted the same design hydrologic modelling approach and parameters as the 1990 Shoalhaven River Flood Study, on the basis that there had not been any significant flood events in the Shoalhaven River between 1990 and 2013, and that the hydrologic model and inputs were fit for use for the purpose of the 2013 Flood Study. The hydrologic model software used for both the 1990 and 2013 Flood Study assessments was the Boyd model (predecessor to the Watershed Bounded Network Model (WBNM)).

Intensity-Frequency-Duration Table

Location: 34.875S 150.600E NEAR.. NOWRA Issued: 24/10/201

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	108	138	173	193	220	254	280
6Mins	101	130	163	181	206	239	264
10Mins	83.2	107	135	151	173	202	223
20Mins	61.2	78.9	102	115	133	156	173
30Mins	49.9	64.6	84.2	95.7	111	131	146
1Hr	33.9	44.0	58.3	66.7	77.7	92.4	104
2Hrs	21.9	28.6	38.5	44.5	52.2	62.6	70.6
3Hrs	16.7	22.0	29.8	34.7	40.9	49.2	55.7
6Hrs	10.5	13.9	19.2	22.4	26.7	32.3	36.8
12Hrs	6.71	8.90	12.4	14.6	17.4	21.2	24.2
24Hrs	4.44	5.88	8.14	9.55	11.4	13.8	15.7
48Hrs	2.94	3.87	5.27	6.13	7.24	8.72	9.88
72Hrs	2.22	2.92	3.95	4.58	5.38	6.46	7.31

(Raw data: 44.44, 8.87, 2.92, 93.43, 21.26, 6.45, skew=0.01, F2=4.27, F50=15.78

Figure 8-5 ARR87 Intensity-Frequency-Duration Table (Shoalhaven River Flood Study WMA, 2013)

It is noted that it appears that a single set of IFD rainfall values has been applied to the entire Shoalhaven River catchment.

8.4.1.2 *Design Losses*

For consistency with the 1990 and 2013 Flood Studies, the same initial and continuing losses were applied uniformly to the catchment:

> Initial Loss: 30.0 mm; and
> Continuing Loss: 2.0 mm/hr.

8.4.1.3 *Model Parameters*

Model parameters are as per the calibrated XP-RAFTS model described in **Section 4.2**.

8.4.1.4 *Areal Reduction Factor*

An ARF was applied in the XP-RAFTS model to all design events, the applied ARF is shown in **Table 8-6** below.

It is noted that the application of ARFs was not documented in either the 1990 Flood Study nor the 2013 Flood Study, however, are assumed to have been applied in accordance with best practice at the time.

Table 8-6 ARR87 Areal Reduction Factor

Storm Duration (hr)	ARI (years)	ARF
36	5	0.817
36	10	0.808
36	20	0.799
36	50	0.786
36	100	0.777

8.4.1.5 *Storm Events and Durations*

The model has been run for a range of events from the 5 year ARI to the 100 year ARI event. The 2013 Flood Study notes the critical duration of peak flows at Nowra Bridge as the 36 hour duration. To allow direct comparison, the 36 hour duration was selected to be run for each design event.

8.4.1.6 *Extreme Event*

The 1990 Lower Shoalhaven River Flood Study developed an 'Extreme Event' hydrograph based on rainfall information derived in the "Riverview Road Area, Preliminary Floodplain Management Study" (Webb McKeown & Associates Pty Ltd, September 1985). This data is understood to be a multiple of the 1% AEP design rainfall, however, a full description of its derivation was not available.

For comparison, the PMF peak flow at Nowra Bridge and the corresponding reported Extreme Event peak flow have been noted in **Section 8.4.2**, however further analysis was outside the scope of this Study.

8.4.2 **Results**

The peak flows at Nowra Bridge for a range of design events is shown in **Table 8-7**. These are compared to the design peak flows reported in the 2013 Flood Study and the current ARR2019 design flood estimates. A comparison of design hydrographs at Nowra Bridge is presented in **Figure 8-6**.

Table 8-7 Peak flows at Nowra Bridge (ARR87)

ARI (years)/ AEP (1 in Y)	1990/2013 Flood Study Peak Flow ARR87 (m^3/s)	Peak Flow ARR87 (m^3/s)	Peak Flows ARR2019 (m^3/s)
5	-	6,352	4,164
10	7,380	7,881	7,010
20	9,466	9,845	9,391
50	12,196	12,006	12,222
100	15,410	13,960	13,834
PMP/Extreme	34,105 (Extreme)	36,328 (GSAM)	36,328 (GSAM)

It can be seen from the above analyses that the current study XP-RAFTS model produces similar results to previous flood studies when using the same ARR87 input parameters. ARR2019 design flood estimates also compare well to previous study adopted flows using ARR87.

The exception is the 1% AEP, where the current study model is predicting lower flows than previously adopted. It is not clear why this is the case, due to lack of information about the previous Boyd hydrology model setup and the representation (if any) of Tallowa Dam within the Boyd hydrology model. However, it is noted that the current study ARR2019 design flood estimates compare well with the FFA derived at Grassy Gully II gauge (215216).

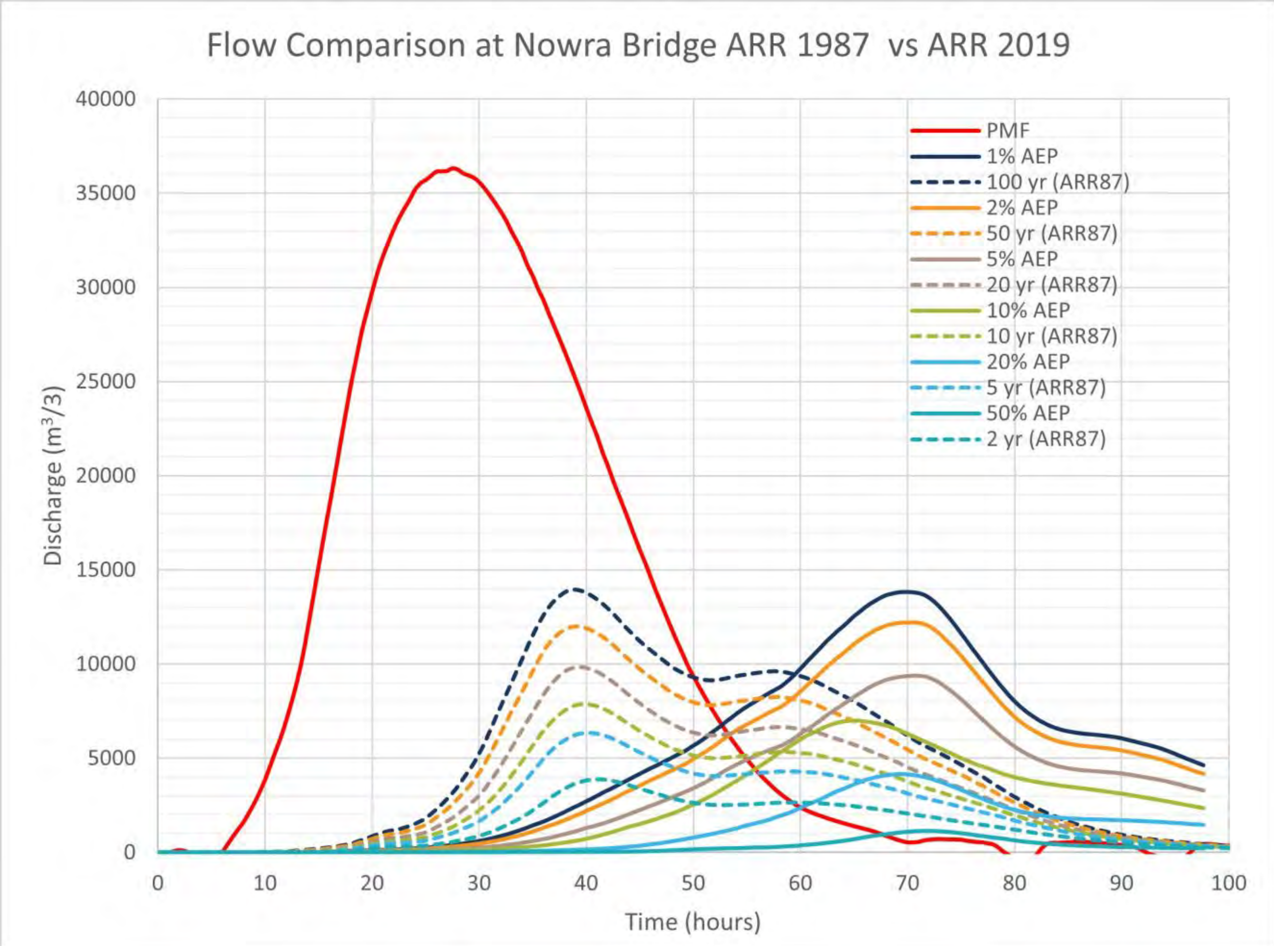

Figure 8-6 Comparison of ARR87 vs ARR2019 hydrology

8.5 Parameter Sensitivity Analysis

Sensitivity of the hydrologic model to a number of parameters was carried out as part of the calibration for historical events in determining the appropriate parameters to use to represent the catchment response. Sensitivity to stream lag time, initial loss, continuing loss and rainfall spatial distribution are discussed in **Section 6.1**. This showed that stream lag and initial loss were appropriate to represent the catchment response and timing of gauged flow hydrographs while more variability was observed for continuing loss. Rainfall spatial distribution was also important and spatial distribution of rainfall IFD across the catchment has been adopted for design events.

Additional parameter sensitivity was undertaken to test the impact on flows and flood water levels for the 1% AEP design event as discussed below.

8.5.1 ARR2019 Temporal Patterns

ARR2019 methods include the modelling of an ensemble of ten rainfall temporal patterns for each storm event and duration to determine a range of possible storm event patterns. The mean of the resulting peak flows from each temporal pattern is chosen as the representative flow for each design event. For the Lower Shoalhaven River, the temporal pattern that produced the flow closest to the mean with a bias for the temporal pattern above the mean was adopted. Temporal patterns for the 1% AEP 18hr critical duration event from the XP-RAFTS hydrology model are shown in **Figure 8-7**.

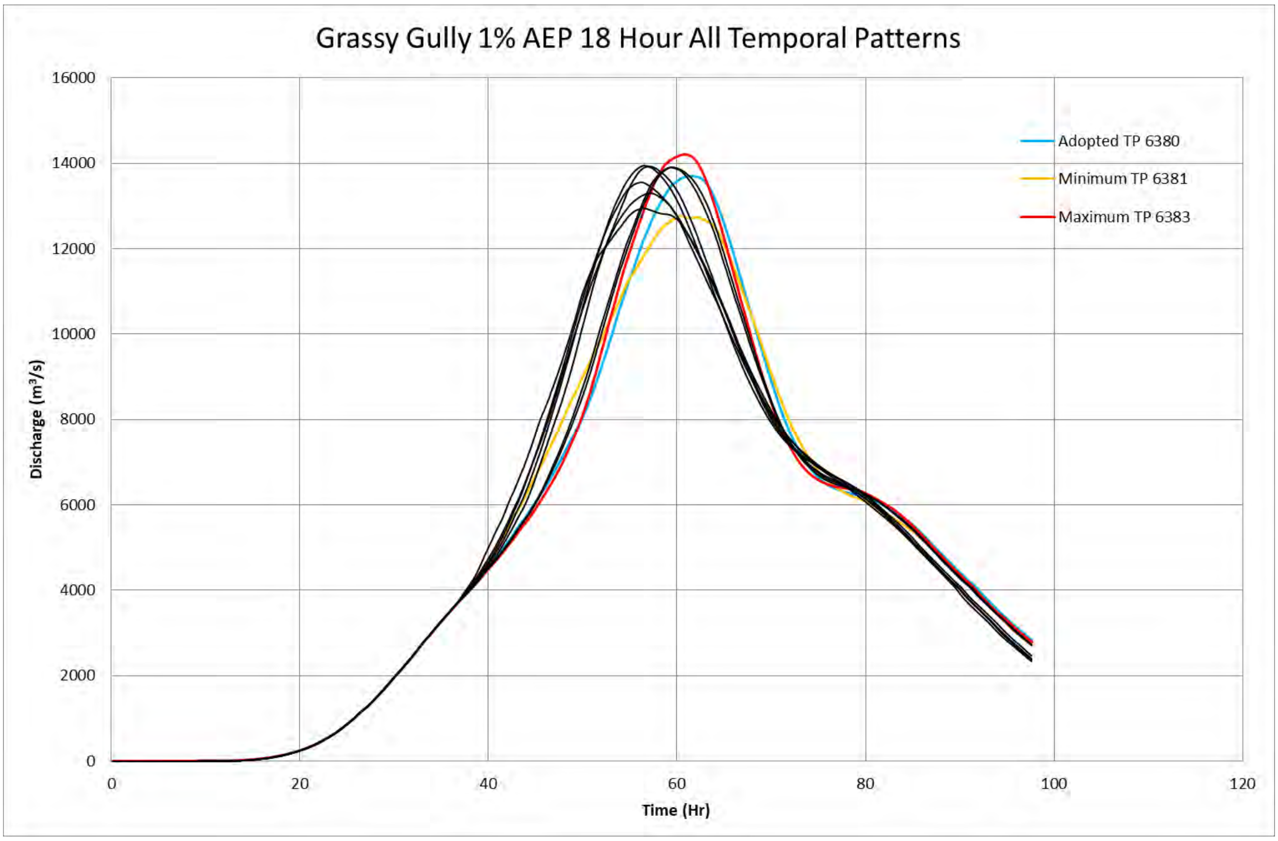

Figure 8-7 Flow hydrographs at Grassy Gully for 1% AEP 18 hr temporal patterns from XP-RAFTS hydrologic model

The 1% AEP peak flow is 13,690m^3/s, 14,215m^3/s and 12,760m^3/s with the adopted, maximum and minimum temporal patterns, respectively.

To test the impact of the range of temporal patterns on Lower Shoalhaven River and floodplain flood levels, the temporal patterns resulting in the minimum and maximum flows at Grassy Gully in the XP-RAFTS hydrologic model were also simulated within the hydraulic model.

8.5.2 Stream lag time

The stream lag time used for routing flows in the hydrologic model is based on assumed velocity/travel times over the stream length. Adjustments to stream lag can affect the timing of flows at different points in the catchment and peak flows. While the stream lags were adjusted to obtain a good fit with historical events, to test the sensitivity of increasing and decreasing stream, the 1% AEP 18hour critical duration event was run using 50% decreased lag time (faster travel times) and 50% increased lag time (slower travel times). Flow hydrographs for the 1% AEP 18hr critical duration event from the XP-RAFTS hydrology model with increased and decreased stream lag are shown in **Figure 8-8**.

The 1% AEP peak flow is 13,690m^3/s, 14,050m^3/s and 8,830m^3/s with the adopted, maximum and minimum temporal patterns, respectively. However, the increased lag time is not a good representation of the catchment response and travel times and provides a poor fit to historical events and the FFA. So while it provides a useful sensitivity, the magnitude of variability of these flows are not considered significant in flood planning decisions.

To test the impact of the effect of changes to stream lag times on Lower Shoalhaven River and floodplain flood levels, the resulting flows at Grassy Gully in the XP-RAFTS hydrologic model were also simulated within the hydraulic model.

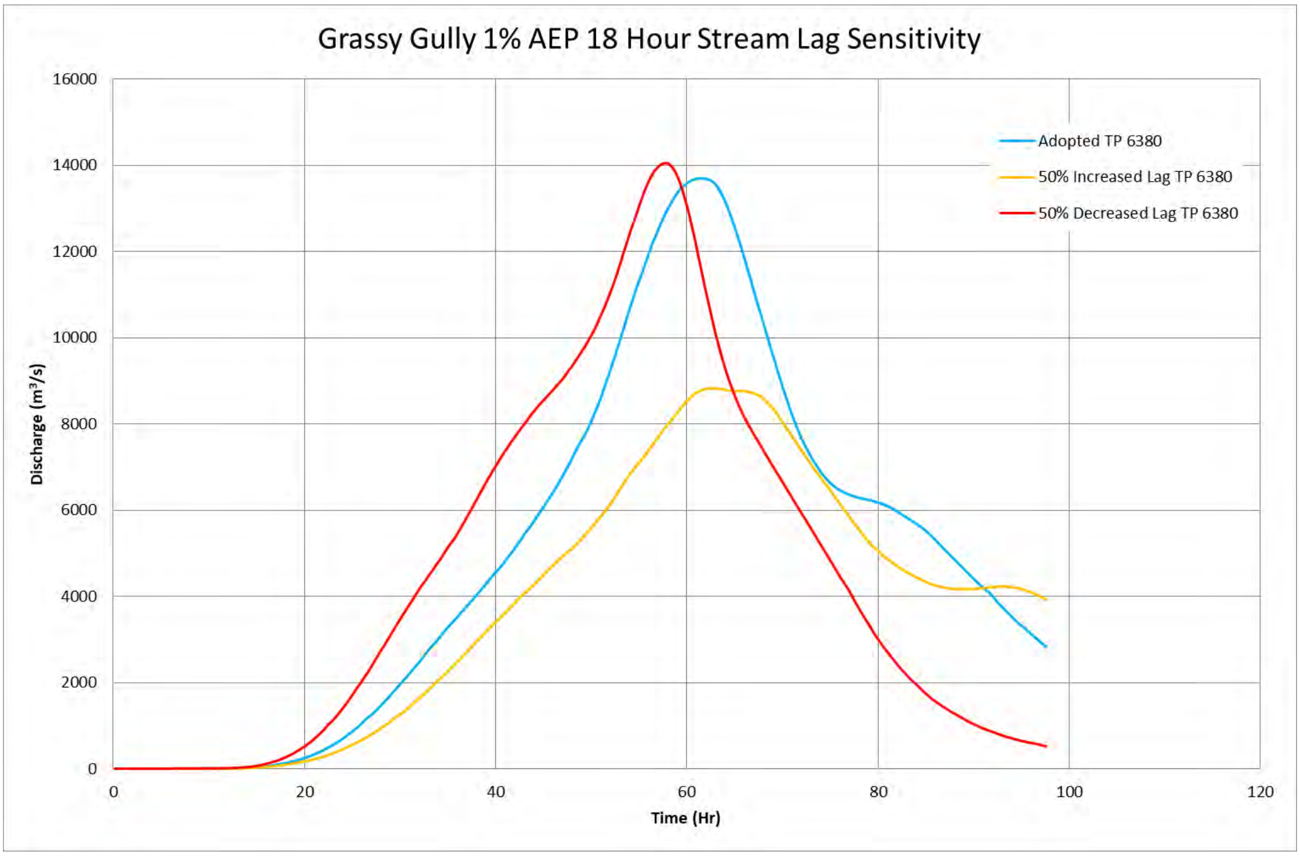

Figure 8-8 Flow hydrographs at Grassy Gully for 1% AEP 18 hr temporal patterns from XP-RAFTS hydrologic model

9 Hydraulic Model Scenarios

The following sections describe the model scenarios undertaken for the Lower Shoalhaven River flood study.

9.1 Design Events

The models have been run for the 20%, 10%, 5%, 2%, 1%, 0.2% AEP Storms and PMF event for the existing, projected 2050 and projected 2100 scenarios.

The following **Table 9-1** shows the durations simulated for each event.

Table 9-1 Design events and durations

AEP	Critical Durations Simulated
50%	6hr, 18hr
20%	90min, 6hr, 18hr
10%	90min, 3hr, 18hr
5%	90min, 3hr, 18hr
2%	12hr, 18hr
1%	12hr, 18hr
0.2%	2hr, 6hr, 36hr
PMF	24hr, 72hr

9.1.2 Tailwater Conditions

The adopted water levels at the downstream boundary of all hydraulic models were selected in accordance with the *NSW Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (NSW OEH, 2015) replicated in **Table 9-2**.

Table 9-2 Combinations of Catchment Flooding and Oceanic Inundation Scenarios (source: Table 8.1 OEH, 2015)

Design AEP for peak levels/velocities	Catchment Flood Scenario	Ocean Water Level Boundary Scenario	Comment/ Reference
50% AEP	50% AEP	HHWS(SS)	Dynamic hydrograph can be taken from Appendix C with peak flood to coincide with HHWS(SS) highest peak for highest water levels Peak HHWS(SS) 1.25m AHD
20%	20% AEP	HHWS(SS)	
10%	10% AEP	HHWS(SS)	
5%	5% AEP	HHWS(SS)	
2%	2% AEP	5% AEP	Dynamic ocean water level boundary hydrograph Appendices A or B for relevant waterway type
1% Envelope level	5% AEP	1% AEP	Envelope provides 1% AEP design flood estimate Dynamic ocean water level boundary hydrograph Appendices A or B for relevant waterway type
1% Envelope level	1% AEP	5% AEP	
1% Envelope velocity	1% AEP	ISLW	Dynamic hydrograph can be taken from Appendix C with peak flood to coincide with ISLW lowest trough for peak velocities in entrance. Fixed ISLW approx. -0.95m AHD
0.5%	0.5% AEP	1% AEP	Dynamic ocean water level boundary hydrograph Appendices A or B for relevant waterway type
0.2%	0.2% AEP	1% AEP	
PMF	PMF	1% AEP	
1% Catchment	1%	HHWS(SS)	Suggested envelopes for analysis of catchment flooding only
PMF Catchment	PMF	HHWS(SS)	

HHWS(SS) – High Water Springs (Summer Solstice)

ISLW – Indian Springs Low Water

The relevant HHWSS, 5% AEP and 1% AEP dynamic hydrograph for Waterway Type B South of Crowdy Head has been used for the ocean boundary. Waterway Type B was selected in consultation with Council and DPE as Crookhaven Heads is trained entrance and Shoalhaven Heads is not a traditional ICOLL (Intermittently Closed and Open Lake and Lagoon) and a single boundary is to be applied to the ocean for both entrances. The 1% AEP and 5% AEP tide comprises the ocean boundary time series Fort Denison May 1974 with 0.55m wave set up (South of Crowdy Head).

A summary of the adopted tailwater boundary conditions is presented in **Table 9-3**.

Table 9-3 Hydraulic Model Tailwater Levels for Design Events

<table>
<tr><th>Event</th><th>Tailwater Scenario</th><th>Peak Level (m AHD)</th></tr>
<tr><td>PMF</td><td rowspan="2">1% AEP Tide (Waterway Type B)</td><td rowspan="2">2.00m AHD</td></tr>
<tr><td>0.2% AEP</td></tr>
<tr><td>1% AEP</td><td rowspan="2">5% AEP Tide (Waterway Type B)</td><td rowspan="2">1.90m AHD</td></tr>
<tr><td>2% AEP</td></tr>
<tr><td>5% AEP</td><td rowspan="3">HHWSS Tide (Waterway Type B)</td><td rowspan="3">1.03 mAHD</td></tr>
<tr><td>10% AEP</td></tr>
<tr><td>20% AEP</td></tr>
<tr><td>HAT</td><td>Highest Astronomical Tide Jervis Bay</td><td>1.12m AHD</td></tr>
</table>

9.1.3 Shoalhaven Heads Entrance Conditions

As described in **Section 5.3**, Shoalhaven Heads breach modelling was undertaken and a relationship derived between the breach width and flows in the Shoalhaven River. For Design Event simulations, Shoalhaven Heads has been modelled as permanently open with bathymetric arrangement setup for the relevant width and depth associated with each particular design event flow. The exception is the 50% AEP event for which the Shoalhaven Heads has been modelled as closed because the flows are not significant enough to generate water levels at Nowra Bridge or Shoalhaven Heads to trigger the manual opening of the Shoalhaven River entrance at Shoalhaven Heads as per Council's entrance management policy. Such flows discharge via Berrys Canal to Crookhaven Heads.

9.2 Sea Level Rise

NSW Flood Risk Management Guide – Incorporating sea level rise benchmarks in flood risk assessments (DECCW, 2010) references the NSW sea level rise planning benchmarks in the *NSW Sea Level Rise Policy Statement* (2009).

The NSW sea level rise planning benchmarks are an increase above 1990 mean sea levels of 40cm by 2050 and 90cm by 2100. These benchmark figures were established by considering the most credible national and international projections of sea level rise for the NSW coast and take into consideration the uncertainty associated with sea level rise projections. This policy was repealed by the NSW Government in 2012 and coastal councils were encouraged to adopt their own sea level rise projections.

Shoalhaven City Council, in partnership with Eurobodalla Shire Council, developed the *South Coast Regional Sea Level Rise Policy and Framework* (Whitehead & Associates, 2014) and Councillors adopted the following sea level rise projections on 10 February 2015,

- 100mm for 2030;
- 230mm for 2050; and
- 360mm for 2100.

These sea level rise projections have been adopted for modelling of the Projected 2050 and Projected 2100 scenarios for the full range of design events. The projected 2050 and projected 2100 scenarios are based on current BoM design event IFD rainfall data (without projected rainfall increases) and Council's SLR projections of 23cm by 2050 and 36cm by 2100. The Sea Level Rise scenarios adopted for this Study are provided in the **Table 9-4**.

Table 9-4 Sea Level Rise scenarios for Design Events

Scenario	Sea Level Rise	Events (AEP)
Projected 2050	SCC 2050 (+0.23m)	20%, 10%, 5%, 2%, 1%, 0.2%
Projected 2100	SCC 2100 (+0.36m)	20%, 10%, 5%, 2%, 1%, 0.2%
NSW Projected 2100	NSW 2100 (+0.90m)	1%

The NSW projected 2050 sea level rise was not modelled as the predicted 40cm increase is very similar to the Council 0.36m SLR scenario.

9.3 Tidal Inundation

To investigate the inundation due to tides, Highest Astronomical Tide (HAT) scenarios have been simulated. HAT levels have been obtained from Table 2.2 of MHL report "*NSW Ocean And River Entrance Tidal Levels Annual Summary 2018–2019*" Report MHL2693 November 2019. As the Crookhaven Heads gauge is known to be influenced by river flows, the Jervis Bay HAT value of 1.12 mAHD was selected.

The peak HHWSS in OEH Floodplain Risk Management Guide (2015) Figure C.1 is 1.03m. This HHWSS tide time series has been scaled up to match the Jervis Bay HAT of 1.12m AHD. No barometric setup or wave setup is considered in the boundary condition.

For the HAT +SLR scenarios, the relevant sea level rise has been added to the time series - i.e. +0.23m for 2050 and +0.36m for 2100.

Tidal inundation scenarios have been run with a closed Shoalhaven Heads entrance for the worst case.

Table 9-5 Sea Level Rise scenarios for HAT Events

Sea Level Rise scenario	Peak Tide Level (m AHD)	Catchment Inflows
HAT	1.12m AHD	Nominal baseflow Inflows
HAT + 2050 (SCC)	1.34m AHD	Nominal baseflow Inflows
HAT + 2100 (SCC)	1.48m AHD	Nominal baseflow Inflows

9.4 Sensitivity Analysis

Sensitivity Analysis is undertaken to examine the effect that varying parameters in the model has on results such as changing model inputs or boundary conditions or to investigate potential future scenarios for prevailing catchment conditions.

Table 9-6 shows the Sensitivity Analysis Scenarios that were investigated for the mainstream model for the Flood Study. Each analysis has been run for the critical duration events to capture the envelope of peak flood level results for comparison with the adopted model setup for a 1% AEP event using ARR2019.

Table 9-6 Sensitivity Analysis Scenarios

ID	Sensitivity Scenario	Description	Event
LagDec	50% Decreased stream lag	Decreased stream lag time by 50% for all links in the XP-RAFTS model i.e. faster travel times between catchment nodes.	1% AEP
LagInc	50% Increased stream lag	Increased stream lag time by 50% for all links in the XP-RAFTS model i.e. slower travel times between catchment nodes.	1% AEP
MinTP	Lowest peak temporal pattern	Inflows derived using the temporal pattern which produced the lowest peak volume/level in the basin for the critical duration	1% AEP
MaxTP	Highest peak temporal pattern	Inflows derived using the temporal pattern which produced the highest peak volume/level in the basin for the critical duration was selected	1% AEP
MAN+20	+20% Mannings Roughness	Increase in the roughness value applied to the materials layer by 20% of adopted values	1% AEP
MAN-20	-20% Mannings Roughness	Decrease in the roughness value applied to the materials layer by 20% of adopted values	1% AEP
50BLK	Blockage Case 1 – 50% blockage	Based off an ARR2019 blockage assessment, 50% blockage applied to all culverts, and bridge and culvert structures with a diagonal length of <1.5m 20% blockage to structures with a diagonal length of >1.5m 0% blockage to structures with a diagonal length of >6m	1% AEP
100BLK	Blockage Case 2 – 100% blockage	100% blockage applied to all culverts, and bridge and culvert structures with a diagonal length of <6m 0% blockage to structures with a diagonal length of >6m	1% AEP
CL	Entrance condition	Adjust entrance bathymetry to represent a closed Shoalhaven Heads entrance	1% AEP
BC	Tailwater - HHWSS	Adopted HHWSS for ocean boundary	1% AEP
LR	Levee Removal	Terara Levees removed to pre-levee ground levels	5% AEP 1% AEP PMF
Ex87	ARR87 – IFD and methods	ARR87 IFD data for Nowra and temporal patterns used. Initial loss 30mm, continuing loss = 2mm/hr (**Section 8.4**)	5% AEP 1% AEP

9.5 Climate Change

It is widely accepted that Climate Change will lead to increases in global temperatures which will lead to increases in the intensity of rainfall along with sea level rise. The NSW Government's Floodplain Development Manual (NSW Government, 2005) requires that flood studies and floodplain risk management studies consider the impact of climate change (rainfall increase and sea level rise) on flood behaviour. This Study has assessed the impacts on flooding of both climate change induced rainfall increases and sea level rise using current industry guidelines.

Climate Change scenarios tested have been adopted from ARR2019 along with consideration of the *OEH Floodplain Risk Management Guides: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (OEH, 2015) and Practical Consideration of Climate Change (DECC, 2007).

9.5.1 Rainfall Increase

Climate change predictions are made based on modelling changes to temperature and rainfall in global climate models for various Representative Concentration Pathways (RCPs), which consider projected increases in greenhouse gas concentrations. Temperature and rainfall for low, medium and high carbon emissions scenarios for years up to 2090 for the Shoalhaven River catchment are shown in **Table 9-7**.

ARR2019 (Ball et al., 2019) recommends the use of RCP 4.5 and RCP 8.5 values. These values are available as a percentage that the rainfall should be factored by from the ARR Data Hub.

Table 9-7 ARR Data Hub recommended Climate Change Data

Year	RCP 4.5		RCP6.5		RCP 8.5	
	Temperature Increase (°C)	Rainfall Increase	Temperature Increase (°C)	Rainfall Increase	Temperature Increase (°C)	Rainfall Increase
2030	0.648	3.20%	0.687	3.40%	0.811	4.00%
2040	0.878	4.40%	0.827	4.10%	1.084	5.40%
2050	1.081	***5.40%***	1.013	5.10%	1.446	***7.30%***
2060	1.251	6.30%	1.229	6.20%	1.862	9.50%
2070	1.381	7.00%	1.46	7.40%	2.298	11.90%
2080	1.465	7.40%	1.691	8.60%	2.719	14.20%
2090	1.496	***7.60%***	1.906	9.70%	3.09	***16.30%***

9.5.2 Sea Level Rise

The Shoalhaven City Council adopted sea level raise projections discussed in Section 9.2, i.e. 23cm by 2050 and 36cm by 2100 based on *South Coast Regional Sea Level Rise Policy and Planning Framework* (Whitehead & Associates, 2014) have been adopted in the Climate Change model scenarios.

9.5.3 Climate Change Scenarios

Based on the above considerations, it was decided to run both the rainfall increase with no sea level rise and running rainfall increase in combination with the expected corresponding sea level rise for two future scenarios – 2050 and 2090. Both RCP 4.5 and RCP 8.5 rainfall increase has been run for each future scenario for both the 5% AEP and 1% AEP events.

Climate Change Scenarios assessed are provided in **Table 9-8**.

Table 9-8 Climate Change Scenarios

ID	Rainfall Scenario	Catchment Event	Ocean Tide	Rainfall Increase	Sea Level Rise (SLR)	Adopted Boundary Peak Water Surface Level
CC1	RCP4.5 – 2050	5% AEP	HHWSS tide – 1.03m AHD	5.40%	Existing	1.03m AHD
		1% AEP	5% AEP tide – 1.90m AHD			1.90m AHD
CC2	RCP8.5 – 2050	5% AEP	HHWSS tide – 1.03m AHD	7.30%	Existing	1.03m AHD
		1% AEP	5% AEP tide – 1.90m AHD			1.90m AHD
CC3	RCP4.5 – 2090	5% AEP	HHWSS tide – 1.03m AHD	7.60%	Existing	1.03m AHD
		1% AEP	5% AEP tide – 1.90m AHD			1.90m AHD
CC4	RCP8.5 – 2090	5% AEP	HHWSS tide – 1.03m AHD	16.30%	Existing	1.03m AHD
		1% AEP	5% AEP tide – 1.90m AHD			1.90m AHD
CC5	RCP4.5 – 2050	5% AEP	HHWSS tide – 1.03m AHD	5.40%	SCC 2050 (+0.23m)	1.26m AHD
		1% AEP	5% AEP tide – 1.90m AHD			2.13m AHD
CC6	RCP8.5 – 2050	5% AEP	HHWSS tide – 1.03m AHD	7.30%	SCC 2050 (+0.23m)	1.26m AHD
		1% AEP	5% AEP tide – 1.90m AHD			2.13m AHD
CC7	RCP4.5 – 2090	5% AEP	HHWSS tide – 1.03m AHD	7.60%	SCC 2100 (+0.36m)	1.39m AHD
		1% AEP	5% AEP tide – 1.90m AHD			2.26m AHD
CC8	RCP8.5 – 2090	5% AEP	HHWSS tide – 1.03m AHD	16.30%	SCC 2100 (+0.36m)	1.39m AHD
		1% AEP	5% AEP tide – 1.90m AHD			2.26m AHD

10 Results and Discussion

Flooding within the Lower Shoalhaven River area begins with small tributaries and overland flow filling both the Broughton Creek floodplain and the Crookhaven Creek swamp areas. As the flows increase in events up to the 1% AEP, the Shoalhaven River rises and a backwater from the Crookhaven River is seen to start filling back up into the Pyree, Brundee and Numbaa areas before the Terara levees are overtopped and then flows break out of the Shoalhaven River and flow across the Crookhaven Creek/Crookhaven River floodplain towards Crookhaven Heads. Broughton Creek floodplain outlet is constrained by the topography/bathymetry of the Broughton Creek channel outlet to Shoalhaven River, with higher ground along the banks of Broughton Creek and the Shoalhaven River and is further constrained by the Shoalhaven River levels preventing flow from discharging from the floodplain. As levels rise sufficiently, spilling begins to occur from the Shoalhaven River to Broughton Creek north of Pig Island.

In the PMF, the same behaviour is observed and with increased flows, the breakout of the Shoalhaven River channel is more pronounced with deeper depths and with more spilling from the Shoalhaven River into the Broughton Creek floodplain.

While the system is tidal for a large extent upstream past Gradys Caravan Park, riverine flood flows are dominant in determining water levels during floods within the Shoalhaven River upstream of Nowra, with entrance conditions, ocean conditions and sea level rise impacting areas up to approximately Pig Island. The Broughton Creek floodplain is relatively uninfluenced by ocean conditions, and is mainly controlled by the constrained outlet to the Shoalhaven River.

The following sections describe the results and processing of results for determining various flood behaviour parameters.

Whilst results are presented in the Bomaderry Creek, Broughton Creek and Nowra & Browns Creek areas in the mapping, there are limitations with the results due to model grid size being too large to accurately represent smaller tributary creeks and flow calibration/validation has focussed on the mainstream Shoalhaven River. Modelling results from the Bomaderry Creek FRMS&P, Broughton Creek FRMS&P and Nowra & Browns Creek FRMS&P take precedence in these areas.

10.1 Peak Flood Levels, Extents and Depths

Flood extent maps for the 20%, 10%, 5%, 2%, 1%, 0.2% AEP and PMF design flood events showing peak flood depths (**Figures G01** to **G07**), peak flood levels and contours (**Figures G08** to **G14**) are provided in **Appendix G.**

Flood levels for the full range of design events corresponding to the key locations in **Figure 10-1** are presented in **Table 10-1**.

For more frequent events up to the 20% AEP, flooding is largely contained within the channel banks of the Shoalhaven River and tributaries, including Bomaderry Creek. Flooding in these frequent events largely affects the following areas:

- Broughton Creek floodplain (with depths of 1.5m or more) including Jaspers Brush, Bolong, Back Forest, Far Meadow and Berry. Bolong Road is affected at the lower end of Broughton Creek;
- Upper Bomaderry Creek and the lower reach of Bomaderry Creek near Shoalhaven River, affecting Bolong Road;
- Swamp area to the east of Nowra between Marriott Park and Millbank Road (with depths generally up to 1.5m), including urban areas around Haigh Avenue and Morton Parade;
- Generally shallow depths (0.5 - 1m) in the swamp area in the north of Brundee;
- Numbaa and Pyree areas including tributaries of Berrys Canal and the Lower Crookhaven River (including Ryans Creek, Macdonald and Salt Pan Creeks) which affect Comerong Island Road and Greenwell Point Road;
- Generally shallow depths (0.5 - 1m) around the Worrigee, Brundee Swamp and Saltwater Swamp areas;
- Low-lying foreshore areas around Shoalhaven Heads (Hay Ave and Jerry Bailey Rd), Coolangatta (affecting Bolong Road), Comerong Island and Culburra Beach; and
- Tributary flows affect properties in Berry, Bomaderry, East Nowra and South Nowra.

For the 10% AEP, flood results show similar affected areas but with greater flood depths and increased flood extents. Properties in low-lying foreshore areas become more flood affected particularly around Culburra Beach, Shoalhaven Heads and Greenwell Point. Protection is afforded to Terara from the Terara levees up to approximately the 10% AEP event, however, overtopping is observed south of Pig Island. Flooding to the west of Millbank Road increases as the swamp areas begin to fill with greater depths. Greenwell Point will begin to become isolated with depths on Greenwell Point Road becoming unsafe for vehicles.

For events larger than the 5% AEP event:

> Flooding is widespread throughout the Shoalhaven and Crookhaven River floodplain with depths becoming greater, commonly exceeding 2m with the various tributaries becoming interconnected to a combined floodplain;

> Depths within the Broughton Creek floodplain are greater than 3m over large areas. The Broughton Creek floodplain becomes connected to the Shoalhaven River;

> Terara Levees are overtopped south of Pig Island;

> More properties around the foreshore areas become inundated including:

  > Shoalhaven Heads - Jerry Bailey Road and Shoalhaven Heads Road.

  > Greenwell Point – widespread flooding of low-lying streets including Adelaide St, Comarong St, West St, South St, Hasler Rd, Keith Ave, Leonore Ave, Fraser Ave, Greens Rd, Bailey Ave, Crookhaven Drive.

  > Orient Point – Orama Crescent.

  > Culburra Beach – Orient Point Rd, Addison Rd, Whistler St and Brighton Parade with sections of Prince Edward Ave becoming submerged.

The 2% AEP event has similar flood extents to the 5% AEP with greater flood depths with some newly flooded areas around East Nowra and near Moorhouse Park/Scenic Drive to the west of Nowra Bridge.

The 1% AEP again has greater depths and extents, particularly around the lower Crookhaven and Greenwell Point and Culburra Beach.

The Riverview Road levee will provide protection from Shoalhaven River flooding up to the 0.2% AEP event with areas behind the levee inundated in the 0.2% AEP event as a result of backwater flooding from the Crookhaven Creek area. In the 0.2% AEP event, almost the entire floodplain now has depths exceeding 3m. Greenwell Point and Culburra Beach becoming significantly affected along with East Nowra and Terara.

The PMF affects large areas of the Broughton Creek, Lower Shoalhaven and Crookhaven River floodplain as well as the tributaries and overland flow areas. Depths are greater with the backwater affecting parts of Nowra, Bomaderry and Berry as well as more severe flooding of the foreshore areas in the lower reaches.

Projected 2050 scenario including 0.23m Sea Level Rise flood extent maps showing peak flood depths and peak flood levels with contours are provided in **Figure G31** to **G38** in **Appendix G**, with flood levels presented in **Table 10-2**.

Projected 2100 scenario including 0.36m Sea Level Rise flood extent maps showing peak flood depths and peak flood levels with contours are provided in **Figure G55** to **G62** in **Appendix G**, with flood levels presented in **Table 10-3**.

Table 10-1 Peak flood level at reference locations for design events – existing scenario

ID	Location	Water Level (mAHD)						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Grassy Gully	16.50	20.16	22.86	25.39	26.72	29.84	41.62
2	Gradys Caravan Park	10.99	14.46	16.75	18.68	19.64	22.47	32.69
3	Bomaderry Creek	4.59	5.17	5.54	5.28	5.48	5.56	7.02
4	Nowra Bridge	3.01	4.19	4.83	5.22	5.38	6.22	8.85
5	Terara Gauge	2.87	3.99	4.61	5.01	5.19	5.70	7.46
6	Terara Town	Not Affected	Not Affected	3.90	4.09	4.25	4.97	6.88
7	Broughton Creek US	3.48	3.93	4.25	4.13	4.31	4.95	6.93
8	Jorams and Broughton Confluence	2.09	3.03	3.70	4.13	4.31	4.94	6.92
9	Broughton Creek Confluence	2.13	2.98	3.60	3.97	4.14	4.76	6.68
10	Hay Street Gauge	1.74	1.98	2.36	2.49	2.92	3.74	5.63
11	Shoalhaven Heads	1.73	1.93	2.22	2.34	2.70	3.46	4.99
12	Crookhaven River and Crookhaven Creek Confluence	1.24	1.29	1.69	2.47	3.00	3.95	6.06
13	Greenwell Point Gauge	1.20	1.24	1.60	2.32	2.71	3.66	5.70
14	Crookhaven Heads Gauge	1.14	1.16	1.41	2.16	2.43	3.30	4.94

*Refer to **Figure 10-1** for reference locations.*

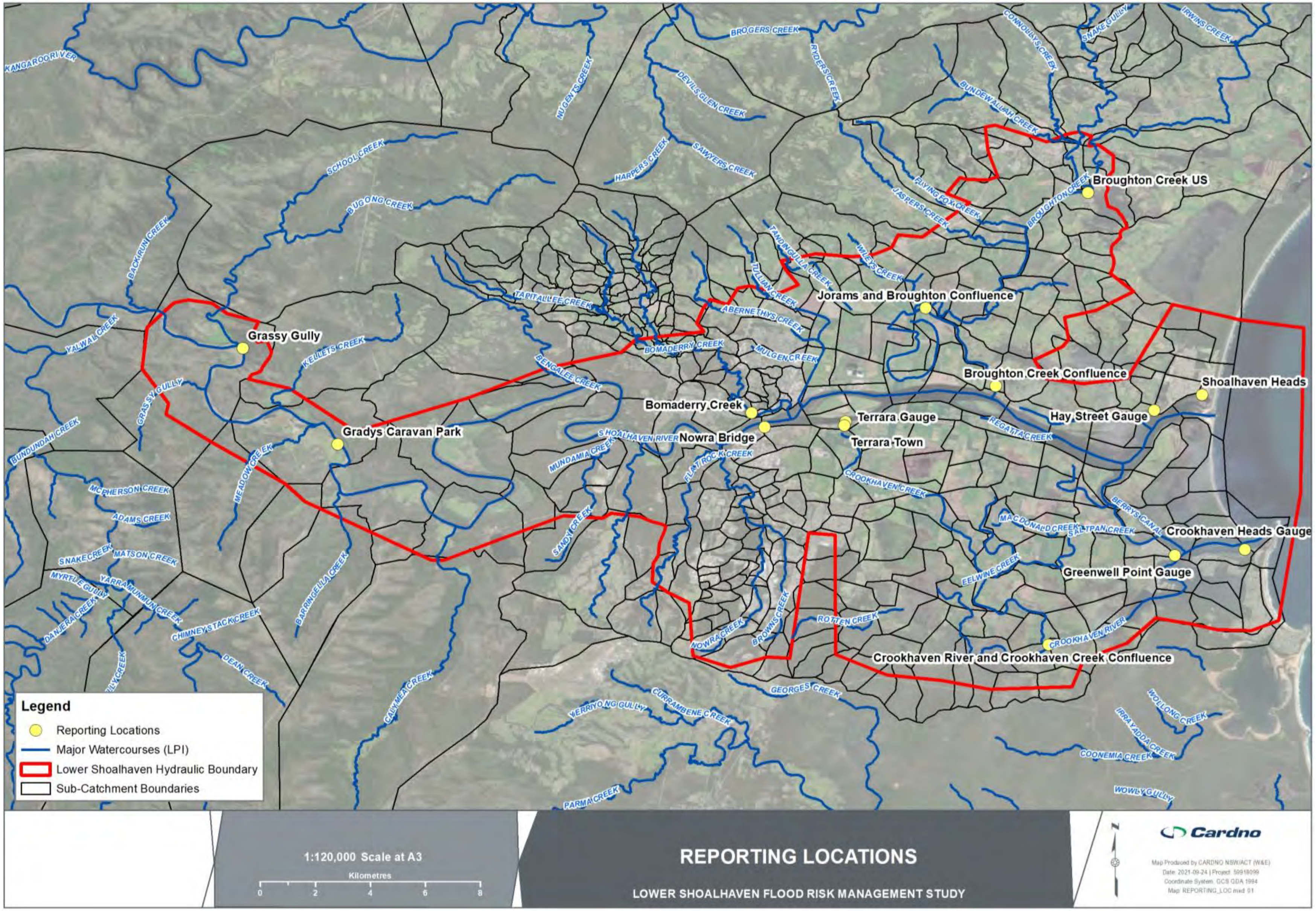

Figure 10-1 Key Reporting Locations

Table 10-2 Peak flood level at reference locations for design events – Projected 2050 scenario

ID	Location	Projected 2050 Water Level (mAHD)				
		10% AEP	5% AEP	2% AEP	1% AEP	PMF
1	Grassy Gully	20.16	22.86	25.39	26.72	41.62
2	Gradys Caravan Park	14.46	16.75	18.68	19.64	32.69
3	Bomaderry Creek	5.18	5.54	5.28	5.48	7.02
4	Nowra Bridge	4.20	4.83	5.22	5.38	8.85
5	Terara Gauge	4.00	4.61	5.01	5.19	7.47
6	Terara Town	Not Affected	3.90	4.10	4.25	6.88
7	Broughton Creek US	3.93	4.25	4.13	4.31	6.93
8	Jorams and Broughton Confluence	3.06	3.70	4.13	4.31	6.92
9	Broughton Creek Confluence	3.00	3.60	3.98	4.14	6.69
10	Hay Street Gauge	2.02	2.38	2.62	3.01	5.64
11	Shoalhaven Heads	1.97	2.24	2.50	2.82	5.00
12	Crookhaven River and Crookhaven Creek Confluence	1.46	1.80	2.60	3.08	6.07
13	Greenwell Point Gauge	1.43	1.73	2.47	2.83	5.71
14	Crookhaven Heads Gauge	1.36	1.56	2.34	2.57	4.95

*Refer to **Figure 10-1** for reference locations.*

Table 10-3 Peak flood level at reference locations for design events – Projected 2100 scenario

ID	Location	Projected 2100 Water Level (mAHD)				
		10% AEP	5% AEP	2% AEP	1% AEP	PMF
1	Grassy Gully	20.16	22.86	25.39	26.72	41.62
2	Gradys Caravan Park	14.46	16.75	18.68	19.64	32.69
3	Bomaderry Creek	5.18	5.54	5.29	5.48	7.02
4	Nowra Bridge	4.20	4.84	5.22	5.38	8.85
5	Terara Gauge	4.00	4.61	5.01	5.19	7.47
6	Terara Town	Not Affected	3.90	4.10	4.25	6.89
7	Broughton Creek US	3.93	4.25	4.14	4.32	6.93
8	Jorams and Broughton Confluence	3.07	3.71	4.14	4.32	6.92
9	Broughton Creek Confluence	3.02	3.61	3.98	4.15	6.69
10	Hay Street Gauge	2.05	2.39	2.70	3.07	5.64
11	Shoalhaven Heads	2.00	2.25	2.59	2.89	5.00
12	Crookhaven River and Crookhaven Creek Confluence	1.56	1.87	2.68	3.14	6.07
13	Greenwell Point Gauge	1.53	1.80	2.56	2.90	5.71
14	Crookhaven Heads Gauge	1.48	1.65	2.44	2.66	4.96

*Refer to **Figure 10-1** for reference locations.*

It is seen that Sea Level Rise predominantly affects the lower reaches of the system towards the entrances, the low lying areas around the foreshore (Shoalhaven Heads, Comerong Island, Greenwell Point, Orient Point and Culburra Beach) and within the Crookhaven River floodplain areas. The following statements are made for each sea level rise scenario:

> The SCC projected 2050 sea level rise of +0.23m results in typically less than 150mm of water level increase and no impacts upstream of the Broughton Creek confluence;

> The SCC projected 2100 sea level rise of +0.36m results in typically less than 200mm of water level increase and no impacts upstream of the Broughton Creek confluence; and

> The NSW 2100 sea level rise of +0.90m results in typically less than 550mm of water level increase locally near the entrances and within the Crookhaven River decreasing moving upstream into the swamp areas to the west. Minor increases of up to 50mm are observed in the Broughton Creek floodplain while in the Shoalhaven River, no impacts are observed upstream of Terara.

Water level differences compared with existing (no sea level rise) are shown in **Table 10-4** and presented in **Figure G51** to **G54** for Projected 2050, **Figure G75** to **G78** for Projected 2100, and **Figure G79** for NSW Projected 2100 in **Appendix G**.

Table 10-4 Sea Level Rise – 1% AEP water level difference

ID	Location	1% AEP	SCC 2050 (+0.23m)		SCC 2100 (+0.36m)		NSW 2100 (+0.90m)	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	26.72	26.72	0.00	26.72	0.00	26.72	0.00
2	Gradys Caravan Park	19.64	19.64	0.00	19.64	0.00	19.64	0.00
3	Bomaderry Creek	5.48	5.48	0.00	5.48	0.01	5.49	0.01
4	Nowra Bridge	5.38	5.38	0.00	5.38	0.00	5.38	0.00
5	Terara Gauge	5.19	5.19	0.00	5.19	0.00	5.19	0.00
6	Terara Town	4.25	4.25	0.00	4.25	0.00	4.26	0.01
7	Broughton Creek US	4.31	4.31	0.00	4.32	0.01	4.35	0.04
8	Jorams and Broughton Confluence	4.31	4.31	0.00	4.32	0.01	4.35	0.04
9	Broughton Creek Confluence	4.14	4.14	0.01	4.15	0.01	4.18	0.05
10	Hay Street Gauge	2.92	3.01	0.09	3.07	0.15	3.36	0.44
11	Shoalhaven Heads	2.70	2.82	0.12	2.89	0.19	3.23	0.54
12	Crookhaven River and Crookhaven Creek Confluence	3.00	3.08	0.09	3.14	0.14	3.42	0.43
13	Greenwell Point Gauge	2.71	2.83	0.12	2.90	0.19	3.25	0.54
14	Crookhaven Heads Gauge	2.43	2.57	0.15	2.66	0.23	3.07	0.64

*Refer to **Figure 10-1** for reference locations.*

10.2 Comparison with Previous Flood Study Results

Previous flood study results, along with historical event flood levels have been sourced from Table 2 of the Lower Shoalhaven River Floodplain Risk Management Plan (Webb, McKeown & Associates, 2008). This is replicated in **Table 10-5** with the current study flood levels for comparison.

The historical event estimated AEP has been updated with the AEP determined for the tabulated historical events from the statistical Flood Frequency Analysis described in Section 7 of this report.

It is noted that water levels are typically lower than the previous flood study results. It is observed that:

> Water levels are 300mm to 500mm lower at Nowra Bridge than the 1990 flood study for the 20% AEP and 5% AEP events;

> Water levels are generally significantly lower by 900mm than the previous flood study at Nowra Bridge in the 1% AEP, due to the lower flows adopted in the current study;

> The Riverview Road levee was previously expected to be overtopped in the 1% AEP event, however, with reductions in the calculated 1% AEP flow and levels at Nowra Bridge, the levee is not expected to be overtopped until a 0.2% AEP event or rarer in the current study; and

> The PMF event yields water levels that are very close (50mm lower than) the previous Lower Shoalhaven River Flood Study (Public Works, 1990) Extreme event at Nowra Bridge.

It is also noted that different methodologies are used in these two studies, i.e. different hydrology, up-to-date data, modelling software and methods, and different tailwater boundary and entrance conditions.

However, comparison of the levels of each AEP event with the estimated AEP of historical events shows that the current study correlates well with observed data, generally within 100mm of the expected flood level for the equivalent return period. Such differences are to be expected given the uncertainty of accuracy of historical flood level values, uncertainty of the consistency of reporting location, localised water level variations due to hydraulic phenomena and changes in flood behaviour due to construction of various Nowra Bridge configurations and the Terara levees.

Table 10-5 Peak flood level of major floods (mAHD) – comparison with previous Flood Study and historical floods – existing scenario

Location	Historical Events				1990 Flood Study Design Events				Current Study Design Events			
	1860	1870	1974	1978	5% AEP	2% AEP	1% AEP	Ext	5% AEP	2% AEP	1% AEP	PMF
Nowra Bridge	5.5	6.55	4.9*	5.3*	5.3	5.8	6.3	8.9	4.83	5.22	5.38	8.85
Shoalhaven River at Terara	4.8	5.7	4.4*	4.7*	4.8	5.1	5.5	7.4	4.61	5.01	5.19	7.46
Numbaa	U	U	U	3.7#	3.3	3.6	4.1	6.0	3.60	3.97	4.14	6.68
Shoalhaven Heads (Wharf Rd)	U	U	U	U	2.7	2.9	3.3	4.2	2.22	2.49	2.92	5.63
Greenwell Point	U	U	1.65#	U	2.4	2.9	3.4	5.2	1.69	2.47	3.00	6.06
Orient Point	U	U	U	U	2.2	2.6	3.0	4.7	1.41	2.16	2.43	4.94
Estimated AEP at Nowra Bridge**	1.6%	0.4%	6.9%	2.8%								
Estimated Average Recurrence Interval (ARI) at Nowra Bridge	62 years	270 years	14 years	35 years								

Note: Exact locations of 1990 Flood Study results are unknown and there may be some differences in the reported location.

The levels for the 1860 and 1870 floods at Nowra Bridge and in the Shoalhaven River at Terara are estimated as no actual levels were recorded. The levels shown are based on historical flood data taken from the Lower Shoalhaven River Flood History at Nowra Bridge 1860-1980.

* Recorded level taken from the Lower Shoalhaven River Flood History at Nowra Bridge 1860-1980.

Recorded level in Shoalhaven River Flood Study Compendium of Data

estimated AEP derived from the FFA at Grassy Gully based on equivalent flows based on the level at Nowra Bridge. It is noted that the AEP is for the level adjusted to current day catchment conditions as described in **Section 7.

10.3 Flow Velocities

Flow velocity maps are provided in **Figures G15** to **G17** for Design Events, **Figures G39** to **G40** for Projected 2050 and **Figures G63** to **G64** for Projected 2100 in **Appendix G.**

Flow velocities in the 1% AEP event are generally greater than 3m/s in the Shoalhaven River main channel upstream of Pig Island, with 2-3m/s velocities in the Shoalhaven River (downstream of Pig Island) and Berrys Canal. Velocities are generally 1.5 m/s within the tributaries and >3 m/s in steeper sections. Low flow velocities of typically around 0.5m/s but up to 1m/s are observed within the floodplain areas due to the water depths.

Flow velocities in the Probable Maximum Flood generally vary from 4 to 6 m/s in the Shoalhaven River main channel upstream of Pig Island, with 2-3m/s velocities in the Shoalhaven River (downstream of Pig Island) and Berrys Canal. Velocities are greater than 3m/s through the entrances. Velocities are generally 1.5 – 2.0 m/s within the tributaries and >3 m/s in steeper sections. Velocities within the floodplain areas are greater as they begin to convey more flow with more areas up to 1m/s and localised flowpaths with up to 1.5m/s.

10.4 Hazard and Hydraulic Categories

10.4.1 Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations.

Historically, the criteria for these relationships has been taken from the NSW Floodplain Development Manual (FDM) (Appendix L; NSW Government, 2005). The Manual defines two major categories for provisional hazard – high and low. A third minor transitional category is also included that requires further investigation of the site in question to define the hazard category.

The NSW FDM hazard curves are shown in **Figure 10-2**.

The provisional hazard mapping for the 1% AEP and PMF is provided in **Figures G25** to **G26** in **Appendix G**.

Recently, a new method of hazard categorisation has been developed by the revised ARR manual Book 6: Flood Hydraulics, Section 7.2.7 (Ball et al. 2019). The classification is still based on depth and velocity, but utilises six categories based on the stability of children, adults, the elderly, vehicles and buildings in flood waters.

The ARR2019 hazard curves are shown in **Figure 10-3**.

The results based on the hazard mapping are provided in **Figures G18** to **G26** for Design Events, **Figures G41** to **G46** for Projected 2050 and **Figures G65** to **G70** for Projected 2100 in **Appendix G**.

For the 20% AEP, flood hazard within the main waterways is predominantly classed as H5 or H6 as a result of the significant depths and the high velocities of the concentrated flow. The depths and velocity make flooding hazardous for both pedestrians and vehicles and buildings are vulnerable to damage and failure.

There are also breakout flowpaths and storage areas along the Shoalhaven River upstream of Nowra that are classed as H5. The Broughton Creek floodplain is classed as H4 to H5 due to the depths. The floodplain areas around Numbaa, Brundee and Pyree are typically H1 to H3.

For most overland flowpaths, a H1 to H2 hazard is expected, and are generally safe for people, larger vehicles and buildings, based on the ARR2019 hazard categories.

For larger events up to the 1% AEP, a H4 and H5 hazard category is more widespread in the floodplain areas as flood depths increase. More H6 category is observed in the Shoalhaven River overbank areas upstream of Nowra Bridge.

In the 1% AEP event almost the entire Broughton Creek and Lower Shoalhaven/Crookhaven River floodplain areas are classified as H5 due to the significant flood depths. In the 0.2% AEP event parts of the floodplain become H6 hazard category, with the remainder H5.

In the PMF event, H5 to H6 hazard regions dominate the flood extent, with only the outer flood fringe classed as H1 to H3 hazard. These H5 to H6 hazard regions may impact properties along the foreshore areas of Greenwell Point, Orient Point and Culburra Beach.

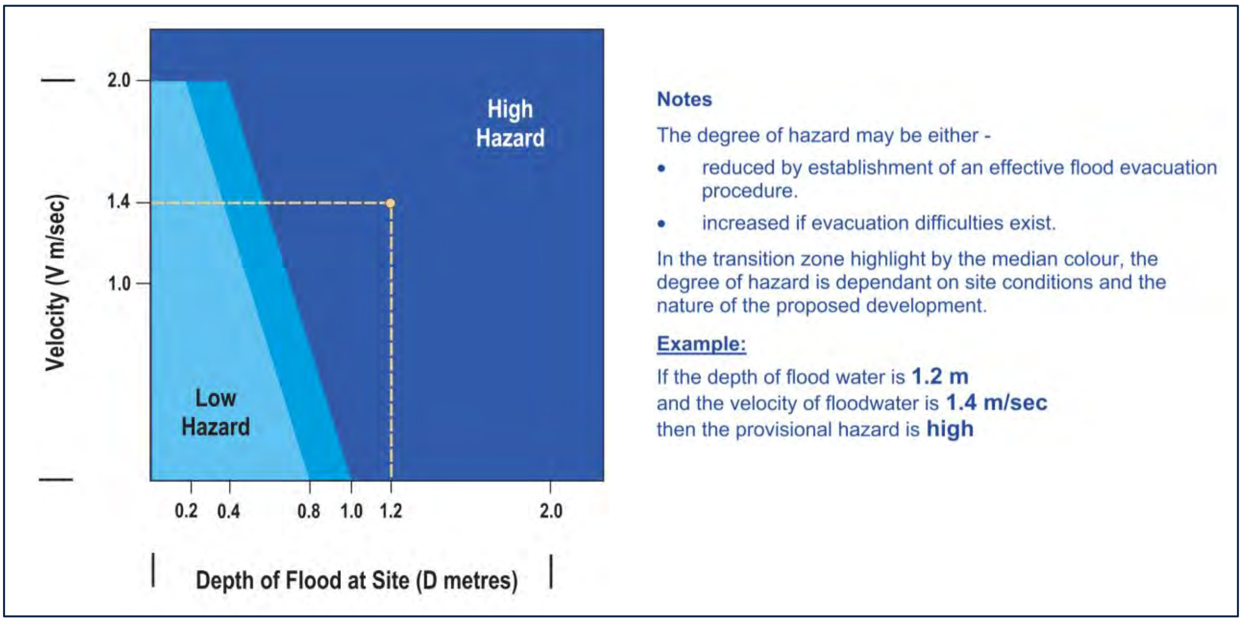

Figure 10-2 Provisional Hazard Categories from Appendix L of the NSW Floodplain Development Manual (2005)

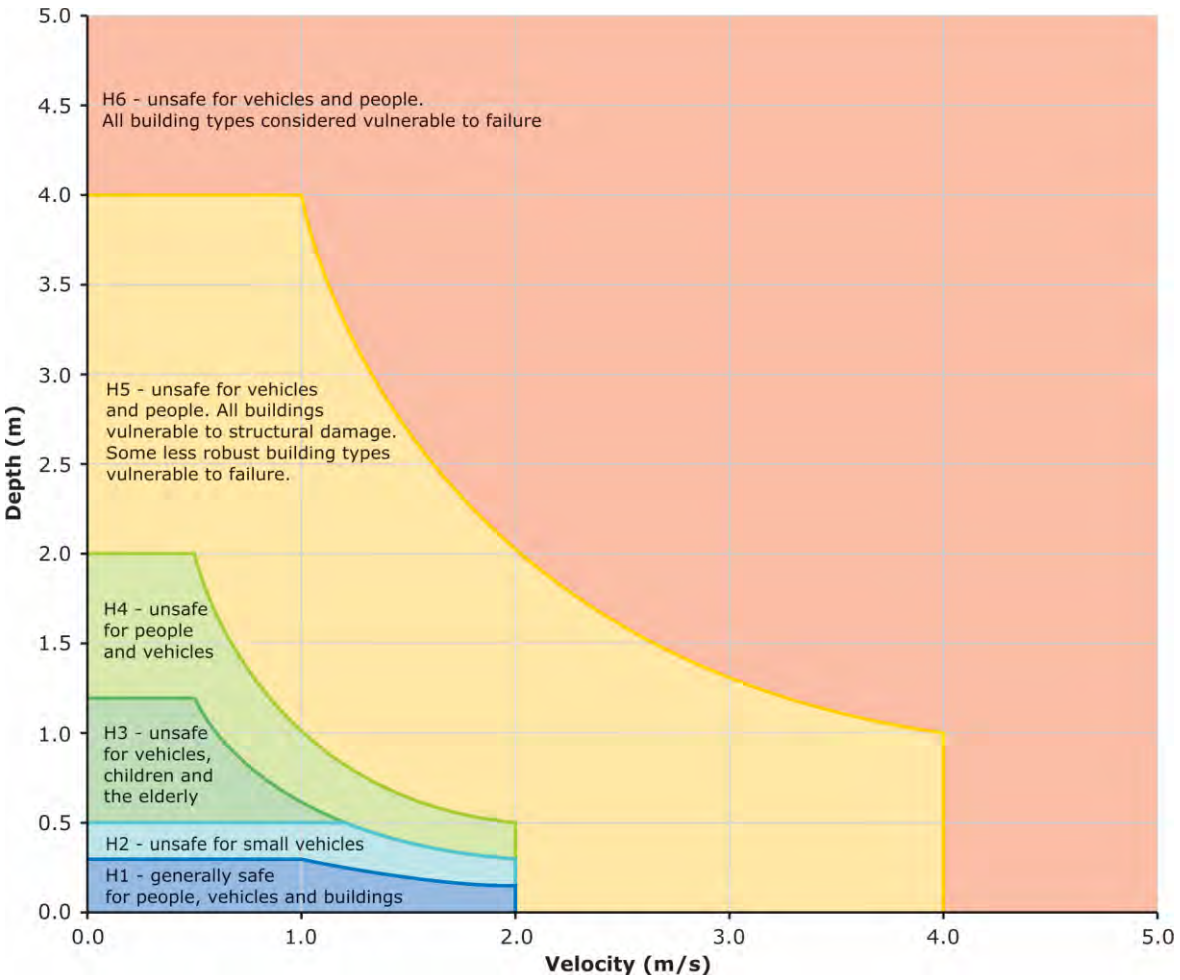

Figure 10-3 Hazard Categories from ARR 2019

10.4.2 Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The NSW Floodplain Development Manual (2005) defines flood prone land to be one of the following three hydraulic categories:

- **Floodway -** areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage -** areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- **Flood Fringe -** remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Floodways were determined by considering those model areas that conveyed a significant portion of the total flow. These floodways, if blocked or removed, would cause a significant redistribution of the flow. There is no technical definition of hydraulic categorisation and different approaches are used by different consultants and authorities. Traditional encroachment methods employed to define floodways using one-dimensional models are complicated and onerous for two-dimensional models and automation is required. Various criteria were trialled to define the floodways as described in Howells et al. (2003) and Thomas and Golaszewski (2012).

The Lower Shoalhaven River is a coastal floodplain which serves as a significant storage and the velocity-depth product is dominated by depth. As a result, it was necessary to adopt a higher velocity-depth product with consideration of velocity in combination to ensure that the storage areas aren't defined as floodways. So the below criteria have been used.

As a minimum, the floodway was assumed to follow the river/creek line from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity x Depth product > 0.5 m^2/s and velocity > 0.5 m/s; OR,
- Velocity > 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by at least 0.1m and/or would cause peak discharge anywhere to increase by more than 10%. The criteria were applied to the model results as described below.

- Depth greater than 0.5m; and
- Not classified as floodway.

All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent, are represented as Flood Fringe.

Encroachment analysis in the hydraulic model was undertaken to test that no impacts were caused by filling of flood fringe areas with various depth thresholds. The 0.5m depth was found to be the most appropriate for all areas of the catchment and the exercise also provided guidance for areas where floodway refinement was required.

Hydraulic Categories for the 1% AEP and PMF as determined by the above methods are provided in **Figure G27** and **G28** for Design Events, **Figures G47** and **G48** for Projected 2050 and **Figures G71** and **G72** for Projected 2100 in **Appendix G.**

10.5 Combined Hazard and Hydraulic Category

Council's Development Control Plan and flood certificates utilise the definition of land as within six categories:

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway

> Low Hazard Flood Storage
> Low Hazard Flood Fringe

The above combined hazard and hydraulic categories have been mapped based on the combination of the NSW FDM (NSW Government, 2005) provisional hazard categories and the hydraulic categories. Note that the transition zone as per Figure L2 in the NSW FDM is included with the high hazard zone. These are presented in **Figure G29** and **G30** for Design Events, **Figures G49** to **G50** for Projected 2050 and **Figures G73** to **G74** for Projected 2100 in **Appendix G.**

10.6 Tidal Inundation

The results for tidal inundation scenarios using Highest Astronomical Tide (HAT) and HAT plus projected Sea Level Rise (2050 and 2100) are shown in **Figures G80** to **G82** in **Appendix G**.

The tidal inundation from HAT events is predominantly limited to the lower estuary and tributaries of the Crookhaven River and Crookhaven Creek. For an HAT event with existing sea level, tidal inundation is expected around the lower estuary, particularly Shoalhaven Heads, Comerong Island, Ryans Creek and Numbaa. It is noted that many areas are protected through floodgates at the outlets of local creeks and drains. Some nominal baseflows from local catchments are assumed and hence tidal flood extents are still shown on the maps.

With HAT + SLR, greater extent and depth of inundation of properties is expected in Shoalhaven Heads, Greenwell Point and Culburra Beach. Numbaa, Pyree and Mayfield areas are affected with the Ryans and Macdonald Creek, Crookhaven River and Crookhaven Creek spilling tidal flows into the adjacent floodplain/swamp areas. Farmland areas within Broughton Creek floodplain would also begin to be inundated by an HAT event with sea level rise.

All results for tidal inundation are lower than flood levels experienced with the adopted tidal boundaries.

It is noted that nominal baseflow inflows have been applied at the tributaries and due to the presence of tide gates on a number of structures, some inundation may be due to ponding behind the tide gates.

Table 10-6 HAT water level

ID	Location	HAT WL (mAHD)	HAT+ SCC SLR 2050 WL (mAHD)	HAT+ SCC SLR 2100 WL (mAHD)
1	Grassy Gully	5.68	5.68	5.68
2	Gradys Caravan Park	1.13	1.38	1.52
3	Bomaderry Creek	0.91	1.16	1.30
4	Nowra Bridge	0.91	1.16	1.30
5	Terara Gauge	0.90	1.15	1.28
6	Terara Town	Not Affected	Not Affected	Not Affected
7	Broughton Creek US	0.95	1.19	1.31
8	Jorams and Broughton Confluence	0.92	1.15	1.28
9	Broughton Creek Confluence	0.89	1.13	1.27
10	Hay Street Gauge	0.91	1.14	1.27
11	Shoalhaven Heads	0.92	1.14	1.27
12	Crookhaven River and Crookhaven Creek Confluence	1.06	1.27	1.40
13	Greenwell Point Gauge	1.00	1.22	1.35
14	Crookhaven Heads Gauge	1.00	1.21	1.34

*Refer to **Figure 10-1** for reference locations.*

10.7 Parameter Sensitivity Analysis

Results of Sensitivity Analysis scenarios are presented in **Figure H17** to **H26** in **Appendix H** as water level difference plots compared with the adopted 1% AEP event peak water levels. Difference maps have been derived by subtracting the existing 1% AEP event water surface level (presented in **Figure G12** in **Appendix G**) from the Sensitivity Scenario water surface level. Areas that were dry in the existing 1% AEP, but experience flooding in the Sensitivity Scenario are indicated as "Was dry, now wet". Areas that were flooded in the existing 1% AEP event, but are no longer flooded in the Sensitivity Scenario are indicated as "Was wet, now dry".

Peak water levels for each Sensitivity Analysis scenario are shown in **Table 10-8** at the water level gauging stations and at reference locations along tributaries. The table also shows water level difference compared to the adopted 1% AEP peak water levels. Reference locations are shown in **Figure 10-1**.

The below sections describe the impacts on flood levels through varying parameters as part of the analysis.

10.7.1 Hydrology Parameter Sensitivity

The results for hydrology parameter sensitivity (changes to stream lag and temporal patterns) discussed in **Section 8.5** are shown in **Figures H17** to **H20** in **Appendix H**. Peak 1% AEP (18 hour event) water levels and water level difference for each Sensitivity Analysis scenario are shown in **Table 10-8.** It is noted that the sensitivity is limited to the 18 hour event which is the critical duration for the Shoalhaven River and floodplain areas. Variability in tributaries is not fully examined for all durations which are critical to each tributary.

Table 10-7 Hydrology Parameter Sensitivity – 1% AEP (48 hour duration) water level difference

ID	Location	1% AEP (18 hour)	50% decreased lag time		50% increased lag time		Min TP		Max TP	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	26.72	26.95	0.23	22.42	-4.30	25.95	-0.77	27.12	0.40
2	Gradys Caravan Park	19.64	19.79	0.14	16.45	-3.19	19.13	-0.52	19.92	0.28
3	Bomaderry Creek	5.27	5.27	0.00	4.72	-0.55	5.28	0.00	5.27	0.00
4	Nowra Bridge	5.38	5.40	0.02	4.79	-0.59	5.31	-0.08	5.43	0.05
5	Terara Gauge	5.19	5.20	0.01	4.56	-0.62	5.11	-0.08	5.22	0.03
6	Terara Town	4.25	4.28	0.03	3.89	-0.36	4.17	-0.07	4.30	0.05
7	Broughton Creek US	4.31	4.34	0.03	3.69	-0.62	4.25	-0.06	4.35	0.04
8	Jorams and Broughton Confluence	4.31	4.33	0.02	3.69	-0.62	4.25	-0.06	4.35	0.04
9	Broughton Creek Confluence	4.14	4.16	0.02	3.59	-0.54	4.08	-0.06	4.17	0.03
10	Hay Street Gauge	2.92	2.75	-0.16	2.45	-0.46	2.86	-0.05	2.93	0.01
11	Shoalhaven Heads	2.70	2.54	-0.15	2.30	-0.40	2.65	-0.05	2.71	0.01
12	Crookhaven River and Crookhaven Creek Confluence	3.00	2.87	-0.12	2.18	-0.81	2.93	-0.07	3.01	0.02
13	Greenwell Point Gauge	2.71	2.53	-0.17	2.15	-0.55	2.65	-0.06	2.73	0.02
14	Crookhaven Heads Gauge	2.43	2.31	-0.11	2.03	-0.39	2.38	-0.04	2.45	0.02

Sensitivity to decreased lag time shows that the 1% AEP level is increased by up to 240mm in the incised part of the Shoalhaven River upstream of Nowra. This impact reduces to less than 30mm downstream of Terara. The reductions seen near the entrance is explained by a difference in timing with the peak of the tidal boundary due to the earlier flow peak. Increased lag time shows that the 1% AEP level is decreased significantly associated with the large reduction in peak flow. Flood level reduction of metres are seen in the incised part of the Shoalhaven River around Grassy Gully and Gradys Caravan Park. This impact reduces to around 500-600mm in the lower reaches downstream of Terara. Again, the reductions seen near the entrance is explained by a difference in timing with the peak of the tidal boundary due to the flatter, delayed flow peak.

Comparing to the adopted temporal pattern closest to the mean, the minimum and maximum temporal patterns would result in flood levels that are up to 80mm lower and up to 60mm higher in the areas downstream of Nowra.

10.7.2 Mannings Roughness

Table 10-8 provides peak water levels and water level difference for +/- 20% Manning Roughness values for the 1% AEP design event and **Figures H21** and **H22** in **Appendix H** show the water level difference maps.

For increased Mannings Roughness:

> Flood levels increase generally by >1m in the Shoalhaven River upstream of Nowra which is the incised valley area of the river with high roughness values due to medium to dense vegetation;
>
> Flood levels increase generally by 200mm to 300mm in the Shoalhaven River near Nowra and in the Crookhaven River floodplain areas; and
>
> Flood levels increase generally by ~150mm in the other areas near the entrances and in Broughton Creek floodplain.

For decreased Mannings Roughness:

> Flood levels decrease generally by >1m in the Shoalhaven River upstream of Nowra which is the incised valley area of the river with high roughness values due to medium to dense vegetation;
>
> Flood levels decrease generally by 200mm to 300mm in the Shoalhaven River near Nowra and in the Crookhaven River floodplain areas; and
>
> Flood levels decrease generally by ~150mm in the other areas near the entrances and in Broughton Creek floodplain.

10.7.3 Blockage

Table 10-8 provides peak water levels and water level difference for blockage sensitivity for the 1% AEP design event. 1% AEP water level differences are presented in **Figures H23** and **H24** in **Appendix H.**

A blockage assessment is undertaken across some types of structures in the study area. Based on the assessment results, the blockage scenario 1 involves applying 50% blockage to pipe culverts, and bridge and culvert structures with a diagonal opening of less than 1.5m, 20% blockage to structures with a diagonal opening of greater than 1.5m and unblocked for those greater than 6m. As the majority of bridges over waterways have large spans greater than 6m diagonal span, blockage sensitivity does not apply at these structures.

Given most of the culverts and pipes are fully submerged in the 1% AEP within the broader floodplain, almost no difference in flood levels is observed upstream of most crossings.

Areas with the greatest sensitivity to blockage are areas along tributaries with culverts under roads.

Impacts due to blockage are observed in the following areas:

> Broughton Creek tributaries under the rail line and Princes Highway at Berry;
>
> Along Nowra Creek under the Princes Highway in South Nowra; and
>
> Under Greenwell Point Road/Kalandar Street in East Nowra.

A second blockage scenario applies 100% blockage to pipe culverts, and bridge and culvert structures with a diagonal opening of less than 1.5m and greater along tributaries respectively. Greater impacts are expected at the same areas as noted above, while structures elsewhere in the floodplain are not sensitive to blockage due to being submerged and not acting as the main hydraulic control determining flood levels.

Only the 1% AEP was investigated for sensitivity to blockage, however, it is expected that blockage will have a greater impact for more frequent events, when flood levels are lower and the culverts are more important for flow conveyance and are therefore hydraulic controls where blockage of the structure will influence the flow behaviour.

10.7.4 Tailwater Level and Shoalhaven Heads Entrance Conditions

Table 10-8 provides peak water levels and water level difference for the 1% AEP design event for a closed Shoalhaven Heads entrance scenario and for tailwater sensitivity using a HHWSS tidal boundary. 1% AEP water level differences are presented in **Figures H25** and **H26** in **Appendix H.**

With a closed entrance bathymetry at Shoalhaven Heads, the entrance berm at approximately 2 m AHD is maintained. The results show that flood levels increase significantly throughout the Lower Shoalhaven and Crookhaven River floodplain:

> Flood level increases of up to 1.5m would be expected around Shoalhaven Heads;

> Flood level increases of 0.5m – 1m are observed throughout the Crookhaven River floodplain (Terara, Brundee, Numbaa, Pyree areas) to Crookhaven Heads; and

> Flood level increases generally by about 300mm in the Broughton Creek floodplain to Berry; and

> Minimal or no impacts are seen upstream of Nowra Bridge or in any tributaries outside the floodplain.

This scenario provides a sensitivity of the order of magnitude of the impacts, however, this would be an unrealistic scenario due to Council's entrance management policy and due to the erodible nature of the berm once overtopped. It has been demonstrated through breach modelling as described in **Section 5.3** that flows will scour the entrance to an equilibrium width with dimensions and capacity to convey the relevant flow.

The HHWSS tailwater boundary is approximately 800mm lower than the adopted 5% AEP Waterway B tide boundary adopted for the 1% AEP design event. With the lower tailwater boundary:

> Flood levels decrease by more than 500mm in the immediate vicinity of the Shoalhaven Heads and Crookhaven Heads entrances;

> Flood levels decrease generally by up to 200-500mm around the low lying areas of Shoalhaven Heads, Comerong Island, Culburra Beach, and in the Lower reaches of the Crookhaven River;

> Decreases of generally up to 200mm between Broughton Creek and Shoalhaven Heads throughout the Crookhaven River floodplain (Brundee, Numbaa and Pyree areas); and

> No changes are seen upstream of Numbaa Island.

10.7.5 Levee Removal

Table 10-8 provides peak water levels and water level difference for the 1% AEP event for removal of the Terara Levees scenario. 5% AEP, 1% AEP and PMF water level differences are presented in **Figures H27** to **H32** in **Appendix H.**

Removal of the levee would allow more flow to breakout from the Shoalhaven River towards the south through Terara to Crookhaven Creek. For events up to the 1% AEP, this would result in decreases in flood levels within Broughton Creek floodplain and around Nowra Bridge of 50-100mm, and localised increases of up to 400mm in Terara. Increases reduce to 50mm across the Crookhaven River floodplain to Greenwell Point.

In the PMF event, due to the significant depth of flow, the levee removal would only lead to localised flow pattern changes around Nowra Bridge and northern side of Comerong Island, resulting in both localised increases and decreases in the flood level of up to 150mm and 80mm respectively. There is no change in the broader Study Area.

10.7.6 Levee Breach

While the above levee removal scenario provides an indication of the maximum changes in flow behaviour and flood levels, a more realistic scenario is for the levee to fail at either a point of overtopping or due to a piping failure through the embankment due to a defect such as a large crack due to tree roots or geotechnical reasons. The worst case for a levee breach is when the water level is high on one side of the levee and low or dry on the other. When a breach occurs in this situation, the levee is eroded and it allows a large volume of water to be suddenly released. However, with a low height levee structure, the breach width is limited and the failure and associated impacts behind the levee are likely to be mainly localised. It is intended to further investigate levee breach scenarios, locations and implications as part of the Floodplain Risk Management Study stage of the project.

Table 10-8 Sensitivity Analysis – water level difference at reference locations – existing scenario

ID	Location	1% AEP	+ 20% Roughness		- 20% Roughness		50% Blockage		100% Blockage		HHWSS Tide Boundary		Closed Entrance		Levee Removal	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	26.72	27.96	1.24	25.35	-1.37	26.72	0.00	26.72	0.00	27.15	0.43	26.72	0.00	27.14	0.42
2	Gradys Caravan Park	19.64	20.58	0.94	18.68	-0.96	19.64	0.00	19.64	0.00	19.64	0.00	19.64	0.00	19.64	0.00
3	Bomaderry Creek	5.48	5.51	0.04	5.44	-0.04	5.48	0.00	5.48	0.00	5.48	-0.01	5.48	0.00	5.48	0.00
4	Nowra Bridge	5.38	5.79	0.41	5.01	-0.37	5.38	0.00	5.38	0.00	5.38	0.00	5.41	0.03	5.29	-0.09
5	Terara Gauge	5.19	5.36	0.17	4.97	-0.22	5.19	0.00	5.19	0.00	5.19	0.00	5.24	0.05	4.98	-0.21
6	Terara Town	4.25	4.51	0.26	4.08	-0.17	4.25	0.00	4.25	0.00	4.25	0.00	4.43	0.18	4.61	0.36
7	Broughton Creek US	4.31	4.49	0.18	4.12	-0.19	4.31	0.00	4.31	0.00	4.31	0.00	4.59	0.28	4.23	-0.08
8	Jorams and Broughton Confluence	4.31	4.48	0.18	4.12	-0.19	4.31	0.00	4.31	0.00	4.31	0.00	4.59	0.28	4.22	-0.08
9	Broughton Creek Confluence	4.14	4.26	0.13	4.01	-0.13	4.14	0.00	4.14	0.00	4.13	-0.01	4.50	0.37	4.07	-0.07
10	Hay Street Gauge	2.92	3.06	0.14	2.77	-0.14	2.92	0.00	2.92	0.00	2.64	-0.28	4.08	1.16	2.89	-0.03
11	Shoalhaven Heads	2.70	2.79	0.09	2.60	-0.10	2.70	0.00	2.70	0.00	2.29	-0.40	4.07	1.37	2.68	-0.02
12	Crookhaven River and Crookhaven Creek Confluence	3.00	3.22	0.22	2.74	-0.26	3.00	0.00	3.00	0.00	2.81	-0.19	4.05	1.05	3.02	0.03
13	Greenwell Point Gauge	2.71	2.86	0.15	2.54	-0.17	2.71	0.00	2.71	0.00	2.35	-0.35	3.81	1.11	2.75	0.04
14	Crookhaven Heads Gauge	2.43	2.51	0.08	2.33	-0.10	2.43	0.00	2.43	0.00	1.87	-0.56	3.32	0.89	2.46	0.03

*Refer to **Figure 10-1** for reference locations.*

10.7.7 ARR87 IFD and Temporal Patterns

Figures H33 to **H40** in **Appendix H** present the flood depths, levels, hazard, hydraulic categories and water level difference for the ARR87 5% AEP and 1% AEP design events and **Table 10-9** provides peak water levels and water level differences for ARR87 sensitivity.

A comparison of peak flows in the main Shoalhaven River inflow (**Table 8-7**) shows that ARR87 flows are very similar and marginally higher than the ARR2019 flows. The Shoalhaven River inflow at Grassy Gully in the ARR2019 1% AEP flow is 13,834 m^3/s, while for the ARR87 1% AEP flow is 13,960 m^3/s.

However, from the water level difference plots, it can be seen that predicted flood levels with ARR87 hydrology are lower, particularly throughout the floodplain areas, but even along the incised section of the Shoalhaven River upstream of Nowra Bridge. ARR87 flood levels are typically up to 400mm lower throughout the floodplain with marginally reduced flood extents across the Study Area in both the 5% AEP and 1% AEP events.

This is explained due to the difference in the critical storm burst duration producing the highest peak flows (**Figure 8-6**). For the ARR87 hydrology, the critical burst duration is 36 hours, while for ARR2019, the critical burst duration is 18 hours. It is also noted that pre-burst rainfall is applied to the ARR2019 design events, while no pre-burst is applied to the ARR87 design events, which likely plays a role in early filling of the estuary.

So while the inflows are similar, the difference in storm duration appears to play a role in the rate of volume change, such that ARR2019 flows are unable to outlet to the ocean at the same rate as the inflow change and leads to storage in the floodplain areas. For the ARR87 hydrograph, the volume to peak flow is much smaller than the ARR2019 hydrograph and hence there is less storage in the floodplain when the peak flow arrives, leading to more available storage and lower flood levels.

Table 10-9 Sensitivity Analysis – ARR87 water level difference at reference locations

ID	Location	ARR2019 5% AEP	ARR87 5% AEP		ARR2019 1% AEP	ARR87 1% AEP	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	WL (mAHD)	Diff (m)
1	Grassy Gully	22.86	23.15	0.29	26.72	26.66	-0.06
2	Gradys Caravan Park	16.75	16.84	0.09	19.64	19.45	-0.20
3	Bomaderry Creek	4.75	4.70	-0.05	5.27	5.11	-0.16
4	Nowra Bridge	4.83	4.79	-0.05	5.38	5.32	-0.06
5	Terara Gauge	4.61	4.54	-0.07	5.19	5.11	-0.08
6	Terara Town	3.90	3.88	-0.02	4.25	4.18	-0.07
7	Broughton Creek US	3.70	3.46	-0.24	4.31	4.21	-0.10
8	Jorams and Broughton Confluence	3.70	3.45	-0.24	4.31	4.21	-0.10
9	Broughton Creek Confluence	3.60	3.36	-0.23	4.14	4.05	-0.08
10	Hay Street Gauge	2.36	2.23	-0.13	2.92	2.73	-0.19
11	Shoalhaven Heads	2.22	2.11	-0.12	2.70	2.49	-0.21
12	Crookhaven River and Crookhaven Creek Confluence	1.69	1.47	-0.22	3.00	2.62	-0.38
13	Greenwell Point Gauge	1.60	1.45	-0.15	2.71	2.36	-0.35
14	Crookhaven Heads Gauge	1.41	1.30	-0.11	2.43	2.14	-0.29

*Refer to **Figure 10-1** for reference locations.*

10.8 Climate Change Scenarios

Results of Climate Change scenarios are presented in **Figures H1 to H16 in Appendix H** as water level difference plots compared with the adopted 1% AEP event peak water levels. Difference maps have been derived by subtracting the existing 1% AEP event water surface level (presented in **Appendix H**) from the Climate Change Scenario water surface level. Areas that were dry in the existing 1% AEP, but experience flooding in the Climate Change Scenario are indicated as "Was dry, now wet". Areas that were flooded in the existing 1% AEP event, but are no longer flooded in the Climate Change Scenario are indicated as "Was wet, now dry".

10.8.1 Increased Rainfall

Peak water levels for each Climate Change Scenario at the water level gauging stations and reference locations are shown in **Table 10-10** for 5% AEP and **Table 10-11** for the 1% AEP event. The tables also show water level difference compared to the adopted 5% AEP and 1% AEP peak water levels. Reference locations are shown in **Figure 10-1**.

Table 10-10 Climate Change – 5% AEP Rainfall Increase (Existing sea level) water level difference

ID	Location	5% AEP	CC 2050 RCP4.5		CC 2050 RCP8.5		CC 2090 RCP4.5		CC 2090 RCP8.5	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	22.86	23.28	0.41	23.42	0.55	23.44	0.58	24.08	1.21
2	Gradys Caravan Park	16.75	17.10	0.35	17.22	0.46	17.23	0.48	17.73	0.97
3	Bomaderry Creek	5.54	5.56	0.02	5.57	0.03	5.57	0.03	5.61	0.07
4	Nowra Bridge	4.83	4.91	0.07	4.93	0.10	4.93	0.10	5.03	0.20
5	Terara Gauge	4.61	4.68	0.08	4.71	0.10	4.71	0.11	4.81	0.21
6	Terara Town	3.90	3.93	0.03	3.94	0.03	3.94	0.04	3.99	0.09
7	Broughton Creek US	4.25	4.28	0.03	4.29	0.04	4.29	0.04	4.33	0.08
8	Jorams and Broughton Confluence	3.70	3.78	0.08	3.81	0.11	3.81	0.11	3.93	0.23
9	Broughton Creek Confluence	3.60	3.67	0.08	3.70	0.10	3.70	0.11	3.80	0.21
10	Hay Street Gauge	2.36	2.43	0.08	2.46	0.10	2.46	0.11	2.57	0.21
11	Shoalhaven Heads	2.22	2.30	0.07	2.32	0.10	2.32	0.10	2.42	0.20
12	Crookhaven River and Crookhaven Creek Confluence	1.69	1.78	0.10	1.82	0.14	1.83	0.14	2.02	0.34
13	Greenwell Point Gauge	1.60	1.67	0.07	1.70	0.10	1.70	0.10	1.81	0.21
14	Crookhaven Heads Gauge	1.41	1.46	0.05	1.48	0.07	1.48	0.07	1.56	0.15

*Refer to **Figure 10-1** for reference locations.*

Increased rainfall due to climate change has the biggest impact in the upper Shoalhaven River due to the increased flows and the incised valley. For the 5% AEP, a 5.4% rainfall increase (2050 RCP 4.5) will have increased flood levels of around 400mm between Grassy Gully and Gradys Caravan Park, but this reduces to <100 mm by Nowra Bridge and through to the ocean. The 2050 RCP8.5 and 2090 RCP4.5, have very similar 7.3% and 7.6% rainfall increases, respectively, and show increases of up to 550mm at Grassy Gully, again reducing to 100 mm downstream of Nowra Bridge. A 16.3% rainfall increase (2090 RCP8.5) would lead to 1.2m increase in flood level at Grassy Gully, almost 1m at Gradys Caravan Park, reducing to approximately 200mm at Pig Island.

For the 1% AEP, a similar trend is observed where increased flows due to increased rainfall leads to increases in flood levels in the Shoalhaven River upstream of Nowra by up to almost 1.4m at Grassy Gully for a 16.3% rainfall increase. Increases in the lower floodplain areas are generally less than 150mm for all scenarios up to 7.6% rainfall increase with increases typically 150 – 250 mm for the 16.3% (2090 RCP 8.5) rainfall increase.

Table 10-11 Climate Change – 1% AEP Rainfall Increase (Existing sea level) water level difference

ID	Location	1% AEP	CC 2050 RCP4.5		CC 2050 RCP8.5		CC 2090 RCP4.5		CC 2090 RCP8.5	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	26.72	27.19	0.47	27.36	0.64	27.38	0.66	28.09	1.37
2	Gradys Caravan Park	19.64	20.01	0.37	20.13	0.49	20.15	0.51	20.73	1.09
3	Bomaderry Creek	5.48	5.49	0.01	5.49	0.02	5.49	0.02	5.52	0.04
4	Nowra Bridge	5.38	5.45	0.06	5.47	0.09	5.47	0.09	5.58	0.20
5	Terara Gauge	5.19	5.24	0.05	5.26	0.07	5.26	0.07	5.35	0.16
6	Terara Town	4.25	4.33	0.08	4.35	0.11	4.35	0.11	4.48	0.23
7	Broughton Creek US	4.31	4.37	0.06	4.39	0.08	4.40	0.09	4.49	0.18
8	Jorams and Broughton Confluence	4.31	4.37	0.06	4.39	0.08	4.39	0.08	4.49	0.18
9	Broughton Creek Confluence	4.14	4.19	0.06	4.21	0.08	4.22	0.08	4.31	0.17
10	Hay Street Gauge	2.92	2.99	0.08	3.02	0.10	3.02	0.11	3.15	0.23
11	Shoalhaven Heads	2.70	2.76	0.07	2.79	0.09	2.79	0.10	2.90	0.20
12	Crookhaven River and Crookhaven Creek Confluence	3.00	3.09	0.10	3.13	0.13	3.13	0.14	3.28	0.28
13	Greenwell Point Gauge	2.71	2.79	0.08	2.82	0.11	2.83	0.12	2.96	0.25
14	Crookhaven Heads Gauge	2.43	2.49	0.07	2.52	0.09	2.52	0.09	2.62	0.20

*Refer to **Figure 10-1** for reference locations.*

10.8.2 Increased Rainfall and SLR Scenarios

Peak water levels for each Climate Change Scenario at the water level gauging stations and reference locations are shown in **Table 10-12** for 5% AEP and **Table 10-13** for 1% AEP. The tables also show water level difference compared to the adopted 5% AEP and 1% AEP peak water levels. Reference locations are shown in **Figure 10-1**.

For 5% AEP event 2050 projections of increased rainfall (up to 7.3%) and sea level rise (+0.23m) in combination, the increased flow dominates changes in expected flood levels to approximately Terara, with sea level rise having impacts in the Shoalhaven River downstream of Terara and in the Crookhaven River/Crookhaven Creek floodplain. Only minor increases in flood level are observed in the Broughton Creek floodplain.

Similar behaviour is observed for the 1% AEP event 2050 projections of increased rainfall (up to 7.3%) and sea level rise (+0.23m) in combination, with increases of up to 500mm at Gradys Caravan Park, 100mm around Nowra Bridge, Bomaderry Creek and Broughton Creek and sea level rise dominating near the entrances (up to 220mm).

While for 1% AEP event 2100 projections of increased rainfall (up to 16.3%) and sea level rise (+0.36m) in combination, increases of up to 1.4m at Grassy Gully and 1.1m at Gradys Caravan Park, 200mm around Nowra Bridge, Bomaderry Creek and Broughton Creek and sea level rise dominating near the entrances (up to 400mm).

Table 10-12 Climate Change – 5% AEP Rainfall Increase + SLR water level difference

ID	Location	5% AEP	CC 2050 RCP4.5 + SLR2050 (SCC)		CC 2050 RCP8.5 + SLR2050 (SCC)		CC 2090 RCP4.5 + SLR 2100 (SCC)		CC 2090 RCP8.5 + SLR 2100 (SCC)	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	22.86	23.28	0.41	23.42	0.55	23.44	0.58	24.08	1.21
2	Gradys Caravan Park	16.75	17.10	0.35	17.22	0.46	17.23	0.48	17.73	0.97
3	Bomaderry Creek	5.54	5.56	0.02	5.57	0.03	5.57	0.03	5.61	0.07
4	Nowra Bridge	4.83	4.91	0.07	4.93	0.10	4.94	0.10	5.03	0.20
5	Terara Gauge	4.61	4.68	0.08	4.71	0.10	4.71	0.11	4.82	0.21
6	Terara Town	3.90	3.93	0.03	3.94	0.04	3.94	0.04	3.99	0.09
7	Broughton Creek US	4.25	4.28	0.03	4.29	0.04	4.29	0.04	4.33	0.08
8	Jorams and Broughton Confluence	3.70	3.79	0.09	3.81	0.11	3.82	0.12	3.93	0.23
9	Broughton Creek Confluence	3.60	3.68	0.08	3.70	0.11	3.71	0.11	3.81	0.21
10	Hay Street Gauge	2.36	2.45	0.09	2.47	0.12	2.49	0.13	2.59	0.23
11	Shoalhaven Heads	2.22	2.31	0.09	2.33	0.11	2.34	0.12	2.44	0.22
12	Crookhaven River and Crookhaven Creek Confluence	1.69	1.89	0.20	1.92	0.24	2.00	0.31	2.18	0.49
13	Greenwell Point Gauge	1.60	1.79	0.18	1.81	0.21	1.89	0.29	1.99	0.39
14	Crookhaven Heads Gauge	1.41	1.61	0.20	1.62	0.21	1.71	0.31	1.79	0.38

Refer to ***Figure 10-1*** *for reference locations.*

Table 10-13 Climate Change – 1% AEP Rainfall Increase + SLR water level difference

ID	Location	1% AEP	CC 2050 RCP4.5 + SLR2050 (SCC)		CC 2050 RCP8.5 + SLR2050 (SCC)		CC 2090 RCP4.5 + SLR 2100 (SCC)		CC 2090 RCP8.5 + SLR 2100 (SCC)	
		WL (mAHD)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)	WL (mAHD)	Diff (m)
1	Grassy Gully	26.72	27.19	0.47	27.36	0.64	27.38	0.66	28.09	1.37
2	Gradys Caravan Park	19.64	20.01	0.37	20.13	0.49	20.15	0.51	20.73	1.09
3	Bomaderry Creek	5.48	5.49	0.02	5.50	0.02	5.50	0.02	5.53	0.05
4	Nowra Bridge	5.38	5.45	0.06	5.47	0.09	5.47	0.09	5.59	0.21
5	Terara Gauge	5.19	5.24	0.05	5.26	0.07	5.26	0.07	5.35	0.16
6	Terara Town	4.25	4.33	0.08	4.36	0.11	4.36	0.11	4.48	0.23
7	Broughton Creek US	4.31	4.38	0.07	4.40	0.09	4.40	0.09	4.50	0.19
8	Jorams and Broughton Confluence	4.31	4.37	0.07	4.40	0.09	4.40	0.09	4.50	0.19
9	Broughton Creek Confluence	4.14	4.20	0.06	4.22	0.08	4.23	0.09	4.33	0.19
10	Hay Street Gauge	2.92	3.08	0.16	3.11	0.19	3.16	0.25	3.27	0.35
11	Shoalhaven Heads	2.70	2.87	0.18	2.90	0.20	2.97	0.27	3.06	0.37
12	Crookhaven River and Crookhaven Creek Confluence	3.00	3.17	0.17	3.20	0.21	3.25	0.26	3.39	0.39
13	Greenwell Point Gauge	2.71	2.90	0.19	2.93	0.22	3.00	0.29	3.11	0.40
14	Crookhaven Heads Gauge	2.43	2.63	0.20	2.65	0.22	2.73	0.30	2.82	0.39

*Refer to **Figure 10-1** for reference locations.*

11 Impacts of Flooding on the Community

11.1 Impacts of Flooding

The community within the Lower Shoalhaven catchment is susceptible to extensive flooding, most notably in low lying foreshore areas of Shoalhaven Heads, Coolangatta, Comerong Island, Greenwell point, Orient Point and Culburra Beach, throughout the Broughton Creek and Crookhaven River floodplains as well as properties around East Nowra, southern Bomaderry and Berry. Numbers and types of properties affected and associated damages are presented in **Section 11.4.5** and flood emergency response classifications are discussed in **Section 11.5**.

Table 11-1 summarises the number of affected properties in the areas within the Lower Shoalhaven River. The number of buildings with predicted overfloor flooding for each design flood event has been calculated based on a database of actual surveyed floor levels which has been supplemented with some assumed floor levels based on building type for buildings where the actual floor level was unknown at the time of this Flood Study preparation. The number of buildings with predicted overfloor flooding for each design flood event can be updated as part of the Floodplain Risk Management Study & Plan following the completion of additional floor level survey.

11.1.1 Shoalhaven Heads, Coolangatta and Comerong Island

Properties in Shoalhaven Heads around Hay Avenue are exposed to above floor flooding in events as frequent as the 50% AEP event when Shoalhaven Heads is closed with five properties affected by over floor flooding. Two properties are impacted in a 20% AEP event, which is a large enough event to trigger entrance management intervention and hence opening of the entrance which mitigates flood levels. The number of properties impacted increases to nine in the 10% AEP event with properties around the Jerry Bailey Road – Renown Ave intersection being impacted. This number increases to 20 in a 5% AEP event as more properties on Jerry Bailey Road experience flooding above floor levels. The Shoalhaven Heads caravan park would also be impacted.

Almost 85 properties will experience above floor flooding in the 1% AEP event with most properties on Hay Avenue and Jerry Bailey Road south of Davenport Road affected along with some properties on Shoalhaven Heads Road, including the three caravan parks – Mountain View Resort, Ingenia Holidays and Coastal Palms. In a 0.2% AEP event a significant number of properties along Jerry Bailey Rd south of Shoalhaven Heads Road will be impacted along with properties around the Hay Avenue – Jerry Bailey Road intersection. Some 258 properties in addition to the caravan parks would have flooding above floor level in a PMF event, including all properties along Jerry Bailey Road and adjacent cross streets, properties on Scott Street, Ablett Circuit and Discovery Place, as well as properties along Bolong Road.

In Coolangatta area, most properties along the Shoalhaven River foreshore are impacted between the 20% AEP and 5% AEP event, with a small number of properties not impacted above floor level until the 1% AEP event. However, these properties would be isolated as Bolong Road becomes inundated in events more frequent than the 5% AEP event.

Properties on Comerong Island closest to Shoalhaven Heads foreshore begin to be impacted from as little as the 50% AEP event with most properties experiencing above floor flooding in the 5% AEP event. Properties on the remainder of Comerong Island are protected from Shoalhaven River flooding by the levee up to approximately the 20% AEP event, however, flood waters back up from the south from Berrys Canal/ Crookhaven River with floodwaters inundating most land. All properties will have above floor flooding in a 5% AEP event as the levee overtops and the Island experiences flooding from both the north and south.

11.1.2 Greenwell Point

Greenwell Point is significantly affected by flooding and becomes isolated with Greenwell Point Road – the only egress – experiencing flooding over the road between a 20% AEP and 10% AEP event and becoming cut off in events rarer than the 10% AEP. Overfloor flooding begins in a 5% AEP event with some 44 foreshore properties impacted as well as the Pine Park and Coral Tree caravan parks becoming inundated, however, this jumps significantly to 250 properties in a 2% AEP event. The number of impacted properties continues to climb with increasing flood depths with almost 310 properties impacted in a 1% AEP event and 433 in the PMF event.

11.1.3 Orient Point and Culburra Beach

Properties along the river foreshore areas of Culburra Beach begin to experience flooding above floor in a 5% AEP event. The number of affected properties increases to almost 70 in a 2% AEP event with nine properties in Orient Point having overfloor flooding. The low point on Prince Edward Avenue near The Strand becomes impassable to vehicles between the 5% AEP event and 2% AEP event. Properties north of this low point would be isolated except for egress by foot via the beachfront. Over 94 properties would have above floor flooding in the 1% AEP event and more than 349 properties in the PMF event with significant flood depths.

Table 11-1 Flood affected properties by location

Event	50% AEP		20% AEP		10% AEP		5% AEP		2% AEP		1% AEP		0.2% AEP		PMF	
Location	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y
SHOALHAVEN HEADS	5	68	2	68	9	84	20	134	34	145	84	192	188	259	258	263
GREENWELL POINT	0	41	0	46	0	55	44	303	249	404	307	428	399	442	433	446
ORIENT POINT	0	0	0	0	0	0	0	3	9	24	12	26	20	33	31	36
CULBURRA BEACH	0	91	0	95	0	95	5	114	59	168	82	204	170	283	318	320
CROOKHAVEN RIVER FLOODPLAIN	1	227	0	223	14	271	80	333	189	344	252	347	299	352	373	392
BROUGHTON CREEK FLOODPLAIN	2	175	5	180	26	184	53	187	63	189	77	191	88	196	153	209
BOMADERRY	0	65	3	71	9	86	18	95	26	101	30	105	36	118	74	144
NOWRA	14	147	14	160	16	188	28	264	40	351	54	383	226	602	737	879
NORTH NOWRA	0	2	1	2	1	2	1	2	1	2	1	2	2	2	2	2
UPSTREAM NOWRA	0	0	0	12	0	15	2	16	4	16	5	16	7	16	13	16
TOTAL	**24**	**816**	**79**	**943**	**197**	**1,293**	**601**	**1,616**	**755**	**1,728**	**1,015**	**1,878**	**1,448**	**2,287**	**2,392**	**2,707**

B – Buildings with overfloor flooding

Y – Yards with flooding

11.1.4 Crookhaven River Floodplain

The Crookhaven River floodplain includes the Terara, Numbaa, Brundee, Worrigee, Mayfield and Pyree areas. Extensive flooding is experienced throughout this floodplain with various swamp areas and floodwaters backing up from Crookhaven River/Crookhaven Creek as well as from the Shoalhaven River breaking its banks around Numbaa. Parts of Comerong Island Road are inundated in the 20% AEP event with properties in the Numbaa and Pyree areas experiencing above floor flooding from the 10% AEP event. Almost 15 properties are affected in the 10% AEP event as well as some properties south of Terara. The Riverview Road and Terara levees provide protection from Shoalhaven River flooding to the Terara township up to almost the 10% AEP event when the Terara levee begins to be overtopped south of Pig Island. Once the levee is overtopped, there is extensive flooding throughout the floodplain with around 80 properties impacted in the 5% AEP event, 190 in a 2% AEP event including Shoalhaven Caravan Village, climbing to more than 250 in the 1% AEP event and around 373 properties in the PMF event.

11.1.5 Nowra

Properties in East Nowra may experience flooding above floor in frequent events, largely from overland flow downstream of Marriott Park including urban areas around Haigh Avenue, Plunkett Street and Morton Parade. Properties adjacent to the swamp area to the east of Nowra experience above floor flooding in the 10% AEP and 5% AEP events with around 30 properties in the Haigh Ave, Morton Parade, Plunkett Street and Dryden Close areas being affected.

The 2% AEP event has similar flood extents to the 5% AEP with greater flood depths with some newly flooded areas around East Nowra, Ferry Lane and Moss Street and near Moorhouse Park/Scenic Drive to the west of Nowra Bridge. In a 1% AEP event, more properties in Ferry Lane as well as Amalfi Crescent become impacted with a total of 54 properties in Nowra affected by overfloor flooding. The number of affected properties jumps to 226 in the 0.2% AEP event as properties around Lyrebird Drive, Moss St, Moorhouse Park and adjacent to Harry Sawkins Reserve become impacted. In a PMF event, there is extensive numbers of above floor flooded properties (some 737) around the edge of the floodplain and south of the river in the Riverview Road areas to Moss Street and adjacent to Moorhouse Park and Harry Sawkins Reserve.

Properties behind Riverview Road levee will be protected from River flooding up to the 1% AEP event, with this area impacted primarily from backwater flooding from the Crookhaven Creek area in events greater than approximately the 0.5% AEP up to the PMF event when flooding is also experienced from overtopping of the levee and the Princes Highway from upstream of Nowra Bridge. The below table provides the level of service for the Riverview Road levee. The levee has one metre or more freeboard in the 1% AEP event, but is close to overtopping near Nowra Bridge in the 0.2% AEP event with a reasonable amount of freeboard (0.7m - 1m) east of Hawthorn Avenue. The levee will overtop along almost its entire length in a PMF event.

Table 11-2 Riverview Road levee level of service

Location	Wharf Road (near Nowra Bridge)	Western End (Hawthorn Avenue)	Mid-point	Eastern End (Ferry Lane)
Levee Crest (m AHD)	6.50	6.52	6.43	6.11
1% AEP (m AHD)	5.43	5.05	5.16	5.25
0.2% AEP (m AHD)	6.30	5.56	5.37	5.42
PMF (m AHD)	8.90	8.63	7.82	6.79

11.1.6 Upstream Nowra, North Nowra and Bomaderry

Upstream of Nowra Bridge the Shoalhaven Ski Park will become impacted in the 10% AEP event, two properties will have overfloor flooding in the 5% AEP event, increasing to five in the 1% AEP event and 13 in the PMF event. Properties in North Nowra are largely on high ground and do not experience flooding even in a PMF event with the exception of Nowra Golf Club and properties along the banks of Bomaderry Creek west of the Princes Highway.

Three properties in Bomaderry around Bolong Road adjacent to Bomaderry Creek and Brinawarr Street will experience overfloor flooding in a 20% AEP event. These impacts increase with increasing flood depths with rarer events largely influenced by backwaters from the Shoalhaven River. Almost 20 properties have overfloor flooding in the 5% AEP event with around 30 properties in the 1% AEP event, while some 74 properties will be impacted in the PMF event around the perimeter of the low lying areas.

11.1.7 Broughton Creek Floodplain

Properties along Bolong Road on the northern bank of the Shoalhaven River will have overfloor flooding from the 20% AEP event along with some isolated properties throughout the floodplain. Approximately 25 properties are impacted in a 10% AEP event, primarily in the lower Broughton Creek floodplain in the Bolong area along Jennings Lane. Flooding reaches overfloor levels for more properties on Jennings Lane along with properties on Hanigans Lane in the 5% AEP and 2% AEP events. In the 1% AEP event there are some 80 properties with above floor flooding with more properties along Hanigans lane affected. Properties around the perimeter of the floodplain are impacted in the PMF with a total of 153 properties having overfloor flooding.

Properties in the Berry area upstream of the railway and highway experience above floor flooding primarily from tributary flooding.

11.2 Flood Intelligence

The following table provides a summary of key flood levels and flood map figure numbers for ease of reference by emergency services.

Table 11-3 Flood intelligence summary information

	Design Flood Level (m AHD)				Map Figure Number			
Event (AEP)	Depth over Tallowa Dam spillway (m)	Tallowa Dam	Grassy Gully gauge	Nowra Bridge gauge	Flood Depth	Water Level	Hazard	Hydraulic Category
20%	2.20	58.54	16.50	3.01	G01	G08	G18	-
10%	3.96	60.30	20.16	4.19	G02	G09	G19	-
5%	5.00	61.34	22.86	4.83	G03	G10	G20	-
2%	5.50	61.84	25.39	5.22	G04	G11	G21	-
1%	5.96	62.30	26.72	5.38	G05	G12	G22	G27
0.2%	7.20	63.54	29.84	6.22	G06	G13	G23	-
PMF	11.05	67.39	41.62	8.85	G07	G14	G24	G28

Indicative flood levels at Tallowa Dam and Grassy Gully gauge with flows that would produce a 3m AHD flood level at Nowra Bridge are provided in **Table 11-4** as early warning of entrance management intervention. Travel times between locations is also provided.

Table 11-4 Shoalhaven Heads entrance management intervention early warning – water levels to achieve 3m AHD at Nowra Bridge

Location	Flood Level (m AHD)	Depth over spillway (m)	Approximate flow (m^3/s)	River segment	Approx. Travel Time (hours)
Tallowa Dam	59.34	3.00	3,500*	Tallowa Dam to Grassy Gully	1.75
Grassy Gully gauge	15.80	-	4,000	Grassy Gully to Nowra Bridge	3.5
Nowra Bridge gauge	3.00	-	4,000	Nowra Bridge to Shoalhaven Heads	1.5

* This flow refers to upper catchment flows into Tallowa Dam that would result in 3m at Nowra Bridge with nominal flows from catchments downstream of Tallowa Dam. It may be possible that the flows and trigger water levels at Grassy Gully and Nowra Bridge may also be reached if there is a large amount of coastal rain and the catchments between Tallowa Dam and Grassy Gully (Ettrema and Yalwal Creek catchments) are contributing to flows in the Shoalhaven River with the depth of flow over Tallowa Dam spillway less than 3m.

The travel times between Tallowa Dam, Grassy Gully and Nowra Bridge will vary based on the magnitude of a flood event and can be investigated further during the Lower Shoalhaven River FRMS&P.

The above early warning levels are approximate only as there are many influences on the levels and travel times including tidal levels, the storm temporal and spatial distribution and the relative contribution of flows from catchments upstream of Tallowa Dam and downstream of Tallowa Dam.

11.3 Flood Planning Levels

The Flood Planning Level (FPL) is a combination of flood levels and freeboards selected for planning purposes to manage risk to properties susceptible to flood risk to life and damage. Freeboard is applied to the selected planning flood to account for uncertainties in flood model accuracy, potential increases due to rainfall increases associated with Climate Change and other factors such as impacts of structure blockage or localised water level differences due to wave action.

The FPL is typically defined as the 1% AEP flood event plus 500mm freeboard for most residential and commercial developments. However, a larger flood event could be selected to determine the FPL based on a catchments flood risk.

The FPL was initially determined for this study based on the 1% AEP DFE. But following comparison against the currently adopted Council FPLs, it was identified that this would result in a reduction in FPL due to the reduced 1% AEP flow in this study. Hence, it was identified that there was an opportunity to adopt a higher DFE to determine the FPL. This approach is supported by changes to the NSW Government Flood Prone Land package and findings from the NSW Flood Inquiry.

Historically, flood planning levels have typically been set at the 1% AEP event plus 500mm freeboard. This was in response to Planning Circular PS-07-003 (2007) which mandated this approach unless significant extenuating circumstances were present, with any deviation requiring approval from the Planning Minister. While the previous approach theoretically allowed for other FPLs to be adopted, in practise this was rarely done.

The recently released NSW Government Flood Prone Land Package (2021) removes this mandated approach and allows councils to set local FPLs based on the flood behaviour and risk identified in Flood Studies and Floodplain Risk Management Studies and Plans. This allows councils to adopt higher planning levels in response to higher flood risks.

During the final stages of this study, the NSW 2022 Flood Inquiry report was released. It is noted that this process is still underway, and the outcomes and consequences of the Flood Inquiry with regard to planning and emergency management are not yet clear.

Early indications from the recommendations in the Flood Inquiry report are that there is the potential for changes to practises and policies related to a number of areas, including the determination of appropriate FPLs, particularly for catchments with a high flood risk. The Shoalhaven River floodplain is noted in the Flood Inquiry report as one of the high risk floodplains within NSW.

Table 11-5 shows the 2050 and 2100 scenario FPL at the water level gauging stations and reference locations for the 1% AEP (SLR and RCP8.5), 0.5% AEP event (SLR and RCP8.5) and the current values used based on the previously adopted FRMS&P. It is noted that the FPL based on the 0.5% AEP DFE is similar to the current FPL values. On this basis, the 0.5% AEP DFE plus 500 mm freeboard has been adopted as the FPL. This FPL can be further investigated during the FRMS&P Review.

The Flood Planning Area (FPA) mapping for this study has been determined by adding 500mm freeboard to the 0.5% AEP flood level and extending the surface laterally to intersect with the adjacent terrain to define the area within the FPL. The FPA has been determined for the existing, projected 2050 and projected 2100 scenarios. Draft Flood Planning Areas maps are provided in **Figures I01** to **I03** in **Appendix I**.

In determining appropriate FPLs, consideration may be given to ensuring areas sensitive to sea level rise, blockage and Climate Change impacts are fully considered in the Flood Planning Area.

Previous flood study results are deemed to have been conservative with regards 1% AEP flow estimates. This Flood Study uses current industry standard guidelines along with up-to-date data, modelling software and methods and the resulting flood levels are considered to be accurate and appropriate.

Various hydrological input parameters have been tested to obtain a good correlation with historical flood event behaviour and validation of design flow estimates against the statistical FFA of historical flood events. Sensitivity analysis in the hydraulic model has provided the magnitude of flood level differences that can be expected through uncertainty of input parameters and changes to tailwater conditions, or if structures were to become blocked. All of these results show that for a 1% AEP, increases in flood levels due to uncertainties are expected to be in the order of 300mm or less and the 1% AEP is not sensitive to blockage of structures.

Climate Change considerations show that flood levels may be expected to increase by up to 150mm for 2050 scenarios and approximately 250mm for 2090 scenarios for areas upstream of Terara while Lower Shoalhaven River and the Crookhaven River floodplain areas may expect increases of up to 500mm due to Sea Level Rise projections for the year 2100.

On this basis, a 500mm freeboard on Projected 2100 scenario 0.5% AEP flood levels may be appropriate for the FPL in the Lower Shoalhaven River areas around Nowra, Bomaderry and Broughton Creek as the freeboard should be able to account for uncertainties in flood model accuracy, potential increases due to rainfall increases associated with Climate Change and other factors.

Areas susceptible to sea level rise (Shoalhaven Heads, Greenwell Point, Orient Point, Culburra Beach and the Crookhaven River floodplain areas) should adopt a higher flood planning level to account for this longer term variation in the planning flood levels. An FPL based on the Projected 2050 or Projected 2100 levels would account for the predicted Sea Level Rise and increase in rainfall due to Climate Change.

This will allow the freeboard to then account for longer term Climate Change due to rainfall increases and other uncertainties. It is noted that the 0.36m SLR is on the lower end of long term sea level rise projections and hence adopting the 0.36m SLR will allow the freeboard to provide some additional protection to properties should sea level rise greater than this eventuate.

In the Shoalhaven River area upstream of Nowra Bridge, greater flood level increases are observed for both sensitivity to selected Manning Roughness and increased rainfall due to Climate Change and a greater freeboard in these areas around Grady's Caravan Park and further upstream would be warranted. However, it is noted that these areas are largely categorised as floodway with high hazard categories of H5 and H6 in the PMF and hence development is not recommended. A freeboard of 1.5m above the 1% AEP flood level would need to be adopted for the FPL in these areas, or alternatively adoption of a planning flood that considers rainfall increases due to Climate Change. Special consideration of existing development may be needed to determine appropriate controls to be applied should existing properties wish to alter their developments. Due to the steep slopes rising from the River, adoption of a higher FPL would not sterilise large areas and development on higher ground would be achievable in these areas to ensure future development would remain above the high risk areas.

Taking into consideration the different flood processes and to simplify the adoption of different flood planning levels and freeboard in different areas, it is recommended to adopt the 0.5% AEP 2090 Climate Change scenario (RCP 8.5 16.3% rainfall increase and 0.36m Sea Level Rise) as the planning flood with a standard 500mm freeboard as the FPL. Thus, for example, a house with a life span of 70 years would have an FPL based on the flood level estimated to be applicable in about 80 years' time. Given the 1% AEP flood level is lower than the previous Flood Study, adopting the higher 0.5% AEP defined flood event for the FPL will maintain a similar FPL to what has currently been adopted across the Lower Shoalhaven River floodplain and could further reduce future flood risk.

Table 11-5 Comparison of FPL Defined by Different Scenarios

ID	Location	1% AEP CC 2050 RCP8.5 + SLR2050 (SCC) FPL (mAHD)	1% AEP CC 2090 RCP8.5 + SLR 2100 (SCC) FPL (mAHD)	0.5% AEP CC 2090 RCP8.5 + SLR 2050 (SCC) FPL (mAHD)	0.5% AEP CC 2090 RCP8.5 + SLR 2100 (SCC) FPL (mAHD)	Previously adopted FRMS&P 2050 Scenario FPL (mAHD)	Previously adopted FRMS&P 2100 Scenario FPL (mAHD)
1	Grassy Gully	27.86	28.59	28.18	29.13	NA*	NA*
2	Gradys Caravan Park	20.63	21.23	21.02	21.83	NA*	NA*
3	Nowra Bridge	5.97	6.09	6.11	6.31	6.56	6.56
4	Terara Gauge	5.76	5.85	5.88	6.02	5.23	5.30
5	Terara Town	4.86	4.98	5.03	5.22	5.22	5.28
6	Broughton Creek US	4.90	5.00	5.09	5.25	5.52	5.55
7	Jorams and Broughton Confluence	4.90	5.00	5.09	5.25	5.43	5.47
8	Broughton Creek Confluence	4.72	4.83	4.93	5.10	4.91	5.00
9	Hay Street Gauge	3.61	3.77	4.06	4.26	4.05	4.26
10	Shoalhaven Heads	3.40	3.56	3.86	4.06	3.65	3.97
11	Crookhaven River and Crookhaven Creek Confluence	3.70	3.89	4.20	4.43	4.09	4.30
12	Greenwell Point Gauge	3.43	3.61	3.96	4.18	3.78	4.02
13	Crookhaven Heads Gauge	3.15	3.32	3.69	3.89	3.34	3.67

*Refer to **Figure 10-1** for reference locations.*

** Outside current FRMS&P Extent*

11.4 Flood Damages Assessment

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are generally categorised as either tangible (direct and indirect) or intangible damage types; these types are summarised in **Table 11-6**.

Table 11-6 Types of Flood Damages

Type of Flood Damage	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc.)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress

Type of Flood Damage	Description
	General inconvenience in post-flood stage

The direct damage costs, as indicated in **Table 11-6**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spread-sheets. For the purposes of this project, an in-house developed program has been used based on a combination of NSW DPE residential damage curves and FLDamage processes.

A flood damage assessment for the existing catchment conditions has been completed as part of this study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and as such, damage curves from other catchments, and available research in the area, is used as a substitute.

DPE has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties. The DPE methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW.

11.4.2 Input Data

11.4.2.1 *Floor Level Assessment*

A floor level database was developed by Council (2021) for all the properties within the earlier adopted PMF flood extent. The floor level database includes actual surveyed floor levels where available and some assumed floor levels based on building type for buildings where the actual floor level was unknown at the time of this Flood Study preparation. The database included data from the ground level and floor level survey undertaken by Council in 2001. The database categorised the properties as below:

Residential Properties:

> R1: Single storey high set (i.e. on piers/footings);
> R2: Single storey slab on ground;
> R3: Two storey;
> R4: Vacant blocks;
> R5: Residential apartments; and
> R6: Other residential buildings, including houses in two main categories:
  - Houses that are too far away from a road to identify the building type using Google street view; and
  - Relatively new houses that were visible in the latest Nearmap imagery but not in Google street view.

Commercial and Industrial Properties:

> C1: Commercial in urban areas;
> C2: Commercial in rural areas. This type includes one point for each farm property (at the biggest shed) for inclusion as a commercial premise;);
> C3: Industrial; and
> C4: Schools.

An evaluation of the surveyed floor levels and ground levels was undertaken by Cardno and it was observed that the majority of properties didn't have surveyed data. Where data was available, there were many cases of inconsistencies between the levels wherein the floor levels were lower than adjoining ground levels. Considering the age of the data provided, a desktop floor level assessment was undertaken to assign average building heights for properties within the PMF extent based on the property types identified above, using the following assumptions:

> R1: Floor Level = Ground Level from Lidar Data + 0.8 m;
> R2, R3 and R4: Floor Level = Ground Level from Lidar Data + 0.3 m;
> R5 and C4: Floor Level = Ground Level from Lidar Data + 0.3 m; and
> R6, C1, C2 and C3: Floor Level = Ground Level from Lidar Data + 0.3 m.

The above assumptions were guided by comparison of the ground levels and floor levels for different property types where survey data was available. However, for R5 and C4 properties the assumption was made based on Google Street views images from Google Maps™ since there was no survey data for these type of properties to be used as a reference.

Note: the new PMF extents result in additional properties being impacted for which floor level assessment has not been undertaken. An update to this should be revisited during the FRMS&P process.

11.4.2.2 *Hydraulic Model Result Inputs*

To inform the damages analysis, water level results are required to determine the depth of over-floor flooding and over-ground flooding for each flood affected lot. To inform this assessment, the maximum depth of flooding at each flood affected lot was calculated using the flood depth grid and cadastre and adopted as the inundation for that lot. Flood levels were extracted from the water level grids at each building entrance point (these points were identified in Council database).

The new PMF results were used for this assessment.

11.4.3 **Damage Analysis Methodology**

11.4.3.1 *Residential Damage Curves*

Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments are not available and recourse is generally made to damage curves from other catchments. NSW DPE has carried out research and prepared a methodology to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The DPE methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. DPE guidelines include a template spreadsheet program that determines damage curves for residential properties including:

> Single storey, slab on ground;
> Two storey, slab on ground; and
> Single storey, high set.

Several input parameters are required to use the DPE curves, such as floor area and level of flood awareness. The following parameters were adopted in developing the residential damage curves for the study area:

> Damages are generally incurred on a property prior to any overfloor flooding. The DPE curves allow for a damage of $17,207 (2021 dollars) to be incurred when the water level reaches the base of the house, with the base of a slab on ground house assumed to be 0.3 m below the floor level. We have assumed that this remains constant until overfloor flooding occurs. This may occur on steeper properties and larger properties where the garden and fences may be impacted, but the flood waters do not reach the house.
> A value of 240 m^2 was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain based on aerial imagery. With a floor area of 240 m^2, the contents value is estimated at $55,000; and
> The effective warning time has been assumed to be zero due to the rural nature of the area and possible low flood awareness as a conservative approach. A long effective warning time allows residents to prepare for flooding by moving valuable household contents and hence reducing the potential damages to household contents.

11.4.3.2 *Average Weekly Earnings*

DPE damage curves were derived for late 2001. To convert damages to today's dollars, it is recommended that values in residential damage curves are adjusted by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). AWE is considered a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home.

The most recent data from the Australian Bureau of Statistics (www.abs.gov.au) at the time of this study was for May 2021. The November 2001 AWE is shown in Table D1 of the NSW Department of Environment and Climate Change (DECC) guidelines. Both are shown in **Table 11-7.** Consequently, all ordinates in the residential flood damage curves were updated to May 2021 dollars. In addition, all damage curves include GST as per DPE recommendations.

Table 11-7 Average Weekly Earnings (AWE) Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$676.40
May	2021	$ 1,737.10 *

**Source: Australian Bureau of Statistics (2021)*

11.4.3.3 *Commercial Damage Curves*

Commercial damage curves were adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

- Low value commercial;
- Medium value commercial; and
- High value commercial.

For the purpose of this assessment all commercial properties have been classified as low value commercial, as no other information was available in the survey obtained for this project. In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

These curves are determined based on the floor area of the property. An indicative value of 400 m^2 was adopted based on the typical building footprints observed within the catchment using aerial image.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2021 dollars (**Table 11-8**), using data from the Australian Bureau of Statistics (2021). It was assumed that the FLDamage data was in June 1990 dollars.

Table 11-8 CPI Statistics for Commercial Damage Curves

Month	Year	CPI
June	1990	$102.50
March	2021	$212.38

11.4.3.4 *Industrial Damage Curves*

Cardno, as a part of a previous floodplain management study (Cardno, 1998), conducted a survey of industrial properties in 1998 for Wollongong City Council. The damage curves derived from that survey are more recent than those presented in FLDamage and have been used in several previous studies. Therefore, these damage curves are considered the most appropriate for use in this study.

The curves were prepared for three categories:

> Low value industrial;
> Medium value industrial; and
> High value industrial.

Industrial areas comprise a very small part of the study area. A low value industrial classification was applied to all the properties within the industrial area. An indicative value of 400 m^2 was adopted as the floor areas.

The survey conducted only accounts for structural and contents damage to the property. Clean-up costs and indirect financial costs were estimated based on the FLDamage Manual (Water Studies Pty Ltd, 1992). Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean-up costs and indirect financial costs could be made. The values were adjusted to March 2021 dollars using the CPI statistics shown in **Table 11-9**.

Table 11-9 CPI Statistics for Industrial Damage Curves

Month	Year	CPI
June	1998	$121.00
March	2021	$212.38

11.4.4 Adopted Damages Curves

The adopted damage curves are shown in **Figure 11-1** and **Figure 11-2** .

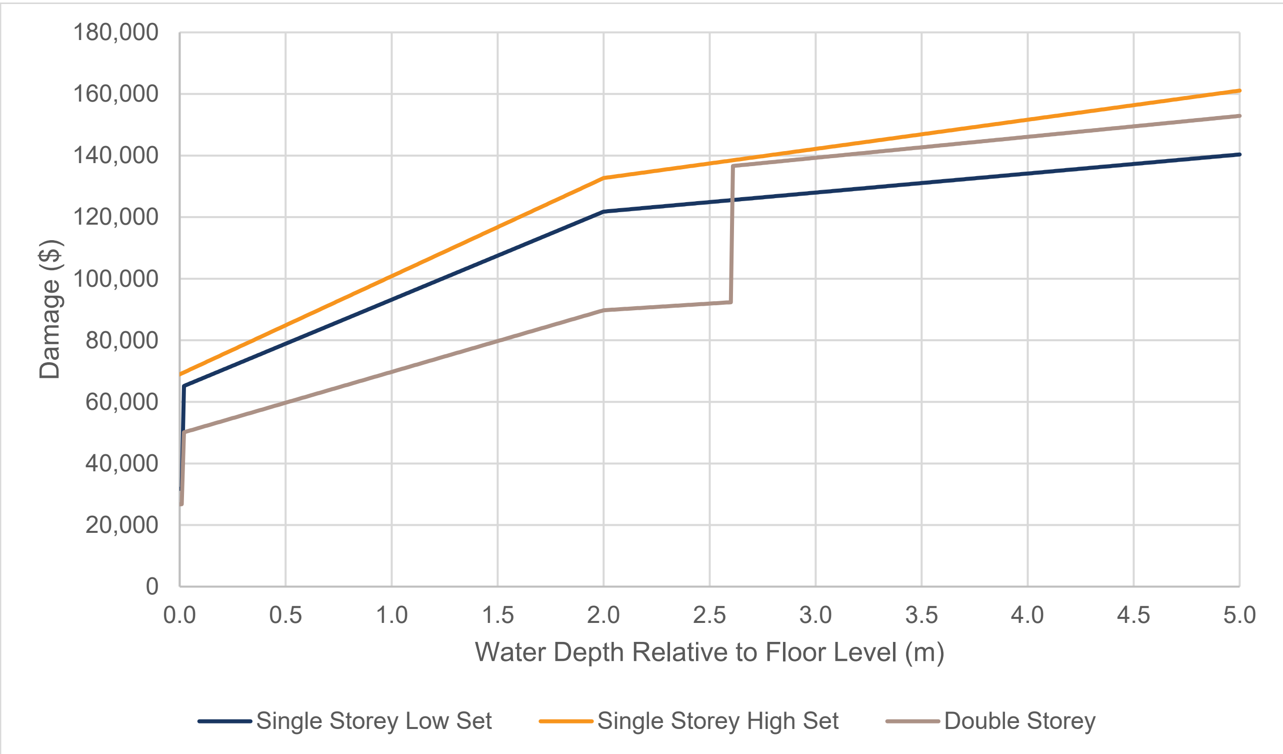

Figure 11-1 Residential Damage Curves

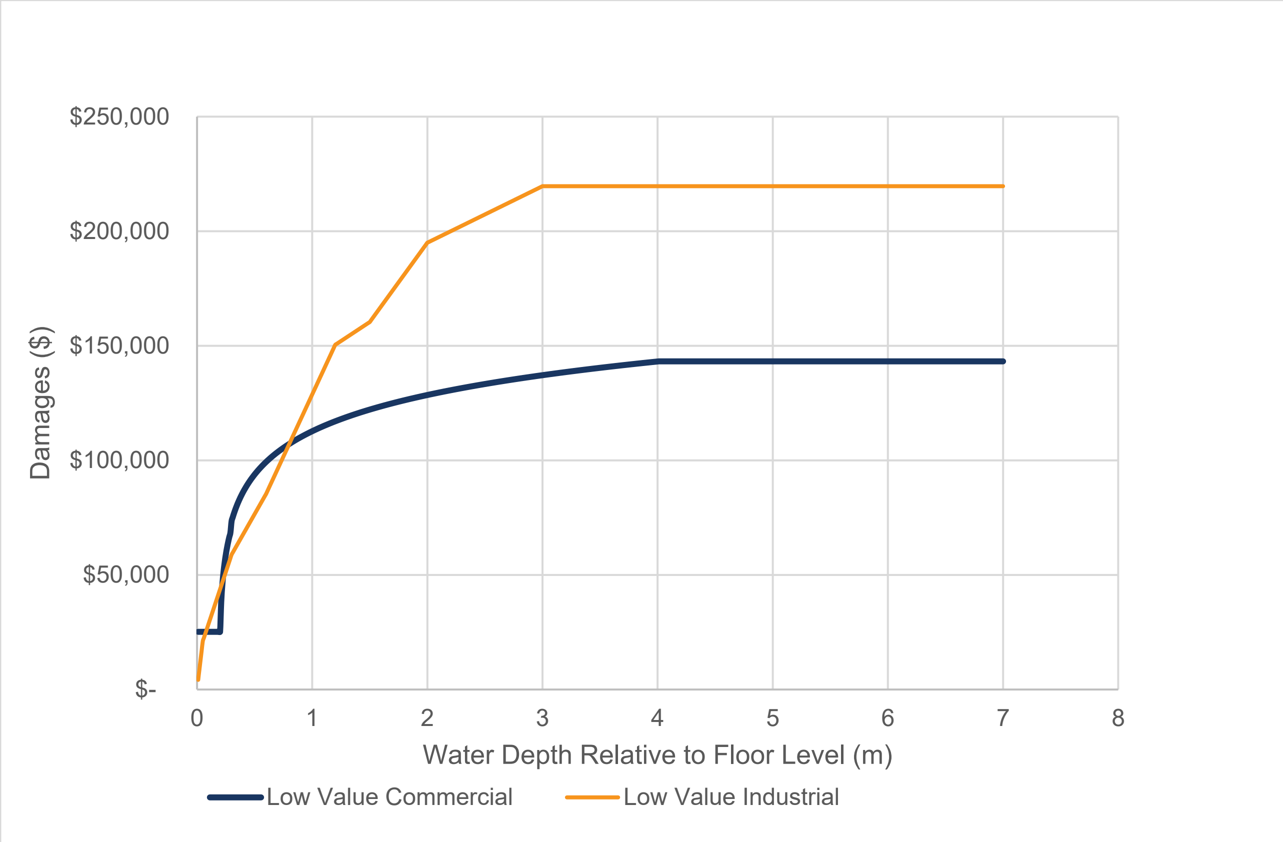

Figure 11-2 Low Value Industrial and Low Value Commercial Damage Curves

11.4.5 Total Damages

A summary of the total damage incurred for the Lower Shoalhaven catchment is shown in **Table 11-10.** This includes:

> The number of residential, commercial and industrial properties with overfloor flooding;

> The average depth of overfloor flooding for residential, commercial and industrial properties;

> The maximum depth of overfloor flooding for residential, commercial and industrial properties;

> The number of residential, commercial and industrial properties with overground flooding; and

> Total damage value for the catchment.

The above results are listed for all design events; 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP and the PMF events.

The existing scenario total damage curve for the Lower Shoalhaven catchment is shown in **Figure 11-3**.

Note: flood damages assessment should be revisited during the FRMS&P process following further floor level survey and also using the recently revised DPE flood damages analysis tools.

Table 11-10 Flood Damages Assessment Summary

Property Type	Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with Overground Flooding	Total Damage ($May 2021)
PMF					
Residential	2,093	2.46	19.24	2,363	$ 368,865,298
Commercial	280	2.60	6.64	313	$ 35,016,784
Industrial	20	1.60	4.34	32	$ 2,936,932
Total	2,393			2,708	$ 406,819,014
0.2% AEP					
Residential	1,241	1.10	8.63	2,020	$ 179,962,050
Commercial	183	1.28	3.38	255	$ 20,470,950
Industrial	11	0.71	2.33	28	$ 1,007,950
Total	**1,435**			**2,303**	**$ 201,440,900**
1% AEP					
Residential	750	0.66	5.24	1,639	$ 96,806,050
Commercial	147	0.77	2.75	232	$ 13,496,350
Industrial	7	0.61	1.46	23	$ 611,150
Total	**904**			**1,894**	**$ 110,913,550**
2% AEP					
Residential	551	0.45	4	1493	$ 68,226,600
Commercial	118	0.66	2.57	228	$ 10,396,250
Industrial	5	0.64	1.03	23	$ 509,100
Total	**674**			**1744**	**$ 79,131,950**
5% AEP					
Residential	168	0.35	2.04	1216	$ 25,724,300
Commercial	79	0.51	2.14	215	$ 6,250,200
Industrial	4	0.53	0.91	20	$ 366,900
Total	251			1451	**$ 32,341,400**
10% AEP					
Residential	44	0.34	1.66	758	$ 7,550,200
Commercial	29	0.43	1.47	207	$ 2,583,300
Industrial	2	0.43	0.72	15	$ 172,050
Total	**75**			**980**	**$ 10,305,600**
20% AEP					
Residential	15	0.43	1.05	657	$ 3,949,300
Commercial	9	0.49	0.86	186	$ 1,289,700
Industrial	1	0.4	0.4	14	$ 106,700
Total	**25**			**857**	**$ 5,345,700**
50% AEP					
Residential	13	0.29	0.93	623	$ 3,481,250
Commercial	9	0.40	0.81	180	$ 1,130,600
Industrial	0	0	0	13	$ 39,000
Total	**22**			**816**	**$ 4,650,850**

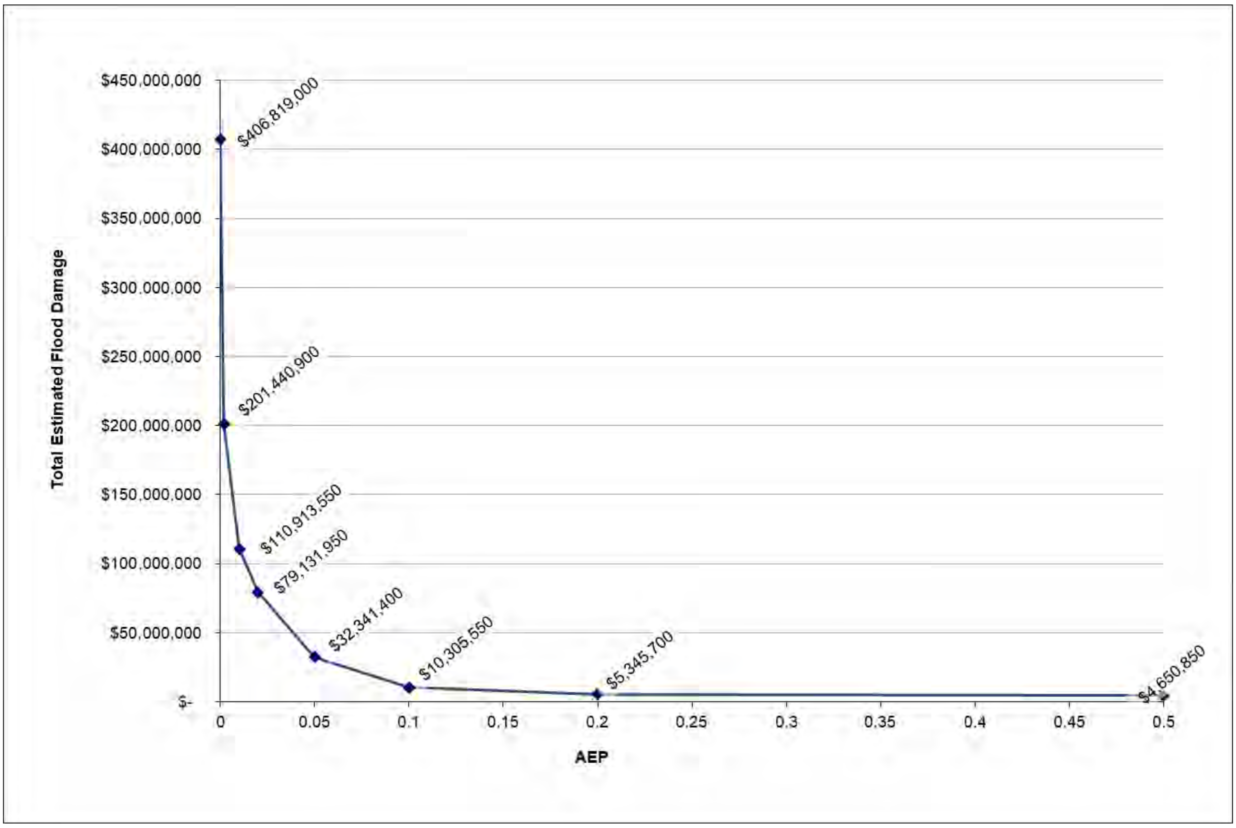

Figure 11-3 Total Damage Curve (Existing Condition) for Lower Shoalhaven

11.4.6 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event. Flood damages (for a design event) are calculated by using the damage curves described above. These damage curves attempt to define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

AAD attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event. For example, the 1% AEP design event has a probability of occurrence of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point (0.01) on the AAD curve. AAD is then calculated by determining the area under the plotted curve.

While the PMF event has a theoretical probability of almost 0% of occurring, to inform the calculation of AAD a representative probability of 0.0001 (or 0.01%) has been adopted for the PMF event (equivalent to a 10,000 year ARI event). Through this method, the PMF accounts for extremely rare flood events in the AAD calculation.

Further information of the calculation of AAD can be found in Appendix M of the *Floodplain Development Manual* (NSW Government, 2005).

Based on the analysis described above, the total AAD for the Lower Shoalhaven floodplain under existing conditions is **$8,988,902**.

11.5 Flood Emergency Response Classification of the Floodplain

To inform emergency response management in the study area, floodplain areas have been classified in regards to isolation and access considerations in accordance with Australian Disaster Resilience (ADR) Handbook 7. This classification provides the basis for understanding the nature, seriousness and scale of isolation problems. ADR guideline 7-2 has defined the classifications as shown in **Table 11.7**

The flood emergency response classifications in a PMF event for the floodplain are mapped in **Appendix J**.

Table 11-11 Flood Emergency Response Classification (source ADR guideline 7-2)

Primary classification	Description	Secondary classification	Description	Tertiary classification	Description	Example figures
Flooded (F)	The area is flooded in the PMF	Isolated (I)	Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/ or impossible terrain as waters rise during a flood event up to and including the PMF. These areas are likely to lose electricity, gas, water, sewerage and telecommunications during a flood.	Submerged (FIS)	Where all the land in the isolated area will be fully submerged in a PMF after becoming isolated.	Figure 1 Figure 7 with levee Figure 8 with impassable terrain
				Elevated (FIE)	Where there is a substantial amount of land in isolated areas elevated above the PMF.	Figure 2
		Exit Route (E)	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities (located on flood-free land).	Overland Escape (FEO)	Evacuation from the area relies upon overland escape routes that rise out of the floodplain.	Figure 3
				Rising Road (FER)	Evacuation routes from the area follow roads that rise out of the floodplain.	Figure 4, Figure 6 with levee
Not Flooded (N)	The area is not flooded in the PMF			Indirect Consequence (NIC)	Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications and transport links due to flooding.	Figure 5
				Flood free	Areas that are not flood affected and are not affected by indirect consequences of flooding.	

Emergency response classification of the floodplain has been undertaken by classifying cadastral lots into one of the tertiary classifications categories in the above **Table 11-11**. Where the flood extent spans a cadastral lot such that part of the lot is within the flood extent and part of the lot is outside the flood extent, the lot is classified based on the location of habitable buildings on the lot. So if a residential dwelling on a lot is located outside the flood extent, this is tagged as “flood free”, even though part of the lot is within the flood extent. This allows emergency response agencies to focus on properties that will become isolated or have evacuation needs.

Main evacuation routes, evacuation centres and major infrastructure have been identified and impacts to these are considered in the classification. Evacuation routes are assessed to determine where an evacuation route from an area continues rising out of the flood allowing continuous evacuation or when it will become cut off by floodwaters during an event due to a low point in the road.

The following locations are listed in the Shoalhaven Local Flood Plan 2014 as suitable for use as evacuation centres or assembly areas dependent on the scale and type of the event. It is noted that the Shoalhaven Local Flood Plan was being reviewed at the time this flood study was completed in 2022. An updated list of evacuation centres and assembly areas should be obtained from the Shoalhaven Local Flood Plan 2022 when available:

> Berry:
- School of Arts, Alexander Street (Can be flood affected)
- Showgrounds, Alexander Street (Can be flood affected)

> Bomaderry:
- Bomaderry High School, Cambewarra Road
- Bomaderry Bowling Club, 154 Meroo Road
- Community Centre, 13-17 Birrelly Street
- Basketball Stadium, Cambewarra Road

> Nowra:
- Nowra Showgrounds, West Street
- Shoalhaven Entertainment Centre, 44 Bridge Road
- Senior Citizens Centre, Graham Place
- Police Boys Club, Park Road

> Shoalhaven Heads:
- Community Centre, Shoalhaven Heads Road
- Celia Hall, Celia Place

> Greenwell Point:
- RSL Hall, Greenwell Point Road (Note: Greenwell Point may become isolated)

> Culburra:
- Community Centre, Prince Edward Drive

There are significant areas of the floodplain that become submerged with evacuation routes cut off in the Lower Shoalhaven catchment.

Comerong Island becomes submerged with most properties experiencing overfloor flooding in a 5% AEP event and no safe water evacuation with the Comerong Island Ferry not in operation during flood and Comerong Island Road cut off. Evacuation to higher ground along Coal Wharf Road would be possible, however, there is no shelter and dense bushland that makes any rescue or delivery of supplies difficult.

Evacuation from Lower Numbaa, Numbaa and Terara is via Comerong Island Road and evacuation from Pyree, Mayfield and Brundee via Greenwell Point Road, with both evacuation routes becoming submerged and impassable to vehicles.

Areas within the Broughton Creek floodplain and Coolangatta will become submerged with sections of the main evacuation route of Bolong cut off in a 10% AEP event.

Greenwell Point has low lying areas that become submerged with the two areas elevated above flood levels, however, evacuation is via Greenwell Point Road which will become impassable in a 20% AEP event and Greenwell Point becomes isolated.

The flood affected foreshore areas of Orient Point and Culburra Beach have rising road egress to flood free land and evacuation is via Prince Edward Avenue and Culburra Road. However, the low point of Prince Edward Avenue near The Strand becomes impassable to vehicles between the 5% AEP event and 2% AEP event. Properties north of this low point would be isolated except for egress by foot via the beachfront. A flood free evacuation centre is available for shelter until flood waters receded.

Properties in Shoalhaven Heads have rising road egress to flood free land within Shoalhaven Heads and to an evacuation centre. Egress from Shoalhaven Heads can be via Gerroa Road – although it is noted that flood free egress of this road is unknown as it is outside the extent of modelling.

Nowra and North Nowra are largely flood free and evacuation from flood affected areas is via rising road egress to higher ground and suitable evacuation centres. West Nowra will be indirectly affected as various roads across tributaries are affected preventing access to Nowra town centre. Transport north across the Shoalhaven River will be cut in the PMF with the Princes Highway and Nowra Bridge submerged.

Flood affected properties in Berry and Bomaderry typically have rising road egress to higher ground and suitable evacuation centres, with some areas around Bomaderry Creek becoming submerged with no egress once Bolong Road is submerged.

11.6 Impacts of Development in the Catchment

The hydrology model has been setup to calculate flows based on the 'present day' catchment impervious percentage associated with current land use derived from aerial photography and the LEP land use zones mapping. A review of the LEP land use zone mapping indicates that there are some areas in the catchment, predominantly in South Nowra and Bomaderry, that have a zoning for potential future development that would increase the %imperviousness. This could potentially lead to higher runoff from those areas assuming full development within these zones.

In addition to the current LEP land use zoning, there is also the West Culburra Planning Proposal, which is on higher ground to the south of Crookhaven River. It is noted that all of these developments would be subject to Council's on-site detention requirements to mitigate flows to existing levels and any increase in runoff as a result of these developments would only have a localised impact in the area immediately downstream of any outlets. Even without on-site detention, any increase in runoff would be insignificant compared to the total catchment and would have no impacts on Shoalhaven River levels.

11.7 Impacts of Works in the Floodplain

A number of infrastructure works were identified as being proposed to be constructed in the floodplain which may have an impact on flood behaviour. These works have been either completed or were under construction during this study and have been included in the hydraulic model. This includes:

- Berry to Bomaderry Princes Highway upgrade - While under construction at the time of this study, this highway upgrade has been included in the model based on the approved design which was provided by TfNSW. This includes the road formation and hydraulic structures including bridges and culverts;
- Nowra Bridge Duplication - While under construction at the time of this study, this highway upgrade has been included in the model based on the approved design which was provided by TfNSW. This includes the road formation and Nowra Bridge duplication and Bomaderry Creek bridge widening;
- Archgate Bridge (near the floodgates) over Crookhaven River – Culburra Road, Pyree – works completed and included in the model; and
- Culverts near Bomaderry Creek (Thurgate Oval – Bolong Rd, Bomaderry) – works completed and included in the model.

In addition, the Far North Collector Road project is proposed which comprises an arterial road between Illaroo Road and Moss Vale Road and crosses the Bomaderry Creek floodplain. However, this project is in the preliminary design stages and the design development, impacts and mitigation are the subject of a separate hydraulic investigation, hence has not been considered further for this study. The project also lies within the upper sections of Bomaderry Creek and can be considered in the next update to the Bomaderry Creek FRMSP.

12 Conclusion

The results of this Flood Study show that both the hydrological and hydraulic models have been successfully calibrated; with a combined calibration/validation to four historical events. Design flood estimates have been validated against a Flood Frequency Analysis of observed annual peak flood levels and flows to provide confidence in the design flow estimates. The models are considered to provide a good representation of flood behaviour in the catchment and can be used with confidence in assessing design flood behaviour.

The study uses the current industry standard methods and guidelines in flood estimation using Australian Rainfall and Runoff 2019 and a series of DPE floodplain management guidelines to define flood behaviour in the Lower Shoalhaven River area for a range of representative design flood events.

The design event flood estimates were validated to a Flood Frequency Analysis of observed annual peak flood levels. As part of this analysis, the Grassy Gully II gauge (215216) level-flow relationship (rating curve) was reviewed and updated using the hydraulic model to inform the extrapolation to higher flows beyond the gauging data. The modelling approach, model setup, parameters, FFA, calibration and design flow estimates have been peer reviewed by an independent consultant on behalf of Council.

The 1% AEP design flood levels in the current Flood Study are lower than those derived from the previous 1990 flood study modelling that Council has adopted. This is due to the design flow estimates being lower using updated data and methods along with differences in model setup and more up-to-date survey and catchment conditions.

The models have been run for the 50%, 20%, 10%, 5%, 2%, 1%, 0.2% AEP storms and Probable Maximum Flood (PMF) event for the existing, Projected 2050 and Projected 2100 scenarios and flood levels, depths and velocities mapped. Provisional hazard, hazard, hydraulic categories and combined hazard and hydraulic categories have also been mapped.

Assessment of the impacts of rainfall increases and sea level rise due to Climate Change was undertaken along with assessment of tidal inundation and sensitivity to various model parameters.

The report also provides guidance on the adoption of Flood Planning Levels and Emergency Response parameters for use in planning and by the NSW SES.

The study will be used by Council and various stakeholders to inform flood planning and emergency management in the Study Area. The outputs of the Flood Study will provide information on current and future flood risk which is important for increasing community awareness and for building resilience.

12.1 Next Stage in Floodplain Risk Management Process

Following Council, DPE and NSW SES review and acceptance of the flood study results, the following steps will be undertaken:

- Present to the Floodplain Management Committee;
- Undertake public exhibition and community consultation for the draft Flood Study;
- Complete the Final Flood Study;
- Undertake flood modification options assessment; and
- Develop Floodplain Risk Management Study.

The Floodplain Risk Management Study will provide an understanding of potential emergency response, planning and flood modification measures for managing flood risk in the catchment, benefit cost analysis and development of the Floodplain Risk Management Plan.

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APPENDIX

A

XP-RAFTS SUB-CATCHMENT DETAILS

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
AB_1.01	0.02	0.045	1.161	91.12	122.76	282053.41	6142471.50
AB_1.02	0.02	0.045	0.803	7.13	87.63	282200.53	6142957.50
AB_1.03	0.02	0.045	1.47	13.97	97.72	280502.22	6143404.50
AB_1.04	0.02	0.045	2.407	0.56	55.41	280215.28	6143541.50
AB_1.05	0.02	0.045	3.599	0.58	57.42	278922.47	6143318.00
AB_1.06	0.02	0.045	2.4	3.15	36.01	279764.00	6143630.00
B_B1	0.02	0.05	8.57	1.71	169.06	290199.91	6152943.50
B_B10	0.02	0.05	7.937	0.88	87.22	289950.00	6154130.00
B_B2	0.02	0.05	8.57	1.30	128.32	290399.00	6153590.00
B_B3	0.02	0.05	8.57	0.92	90.88	291259.00	6152430.00
B_B4	0.02	0.05	8.57	1.43	141.47	290683.00	6152140.00
B_B5	0.02	0.05	8.57	0.47	46.49	291458.00	6152570.00
B_B6	0.02	0.05	8.57	1.47	145.76	291828.31	6153115.00
B_B7	0.02	0.05	8.57	1.16	115.10	291771.13	6152434.50
B_B8	0.02	0.05	7.937	2.92	289.28	289720.75	6154111.00
B_B9	0.02	0.05	7.937	4.16	411.64	290869.78	6155590.00
B_BC_AL1	0.02	0.05	1.864	1.86	184.58	286406.81	6148001.00
B_BC_AL2	0.02	0.05	1.121	7.29	104.77	287834.97	6147931.50
B_BC_AL3	0.02	0.05	2.176	17.94	199.66	289119.13	6147779.50
B_BC_BC1	0.02	0.05	2.636	2.64	261.01	293413.75	6158388.50
B_BC_BC2	0.02	0.05	6.2	6.20	613.90	294910.13	6156283.00
B_BC_BC3	0.02	0.05	8.788	8.79	870.06	295350.84	6155391.50
B_BC_BC4	0.02	0.05	4.381	4.38	433.75	295481.97	6154227.50
B_BC_BC5	0.02	0.05	5.641	5.64	558.65	294626.09	6153436.00
B_BC_BC6	0.02	0.05	10.737	22.20	1051.47	291785.56	6150303.50
B_BC_BC7	0.02	0.05	2.314	5.02	226.41	290456.31	6149728.50
B_BC_BC8	0.02	0.05	1.942	1.79	192.40	290545.31	6148920.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
B_BC_BC9	0.02	0.05	1.957	7.26	188.45	289313.97	6147804.00
B_BC_BM1	0.02	0.05	1.348	1.35	133.47	291570.59	6156551.00
B_BC_BM3	0.02	0.05	8.57	0.11	11.21	290709.16	6151909.50
B_BC_BM4	0.02	0.05	4.644	7.44	454.23	290121.69	6149883.00
B_BC_BM5	0.02	0.05	0.787	6.06	72.67	290258.34	6148210.00
B_BC_BW1	0.02	0.05	6.806	6.81	673.76	286033.97	6152138.00
B_BC_BW2	0.02	0.05	7.451	7.45	737.72	287870.22	6150669.00
B_BC_BW3	0.02	0.05	0.889	0.93	87.82	289837.97	6149854.00
B_BC_CN1	0.02	0.05	5.947	5.97	591.45	289495.34	6149962.50
B_BC_CP1	0.02	0.05	0.645	25.75	38.75	288556.16	6149648.00
B_BC_CP2	0.02	0.05	0.93	51.06	41.97	289449.91	6148973.00
B_BC_CP3	0.02	0.05	0.361	4.17	31.96	289980.31	6148159.00
B_BC_HL1	0.02	0.05	0.716	12.81	58.75	287588.81	6149575.50
B_BC_HL2	0.02	0.05	1.472	50.99	96.20	288097.44	6148567.00
BC_ALTrib1	0.02	0.05	1.978	1.98	195.86	287242.53	6148316.50
BC_BCTrib 1	0.02	0.05	4.553	4.55	450.83	290613.25	6149708.00
BD_1.00a	0.02	0.045	9.2	3.73	368.79	272038.72	6143494.50
BD_1.01a	0.015	0.09	13.866	1.16	114.56	272922.00	6143899.00
BD_1.01b	0.015	0.09	21.74	1.71	169.26	273011.94	6145144.00
BD_1.01c	0.015	0.09	19.232	0.93	92.12	272938.09	6144846.50
BD_1.01d	0.015	0.09	10.24	0.80	79.29	273082.72	6144336.50
BD_1.01e	0.015	0.09	5.844	0.34	33.32	273284.84	6143814.50
BD_1.02	0.015	0.06	5.287	0.54	53.81	273975.75	6143664.00
BD_1.03	0.015	0.06	2.78	0.35	29.39	274481.34	6143712.50
BD_1.04	0.015	0.06	5.139	0.30	30.03	275088.91	6143636.00
BD_1.05a	0.015	0.06	4.369	0.12	12.09	275512.59	6143519.50
BD_1.05b	0.015	0.06	1.772	0.16	16.24	275999.22	6143302.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
BD_1.06	0.015	0.06	1.352	0.13	24.01	276445.38	6142997.50
BD_1.07	0.015	0.06	2.309	0.36	35.60	276922.31	6142432.50
BD_1.08a	0.015	0.06	6.394	4.02	42.13	276758.66	6142259.00
BD_1.08b	0.015	0.06	0.839	0.32	37.86	277415.09	6142089.00
BD_1.09	0.015	0.06	0.785	0.35	34.99	278141.97	6141969.00
BD_1.10	0.015	0.06	0.889	0.36	35.48	278648.75	6142010.00
BD_1.11	0.015	0.06	4.117	3.74	25.24	278823.44	6142011.00
BD_1.12a	0.015	0.06	6.671	22.32	27.04	279500.19	6142092.50
BD_1.12b	0.015	0.06	0.861	0.33	32.77	279377.75	6142002.50
BD_1.13	0.015	0.1	4.393	1.47	54.52	279619.91	6141267.00
BD_1.14	0.015	0.1	9.119	11.93	67.69	279763.81	6140232.50
BD_1.15	0.015	0.06	6.033	13.60	33.81	280619.66	6139708.50
BD_1.16a	0.015	0.04	1.541	1.48	8.09	281019.19	6139864.00
BD_1.16b	0.015	0.04	1.561	3.01	15.69	281494.00	6139920.00
BD_1.17	0.015	0.04	6.102	5.10	4.02	281555.06	6140210.50
BD_10.01	0.015	0.05	4.072	5.84	10.52	276103.38	6143726.50
BD_11.01	0.015	0.06	2.315	6.69	34.68	275165.13	6143235.50
BD_11.02a	0.015	0.06	1.019	0.25	24.54	275767.28	6143216.50
BD_11.02b	0.015	0.06	3.751	2.37	21.53	276013.44	6143161.50
BD_12.01	0.015	0.05	4.766	8.30	17.50	276237.81	6143303.50
BD_13.01	0.015	0.06	3.073	14.87	15.31	275502.41	6142788.50
BD_13.02	0.015	0.06	2.432	8.49	44.95	276413.19	6142498.00
BD_14.01a	0.015	0.09	24.607	0.82	81.49	276899.59	6145424.00
BD_14.01b	0.015	0.09	27.671	1.29	127.33	276874.97	6145975.50
BD_14.01c	0.015	0.09	23.758	1.60	158.50	276839.97	6145970.00
BD_14.01d	0.015	0.09	19.886	1.68	166.32	276659.59	6145642.50
BD_14.01e	0.015	0.06	15.009	0.12	11.74	276655.81	6145465.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
BD_14.01f	0.015	0.06	11.606	0.07	6.77	276746.69	6145398.00
BD_14.01g	0.015	0.09	5.165	0.28	27.57	276971.31	6145095.50
BD_14.01h	0.015	0.06	6.587	0.17	16.67	276967.75	6144840.00
BD_14.01i	0.015	0.06	6.163	0.34	9.28	276937.94	6144721.50
BD_14.02	0.015	0.06	1.504	1.86	14.01	277264.09	6144446.00
BD_14.03	0.015	0.06	3.066	2.26	14.14	277088.25	6143980.00
BD_14.04	0.015	0.04	1.818	0.20	10.09	277134.88	6143524.50
BD_14.05	0.015	0.04	6.15	0.11	10.73	277123.97	6143522.00
BD_14.06	0.015	0.06	3.168	2.00	13.55	277297.94	6142945.00
BD_14.07	0.015	0.06	0.955	0.23	23.02	277532.03	6142364.50
BD_14.08	0.015	0.06	3.091	0.17	17.24	277734.72	6142318.50
BD_15.01a	0.015	0.08	36.315	0.44	43.94	277237.84	6145525.00
BD_15.01b	0.015	0.08	5.794	0.15	15.01	277243.03	6144843.50
BD_15.02	0.015	0.06	3.13	0.04	3.70	277173.44	6144851.00
BD_16.01	0.015	0.08	18.68	0.27	26.81	277289.44	6144835.50
BD_17.01a	0.015	0.07	15.467	0.14	13.95	277443.75	6144812.00
BD_17.01b	0.015	0.06	5.268	0.21	20.78	277463.88	6144293.00
BD_18.01	0.015	0.04	6.129	13.59	6.38	276865.03	6144263.50
BD_18.02	0.015	0.04	5.092	15.82	6.86	277001.16	6143913.00
BD_19.01	0.015	0.06	1.437	0.09	8.68	277310.50	6143653.00
BD_2.01a	0.015	0.09	20.637	1.20	118.60	274511.63	6144263.50
BD_2.01b	0.015	0.09	23.578	0.61	60.44	274507.59	6144270.50
BD_2.02	0.015	0.06	1.819	0.34	33.93	274440.63	6143833.00
BD_20.01a	0.015	0.06	5.73	0.17	16.86	277508.13	6143790.00
BD_20.01b	0.015	0.06	1.592	0.24	23.90	277306.47	6142957.50
BD_21.01	0.015	0.06	0.002	0.07	6.61	277829.31	6143741.50
BD_21.02a	0.015	0.06	4.646	0.07	6.81	277887.53	6143697.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
BD_21.02b	0.015	0.06	1.485	0.21	20.78	277518.53	6142856.00
BD_21.02c	0.015	0.06	3.363	0.21	20.77	277528.00	6142851.50
BD_22.01	0.015	0.06	3.501	0.14	13.93	277144.56	6142818.50
BD_23.01	0.015	0.05	3.386	25.04	32.06	278034.53	6141744.50
BD_24.01	0.015	0.06	6.552	0.24	23.72	278554.53	6142544.50
BD_25.01	0.015	0.07	3.66	10.09	44.38	278610.88	6141949.50
BD_26.01	0.015	0.06	2.682	2.61	46.75	278964.25	6142491.00
BD_27.01	0.015	0.1	5.044	0.57	32.79	279645.69	6141281.00
BD_28.01	0.015	0.04	3.385	36.22	31.82	278997.63	6140238.00
BD_28.02	0.015	0.05	5.28	26.81	41.37	279690.03	6140225.00
BD_29.01a	0.015	0.04	3.843	12.17	10.23	280946.06	6141084.50
BD_29.01b	0.015	0.04	3.644	7.82	5.02	280734.22	6140917.50
BD_29.02	0.015	0.04	3.644	23.61	17.79	280830.31	6140555.00
BD_29.03	0.015	0.04	4.405	14.80	13.20	281179.69	6140194.50
BD_3.01	0.015	0.06	19.313	0.43	43.02	274592.81	6144191.50
BD_30.01	0.015	0.04	6.499	0.13	12.76	280734.72	6140224.50
BD_30.02a	0.015	0.04	7.743	1.67	1.60	280823.69	6140202.00
BD_30.02b	0.015	0.04	4.078	6.37	7.64	280676.94	6139924.50
BD_4.01	0.015	0.09	23.831	1.81	178.94	275622.66	6145040.00
BD_4.02	0.015	0.06	4.363	0.15	15.06	276051.28	6144624.00
BD_4.03	0.015	0.06	5.429	0.23	22.86	275947.63	6144296.50
BD_4.04	0.015	0.06	5.686	0.10	9.62	275935.31	6143969.00
BD_4.05	0.015	0.06	1.022	0.11	10.49	275857.56	6143546.00
BD_5.01	0.015	0.07	22.544	0.29	28.52	275616.03	6144933.00
BD_6.01	0.015	0.09	17.96	0.70	68.85	275925.16	6145129.50
BD_6.02	0.015	0.06	8.857	0.40	39.33	276148.34	6144768.50
BD_7.01	0.015	0.06	4.691	0.46	45.76	275885.16	6144305.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
BD_8.01	0.015	0.06	5.149	2.74	13.71	276101.00	6143957.00
BD_9.01a	0.015	0.06	6.87	0.20	20.01	275548.09	6144040.00
BD_9.01b	0.015	0.06	3.704	0.29	28.89	275842.06	6143580.00
BEV_1.01	0.02	0.045	4.745	0.66	160.76	290643.66	6139976.00
BEV_1.02	0.02	0.045	9.345	11.33	148.72	291292.78	6140265.00
BEV_1.03	0.02	0.045	11.61	11.79	76.27	291422.66	6140441.50
BEV_1.04	0.02	0.045	0.05	1.38	141.57	291849.69	6139963.50
BEV_1.05	0.02	0.045	0.179	3.28	11.36	291781.13	6140089.50
BOM_1.02	0.02	0.045	1.549	47.59	38.90	281838.75	6140209.00
BR_1.03	0.02	0.05	4.92804134	7.63	131.21	289372.75	6147747.00
BR_1.04	0.02	0.045	0.768	9.77	101.46	289008.00	6147110.00
BR_1.11	0.02	0.045	0.067	0.35	34.60	288626.00	6146007.00
BR_1.12	0.02	0.045	0.36	1.07	105.58	287811.78	6144887.50
BR_1.13	0.02	0.045	1	0.16	100.68	288382.16	6144968.50
BR_1.14	0.02	0.045	4.252	19.91	78.44	289837.41	6145480.50
BR_1.15	0.02	0.045	9.106	7.16	70.46	290245.38	6146029.00
BR_1.16	0.02	0.045	0.1	1.54	96.07	285732.25	6143781.00
BR_1.17	0.02	0.045	0.059	1.17	115.58	286228.00	6143600.00
BR_1.18	0.02	0.045	0.144	1.43	109.67	286465.59	6143053.50
BR_1.19	0.02	0.045	4.641	10.45	138.16	286641.81	6143245.50
BR_1.20	0.02	0.045	1.413	7.20	145.03	287697.00	6140760.00
BR_1.21	0.02	0.045	0.075	4.96	138.25	286744.31	6141785.00
BR_2.01	0.02	0.045	1.826	6.00	91.09	287418.75	6143543.00
BR_2.02	0.02	0.045	2.954	7.60	147.12	288276.50	6144387.50
BR_2.03	0.02	0.045	0.959	1.71	80.09	289295.22	6144887.50
BR_2.04	0.02	0.045	2.131	2.98	90.62	290045.31	6144778.00
BR_2.05	0.02	0.045	3.008	9.08	101.65	290759.16	6144615.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
BR_3.01	0.02	0.045	0.079	1.27	126.17	287523.22	6144209.00
BR_3.02	0.02	0.045	2.384	7.02	134.71	286793.88	6145378.00
BR_3.03	0.02	0.045	7.665	13.40	146.20	289820.81	6144081.00
BR_3.04	0.02	0.045	7.886	9.97	175.49	290602.91	6144043.00
BR_4.01	0.02	0.045	4.84	1.97	108.92	288279.78	6143401.50
BR_4.02	0.02	0.045	4.21	5.52	146.07	288974.75	6143257.00
BR_4.03	0.02	0.045	9.39	12.40	136.91	289376.44	6142788.00
BR_5.01	0.02	0.045	6.49	0.91	89.80	287683.13	6141506.50
BR_5.02	0.02	0.045	5.822	0.99	98.14	288151.91	6141220.50
CAB_1.01	0.02	0.045	1.32	225.81	545.82	276568.03	6136081.50
CAB_1.02	0.02	0.045	1.089	45.98	136.59	277148.50	6136043.00
CAB_1.03	0.02	0.045	0.982	3.75	370.95	277118.31	6138200.50
CC_1.01	0.02	0.045	0.089	2.36	120.38	289364.88	6131680.50
CC_1.02	0.02	0.045	0.009	0.84	110.43	289871.78	6131778.00
CC_1.03	0.02	0.045	0.118	4.47	153.35	289257.03	6132714.00
CC_1.04	0.02	0.045	0.116	3.16	147.33	287896.84	6132776.00
CC_1.05	0.02	0.045	0.053	0.27	105.41	287282.56	6133882.00
CC_1.06	0.02	0.045	0.013	2.09	89.94	287226.69	6134736.00
CC_1.07	0.02	0.045	0.208	5.30	138.56	286500.66	6135704.00
CC_1.08	0.02	0.045	0.723	5.59	145.20	285257.41	6136985.00
CC_1.09	0.02	0.045	1.086	24.88	104.54	283872.81	6137067.50
CC_1.10	0.02	0.045	0.099	11.90	116.90	283238.31	6137673.50
CC_1.11	0.02	0.045	0.861	12.33	79.79	282374.63	6137628.50
CC_1.12	0.02	0.045	2.407	42.59	26.28	282452.56	6136612.00
CC_1.13	0.02	0.045	0.134	11.27	87.77	282266.31	6138729.00
CC_2.01	0.02	0.045	0.003	1.68	109.73	288776.97	6133761.50
CC_3.01	0.02	0.045	0.087	0.58	88.72	288147.31	6132693.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
COB_1.01	0.02	0.045	0.017	1.42	140.68	293081.03	6136948.00
COB_1.02	0.02	0.045	0.068	1.59	116.83	292194.31	6136929.50
COB_1.03	0.02	0.045	0.079	0.72	111.10	291515.00	6136590.00
COB_1.04	0.02	0.045	0.083	1.36	135.07	292594.00	6135750.00
COB_1.05	0.02	0.045	0.191	0.45	109.46	293643.88	6135145.50
COM_1.01	0.02	0.045	0.37970035	1.10	109.16	294338.84	6135641.00
COM_1.02	0.02	0.045	0.311	1.56	154.81	293620.53	6136254.50
CR_1.01	0.02	0.045	0.849	1.56	154.71	296294.13	6136426.50
CR_1.02	0.02	0.045	0.566	16.23	135.36	295211.28	6135325.50
CR_1.03	0.02	0.045	0.673	17.61	133.36	293306.09	6134773.50
CR_1.04	0.02	0.045	1.478	29.91	97.36	293500.28	6133568.00
CR_1.05	0.02	0.045	0.854	19.06	122.45	292582.56	6133503.00
CR_1.06	0.02	0.045	1.929	10.17	103.41	292539.41	6133177.50
CR_1.07	0.02	0.045	1.645	1.87	139.12	291526.50	6132319.50
CR_1.08	0.02	0.045	1.046	2.78	147.45	290850.25	6131703.00
CR_1.09	0.02	0.045	0.173	0.25	111.18	289404.53	6131529.50
CR_1.10	0.02	0.045	2.664	1.58	156.64	289548.06	6130616.00
CR_1.11	0.02	0.045	1.856	1.47	145.23	288950.38	6130580.00
CR_1.12	0.02	0.045	0.108	1.51	149.03	288344.59	6131147.50
CR_1.13	0.02	0.045	2.834	1.00	99.26	287565.03	6130685.50
CR_1.14	0.02	0.045	1.768	1.15	113.38	286974.38	6131677.00
CR_1.15	0.02	0.045	0.28	1.28	96.23	287534.19	6132027.00
CR_1.16	0.02	0.045	0.737	0.66	91.70	287090.66	6132818.50
CR_1.17	0.02	0.045	0.12	10.19	133.37	286339.19	6134654.00
CR_1.18	0.02	0.045	0.6	38.09	136.85	285738.03	6134202.00
CR_1.19	0.02	0.045	0.09	0.36	113.74	286176.59	6135052.00
CR_1.20	0.02	0.045	0.11	10.32	212.92	285376.59	6135771.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
CR_2.01	0.02	0.045	1.912	1.60	334.88	286878.31	6131855.50
CR_3.01	0.02	0.045	2.534	0.28	151.74	285022.91	6130925.00
CR_3.02	0.02	0.045	2.367	0.90	88.77	284747.00	6130768.00
CR_3.03	0.02	0.045	2.762	1.10	108.80	284458.13	6130994.00
CR_3.04	0.02	0.045	1.157	4.96	140.00	285384.78	6131632.00
CR_3.05	0.02	0.045	0.338	4.88	137.16	286210.16	6133091.50
CR_4.01	0.02	0.045	0.041	1.09	107.60	290867.44	6132118.50
CR_4.02	0.02	0.045	0.059	1.52	150.45	290274.84	6133017.00
CR_5.01	0.02	0.045	0.949	25.67	42.99	284355.66	6136035.00
CR_5.02	0.02	0.045	0.587	33.07	37.32	284037.19	6135596.00
CR_5.03	0.02	0.045	2.476	29.55	16.53	283500.16	6135688.00
CR_5.04	0.02	0.045	1.845	53.01	64.70	283429.03	6134920.00
CR_5.05	0.02	0.045	1.596	16.29	121.99	283656.78	6134774.00
CUB_1.01	0.02	0.045	0.012	0.98	96.67	293864.06	6133734.50
CUB_1.02	0.02	0.045	0.912	25.43	106.52	293867.16	6133454.00
CUB_1.03	0.02	0.045	0.625	32.31	81.87	294822.84	6133990.50
CUB_1.04	0.02	0.045	0.667	81.09	74.07	295183.53	6133334.00
DUM_01	0.02	0.08	0.002	0.00	0.00	193376.33	6053838.50
DUM_02	0.02	0.06	0.002	0.00	0.00	202177.44	6088982.00
DUM_03	0.02	0.06	0.002	0.00	0.00	203203.53	6076990.00
DUM_04	0.02	0.06	0.002	0.00	0.00	225735.00	6103943.00
DUM_05	0.02	0.06	0.002	0.00	0.00	224749.55	6112334.50
DUM_06	0.02	0.06	0.002	0.00	0.00	230769.72	6122278.00
DUM_07	0.02	0.06	0.002	0.00	0.00	230516.77	6146845.50
DUM_08	0.02	0.08	0.002	0.00	0.00	250721.38	6153258.50
DUM_09	0.02	0.05	0.002	0.00	0.00	289984.59	6149753.00
DUM_10	0.02	0.05	0.002	0.00	0.00	290491.94	6149616.50

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DUM_100	0.02	0.045	0.002	0.00	0.00	281305.69	6137073.00
DUM_101	0.02	0.045	0.002	0.00	0.00	281710.22	6137162.50
DUM_102	0.02	0.045	0.002	0.00	0.00	279773.41	6143496.00
DUM_103	0.02	0.045	0.002	0.00	0.00	277759.84	6133368.50
DUM_104	0.02	0.045	0.002	0.00	0.00	276825.25	6136233.00
DUM_105	0.015	0.045	0.002	0.00	0.00	274542.59	6144269.00
DUM_106	0.015	0.045	0.002	0.00	0.00	277551.78	6142206.00
DUM_107	0.015	0.045	0.002	0.00	0.00	277232.25	6144811.50
DUM_108	0.015	0.045	0.002	0.00	0.00	276993.91	6144784.00
DUM_109	0.015	0.045	0.002	0.00	0.00	277401.66	6144273.00
DUM_11	0.02	0.05	0.002	0.00	0.00	290411.44	6148159.50
DUM_110	0.015	0.045	0.002	0.00	0.00	277826.09	6143694.00
DUM_111	0.015	0.045	0.002	0.00	0.00	277141.84	6143512.00
DUM_112	0.015	0.045	0.002	0.00	0.00	279385.03	6141968.00
DUM_113	0.015	0.045	0.002	0.00	0.00	279644.84	6141257.50
DUM_12	0.02	0.05	0.002	0.00	0.00	289238.41	6147745.00
DUM_14	0.02	0.045	0.002	0.00	0.00	288936.91	6147138.00
DUM_15	0.02	0.045	0.002	0.00	0.00	288260.53	6144971.00
DUM_16	0.02	0.045	0.002	0.00	0.00	285627.56	6143710.00
DUM_17	0.02	0.045	0.002	0.00	0.00	284884.84	6144697.50
DUM_18	0.02	0.045	0.002	0.00	0.00	286858.84	6141780.50
DUM_19	0.02	0.045	0.002	0.00	0.00	287513.34	6141443.00
DUM_26	0.015	0.045	0.002	0.00	0.00	280791.50	6140193.50
DUM_27	0.015	0.045	0.002	0.00	0.00	280753.63	6139791.00
DUM_28	0.015	0.045	0.002	0.00	0.00	279729.50	6140182.50
DUM_29	0.015	0.045	0.002	0.00	0.00	278658.44	6141995.50
DUM_30	0.015	0.045	0.002	0.00	0.00	278826.03	6142026.50

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DUM_31	0.015	0.045	0.002	0.00	0.00	279014.91	6142302.00
DUM_32	0.015	0.045	0.002	0.00	0.00	278583.66	6142278.50
DUM_33	0.015	0.045	0.002	0.00	0.00	277316.41	6142941.00
DUM_34	0.015	0.045	0.002	0.00	0.00	277516.19	6142840.00
DUM_35	0.015	0.045	0.002	0.00	0.00	276904.09	6142269.00
DUM_36	0.015	0.045	0.002	0.00	0.00	276032.59	6143226.00
DUM_37	0.015	0.045	0.002	0.00	0.00	275846.31	6143534.50
DUM_38	0.015	0.045	0.002	0.00	0.00	275914.72	6144295.00
DUM_39	0.015	0.045	0.002	0.00	0.00	276867.16	6145957.00
DUM_40	0.015	0.045	0.002	0.00	0.00	276802.78	6145321.50
DUM_41	0.02	0.045	0.002	0.00	0.00	281347.69	6131889.50
DUM_42	0.02	0.045	0.002	0.00	0.00	279790.78	6132677.50
DUM_43	0.02	0.045	0.002	0.00	0.00	280283.09	6133155.00
DUM_44	0.02	0.045	0.002	0.00	0.00	280631.50	6133533.50
DUM_45	0.02	0.045	0.002	0.00	0.00	279635.50	6133969.00
DUM_46	0.02	0.045	0.002	0.00	0.00	280461.09	6134450.00
DUM_47	0.02	0.045	0.002	0.00	0.00	280736.59	6134842.00
DUM_48	0.02	0.045	0.002	0.00	0.00	279840.97	6135256.50
DUM_49	0.02	0.045	0.002	0.00	0.00	281462.75	6135306.00
DUM_50	0.02	0.045	0.002	0.00	0.00	280886.19	6135698.00
DUM_51	0.02	0.045	0.002	0.00	0.00	280361.66	6135989.50
DUM_52	0.02	0.045	0.002	0.00	0.00	279888.28	6137038.50
DUM_53	0.02	0.045	0.002	0.00	0.00	284704.66	6130847.50
DUM_54	0.02	0.045	0.002	0.00	0.00	283518.97	6131382.00
DUM_55	0.02	0.045	0.002	0.00	0.00	283315.56	6132164.50
DUM_56	0.02	0.045	0.002	0.00	0.00	284685.69	6132579.00
DUM_57	0.02	0.045	0.002	0.00	0.00	289475.03	6131580.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
DUM_58	0.02	0.045	0.002	0.00	0.00	290910.25	6131881.00
DUM_59	0.02	0.045	0.002	0.00	0.00	293665.94	6133742.50
DUM_60	0.02	0.045	0.002	0.00	0.00	294928.59	6133662.50
DUM_61	0.02	0.045	0.002	0.00	0.00	288700.78	6135915.50
DUM_62	0.02	0.045	0.002	0.00	0.00	280885.38	6137810.50
DUM_63	0.02	0.045	0.002	0.00	0.00	282134.97	6138616.00
DUM_64	0.02	0.08	0.002	0.00	0.00	193230.70	6050591.00
DUM_65	0.02	0.08	0.002	0.00	0.00	194525.14	6058311.00
DUM_66	0.02	0.06	0.002	0.00	0.00	218812.27	6095717.50
DUM_67	0.02	0.06	0.002	0.00	0.00	229363.33	6108459.00
DUM_68	0.02	0.06	0.002	0.00	0.00	224363.69	6115471.50
DUM_69	0.02	0.06	0.002	0.00	0.00	229401.08	6145637.50
DUM_70	0.02	0.08	0.002	0.00	0.00	261506.77	6132390.00
DUM_71	0.02	0.08	0.002	0.00	0.00	259533.67	6141522.00
DUM_72	0.02	0.08	0.002	0.00	0.00	261120.17	6143151.00
DUM_73	0.02	0.08	0.002	0.00	0.00	255846.56	6151290.50
DUM_74	0.02	0.08	0.002	0.00	0.00	259659.72	6152397.50
DUM_75	0.02	0.06	0.002	0.00	0.00	273748.25	6154698.00
DUM_76	0.02	0.06	0.002	0.00	0.00	280242.53	6158878.50
DUM_77	0.02	0.06	0.002	0.00	0.00	277003.38	6154734.50
DUM_78	0.02	0.08	0.002	0.00	0.00	264008.88	6142116.50
DUM_79	0.02	0.08	0.002	0.00	0.00	266389.03	6139600.00
DUM_80	0.02	0.08	0.002	0.00	0.00	268180.59	6136574.00
DUM_81	0.02	0.045	0.002	0.00	0.00	271199.53	6138915.00
DUM_82	0.02	0.045	0.002	0.00	0.00	271830.41	6135661.00
DUM_84	0.02	0.08	0.002	0.00	0.00	267312.13	6138990.50
DUM_85	0.02	0.045	0.002	0.00	0.00	284912.00	6131030.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
DUM_86	0.02	0.045	0.002	0.00	0.00	283646.56	6132057.00
DUM_87	0.02	0.045	0.002	0.00	0.00	289946.69	6131654.50
DUM_88	0.02	0.045	0.002	0.00	0.00	288957.38	6131204.00
DUM_89	0.02	0.045	0.002	0.00	0.00	289173.56	6130736.50
DUM_90	0.02	0.045	0.002	0.00	0.00	286345.59	6133136.00
DUM_91	0.02	0.045	0.002	0.00	0.00	283641.69	6134923.50
DUM_92	0.02	0.045	0.002	0.00	0.00	286835.13	6135227.50
DUM_93	0.02	0.045	0.002	0.00	0.00	287435.78	6133868.50
DUM_94	0.02	0.045	0.002	0.00	0.00	291296.00	6135682.00
DUM_95	0.02	0.045	0.002	0.00	0.00	292618.94	6135620.00
DUM_96	0.02	0.045	0.002	0.00	0.00	293951.41	6135418.50
DUM_97	0.02	0.045	0.002	0.00	0.00	283861.66	6137377.50
DUM_98	0.02	0.045	0.002	0.00	0.00	291896.13	6140074.00
DUM_99	0.02	0.045	0.002	0.00	0.00	292418.13	6139990.00
DUM_B1	0.02	0.05	8.57	0.00	0.00	289990.00	6153460.00
Dum_B2	0.02	0.05	7.937	0.00	0.00	289881.00	6153960.00
EW_1.01	0.02	0.045	0.17	3.21	144.15	287540.34	6134020.50
EW_1.02	0.02	0.045	0.06	3.43	167.70	287714.16	6135599.00
EW_1.03	0.02	0.045	0.094	0.78	121.48	288912.00	6136982.00
EW_1.04	0.02	0.045	0.095	1.10	82.48	287487.38	6137250.50
EW_1.05	0.02	0.045	0.088	0.46	98.25	286798.31	6137211.50
EW_1.06	0.02	0.045	0.051	1.52	150.49	286977.72	6138157.50
EW_1.07	0.02	0.045	0.066	2.68	147.88	288706.81	6138058.00
EW_2.01	0.02	0.045	0.186	1.71	149.62	284991.22	6138285.00
EW_2.02	0.02	0.045	0.101	1.35	133.29	286103.00	6137397.50
EW_2.03	0.02	0.045	0.13	3.96	145.03	285082.16	6138913.00
EW_2.04	0.02	0.045	0.219	1.47	145.91	286110.50	6138563.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
FF_1.01	0.02	0.045	6.249	3.83	379.49	287128.72	6146849.50
FF_1.02	0.02	0.045	0.652	1.39	137.64	288453.81	6146480.50
FLA_1.01	0.02	0.045	2.612	1.79	203.22	277488.97	6133208.50
FLA_1.02	0.02	0.045	4.976	6.13	115.83	277891.41	6133161.50
FLA_1.03	0.02	0.045	1.21	56.50	75.54	278248.25	6134575.50
FLA_1.04	0.02	0.045	1.272	14.03	112.63	278376.16	6134156.50
FLA_1.05	0.02	0.045	0.776	10.82	64.39	278568.06	6135902.00
FLA_1.06	0.02	0.045	0.716	9.16	91.31	278618.94	6135562.50
FLA_1.07	0.02	0.045	1.488	7.10	129.85	278573.97	6137180.50
FLA_1.08	0.02	0.045	2.026	1.46	144.62	279478.06	6138124.50
JO_1.01	0.02	0.045	0.392	0.90	101.83	285470.59	6143709.50
JS_1.01	0.02	0.045	6.025	13.30	1316.21	286841.41	6146460.00
JS_1.02	0.02	0.045	0.807	10.13	104.06	288532.06	6145847.50
LSH_1.01	0.02	0.045	3.62579762	2.11	208.69	273305.94	6137145.00
LSH_1.02	0.02	0.045	4.59170594	7.30	722.84	272508.81	6139320.50
LSH_1.03	0.02	0.045	2.204	3.87	382.83	275740.59	6140724.00
LSH_1.04	0.02	0.045	2.101	78.85	360.99	276494.00	6140211.50
LSH_1.05	0.02	0.045	1.569	8.93	636.37	277677.81	6138266.00
LSH_1.06	0.02	0.045	2.484	34.25	242.94	279573.00	6138614.00
LSH_1.07	0.02	0.045	2.194	24.99	86.37	280726.00	6139435.50
LSH_1.08	0.02	0.045	0.507	0.68	75.45	282090.19	6139643.00
LSH_1.09	0.02	0.045	0.244	10.48	104.40	283188.53	6140482.00
LSH_1.10	0.02	0.045	0.193	10.22	84.37	283619.81	6139702.50
LSH_1.11	0.02	0.045	0.106	8.95	136.46	284532.69	6140470.00
LSH_1.12	0.02	0.045	0.492	4.64	115.76	285340.19	6140640.50
LSH_1.13	0.02	0.045	0.086	1.40	138.57	286667.13	6139875.50
LSH_1.14	0.02	0.045	0.273	1.49	114.49	286489.41	6140591.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
LSH_1.15	0.02	0.045	0.051	3.33	137.99	287993.84	6140129.00
LSH_1.16	0.02	0.045	2.166	2.98	150.82	289266.00	6139222.00
LSH_1.17	0.02	0.045	0.113	0.77	153.13	290448.28	6138679.00
LSH_1.18	0.02	0.045	0.042	1.53	151.40	292048.63	6138742.00
LSH_1.19	0.02	0.045	0.056	3.41	145.97	293160.22	6140091.50
LSH_1.20	0.02	0.045	0.063	55.44	53.21	292484.69	6140180.00
LSH_1.21	0.02	0.045	0.329	5.62	191.41	294621.50	6140126.50
LSH_1.22	0.02	0.045	0.129	3.19	141.62	293413.97	6138095.00
LSH_1.23	0.02	0.045	0.099	5.84	143.34	293011.66	6138328.50
LSH_2.01	0.02	0.045	6.28131023	6.56	649.76	270900.75	6138996.00
LSH_3.01	0.02	0.045	4.197	0.85	84.12	275449.25	6140843.00
LSH_4.01	0.02	0.045	3.502	45.44	61.68	280155.19	6139396.00
LSH_5.01	0.02	0.045	1.991	40.27	20.78	281370.50	6136505.00
LSH_5.02	0.02	0.045	1.578	27.95	31.56	281786.69	6137569.00
LSH_5.03	0.02	0.045	2.892	10.81	8.08	281196.28	6137076.00
LSH_5.04	0.02	0.045	1.741	29.05	16.52	281773.00	6136977.50
LSH_5.05	0.02	0.045	2.94	21.38	11.58	281025.81	6137714.00
LSH_5.06	0.02	0.045	2.954	17.11	11.19	280617.09	6137733.00
LSH_5.07	0.02	0.045	1.683	54.28	96.69	282006.28	6138554.50
LSH_5.08	0.02	0.045	0.797	34.66	78.65	282236.00	6139385.00
LSH_5.09	0.02	0.045	2.799	34.02	21.84	281103.25	6138657.50
LSH_6.01	0.02	0.045	0.125	34.83	114.91	284360.38	6141066.50
LSH_6.02	0.02	0.045	0.083	1.51	29.43	285702.22	6141449.00
LSH_6.03	0.02	0.045	0.113	3.24	142.19	284490.41	6141394.50
LSH_6.04	0.02	0.045	0.109	1.15	113.96	284536.41	6143079.50
LSH_7.01	0.02	0.045	0.193	1.63	88.61	286777.84	6139625.00
LSH_8.01	0.02	0.045	4.42	15.70	55.85	292442.47	6140321.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
LSH_8.02	0.02	0.045	18.056	1.65	36.27	292264.28	6141335.00
MN_1.01	0.02	0.045	2.451	2.86	282.75	276467.25	6138761.00
MUL_1.01	0.02	0.045	0.312	9.23	114.26	282074.22	6140909.50
MUL_1.02	0.02	0.045	1.861	52.15	57.51	281873.19	6141518.50
MUL_1.03	0.02	0.045	1.31	17.65	9.94	280425.81	6142058.00
N_1.00	0.02	0.045	6.9	2.81	107.55	279734.78	6131853.00
N_1.01	0.02	0.045	1.64	1.19	60.27	280516.13	6132305.00
N_1.02	0.02	0.045	1.35	18.36	56.07	280635.38	6133492.50
N_1.04	0.02	0.045	2.1	7.68	11.41	280720.47	6133851.00
N_1.05	0.02	0.045	1.97	27.40	17.34	280768.69	6134823.50
N_1.07	0.02	0.045	1.1	8.77	48.37	280907.13	6135666.50
N_1.09	0.02	0.045	2.3	0.18	18.68	280363.63	6135955.00
N_1.11	0.02	0.045	2.53	11.36	28.90	280220.97	6136387.00
N_1.12	0.02	0.045	3.22	9.90	14.30	280445.69	6136699.50
N_1.13	0.02	0.045	3.2	16.22	9.80	280532.13	6136874.00
N_1.15	0.02	0.045	0.002	13.12	21.31	279935.25	6137034.50
N_1.16	0.02	0.045	4.1	6.84	97.52	279609.53	6138211.00
N_1.17	0.02	0.045	7.8	0.05	4.72	279546.63	6138405.00
N_10.00	0.02	0.045	1.76	5.74	40.14	279779.78	6135249.50
N_11.00	0.02	0.045	2.6	46.59	82.61	279931.25	6136993.50
N_2.02	0.02	0.045	2	9.24	18.09	280546.88	6133496.50
N_2.10	0.02	0.045	2.45	0.86	46.07	279699.06	6132666.00
N_2.20	0.02	0.045	2.45	1.02	47.74	279388.88	6132191.50
N_2.21	0.02	0.045	2.45	0.19	28.26	279768.16	6132618.50
N_2.23	0.02	0.045	2.45	5.71	35.17	280266.13	6133049.00
N_3.10	0.02	0.045	1.85	1.13	6.57	279395.13	6133133.50
N_3.11	0.02	0.045	1.85	0.54	39.53	280078.06	6133147.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
N_4.02	0.02	0.045	2.25	2.33	24.97	280698.63	6134814.00
N_4.10	0.02	0.045	1.6	12.03	5.16	279600.81	6133989.50
N_4.20	0.02	0.045	1.6	1.05	6.01	279272.72	6133617.50
N_4.21	0.02	0.045	1.6	10.93	10.29	279593.56	6133928.50
N_4.23	0.02	0.045	1.6	15.21	31.24	280422.41	6134415.50
N_5.10	0.02	0.045	1.8	1.80	12.92	279931.88	6133533.50
N_5.11	0.02	0.045	1.8	3.59	16.76	280382.00	6133885.50
N_5.12	0.02	0.045	1.8	7.30	7.86	280470.59	6134412.50
N_6.00	0.02	0.045	25	10.21	174.64	280830.19	6131461.00
N_6.01	0.02	0.045	1.8	1.14	29.19	281309.75	6131803.00
N_6.03	0.02	0.045	1.5	2.24	56.31	281488.66	6132688.00
N_6.04	0.02	0.045	0.73	42.50	98.14	281547.78	6134394.50
N_6.05	0.02	0.045	1.1	34.31	39.03	281540.34	6135234.50
N_6.07	0.02	0.045	2	14.70	35.12	280935.97	6135684.00
N_7.00	0.02	0.045	1.8	1.30	109.35	281379.97	6131795.50
N_8.00	0.02	0.045	1.75	14.29	18.08	281547.72	6135349.00
N_9.00	0.02	0.045	2.3	21.97	61.03	279843.50	6135218.50
N_9.02	0.02	0.045	1.8	1.84	47.10	280327.19	6135952.00
Ocean	0.02	0.045	0.002	0.00	0.00	306528.44	6144923.50
RC_1.01	0.02	0.045	2.53	0.81	80.00	283585.66	6131281.50
RC_1.02	0.02	0.045	2.485	1.00	99.11	283399.44	6131407.00
RC_1.03	0.02	0.045	2.204	1.06	104.55	283285.00	6131982.00
RC_1.04	0.02	0.045	1.66	0.19	146.63	283224.81	6132265.00
RC_1.05	0.02	0.045	1.207	1.54	137.33	284383.03	6132352.00
RC_1.06	0.02	0.045	1.891	0.94	118.49	283231.78	6133152.00
RC_1.07	0.02	0.045	1.082	18.07	97.74	284302.41	6132720.50
RC_1.08	0.02	0.045	0.663	5.13	148.65	286126.88	6133199.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
RC_1.09	0.02	0.045	0.711	10.56	53.56	284896.50	6133138.00
RY_1.01	0.02	0.045	0.07	0.25	52.00	291074.09	6136667.50
RY_1.02	0.02	0.045	0.149	2.40	120.67	290188.91	6137232.50
RY_1.03	0.02	0.045	0.19	2.82	91.20	290099.53	6137679.00
SAN_1.01	0.02	0.045	1.957	1.09	270.86	275679.34	6135949.50
SAN_1.02	0.02	0.045	3.222	14.91	97.31	275496.31	6136960.50
SAN_1.03	0.02	0.045	2.619	1.91	189.21	275821.16	6138033.00
SM_1.01	0.02	0.045	2.904	3.79	43.42	292677.31	6141617.50
SM_1.02	0.02	0.045	12.13	18.32	159.55	292627.47	6142622.50
SM_1.03	0.02	0.045	2.875	6.20	145.71	293699.16	6143383.50
SM_1.04	0.02	0.045	0.446	14.49	115.08	294132.28	6142349.50
SM_1.06	0.02	0.045	0.625	1.56	153.96	294870.63	6142705.50
SW_1.01	0.02	0.045	2.1	28.91	72.45	292559.31	6135517.00
SW_1.02	0.02	0.045	0.05	1.32	130.45	291703.22	6135652.00
SW_1.03	0.02	0.045	0.04221739	1.88	138.29	288711.50	6136073.50
SW_1.04	0.02	0.045	0.047	1.44	146.86	291320.72	6135604.00
SW_2.01	0.02	0.045	0.046	1.21	97.79	289227.50	6135547.00
SW_2.02	0.02	0.045	0.13	0.93	128.12	288633.63	6135850.50
SW_3.01	0.02	0.045	0.098	3.35	128.93	289818.06	6135142.00
SW_3.02	0.02	0.045	0.095	2.70	147.41	290420.53	6135767.50
TAN_1.01	0.02	0.045	0.036	0.24	128.97	285233.25	6143503.00
TAN_1.02	0.02	0.045	0.619	0.41	140.70	284285.06	6143904.00
TAN_1.03	0.02	0.045	3.6	1.18	116.62	283249.88	6144780.50
TAN_1.04	0.02	0.045	1.3	1.88	72.74	282754.31	6144242.50
TAN_1.05	0.02	0.045	0.088	7.43	142.28	283767.63	6143428.50
TAN_1.06	0.02	0.045	5.45	5.60	55.98	282140.00	6145266.00
TAN_1.07	0.02	0.045	8.58	2.02	33.70	282168.00	6145500.00

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TU_1.01	0.02	0.045	0.089	2.21	124.40	282510.75	6142184.50
TU_1.02	0.02	0.045	0.372	2.23	47.93	282292.47	6143368.00
TU_1.03	0.02	0.045	1.2	5.99	121.36	281729.56	6143570.00
TU_1.04	0.02	0.045	1.359	0.13	59.89	280967.59	6144000.00
US_001	0.02	0.08	2.035	74.20	7345.90	196608.80	6027015.50
US_002	0.02	0.08	2.358	98.36	9738.08	193357.42	6024448.50
US_003	0.02	0.08	2.251	91.99	9106.53	190426.75	6037616.50
US_004	0.02	0.08	1.764	98.25	9726.30	197216.75	6037779.00
US_005	0.02	0.08	1.044	84.57	8372.17	194310.72	6049813.50
US_006	0.02	0.08	2.578	90.65	8973.88	193723.50	6053118.50
US_007	0.02	0.08	3.353	83.25	8242.01	192700.08	6054226.00
US_008	0.02	0.08	1.14	98.38	9739.37	197234.95	6063368.00
US_009	0.02	0.08	2.839	83.47	8263.64	192985.30	6058219.00
US_010	0.02	0.08	1.601	73.71	7296.94	189386.56	6083267.50
US_011	0.02	0.08	2.744	89.26	8837.03	199336.00	6075380.00
US_012	0.02	0.08	3.645	79.58	7878.76	201914.91	6069482.50
US_013	0.02	0.08	0.543	60.14	5953.82	201617.25	6076019.50
US_014	0.02	0.06	1.479	93.56	9262.34	212958.75	6067295.50
US_015	0.02	0.06	1.179	99.24	9924.32	221880.00	6069070.00
US_016	0.02	0.06	2.215	286.68	9727.39	205991.91	6075838.50
US_100	0.02	0.045	2.668	1.00	96.50	284861.13	6144763.50
US_101	0.02	0.045	4.232	2.99	184.22	285772.25	6145661.50
US_108	0.02	0.045	2.278	6.13	1424.50	294978.81	6145228.00
US_115	0.02	0.06	4.131	29.02	2873.16	286966.75	6155554.50
US_116	0.02	0.06	4.624	37.52	3714.97	281342.56	6159035.50
US_117	0.02	0.06	4.284	53.27	5273.64	280324.50	6162238.00
US_118	0.02	0.06	4.442	151.70	5593.75	275609.31	6163714.00

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
US_119	0.02	0.08	2.068	87.47	9894.15	260110.73	6158876.00
US_120	0.02	0.08	3.076	537.27	7307.83	253755.48	6154160.50
US_123	0.02	0.06	4.055	52.37	5185.00	231530.50	6128239.00
US_124	0.02	0.06	2.504	65.07	6441.75	233880.70	6132288.00
US_125	0.02	0.08	3.155	50.67	5016.16	244172.98	6125435.00
US_126	0.02	0.045	11.291	2.54	251.84	279056.38	6143656.00
US_17	0.02	0.06	2.188	92.02	9110.35	203587.17	6085693.00
US_18	0.02	0.08	1.227	35.79	3543.55	190242.20	6089844.50
US_19	0.02	0.06	1.306	74.01	7326.97	199501.64	6089850.50
US_20	0.02	0.06	0.703	96.72	9575.09	206069.28	6090385.50
US_21	0.02	0.06	1.063	72.76	7203.28	207859.58	6086598.50
US_22	0.02	0.06	0.867	69.80	6910.06	212405.09	6082999.00
US_23	0.02	0.06	1.068	57.76	5718.49	222090.91	6079513.50
US_24	0.02	0.06	2.377	100.31	9930.89	225206.22	6085012.50
US_25	0.02	0.06	1.057	58.90	5831.43	221750.08	6089207.00
US_26	0.02	0.06	0.659	79.01	7822.23	219313.17	6092682.00
US_27	0.02	0.06	0.725	92.84	9191.59	221380.98	6097931.00
US_28	0.02	0.06	1.172	59.14	5854.51	210995.80	6093770.00
US_29	0.02	0.06	0.901	78.85	7806.62	192943.36	6098568.50
US_30	0.02	0.06	1.371	96.49	9552.96	202918.77	6100968.50
US_31	0.02	0.06	1.109	98.07	9708.58	210399.88	6098960.00
US_32	0.02	0.06	0.464	66.34	6568.13	219367.70	6109205.50
US_33	0.02	0.06	0.479	99.50	9850.45	226212.86	6106789.50
US_34	0.02	0.06	1.705	63.50	6286.24	227085.28	6097696.00
US_35	0.02	0.06	1.496	100.52	9951.05	230809.86	6103031.50
US_36	0.02	0.06	1.504	80.88	8006.92	239136.63	6109140.00
US_37	0.02	0.06	2.263	83.38	8254.84	225810.20	6111755.50

Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
US_38	0.02	0.06	1.731	99.57	9857.49	228729.45	6116788.50
US_39	0.02	0.06	0.935	99.35	9835.29	217145.17	6112587.00
US_45	0.02	0.06	0.999	90.88	8996.75	216811.48	6121574.50
US_46	0.02	0.06	1.262	84.39	8355.04	216140.27	6127567.50
US_47	0.02	0.06	1.18	63.55	6291.11	223379.91	6126944.50
US_48	0.02	0.06	1.342	53.25	5272.13	224242.91	6126656.50
US_49	0.02	0.06	4.003	38.09	3770.64	229962.59	6123013.00
US_50	0.02	0.06	3.066	84.48	8363.91	230910.52	6121553.50
US_51	0.02	0.06	1.139	64.90	6425.37	238060.94	6112418.50
US_52	0.02	0.08	2.016	100.43	9942.09	263024.88	6126262.00
US_53	0.02	0.08	2.204	94.62	9367.57	257727.95	6128998.00
US_54	0.02	0.08	2.819	94.86	9391.00	254871.53	6129296.00
US_55	0.02	0.08	2.75	91.82	9089.93	249099.17	6132866.50
US_56	0.02	0.06	2.381	94.58	9363.04	232708.80	6134914.50
US_57	0.02	0.06	2.267	97.29	9631.62	229484.44	6145176.00
US_58	0.02	0.06	0.743	79.39	7859.68	222102.97	6140999.50
US_59	0.02	0.06	1.725	56.64	5607.16	215151.58	6137235.50
US_60	0.02	0.06	1.047	51.20	5069.21	218931.48	6143297.00
US_61	0.02	0.06	5.014	65.48	6482.81	226753.23	6145868.50
US_62	0.02	0.06	2.119	430.30	8582.31	229592.73	6149440.50
US_63	0.02	0.08	2.684	97.29	9999.00	238815.41	6143047.00
US_64	0.02	0.08	3.412	75.95	7519.32	247073.66	6146017.00
US_65	0.02	0.08	4.258	73.37	7264.05	253770.61	6139888.50
US_66	0.02	0.08	2.007	42.42	4199.59	259364.44	6138252.00
US_67a	0.02	0.08	1.785	28.24	2796.02	258795.00	6133970.00
US_67b	0.02	0.08	1.785	19.63	1963.41	260354.00	6136320.00
US_68	0.02	0.08	1.102	70.18	6947.97	262640.75	6132463.00

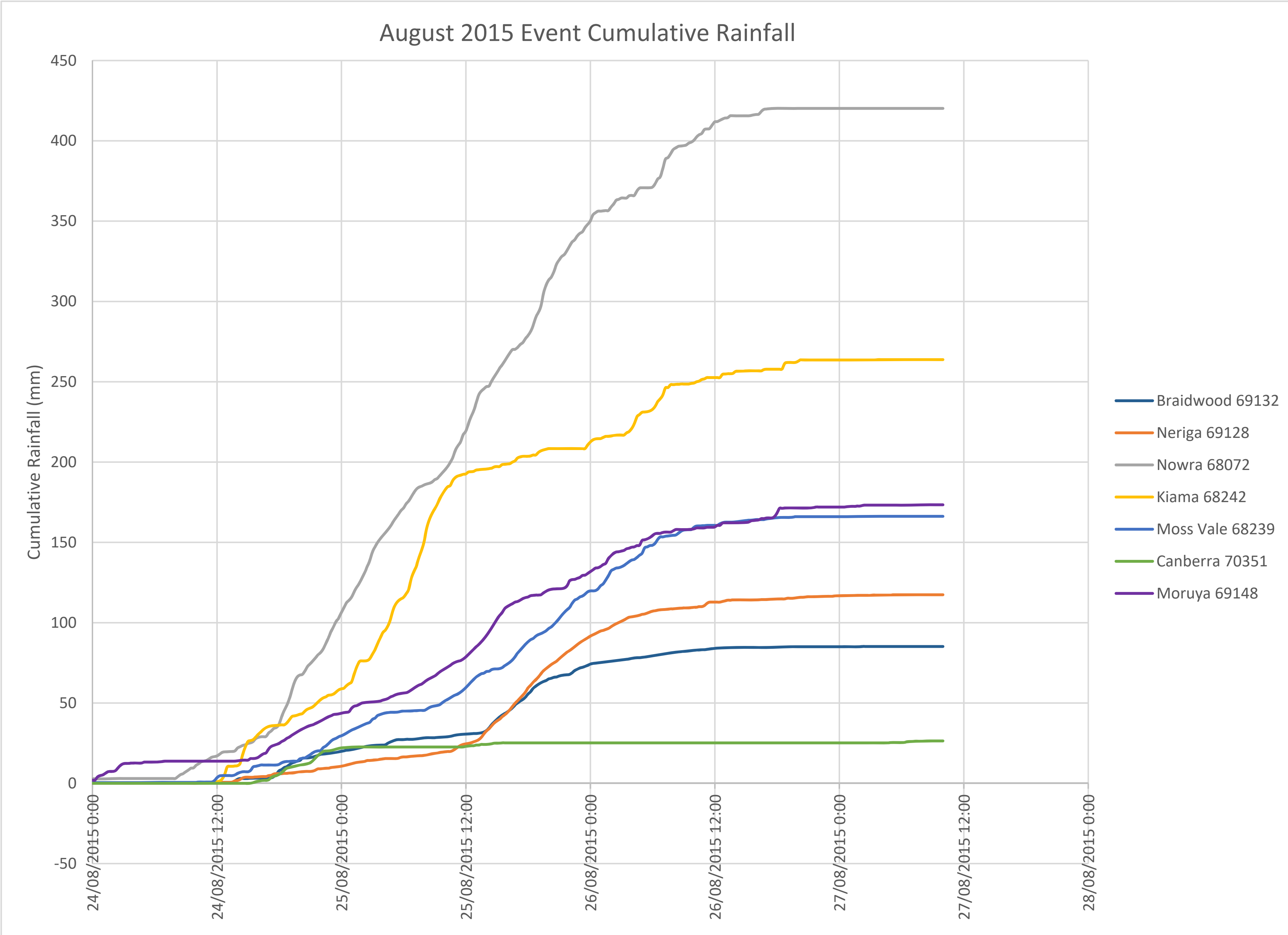
Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
US_69	0.02	0.08	1.3	64.60	6395.55	271211.44	6134299.50
US_69.1	0.02	0.08	0.7	5.66	560.14	273629.25	6131760.00
US_70	0.02	0.08	2.266	12.26	1213.65	268106.41	6135993.50
US_71	0.02	0.045	2.966	6.72	664.96	273090.13	6136527.50
US_72	0.02	0.045	3.179	7.50	742.99	270961.91	6135885.00
US_73	0.02	0.08	4.365	5.62	556.04	267645.06	6136418.50
US_74	0.02	0.08	4.063	11.73	1161.53	265480.94	6137854.50
US_75	0.02	0.08	3.7	10.87	1075.93	267902.22	6137589.50
US_76	0.02	0.08	6.5	17.24	1707.12	266454.25	6140044.50
US_77	0.02	0.08	2.218	20.26	2005.67	264849.31	6139259.50
US_78	0.02	0.08	2.797	56.09	5553.10	261018.00	6142440.00
US_79	0.02	0.08	2.439	71.68	7096.55	262499.03	6143050.50
US_80	0.02	0.08	3.14	34.04	3369.70	253372.44	6149235.00
US_81	0.02	0.08	2.794	92.12	9119.52	250311.36	6152766.50
US_82	0.02	0.08	3.447	89.41	6129.12	249983.34	6154324.50
US_83	0.02	0.08	3.533	47.19	4671.91	255559.56	6151536.50
US_84	0.02	0.08	1.81	994.38	8202.59	254138.58	6149409.00
US_85	0.02	0.08	2.83	56.11	5555.14	264663.16	6143279.50
US_86	0.02	0.045	4.537	9.50	940.49	274818.38	6141276.50
US_87	0.02	0.045	5.65	187.80	1.90	270721.00	6135410.00
US_89	0.02	0.045	14.05	1.42	140.25	280079.16	6144339.00
US_90	0.02	0.06	6.405	28.53	2824.66	277082.06	6151691.50
US_91	0.02	0.06	3.658	89.20	4446.46	272001.97	6153468.00
US_92	0.02	0.08	2.857	81.07	8026.24	261094.77	6155062.50
US_93	0.02	0.06	6.078	53.40	5286.34	273969.25	6156169.50
US_94	0.02	0.06	4.965	30.10	2980.24	277372.41	6155021.50
US_95	0.02	0.06	2.688	40.86	4045.54	277577.41	6154488.50

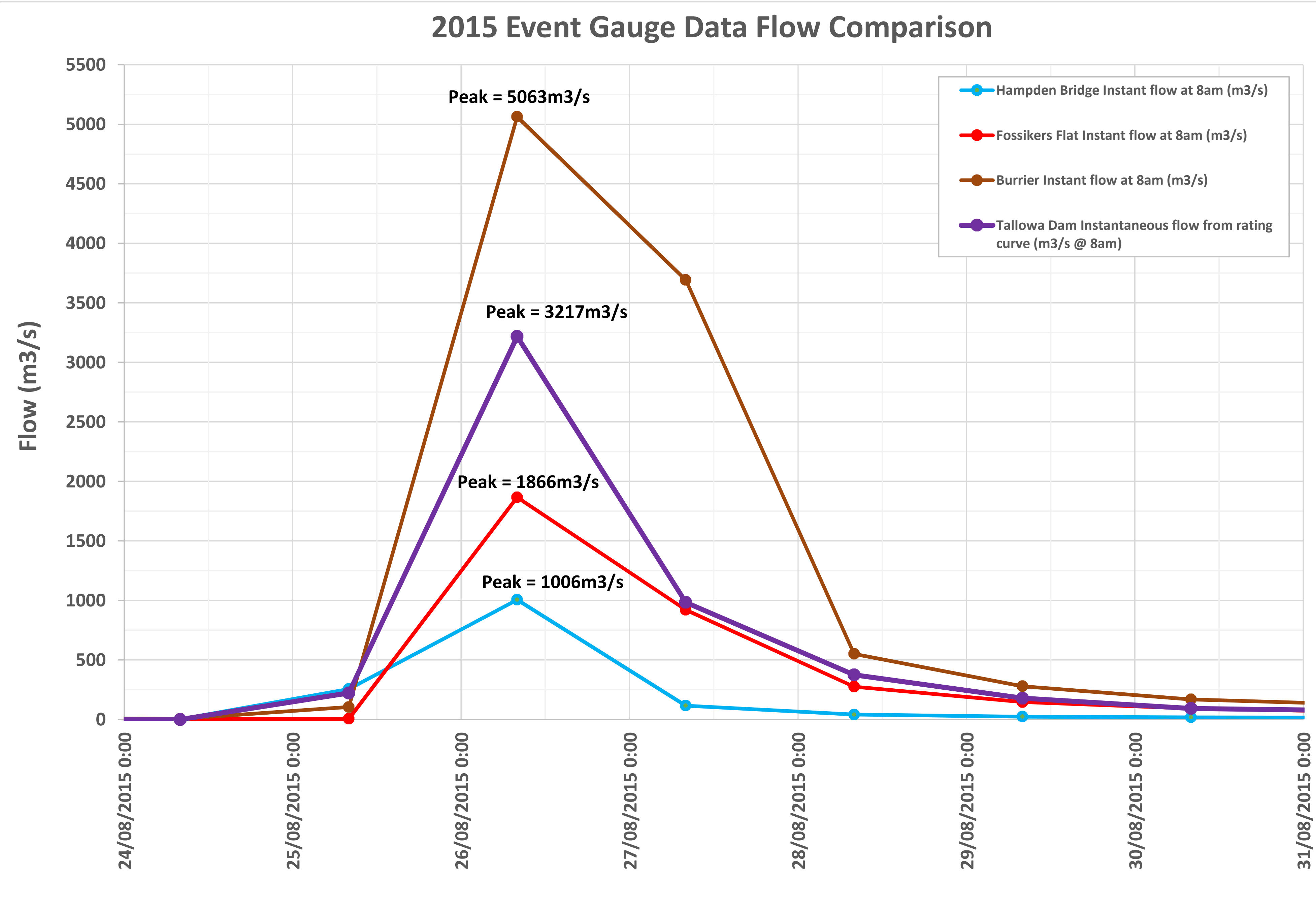
Node Name	Catchment Mannings 'n' Impervious Area	Catchment Mannings 'n' Pervious Area	Vectored Slope [%]	Total Area Impervious [ha]	Total Area Pervious [ha]	Node X Co-ordinate	Node Y Co-ordinate
US_96	0.02	0.045	5.494	2.89	286.18	280435.78	6144940.50
US_97	0.02	0.045	3.915	0.97	96.51	280907.69	6144600.00
US_98	0.02	0.045	11.97	2.95	292.29	281372.81	6145275.00
US_99	0.02	0.045	8.1	1.98	376.63	283547.16	6145406.50
WI_1.01	0.02	0.045	1.075	0.28	103.02	284811.94	6144664.00

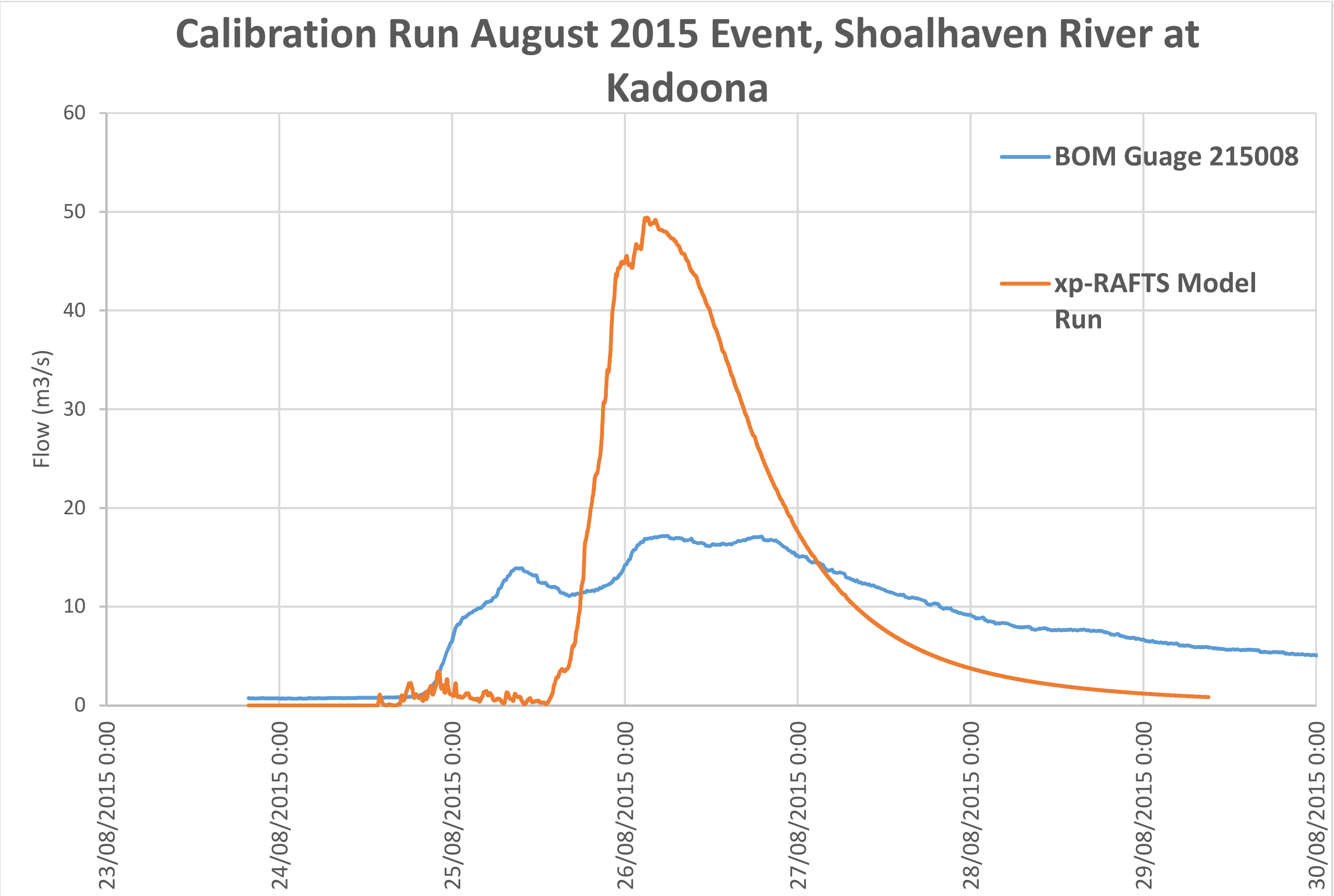
APPENDIX

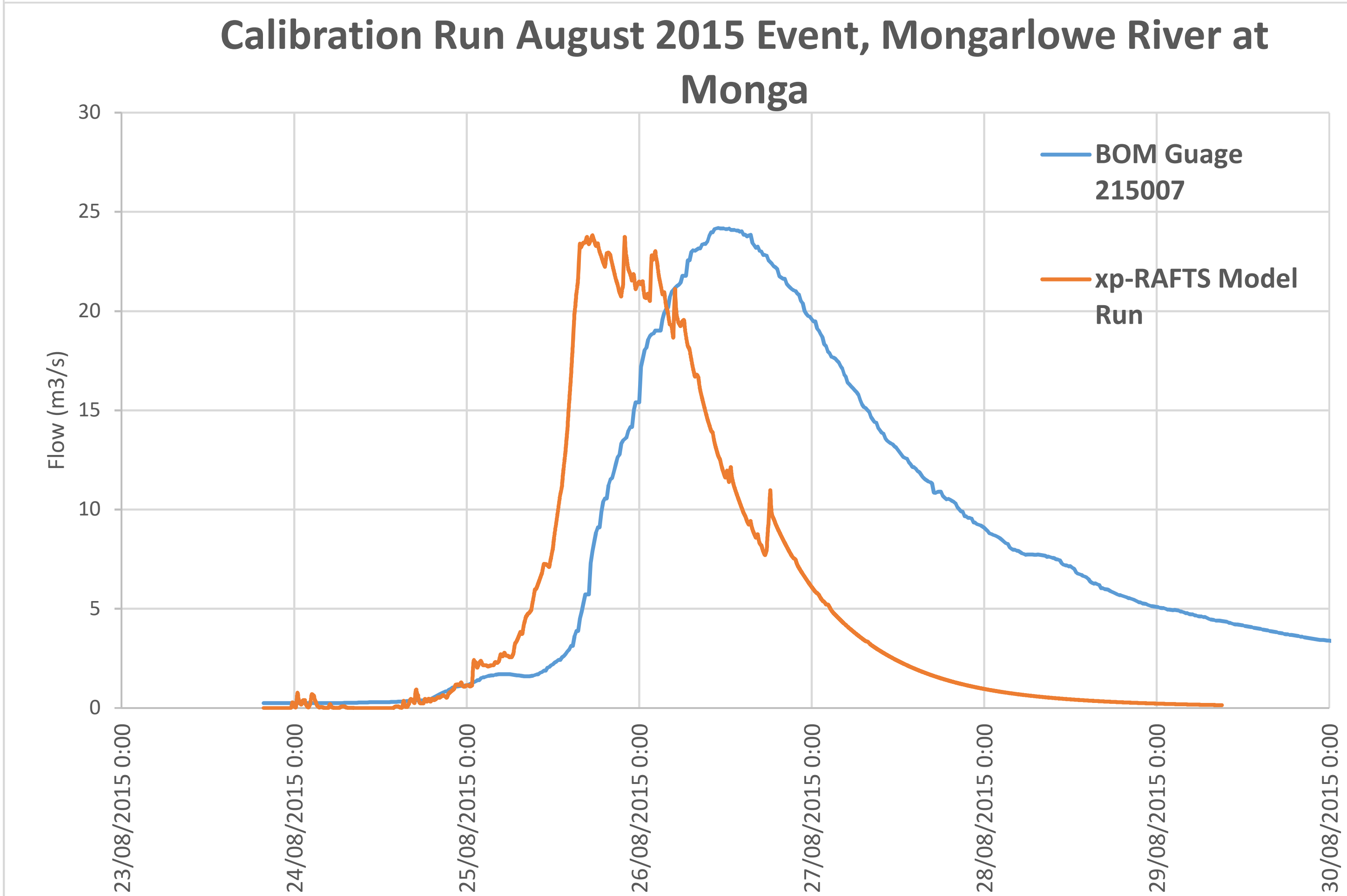
B

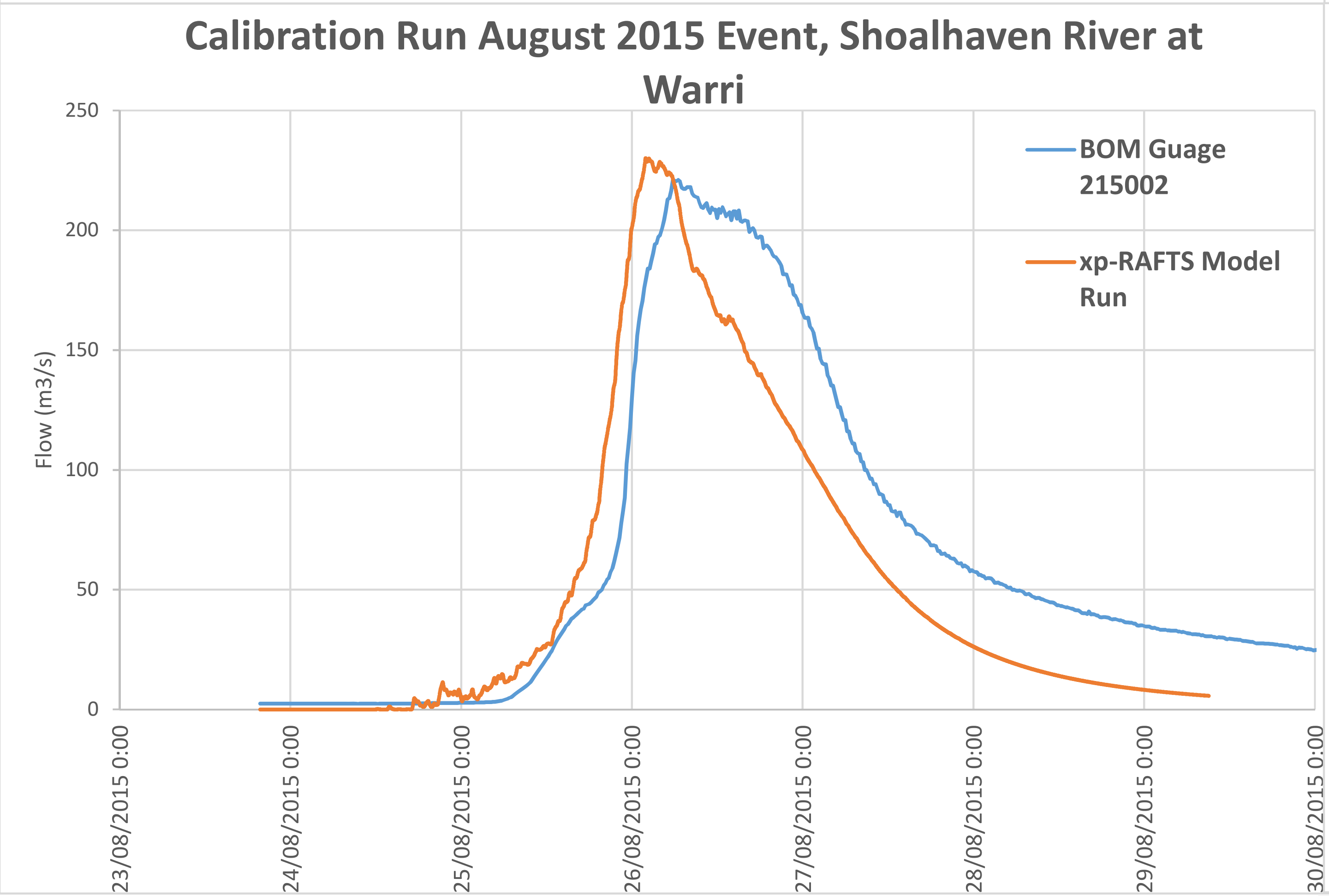
HYDROLOGICAL MODEL - CALIBRATION AND VALIDATION

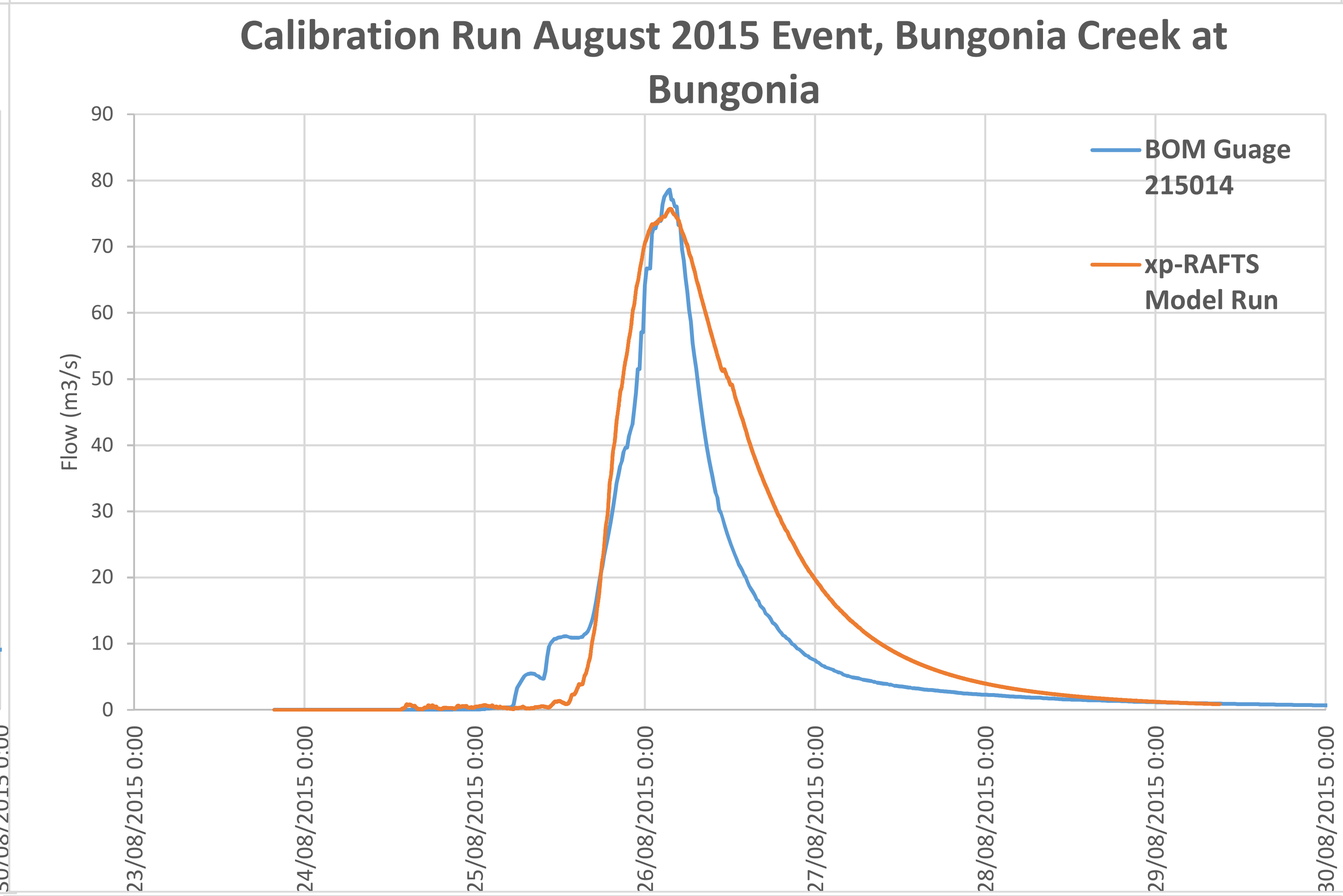

August 2015 Event Cumulative Rainfall
Cumulative Rainfall (mm)
450
400
350
300
250
200
150
100
50
0
-50
24/08/2015 0:00
24/08/2015 12:00
25/08/2015 0:00
25/08/2015 12:00
26/08/2015 0:00
26/08/2015 12:00
27/08/2015 0:00
27/08/2015 12:00
28/08/2015 0:00
Braidwood 69132
Neriga 69128
Nowra 68072
Kiama 68242
Moss Vale 68239
Canberra 70351
Moruya 69148

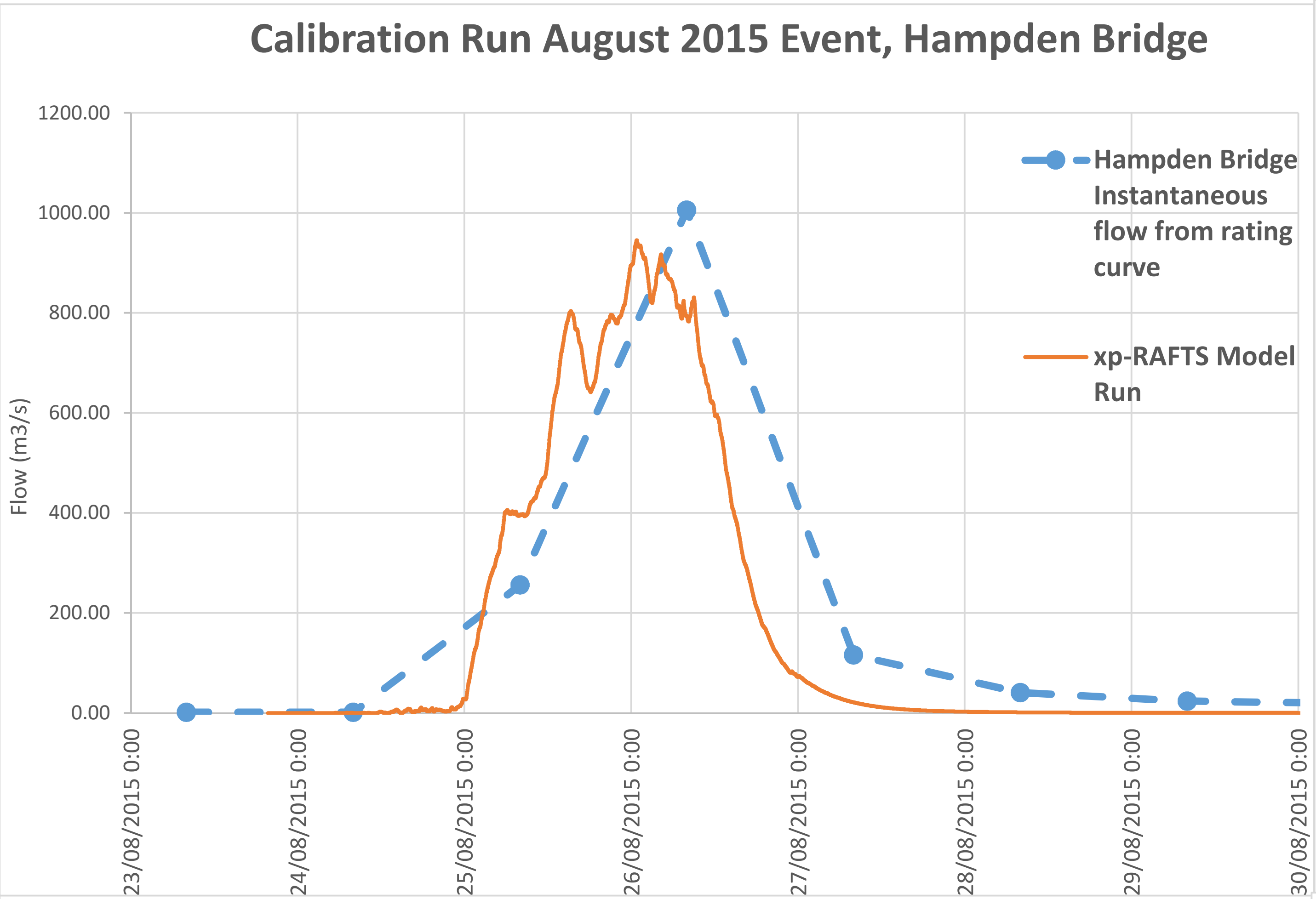

2015 Event Gauge Data Flow Comparison
Flow (m3/s)
Peak = 5063m3/s
Peak = 3217m3/s
Peak = 1866m3/s
Peak = 1006m3/s
Hampden Bridge Instant flow at 8am (m3/s)
Fossikers Flat Instant flow at 8am (m3/s)
Burrier Instant flow at 8am (m3/s)
Tallowa Dam Instantaneous flow from rating curve (m3/s @ 8am)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00
31/08/2015 0:00


Calibration Run August 2015 Event, Shoalhaven River at Kadoona
BOM Guage 215008
xp-RAFTS Model Run
Flow (m3/s)
0
10
20
30
40
50
60
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00

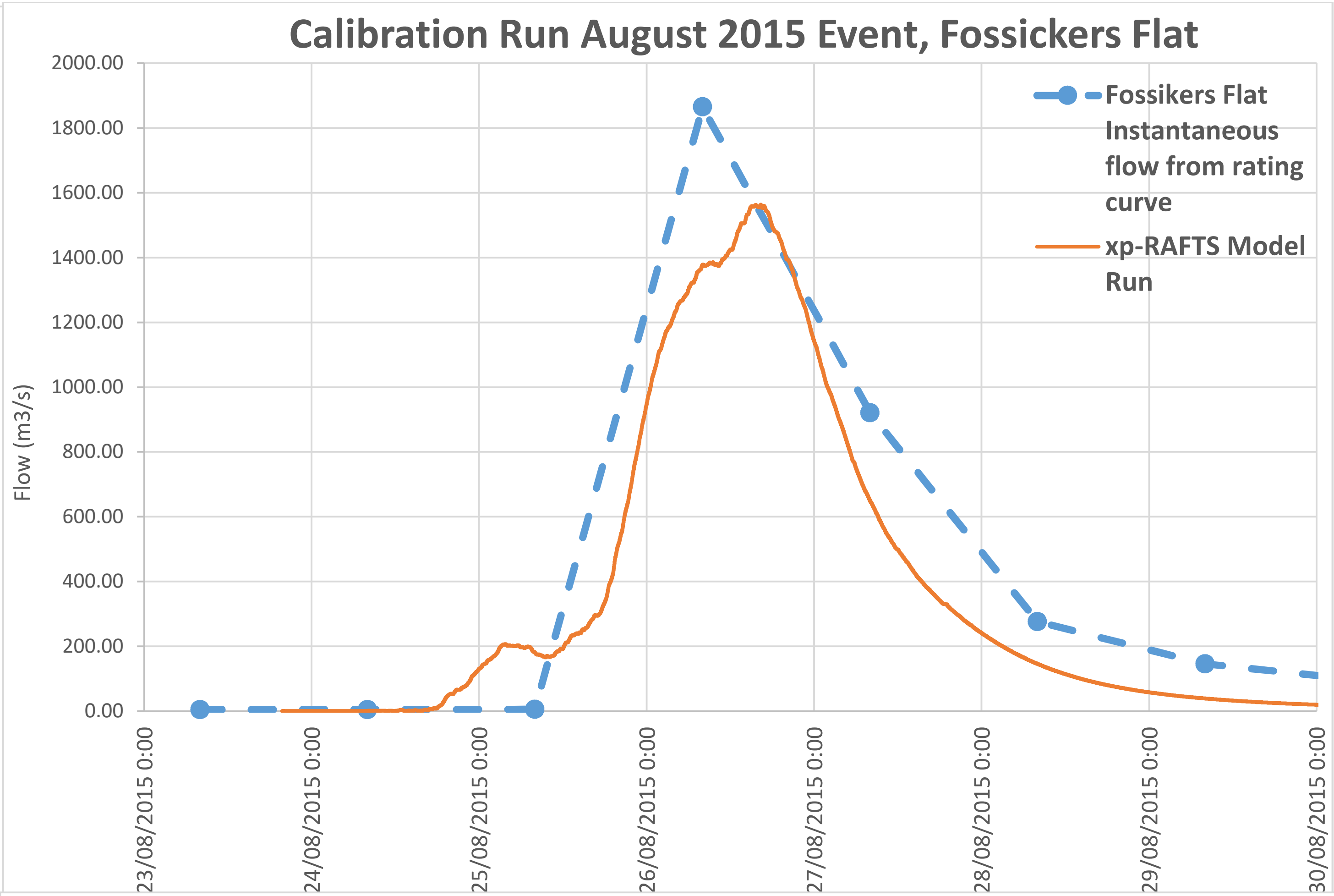

Calibration Run August 2015 Event, Mongarlowe River at Monga
BOM Guage 215007
xp-RAFTS Model Run
Flow (m3/s)
0
5
10
15
20
25
30
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00


Calibration Run August 2015 Event, Shoalhaven River at Warri
BOM Guage 215002
xp-RAFTS Model Run
Flow (m3/s)
0
50
100
150
200
250
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00

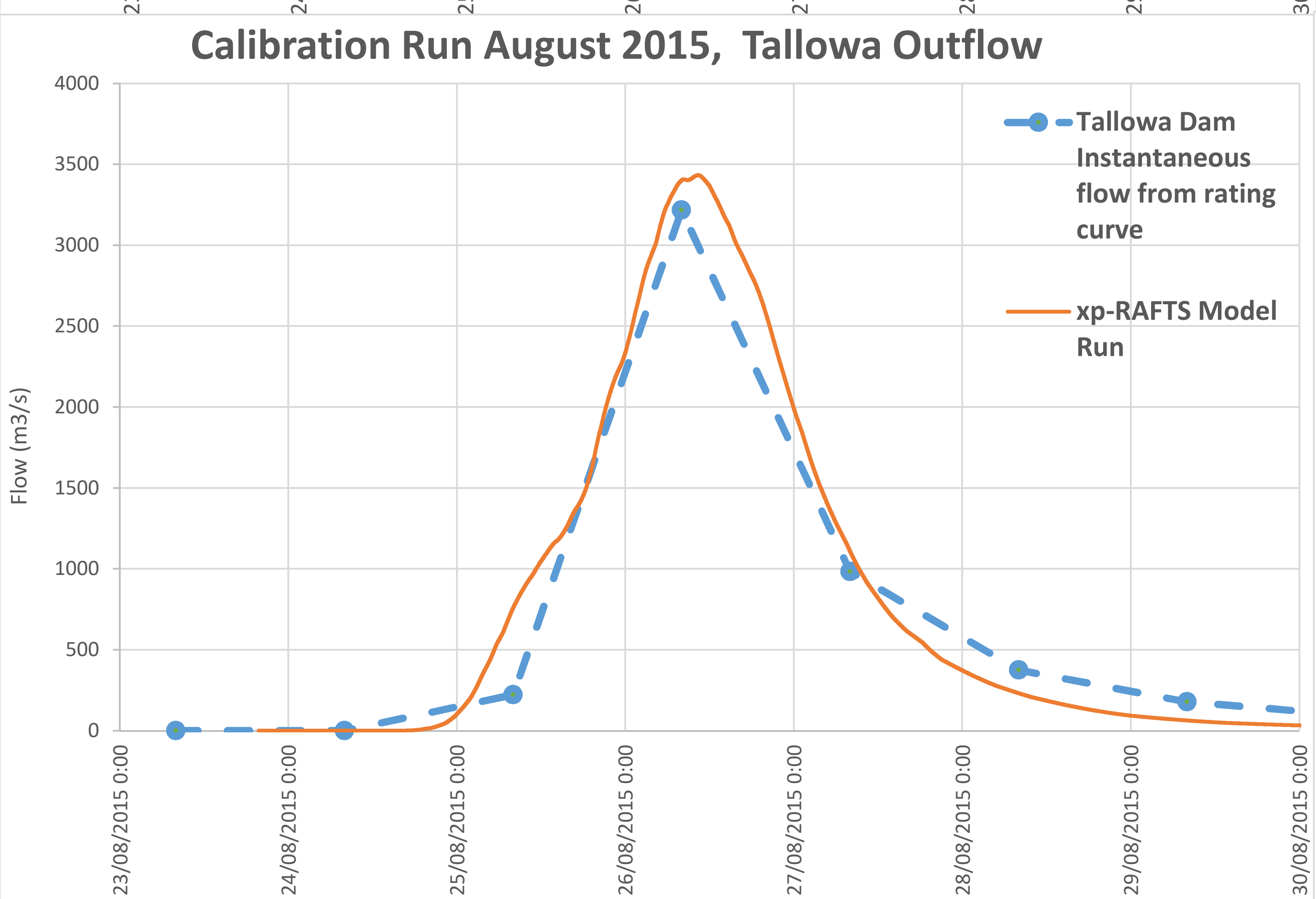

Calibration Run August 2015 Event, Bungonia Creek at Bungonia
BOM Guage 215014
xp-RAFTS Model Run
Flow (m3/s)
0
10
20
30
40
50
60
70
80
90
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00



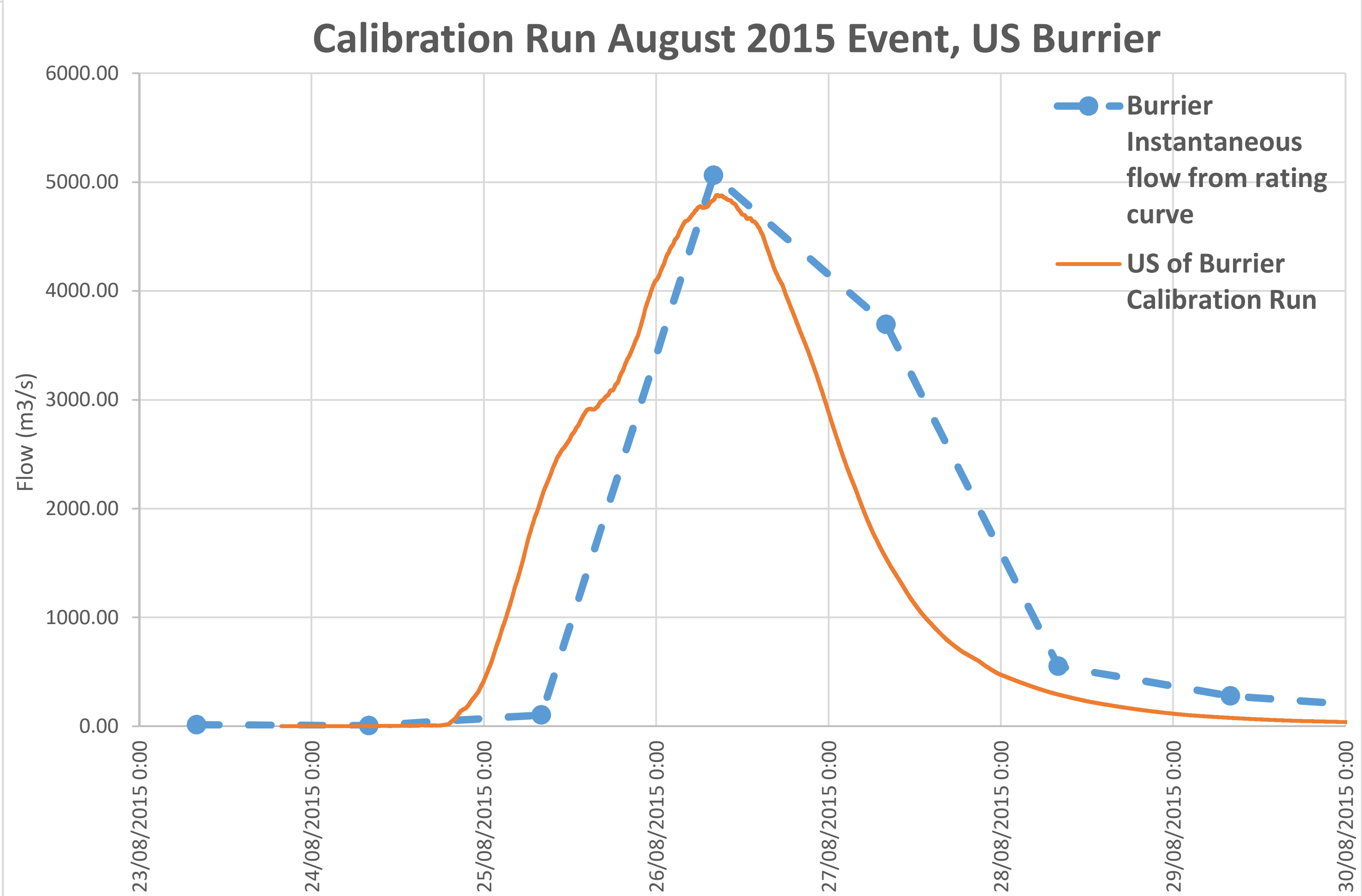
Calibration Run August 2015 Event, Hampden Bridge
Flow (m3/s)
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00
Hampden Bridge Instantaneous flow from rating curve
xp-RAFTS Model Run



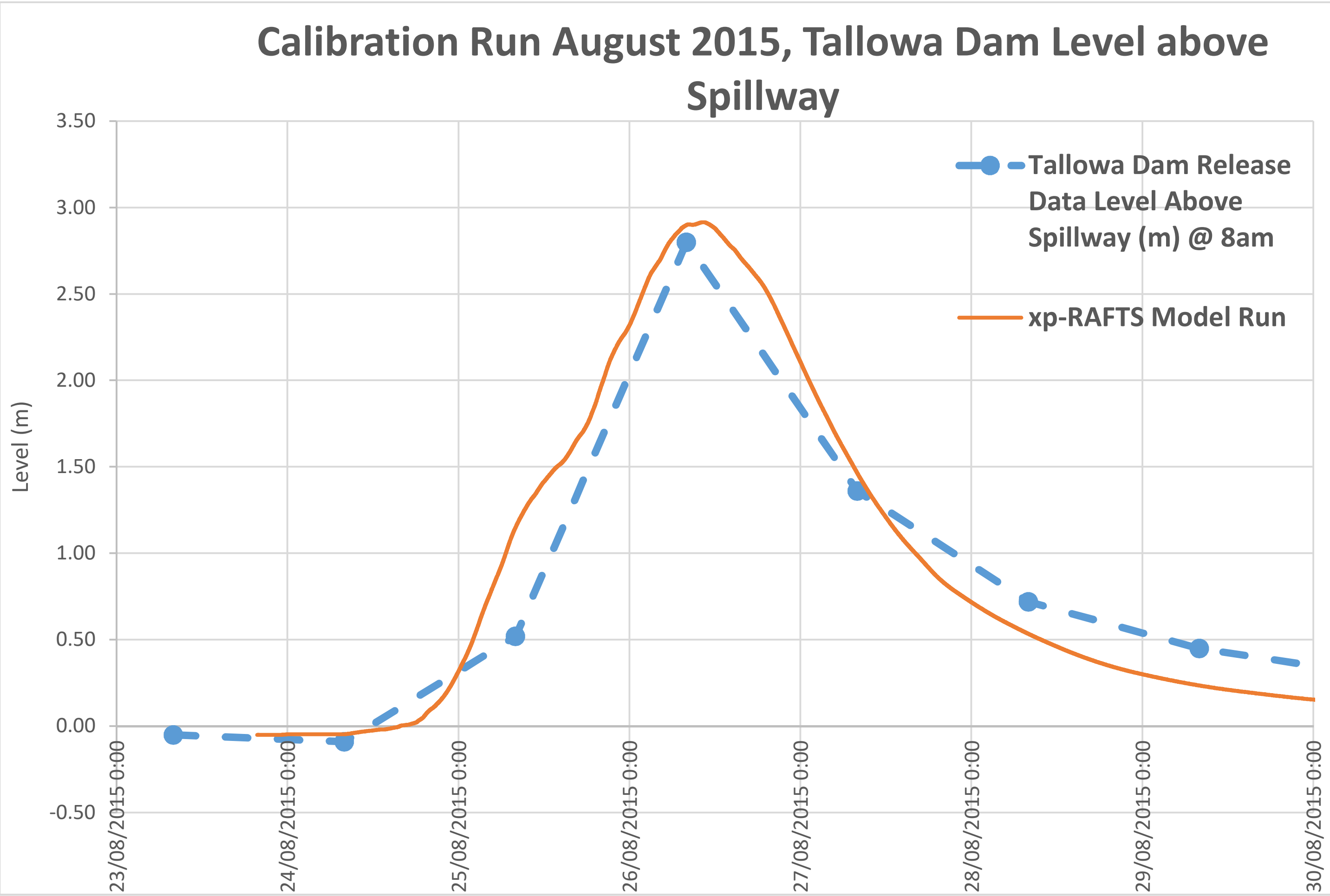
Calibration Run August 2015 Event, Fossickers Flat
Flow (m3/s)
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00
Fossikers Flat Instantaneous flow from rating curve
xp-RAFTS Model Run

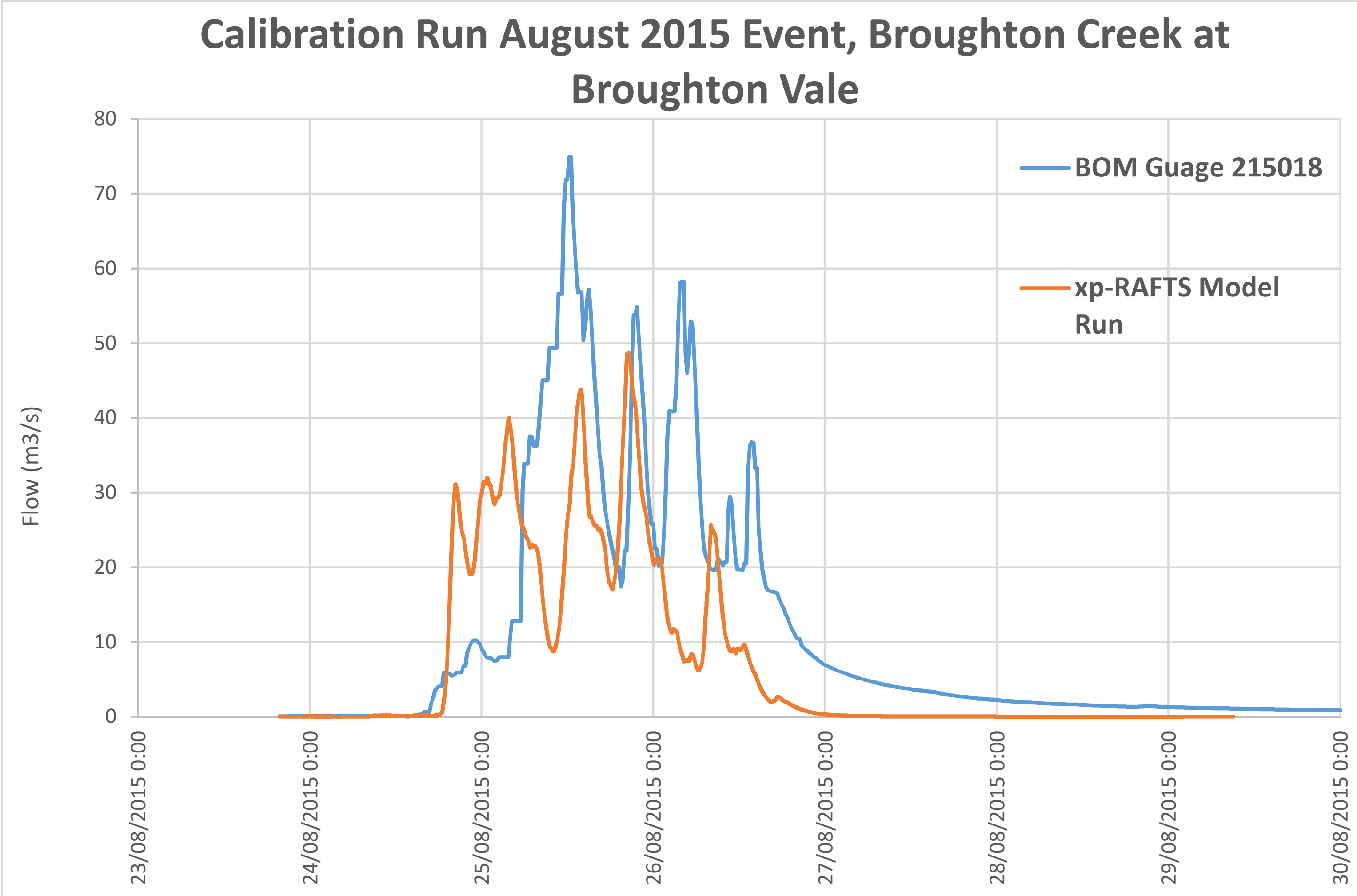


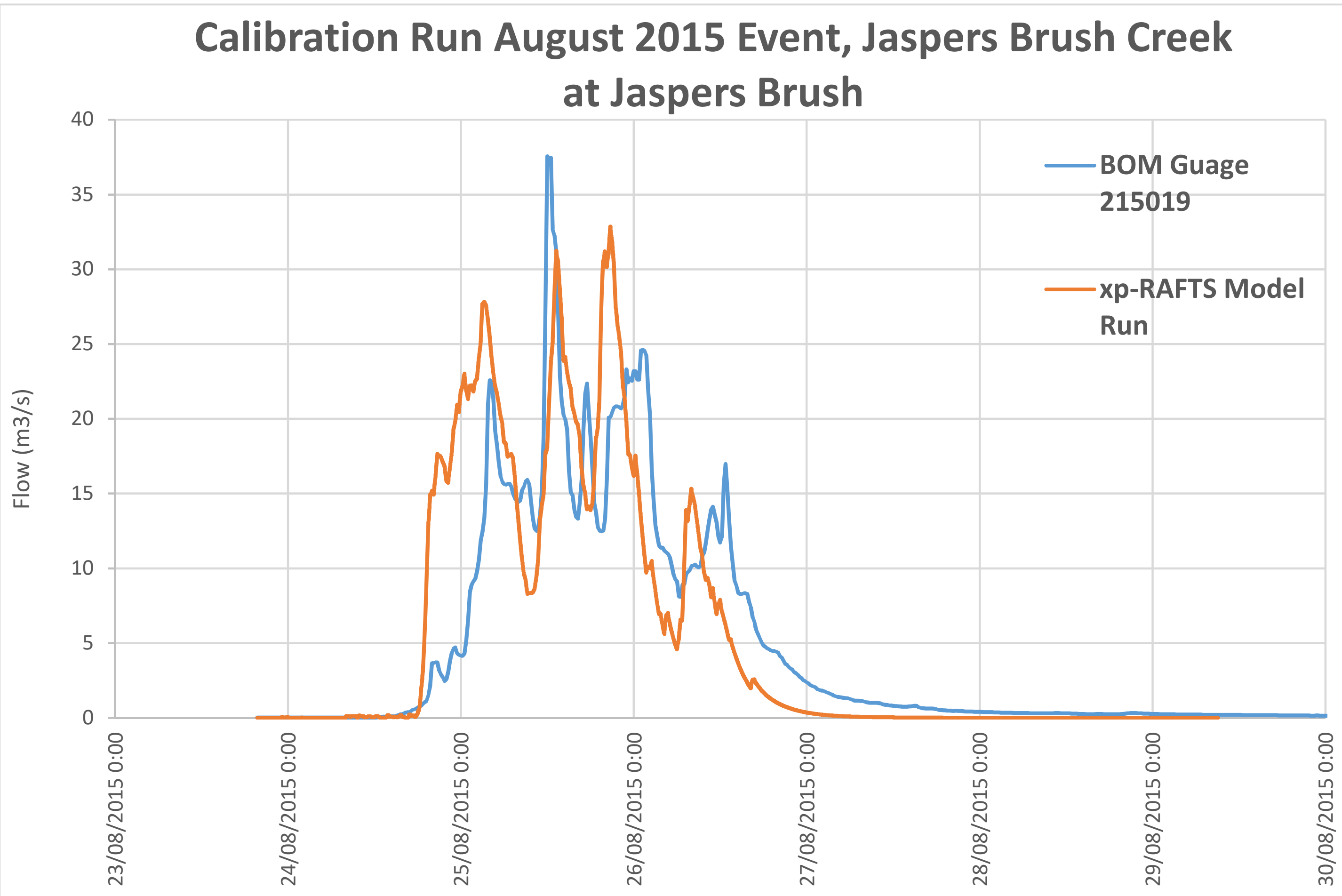
Calibration Run August 2015, Tallowa Outflow
Flow (m3/s)
4000
3500
3000
2500
2000
1500
1000
500
0
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00
Tallowa Dam Instantaneous flow from rating curve
xp-RAFTS Model Run

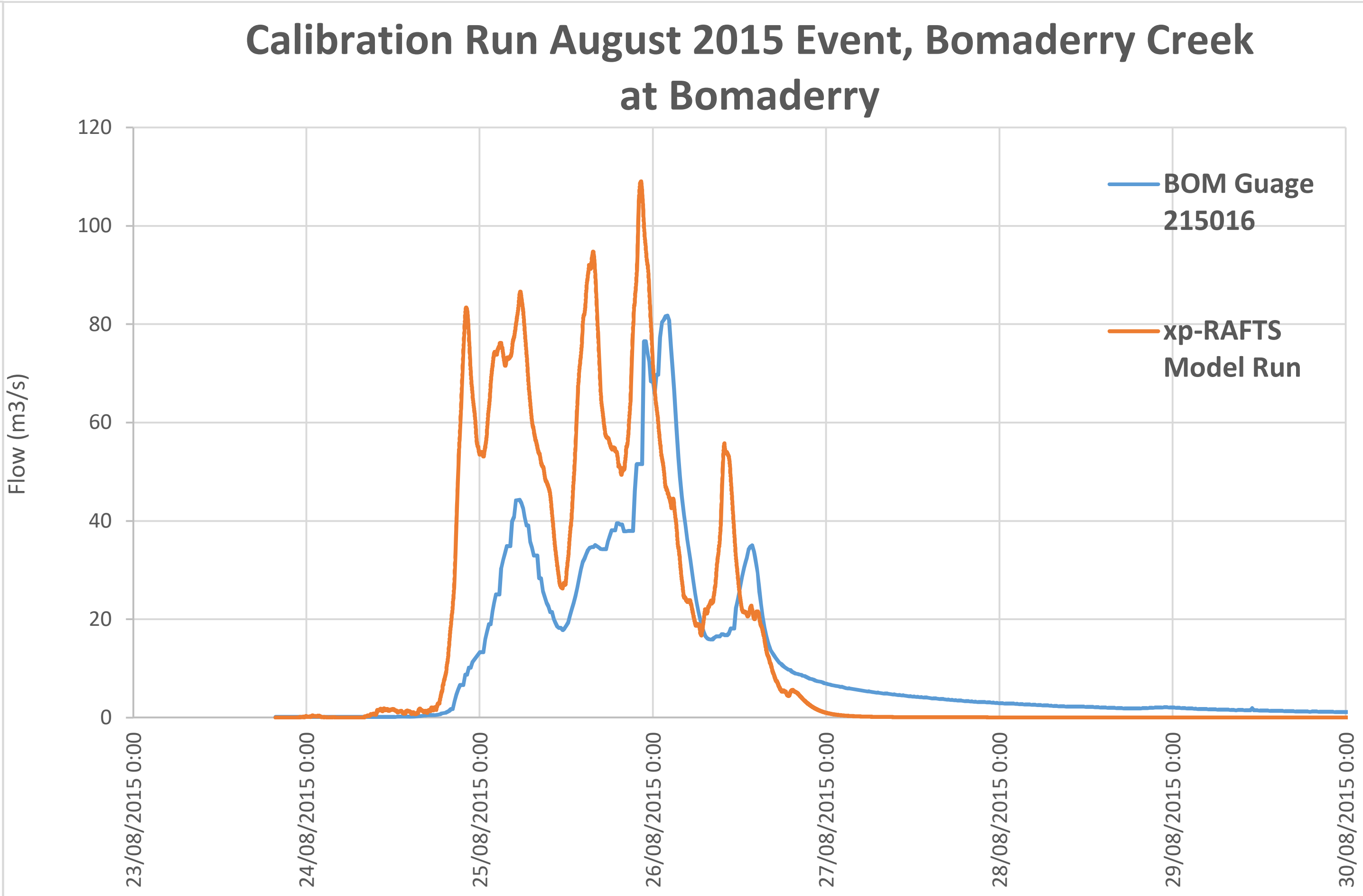


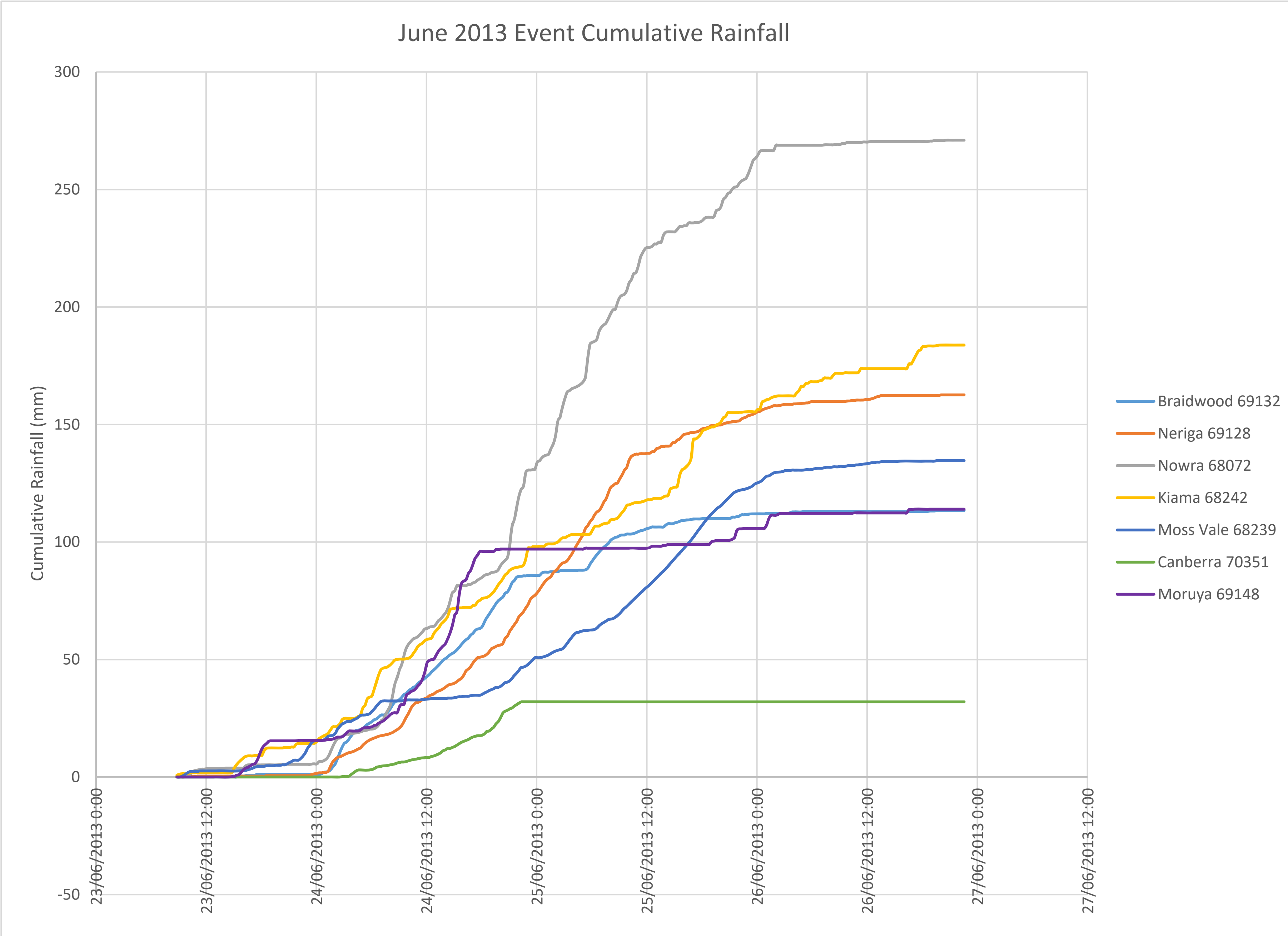
Calibration Run August 2015 Event, US Burrier
Flow (m3/s)
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00
Burrier Instantaneous flow from rating curve
US of Burrier Calibration Run

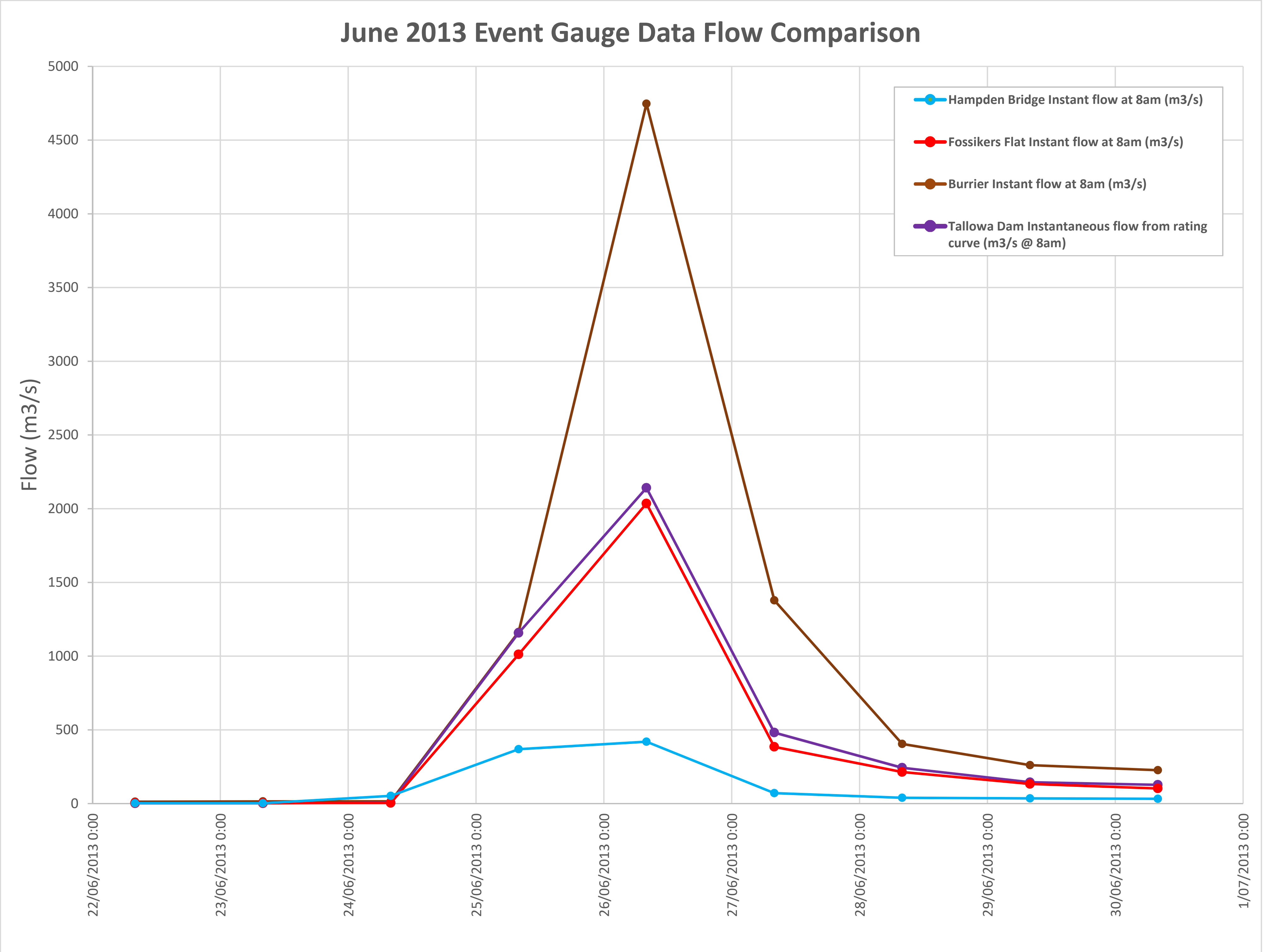

Calibration Run August 2015, Tallowa Dam Level above Spillway
Level (m)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
Tallowa Dam Release Data Level Above Spillway (m) @ 8am
xp-RAFTS Model Run
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00


Calibration Run August 2015 Event, Broughton Creek at Broughton Vale
Flow (m3/s)
80
70
60
50
40
30
20
10
0
BOM Guage 215018
xp-RAFTS Model Run
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00

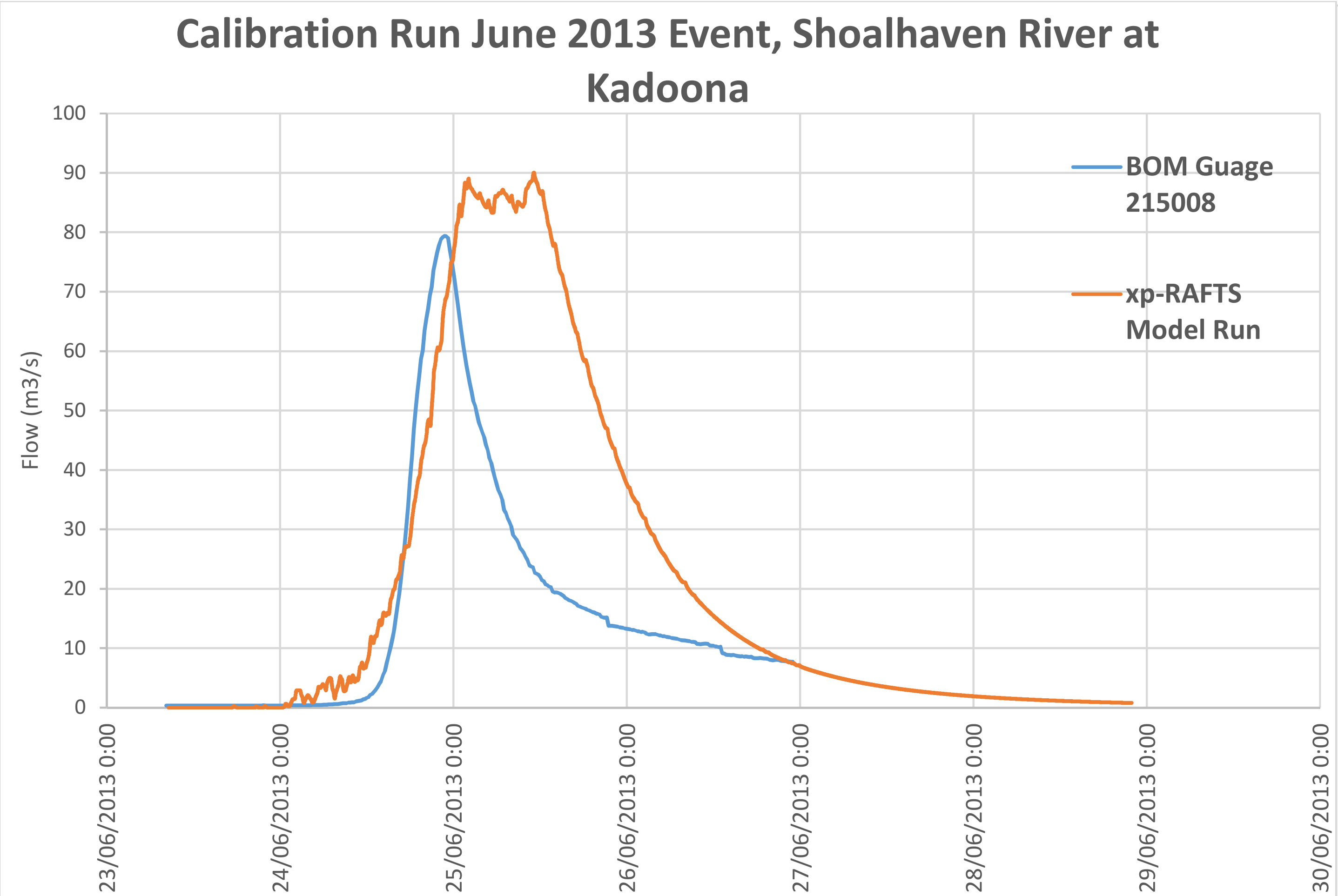

Calibration Run August 2015 Event, Jaspers Brush Creek at Jaspers Brush
Flow (m3/s)
40
35
30
25
20
15
10
5
0
BOM Guage 215019
xp-RAFTS Model Run
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00

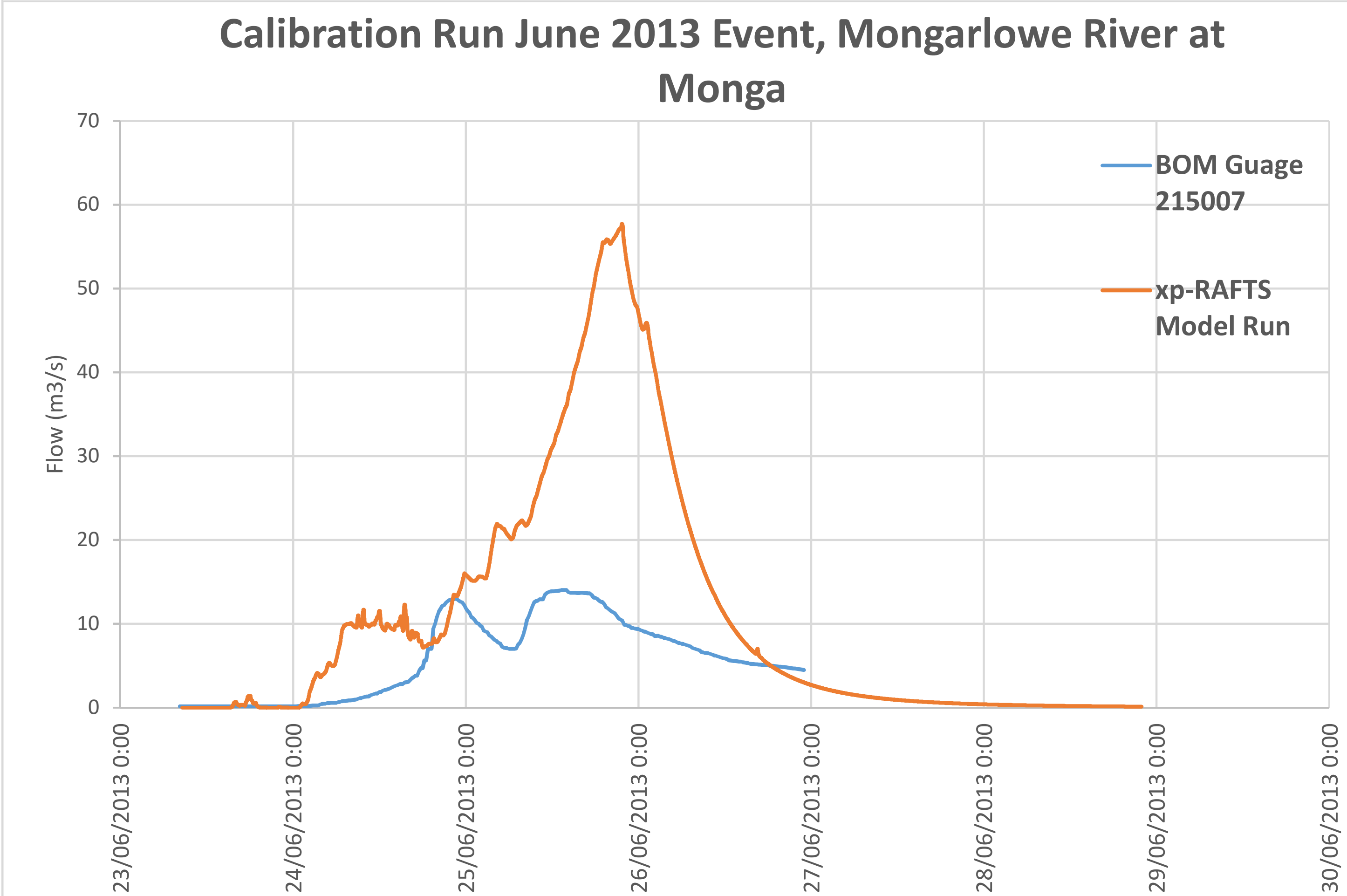

Calibration Run August 2015 Event, Bomaderry Creek at Bomaderry
Flow (m3/s)
120
100
80
60
40
20
0
BOM Guage 215016
xp-RAFTS Model Run
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00
30/08/2015 0:00

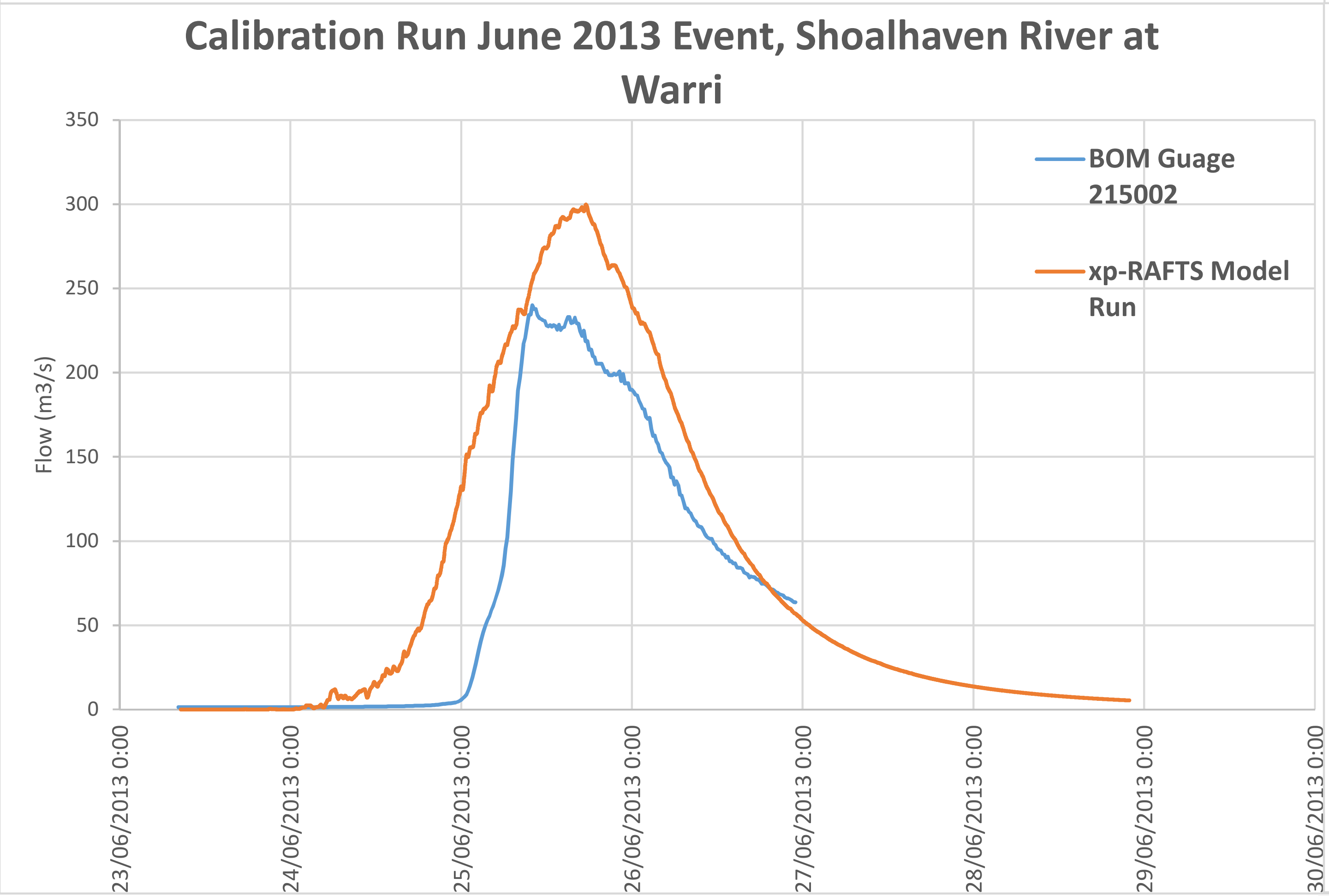

June 2013 Event Cumulative Rainfall
Cumulative Rainfall (mm)
300
250
200
150
100
50
0
-50
23/06/2013 0:00
23/06/2013 12:00
24/06/2013 0:00
24/06/2013 12:00
25/06/2013 0:00
25/06/2013 12:00
26/06/2013 0:00
26/06/2013 12:00
27/06/2013 0:00
27/06/2013 12:00
Braidwood 69132
Neriga 69128
Nowra 68072
Kiama 68242
Moss Vale 68239
Canberra 70351
Moruya 69148

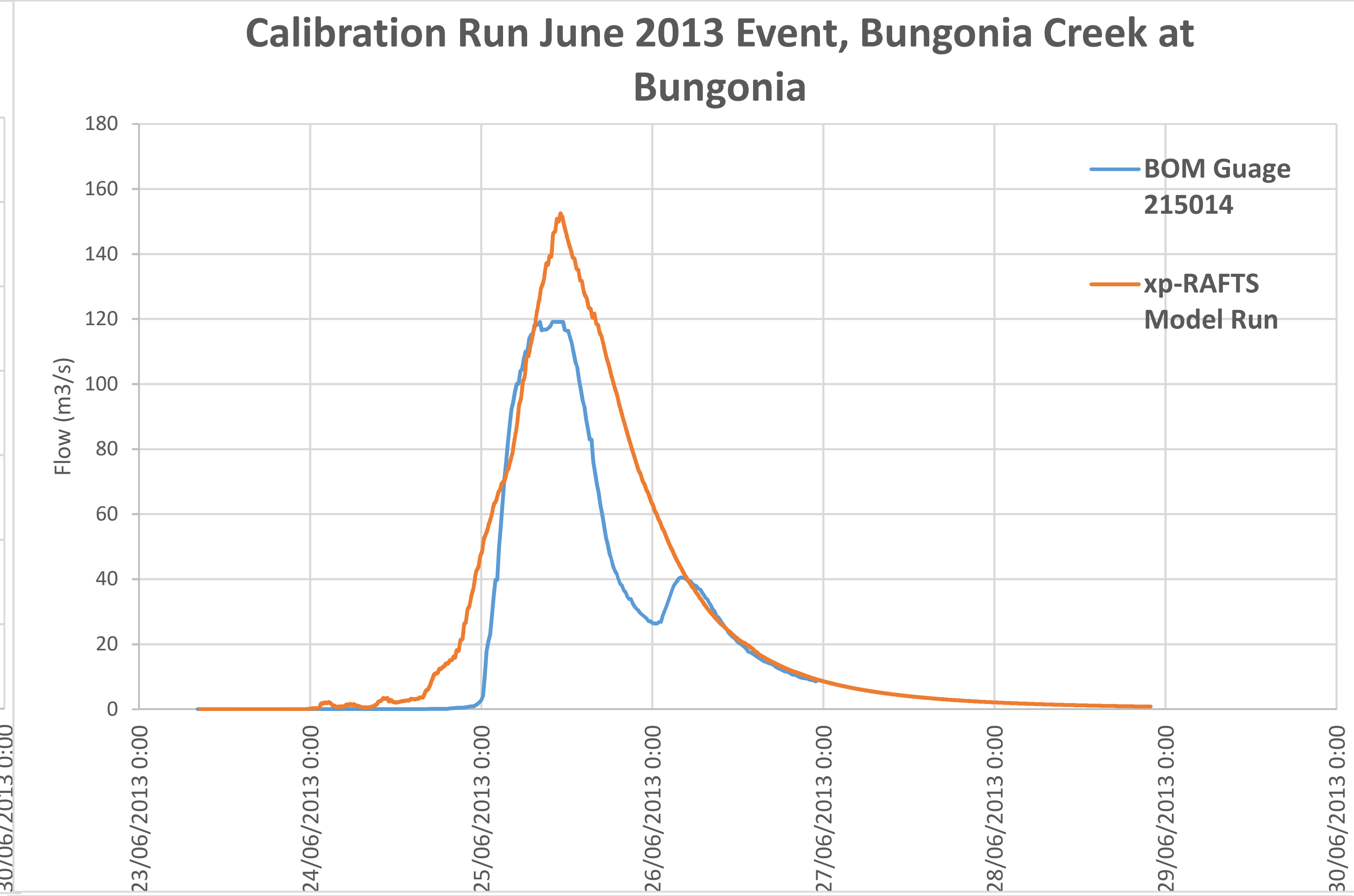


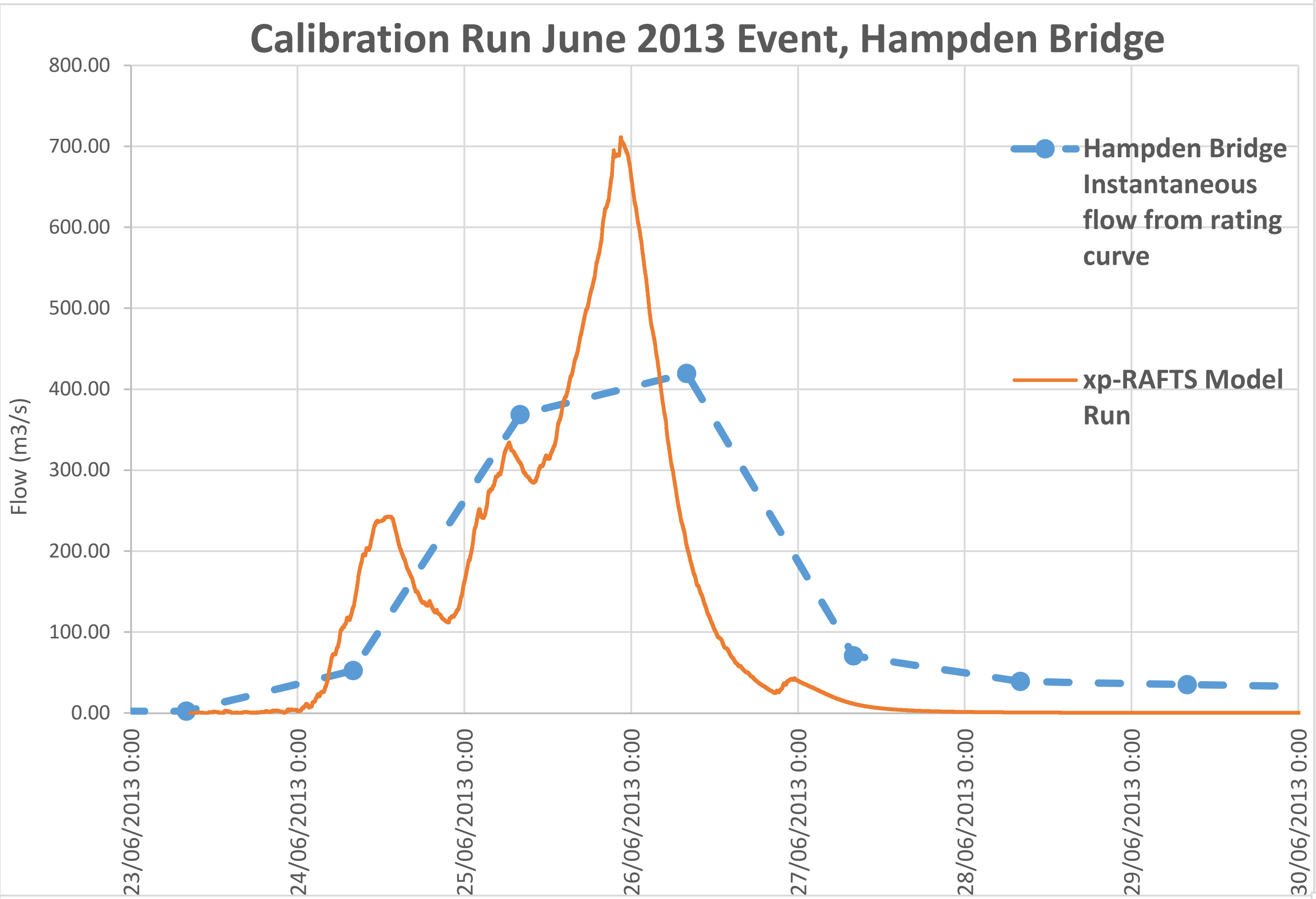
June 2013 Event Gauge Data Flow Comparison
Flow (m3/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
22/06/2013 0:00
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
1/07/2013 0:00
Hampden Bridge Instant flow at 8am (m3/s)
Fossikers Flat Instant flow at 8am (m3/s)
Burrier Instant flow at 8am (m3/s)
Tallowa Dam Instantaneous flow from rating curve (m3/s @ 8am)


Calibration Run June 2013 Event, Shoalhaven River at Kadoona
Flow (m3/s)
0
10
20
30
40
50
60
70
80
90
100
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215008
xp-RAFTS Model Run

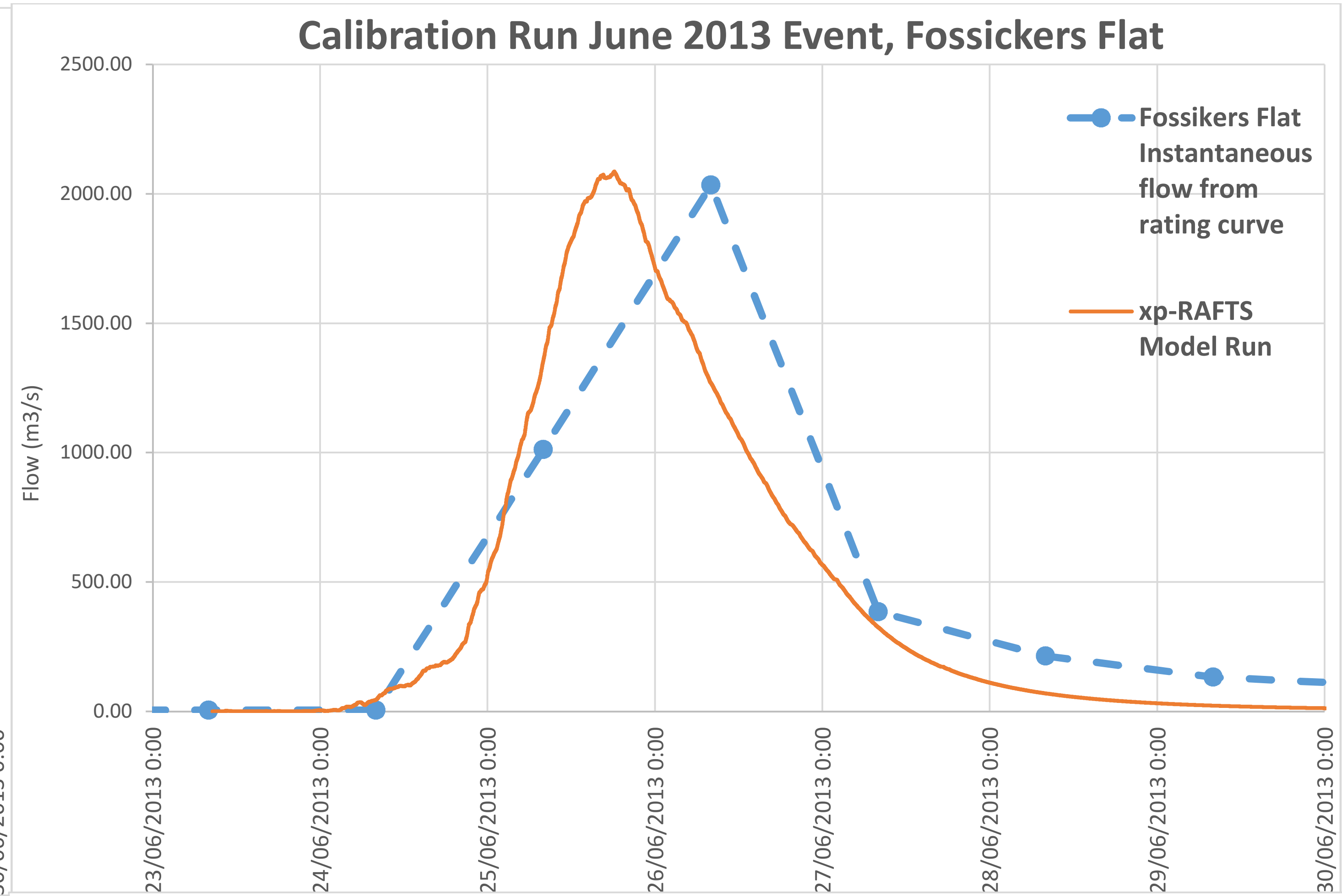

Calibration Run June 2013 Event, Mongarlowe River at Monga
Flow (m3/s)
0
10
20
30
40
50
60
70
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215007
xp-RAFTS Model Run


Calibration Run June 2013 Event, Shoalhaven River at Warri
Flow (m3/s)
0
50
100
150
200
250
300
350
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215002
xp-RAFTS Model Run

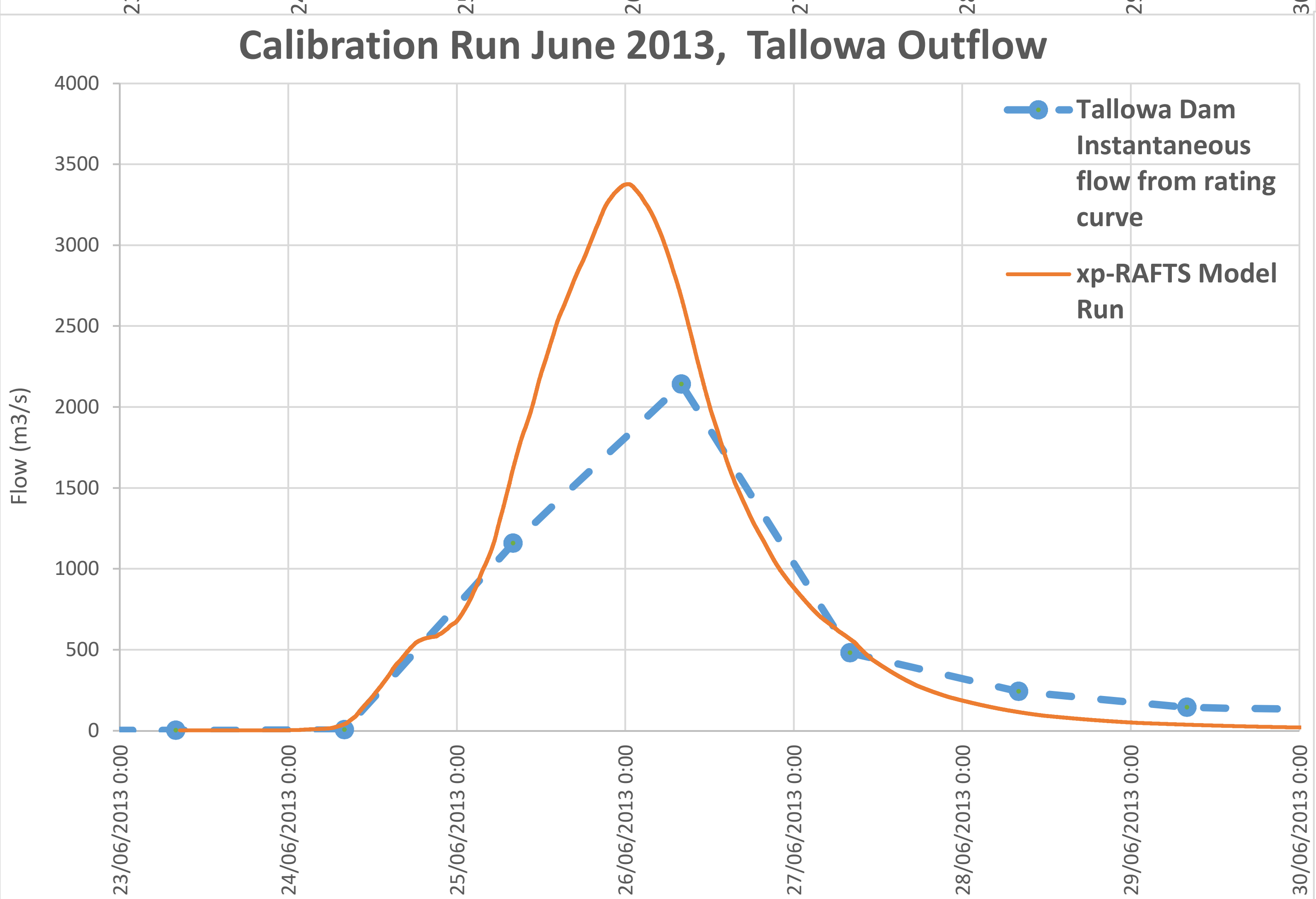

Calibration Run June 2013 Event, Bungonia Creek at Bungonia
Flow (m3/s)
0
20
40
60
80
100
120
140
160
180
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215014
xp-RAFTS Model Run



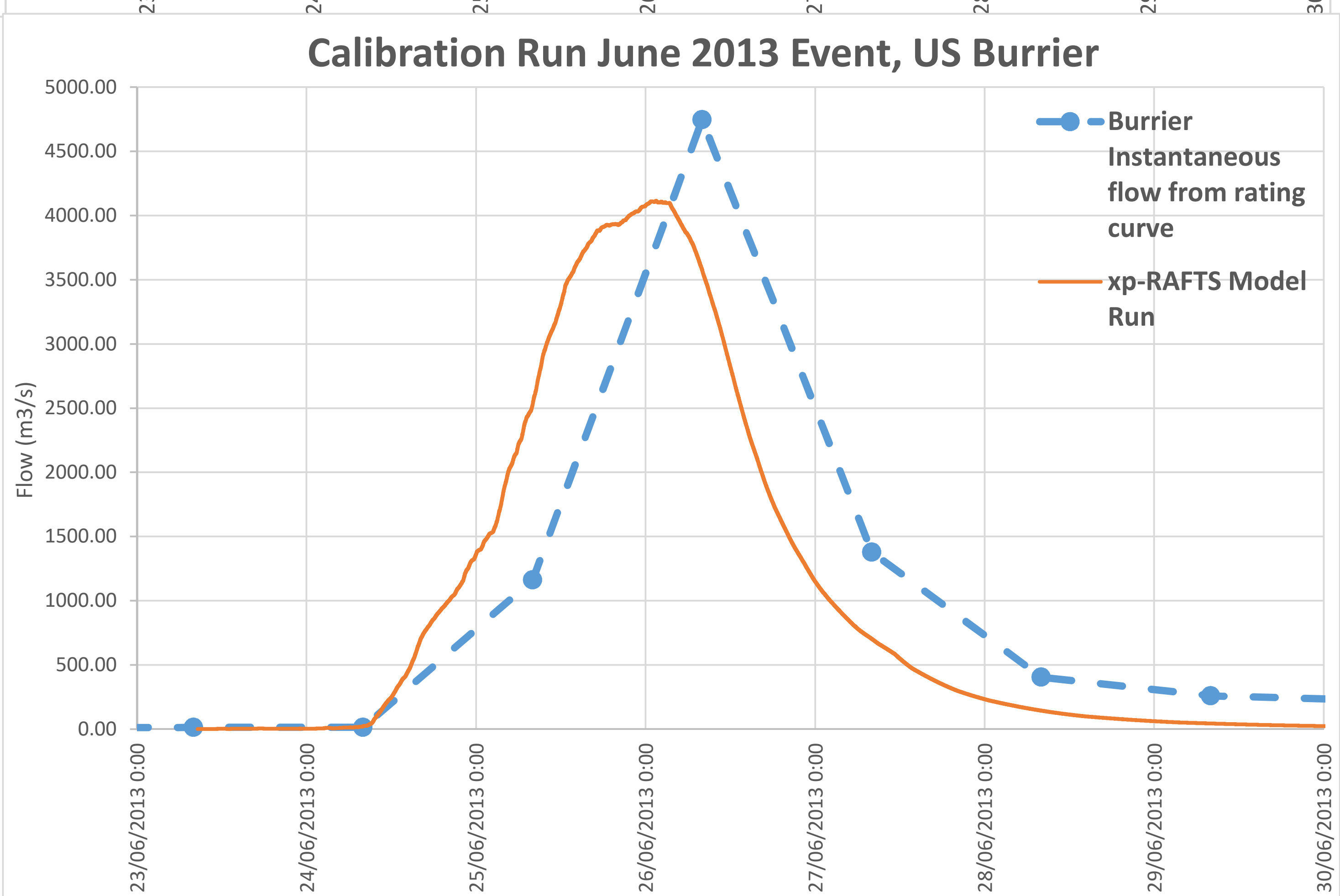
Calibration Run June 2013 Event, Hampden Bridge
Flow (m3/s)
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
Hampden Bridge Instantaneous flow from rating curve
xp-RAFTS Model Run



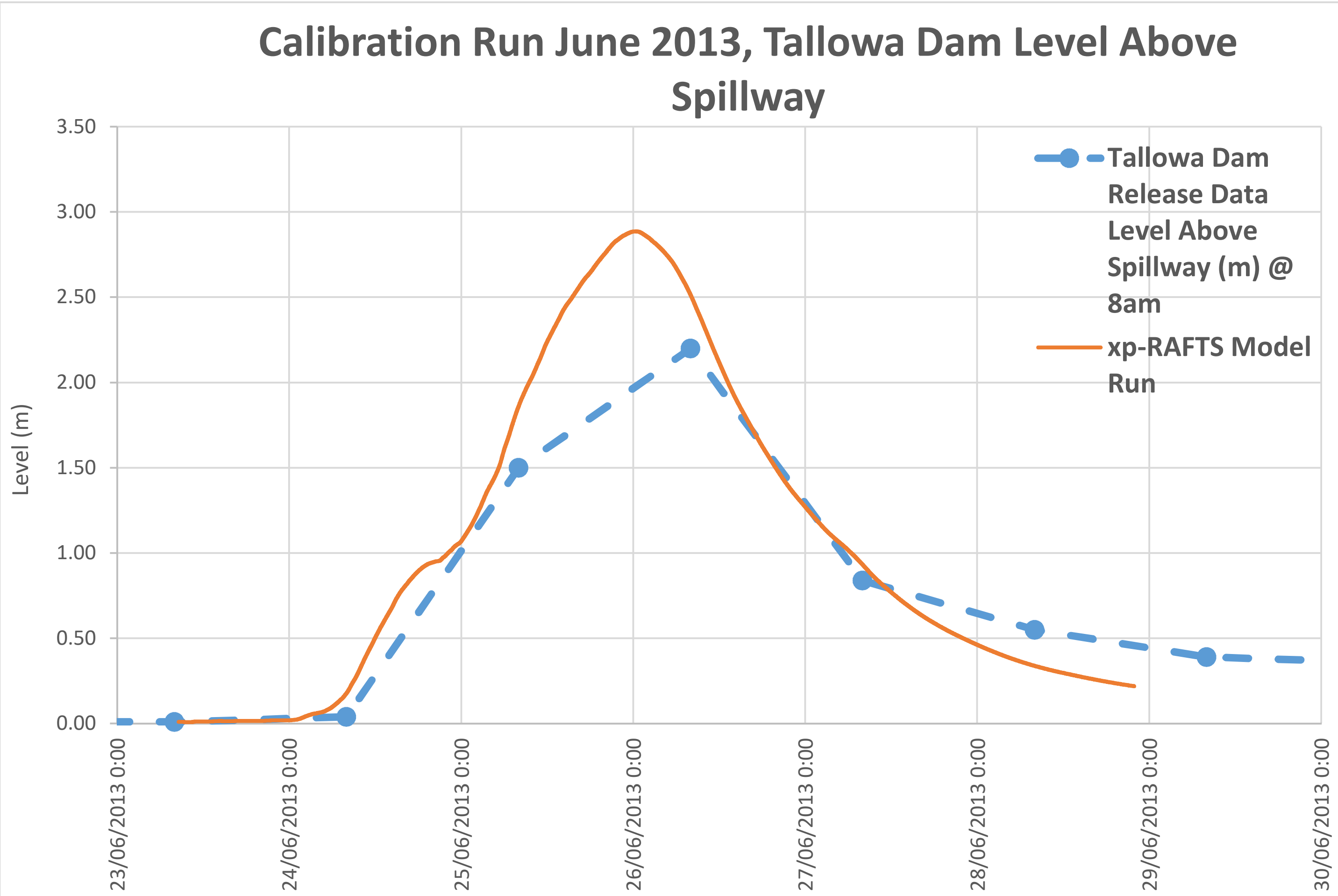
Calibration Run June 2013 Event, Fossickers Flat
Flow (m3/s)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
Fossikers Flat Instantaneous flow from rating curve
xp-RAFTS Model Run



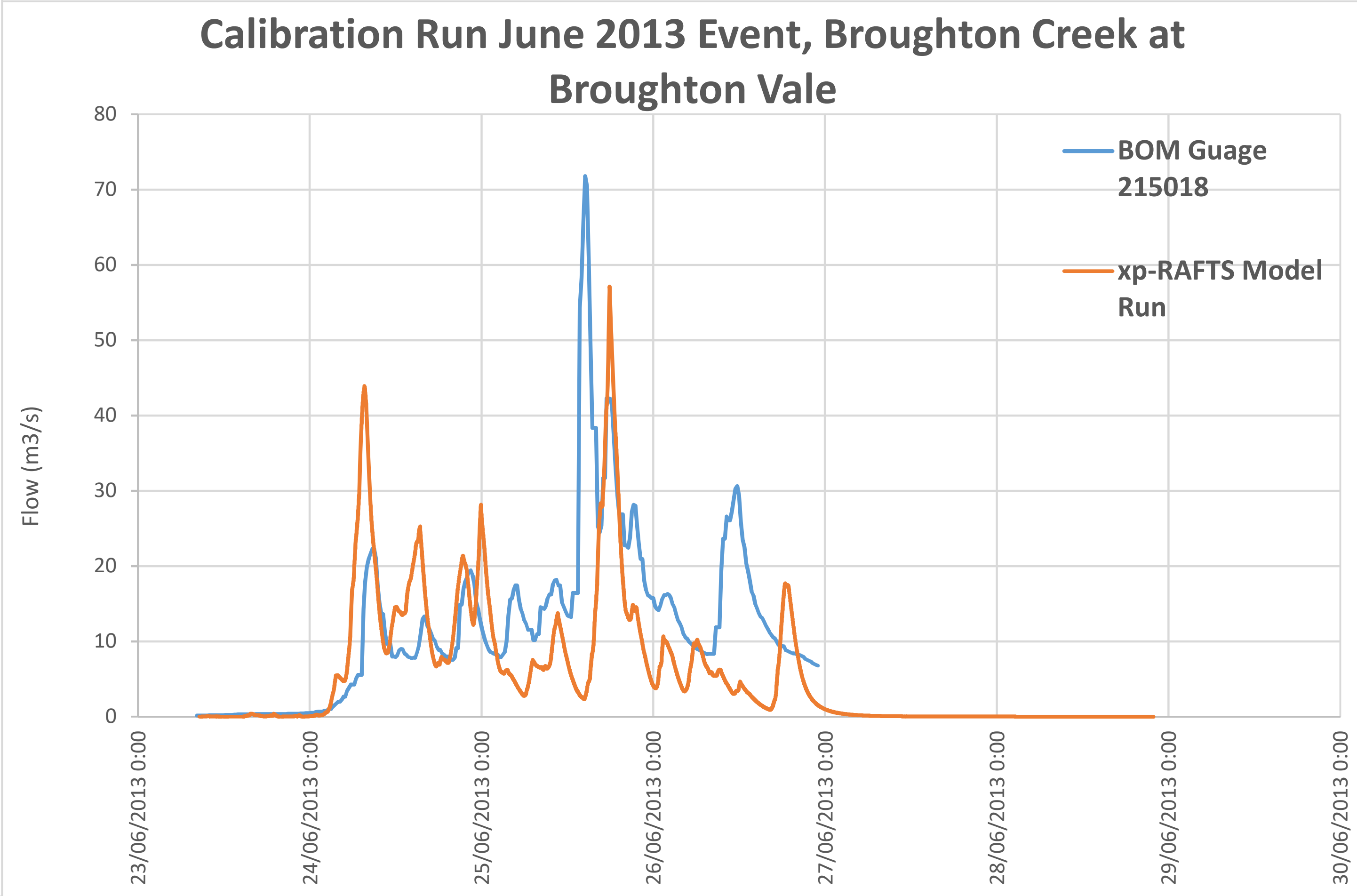
Calibration Run June 2013, Tallowa Outflow
Flow (m3/s)
4000
3500
3000
2500
2000
1500
1000
500
0
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
Tallowa Dam Instantaneous flow from rating curve
xp-RAFTS Model Run



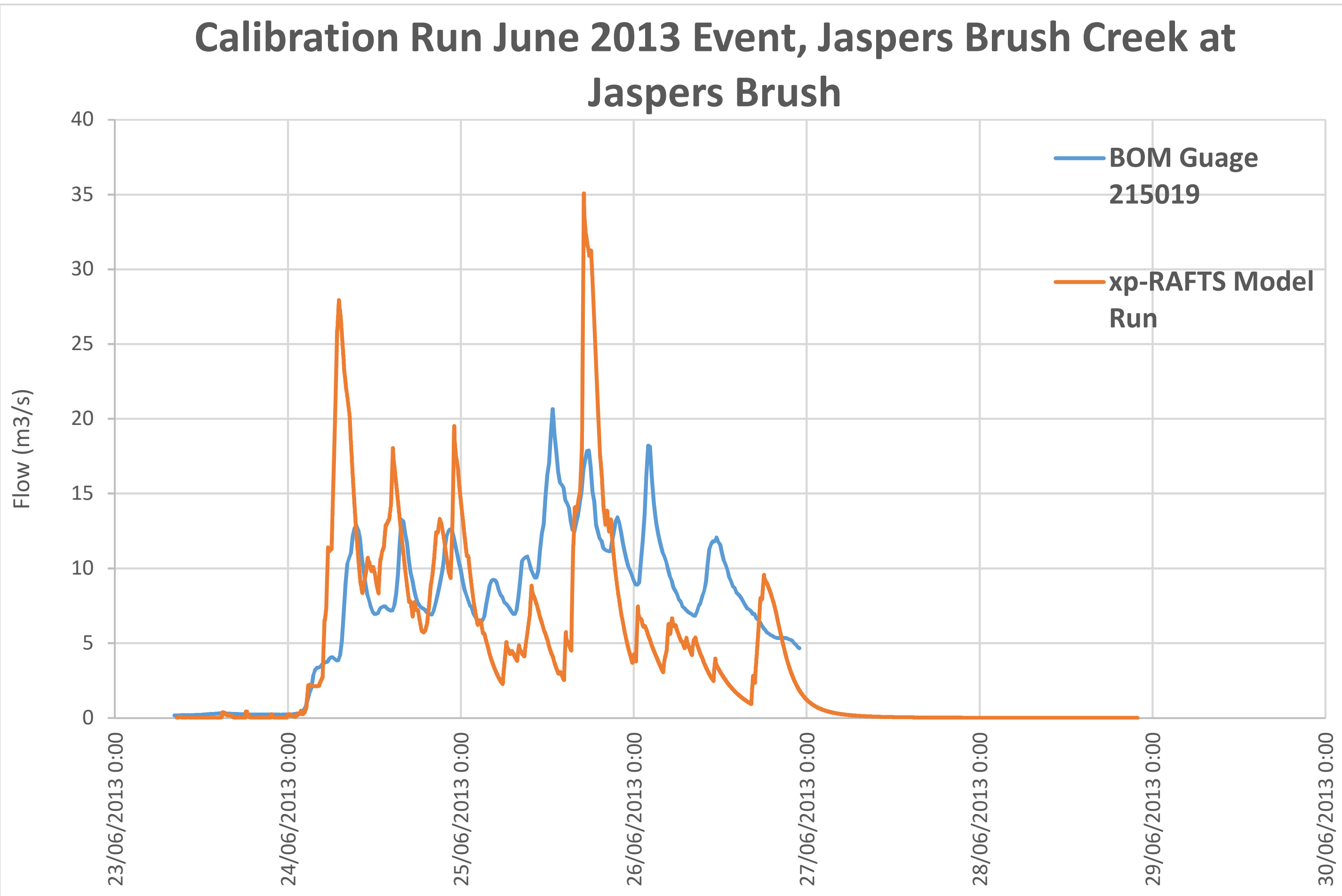
Calibration Run June 2013 Event, US Burrier
Flow (m3/s)
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
Burrier Instantaneous flow from rating curve
xp-RAFTS Model Run



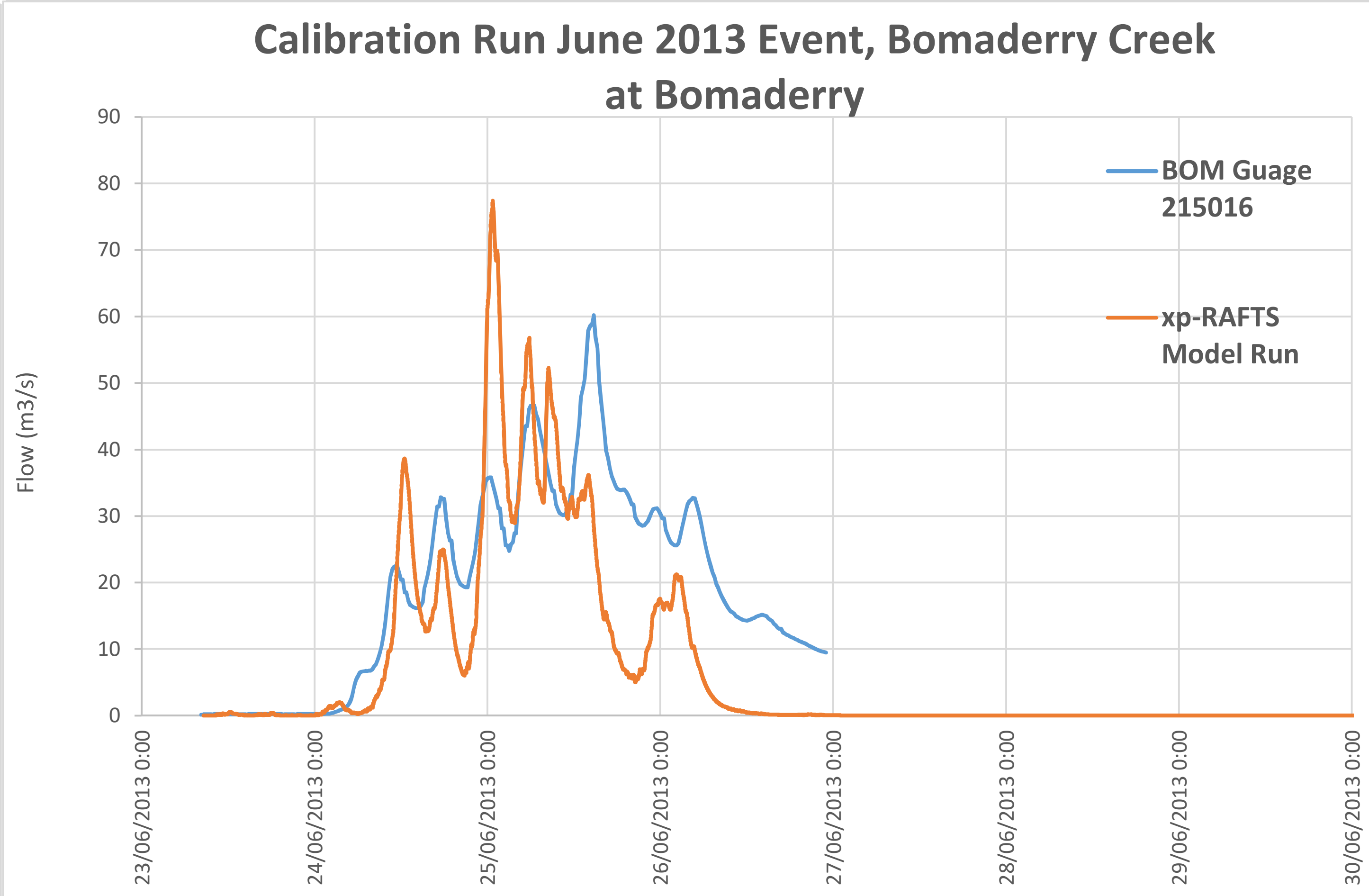
Calibration Run June 2013, Tallowa Dam Level Above Spillway
Level (m)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
Tallowa Dam Release Data Level Above Spillway (m) @ 8am
xp-RAFTS Model Run



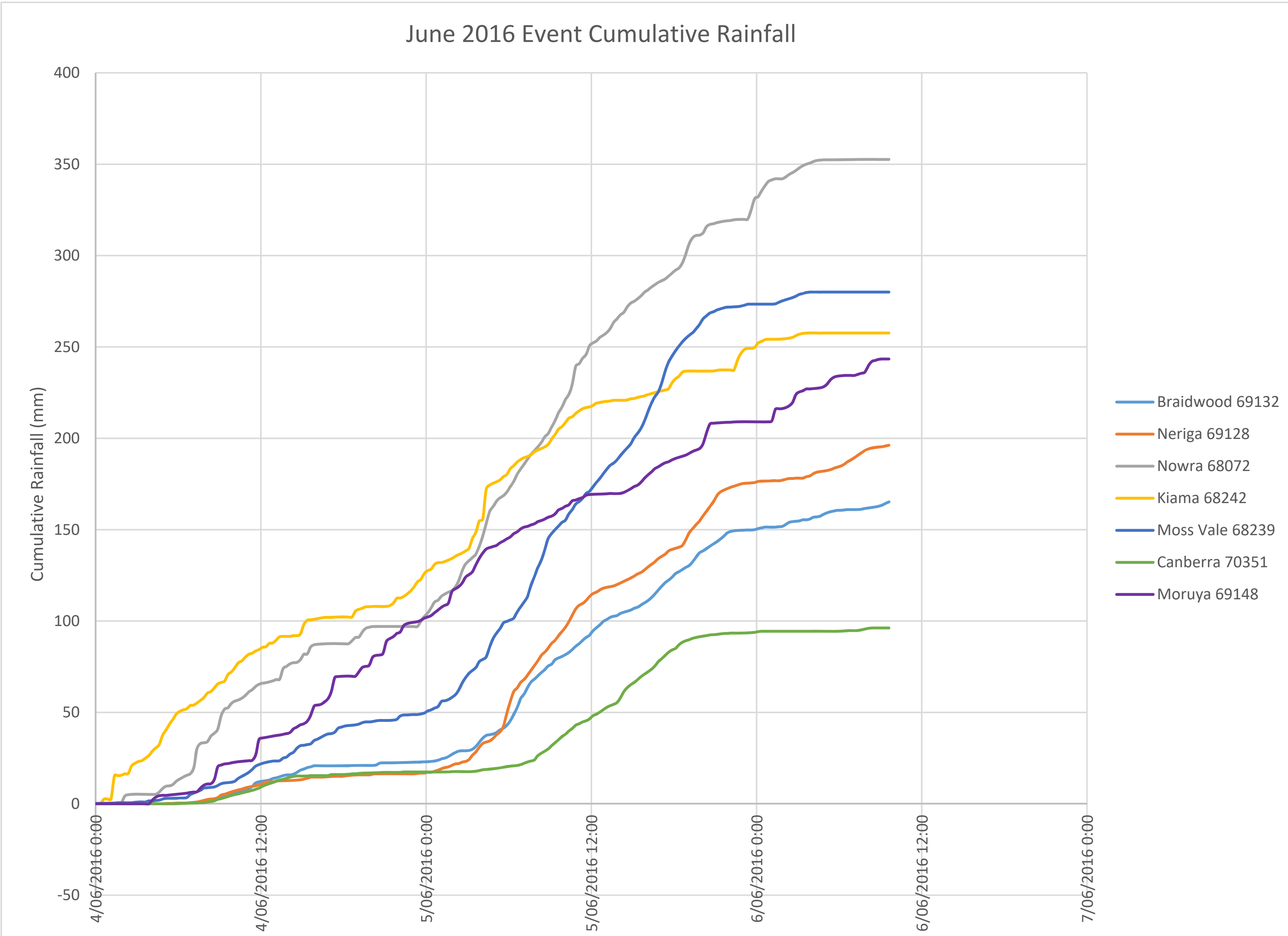
Calibration Run June 2013 Event, Broughton Creek at Broughton Vale
Flow (m3/s)
80
70
60
50
40
30
20
10
0
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215018
xp-RAFTS Model Run



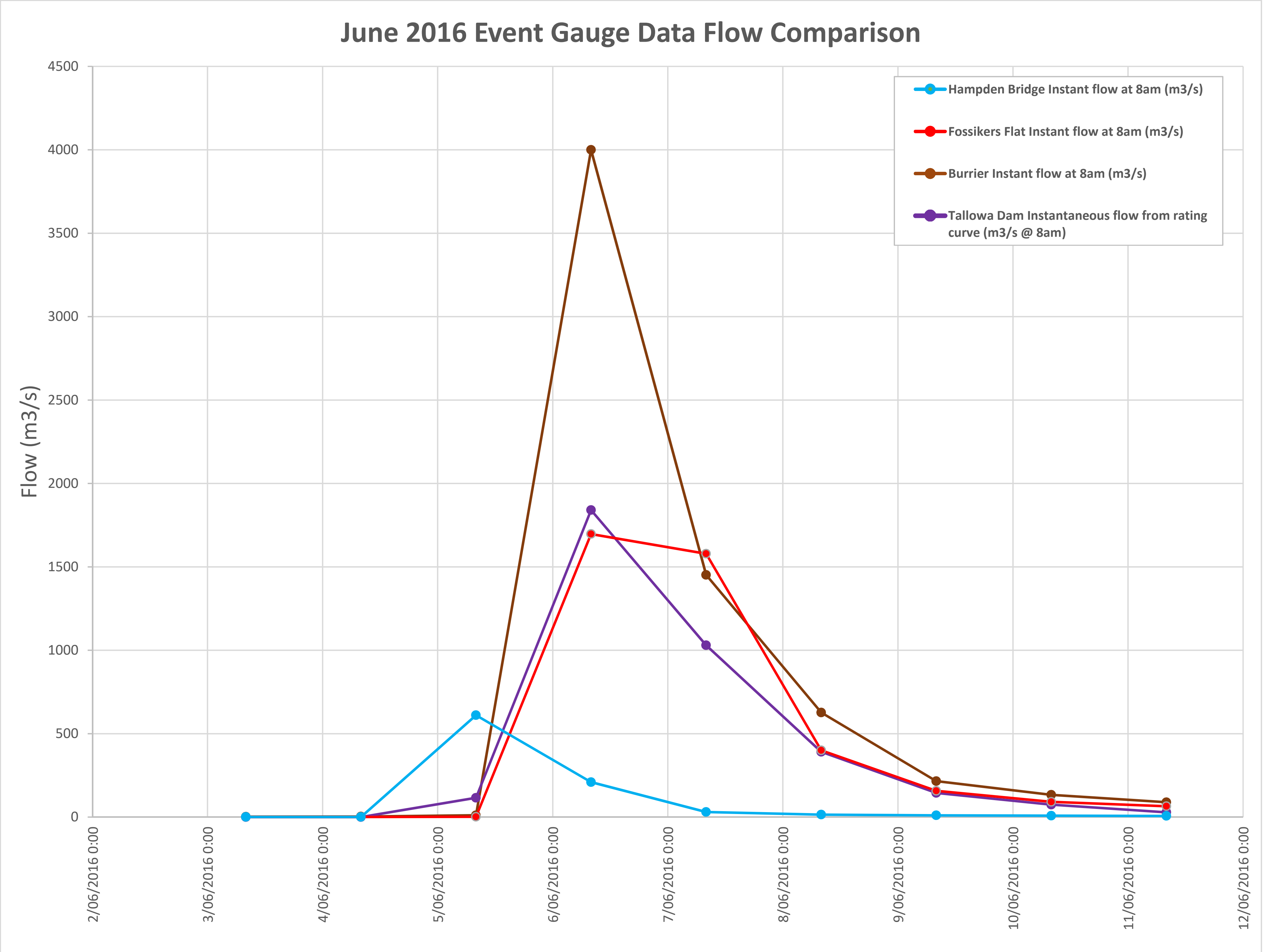
Calibration Run June 2013 Event, Jaspers Brush Creek at Jaspers Brush
Flow (m3/s)
40
35
30
25
20
15
10
5
0
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215019
xp-RAFTS Model Run



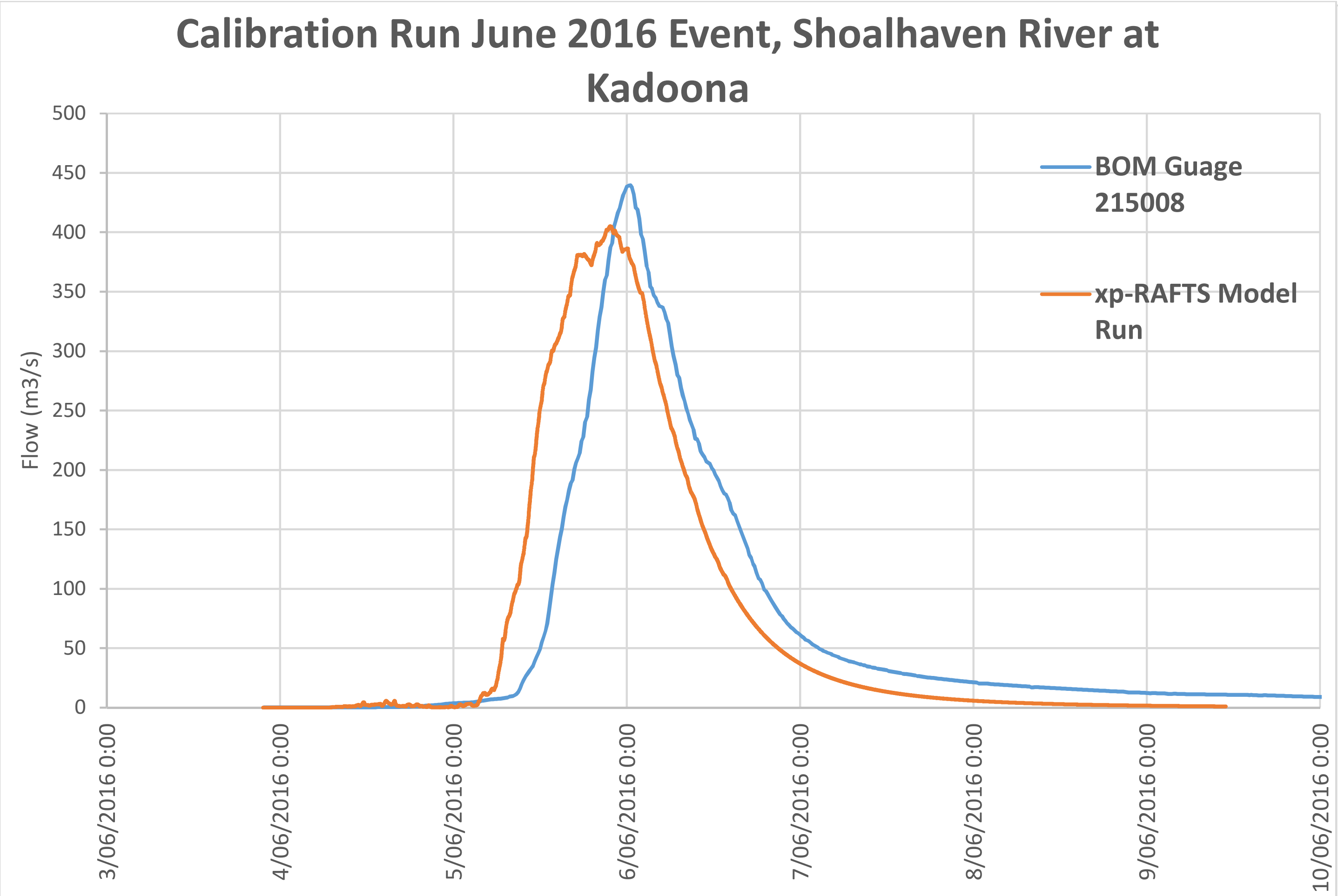
Calibration Run June 2013 Event, Bomaderry Creek at Bomaderry
Flow (m3/s)
90
80
70
60
50
40
30
20
10
0
23/06/2013 0:00
24/06/2013 0:00
25/06/2013 0:00
26/06/2013 0:00
27/06/2013 0:00
28/06/2013 0:00
29/06/2013 0:00
30/06/2013 0:00
BOM Guage 215016
xp-RAFTS Model Run

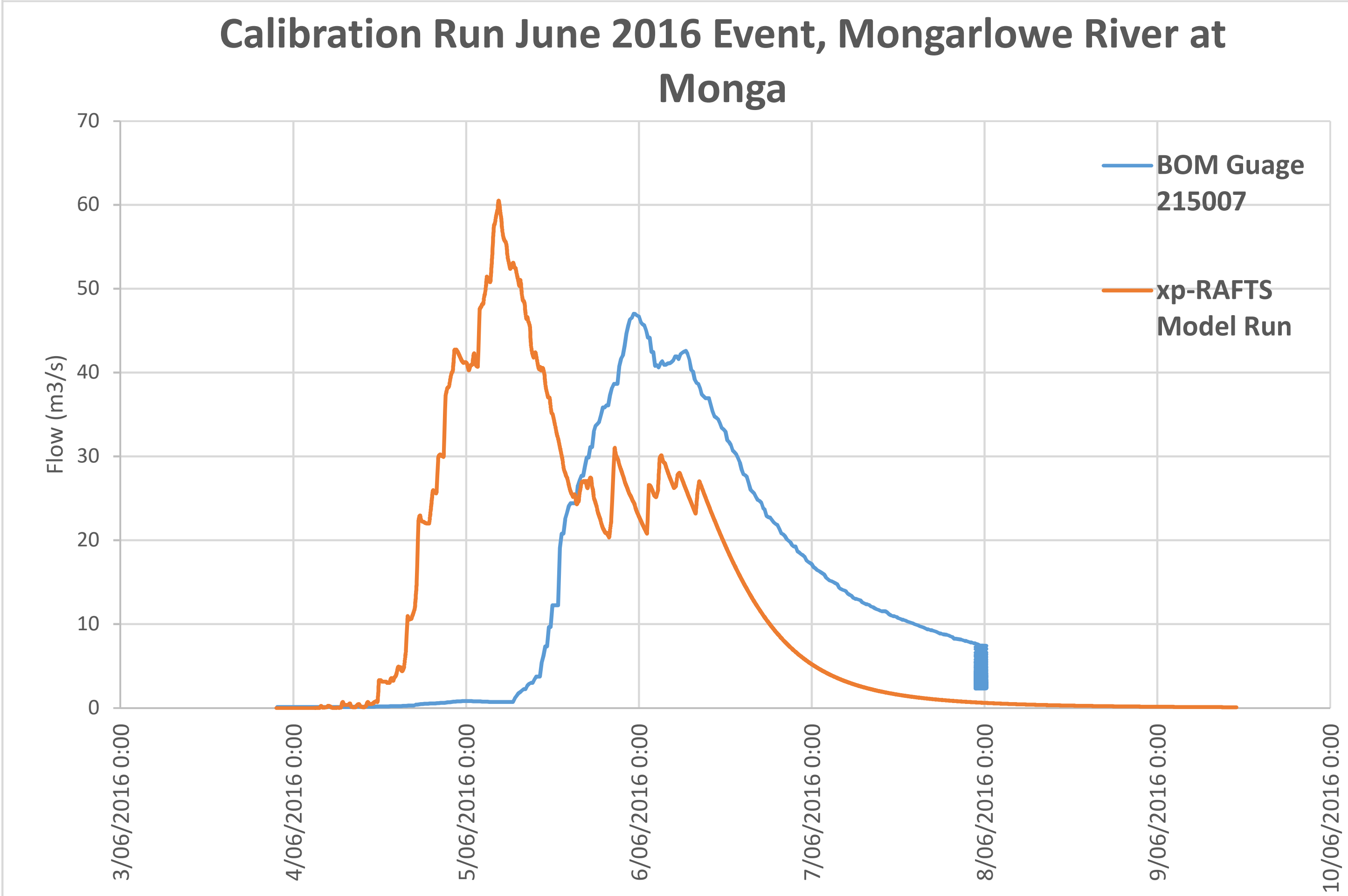


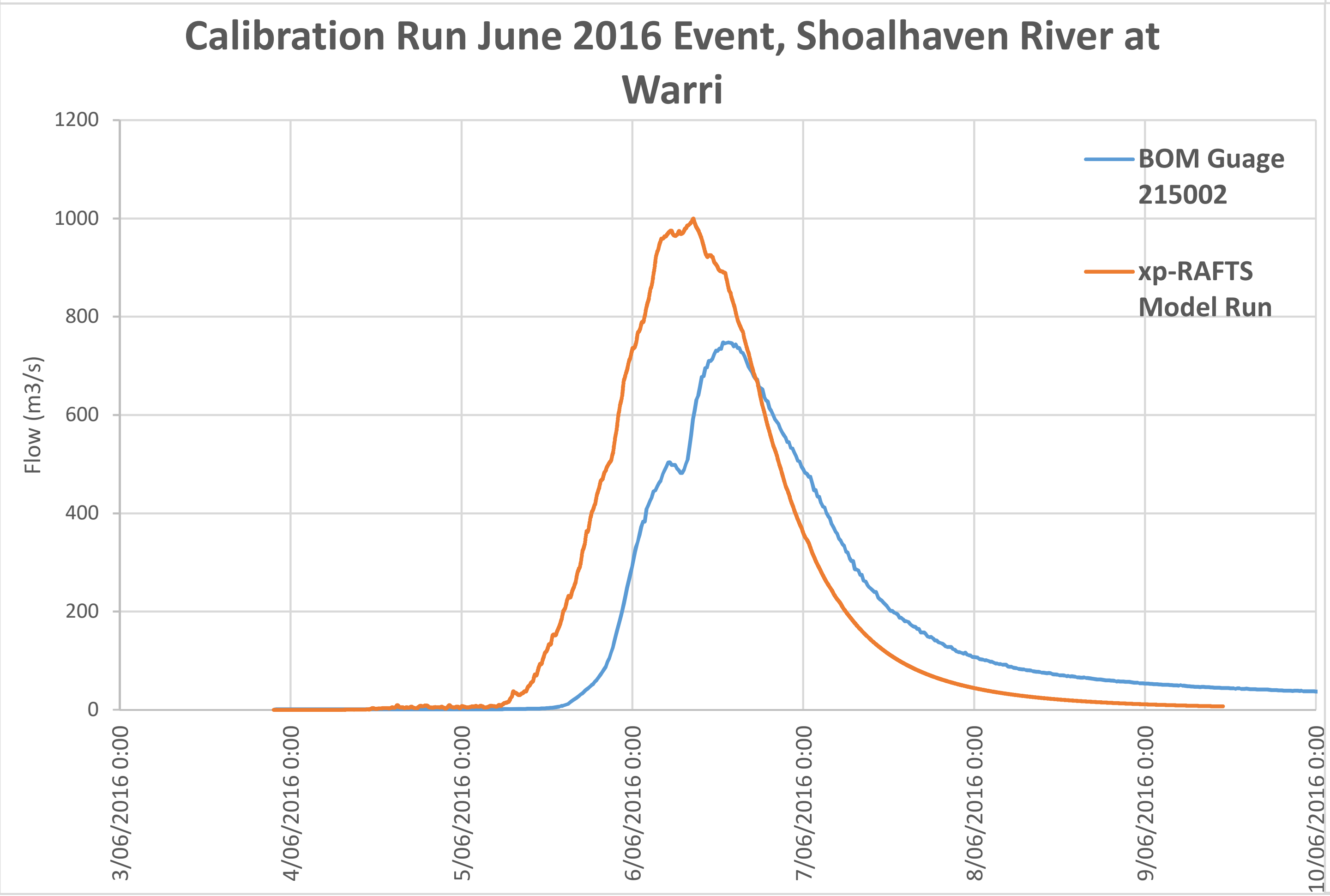
June 2016 Event Cumulative Rainfall
Cumulative Rainfall (mm)
400
350
300
250
200
150
100
50
0
-50
4/06/2016 0:00
4/06/2016 12:00
5/06/2016 0:00
5/06/2016 12:00
6/06/2016 0:00
6/06/2016 12:00
7/06/2016 0:00
Braidwood 69132
Neriga 69128
Nowra 68072
Kiama 68242
Moss Vale 68239
Canberra 70351
Moruya 69148

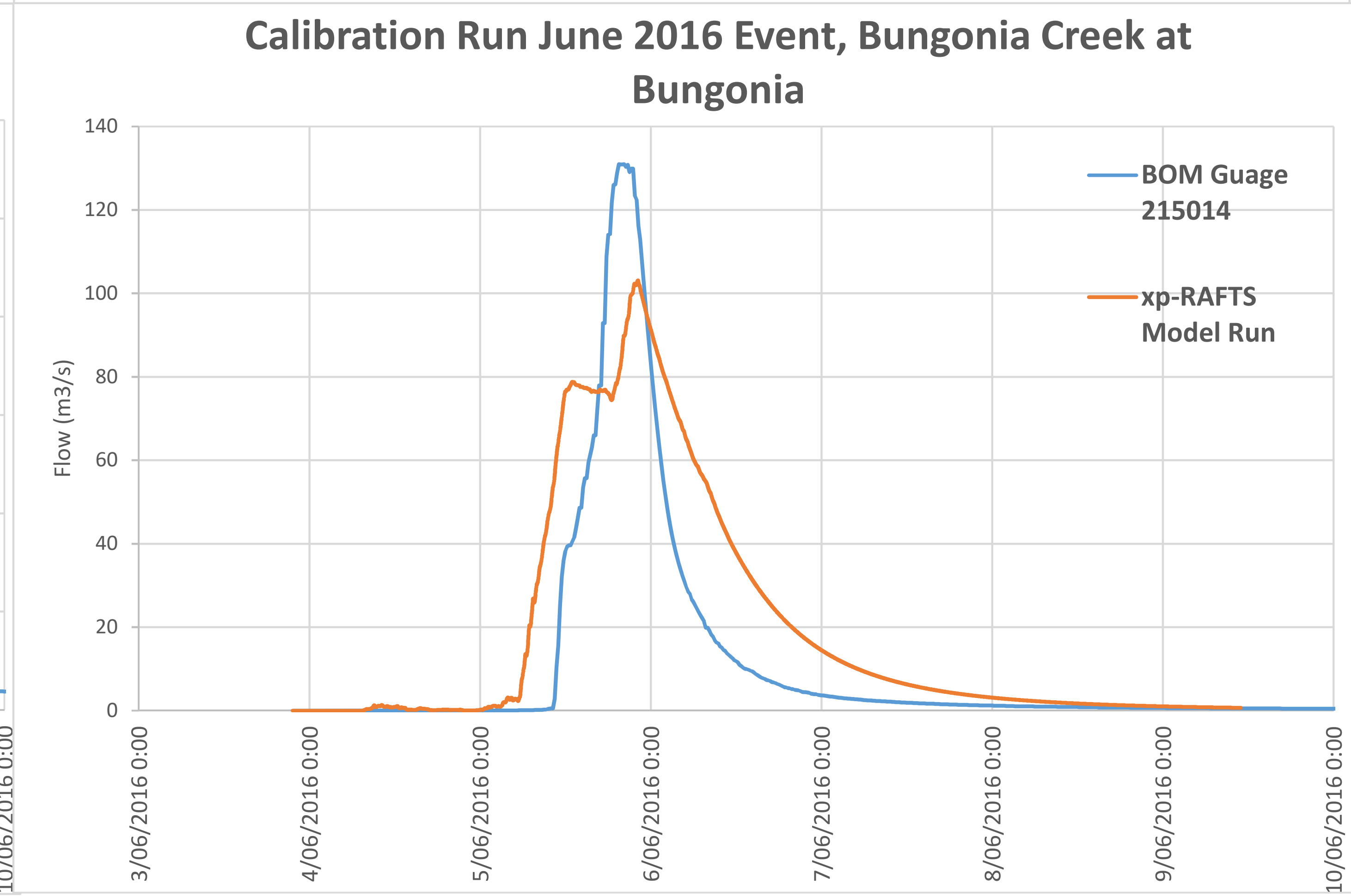


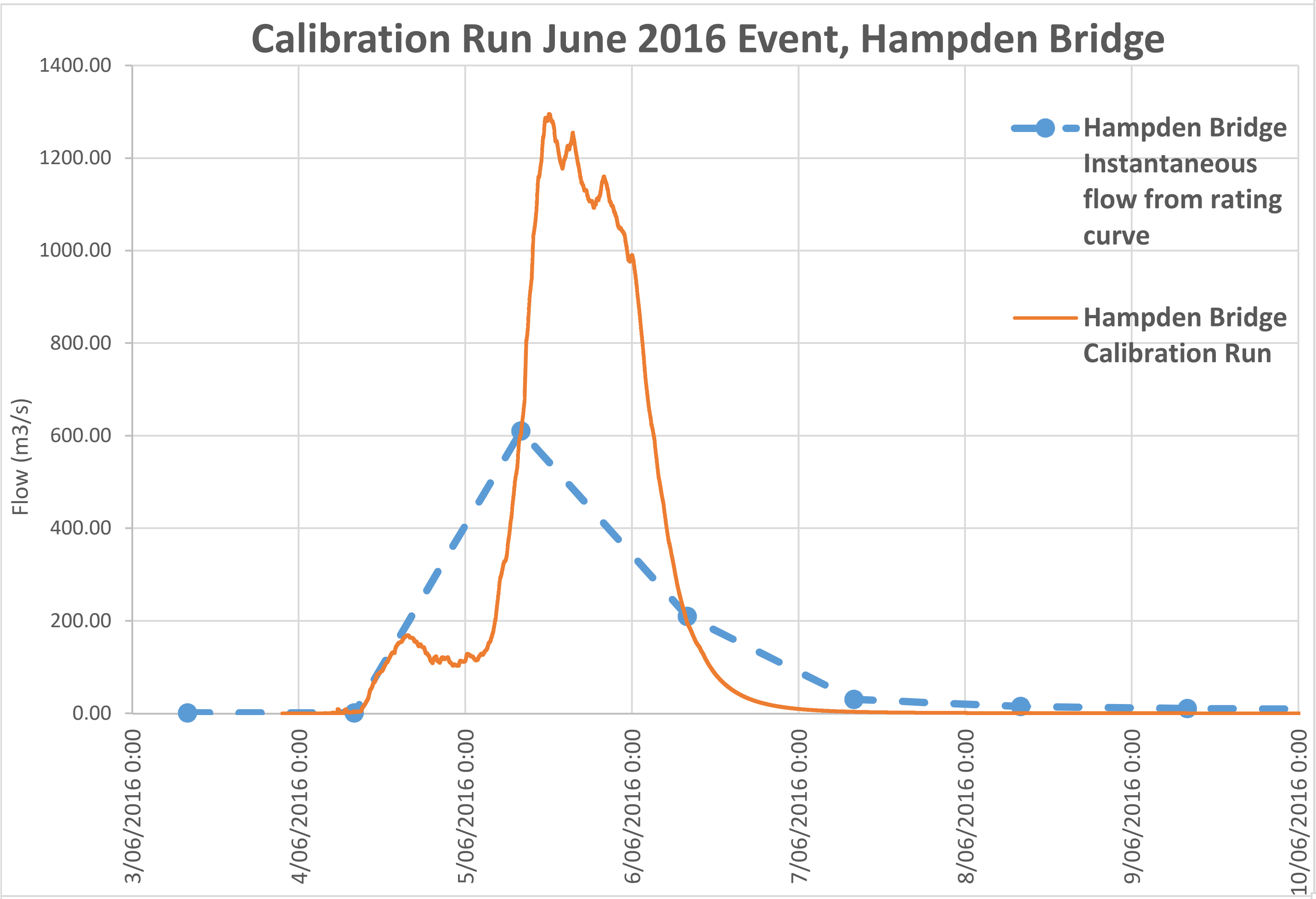
June 2016 Event Gauge Data Flow Comparison
Flow (m3/s)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2/06/2016 0:00
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
11/06/2016 0:00
12/06/2016 0:00
Hampden Bridge Instant flow at 8am (m3/s)
Fossikers Flat Instant flow at 8am (m3/s)
Burrier Instant flow at 8am (m3/s)
Tallowa Dam Instantaneous flow from rating curve (m3/s @ 8am)

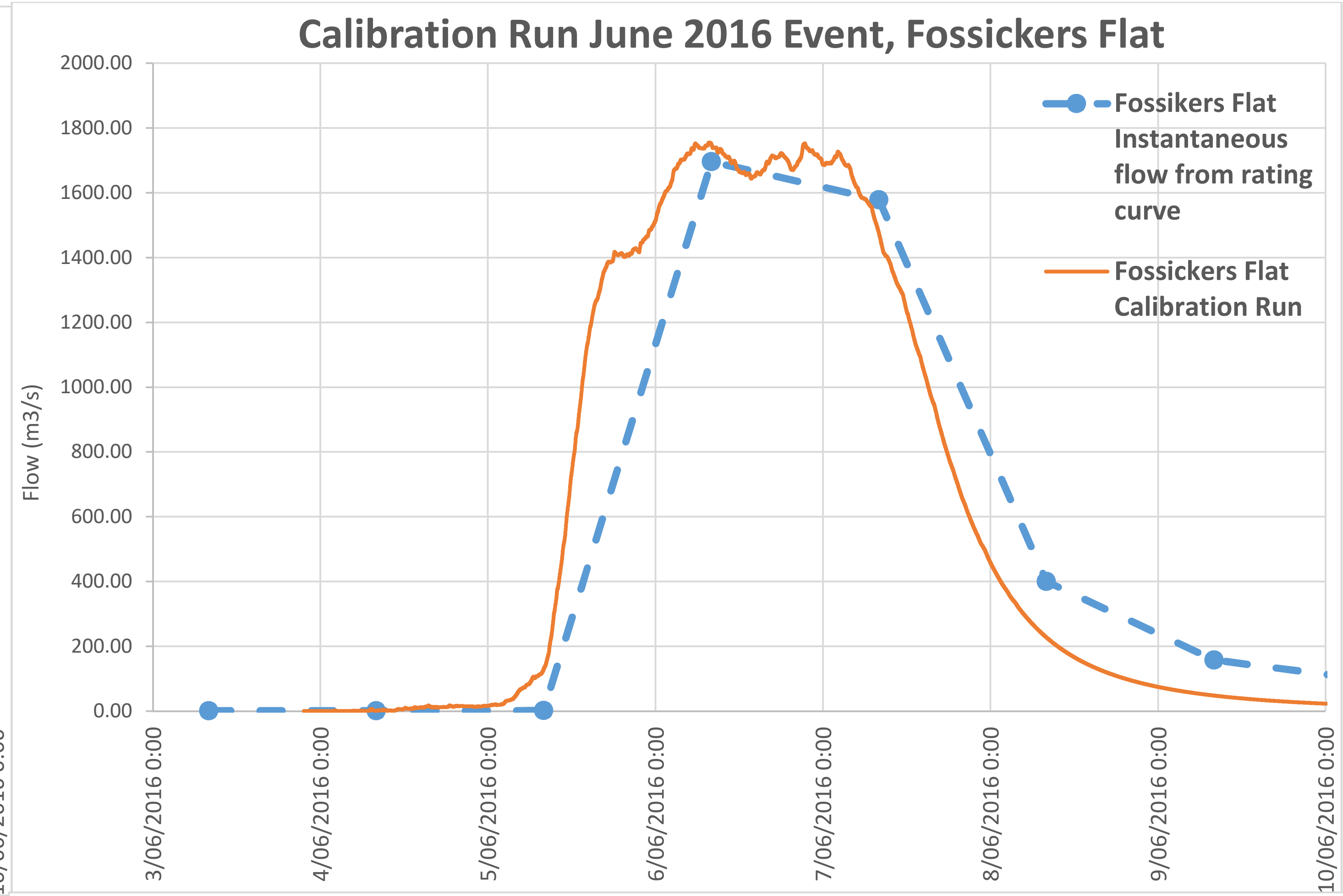

Calibration Run June 2016 Event, Shoalhaven River at Kadoona
Flow (m3/s)
0
50
100
150
200
250
300
350
400
450
500
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215008
xp-RAFTS Model Run

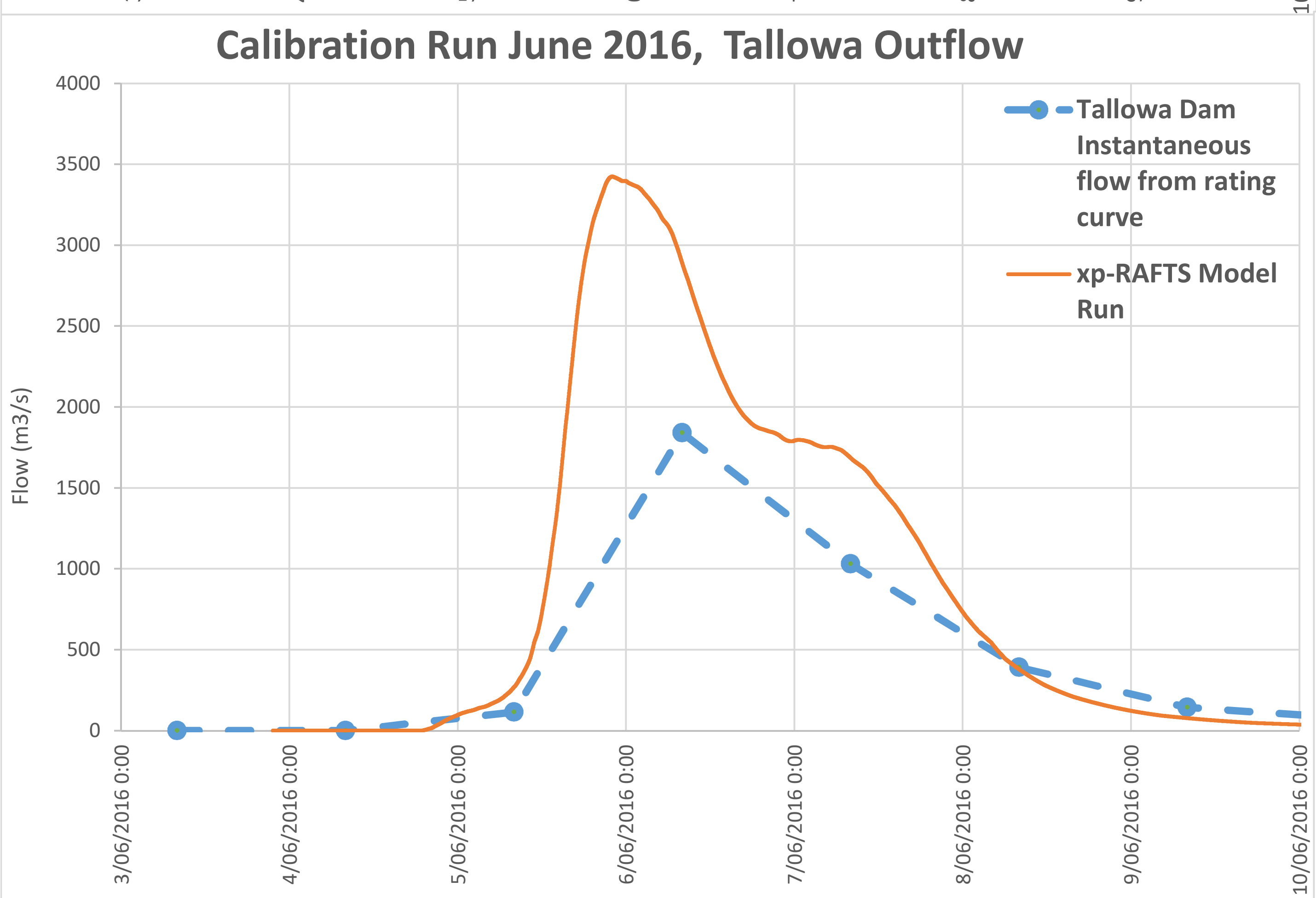

Calibration Run June 2016 Event, Mongarlowe River at Monga
Flow (m3/s)
0
10
20
30
40
50
60
70
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215007
xp-RAFTS Model Run

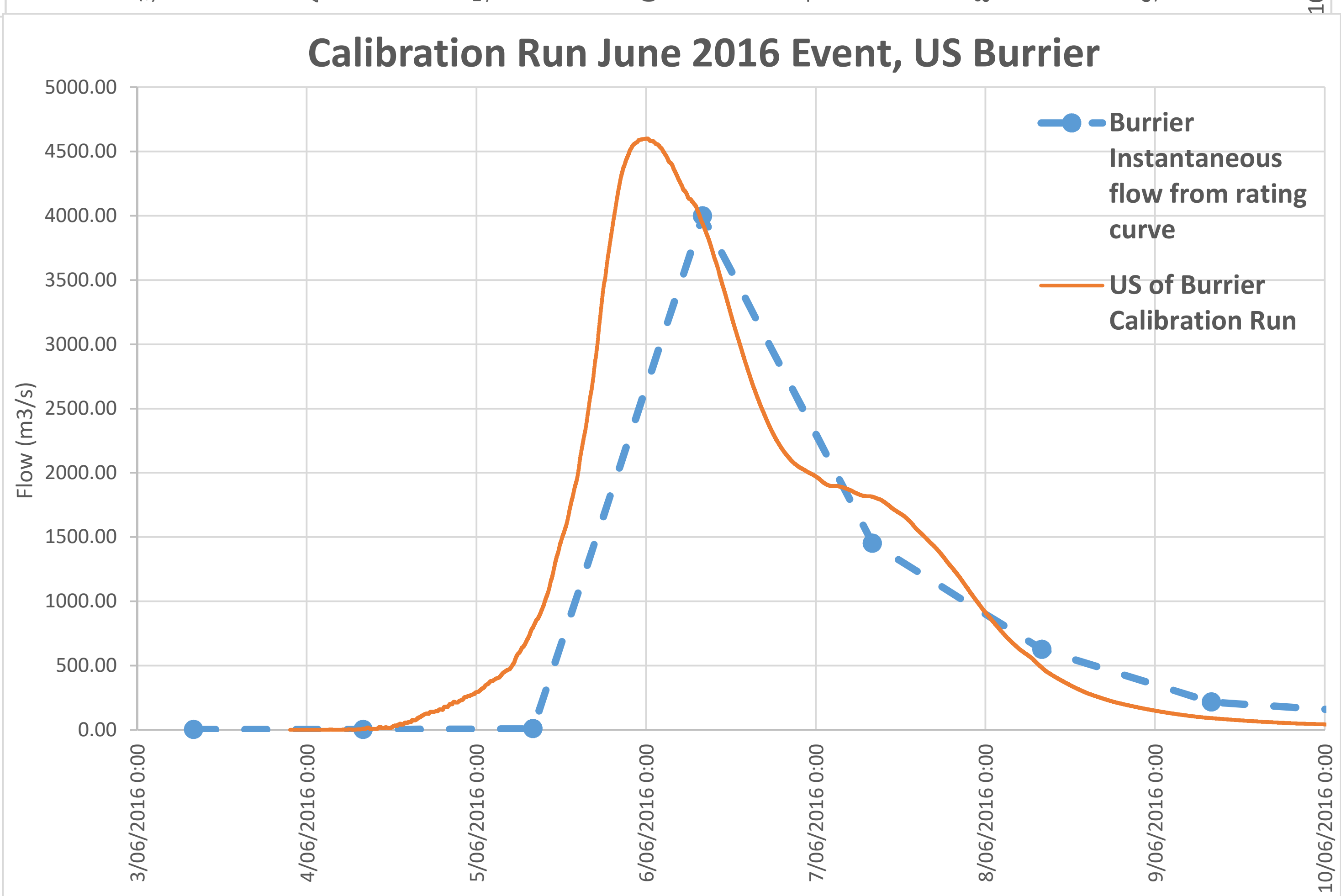

Calibration Run June 2016 Event, Shoalhaven River at Warri
Flow (m3/s)
0
200
400
600
800
1000
1200
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215002
xp-RAFTS Model Run

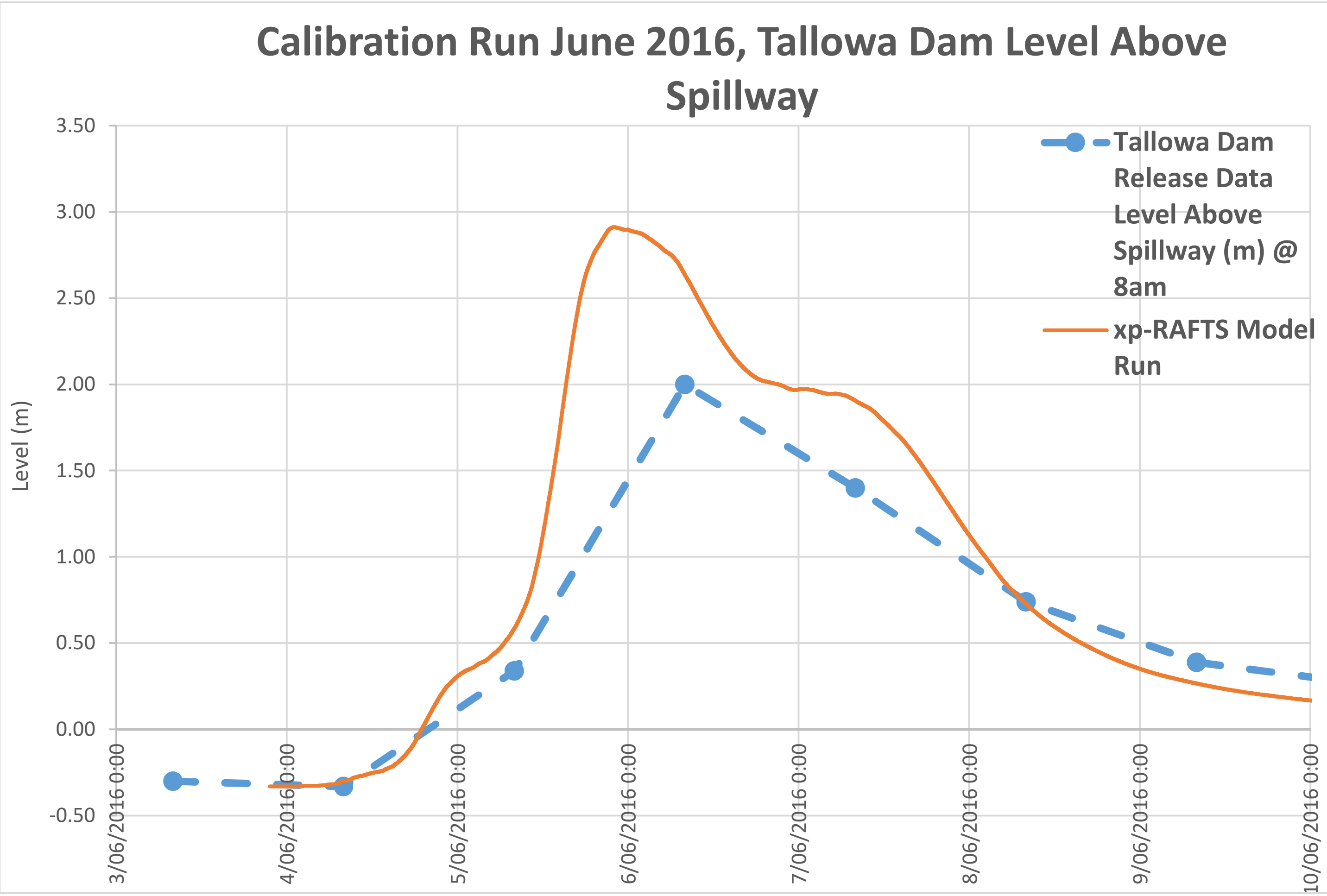

Calibration Run June 2016 Event, Bungonia Creek at Bungonia
Flow (m3/s)
0
20
40
60
80
100
120
140
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215014
xp-RAFTS Model Run

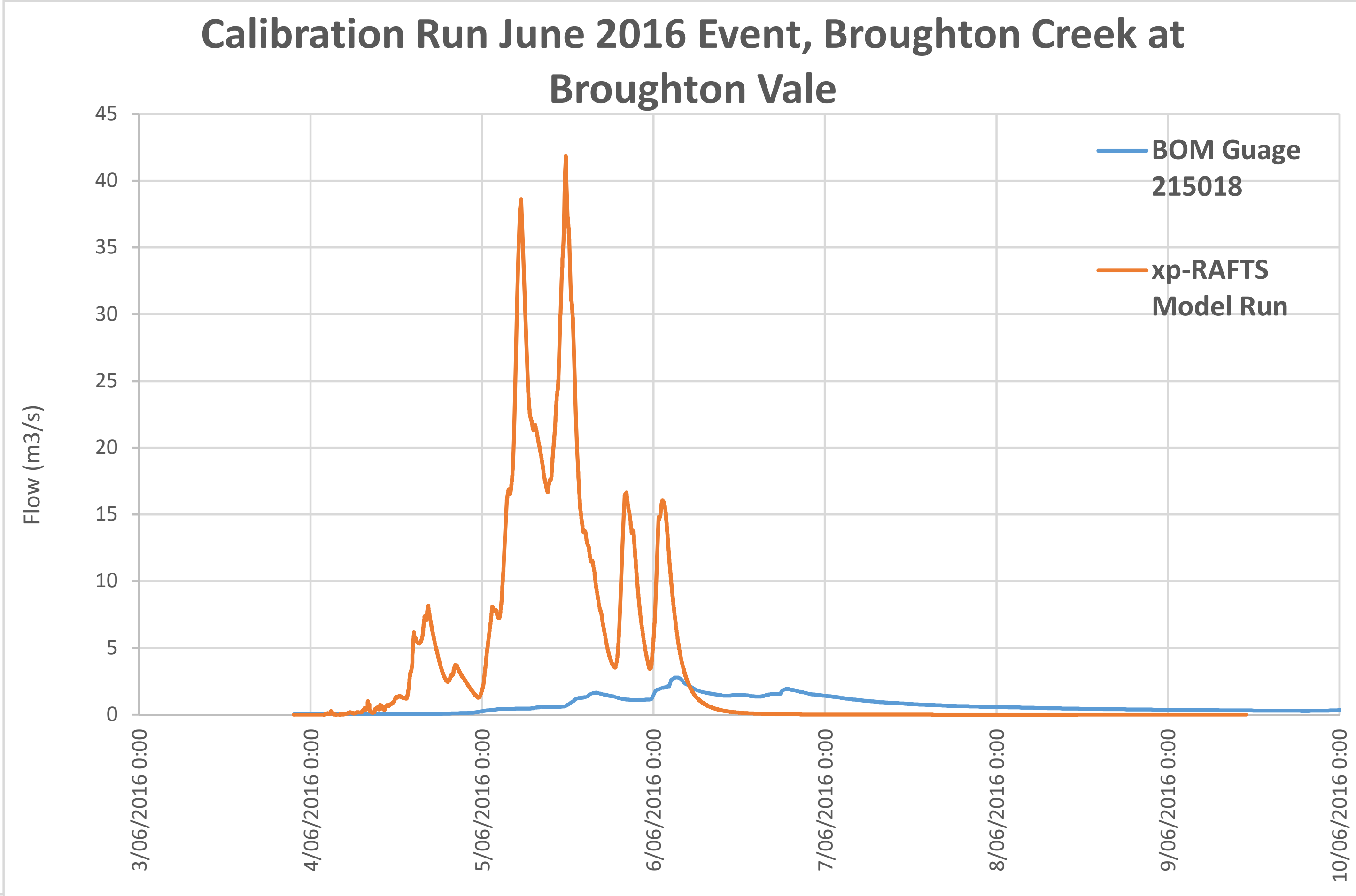

Calibration Run June 2016 Event, Hampden Bridge
Flow (m3/s)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
Hampden Bridge Instantaneous flow from rating curve
Hampden Bridge Calibration Run

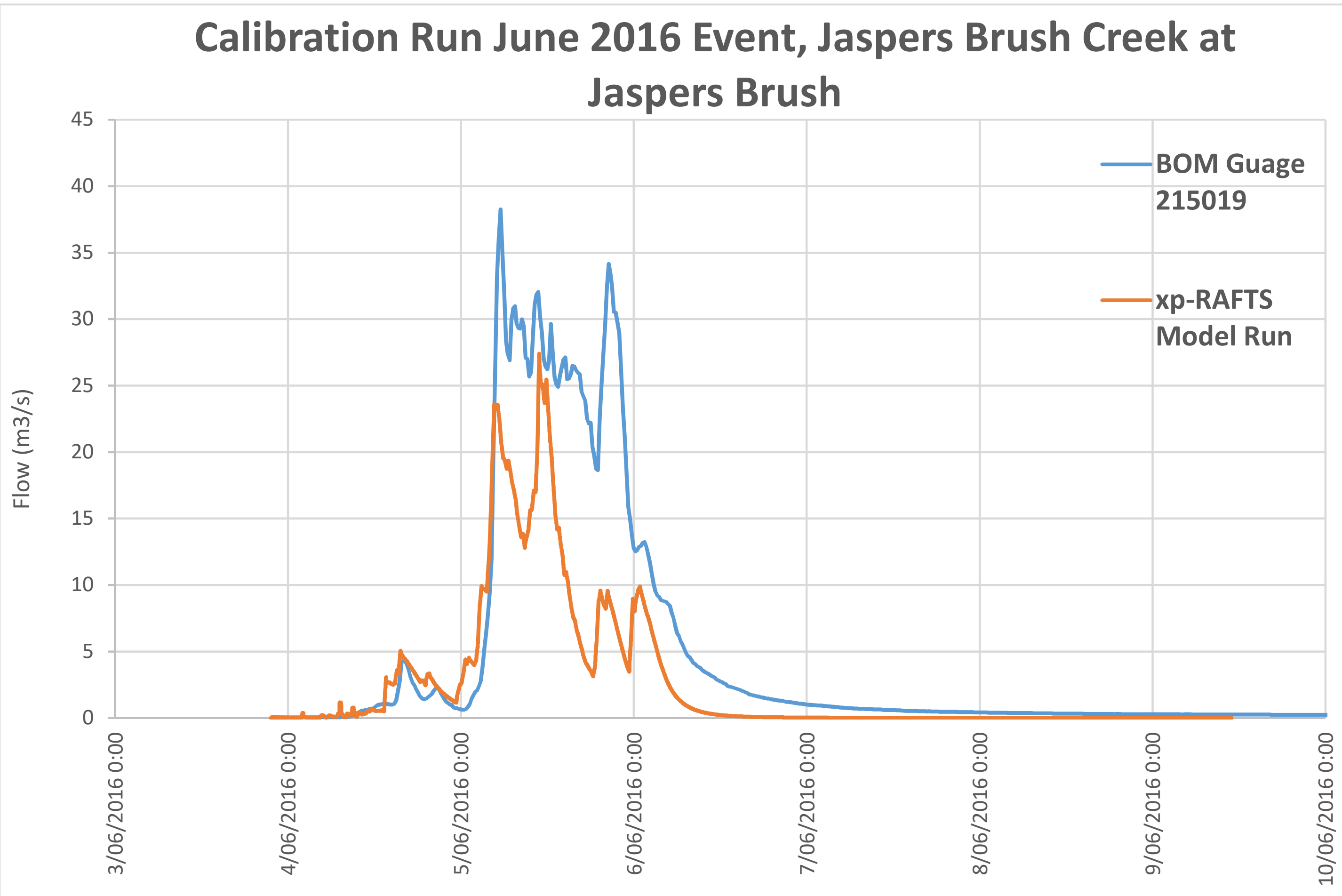

Calibration Run June 2016 Event, Fossickers Flat
Flow (m3/s)
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
Fossikers Flat Instantaneous flow from rating curve
Fossickers Flat Calibration Run

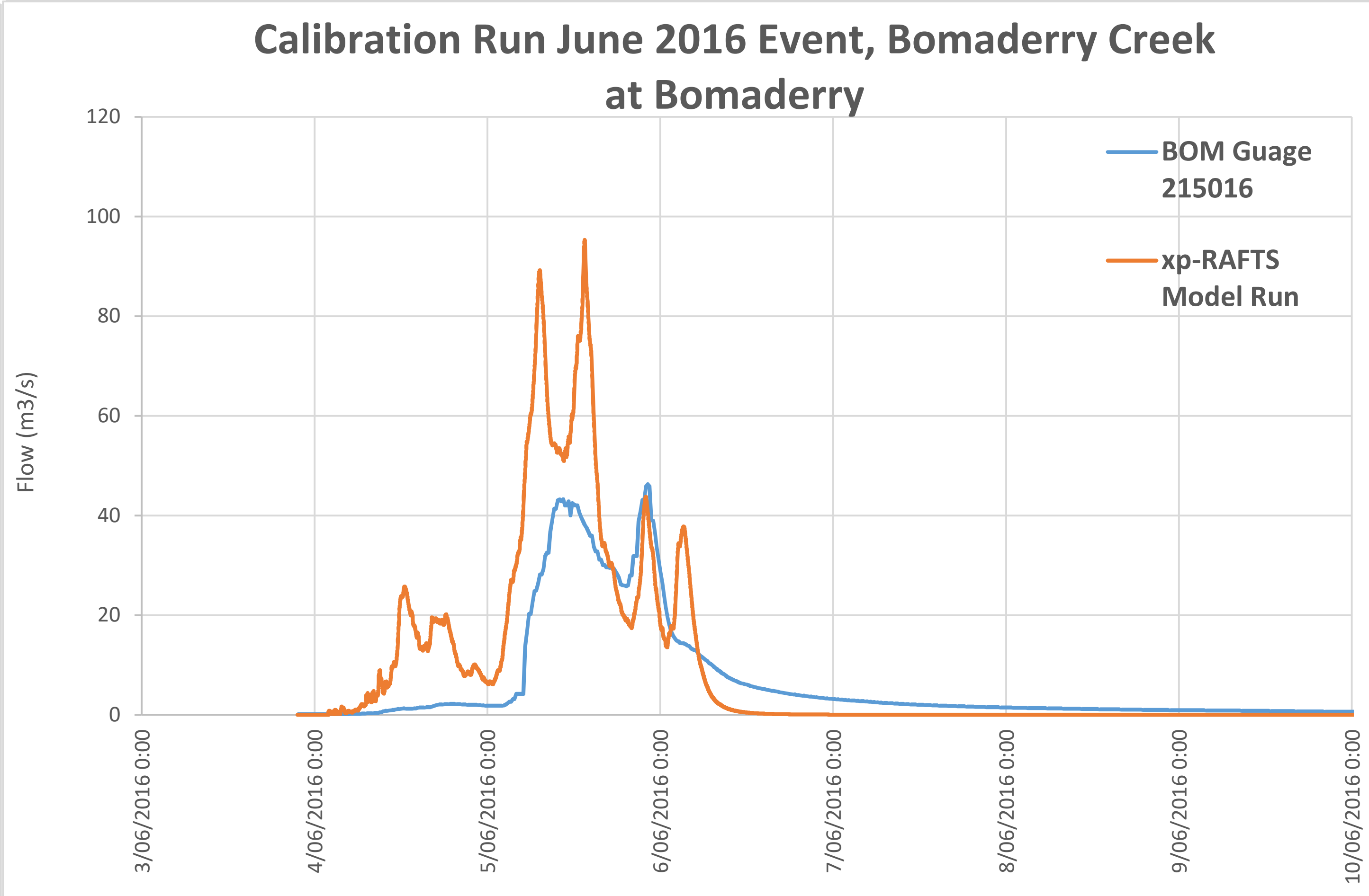

Calibration Run June 2016, Tallowa Outflow
Flow (m3/s)
4000
3500
3000
2500
2000
1500
1000
500
0
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
Tallowa Dam Instantaneous flow from rating curve
xp-RAFTS Model Run


Calibration Run June 2016 Event, US Burrier
Flow (m3/s)
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
Burrier Instantaneous flow from rating curve
US of Burrier Calibration Run


Calibration Run June 2016, Tallowa Dam Level Above Spillway
Level (m)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
Tallowa Dam Release Data Level Above Spillway (m) @ 8am
xp-RAFTS Model Run


Calibration Run June 2016 Event, Broughton Creek at Broughton Vale
Flow (m3/s)
45
40
35
30
25
20
15
10
5
0
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215018
xp-RAFTS Model Run

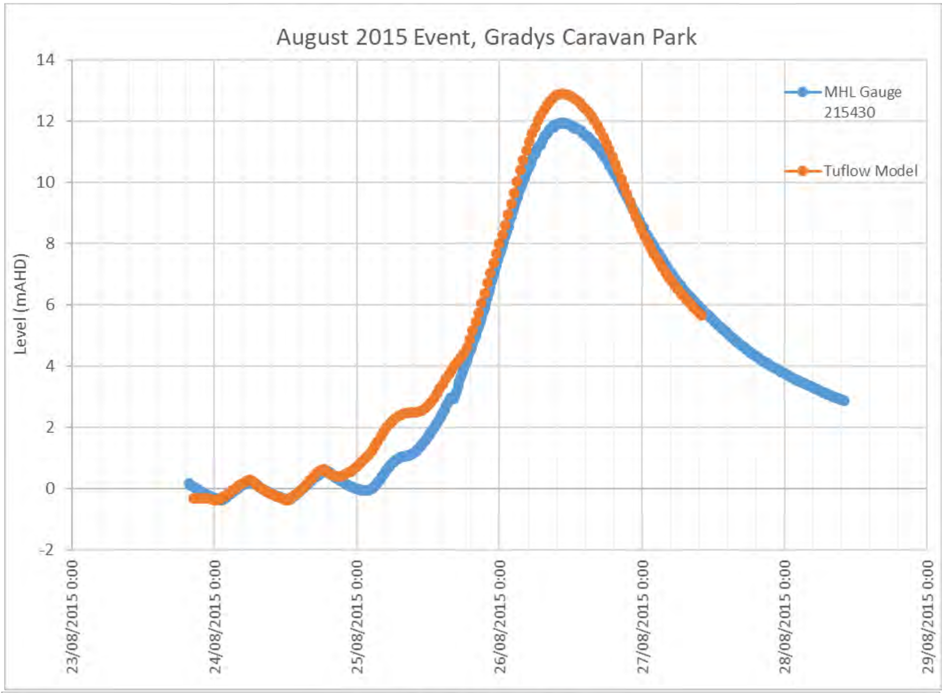

Calibration Run June 2016 Event, Jaspers Brush Creek at Jaspers Brush
Flow (m3/s)
45
40
35
30
25
20
15
10
5
0
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215019
xp-RAFTS Model Run

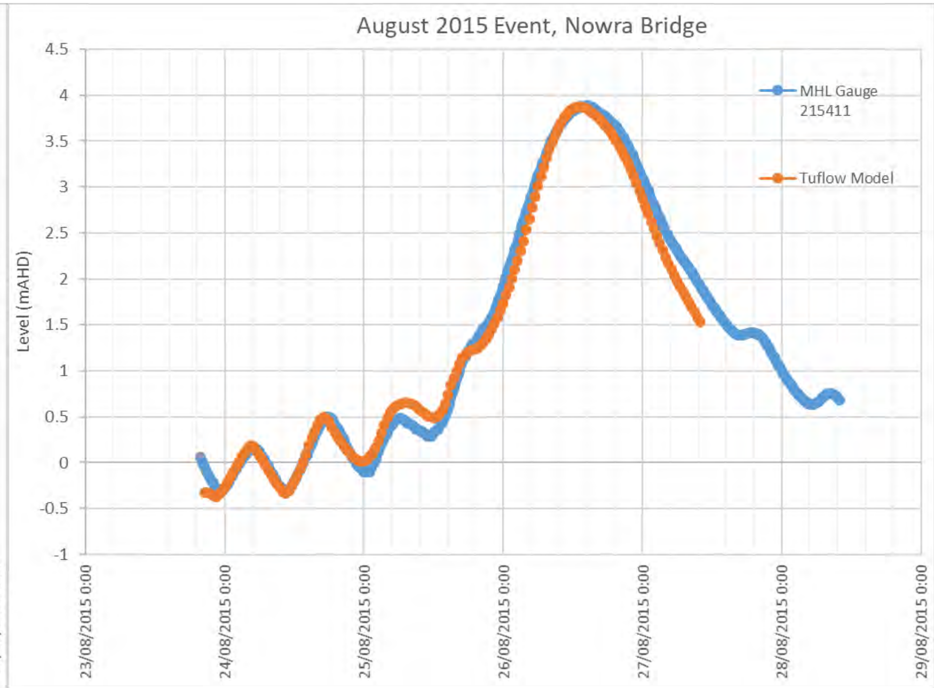

Calibration Run June 2016 Event, Bomaderry Creek at Bomaderry
Flow (m3/s)
120
100
80
60
40
20
0
3/06/2016 0:00
4/06/2016 0:00
5/06/2016 0:00
6/06/2016 0:00
7/06/2016 0:00
8/06/2016 0:00
9/06/2016 0:00
10/06/2016 0:00
BOM Guage 215016
xp-RAFTS Model Run

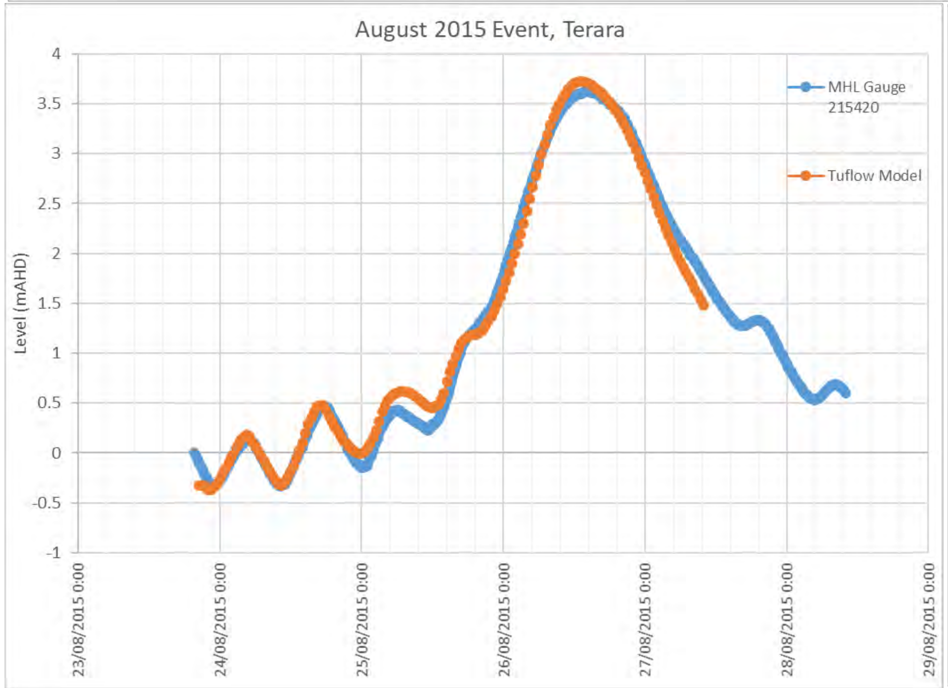
APPENDIX

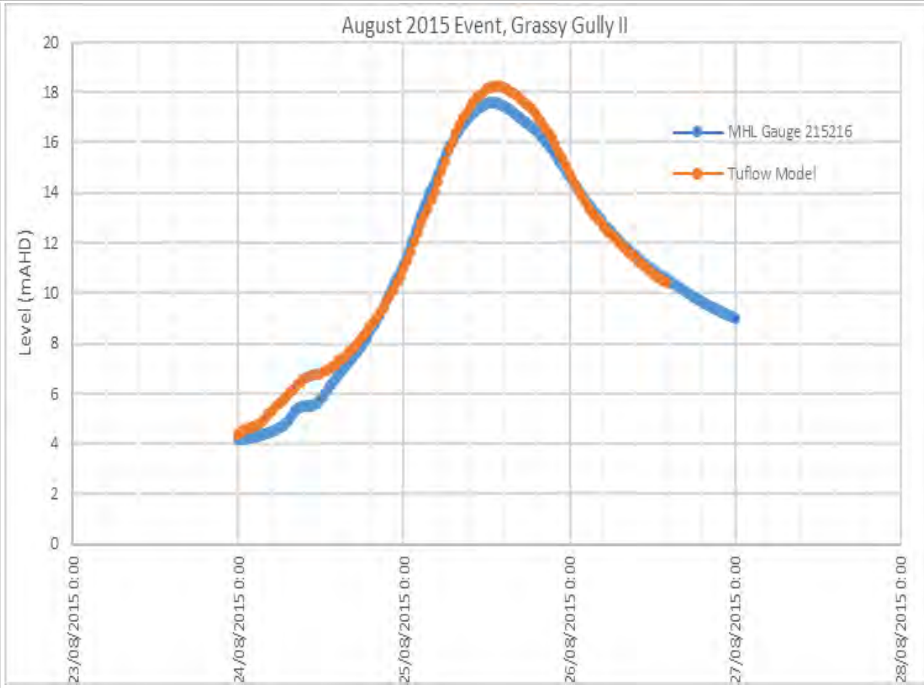
C

HYDRAULIC MODEL - CALIBRATION AND VALIDATION


August 2015 Event, Gradys Caravan Park
Level (mAHD)
14
12
10
8
6
4
2
0
-2
MHL Gauge 215430
Tuflow Model
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00


August 2015 Event, Nowra Bridge
Level (mAHD)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
MHL Gauge 215411
Tuflow Model
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00


August 2015 Event, Terara
Level (mAHD)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
MHL Gauge 215420
Tuflow Model
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
26/08/2015 0:00
27/08/2015 0:00
28/08/2015 0:00
29/08/2015 0:00


August 2015 Event, Grassy Gully II
Level (mAHD)
20
18
16
14
12
10
8
6
4
2
0
MHL Gauge 215216
Tuflow Model
23/08/2015 0:00
24/08/2015 0:00
25/08/2015 0:00
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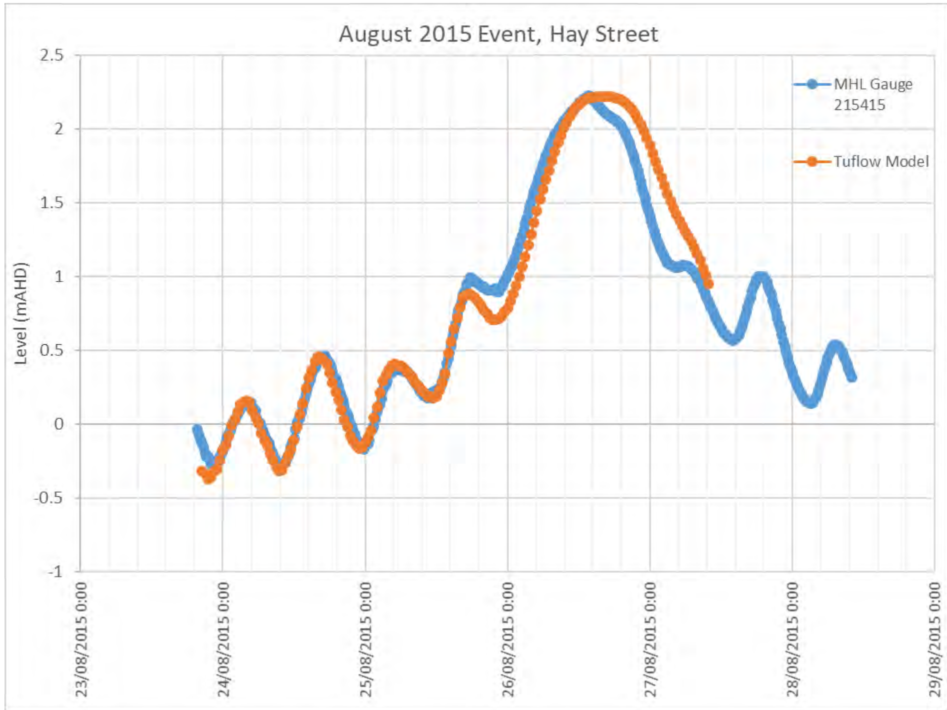
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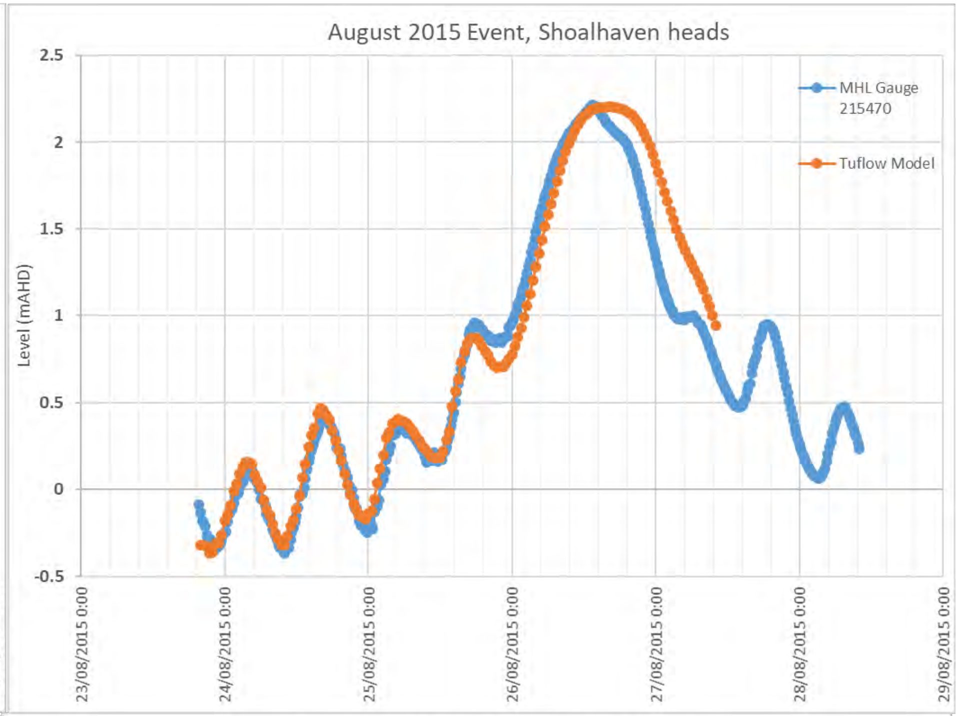
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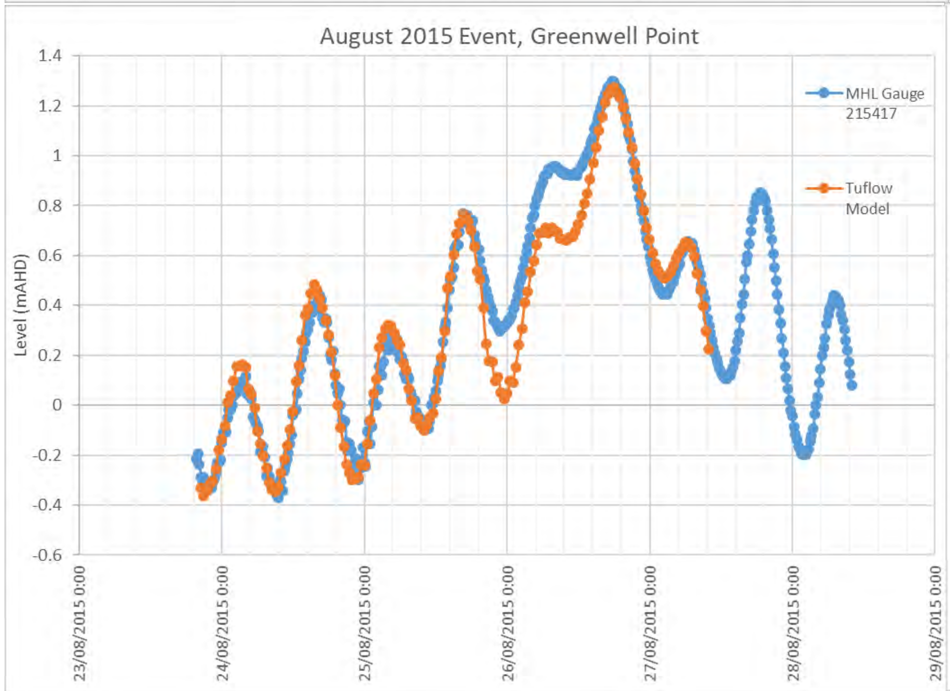
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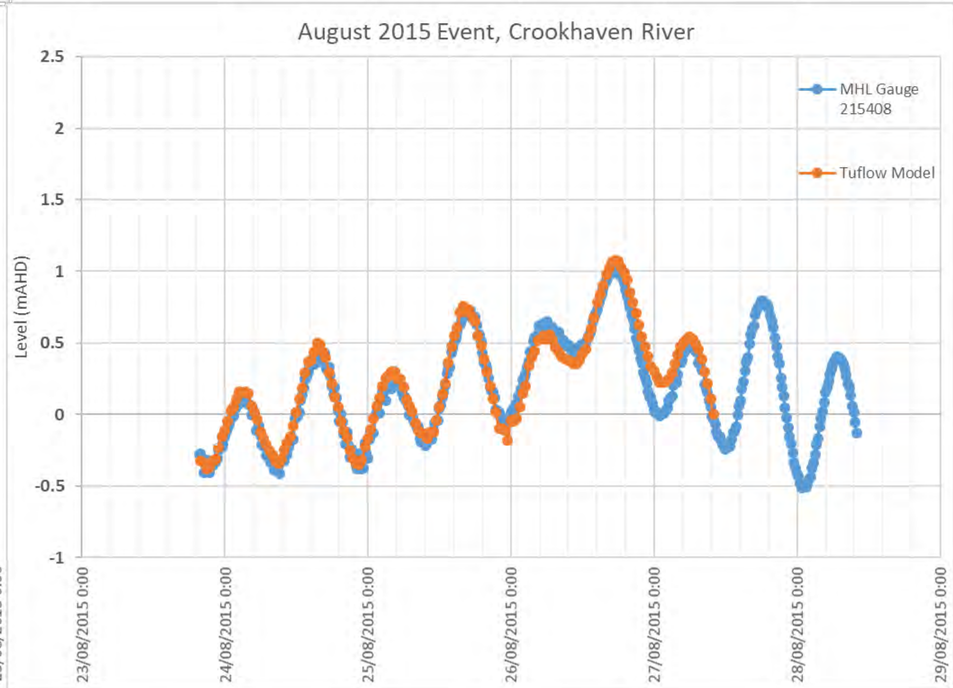
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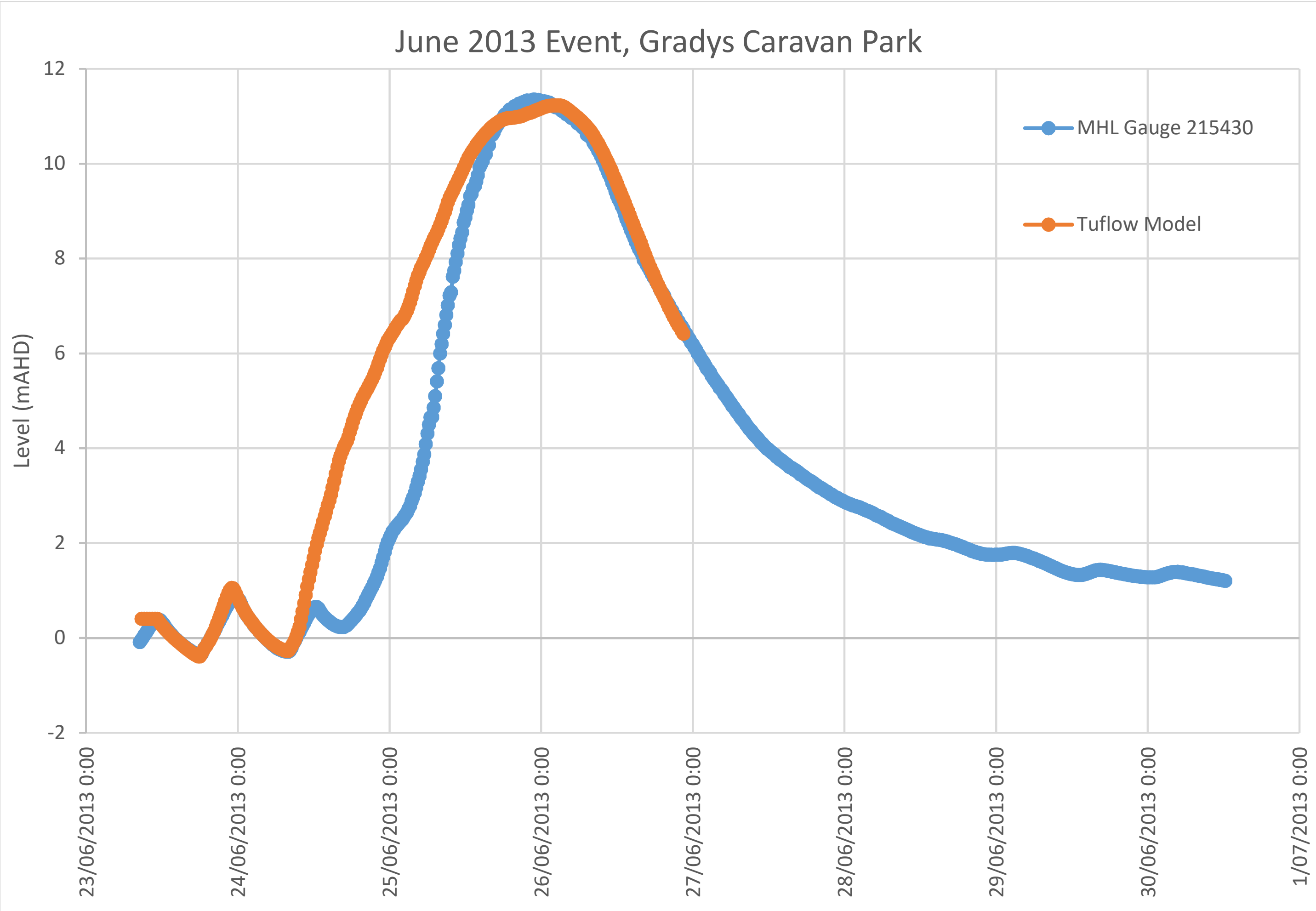
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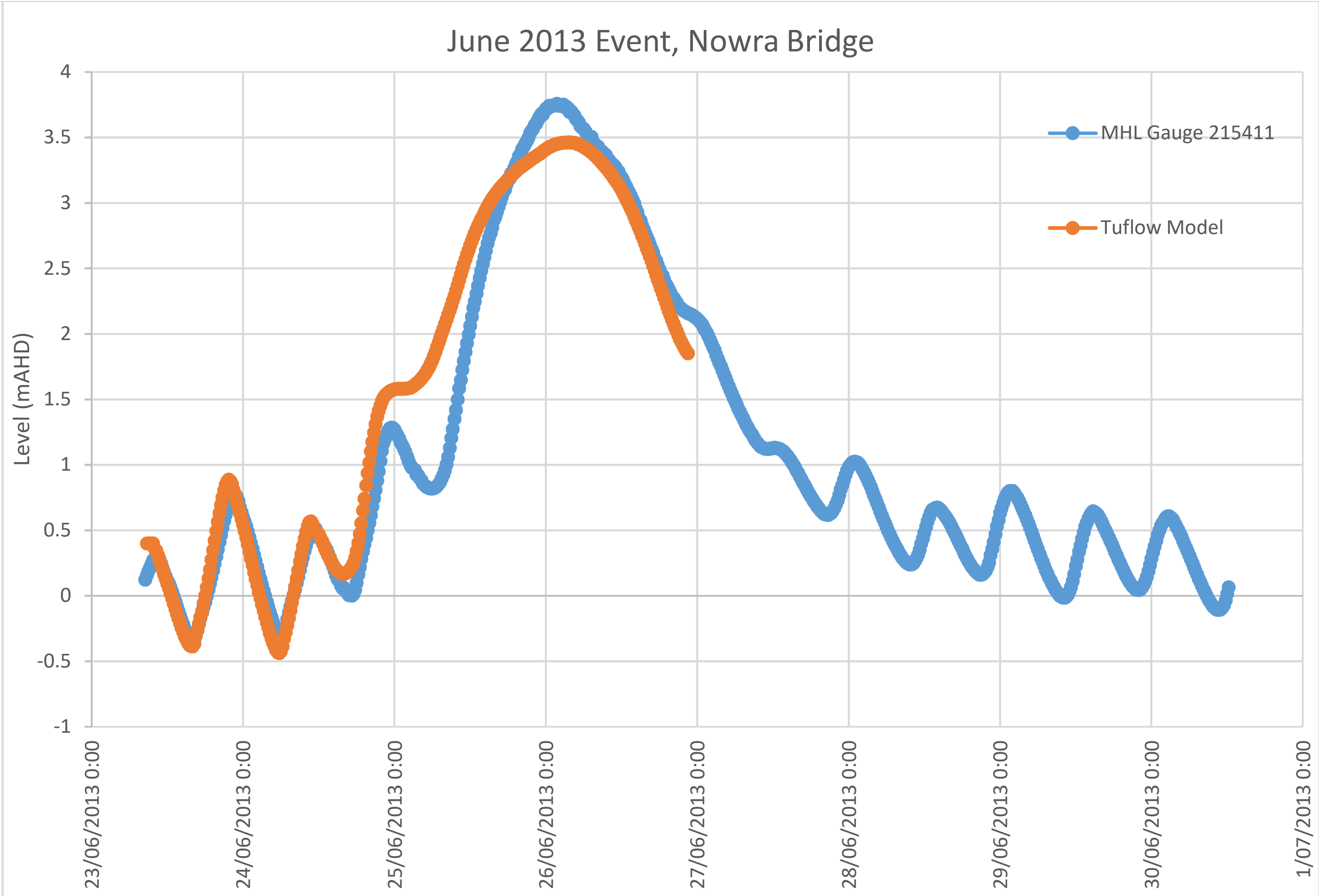
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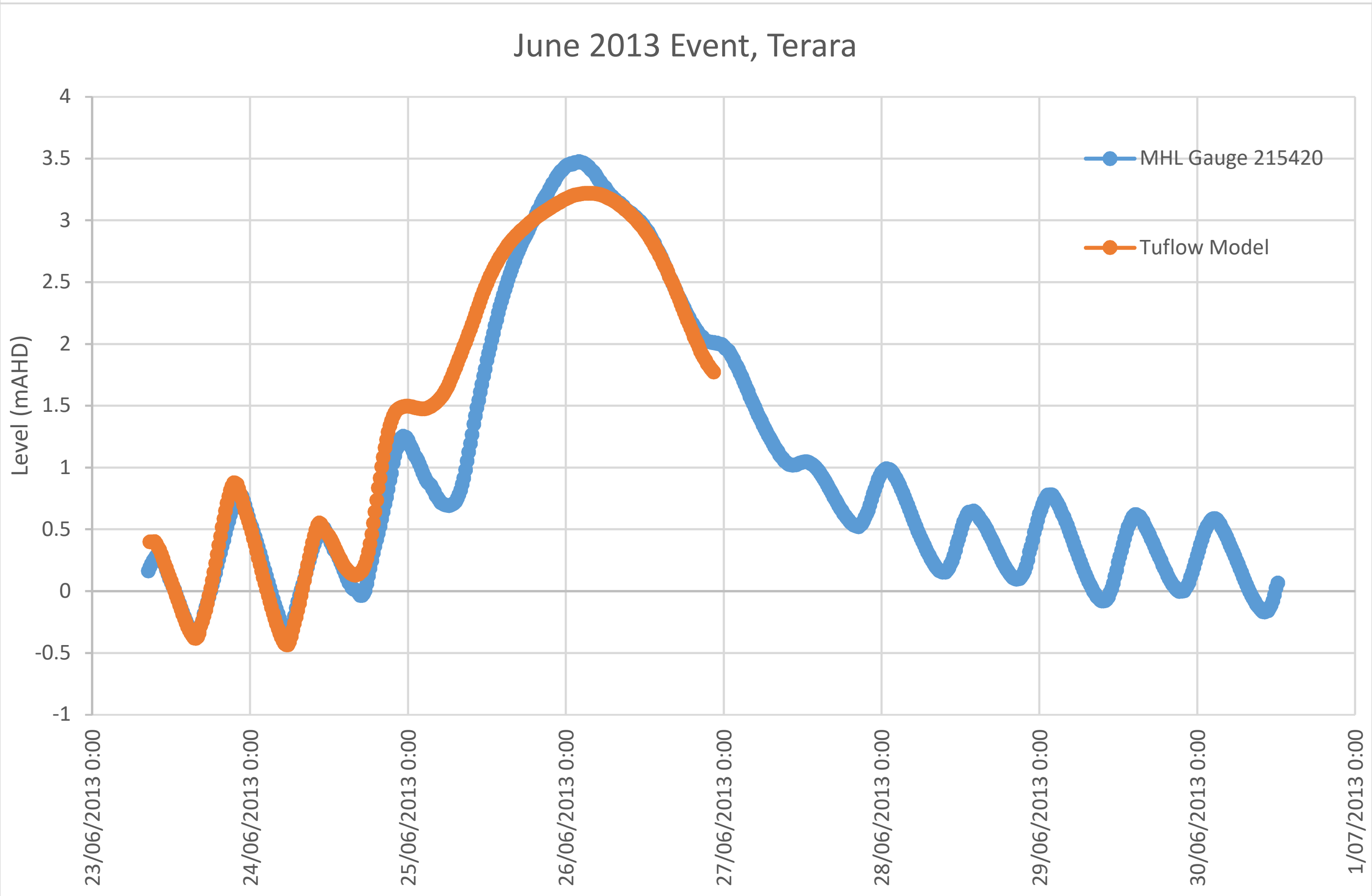
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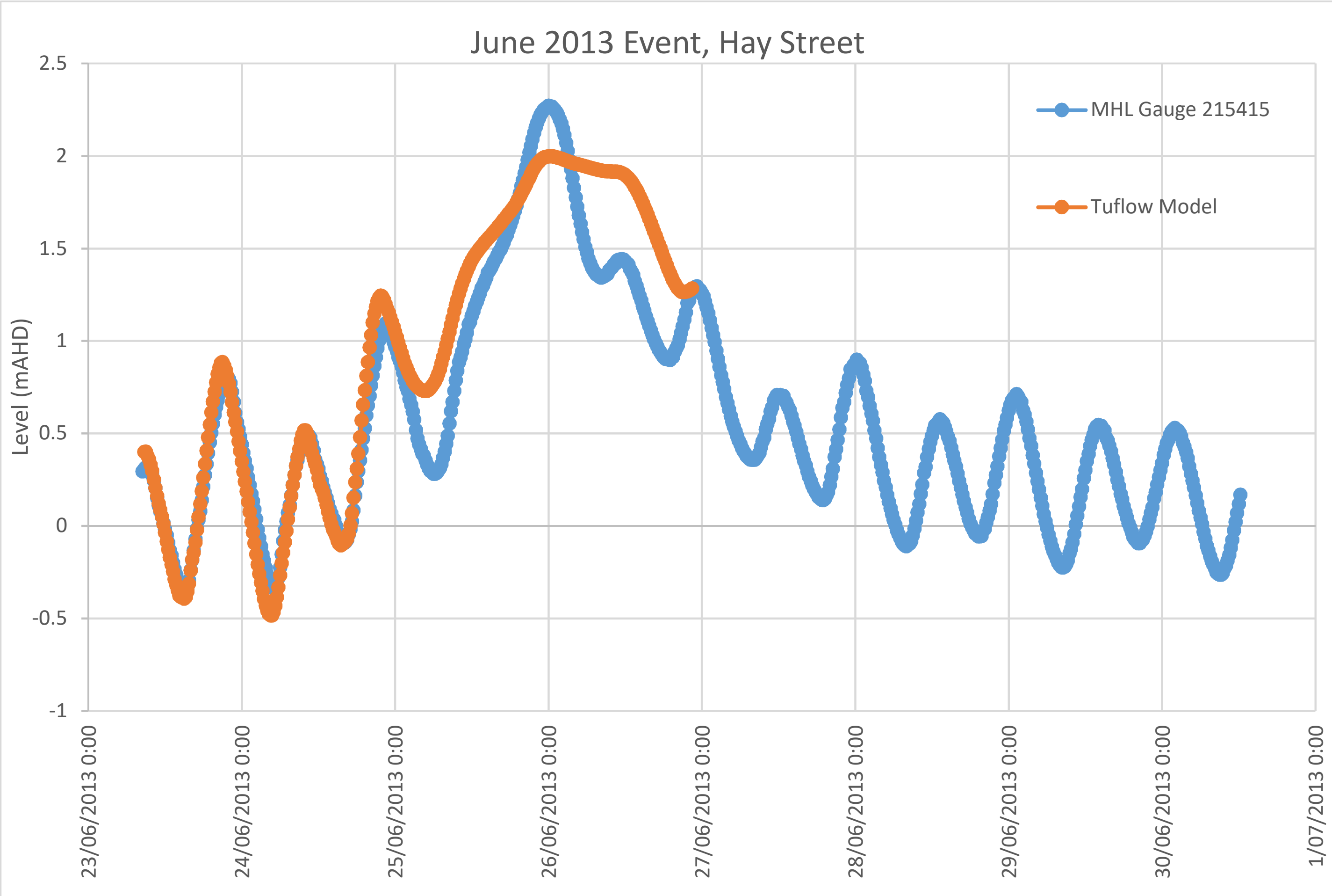
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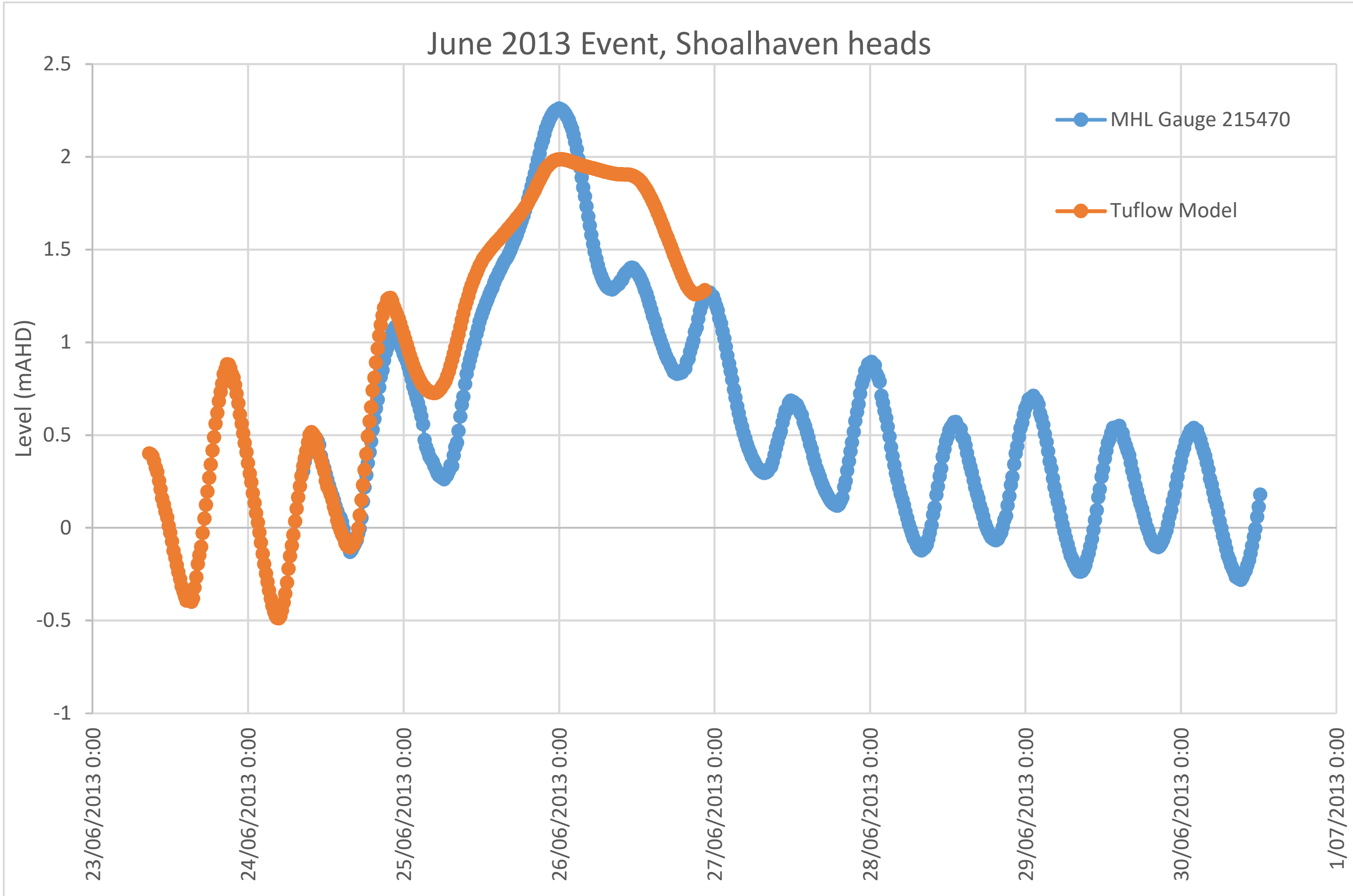
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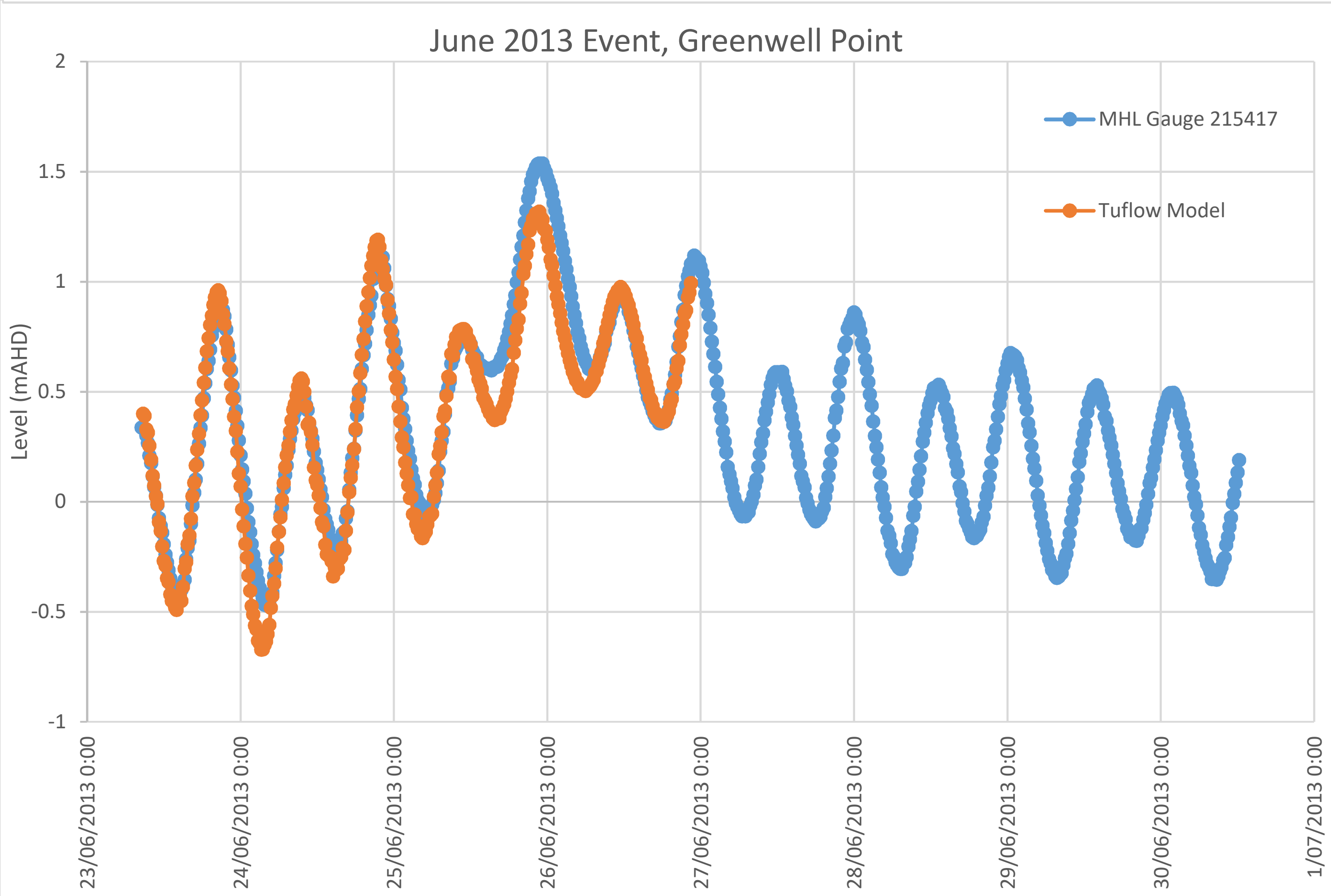
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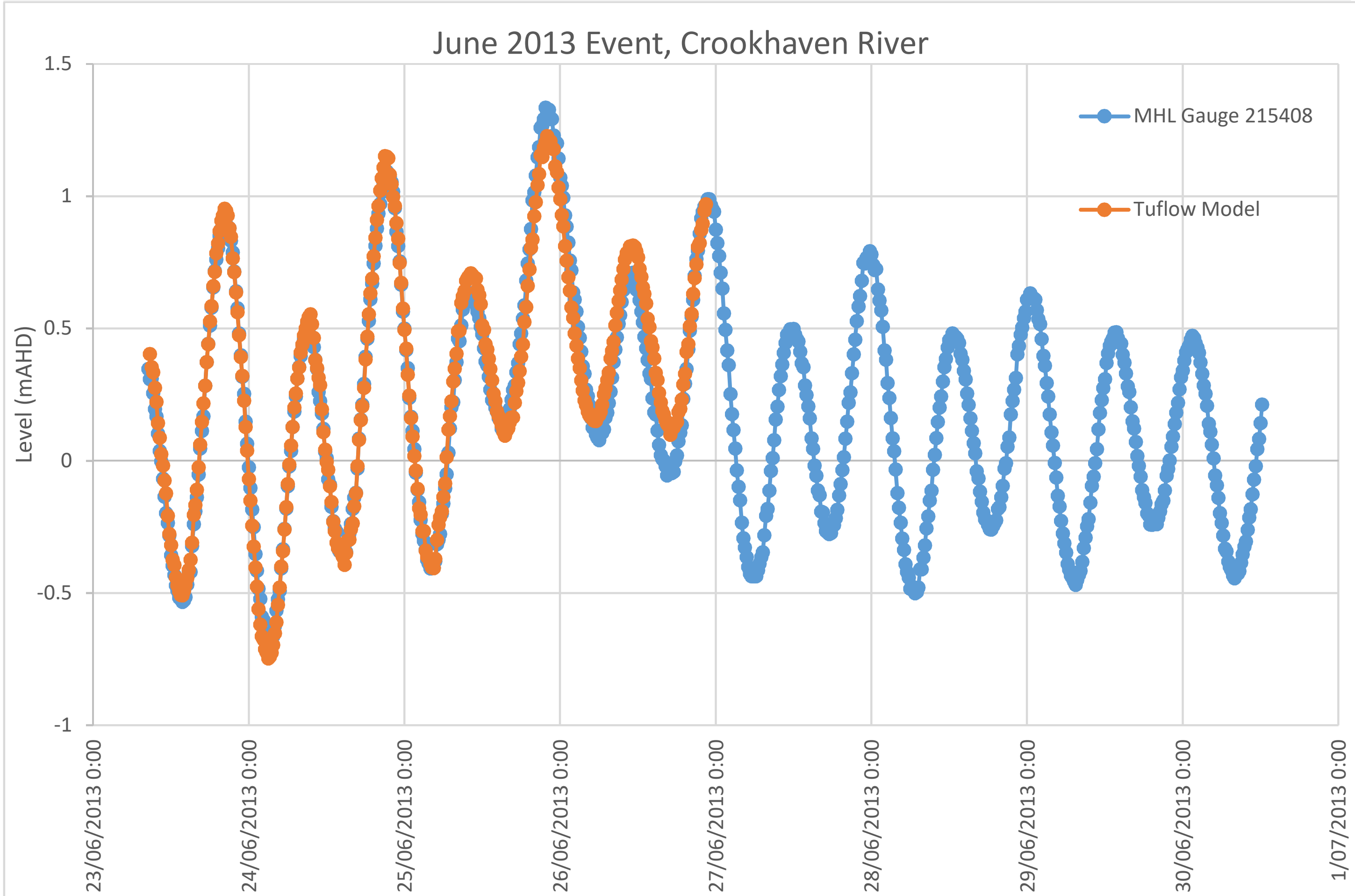
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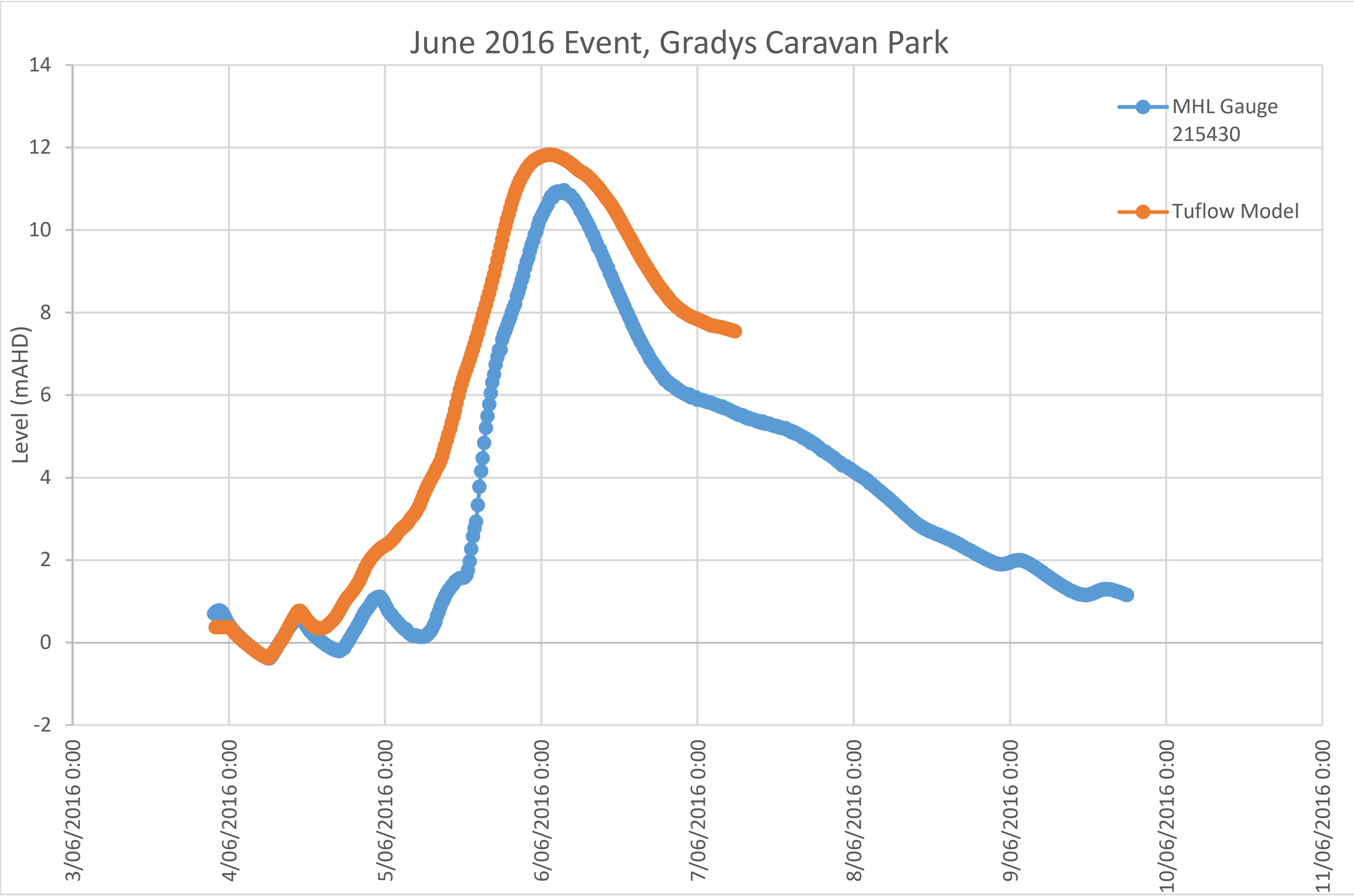
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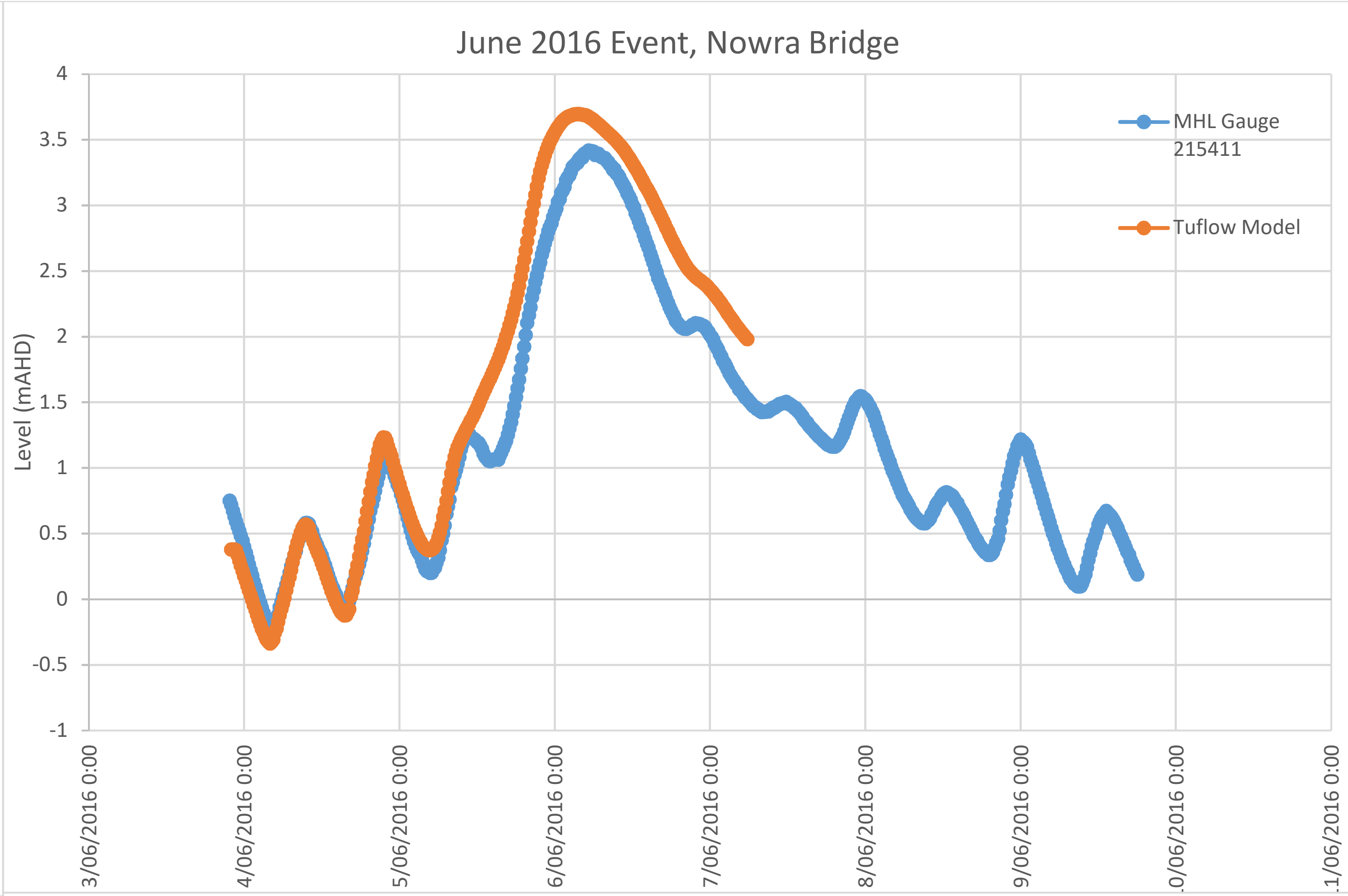
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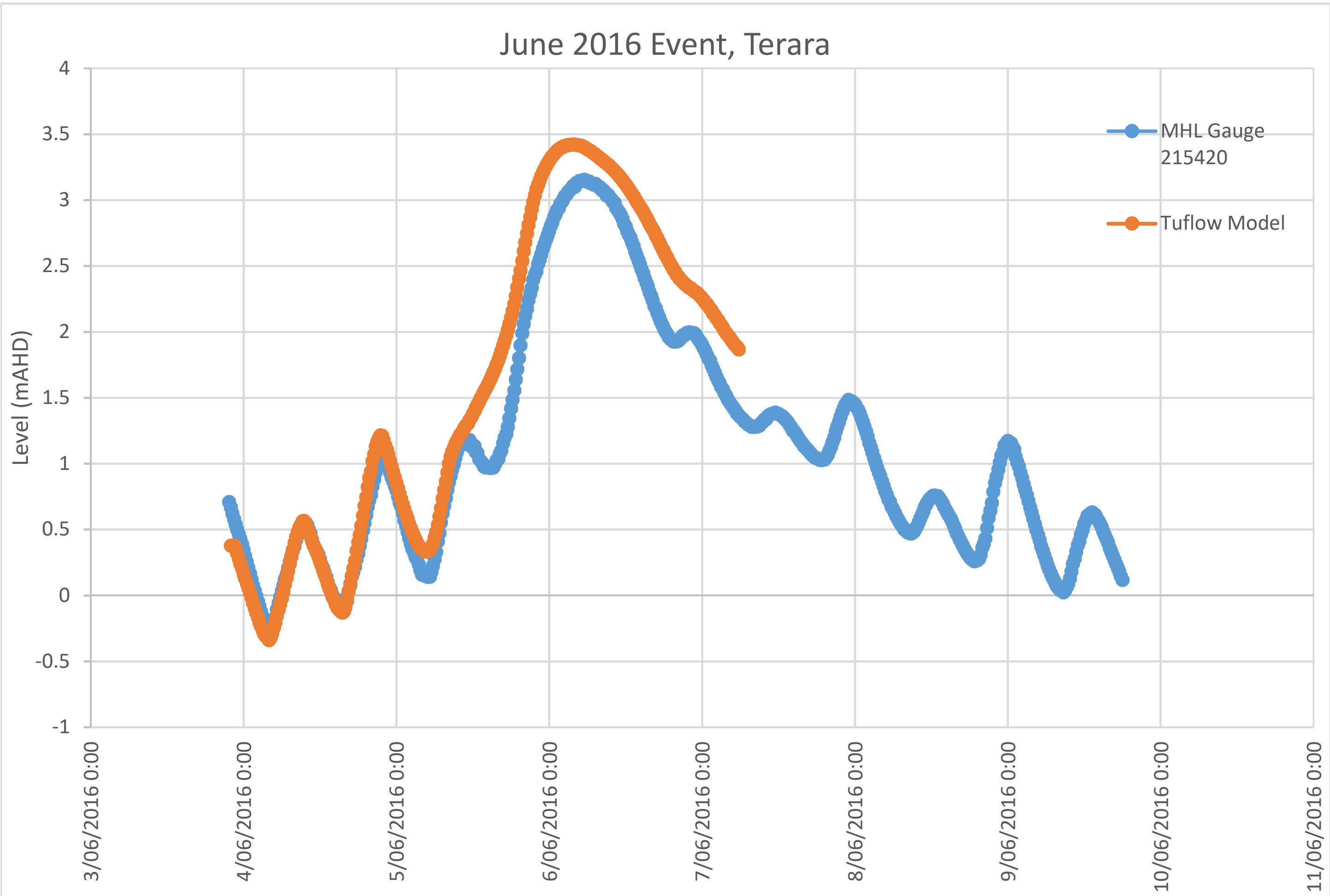
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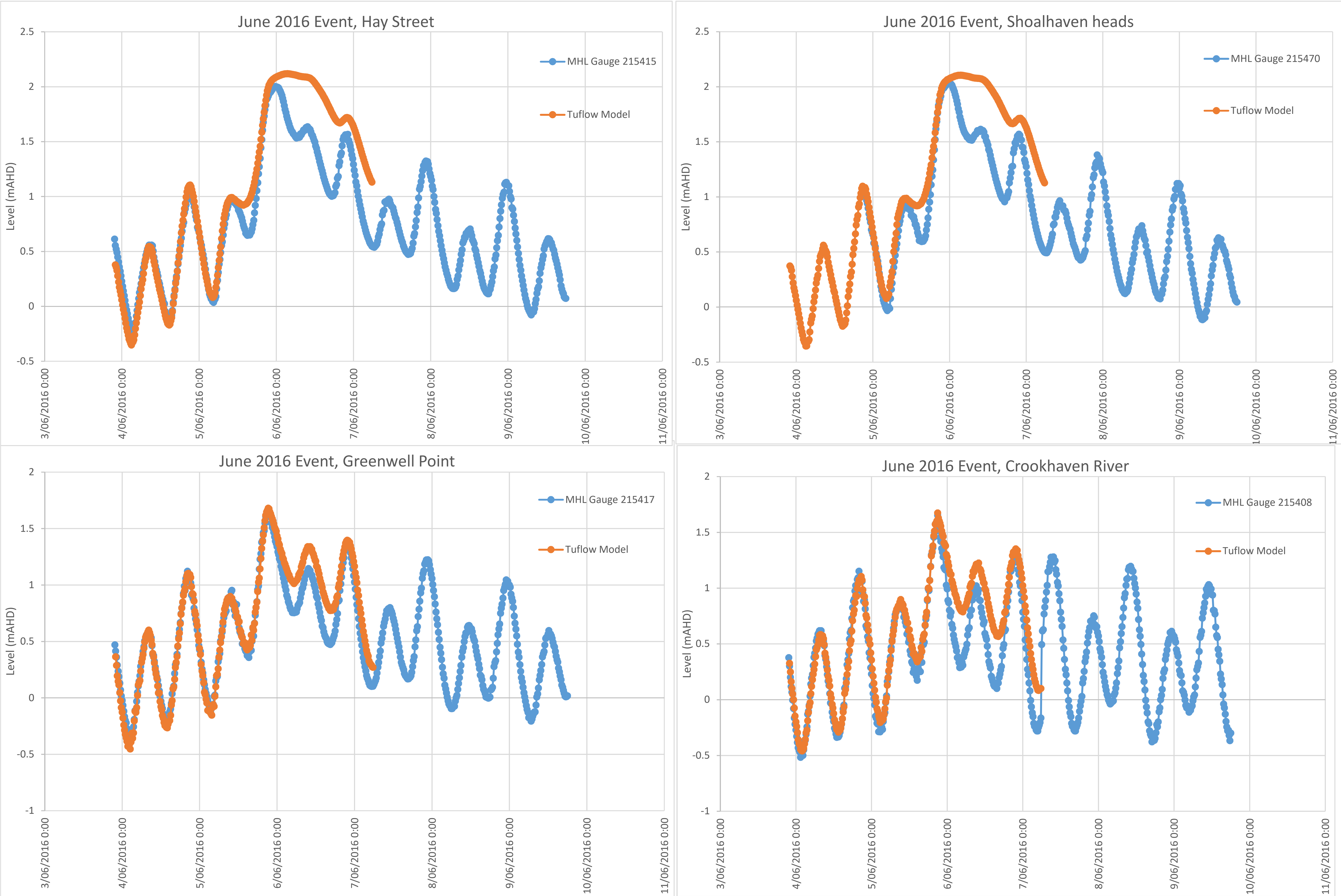
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June 2016 Event, Crookhaven River
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APPENDIX

D

COMMUNITY CONSULTATION REPORT

Stage 2 - Consultation

Lower Shoalhaven River Floodplain Risk Management Study and Plan

59918099

Prepared for
Shoalhaven City Council

28 Feb 2019

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Document Information

Prepared for	Shoalhaven City Council
Project Name	Lower Shoalhaven River Floodplain Risk Management Study and Plan
File Reference	59918099_R002_RevA_Stage 2 Consultation.docx
Job Reference	59918099
Date	18 Feb 2019
Version Number	RevA

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Effective Date 28/02/2019

Approved By:

David Whyte
Principal Engineer

Date Approved 28/02/2019

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
RevA	28/02/2019	Draft Consultation Report	Abhishek Gupta	David Whyte

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1 Consultation

1.1 Consultation Process

Consultation with the community and stakeholders is an important component in the development of a Floodplain Risk Management Study and Plan. Consultation provides an opportunity to collect feedback and observations from the community on problem areas and potential floodplain management measures. It also provides a mechanism to inform the community about the current study and flood risk within the study area and seeks to improve their awareness and readiness for dealing with flooding.

Table 1-1 details the community and stakeholder consultation plan that forms basis of the consultation process to be undertaken as part of this study.

Table 1-1 Consultation Plan

Task	Description	Expected Outcome	Status
Media Release & Project Website	Cardno will draft a media release for Council's consideration and publication. Cardno will provide the relevant information to Council to upload onto the project website.	• Public awareness of the study. • Assist in engagement with the community through the newsletter/questionnaire, workshops and public exhibition. • Assist in the public acceptance of the study outcomes and implications for development and floodplain risk management in the future. • Provide key information to the community.	•
Community Newsletter and Questionnaire	Cardno will draft a newsletter and questionnaire for Council's consideration. Once finalised Council will distribute them to flood affected communities within the catchment. The brochure and survey will also be made available online by Council.	• Inform the community about the study and provide background information. • Identify community concerns and awareness. • Gather information from the community on potential flood mitigation options. • Develop and maintain community confidence in the study results.	•
Stakeholder Consultation	Cardno will contact relevant agency stakeholders via letter and follow up email and/or phone. Meetings will be held with key stakeholders and community groups.	• Inform the agencies of the study. • Obtain relevant information. • Provide an opportunity for input from the relevant agencies.	•
Community Workshops	Cardno will prepare materials for and present at 2 community workshops. The first workshop will obtain feedback on flood modification options while the second workshop will be held during public exhibition.	• Provide the community with an understanding of the preliminary findings of the study and provide an opportunity for input prior to the preparation of the Draft and Final FRMS&P.	•

Community Liaison	Cardno will liaise with residents which may be affected by any proposed flood mitigation options.	• Provide an opportunity to residents to ask questions, get an understanding of the impacts (if any), and provide feedback.	•
Public Exhibition Period	Council will arrange for the public exhibition of the Draft Floodplain Risk Management Study and Plan.	• Provide an opportunity for the community to review and provide comment on the Draft Study and Plan.	•

The consultation plan identified that consultation was to be undertaken at key stages of the study. The main consultation elements for this study are:

- A press release, project website and newsletter introducing the project to the community and keeping them updated;
- A questionnaire sent to the community in digital and hard copy format;
- A call for information from all affected stakeholders within the catchment;
- Community workshops during the study;
- Public Exhibition of Draft Floodplain Risk Management Study; and
- Collation and acknowledgement of written submissions during the public exhibition.

This process ensures that community participation is maximised during the development of the FRMS&P.

1.2 Project Website

A project website was published by Council to inform the community of the flood management process and how they could participate in it. It also included the details of the study area, the future steps and details of relevant contacts. Cardno prepared information for the website. The website address is:

https://getinvolved.shoalhaven.nsw.gov.au/review-of-the-lower-shoalhaven-floodplain-risk-management-study-and-plan.

The website has been developed to provide the community with detailed information about the study and gather information. The website will be updated during the duration of the project to provide relevant information at each stage of the study.

1.3 Community Newsletter and Questionnaire

An information newsletter was prepared for the digital and physical distribution to the residents within the catchment. The newsletter informed residents about the study and how to complete the survey either online or submit their responses on a hard copy questionnaire. The brochure provided an outline of the floodplain risk management process and the objectives of the study. Council opted to publish this information through targeting advertising and community forums.

The online questionnaire was prepared on the SurveyMonkey platform. The survey sought information about historical flooding events and flood awareness within the community. The online and physical copy of the questionnaires are attached in **Appendix A**.

The survey was open from 19 November 2018 to 1 February 2019. A total of 61 responses were recorded from the online consultation. All responses are provided in **Appendix B**. It was noted that some responses were outside the study area or were addressing the St Georges Basin Flood Risk Management Study and Plan. It is recommended that the other responses are not used as an indicator for the flood behaviour within the Lower Shoalhaven catchment.

Figure 1-1 Locations of Community Responses

1.3.2 Demographic Information

- On average, respondents have lived in the area for over 20 years, with the majority of respondents within the 5-10 year range as shown in **Figure 1-2** ;

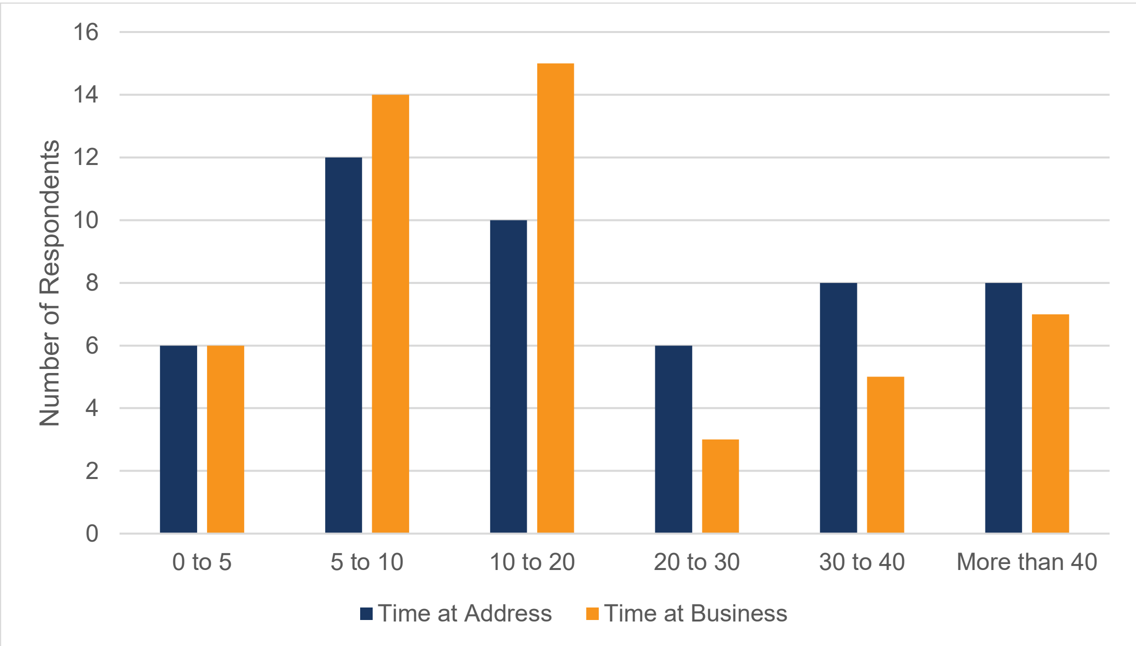


Figure 1-2 Residence time within catchment

- Majority of residents (86%) did not have any individuals within the household that required care;

1.3.3 Community Flood Experiences

> Majority of respondents (76%) experienced flooding. **Figure 1-3** shows the areas of flooding on the property;

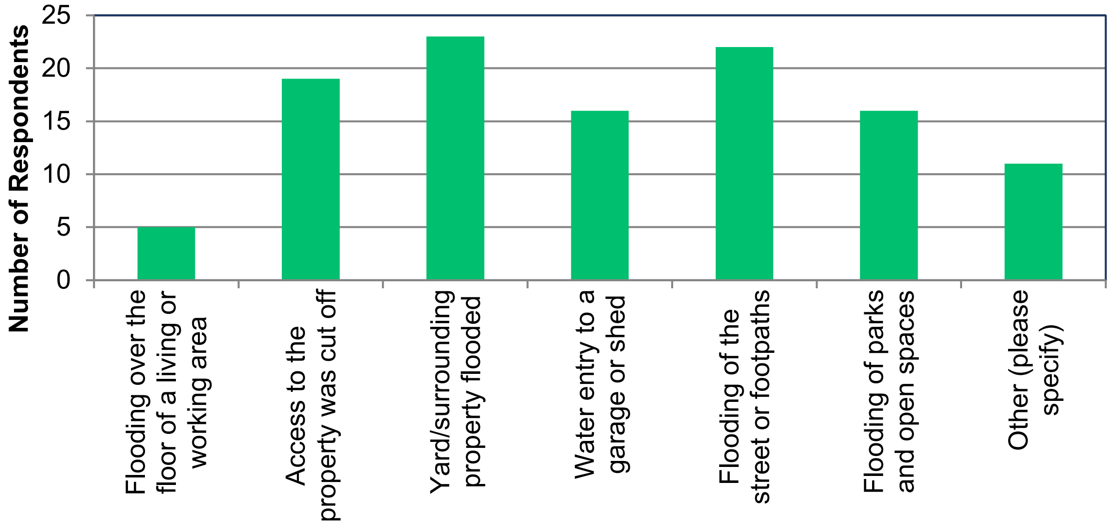


Figure 1-3 Areas impacted by flooding

> For past flood events, majority of respondents (53%) did not take action to protect their property or business against flood damage;

> For those residents/businesses that did take actions, these are summarised in **Figure 1-4**. Results indicate that several respondents were forced to move their belongings and assets;

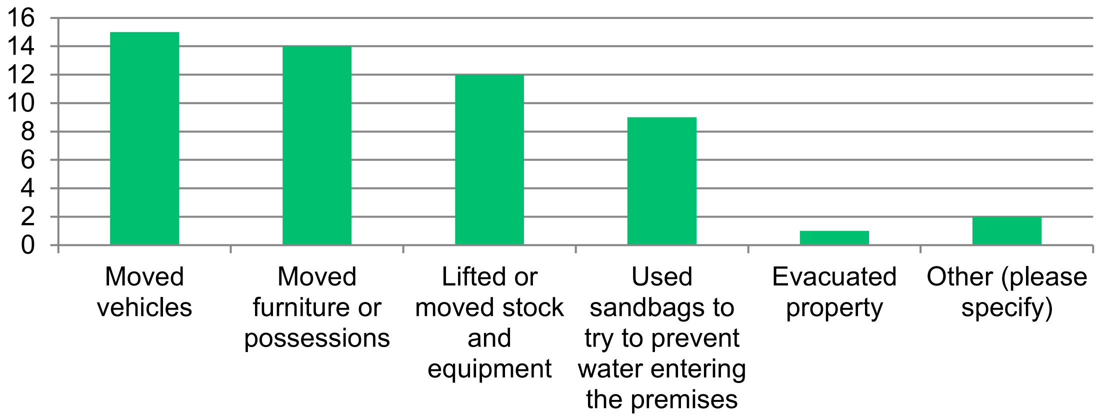


Figure 1-4 Actions taken against flood damage

> For the majority of those impacted by flooding, 59% experienced no damages;

> The community considers risk to property as the greatest flood risk in the catchment, with 50% of respondents concerned about property damages as shown in **Figure 1-5**; and

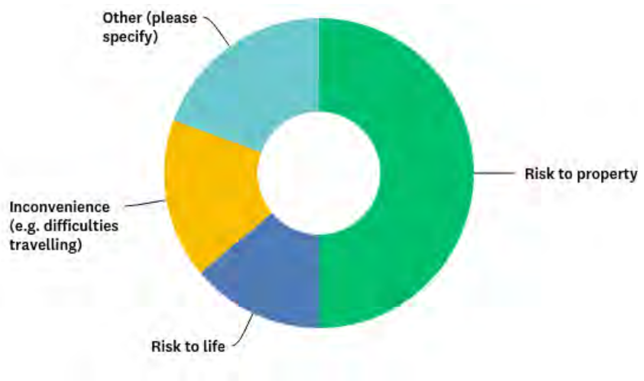


Figure 1-5 Flood risks in the catchment

> The majority of respondents are concerned about their home or business being flood affected in the future as shown in **Figure 1-6**;

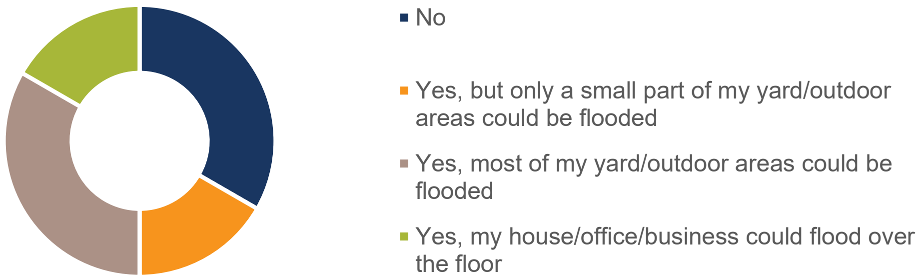


Figure 1-6 Future flooding expectations

1.3.4 Community Preferred Flood Mitigation Options

> Respondents were invited to provide feedback on their preferred flood mitigation options. 71% of respondents believe that Council should undertake additional works to reduce the flood risk at their property;

> The local community was also given a platform to share any ideas to reduce flood risks by suggesting future flood management options. Several options were suggested with provision for input of additional ideas. Respondents chose the options with an order of preference. These preferences were ranked based on the number of respondents for each preference. A high ranking average score indicates that the response was more heavily favoured amongst the community. Results strongly indicate that an improved entrance management strategy is required. Improved flow paths and channel improvements are also strongly favoured mitigation options. **Figure 1-7** shows the various options and their respective scores.

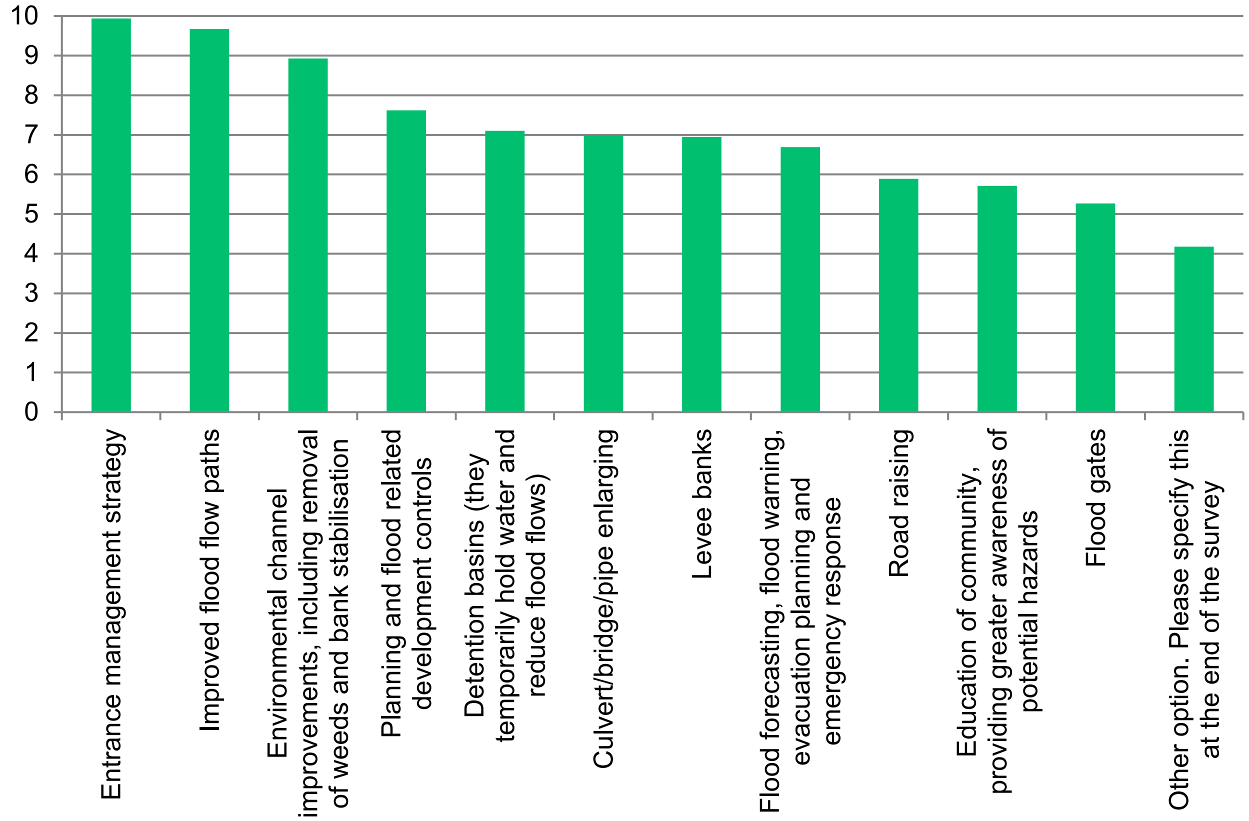


Figure 1-7 Actions required to reduce future flood risk

> Respondents also voiced their concern on new developments. The general consensus was that some level of control is necessary however developments should not be halted. Rather a combination of advisory and restrictive policies was favoured to reduce flood damages; and

> Majority of respondents (84%) are interested in receiving further information from Council about flooding in the study area. The preferred method of receiving information is primarily through email newsletters.

APPENDIX

A

COMMUNITY QUESTIONNAIRE

Lower Shoalhaven River Floodplain Risk Management Study and Plan

Information Brochure 2018

Shoalhaven City Council has engaged Cardno to assist with the preparation of the Lower Shoalhaven River Floodplain Risk Management Study and Plan. The purpose of this Risk Management Study and Plan is to identify and recommend appropriate measures to manage flood risks in the Lower Shoalhaven catchment.

This is an introduction to the Risk Management Study and Plan. Further details can be obtained from the Council's website at INSERT COUNCIL WEBSITE LINK.

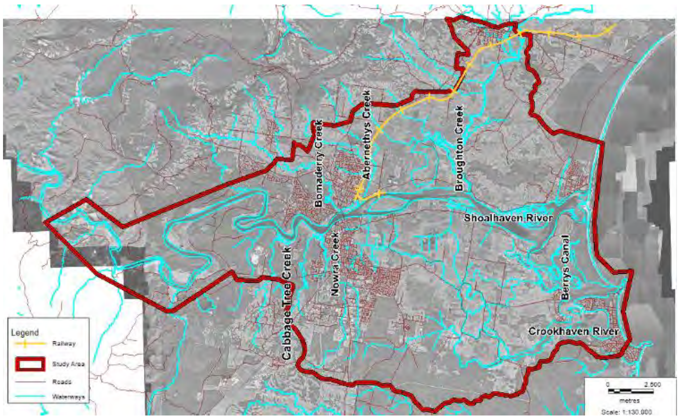
As part of this study, we are seeking community input in the form of a questionnaire. Please find the questionnaire online at **www.surveymonkey.com/r/LowerShoalhavenFRMSP**

Alternatively, you may request a hard copy of the questionnaire if you prefer.

Study Area

The study area comprises of the Lower Shoalhaven River and Crookhaven River catchment. The Shoalhaven River catchment covers an area of some 7,000 square kilometres with approximately 120 square kilometres of floodplain downstream of Nowra. Shoalhaven River has number of tributaries including Cabbage Tree Creek, Nowra Creek, Broughton Creek, Bomaderry Creek, and Abernethys Creek.

Flood behaviour in the Lower Shoalhaven River is dependent on the conditions at the Shoalhaven Heads entrance at the commencement of flooding. The different entrance condition becomes insignificant upstream of Pig Island (Public Works, 1990). The Study Area is outlined in the diagram below.



Floodplain Management Process

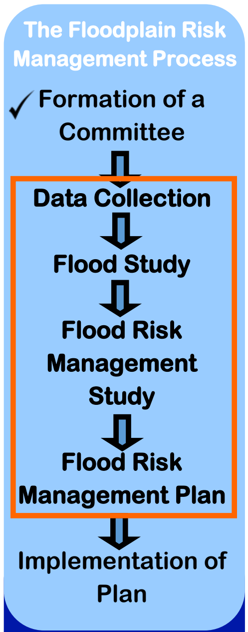
Local councils have lead responsibility for managing flood prone areas, and the State Government assists local council by providing financial and technical support under the Floodplain Management Program.

Council's Shoalhaven River Natural Resource and Floodplain Risk Management Committee (the Committee) oversees the Floodplain Management process for the Shoalhaven Local Government Area. The Committee meets regularly and includes representatives from Council, the NSW Office of Environment and Heritage (OEH), State Emergency Service (SES), NSW Department of Primary Industries (DPI) and the local community.

Updated Flood Study

Previous flood information available for the catchment was undertaken more than 10 years ago using older software and methods. Council are taking the opportunity to update the flood models using the latest software and survey information and expanding the model extents to improve the accuracy and currency of the flood information. This can then be used as the basis for assessing flood risk in the study area and assessing the performance of proposed flood mitigation measures which will be developed as part of the Floodplain Risk Management Study.

Floodplain Risk Management Study and Plan Objectives



This project is supported by the NSW Government's Floodplain Management Program

The preparation and implementation of a Floodplain Risk Management Plan is the culmination of the NSW Government Floodplain Management Program.

Management plans can eliminate the ad-hoc decision making process which has contributed to many present day flooding problems. The Floodplain Risk Management Study and Plan is the focus of the current project. The objectives of the Study and Plan are:

Floodplain Risk Management Study

Find an appropriate mix of management measures and strategies to effectively manage the full range of flood risks in accordance with the NSW Government Floodplain Development Manual (2005) through an effective public participation and community consultation program. The information from this study will enable Council to formulate a Floodplain Risk Management Plan for the study area.

Floodplain Risk Management Plan

Formulate a cost effective plan for the study area based on the findings of the Floodplain Risk Management Study and provide a priority program for implementation of the recommended works and measures in accordance with the NSW Government Floodplain Development Manual. The plan will detail how the existing and future flood risk within the study area will be managed.

What does this mean for me?

The outcomes of this project can help provide protection of you, your family and your property from flooding.

This may mean there are works undertaken in the future near your home or work, or you may have to incorporate flood compatible design into any future development. At the very least you will receive advice and information to assist you in making your home or work 'flood safe', or what to do during a flood event.

Floodplain Risk Management Options

The following list of Floodplain Risk Management options represent some of the strategies that could be considered to minimise the risk and reduce the impact of flooding throughout the floodplain. These options will be considered in further detail during the preparation of the Management Study and Plan.

Examples of Flood Management Options:	
Flood Modification Options	• Construction of levees where properties are most at risk. • Upgrading of drainage systems • Revision of entrance management procedures.
Property Modification and Planning Control Options	• Building and development controls • Voluntary house raising program (for selected properties) • Voluntary house rebuilding subsidy scheme (for selected properties) • Voluntary property purchase program (for selected properties).
Emergency Response Modification Options	• Revision of the Local Disaster Plan (DISPLAN) • Public awareness and education—locality based flooding information for residents • Public awareness and education—flooding information for schools • Flood depth markers at major (flood affected) road crossings • Continuation of existing public awareness and education campaigns • Data collection strategies for future floods

Ground Level and Property Level Survey

As part of the study, a survey team from Council will be collecting floor levels and ground levels of properties and structures within the Shoalhaven and Crookhaven River floodplain. This data is being collected to enable us to accurately determine how properties are affected by flooding. The levels will also be used to calculate damages resulting from flood events and to assess the effectiveness of proposed flood mitigation options. The survey will be conducted from now until end of 2018.

Consultation

During the Floodplain Risk Management Study and Plan process, consultation will be undertaken with the community.

The first consultation stage is a questionnaire in order to:

- Understand how residents and businesses are impacted by flooding.
- Canvas which types of flood management options are most preferred by the community.

We would appreciate your input to this project by completing the questionnaire which can be accessed online at the details below.

In addition to the questionnaire, you will have further opportunities to comment on the direction of the project during community workshops.

The workshops will introduce the study, and discuss potential mitigation strategies with the community.

Any comments received during the workshops will be taken into account before finalisation of the study and plan.

The final community consultation stage will occur during the public exhibition periods of the Draft Floodplain Risk Management Study and Plan, that will be accompanied by community workshops conducted by Council and Cardno.

I have questions. Who can I contact?

For further information regarding this project please see Council's website: INSERT PROJECT WEBSITE or contact Shoalhaven City Council via the details below.

Ali Sevenler Senior Floodplain Engineer Shoalhaven City Council P: (02) 4429 3237 (9am - 5pm; Mon-Fri) Ali.Sevenler@shoalhaven.nsw.gov.au	David Whyte Manager - Water Engineering Cardno P: 9496 7700 (9am - 5pm; Mon-Fri) david.whyte@cardno.com.au

Please complete the survey online at www.surveymonkey.com/r/LowerShoalhavenFRMSP

Resident / Landowner Survey 2018

Shoalhaven City Council has engaged Cardno to assist with the preparation of a Floodplain Risk Management Study and Plan for the Lower Shoalhaven River and Crookhaven River catchments.

This survey will help us collect information about riverine flooding in the area through community experiences. The survey will also allow you to tell us about the flooding issues that are important to you and collect your ideas and preferences on how flood risk can be managed with the Lower Shoalhaven and Crookhaven River catchments.

1. Please provide us with the following details, as this allows us to locate specifically where your comments and responses relate to. This information will not be shared without your consent.

Name	
Address	
Address 2	
Email Address	
Phone Number	

2. Do you give permission for someone from Council or Cardno to contact you to discuss any of the information you have provided us?

- ◯ Yes
- ◯ No

A. General information about your household

To begin with, we just need some information to help us understand whether you live or work in the Lower Shoalhaven River study area and to gain information about your building to assist with the floodplain risk management study.

3. Is your property (please select all that apply):

- ☐ Residential – Owner occupied
- ☐ A business
- ☐ Residential – Occupied by a tenant
- ☐ Farmland
- ☐ Holiday Home
- ☐ Other (please specify)

4. What is your property?

- ◯ House
- ◯ Commercial
- ◯ Unit/Flat/Apartment
- ◯ Industrial
- ◯ Other (please specify)

5. Which of the following construction materials best describes the building?

- ◯ Full brick
- ◯ Timber
- ◯ Brick veneer
- ◯ Concrete
- ◯ Weatherboard or fibro
- ◯ Steel
- ◯ Other (please specify)

6. How long have you lived, worked at and/or owned your property?

Years

Months

7. How long have you lived in the Lower Shoalhaven area?

Years

Months

8. How many people occupy your property?

People

9. Is there anyone in your household who:

- ◯ Requires care (e.g. infants, elderly or has a disability)
- ◯ Requires assistance with speaking or reading English
- ◯ None of the above

B. Flood Experience

A focus of this survey is to hear about any flooding you or members of your household have ever experienced in the study area. This provides useful information on where are the most frequently flooded areas and also provides data to compare with model results.

* 10. Have you or anyone in your household ever experienced flooding since living / working / owning your property? (please select all that apply)

- ◯ Never experience flooding
- ◯ Yes, I have been impacted by flooding

11. What were the areas of flooding (select all that apply)

- [ ] Flooding over the floor of a living or working area
- [ ] Water entry to a garage or shed
- [ ] Access to the property was cut off
- [ ] Flooding of the street or footpaths
- [ ] Yard/surrounding property flooded
- [ ] Flooding of parks and open spaces
- [ ] Other (please specify)

12. Please provide as much detail of the time and date as possible for up to 5 events *(your best estimate is fine – but the more accurate the date and time information the more valuable the data is for the flood modelling)*

Event 1

Event 2

Event 3

Event 4

Event 5

13. If your property was ever flooded above the house/garage floor level, please specify the depth above floor level and date(s) of the flood event(s):

- ◯ No, property never flooded above floor level
- ◯ Yes, please specify depth and date (as best as you can remember)

14. If your property grounds were ever flooded, please specify the depth and date(s) of the flood event(s):

- ◯ No, property grounds never flooded
- ◯ Yes, please specify depth and date (as best as you can remember)

* 15. In any flood event you have experienced in the past, did you have to take action to protect your property or business against flood damage?

- ◯ No
- ◯ Yes

16. What action did you take to protect your property or business against flood damage (Select all that apply)?

- [ ] Moved vehicles
- [ ] Used sandbags to try to prevent water entering the premises
- [ ] Moved furniture or possessions
- [ ] Evacuated property
- [ ] Lifted or moved stock and equipment
- [ ] Other (please specify)

17. In any flood event you have experienced in the past, what was the approximate cost to you (at the time) from the damage caused by the flood?

- ○ No damage
- ○ Yes, damages caused, please specify approximate cost and date

18. Do you have any photographs or video footage taken during or after any flooding event that you would like to share with Council? (Please select all that apply)

- [ ] Yes, photos (please attach below or provide to council)
- [ ] Yes, videos (please provide to council separately)
- [ ] No

19. If you have any photos, please attach them here or provide to council.
(Labels or descriptions with this information will assist)

Choose File   No file chosen

C. Flood Risk and Management

The objective of the study is to define flood risk and develop a plan for managing risk through a combination of structural mitigation measures, planning and property measures and emergency response. The information you provide will help guide this process to develop the best solutions for managing flood risk for this community.

20. In your opinion, what is the greatest flood risk in the catchment?

- Risk to property
- Inconvenience (e.g. difficulties travelling)
- Risk to life
- Other (please specify)

21. Do you think your property may be flooded sometime in the future?

- No
- Yes, but only a small part of my yard/outdoor areas could be flooded
- Yes, most of my yard/outdoor areas could be flooded
- Yes, my house/office/business could flood over the floor

22. Are there any works that you think Council should consider to reduce the flood risk at your property?

- No
- Yes, please specify

23. As a local resident, who has witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer? Please rank them where '1' is most preferable. *(You can drag the options to rank them)*

- Road raising
- Improved flood flow paths
- Detention basins (they temporarily hold water and reduce flood flows)
- Culvert/bridge/pipe enlarging
- Flood gates
- Levee banks
- Entrance management strategy
- Environmental channel improvements, including removal of weeds and bank stabilisation
- Planning and flood related development controls
- Education of community, providing greater awareness of potential hazards
- Flood forecasting, flood warning, evacuation planning and emergency response
- Other option. Please specify this at the end of the survey

24. What level of control do you consider Council should place on new development to minimise flood – related risk?

- ○ Stop all new development only in areas where flooding is most severe (i.e. deep and fast flowing)
- ○ Stop all new development on land with any potential to flood
- ○ Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)
- ○ Advise people of flood risks and allow individuals to choose how they would reduce flood damage
- ○ There should be no control on development in flood affected areas

D. Further Information

* 25. Would you like to receive more information from Council regarding flooding in your catchment?

○ I do not wish to receive further information

○ Yes

26. How would you like to receive that information? (please select all that apply)

- [ ] Council Website
- [ ] Public displays or exhibitions
- [ ] Email Newsletters
- [ ] Phone call
- [ ] Mail
- [ ] Other (please specify)

27. If you have any further comments that relate to flooding in this catchment, please express them below:

Thank you for your time in completing the survey.

For further information regarding this project please contact:

Ali Sevenler
Senior Floodplain Engineer
Shoalhaven City Council
P: (02) 4429 3237 (9am - 5pm; Mon-Fri)
E: Ali.Sevenler@shoalhaven.nsw.gov.au

Q20. As a local resident, who has witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer? Please rank them where '1' is most preferable and '5' is least preferable.	☐ Road raising ☐ Improved flood flow paths ☐ Detention basins (they temporarily hold water and reduce flood flows) ☐ Culvert/bridge/pipe enlarging ☐ Flood gates ☐ Levee banks ☐ Entrance management strategy ☐ Environmental channel improvements, including removal of weeds and bank stabilisation ☐ Planning and flood related development controls ☐ Education of community, providing greater awareness of potential hazards ☐ Flood forecasting, flood warning, evacuation planning and emergency response ☐ Other, please specify: …………………………………………………………… ………………………………………………………………………………………
Q21. What level of control do you consider Council should place on new development to minimise flood – related risk?	☐ Stop all new development only in areas where flooding is most severe (i.e. deep and fast flowing) ☐ Stop all new development on land with any potential to flood ☐ Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials) ☐ Advise people of flood risks and allow individuals to choose how they would reduce flood damage ☐ There should be no control on development in flood affected areas

D. Further Information

Q22. If you would like to receive more information, how would you like to receive that information? *(please select all that apply)*	☐ I do not wish to receive further information ☐ Council Website ☐ Email Newsletters ☐ Mail ☐ Public displays or exhibitions ☐ Phone call ☐ Other, please specify: ………………………………………

Q23. If you have any further comments that relate to flooding in this catchment, please express them below:

……

……

……

Thank you for your time in completing the survey

Lower Shoalhaven River Floodplain Risk Management Study and Plan

Resident / Landowner Survey | 2018

Shoalhaven City Council has engaged Cardno to assist with the preparation of a Floodplain Risk Management Study and Plan for the Lower Shoalhaven River and Crookhaven River catchments.

This survey will help us collect information about riverine flooding in the area through community experiences. The survey will also allow you to tell us about the flooding issues that are important to you and collect your ideas and preferences on how flood risk can be managed with the Lower Shoalhaven and Crookhaven River catchments.

Please take a few minutes to complete the survey and return it in the reply paid envelope provided. Please note that you can also complete this survey online by going to Council's website and accessing the survey at this link:

www.surveymonkey.com/r/LowerShoalhavenFRMSP

Q1. Please provide us with the following details, as this allows us to locate specifically where your comments and responses relate to. This information will not be shared without your consent.	Name: …………………………………………… Street Address: …………………………… …………………………………………………… Phone Number: …………………………… Email: ……………………………………………
Q2. Do you give permission for someone from Council or Cardno to contact you to discuss any of the information you have provided us?	☐ Yes ☐ No

Shoalhaven City Council | NSW Government Office of Environment & Heritage | Cardno

This project is supported by the NSW Government's Floodplain Management Program.

A. General Information about your household/business

Q3. Is your property (please select all that apply):
- ☐ Residential – Owner occupied
- ☐ Residential – Occupied by a tenant
- ☐ Holiday Home
- ☐ A business
- ☐ Farmland
- ☐ Other, please specify: ……………………………………………

Q4. What is your property?
- ☐ House
- ☐ Unit/Flat/Apartment
- ☐ Commercial
- ☐ Industrial
- ☐ Other, please specify: ……………………………………………

Q5. Which of the following construction materials best describes the building?
- ☐ Full brick
- ☐ Brick veneer
- ☐ Weatherboard or fibro
- ☐ Timber
- ☐ Concrete
- ☐ Steel
- ☐ Something else (please specify): ………………………………

Q6. How long have you lived, worked at and/or owned your property?
______Years
______ Months

Q7. How long have you lived in the Lower Shoalhaven area?
______ Years
______ Months

Q8. How many people occupy your property?
____ People

Q9. Is there anyone in your household who:
- ☐ Requires care (e.g. infants, elderly or has a disability)
- ☐ Requires assistance with speaking or reading English
- ☐ None of the above

B. Flood Experience

Q10. Have you or anyone in your household ever experienced flooding since living / working / owning your property? (please select all that apply)
- ☐ Never experience flooding
- ☐ Flooding over the floor of a living or working area
- ☐ Access to the property was cut off
- ☐ Yard/surrounding property flooded
- ☐ Water entry to a garage or shed
- ☐ Flooding of the street or footpaths
- ☐ Flooding of parks and open spaces
- ☐ Other, please specify ……………………………………………

Q11. Please provide as much detail of the time and date as possible for up to 3 events or attach additional information for more than 3 events [your best estimate is fine – but the more accurate the date and time information the more valuable the data is for the flood modelling]

Event	Year	Month	Date	Time
1				
2				
3				

Q12. If your property was ever flooded above the house/garage floor level, please specify the depth above floor level and date(s) of the flood event(s):
- ☐ No, property never flooded above floor level
- ☐ Yes, please specify depth and date (as best as you can remember)

……………………………………………………………………………

Q13. If your property grounds were ever flooded, please specify the depth and date(s) of the flood event(s):
- ☐ No, property grounds never flooded
- ☐ Yes, please specify depth and date (as best as you can remember)

……………………………………………………………………………

Q14. In any flood event you have experienced in the past, what action did you take to protect your property or business against flood damage?
- ☐ None
- ☐ Moved vehicles
- ☐ Moved furniture or possessions
- ☐ Lifted or moved stock and equipment
- ☐ Used sandbags to try to prevent water entering the premises
- ☐ Evacuated property
- ☐ Other, please specify

……………………………………………

Q15. In any flood event you have experienced in the past, what was the approximate cost to you (at the time) from the damage caused by the flood?
- ☐ No damage
- ☐ Yes, damages caused, please specify approximate cost and date

……………………………………………

Q16. Do you have any photographs or video footage taken during or after any flooding event that you would like to share with Council?
- ☐ Yes, please attach or send through to Council (Labels or descriptions with this information will assist)
- ☐ No

C. Flood Risk and Management

Q17. In your opinion, what is the greatest flood risk in the catchment?
- ☐ Risk to property
- ☐ Risk to life
- ☐ Inconvenience (e.g. difficulties travelling)
- ☐ Other, please specify:

……………………………………………………………………………

Q18. Do you think your property may be flooded sometime in the future?
- ☐ No
- ☐ Yes, but only a small part of my yard/outdoor areas could be flooded
- ☐ Yes, most of my yard/outdoor areas could be flooded
- ☐ Yes, my house/office/business could flood over the floor

Q19. Are there any works that you think Council should consider to reduce the flood risk at your property?
- ☐ No
- ☐ Yes, please specify:

……………………………………………………………………………

APPENDIX

B

COMMUNITY RESPONSES

ID	Do you give permission for someone from Council or Cardno to contact you to discuss any of the information you have provided us?	Is your property (please select all that apply):	What is your property?	Which of the following construction materials best describes the building?	How long have you lived, worked at and/or owned your property?	Not Provided	How long have you lived in the Lower Shoalhaven area?	Not Provided	How many people occupy your property?	Is there anyone in your household who:	Have you or anyone in your household ever experienced flooding since living / working / owning your property? (please select all that apply)	What were the areas of flooding (select all that apply)
	Response	Response	Response	Response	Years	Months	Years	Months	People	Response	Response	Flooding over the floor of a living or working area
1	Yes	Holiday Home	House,	Weatherboard or fibro,	86	Not Provided	72	Not Provided	6	None of the above	Yes, I have been impacted by flooding	Flooding over the floor of a living or working areaAccess to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths,
2	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	54	Not Provided	3	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Flooding of non-habitable ground floor area
3	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	49	Not Provided	50	Not Provided	3	None of the above	Never experience flooding	Not Provided
4	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	45	Not Provided	45	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off Flooding of parks and open spaces,
5	Yes	Holiday Home	House,	Weatherboard or fibro,	42	2	42	2	6	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
6	Yes	Interested in Shoalhaven River as I work for Riverwatch and written the flood intellegence/Action Plan fro State Emergency Services	Other (please specify), I have an interest and knowledge of the Shoalhaven River, during flood times	Other (please specify), I have been involved in ever flood during thepast 40 years working for Shoalhaven City Council and SES	40	Not Provided	40	Not Provided	1	None of the above	Yes, I have been impacted by flooding	Been involved in the whole of the Shoalhaven, every flood during last 40 years
7	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	40	Not Provided	14	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Not Provided
8	Yes	Residential – Occupied by a tenant A business	House,	Weatherboard or fibro,	37	Not Provided	37	Not Provided	5	Requires care (e.g. infants, elderly or has a disability)	Yes, I have been impacted by flooding	Flooding over the floor of a living or working areaAccess to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
9	Yes	Residential – Owner occupied A business	Commercial,	Brick veneer,	33	Not Provided	33	Not Provided	200	None of the above	Yes, I have been impacted by flooding	,Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
10	Yes	Residential – Owner occupied	House,	Timber,	32	Not Provided	32	Not Provided	2	None of the above	Yes, I have been impacted by flooding	,Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
11	Yes	Holiday Home	House,	Weatherboard or fibro,	31	Not Provided	20	Not Provided	6	None of the above	Yes, I have been impacted by flooding	Flooding over the floor of a living or working areaAccess to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
12	Yes	Holiday Home	House,	Brick veneer,	30	Not Provided	30	Not Provided	6	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off,Flooding of the street or footpaths, Flooding of parks and open spaces,
13	Yes	Residential – Owner occupied Residential – Occupied by a tenant A business	Commercial,	Weatherboard or fibro,	29	Not Provided	29	Not Provided	4	None of the above	Yes, I have been impacted by flooding	Not Provided
14	No	Residential – Owner occupied	House,	Full brick,	20	Not Provided	70	Not Provided	4	None of the above	Never experience flooding	Not Provided
15	Yes	Residential – Owner occupied	House,	Brick veneer,	20	Not Provided	39	Not Provided	2	Requires care (e.g. infants, elderly or has a disability)	Never experience flooding	Not Provided
16	Yes	Residential – Owner occupied	House,	Full brick,	19	Not Provided	24	Not Provided	2	None of the above	Never experience flooding	Not Provided
17	Yes	Holiday Home	House,	Timber,	18	Not Provided	18	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Flooding of the street or footpaths,
18	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	18	Not Provided	18	Not Provided	4	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
19	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	17	Not Provided	17	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Not Provided
20	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	17	Not Provided	17	Not Provided	2	Requires care (e.g. infants, elderly or has a disability)	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
21	Yes	Holiday Home	House,	Brick veneer,	17	Not Provided	17	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths,
22	Yes	Residential – Owner occupied A business Farmland Oyster farm depot site	Commercial,	Full brick,	15	Not Provided	30	Not Provided	4	None of the above	Yes, I have been impacted by flooding	Flooding over the floor of a living or working areaAccess to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
23	Yes	A business	Commercial,	Weatherboard or fibro,	15	Not Provided	Not Provided	Not Provided	30	None of the above	Yes, I have been impacted by flooding	Not Provided
24	Yes	Residential – Occupied by a tenant Farmland Golf Course closed. (Subject to DA 10570 for Residential R2 Developoment)	House,	Brick veneer,	13	Not Provided	30	Not Provided	3	None of the above	Yes, I have been impacted by flooding	Not Provided

ID	Do you give permission for someone from Council or Cardno to contact you to discuss any of the information you have provided us?	Is your property (please select all that apply):	What is your property?	Which of the following construction materials best describes the building?	How long have you lived, worked at and/or owned your property?	Not Provided	How long have you lived in the Lower Shoalhaven area?	Not Provided	How many people occupy your property?	Is there anyone in your household who:	Have you or anyone in your household ever experienced flooding since living / working / owning your property? (please select all that apply)	What were the areas of flooding (select all that apply)
	Response	Response	Response	Response	Years	Months	Years	Months	People	Response	Response	Flooding over the floor of a living or working area
25	Yes	Residential – Owner occupied	Unit/Flat/Apartment,	Brick veneer,	12	Not Provided	30	Not Provided	1	None of the above	Never experience flooding	Not Provided
26	Yes	Residential – Owner occupied A business	House,	Other (please specify), Brick base & fibro top storey	10	Not Provided	20	Not Provided	4	None of the above	Yes, I have been impacted by flooding	Not Provided
27	No	Residential – Owner occupied	House,	Weatherboard or fibro,	10	Not Provided	16	Not Provided	3	Requires care (e.g. infants, elderly or has a disability)	Yes, I have been impacted by flooding	Flooding of parks and open spaces,
28	Yes	Residential – Owner occupied	Unit/Flat/Apartment,	Brick veneer,	10	2	10	2	1	None of the above	Yes, I have been impacted by flooding	Flooding of the street or footpaths,Unable to leave the area
29	Yes	Residential – Owner occupied	House,	Brick veneer,	10	Not Provided	10	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths,
30	Yes	Residential – Owner occupied	House,	Brick veneer,	10	Not Provided	10	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths,
31	Yes	Residential – Owner occupied	Unit/Flat/Apartment,	Full brick,	9	4	9	8	2	None of the above	Yes, I have been impacted by flooding	Not Provided
32	Yes	Residential – Owner occupied	House,	Other (please specify), Timber frame, steel and timber clad	9	Not Provided	4	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Flooding of the street or footpaths,
33	Yes	Residential – Owner occupied	Unit/Flat/Apartment,	Full brick,	8	6	9	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Flooding of the street or footpaths, Flooding of parks and open spaces,
34	Yes	Residential – Owner occupied	House,	Brick veneer,	7	6	20	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths,Flooding in a bathroom
35	Yes	Residential – Owner occupied	House,	Brick veneer,	7	6	7	6	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces,
36	No	Residential – Owner occupied	House,	Brick veneer,	7	Not Provided	7	Not Provided	2	None of the above	Never experience flooding	Not Provided
37	Yes	Residential – Owner occupied	House,	Brick veneer,	7	Not Provided	7	Not Provided	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut offRun off from hills/altered drainage
38	Yes	Residential – Owner occupied	House,	Brick veneer,	6	6	67	Not Provided	2	None of the above	Never experience flooding	Not Provided
39	Yes	Residential – Owner occupied	House,	Brick veneer,	6	10	9	Not Provided	4	None of the above	Yes, I have been impacted by flooding	Access to the property was cut offC
40	Yes	Residential – Owner occupied A business Farmland	House,	Full brick,	6	6	6	6	2	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off,Flooding of the street or footpaths, Flooding of parks and open spaces, Isolated in one flood for 8 days
41	Yes	Residential – Owner occupied	House,	Full brick,	5	Not Provided	21	Not Provided	5	None of the above	Yes, I have been impacted by flooding	Access to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths, Flooding of parks and open spaces, This was when we lived at Shoalhaven Heads from 1997 - 2014

ID	Do you give permission for someone from Council or Cardno to contact you to discuss any of the information you have provided us?	Is your property (please select all that apply):	What is your property?	Which of the following construction materials best describes the building?	How long have you lived, worked at and/or owned your property?	Not Provided	How long have you lived in the Lower Shoalhaven area?	Not Provided	How many people occupy your property?	Is there anyone in your household who:	Have you or anyone in your household ever experienced flooding since living / working / owning your property? (please select all that apply)	What were the areas of flooding (select all that apply)
	Response	Response	Response	Response	Years	Months	Years	Months	People	Response	Response	Flooding over the floor of a living or working area
42	Yes	Residential – Owner occupied	House,	Other (please specify), Brick and weatherboard	5	Not Provided	5	Not Provided	1	None of the above	Yes, I have been impacted by flooding	Flooding over the floor of a living or working areaAccess to the property was cut off, Water entry to a garage or shed, Flooding of the street or footpaths,
43	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	5	Not Provided	5	Not Provided	2	None of the above	Yes, I have been impacted by flooding	traffic redirected to my street when flooding from creek and river.
44	Yes	Residential – Owner occupied	House,	Brick veneer,	5	6	5	6	2	Requires care (e.g. infants, elderly or has a disability)	Never experience flooding	Not Provided
45	Yes	Residential – Owner occupied	House,	Weatherboard or fibro,	4	10	6	2	4	Requires care (e.g. infants, elderly or has a disability)	Never experience flooding	Not Provided
46	No	Residential – Owner occupied	Other (please specify), Townhouse	Full brick,	3	Not Provided	6	Not Provided	3	None of the above	Yes, I have been impacted by flooding	Not Provided
47	Yes	Residential – Owner occupied	House,	Full brick,	3	5	3	5	2	Requires care (e.g. infants, elderly or has a disability)	Yes, I have been impacted by flooding	Flooding of parks and open spaces, Flooding in Shoalhaven Heads and surrounding areas affected egress and access within and to and from the village
48	Yes	Residential – Owner occupied	House,	Brick veneer,	3	Not Provided	3	Not Provided	2	Requires care (e.g. infants, elderly or has a disability)	Never experience flooding	Not Provided
49	Yes	Residential – Owner occupied	House,	Brick veneer,	3	4	3	4	2	None of the above	Never experience flooding	Not Provided
50	Yes	Residential – Occupied by a tenant	House,	Brick veneer,	1	6	40	Not Provided	3	None of the above	Yes, I have been impacted by flooding	A small part of Lyrebird Drive at its eastern end was covered in water - very minor.Two events around 1990. When I lived in Elia Avenue at the time
51	Yes	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
52	No	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Yes, I have been impacted by flooding	Not Provided
53	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Never experience flooding	Not Provided
54	Yes	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
55	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Yes, I have been impacted by flooding	Not Provided
56	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Never experience flooding	Not Provided
57	Yes	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
58	Yes	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
59	Yes	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
60	Yes	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
61	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Yes, I have been impacted by flooding	Not Provided

ID	Please provide as much detail of the time and date as possible for up to 5 events (your best estimate is fine – but the more accurate the date and time information the more valuable the data is for the flood modelling)					If your property was ever flooded above the house/garage floor level, please specify the depth above floor level and date(s) of the flood event(s):	If your property grounds were ever flooded, please specify the depth and date(s) of the flood event(s):	In any flood event you have experienced in the past, did you have to take action to protect your property or business against flood damage?	What action did you take to protect your property or business against flood damage (Select all that apply)?	In any flood event you have experienced in the past, what was the approximate cost to you (at the time) from the damage caused by the flood?	In your opinion, what is the greatest flood risk in the catchment?	Do you think your property may be flooded sometime in the future?
	Event 1	Event 2	Event 3	Event 4	Event 5	Response	Response	Response	Moved vehicles	Response	Response	Response
1	26th August 2015	June 2016	1990	1974, 1975, 1976, 1978 x 2	Not Provided	Yes, please specify depth and date (as best as you can remember), August 2015 garage flooded 15cm high of water	Yes, please specify depth and date (as best as you can remember), 26th August 2015, 1 metre high at front gate	Yes	Yes,Moved furniture or possessions	Yes, damages caused, please specify approximate cost and date, $200 approx	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
2	1974	1991	2013	2015	2016	Yes, please specify depth and date (as best as you can remember), Up to 1m in the ground floor boasted area	Yes, please specify depth and date (as best as you can remember), Up to 1m on part of the property	Yes	Yes	Not Provided	Not Provided	Not Provided
3	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to property,	No
4	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Other (please specify), Erosion	Yes, most of my yard/outdoor areas could be flooded
5	6.06.16 flooding 800cm	26.08.15 flooding 1.1mtr	26.06.13 flooding 1.1mtr	1995 flooding 1.1mtr	Not Provided	Yes, please specify depth and date (as best as you can remember), 1.1mtr	Yes, please specify depth and date (as best as you can remember), 6.6.16. 1.1mtr	No	No	Yes, damages caused, please specify approximate cost and date, $700. 1995	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
6	1975	1976	1988	2013	2015	Yes, please specify depth and date (as best as you can remember), Flood Intelegence information collected during time with Council and SES	Yes, please specify depth and date (as best as you can remember), 1975	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment, Used sandbags to try to prevent water entering the premises, Evacuated property,	Yes, damages caused, please specify approximate cost and date, $0	Risk to property,	Yes, my house/office/business could flood over the floor
7	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
8	1988? APPROX: Do not have exact year on hand	1990? APPROX: Do not have exact year.	2011?APPROX: Do not have exact year.	2013? APPROX: Do not have exact year.	2014?APPROX: Do not have exact year	No, property never flooded above floor level,	Yes, please specify depth and date (as best as you can remember), The late 80's, 90's floods. Family home on Hay Ave and Oyster Storage Yard.	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment	Yes, damages caused, please specify approximate cost and date, As oyster farmers there are always associated losses and costs with a flood. These differ depending on the extent of the flooding.	Other (please specify), With uncontrolled erosion in Berry's Canal flooding is impacting the natural progression of the river thalweg and course of the river. My fear is that a large enough flood could rip a hole through the middle of Commerong Island, going through Commerang Bay, causing devastaion to property and changing the dynamics of the entire lower estuary forever. Shoalhaven Heads estuary becomes a sand and silt deposit and rendering the Heads entrance useless, creating a backwater.	No
9	1988	Several times haven't recorded dates	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	Yes, please specify depth and date (as best as you can remember), 1.5 metre	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment	Yes, damages caused, please specify approximate cost and date, Many many hours of work	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
10	2016	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	Yes, please specify depth and date (as best as you can remember), 200mm 2016	No	No	No damage,	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
11	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), June 2017	Yes, please specify depth and date (as best as you can remember), june 2017	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment	Yes, damages caused, please specify approximate cost and date, $5000	Risk to property,	Yes, my house/office/business could flood over the floor
12	1991 approx	2016	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	Yes, please specify depth and date (as best as you can remember), small intrusion of water into the property, backyard. (approx 1m) from adjacent canal	No	No	No damage,	Inconvenience (e.g. difficulties travelling),	Yes, but only a small part of my yard/outdoor areas could be flooded
13	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
14	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	Yes	YesUsed sandbags to try to prevent water entering the premises,	No damage,	Not Provided	Not Provided
15	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Not Provided	Not Provided
16	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to property,	Yes, my house/office/business could flood over the floor
17	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	Yes	Yes, Moved vehicles,Lifted or moved stock and equipment, Used sandbags to try to prevent water entering the premises,	No damage,	Risk to property,	Yes, but only a small part of my yard/outdoor areas could be flooded
18	2010	2013	2015	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), 600mm in shed	Yes, please specify depth and date (as best as you can remember), 300mm to 700 mm	Yes	Yes, Moved vehicles, Moved furniture or possessions,Used sandbags to try to prevent water entering the premises,	Yes, damages caused, please specify approximate cost and date, Loss of wages and small amount of damage	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
19	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
20	Flood 6 years ago. Rose to one metre	Flood 3 years ago. Inadequate warning from authorities. Flood sensors either inaccurate or non-existent e.g. Broughton Creek. 9.30 at night, only internet indicator was "minor flooding possible tomorrow afternoon.' Awoke next morning to find floodwater 1.2m deep everywhere. We lost two cars parked underneath house because of this failure.	Not Provided	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), See above answer. First flood reached 1.0m, second 1.2m	Yes, please specify depth and date (as best as you can remember), as above	Yes	Yes, Moved vehicles,Lifted or moved stock and equipment Had warning of first mentioned flood	Yes, damages caused, please specify approximate cost and date, Second mentioned flood - lost two cars and many electrical tools in sheds. No warning, so no action taken to raise at risk items or move cars to higher ground	Not Provided	Not Provided
21	June 2016	Not Provided	Not Provided	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), 5mm	Yes, please specify depth and date (as best as you can remember), 30cm approx	No	No	No damage,	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
22	Look it up	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment	Yes, damages caused, please specify approximate cost and date, Have to look it up. Thousands.	Other (please specify), Risk to business. Oyster farm suffers significantly with every flood event.	Yes, my house/office/business could flood over the floor
23	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
24	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	Not Provided	No	No	Not Provided	Not Provided	Not Provided

ID	Please provide as much detail of the time and date as possible for up to 5 events (your best estimate is fine – but the more accurate the date and time information the more valuable the data is for the flood modelling)					If your property was ever flooded above the house/garage floor level, please specify the depth above floor level and date(s) of the flood event(s):	If your property grounds were ever flooded, please specify the depth and date(s) of the flood event(s):	In any flood event you have experienced in the past, did you have to take action to protect your property or business against flood damage?	What action did you take to protect your property or business against flood damage (Select all that apply)?	In any flood event you have experienced in the past, what was the approximate cost to you (at the time) from the damage caused by the flood?	In your opinion, what is the greatest flood risk in the catchment?	Do you think your property may be flooded sometime in the future?
	Event 1	Event 2	Event 3	Event 4	Event 5	Response	Response	Response	Moved vehicles	Response	Response	Response
25	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
26	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
27	August 2016 - The Big Flood	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Other (please specify), Inundation of sewer line in reserve adjacent back fence for several days - risk to health from mosquitoes and raw sewage flowing out of inspection pits. Possibility of toilets etc backing up.	Yes, but only a small part of my yard/outdoor areas could be flooded
28	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Inconvenience (e.g. difficulties travelling),	No
29	Day time 9 Mar 2012 - Big Fresh, very high tides and borderline inundation. I have Photos of this event	Night time 25 June 2013 - large flood, highest and first inundation of residential land in 18 yrs. Council failed to manage the opening of the dry notch and this resulted in longer time of inundation. I have photos of this event.	Day time 26 Aug 2015 - 50 mm less than flood in 2013. Lots of rain in highlands and coastal plains from East coast low event. Council mismanaged the opening of the heads.	2 day event 5 & 6 June 2016 - 100mm less than flood in 2013. Severe East Coast Low weather event, wind swell opened heads early, resulting in less inundation but wind swell did most of the damage to the river bank on River Rd	Just waiting for the next one......lets hope the new plan resolves the issues regarding opening of the heads.	Yes, please specify depth and date (as best as you can remember), Garage has flood twice, 25 June 2013, 300mm (2.360 AHD); 26 Aug 2015, 250mm (2.110 AHD)	Yes, please specify depth and date (as best as you can remember), Grounds flooded 23 June 2013, various levels to 2.360m AHD; 26 Aug 2015, various levels to 2.110m AHD; 5 & 6 June 2016, various levels to 2.010m AHD.	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment, Used sandbags to try to prevent water entering the premises,	Yes, damages caused, please specify approximate cost and date, $30,000 insurance claim in 2013.	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
30	Day time 9 Mar 2012 - Big Fresh, very high tides and borderline inundation. I have Photos of this event	Night time 25 June 2013 - large flood, highest and first inundation of residential land in 18 yrs. Council failed to manage the opening of the dry notch and this resulted in longer time of inundation. I have photos of this event.	Day time 26 Aug 2015 - 50 mm less than flood in 2013. Lots of rain in highlands and coastal plains from East coast low event. Council mismanaged the opening of the heads.	2 day event 5 & 6 June 2016 - 100mm less than flood in 2013. Severe East Coast Low weather event, wind swell opened heads early, resulting in less inundation but wind swell did most of the damage to the river bank on River Rd	Just waiting for the next one......lets hope the new plan resolves the issues regarding opening of the heads.	Yes, please specify depth and date (as best as you can remember), Garage has flood twice, 25 June 2013, 300mm (2.360 AHD); 26 Aug 2015, 250mm (2.110 AHD)	Yes, please specify depth and date (as best as you can remember), Grounds flooded 23 June 2013, various levels to 2.360m AHD; 26 Aug 2015, various levels to 2.110m AHD; 5 & 6 June 2016, various levels to 2.010m AHD.	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment, Used sandbags to try to prevent water entering the premises,	Yes, damages caused, please specify approximate cost and date, $30,000 insurance claim in 2013.	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
31	2013 or 2014 not sure exactly- the Shoalhaven river flooded and one of the wharfs near the wharf road floated away. The paths and park near there were flooded and I couldn't walk my usual walk due to the flooding, at home the street in front of our house was flooded and we had to park in another location	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	Not Provided	Not Provided	Not Provided
32	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to property,	Yes, but only a small part of my yard/outdoor areas could be flooded
33	26 08 2015- Shoalhaven River flooded and there was no access to the path & parks for my usual river walk, at home we couldn't park out the front of our house due to the street being flooded we had to park somewhere else	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Inconvenience (e.g. difficulties travelling),	No
34	July 2013	August 2015	June 2016	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), The flood has been about 300 ml above the garage floor	Yes, please specify depth and date (as best as you can remember), June 2016 - the flood waters were approx 300 ml above ground level	Yes	Yes, Moved vehicles, Moved furniture or possessions,Used sandbags to try to prevent water entering the premises,	Yes, damages caused, please specify approximate cost and date, $35,000 in 2015	Risk to life,	Yes, my house/office/business could flood over the floor
35	26 June 2013 ??	26 August 2015	5 June 2016	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), June 2013 530 mm above garage floor level / August 2015 470 mm / June 2016 250mm / but none were above house floor lvel	Yes, please specify depth and date (as best as you can remember), As at 13 above	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment, Used sandbags to try to prevent water entering the premises,	Yes, damages caused, please specify approximate cost and date, Because of evasive action (moving vehicles, lifting equipment, etc) only minor and nuisance damage during each of above 3 events. This was not sufficient to warrant making insurance claims.	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
36	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Inconvenience (e.g. difficulties travelling),	Yes, but only a small part of my yard/outdoor areas could be flooded
37	During heavy rainfall down-pours, water running off the surrounding land causes flooding requiring measures to redirect the water.	Road to Berry etc. cut off but only really a concern in the evetn of a medical emergency.	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	Yes, please specify depth and date (as best as you can remember), Floods due to heavy run-off can occur whenever there is a serious downpour. Water mostly redirected to avoid/reduce flooding to building and washouts.	Yes	Yes	Not Provided	Not Provided	Not Provided
38	Construction of Berry Bypass has changed Town Creek flood conditions. This should be reflected in Council's flood zone mapping as it impacts insurance cover.	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Other (please specify), Town Creek flood impacts in Berry reduced by diversion to Bundewalla Creek. Flood mapping needs to be reviewed. Photos and videos available for 25082015 event.	No
39	April 2015	March 2010	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Inconvenience (e.g. difficulties travelling),	No
40	June 25 2013 10pm isolated for 8 days	2015 unsure of exact time and date-working overseas then so not here	2016 Not sure of exact time and date - working overseas then so away from property	Not Provided	Not Provided	No, property never flooded above floor level,	Yes, please specify depth and date (as best as you can remember), June 2013 grounds flooded approximately 1metre depth	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment	Yes, damages caused, please specify approximate cost and date, Fencing approximately $300 fixed ourselves	Risk to property,	Yes, most of my yard/outdoor areas could be flooded
41	1998 - #97 Jerry Bailey Rd Shoalhaven Heads	2001 - #97 Jerry Bailey Rd Shoalhaven Heads	2002 - #97 Jerry Bailey Rd Shoalhaven Heads	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), Knee deep (~400mm) above garage floor level in 1998, not quite so high in 2001, and again in 2002	Yes, please specify depth and date (as best as you can remember), Knee deep (~400mm) around most of the yard surrounding house - 1998.	Yes	Yes, Moved vehicles, Moved furniture or possessions, Lifted or moved stock and equipment	Yes, damages caused, please specify approximate cost and date, Relatively minor damage to internal garage walls and frames. Water staining, damaged pool pump.	Risk to property,	Yes, but only a small part of my yard/outdoor areas could be flooded

ID	Please provide as much detail of the time and date as possible for up to 5 events (your best estimate is fine – but the more accurate the date and time information the more valuable the data is for the flood modelling)					If your property was ever flooded above the house/garage floor level, please specify the depth above floor level and date(s) of the flood event(s):	If your property grounds were ever flooded, please specify the depth and date(s) of the flood event(s):	In any flood event you have experienced in the past, did you have to take action to protect your property or business against flood damage?	What action did you take to protect your property or business against flood damage (Select all that apply)?	In any flood event you have experienced in the past, what was the approximate cost to you (at the time) from the damage caused by the flood?	In your opinion, what is the greatest flood risk in the catchment?	Do you think your property may be flooded sometime in the future?
	Event 1	Event 2	Event 3	Event 4	Event 5	Response	Response	Response	Moved vehicles	Response	Response	Response
42	2015 mid year	2016 mid year	Not Provided	Not Provided	Not Provided	Yes, please specify depth and date (as best as you can remember), Knee high on ground floor	Yes, please specify depth and date (as best as you can remember), 1 metre	Yes	Yes, Moved vehicles, Moved furniture or possessions,Used sandbags to try to prevent water entering the premises,	Yes, damages caused, please specify approximate cost and date, 5000 2015	Other (please specify), Damage to furniture/walls	Yes, my house/office/business could flood over the floor
43	August 2013	March 2017	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Inconvenience (e.g. difficulties travelling),	No
44	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	Yes	Yesno action with current properity	No damage,	Other (please specify), stupid people driving through or playing in flood waters	Yes, most of my yard/outdoor areas could be flooded
45	NA - no flooding	Not Provided	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to life,	No
46	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
47	August/September 2015	Similar time 2016	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to life,	No
48	0	0	0	0	0	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to life,	No
49	August/September 2015	September ? 2016	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to property,	No
50	Around 1990	Around 1990	Not Provided	Not Provided	Not Provided	No, property never flooded above floor level,	No, property grounds never flooded,	No	No	No damage,	Risk to life,	No
51	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
52	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
53	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
54	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
55	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	No	No	Not Provided	Not Provided	Not Provided
56	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
57	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
58	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
59	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
60	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
61	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Yes	Yes	Not Provided	Not Provided	Not Provided

ID	Are there any works that you think Council should consider to reduce the flood risk at your property?	As a local resident, who has witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer? Please rank them where '1' is most preferable. (You can drag the options to rank them)												What level of control do you consider Council should place on new development to minimise flood – related risk?	If you have any further comments that relate to flooding in this catchment, please express them below:
	Response	Road raising	Improved flood flow paths	Detention basins (they temporarily hold water and reduce flood flows)	Culvert/bridge/pipe enlarging	Flood gates	Levee banks	Entrance management strategy	Environmental channel improvements, including removal of weeds and bank stabilisation	Planning and flood related development controls	Education of community, providing greater awareness of potential hazards	Flood forecasting, flood warning, evacuation planning and emergency response	Other option. Please specify this at the end of the survey	Response	Open-Ended Response
1	Yes, please specify, Open the Heads before the water levels rise too high	10	2	6	8	7	3	1	4	5	11	9	12	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Not Provided
2	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
3	No,	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	It is important to be aware of why the Shoalhaven River causes flooding. It is due to the canal build by Alexander Berry but it is not necessary to change this canal. With proper engineering advice I feel a diversion barrier could be constructed to divert flood water to the original mouth of the river. I feel this will keep the river open at all times and direct early flood water to the original river mouth with minimal retention in the built-up area.
4	Yes, please specify, Dredging	Not Provided	1	Not Provided	Not Provided	Not Provided	Not Provided	2	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Not Provided
5	Yes, please specify, Open the heads earlier	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	1	Not Provided	12	4	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
6	Yes, please specify, Early warning, close liason with emergency services	Not Provided	Not Provided	9	8	4	Not Provided	7	3	Not Provided	2	1	Not Provided	Stop all new development only in areas where flooding is most severe (i.e. deep and fast flowing)	Not Provided
7	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
8	Yes, please specify, Bank stabilisation, dredging of the Shoalhaven Heads Entrance to create a channel to assist an Entrance opening in the event of a flood.	12	3	5	7	8	9	2	6	1	4	11	10	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	I would like to see an overall Strategic Management Plan for the Shoalhaven River that encompasses the environmental, social and economic value of the river for it's ongoing protection and benefit to the community. Any flood or strategic management plan would need to include the entire floodplain, as i believe certain land and building developments have significantly impacted the overflow areas during a flood and therefore have changed the historical path of flood waters and will continue to if a holistic approach to estuary management is not considered.
9	Yes, please specify, Open heads before river to high	1	2	3	4	5	6	7	8	9	10	11	12	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	When it like there is a risk of flooding get excavator to start digging before river gets to high so if night falls it will open even if you carnt get to ocean
10	Yes, please specify, Open Shoalhaven Heads earlier	9	3	10	4	8	2	1	5	6	Not Provided	7	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	There needs to be better coordination between the water resources at Tallowa Dam and the river tide information so flood waters released from the dam do not coincide with high tides at the entrance of the river. This is what caused the last big flood in 2016.
11	Yes, please specify, Levee re construction	7	1	Not Provided	Not Provided	Not Provided	2	3	6	4	Not Provided	5	8	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Mitigate the effect of flooding at Shoalhaven Heads by opening the river to the sea at the earliest time
12	No,	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	10	Not Provided	Not Provided	Not Provided	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
13	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
14	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
15	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
16	Not Provided	Not Provided	Not Provided	Not Provided	4	12	1	2	Not Provided	5	7	3	11	Stop all new development on land with any potential to flood	Not Provided
17	No,	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	1	2	3	Not Provided	4	Not Provided	Not Provided	The reason there is flooding in Hay Ave Shoalhaven Heads id because the flood waters are trapped and cannot drain out to the sea. A permanent opening at the 'Heads' would solve the problem plus create a much healthier water way for locals and holiday makers alike. The water quality is currently appalling and desperately needs to be flushed out with easy tidal access. Therefore 2 wins would be achieved.
18	Yes, please specify, Make the estuary deeper to hold more water in crease water flow to the heads to keep the heads open / open the heads mechaniy more often	12	3	7	8	2	9	1	4	5	10	6	11	Not Provided	Stop spending money on more studies and try something
19	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
20	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
21	Yes, please specify, Amend the procedures so that Shoalhaven Heads is opened earlier than is currently the practice.	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	1	Not Provided	2	Not Provided	3	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
22	Yes, please specify, Maintain Shoalhaven Heads spit to open up during flood events like it is supposed to. This takes pressure off the entire estuary and allows the salt to return into the estuary soon enough to prevent mortalities throughout the estuary. The flood gates are not maintained and do not help.	6	4	5	2	9	7	1	3	10	8	11	12	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
23	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
24	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided

ID	Are there any works that you think Council should consider to reduce the flood risk at your property?	As a local resident, who has witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer? Please rank them where '1' is most preferable. (You can drag the options to rank them)												What level of control do you consider Council should place on new development to minimise flood – related risk?	If you have any further comments that relate to flooding in this catchment, please express them below:
	Response	Road raising	Improved flood flow paths	Detention basins (they temporarily hold water and reduce flood flows)	Culvert/bridge/pipe enlarging	Flood gates	Levee banks	Entrance management strategy	Environmental channel improvements, including removal of weeds and bank stabilisation	Planning and flood related development controls	Education of community, providing greater awareness of potential hazards	Flood forecasting, flood warning, evacuation planning and emergency response	Other option. Please specify this at the end of the survey	Response	Open-Ended Response
25	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
26	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
27	No,	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	1	2	3	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Since the major flooding at Sanctuary Point approx 3 years ago the timber edging has not been reinstated at Palm Beach, resulting in continual erosion of the grass/parkland by wave action and humans walking there.
28	Yes, please specify, Prevent silt build up at the Heads and open the mouth more regularly. Ideally permanently	Not Provided	3	Not Provided	Not Provided	Not Provided	Not Provided	1	2	4	Not Provided	Not Provided	5	Stop all new development on land with any potential to flood	Not Provided
29	Yes, please specify, Review the Heads Management Plan re opening triggers	Not Provided	3	Not Provided	Not Provided	Not Provided	Not Provided	1	2	Not Provided	Not Provided	4	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	I have numerous photos of flood events which I would be happy to share. They are too numerous to share via this study. I can also arrange a meeting of residents of Hay Ave Shoalhaven Heads to discuss their experiences in floods. I am a member of the Shoalhaven Heads Estuary Task Force and I would expect that this task force would be updated during the progress of this study.
30	Yes, please specify, Review the Heads Management Plan re opening triggers	Not Provided	6	Not Provided	Not Provided	Not Provided	Not Provided	1	2	3	5	4	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Not Provided
31	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
32	Yes, please specify, Possibly look at what could be done with the creek that runs at the back of the homes on thewestern side of Hay Ave. This creek runs parallel to Hay Ave and Jerry Bailey Road. The sand spit to the ocean should be opened at the FIRST signs of heavy rain which may cause the flooding as a preventative instead of leaving it too late which has occurred in the past.	9	3	10	7	11	8	1	5	4	6	2	12	Stop all new development only in areas where flooding is most severe (i.e. deep and fast flowing)	Proactively open the sandspit at Shoalhaven Heads when potential heavy flood causing rain occurs no matter what tide level is occurring at the time.. We have witnessed this being done too late which has caused flooding in the past. Once the heads are opened we have witnessed the water level immediately receding no matter what the tide. The river at Shoalhaven Heads requires dredging.
33	No,	Not Provided	Not Provided	12	Not Provided	7	8	Not Provided	1	4	9	3	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
34	Yes, please specify, Reassess the notch level at Shoalhaven Heads and then ensure that the notch is always kept at the agreed level	Not Provided	1	Not Provided	Not Provided	Not Provided	Not Provided	2	Not Provided	Not Provided	Not Provided	Not Provided	3	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	The estuary has now significantly silted up. If there were to be another flood the backing up of water would be substantial vs floods in the past. I recommend dredging a channel up to but not through the heads. This would allow a channel to provide a breakthrough of the heads should there be a flood and minimise damage and impact to assets
35	Yes, please specify, Timely opening of the dry notch at Shoalhaven Heads is crucial to minimising the flood impact at our place. Thus far we have not had flood water come into our house, but on 2 occasions we were spared this problem by the Heads being opened just in time.Early warning information is also crucial to to our preventive preparations (shifting cars, lifting equipment, etc).	Not Provided	6	Not Provided	Not Provided	Not Provided	Not Provided	1	3	4	5	2	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	River bank erosion problems have become a serious issue at Shoalhaven Heads. In large part, these seem to be flood related. I have about 40 good photos illustrating the flood situation at our house, but I only managed to attach one of these at item 19 above.
36	No,	1	8	7	2	12	6	5	3	9	4	11	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Not Provided
37	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
38	No,	11	8	6	10	7	9	1	5	2	4	3	12	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Photos and videos of 25082015 Town Creek flood post Berry Bypass available on request.
39	No,	7	2	3	4	10	11	9	1	6	5	8	12	Not Provided	Not Provided
40	Yes, please specify, Opening of Shoalhaven River permanently or other funnelling of water (possibly through Duck Creek) to mitigate damage	12	6	4	10	11	9	2	3	5	7	8	1	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	The fact that the Shoalhaven River is closed is a major issue with flooding. This needs to be addressed.
41	Yes, please specify, Maintain the river opening at Shoalhaven Heads	Not Provided	2	Not Provided	Not Provided	Not Provided	Not Provided	1	3	Not Provided	Not Provided	Not Provided	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Not Provided

ID	Are there any works that you think Council should consider to reduce the flood risk at your property?	As a local resident, who has witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer? Please rank them where '1' is most preferable. (You can drag the options to rank them)												What level of control do you consider Council should place on new development to minimise flood – related risk?	If you have any further comments that relate to flooding in this catchment, please express them below:
	Response	Road raising	Improved flood flow paths	Detention basins (they temporarily hold water and reduce flood flows)	Culvert/bridge/pipe enlarging	Flood gates	Levee banks	Entrance management strategy	Environmental channel improvements, including removal of weeds and bank stabilisation	Planning and flood related development controls	Education of community, providing greater awareness of potential hazards	Flood forecasting, flood warning, evacuation planning and emergency response	Other option. Please specify this at the end of the survey	Response	Open-Ended Response
42	Yes, please specify, Ability to reduce water rising... water to the sea rather than back up into property	11	2	1	5	6	3	4	8	9	10	7	12	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
43	No,	1	4	3	7	8	6	12	5	10	11	9	2	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Even with our best efforts floods happen. When they do all traffic north and south is redirected down Brinawarr St when Bolong Rd floods. Our little street isn't surfaced to cope with these volumes nor heavy vehicles. A clearly signed alt flood route would be a great help to all during these events. Or, resurface this street to take the impact of increased traffic.
44	Yes, please specify, neighbour to install drainige in his back yard	3	2	1	4	11	12	6	10	5	7	8	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	while living in Fairfield i spent many years serving on catchment management committees & i am interested to see if anything has changed
45	Yes, please specify, Not at my property, but dredging and establishment of estuary groynes could be considered in certain areas as preventative measure	8	4	9	10	11	1	2	3	5	7	6	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	Not Provided
46	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
47	Yes, please specify, Be extremely vigilant with maintenance of the entrance to Shoalhaven River to ensure it is kept at the appropriate AHD	Not Provided	2	Not Provided	Not Provided	4	5	1	3	Not Provided	Not Provided	Not Provided	Not Provided	Advise people of flood risks and allow individuals to choose how they would reduce flood damage	It might be time to spend money on action rather than further studies, there cannot be that much that has changed since the last study was done. Stop looking and start doing could be an action plan worthy of consideration.
48	Yes, please specify, Fix the drainage on the other side of the street from our house so that the water makes it way, in a defined course, down to the storm water at its lowest point.	4	3	11	5	6	7	8	1	2	10	9	Not Provided	Stop all new development on land with any potential to flood	Living in one of the villages - the highest impact would for me, the disruption to travel for personal activities. I am also active in community groups so those assets need to be protected - the survey doesn't really address this from that perspective. So therefore, those operating businesses or school attendance by both teachers and students becomes an issue and an economic loss to the community. Water will always find its own level. Not a fan of drainage ponds as in a coastal area these are prone to become a mosquito breeding areas. Subsequent damage to roads etc. becomes a cost to residents and businesses in wear and tear on vehicles. I was in S.E. Qld during the Brisbane floods of 1974 - so have experience first hand. Communication and management of upstream activities - LGA to LGA talking, working together to manage the flows. Residents awareness to manage the inflows to flooded sewage systems - only flush for poos, limit washing, don't fill the bath, limit showers etc.
49	Yes, please specify, Open the mouth of the Shoalhaven River permanently	8	4	5	7	6	3	1	2	9	10	11	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	Some dredging of the Shoalhaven Estuary and permanent opening of the mouth would assist any flood to disperse
50	No,	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Place restrictions on development on flood prone land (e.g. minimum floor levels, use of flood – compatible materials)	I grew up in Elia Avenue in the late 1970s and early 1980s and my parents then moved to Lyrebird Drive. I have since purchased their home which was built with a floor level (I believe) 300mm above the 1:100 year known at the time and with additional structural works to withstand a more intense flood event. During the time I lived there the only flooding impact the eastern end of Lyrebird Drive filling through the stormwater drains - there were two events - around 1988 and 1990. The water level was higher than the level of the flooded river at the time. The subsequent minimum floor heights appear to be at least one metre higher than our house, which when it was built seemed more than adequate
51	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
52	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
53	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
54	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
55	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
56	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
57	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
58	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
59	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
60	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided
61	Not Provided	3	2	1	4	5	6	7	8	9	10	11	12	Not Provided	Not Provided

APPENDIX

E

RATING CURVE REVIEW, FFA AND ARR2019 METHODS

1 Introduction

1.1 Background

The Shoalhaven River catchment covers an area of 7,250 km^2, spanning from elevations of 1,400 mAHD in the upper reaches to sea level at Shoalhaven and Crookhaven Heads, over a river length of over 290 km.

The scope of the Lower Shoalhaven FRMS&P includes updating the hydrologic model to implement Australian Rainfall and Runoff 2019 (ARR2019) methodologies. A new hydrology model was developed and calibrated against historical events. However, initial model results using calibrated loss values suggested the peak design event flows derived using standard ARR2019 data and methods are substantially lower than previously adopted design flows derived using ARR1987.

As such, additional hydrologic investigations have been undertaken to improve confidence in design flow estimates for use moving forward in subsequent stages of the FRMS&P. These investigations have included flood frequency analyses at three locations, and a range of sensitivity analyses to investigate the influence of parameters and approaches applied using ARR2019 guidelines.

1.2 Objectives

This technical memorandum has been prepared to document the modelling approaches, inputs and outcomes of these hydrologic investigations which influenced the adopted parameters and methods for design flood estimation for use in the Flood Study.

2 ARR2019 Design flows vs ARR1987 flows

The preliminary ARR2019 design flood estimates using calibrated losses with the XP-RAFTS model produces design flood event peak flows substantially lower than using the previously adopted ARR1987 peak flows as shown in **Table 2-1**.

Table 2-1 Flow comparison between current study ARR87 results for single IFD and ARR2019 peak flows

AEP (1 in Y)	WMAwater 2013 Peak Flow ARR1987 – Single IFD and losses (m^3/s)	Current Study Peak Flow ARR2019 – calibrated losses (m^3/s)
5	-	3,684
10	7,380*	4,997
20	9,466	6,383
50	12,196	8,164
100	15,410	9,562

* This values is the 10 year ARI which does not directly translate to a 1 in 10 AEP, however, is similar for the purposes of comparison in this table

It is noted that the reduction in flows may be due in part to the model setup and choice of parameters, such as Bx, lag, PERN. However, the model has been calibrated against historical events and shows a reasonable correlation.

However, given the disparity in design flows, particularly for the 1% AEP event, it was decided in consultation with Council and DPIE that further investigation was needed to improve confidence in design flow estimates. This investigation is presented in the following sections, and included:

- Flood frequency analysis at three locations (**Section 3**);
- A closer look at the way ARR2019 methodologies were applied (**Section 4**); and
- Testing the effect of applying various preburst and continuing loss values on resulting peak flows and validation to FFA (discussed throughout **Section 3**).

3 Flood Frequency Analysis

Flood Frequency Analysis (FFA) has been undertaken at the below three locations (shown on **Figure 3-1**) to improve confidence in the estimation of design flood behaviour in the Lower Shoalhaven River:

> Shoalhaven River at Warri (215002)

> Kangaroo River at Hampden Bridge (215220)

> Shoalhaven River at Grassy Gully II (215216)

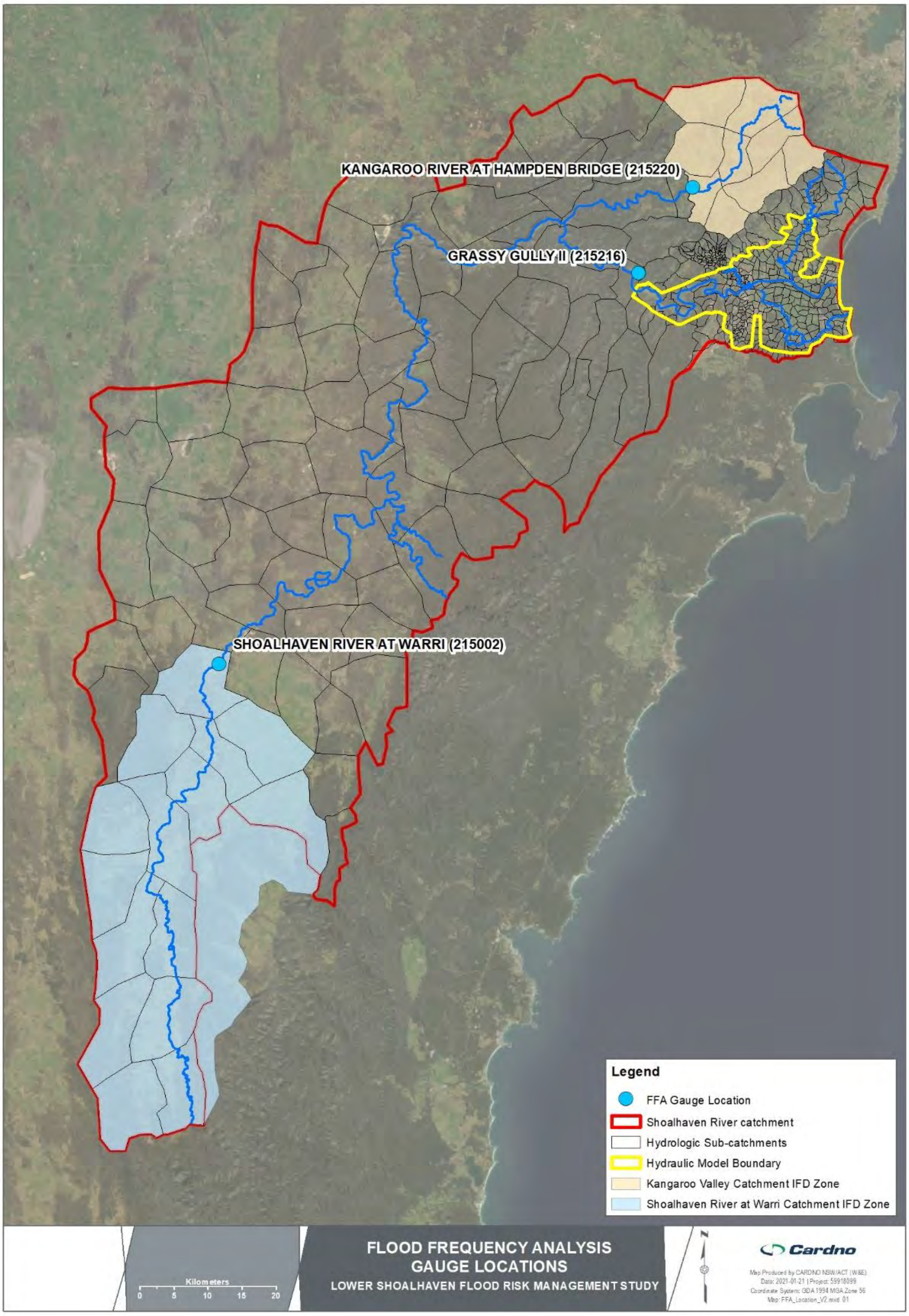


Figure 3-1 Flood Frequency Analysis Gauge Locations

3.2 ARR2019 Validation with FFA

For the Flood Frequency Analysis at each gauge, the ARR2019 design flood estimates from the hydrologic models were compared to validate them with the FFA derived flow estimates from historical observations.

For the Shoalhaven River at Warri and the Kangaroo River at Hampden Bridge gauges, modelled peak design flows were obtained using a cut-down version of the calibrated XP RAFTS model for the catchment to each gauge only (i.e. Shoalhaven River catchment to the Warri gauge only and Kangaroo River catchment to the Hampden Bridge gauge only). All model parameters used in these models are as per described in **Section 2**, except for the IFD (based on the Warri or Hampden Bridge catchment centroid, and ARF, which was calculated based on the catchment area to each gauge only).

Due to the preliminary ARR2019 design flood estimates developed using calibrated losses being substantially lower than peak flows adopted in previous flood studies (**Section 2**), sensitivity was undertaken to understand the impact of application of different parameters for the ARR2019 methods, in particular, altering losses and pre-burst (as described in **Section 4.2** and **4.3**).

The various ARR2019 peak flow estimates using different parameters is plotted on each FFA figure to demonstrate the validation against the FFA.

3.3 Shoalhaven River at Warri (215002)

3.3.1 Available Data

The Shoalhaven River at Warri Gauge (215002) is located near Warri Bridge on the Kings Highway over the Shoalhaven River in the upper reaches of the catchment. The Shoalhaven River at Warri Gauge was opened on the 2nd of September 1914, and is currently operated by WaterNSW. There are numerous years with missing or partial data between 1914 and 1969, with continuous data available from 1969 to present. Of these years 20 years have partial data and 13 years with no recorded data.

3.3.2 Review of Rating Table

The most recent rating curve produced by WaterNSW was published on the 18th November 2017, and is used to convert continuous stream level data into flows (in megalitres per day). The relationship between height (or stage) to flow is defined by a series of instantaneous velocity measurements at known heights, converted to flows using cross-sectional data at the gauge location. To assess the suitability of the provided rating curve, Cardno reviewed the gauging record (**Figure 3-2**) and compared the Annual Maximum Flows provided directly by WaterNSW with flows calculated using the corresponding stage level and the provided rating curve (**Figure 3-3**).

As shown in **Figure 3-2**, gaugings have been completed across a range of stream levels up to approximately 7 m at the gauge, and the comparison of provided and calculated annual maximum flows shows generally good agreement (**Figure 3-3**). While uncertainty remains regarding the relationship between stage and flow for river levels above 7 m, the current rating curve and flow data provided by WaterNSW was considered fit for use in the FFA.

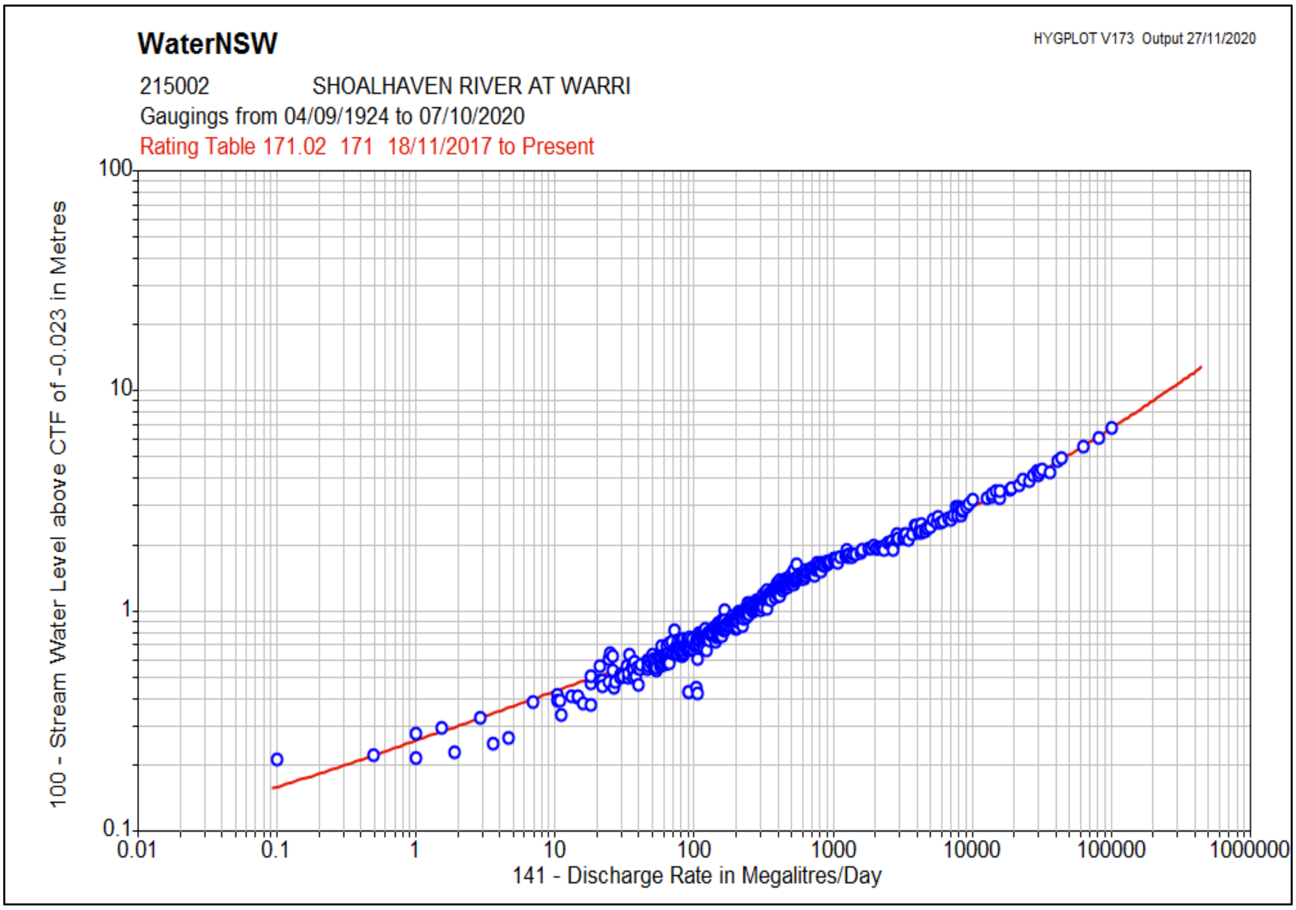


Figure 3-2 Gauging record (215002) obtained from WaterNSW RealTime Data Online

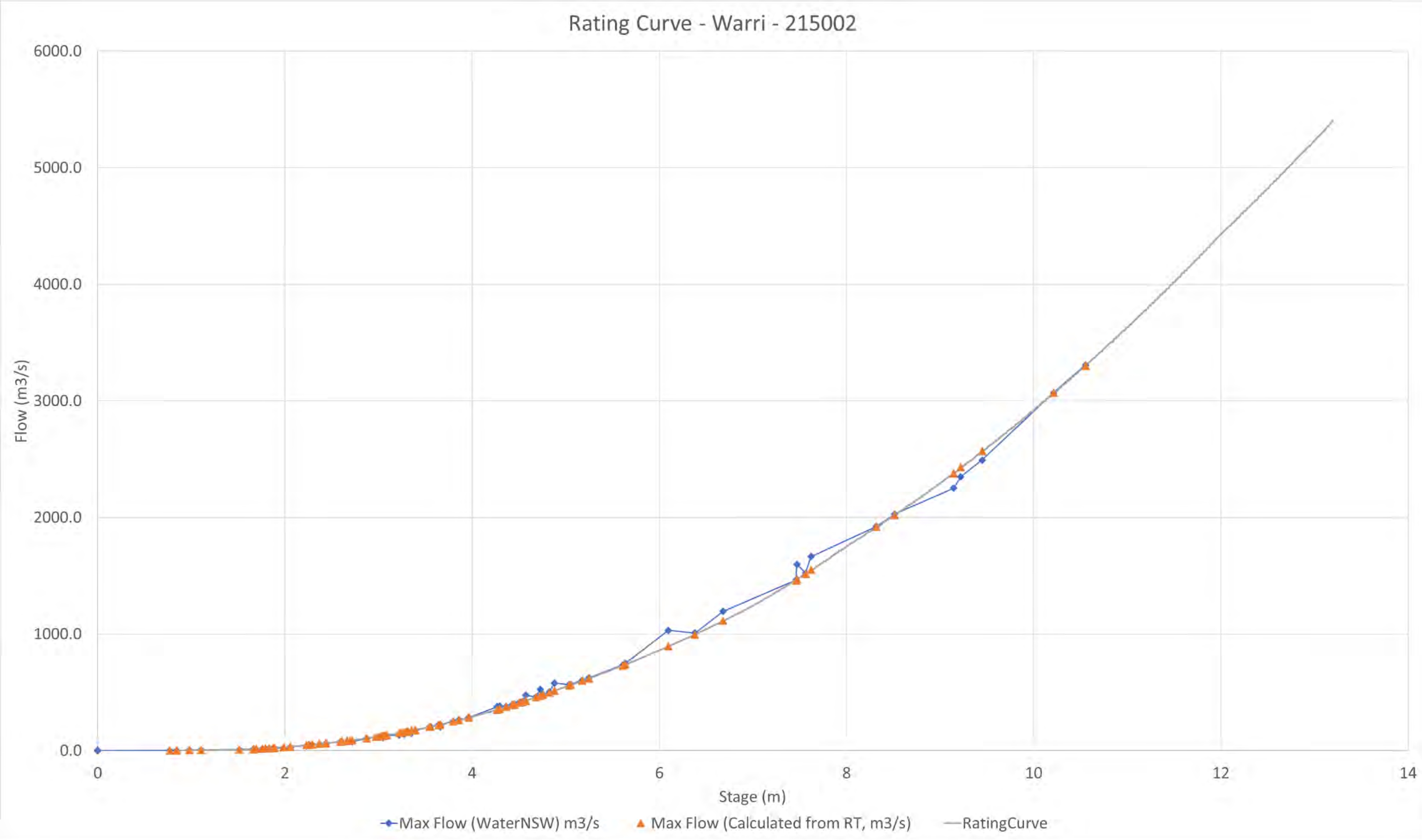


Figure 3-3 Comparison of Annual Maximum Flows as provided by WaterNSW and as calculated from Stage Data using the Rating Table at the Shoalhaven River at Warri Gauge (215002).

3.3.3 FFA Inputs and Approach

An Annual Maximum Series was developed based on annual maximum flow data provided by WaterNSW and is provided in **Table 3-1**. For this FFA a Bayesian maximum likelihood approach was adopted, and a Log Pearson III (LP3) distribution fitted using the TUFLOW FLIKE FFA software developed by Kuczera (2001). A multiple Grubbs-Beck censoring was applied, and years with no data were excluded from the AMS using the 'Block Exclude' function.

Table 3-1 Available Annual Maxima Flows at Shoalhaven River at Warri Gauge (215002)

Year	Annual Maximum Flow (m^3/s)	Year	Annual Maximum Flow (m^3/s)	Year	Annual Maximum Flow (m^3/s)
1914	113*	1950	207	1986	393
1915	152	1951	378	1987	21*
1916	1,664	1952	1,193*	1988	2*
1917	205	1953	n/a	1989	115*
1918	77	1954	n/a	1990	737
1919	59	1955	n/a	1991	1,523
1920	277	1956	n/a	1992	502
1921	205	1957	n/a	1993	124
1922	2,492	1958	n/a	1994	152
1923	113	1959	2,349*	1995	461
1924	31	1960	23*	1996	223
1925	474*	1961	n/a	1997	605
1926	21	1962	n/a	1998	568*
1927	53	1963	76*	1999	396
1928	141	1964	n/a	2000	57
1929	527	1965	n/a	2001	175*
1930	113	1966	n/a	2002	127
1931	474	1967	n/a	2003	19
1932	59	1968	n/a	2004	17
1933	48	1969	121*	2005	41*
1934	1,597	1970	263	2006	2*
1935	73	1971	567	2007	128
1936	381	1972	163	2008	14
1937	113	1973	104	2009	1
1938	579	1974	3,070	2010	252
1939	152	1975	1,923	2011	379
1940	15	1976	2,029	2012	421
1941	82	1977	1,009*	2013	399
1942	134	1978	3,308*	2014	284
1943	1,031	1979	624	2015	221
1944	283	1980	12*	2016	748
1945	2,251	1981	159*	2017	49
1946	62	1982	3*	2018	9
1947	218	1983	413	2019	13
1948	283	1984	201*	2020	1,464
1949	77	1985	481		

(*Indicates partial record of flow in that year)

3.3.4 FFA Results

The resulting FFA fit is shown on **Figure 3-4**, with peak flows for design events listed in **Table 3-2.**

Table 3-2 Shoalhaven River at Warri (215002) FFA Peak Flow Results

AEP Event	FFA Expected Flow (m^3/s)	ARR87 Design Flow (m^3/s)	ARR2019 Design Flow (m^3/s) Calibrated Losses	ARR2019 Design Flow (m^3/s) CL = 0mm/hr
50%	204	768	235	911
20%	724	1,241	535	1,377
10%	1,278	1,542	759	1,680
5%	1,954	1,966	1,049	1,995
2%	3,006	2,495	1,499	2,461
1%	3,901	2,959	1,871	2,848

Note: Modelled peak design flows were obtained using a cut-down version of the calibrated XP RAFTS model for the Shoalhaven River catchment to the Warri gauge only. All model parameters used in this model are as per the overall Shoalhaven River catchment model, except for the IFD (based on the Warri Catchment centroid, and ARF, which was calculated based on the catchment area to Warri only).

The resulting FFA curve plots well through recorded data up to the 10% AEP event, with relatively confined confidence limits. At the upper end (from the 2% AEP and above) however, the fit generally trends higher than recorded data at higher flows.

The envelope of ARR2019 design results indicates that it is not possible to validate the model to the FFA using uniform losses applied across the suite of design flood events. The gradient of the model derived peak flows is much flatter than the FFA fit such that the more frequent events tend to be overestimated and the rarer events tend to be underestimated. Results derived using calibrated losses provide a good match to the 20% AEP expected quantile, however, significantly underestimate the 1% AEP flows. Using 0 mm/hr continuing losses would be required to achieve ARR2019 design flow estimates that approach the 1% AEP expected flow, which then plots reasonably well with observed flows.

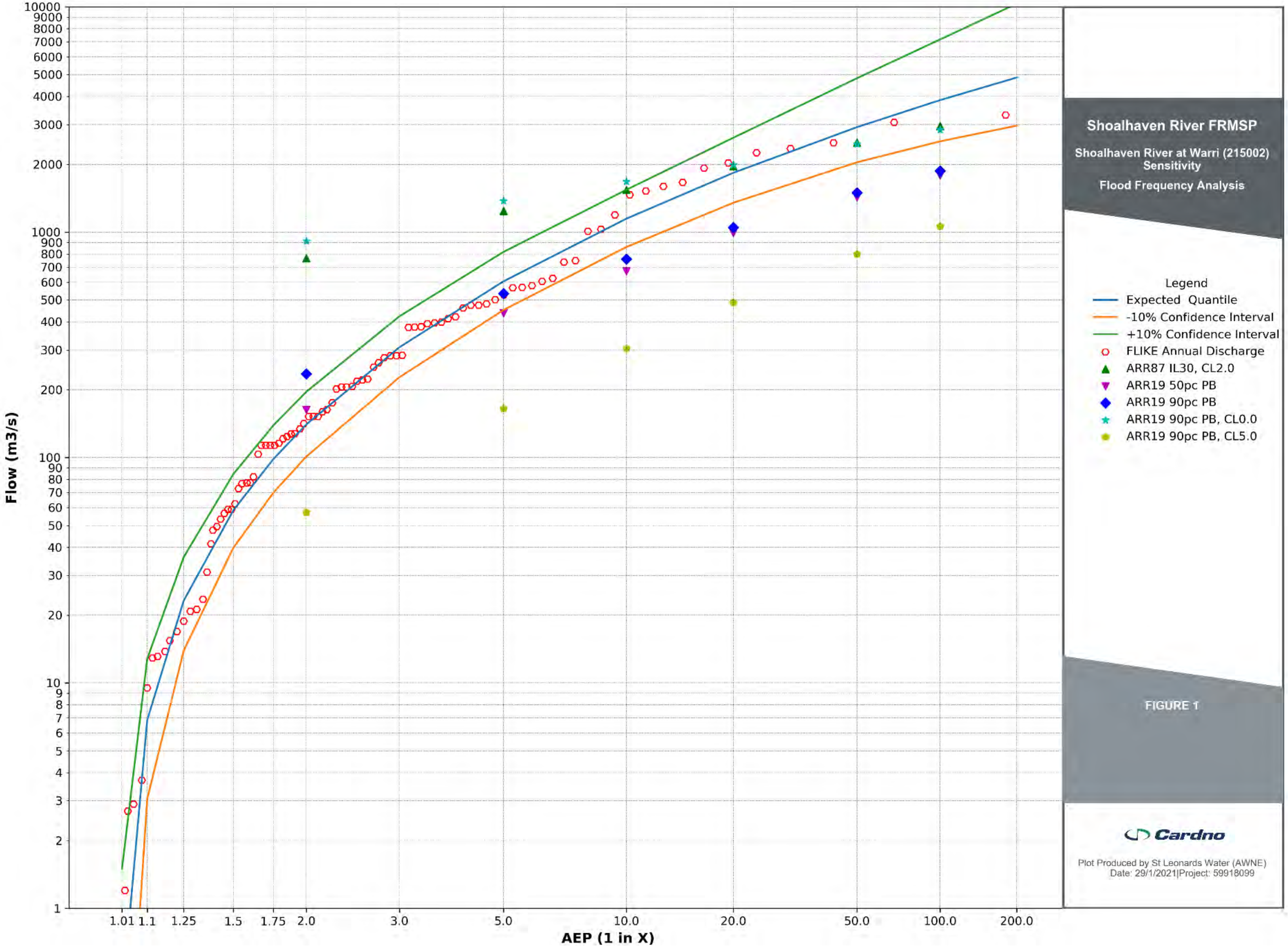


Figure 3-4 Flood Frequency Analysis Results – Shoalhaven River at Warri (215002)

3.4 Kangaroo River at Hampden Bridge (215220)

3.4.1 Available Data

The Kangaroo River at Hampden Bridge gauge (215220) is located in Kangaroo Valley upstream of Tallowa Dam. The Hampden Bridge gauge was reportedly opened on the 12th of July 1966, with data available from November 1973, and is currently operated by WaterNSW.

3.4.2 Review of Rating Table

As for the Shoalhaven River at Warri, Cardno assessed the suitability of the Hampden Bridge rating table for use in the FFA by reviewing the available gauging record. As shown in **Figure 3-5**, gaugings have been undertaken at the Hampden Bridge gauge in a range of events up to levels of approximately 8 m at the gauge. This provides confidence in the relationship between stage and flow for events below 8 m, however there is still uncertainty for events above 8 m at the gauge.

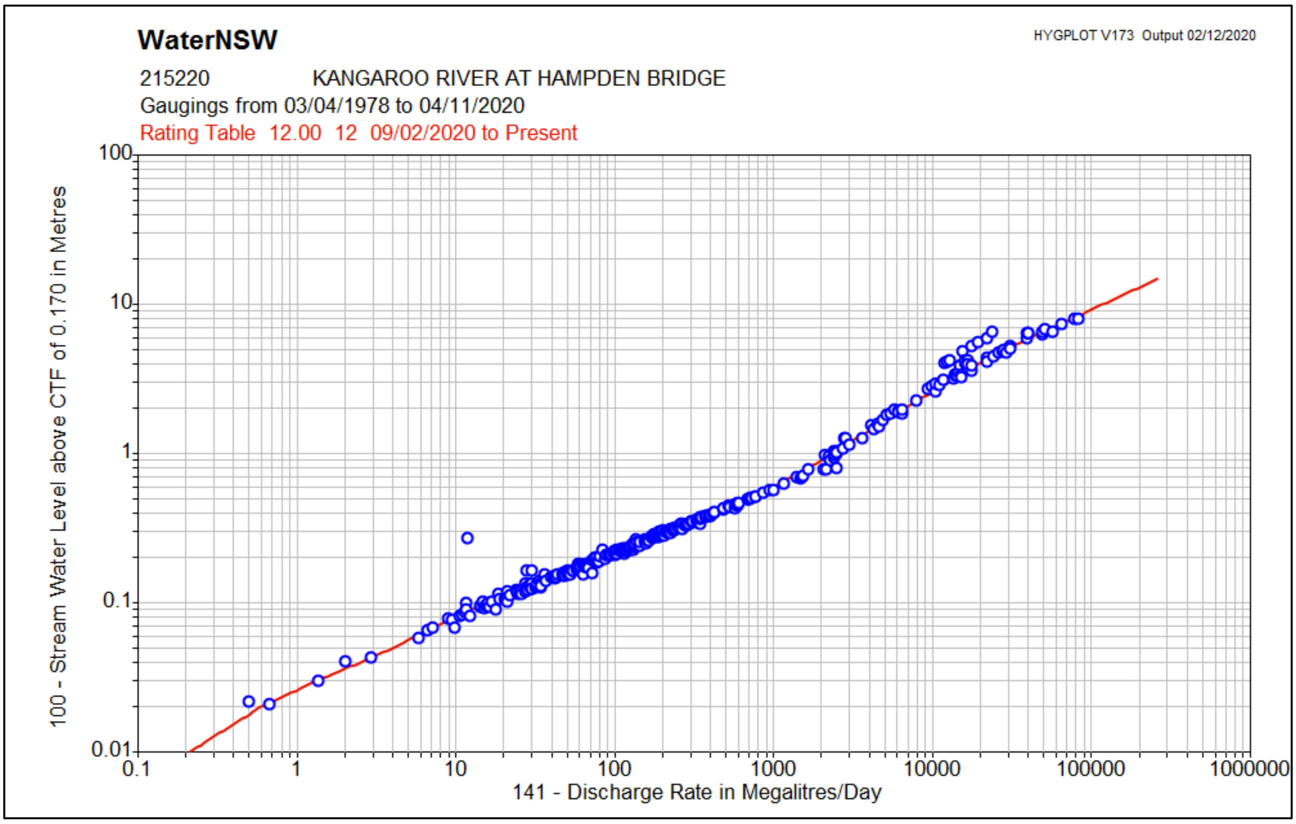


Figure 3-5 Gauging record (215220) obtained from WaterNSW RealTime Data Online

In addition, the flow data provided by WaterNSW was compared with flows derived from stage data using the available rating table. The current rating table was published on the 9th February 2020. As seen in **Figure 3-6** there is generally a good agreement between the flow data provided by WaterNSW and the flows calculated by converting the stage data to flow using the provided rating table (note the annual maximums only are shown).

The 1974 event however appears to be an outlier: the recorded peak level during this event was 11.803 m at the gauge. The corresponding flow provided by WaterNSW is 1003.3 m^3/s, however, when 11.803 m is converted to flow using the provided rating table, a peak flow of 1840.3 m^3/s is found. For the purposes of the FFA Annual Maximum Series, the 1974 peak flow was corrected to 1840.3 m^3/s. This is considered reasonable given the recently recorded 2020 event peaked at approximately the same level (11.79 m) and was attributed a flow of 1840 m^3/s.

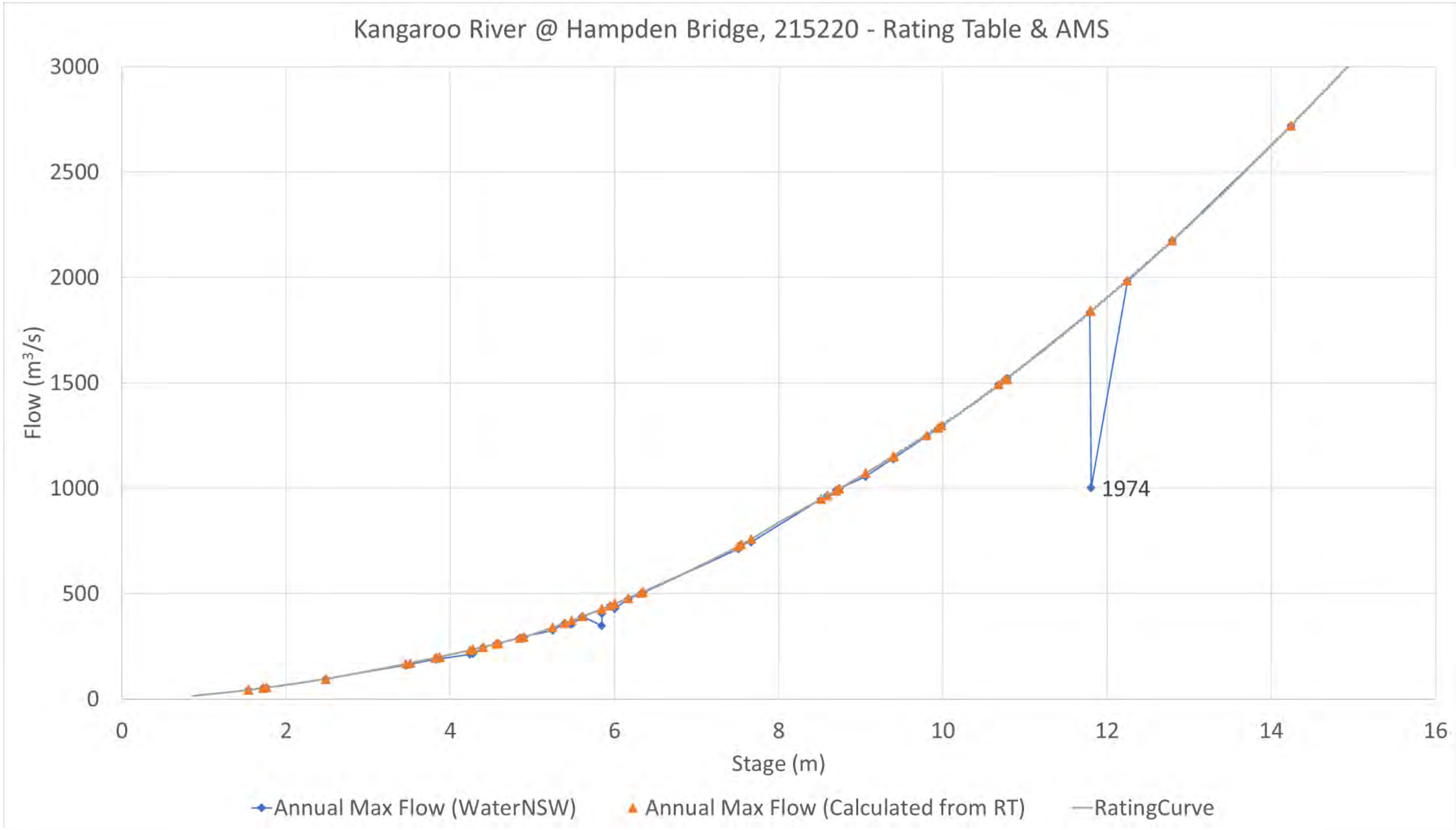


Figure 3-6 Kangaroo River at Hampden Bridge (Gauge 215220) – Rating Table and Annual Maximum Series

An Annual Maximum Series (AMS) was developed based on annual maximum flow data provided by WaterNSW, with the 1974 peak flow corrected as described above. The resulting AMS is provided in **Table 3-3**. For this FFA a Bayesian maximum likelihood approach was adopted, and a Log Pearson III (LP3) distribution fitted using the TUFLOW FLIKE FFA software developed by Kuczera (2001).

Table 3-3 Available Annual Maxima Flows at Hampden Bridge gauge (215220)

Year	Annual Maximum Flow (m3/s)	Year	Annual Maximum Flow (m3/s)	Year	Annual Maximum Flow (m3/s)
1973	426	1989	372	2005	997
1974	1,840	1990	1,493	2006	96
1975	2,720	1991	2,176	2007	295
1976	723	1992	1,517	2008	170
1977	1,150	1993	428	2009	43
1978	1,984	1994	236	2010	291
1979	232	1995	989	2011	504
1980	451	1996	247	2012	166
1981	340	1997	264	2013	966
1982	52	1998	479	2014	734
1983	1,154	1999	509	2015	197
1984	1,250	2000	443	2016	1,516
1985	759	2001	200	2017	949
1986	1,072	2002	360	2018	391
1987	1,285	2003	262	2019	54
1988	1,296	2004	196	2020	1,840

3.4.3 FFA Results

The resulting FFA fit is shown on **Figure 3-7**, with peak flows for design events listed in **Table 3-4**.

Table 3-4 Adopted expected design event flows at Hampden Bridge gauge (215220)

AEP Event	FFA Expected Flow (m^3/s)	ARR87 Design Flow (m^3/s)	ARR2019 Design Flow (m^3/s) Calibrated Losses	ARR2019 Design Flow (m^3/s) Zero CL
50%	556	1,244	772	990
20%	1,213	1,898	1,228	1,443
10%	1,711	2,307	1,547	1,760
5%	2,202	2,825	1,864	2,075
2%	2,834	3,338	2,273	2,483
1%	3,293	3,866	2,578	2,788

The fit generally aligns well with recorded flows at the lower end (more frequent than 1 in 2 AEP), however there appears to be a step in the recorded data just above this point. Above the 10% AEP event the FFA fit generally trends higher than the recorded flows and is considered a poor fit, providing overestimates of the expected flow for the 5% AEP and rarer events.

As with the Warri FFA, comparing the envelope of ARR2019 design results to the FFA fit indicates, it is not possible to validate design flows to the FFA using a uniform set of loss parameters across the design events. At this location, while using a continuing loss of 0 mm/hr does not generate sufficient flow to reach the expected quantile, the design flow estimates compare well with the observed data from the 5% AEP to the 1% AEP. Higher continuing loss would be required for more frequent events to compare with the FFA fit.

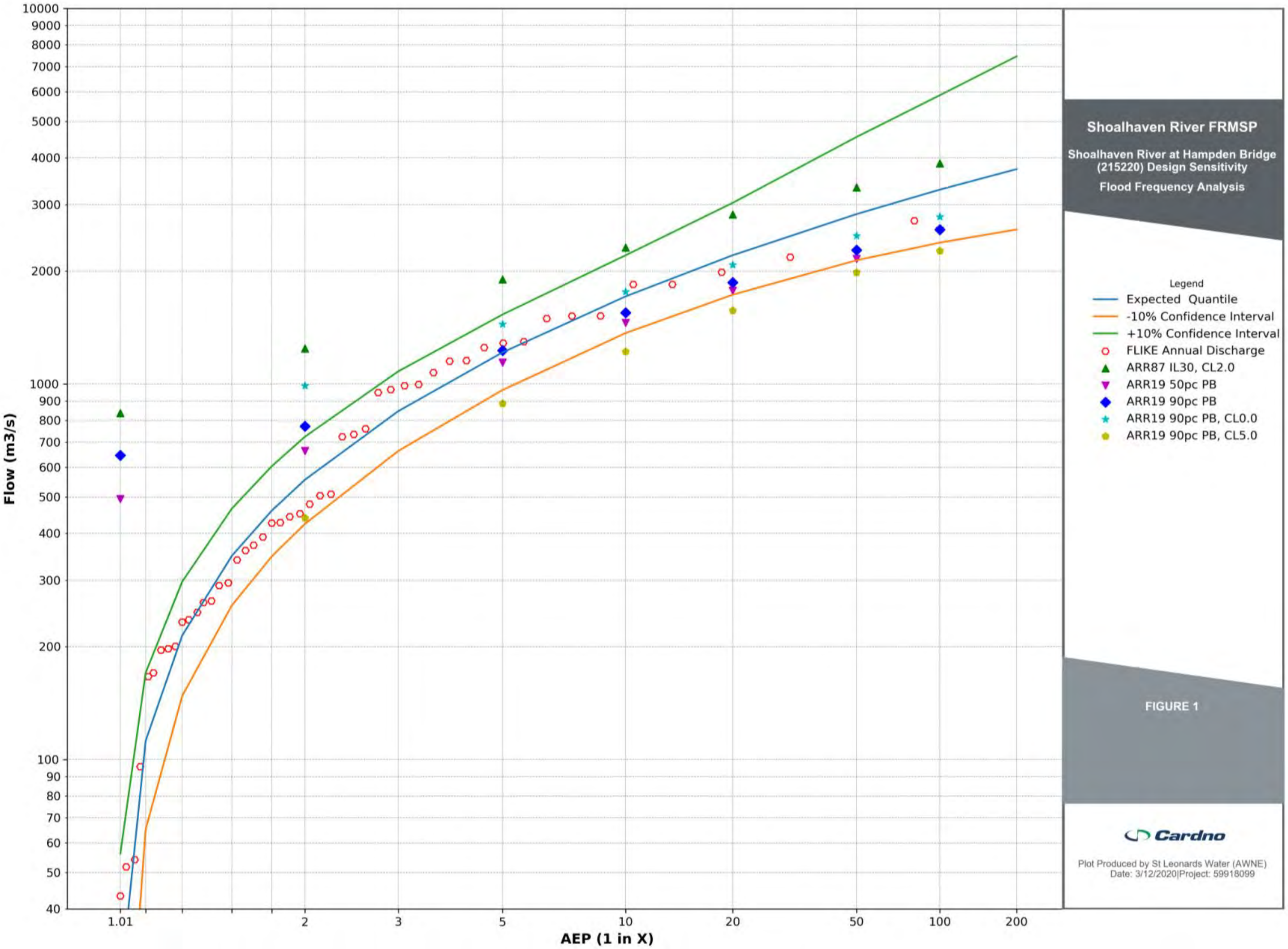


Figure 3-7 Flood Frequency Analysis Results

3.5 Shoalhaven River at Grassy Gully II (215216)

3.5.1 Available Data

The Grassy Gully II gauge is located on the Shoalhaven River approximately 38 km upstream of Nowra Bridge. This is a valuable location to undertake a flood frequency analysis, as it is sufficiently downstream to capture inflows from the majority of the catchment, and sufficiently upstream to not be tidally influenced (unlike Nowra Bridge), while still being close to our area of interest in the Lower Shoalhaven River area.

The Grassy Gully II gauge (215216) was opened on the 20th October 1982 with continuous flow data available from this date to present. Prior to this gauge opening, Grassy Gully I was located approximately 500 m downstream of Grassy Gully II. Flow data at this gauge was requested from WaterNSW but was unable to be obtained. It is noted also that according to the 1990 Lower Shoalhaven River Flood Study (PWD,1990), the recorder at Grassy Gully failed during the 1974 and 1975 floods.

3.5.2 Review of Rating Table

A rating curve review at the Grassy Gully II gauge (215216) was undertaken to assess its suitability for use in the FFA. The gauging record was provided by WaterNSW (via Shoalhaven City Council), along with the current rating table (from 2013). Using the Annual Maximum Stage data, the provided rating table was used to convert recorded stage data into flows, to compare with the WaterNSW-provided flow data. These are plotted on **Figure 3-8.**

As can be seen in **Figure 3-8**, there is generally good agreement in calculated and provided flows below levels of approximately 5 m at the gauge. However, above this level, there is a discrepancy between provided and calculated flow values, and a clear change in rating curves over time, shown around the 8 m mark. Investigation through the PINEENA database revealed a number of rating curve changes over time, with a recent more notable change that appears to place more confidence in recent gaugings using ADCP than other manual gauging methods used to define previous rating tables. It is noted that the gaugings shown between 10-12 m were recorded using Acoustic Doppler methods during the 2013 event, and may have inspired a greater level of confidence than other manual gauging methods used to define previous rating tables. The reasons for (and suitability) of this change in rating table however are not clearly understood.

There was considered to be sufficient uncertainty in the relationship between stage and flow at Grassy Gully II to warrant the development of a rating curve using a localised TUFLOW hydraulic model. Confirmation of the rating curve through hydraulic modelling was used to improve confidence in the AMS for use in the FFA to develop design flow estimates that were robust for use in the flood study. The rating curve was validated by establishing a TUFLOW two-dimensional hydraulic model of the river reach at Grassy Gully. The model used available LiDAR and bathymetry data, and selection of hydraulic roughness parameters (Manning's 'n') was based on land use and vegetation cover. The model was run for an extreme event inflow hydrograph to develop a relationship between stage and flow at the Grassy Gully II (215216) gauge location over a full range of flows.

Two additional scenarios were also investigated to determine the influence of Manning's 'n' applied within the cut-down Study Area on the results. The model outputs, along with gauging records and AMS (derived from the 2013 WaterNSW rating curve *and* as provided by WaterNSW directly) are presented in **Figure 3-9.** Note that in this figure, stage is plotted in mAHD (rather than Gauge m). Gauge zero (215216) = 2.732 mAHD.

Note: The sensitivity of the model results to the assigned Manning's 'n' was tested as part of the rating curve development. The scenarios are shown in **Table 3-5**.

Table 3-5 Hydraulic roughness sensitivity values applied

Hydraulic Roughness	Standard Manning's 'n'	S1 - Increased Manning's 'n'	S2 - Decreased Manning's 'n'
Watercourse	0.03	0.035	0.025
Grassy/lightly Vegetated	0.035	0.04	0.03
Light Vegetation	0.045	0.05	0.04
Medium Vegetation	0.05	0.06	0.04
Dense Vegetation	0.1	0.12	0.08

Figure 3-9 indicates that the rating curves derived from the TUFLOW model using the 'standard' and 'increased' values of Manning's 'n' provide the most agreement with the recorded gaugings. Following discussion with Council and DPIE, it was considered appropriate to proceed using the rating table developed using the Standard Manning's 'n' values. This curve shows a better agreement with gaugings around the 11 m level and below, while there is less confidence in the higher gaugings.

Following peer review, further refinements were made to the model parameters and the adopted rating curve. The final adopted TUFLOW rating curve is shown in **Figure 3-10** compared with the latest WaterNSW rating curve (from 2013-present) and the previously adopted rating curve (2007-2013).

It was found that the hydraulic model rating plots well through the majority of gauging points for low flows and compares well with the WaterNSW 2007-2013 rating curve. This allows effective extrapolation of the rating relationship for larger flows beyond the field gaugings using the TUFLOW derived rating curve. The rating relationship is based on the hydraulic characteristics of the channel reach as assessed by the model, rather than an extrapolation from lower values.

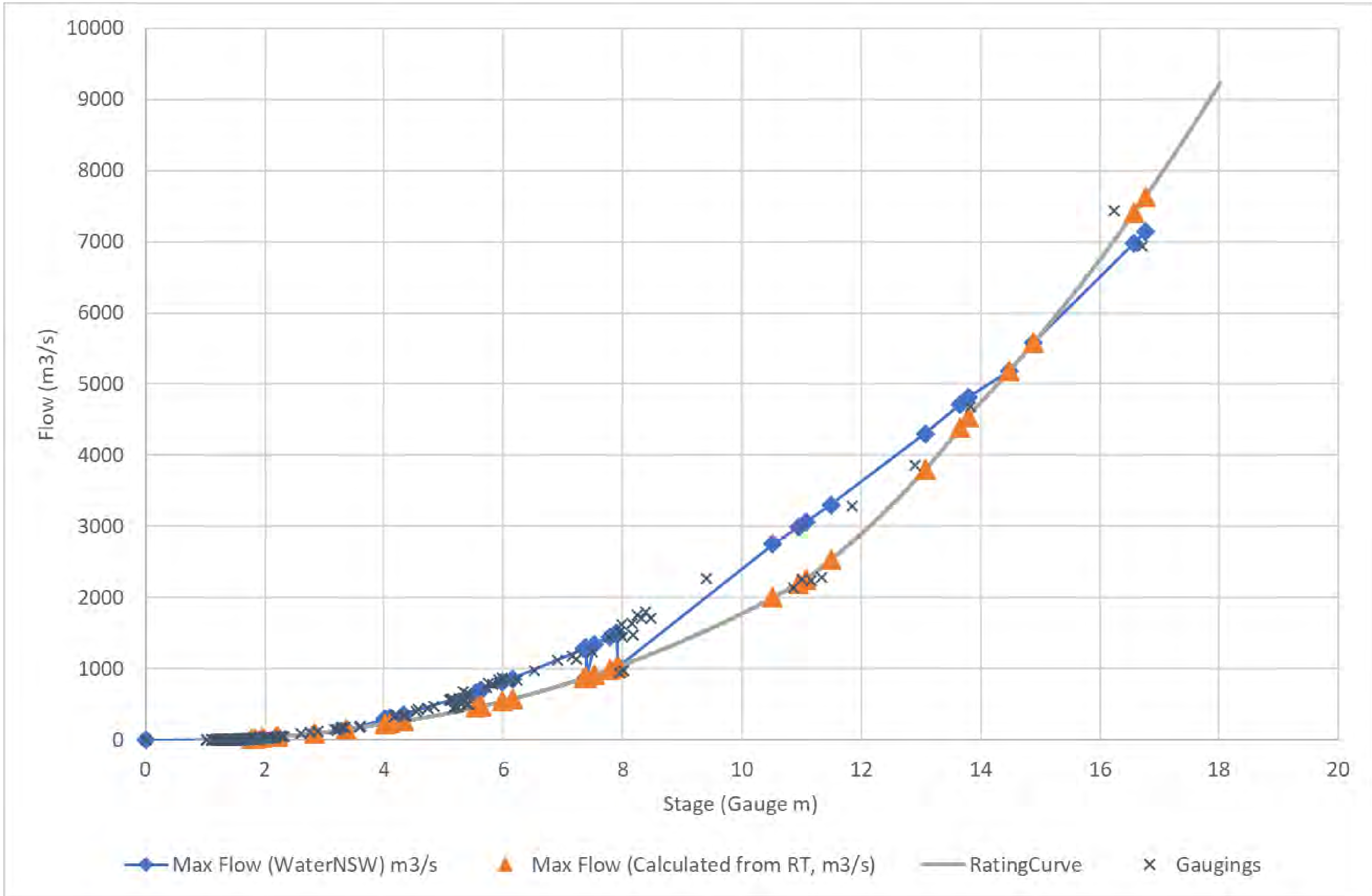


Figure 3-8 Shoalhaven River at Grassy Gully II (215216) – Rating Table, Annual Maximum Series and Gaugings

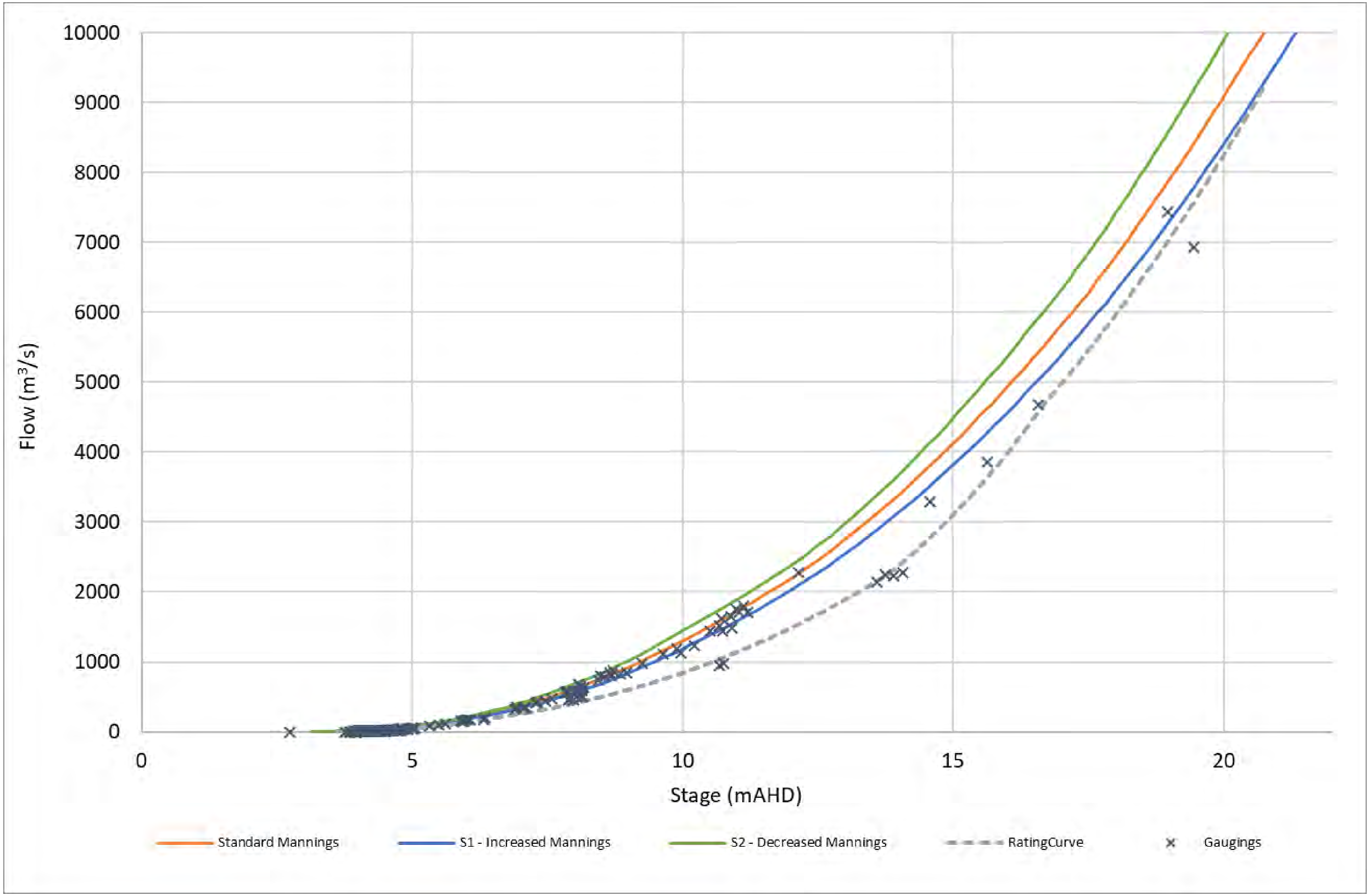


Figure 3-9 Shoalhaven River at Grassy Gully II (215216) – TUFLOW derived rating curves.

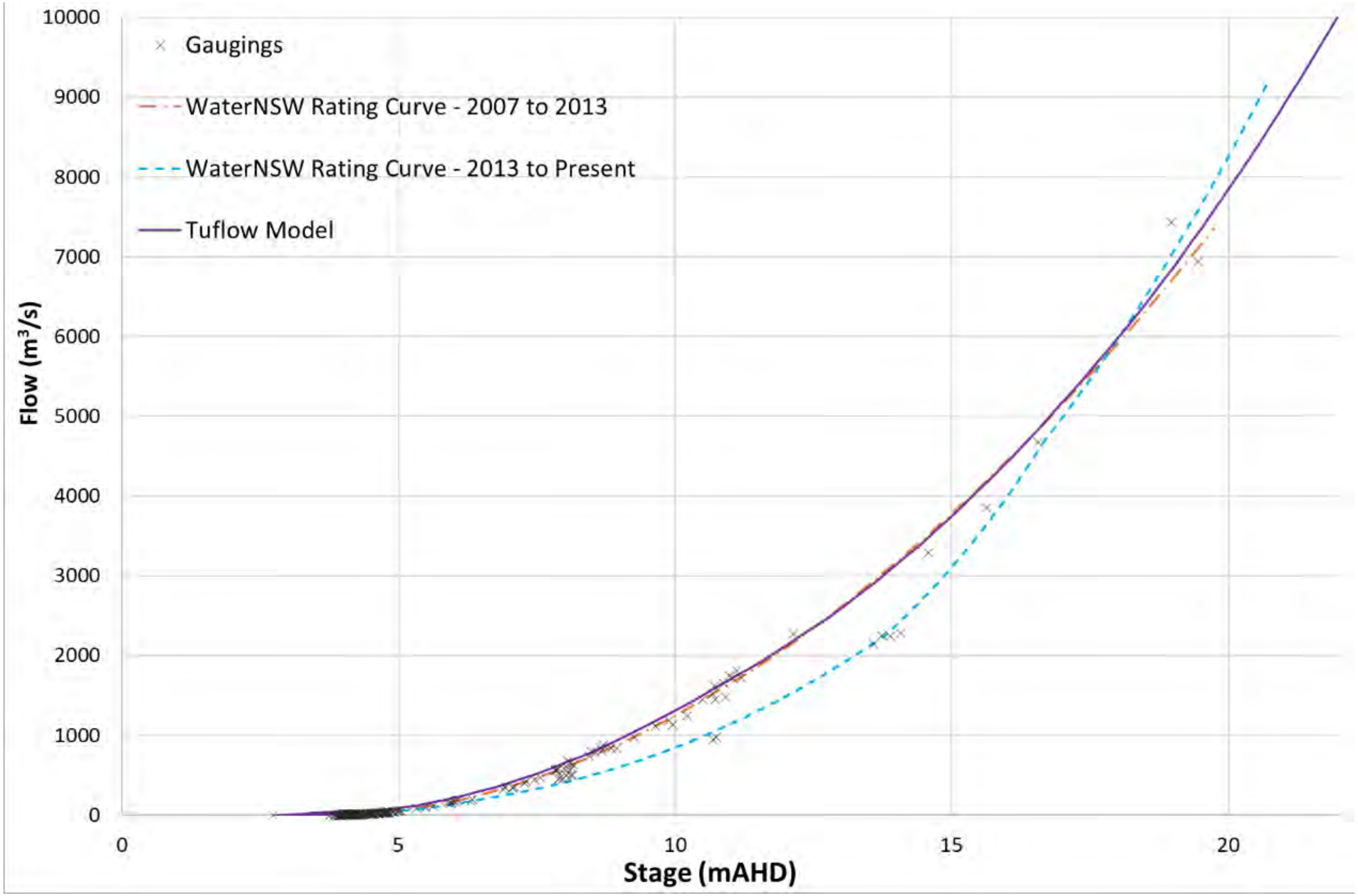


Figure 3-10 Shoalhaven River at Grassy Gully II (215216) – Adopted TUFLOW derived rating curve.

3.5.3 Annual Maximum Series

Using the rating table described above (with the standard Manning's 'n'), recorded stage data at Grassy Gully II (215216) was converted into an annual maximum series (AMS) of flows for use in the Flood Frequency Analysis. The AMS is presented in **Table 3-6**.

Table 3-6 Annual Maximum Series at Grassy Gully II (215216)

Year	Maximum Flow (m^3/s)	Year	Maximum Flow (m^3/s)
1987	55	2004	82
1988	7,332	2005	1,355
1989	2,960	2006	81
1990	7,150	2007	862
1991	4,818	2008	745
1992	3,267	2009	56
1993	365	2010	1,550
1994	915	2011	1,505
1995	1,406	2012	3,025
1996	1,339	2013	5,340
1997	2,720	2014	1,560
1998	4,283	2015	5,667
1999	4,713	2016	~4,200*
2000	414	2017	1,355
2001	754	2018	150
2002	728	2019	63
2003	346	2020	5,893

*Level data at Grassy Gully during this event is poor. Estimated from Burrier gauge

3.5.4 Extending the record – Historic Flood Levels recorded at Nowra Bridge

Though commissioned in 1982, the Shoalhaven River at Grassy Gully II gauge (215216) has only been recording water levels since 1987, providing a record of 34 years, which is considered to be a short record. While providing a generally reliable insight into the magnitude of relatively frequent events (up to say the 5% AEP event), to improve confidence in the estimate of rarer events it is beneficial to extent the record period as much as possible.

Observed peak flood levels at Nowra Bridge are available from as early as 1860 from the Shoalhaven River Flood History 'compendium', presented in **Figure 3-11** (Condon, 1986). It is noted that there are a range of uncertainties surrounding the recorded peak flood levels due to a variety of factors including:

> Conjecture/disagreement of recorded flood levels in 1920 and 1925 (documented in the same compendium);

> Location and timing of recorded levels; and

> Impact of tidal influence and/or storm surge on recorded levels.

There are also challenges associated with uncertainty around floodplain conditions (e.g. vegetation, changes in topography and bathymetry over time), influence of tailwater and entrance conditions at the time of the event, and the location of rainfall that contributed to the flood (whether upstream or downstream of Tallowa Dam, for example).

APPENDIX 4.

ANNUAL SERIES

STANDARD DATUM

April	1842	--
March	1857	--
February	1860	5.7
June	1864	5.2
April	1867	5.1
April	1870	6.5
May	1871	4.7
February	1873	6.2
June	1891	5.3
February	1898	5.0
July	1899	2.7
July	1900	4.4
July	1904	3.7
January	1911	3.6
October	1916	5.3
December	1920	4.2
July	1922	4.4
11 May	1925	5.4
April	1927	2.5
January	1934	--
September	1938	--
April	1945	--
May	1948	3.0
June	1949	4.0
June	1951	3.0
May	1955	3.2
February	1956	4.6
July	1958	3.0
October	1959	4.7
March	1961	4.2
June	1964	3.5
September	1967	3.2
August	1974	4.9
June	1975	4.9
October	1976	4.1
March	1978	5.3

Figure 3-11 Annual Series (developed by J Condon), included in the Shoalhaven River Flood History document.

There have been a number of changes in the catchment over time that may influence the homogeneity of the water level record at Nowra Bridge, i.e. for a given flow, the water level that was experienced at the time of the event may be different if the same rainfall event was experienced under ‘present day’ conditions. Some notable changes in the catchment that would have an influence on flood levels at Nowra Bridge include:

> Hydraulic Structures:
  - Original Nowra Bridge (now southbound carriageway) – 1881
  - Terara Levees – approx. 1974 and 1978 and repair in 2005
  - Nowra Bridge duplication (northbound carriageway) - 1981
> Dams in the catchment
  - Fitzroy Falls Reservoir – completed 1974 and
  - Tallow Dam – completed 1976
  - Danjera Dam – completed 1971

Based on the above, it is seen that historical water levels cannot be converted to flows using the rating curve at Nowra Bridge for ‘present day’ catchment conditions. The flow associated with the reported historical flood level needs to be determined using a rating curve for the catchment conditions that prevailed at the time of each event.

It is then necessary to (as best as possible) estimate the magnitude of historic event flows if they had occurred under 'present day' conditions, so that a homogeneous record can be established for use in the Flood Frequency Analysis.

Using the available hydrologic and hydraulic modelling tools, the available historical flood level information at Nowra Bridge has been used by converting it to flows at Grassy Gully II under current catchment conditions using a series of adjustments involving the following steps:

> Convert recorded stage levels (shown in **Figure 3-11**) in m (Standard Datum) to mAHD;

> Investigate the sensitivity of levels at Nowra Bridge to Tailwater Conditions (**Section 3.5.4.2**);

> Convert levels at Nowra Bridge to flows under prevailing catchment conditions at the time of each event (**Section 3.5.4.3**);

> Convert flows at Nowra Bridge to flows at Grassy Gully II (215216) (**Section 3.5.4.4**);

> Investigate the effect of Tallowa Dam on peak flows at Grassy Gully II (**Section 3.5.4.5**) and make adjustments to flows to "present day" catchment conditions; and

> Develop a homogeneous dataset for use in the FFA (**Section 3.5.5**).

3.5.4.2 Sensitivity to Tailwater Conditions

The sensitivity of flood levels at Nowra Bridge to tailwater conditions was investigated by running the PMF in the hydraulic model with three fixed tailwater conditions: a low tide level (-0.5 mAHD); mean sea level (0 mAHD), and Highest Astronomical Tide (HAT) (1.01 mAHD). The results (plotted in **Figure 3-12)** show some variation for levels less than around 1.2 mAHD, but minimal difference for levels greater than 2.5 mAHD. Given that we are most interested in levels above 2.5 mAHD (the lowest recorded level at Nowra Bridge noted in Figure **3-11**), the influence of tailwater conditions on recorded levels has been assumed to be negligible, and on this basis, no adjustment has been applied to the recorded levels at Nowra Bridge;

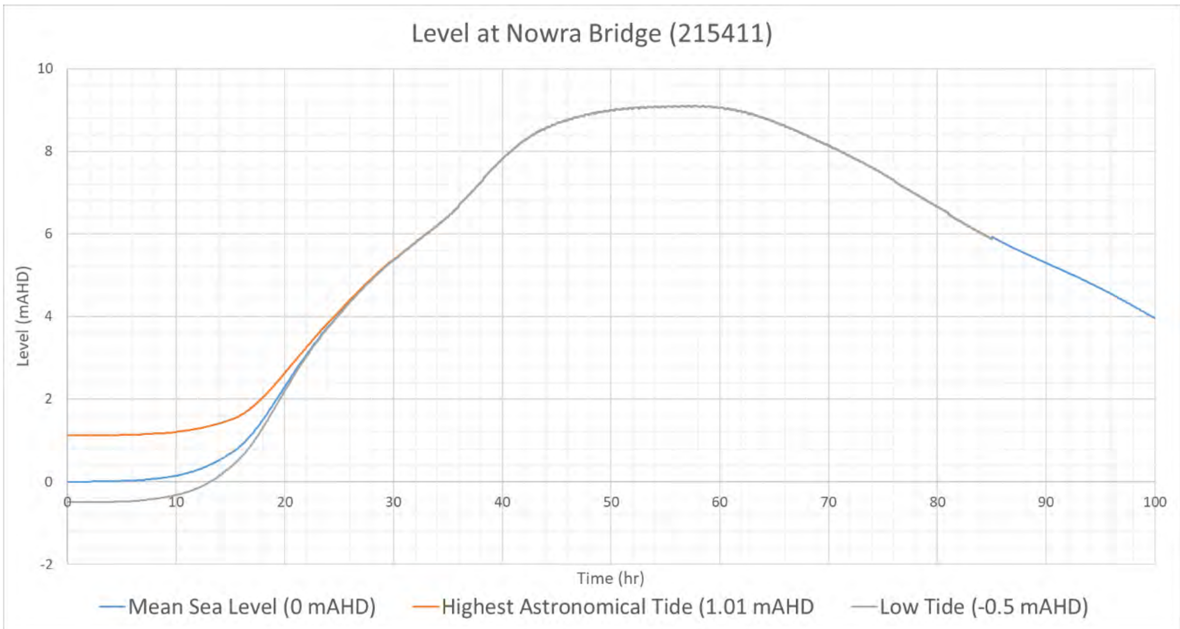


Figure 3-12 Effect of tailwater tidal conditions on levels at Nowra Bridge

3.5.4.3 Conversion of historical levels to flows under "prevailing catchment conditions"

In order to determine the flow associated with historical reported flood levels at Nowra Bridge, the hydraulic model was modified to represent two historic scenarios in addition to current catchment conditions (post 1981). These scenarios included:

- Pre 1881 – as per current catchment conditions, but omitting the Tier 1 Terara Levees (from downstream of Nowra Bridge to the eastern end of the township of Terara) and omitting both Nowra Bridges, shown in Figure 3-15;
- 1881 – 1974 – as per current catchment conditions, omitting the Terara Levees (as above), and including only the original Nowra Bridge (southbound) (completed in 1881);

Note: Analysis found that the addition of the Terara Levees (1974) and newer Nowra Bridge (1981) did not make a material difference to the results at Nowra Bridge compared to the 1881-1974 scenario, and so records between 1974 to 1978 were assumed to be as per current (post 1981) conditions.

For each scenario, a rating curve was derived at Nowra Bridge using the hydraulic model. This was used to convert reported flood levels (in mAHD) to flow (in m^3/s) for catchment conditions at the time of each event.

3.5.4.4 Relate flows at Nowra Bridge to flows at Grassy Gully II

Using the XP-RAFTS hydrologic model, a series of hydrographs were run to establish a relationship between peak flows at Grassy Gully II and Nowra Bridge. The theoretical flow scenarios were selected arbitrarily to cover a range of flows and included:

- The August 2015 calibration event (~5000 m^3/s);
- A theoretical event equivalent to ~10,000 m^3/s;
- An ‘August 2015’ event using Nowra rainfall across the catchment equivalent to ~12,000 m^3/s;
- A ‘2 x August 2015’ event using Nowra rainfall across the catchment equivalent to ~24,000 m^3/s; and
- The PMP event (~25,000 m^3/s).

The results of these scenarios are shown on **Figure 3-16**. The peak flows at each location were plotted against each other in **Figure 3-13**, which indicated that the relationship between the two gauges was best expressed through a linear fit. This is considered reasonable given the proximity of the two gauges (some 38 km).

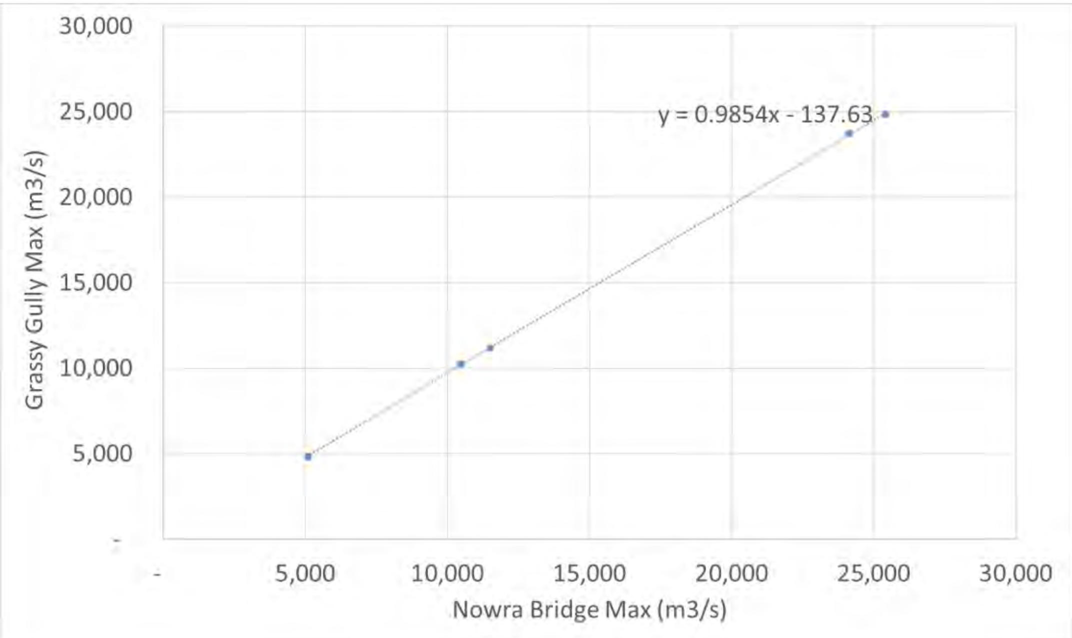


Figure 3-13 Relationship between peak flows at Grassy Gully and Nowra Bridge

3.5.4.5 Investigate effect of Tallowa Dam on peak flows at Grassy Gully II

Three scenarios were run in the XP-RAFTS hydrologic model with and without Tallowa Dam, to assess any adjustment required for flood levels recorded prior to its construction in 1976. It is noted that although Tallowa Dam is assumed to be full at the start of each model run, there is likely to be some storage and attenuation offered before the dam begins to spill.

The results are presented on **Figure 3-16**, and the correlating peak flows plotted on **Figure 3-14**. It is noted that while only three flow events were available for use at the time of assessment, these strongly suggest a linear relationship between peak flows derived with and without Tallowa Dam included in the hydrologic model. This relationship was used to adjust flows recorded prior to 1976 for use in the AMS.

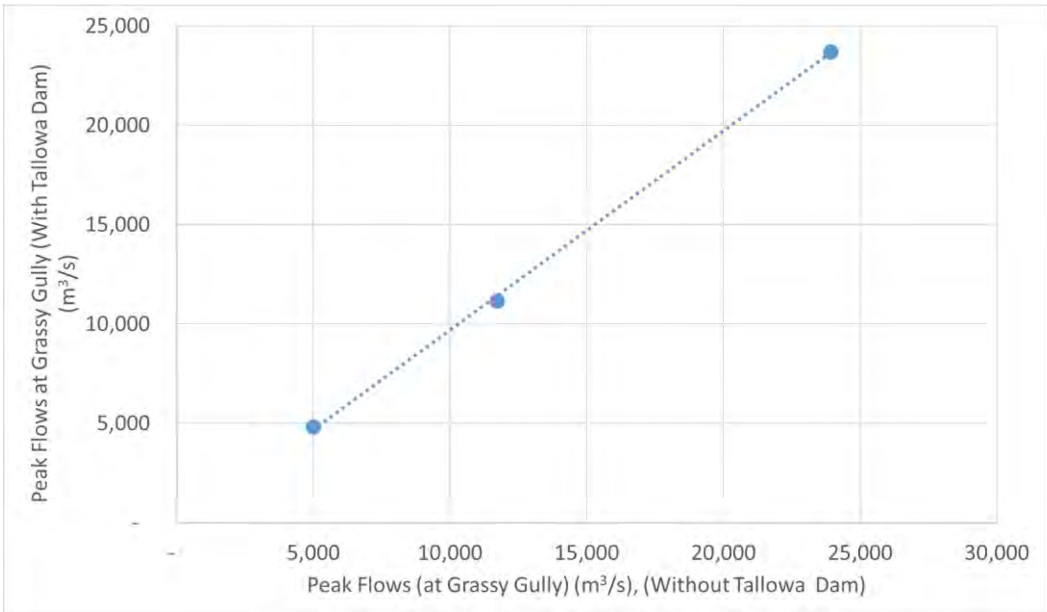


Figure 3-14 Relationship between peak flows at Grassy Gully II (215216) with and without Tallowa Dam.

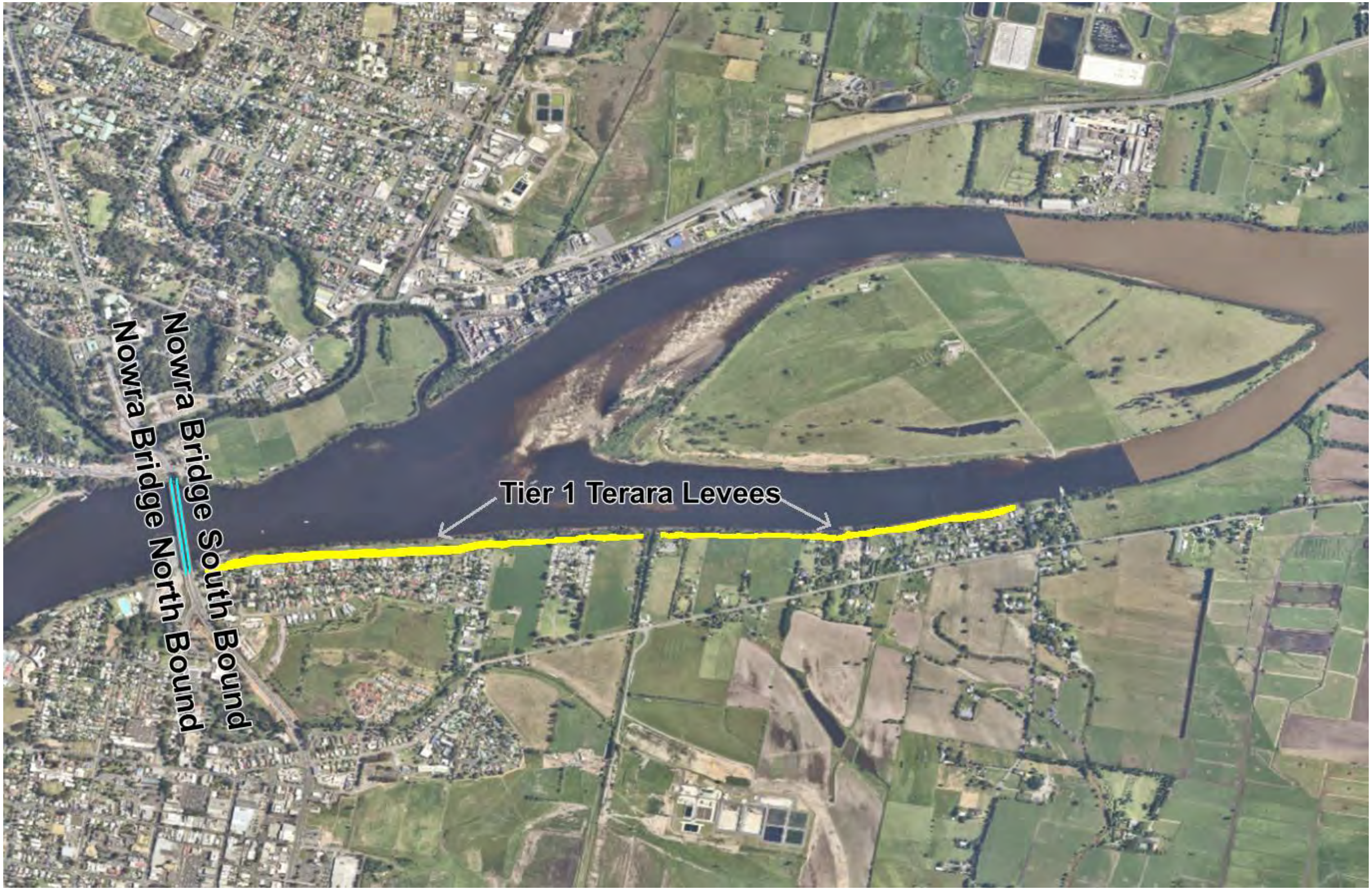


Figure 3-15 Location of Tier 1 Terara Levees

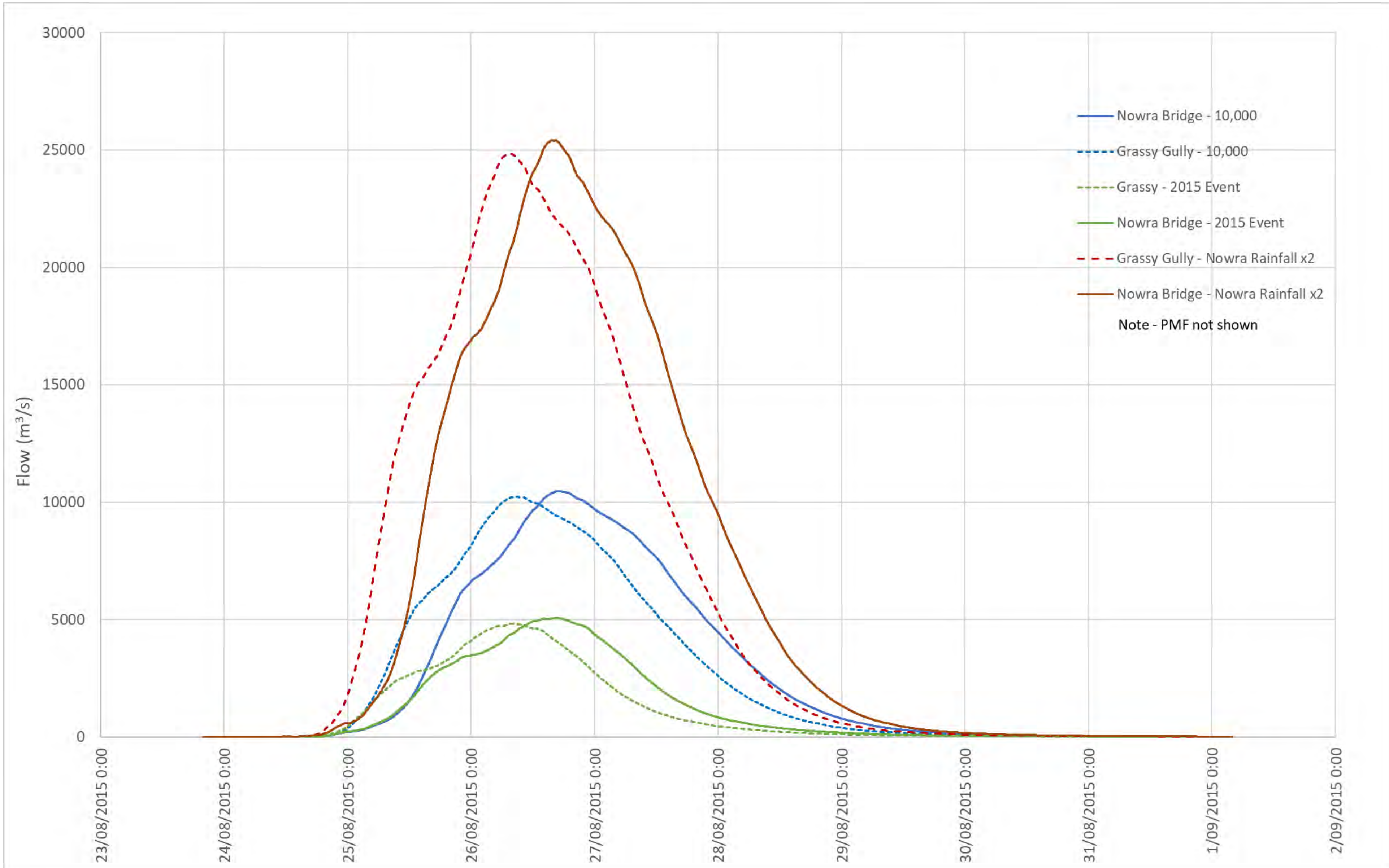


Figure 3-16 Relationships between flows at Nowra Bridge and Grassy Gully

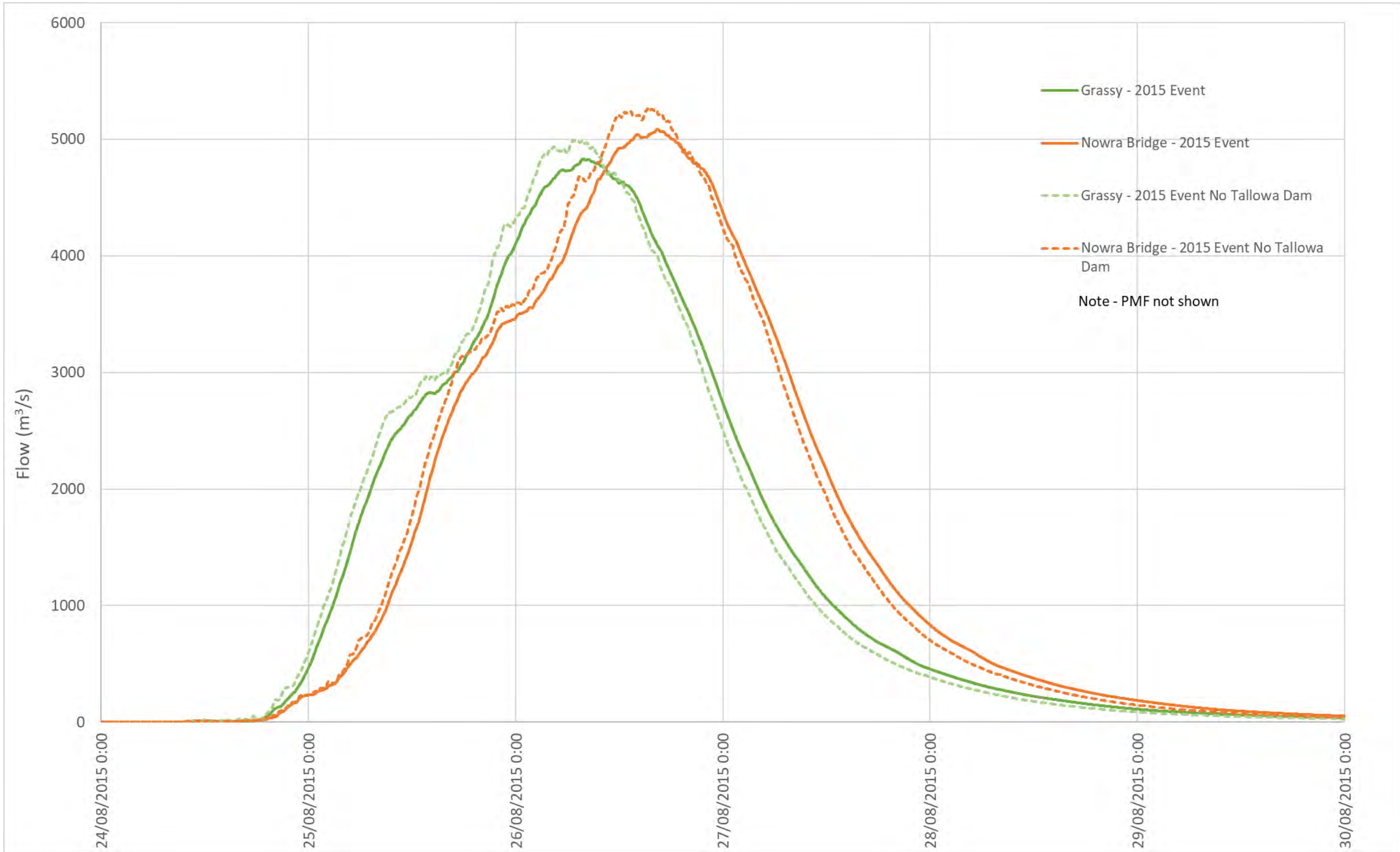


Figure 3-17 Relationships between flows with and without Tallowa Dam at Nowra Bridge and Grassy Gully

3.5.4.6 Resulting data set at Grassy Gully II

The series of adjustments described in **Section 3.5.4** resulted in the peak flow estimates for historical events at Grassy Gully II presented in **Table 3-7**.

Table 3-7 Historic Levels at Nowra Bridge and Corresponding Flows at Grassy Gully

Catchment Conditions	Month	Year	Flood Level at Nowra Bridge (m standard datum)	Flow at Grassy Gully (m^3/s)
Pre 1881	April	1842		
	March	1857		
	February	1860	5.7	11,350
	June	1864	5.2	8,939
	April	1867	5.1	8,536
	April	1870	6.5	15,195
	May	1871	4.7	7,223
	February	1873	6.2	13,861
1881-1974	June	1891	5.3	9,173
	February	1898	5	8,039
	July	1899	2.7	3,065
	July	1900	4.4	6,337
	July	1904	3.7	4,791
	January	1911	3.6	4,603
	October	1916	5.3	9,173
	December	1920	4.2	5,867
	July	1922	4.4	6,337
	May	1925	5.4	9,608
	April	1927	2.5	2,765
	January	1934	-	-
	September	1938	-	-
	April	1945	-	-
	May	1948	3	3,534
	June	1949	4	5,398
	June	1951	3	3,534
	May	1955	3.2	3,888
	February	1956	4.6	6,852
	July	1958	3	3,534
	October	1959	4.7	7,118
	March	1961	4.2	5,867
	June	1964	3.5	4,426
	September	1967	3.2	3,888
"Current"	August	1974	4.9	7,516*
	June	1975	4.9	7,516*
	October	1976	4.1	5,863*
	March	1978	5.3	9,232*

*The 1970s peak flows at Grassy Gully that have been 'back-calculated' from levels at Nowra Bridge differ notably from corresponding flows reporting in the 1990 Flood Study (PWD), reproduced in **Table 3-8**. Without level information for these events at Grassy Gully II, it is not possible to confirm the appropriate flows. For consistency, the 'back calculated' 1970s peak flows (in **Table 3-7**) have been used in the Grassy Gully II FFA.

Table 3-8 Reported Peak Flows at Grassy Gully (PWD, 1990)

Year	Peak Flow (m^3/s)
1974	8,900
1975	8,100
1976	5,610
1978	9,630
1988	7,060

3.5.5 FFA Inputs and Approach

Following the above process, the 'best possible' homogenous record of flows was produced at Grassy Gully II (215216). This record was subsequently used to inform FFA approaches described below.

Cardno assessed a range of approaches to the Flood Frequency Analysis, testing the influence of alternate rating curves (WaterNSW provided, standard Manning's 'n' versus alternate Manning's 'n'), and a range of scenarios with censored events and exceedances above various thresholds. In the end, two approaches were settled on as the most defensible approaches – including historical records as censored values; and, extending the AMS record with historical flow values. Following peer review, the approach was further refined with regards final rating curve and censoring values selected. These are described below:

3.5.5.1 Include 1860-1986 as censored events, and use gauge record period as AMS

In this approach (Termed ID A), only the gauge record AMS from 1987-2020 (presented in **Table 3-6**) was applied. The period from 1860 to 1986 was captured in the 'Censored Values' tab in FLIKE, with 9 exceedances greater than the 1988 peak flow (8,474 m^3/s) and 118 years below this threshold flow.

3.5.5.2 Extend AMS back to 1860

In the second approach (ID B), the AMS presented in **Table 3-6** was extended back to 1860 using the flows presented in **Table 3-7**. Years with no data (96) were assigned a peak flow of 0 m^3/s, and excluded from the record using the "Block Exclude" function in TUFLOW FLIKE. Using the "Censored Values" function, it was assumed that these 96 records would be below 2000 m^3/s, based on the assumption that all other years had flows lower than the lowest historical observation in 1927), which is estimated at around 2,700 m^3/s (a 1 in 2 to 1 in 5 AEP).

Following peer review, this approach was deemed most representative, however, further refinement was undertaken to adopt different censoring threshold values for the pre-1900 and post-1900 periods (discussed in Section 3.5.7).

3.5.6 FFA at Grassy Gully II Results and Discussion

The resulting design peak flows of each approach (ID A and ID B) are presented in **Table 3-9**, and fits presented in **Figure 3-18** and **Figure 3-19** respectively. The two approaches yield similar results above the 5% AEP event, however show more variation at the lower end due to the influence of lower flows on the overall record, which are represented differently in the two censoring approaches. It is noted that with an estimated flow of 15,195 m^3/s, the 1870 event and largest on record, is expected to have a recurrence interval around 1 in 200 AEP (ID A) or 1 in 268.7 AEP (ID B), with the 1873 event being a 1 in 100 AEP event. This is considered realistic given the available record, and provides greater confidence in both FFA outputs at Grassy Gully II.

For FFA ID A (**Figure 3-18**) there is uncertainty in the extrapolation of the fit beyond the largest value in the gauge record (approx. 1 in 20 AEP) as can be seen by the broader confidence limit range. For FFA ID B using the full AMS (**Figure 3-19**) there is more certainty in the fit at the upper end, however, it is noted that the fit the data for all events, particularly for flows >2,500 m_3/s and trends higher than the historical flows at the upper end. It appears there is two parts to the fit and a better fit may be achieved by fitting a curve to the flows >2,500 m^3/s. This would likely flatten the gradient and provide slightly lower expected quantiles for the 1 in 20 AEP and rarer events.

Again, the comparison with the envelope of ARR2019 design flow estimates indicates that the application of a single set of losses for all design events would not validate well to the FFA. However, it appears that within the envelope of tested losses there would be a suitable combination that could be applied, with the ‘zero continuing loss’ plotting below the FFA fit, but showing good correlation with historical events and well within the confidence limits at the 1% AEP event. Higher losses would need to be applied in the more frequent events to achieve a better fit to the data and FFA.

Table 3-9 FFA derived expected design event flows at Grassy Gully II Gauge (215216)

AEP Event	FFA Expected Flow (m^3/s) ID A	FFA Expected Flow (m^3/s) ID B
50%	1,388	720
20%	4,445	3,465
10%	6,962	6,165
5%	9,379	8,905
2%	12,236	12,184
1%	14,091	14,274

3.5.7 Adopted FFA

Where the extended record has missing years, these are considered by including the number of years with flow above or below threshold flow values. This allows the number of values to be extended to cover the full period and the plotting positions are adjusted accordingly to provide a better fit to the data. For the Nowra Bridge record, it was identified that the lowest flow noted as a flood pre-1900 was around 7000m^3/s, while the period between 1900 to 1987, floods greater than approximately 2700m^3/s are documented. These two values have been used as the thresholds to add the missing years as censored values. A multiple Grubbs-Beck test for censoring potentially influential low discharges was also applied.

Years with no data (96 records) were assigned a peak flow of 0 m^3/s, and excluded from the record using the “Block Exclude” function in TUFLOW FLIKE. Using the “Censored Values” function, it was assumed that 31 values are below 7000m^3/s, with 65 records below 2700 m^3/s. The multiple Grubbs-Beck censoring identified a further 22 records below 2450m^3/s and these values were excluded.

The adopted FFA is shown in **Figure 3-20** and the design peak flood quantiles are presented in **Table 3-10**.

It is noted that with an estimated flow of 15,195 m^3/s, the 1870 event and largest on record, is expected to have a recurrence interval around 1 in 200 AEP (ID A) or 1 in 268.7 AEP (ID B), with the 1873 event being a 1 in 100 AEP event. This is considered realistic given the available record, and provides greater confidence in the FFA outputs at Grassy Gully II.

Table 3-10 FFA derived expected design event flows at Grassy Gully II Gauge (215216)

AEP Event	FFA Expected Flow (m3/s)
50%	1,202
20%	4,140
10%	6,623
5%	9,017
2%	11,832
1%	13,641

It is noted that the FFA provides an expected quantile for the 1 in 100,000 AEP as around 22,000m^3/s and the PMP event design flood estimate is approximately 27,000 m^3/s with an expected recurrence interval of around 1 in 200,000 which is a reasonable correlation.

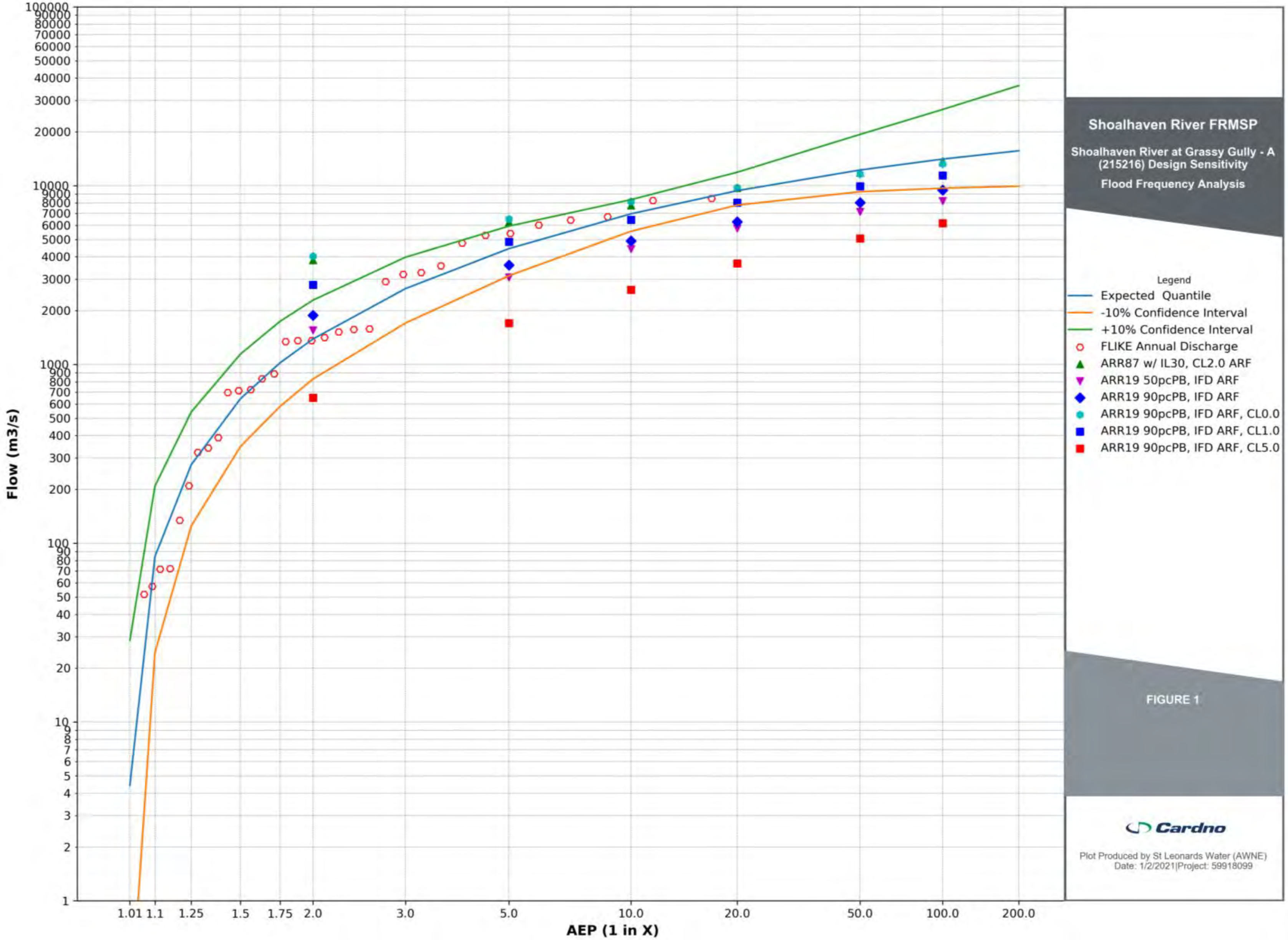


Figure 3-18 FFA at Grassy Gully II (215216) using record period (1987-2020) as AMS, and 1860-1986 as censored events

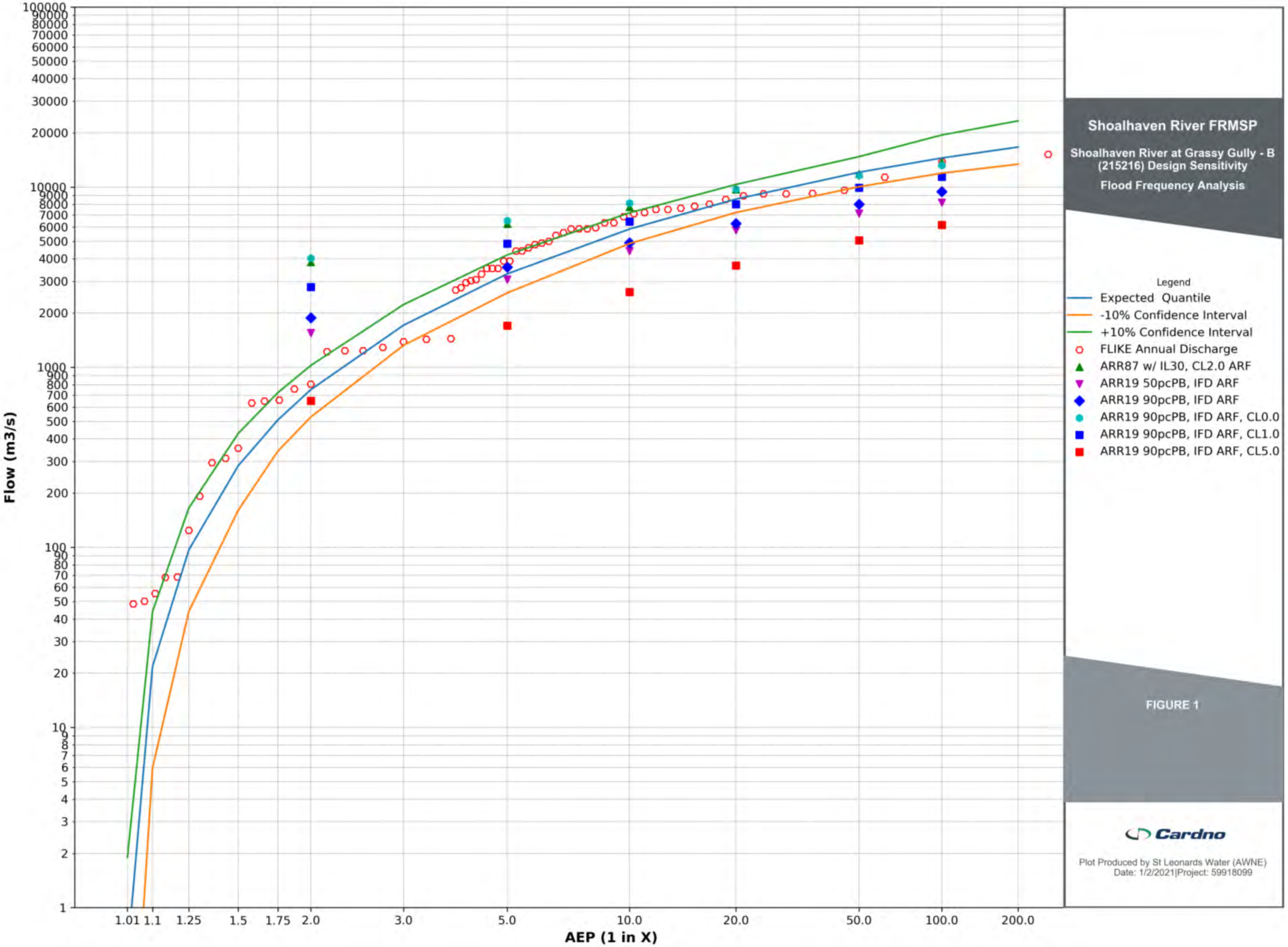


Figure 3-19 FFA at Grassy Gully II, extending the AMS back to 1860, using censored flows less than 2000 cumecs

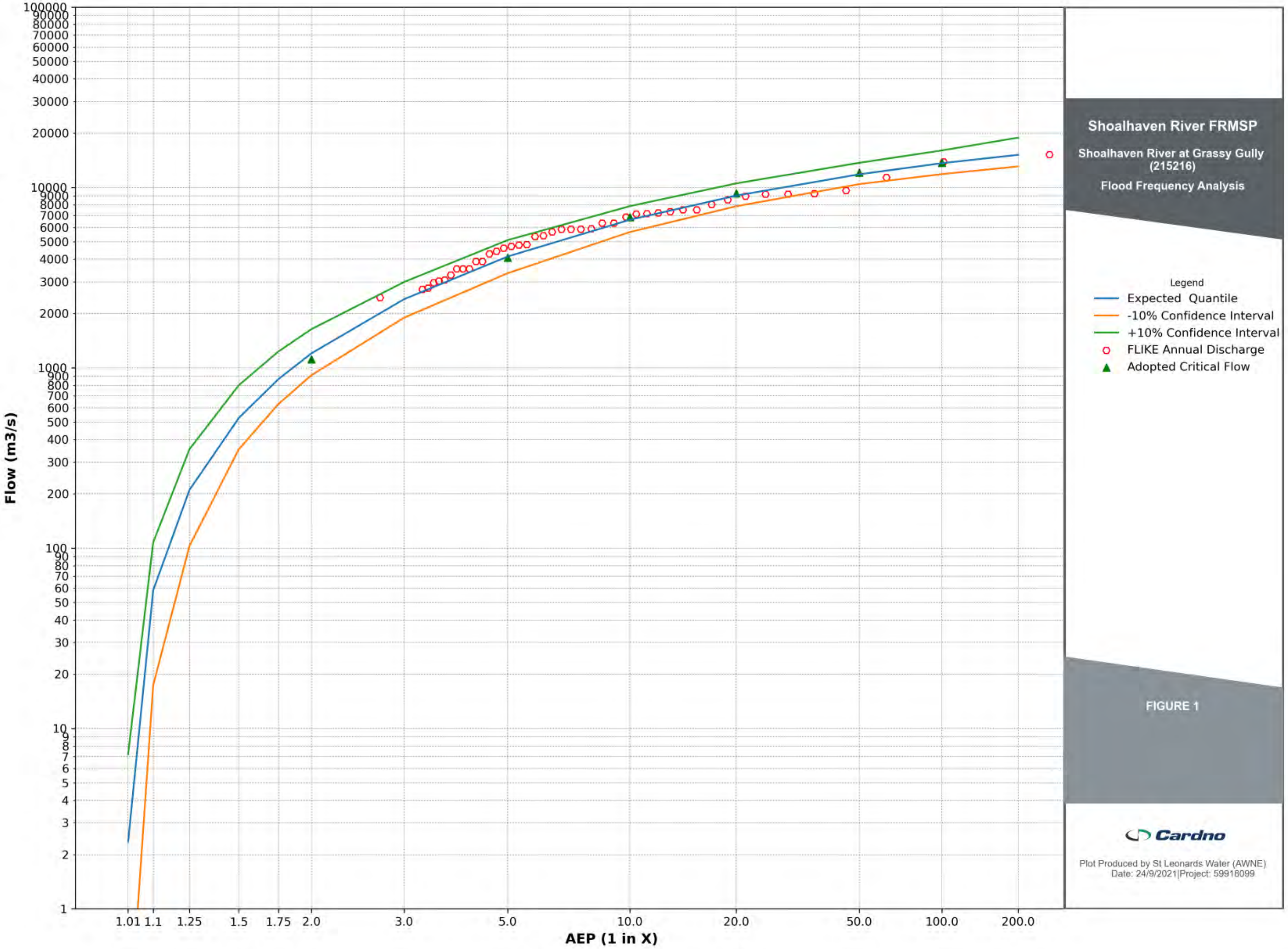


Figure 3-20 Adopted Flood Frequency Analysis – Shoalhaven River at Grassy Gully II gauge (215216) extended back to 1860 with two censored flows thresholds

3.6 Summary of FFA Results vs ARR2019 design flood estimates

Table 3-11 Shoalhaven River at Warri (215002) FFA Peak Flow Results

WARRI (215002)

AEP Event	FFA Expected Flow (m^3/s)	ARR87 Design Flow (m^3/s) - WMA 2013 Losses with catchment IFD	ARR2019 Design Flow (m^3/s) Calibrated Losses	ARR2019 Design Flow (m^3/s) CL: 0mm/hr	ARR2019 Design Flow (m^3/s) CL: 5 mm/hr
50%	204	768	235	911	57
20%	724	1,241	535	1,377	165
10%	1,278	1,542	759	1,680	306
5%	1,954	1,966	1,049	1,995	488
2%	3,006	2,495	1,499	2,461	801
1%	3,901	2,959	1,871	2,848	1,063

Table 3-12 Adopted expected design event flows at Hampden Bridge gauge (215220)

Kangaroo Valley (215220)

AEP Event	FFA Expected Flow (m^3/s)	ARR87 Design Flow (m^3/s)	ARR2019 Design Flow (m^3/s) Calibrated Losses	ARR2019 Design Flow (m^3/s) CL: 0mm/hr	ARR2019 Design Flow (m^3/s) CL: 5 mm/hr
50%	556	1,244	772	990	440
20%	1,213	1,898	1,228	1,443	887
10%	1,711	2,307	1,547	1,760	1,221
5%	2,202	2,825	1,864	2,075	1,570
2%	2,834	3,338	2,273	2,483	1,980
1%	3,293	3,866	2,578	2,788	2,260

Table 3-13 Adopted expected design event flows at Grassy Gully Gauge (215216)

GRASSY GULLY II (215216)

AEP Event	FFA Expected Flow (m^3/s)*	ARR87 Design Flow (m^3/s)	ARR2019 Design Flow (m^3/s) Calibrated Losses	ARR2019 Design Flow (m^3/s) CL: 0mm/hr*	ARR2019 Design Flow (m^3/s) CL: 1mm/hr	ARR2019 Design Flow (m^3/s) CL: 5 mm/hr
50%	1,202	3,831	1,881	4,029	2,788	651
20%	4,140	6,261	3,597	6,524	4,863	1,701
10%	6,623	7,768	4,916	8,157	6,445	2,617
5%	9,017	9,707	6,291	9,753	8,052	3,672
2%	11,832	11,828	8,053	11,601	9,913	5,078
1%	13,641	13,751	9,437	13,209	11,411	6,167

*Note: Post peer review, the rating curve and FFA were slightly adjusted and final ARR2019 design flows were re-calculated after this sensitivity.

4 Discussion of ARR2019 Application and Sensitivity

In parallel to investigating flood frequency analyses, investigation of the methods used to apply ARR2019 has been undertaken to better understand the sensitivity of peak flows to various inputs and parameters. The purpose of this investigation is to ultimately build confidence in the application of ARR2019 methodologies, and rule out sources of uncertainty associated with the hydrologic modelling process.

4.1 Selection of IFD Zones

The Shoalhaven River catchment area is sufficiently large to warrant the application of spatially varying IFDs. Cardno's method of delineating IFD Zones (presented in **Figure 4-3**) was based on grouping sub-catchments (in the XP-RAFTS model). The aim was to develop groupings where the IFD at the centroid of that group was within 5% of the average of the corresponding IFD for each sub-catchment's centroid.

Table 4-1 below indicates (for each storm duration in the 1% AEP event) this difference. Values in bold text are over the 5% threshold, and indicate that further delineation of IFD zones may be warranted. However, when looking at the 18-hour event (which was critical for the 1% AEP event) – we can see that the assigned IFD zones are within or close to the 5% margin. For this reason, we do not expect changes to the IFD zone delineation to materially influence peak design flows.

Table 4-1 IFD Zone Percentage variation

1% AEP Event Percentage difference IFD Zone to sub-catchment average							
Duration	**IFD Zone 1**	**IFD Zone 2**	**IFD Zone 3**	**IFD Zone 4**	**IFD Zone 5**	**IFD Zone 6**	**IFD Zone 7**
2 min	1.5	-1.2	0.1	2.6	**-8.2**	**-5.7**	2.1
3 min	0.9	-0.8	0.0	2.3	**-7.9**	**-5.3**	1.7
4 min	0.6	-1.7	-0.1	1.7	**-7.7**	-4.8	1.3
5 min	0.7	-1.7	-0.2	1.3	**-8.1**	-4.4	1.1
10 min	1.0	-1.6	-0.4	0.0	**-9.0**	-3.8	0.8
15 min	1.0	-1.5	-0.4	-0.3	**-9.3**	-3.7	0.8
30 min	0.8	-0.8	-0.3	0.0	**-9.0**	-4.2	0.9
1 hour	0.5	-1.5	0.0	1.3	**-8.0**	-4.9	1.2
2 hour	0.4	-1.3	1.1	2.9	**-8.2**	**-5.3**	1.8
3 hour	0.2	-1.4	1.8	3.7	-4.6	**-5.3**	2.2
6 hour	-2.6	-1.7	1.8	4.4	-1.5	-4.5	2.7
12 hour	**-5.9**	1.6	-1.1	3.9	0.4	-2.7	3.3
24 hour	**-9.0**	-0.7	-3.1	2.4	0.8	-3.2	4.3
48 hour	**-9.5**	3.3	-3.9	0.2	1.0	-3.4	**5.0**
72 hour	**-10.2**	**5.0**	-4.9	-0.8	1.1	-3.4	**5.6**
96 hour	**-10.8**	**5.7**	**-5.5**	-1.1	1.1	-3.5	**5.5**
120 hour	**-11.2**	**5.9**	**-5.4**	-1.0	1.1	-3.4	**5.2**
144 hour	**-11.5**	**5.7**	**-5.0**	-0.6	1.3	-3.4	**5.1**
168 hour	**-11.7**	**5.3**	**-5.0**	0.0	1.5	-3.3	**5.0**
Note: Percentage difference in IFD Zone is calculated as the difference between the depth at the IFD Zone Centroid and the average depth of all sub-catchments within that zone.							

4.2 Sensitivity Analysis for Pre-burst

The influence of the application of pre-burst on peak flows was investigated by comparing results generated using the 90th percentile pre-burst and median pre-burst. The results at Grassy Gully II, Warri and Hampden Bridge are shown in **Table 4-2**.

Table 4-2 Pre-burst comparison at gauge locations

AEP Event	Grassy Gully II (215216) Flow (m^3/s)			Shoalhaven River at Warri (213002) Flow (m^3/s)			Kangaroo River at Hampden Bridge (213220) Flow (m^3/s)		
	Median	90th Percentile	% Increase in Flow*	Median	90th percentile	% Increase in Flow*	Median	90th percentile	% Increase of Flow*
50%	1,550	1,881	18	163	235	31	664	772	14
20%	3,076	3,597	14	438	535	18	1,142	1,228	7
10%	4,420	4,916	10	673	759	11	1,455	1,547	6
5%	5,771	6,291	8	995	1,049	5	1,771	1,864	5
2%	7,155	8,053	11	1,430	1,499	5	2,156	2,273	5
1%	8,224	9,437	13	1,790	1,871	4	2,557	2,578	1

*Percent increase of flow from median pre-burst application to 90th Percentile pre-burst.

** All flows presented are using losses adopted from calibration to historical events

At locations in the upper catchment (Warri and Hampden Bridge), the percentage difference is greatest in the more frequent events, however, has less impact at the 2% and 1% AEP event. However, lower in the catchment at Grassy Gully II, the selection of pre-burst makes 10-18% difference across the suite of design events.

4.3 Sensitivity Analysis: Initial and Continuing Losses

Consideration of the effect of initial and continuing losses throughout the Shoalhaven River Catchment was undertaken.

Initial application of calibrated losses provided lower flows than expected within the FFA analysis. In order to increase the flow an envelope of continuing losses were applied in order to determine the effect. The losses applied were 0 mm/hr, 1mm/hr and 5mm/hr. The results at Grassy Gully II, Warri and Hampden Bridge are shown in **Table 4-3**. The results are plotted against the expected FFA values for each of the Warri, Kangaroo Valley and Grassy Gully gauge locations in **Figure 3-4**, **Figure 3-7** and **Figure 3-20**, respectively. A summary of corresponding peak design flows is presented in **Section 3.5.6**.

Table 4-3 Continuing loss comparison at gauge locations

AEP Event	Grassy Gully II (215216) Flow (m^3/s)		Shoalhaven River at Warri (213002) Flow (m^3/s)		Kangaroo River at Hampden Bridge (213220) Flow (m^3/s)	
	0 CL	**5 CL**	**0 CL**	**5 CL**	**0 CL**	**5 CL**
50%	4,029	651	911	57	990	440
20%	6,524	1,701	1,377	165	1,443	887
10%	8,157	2,617	1,680	306	1,760	1,221
5%	9,753	3,672	1,995	488	2,075	1,570
2%	11,601	5,078	2,461	801	2,483	1,980
1%	13,209	6,167	2,848	1,063	2,788	2,260

4.4 Sensitivity Analysis: Application of Areal Reduction Factor

In accordance with ARR2019, ARFs are determined based on a formula relating to catchment area. In large catchments however, there is a risk that applying one ARF across the total area would artificially reduce the total effective rainfall, and underestimate peak flows.

To examine the effect of this in the Shoalhaven River catchment, Cardno tested three scenarios to determine the appropriate application of ARFs. The scenarios were run for the 1% AEP event only, and included:

> S1 - Standard ARR 2019 Guidelines (single ARF applied to the whole catchment based on total catchment area of 7,250km^2);

> S2 - Application of an ARF over a sub-region, the area of IFD Zones 3-7 (Refer to **Figure 4-3**); and

> S3 - Application of individual ARFs for catchment area of each IFD zone (shown in **Figure 4-3**).

The resulting hydrographs at Nowra Bridge for each scenario (along with the results derived from ARR1987) are shown in **Figure 4-2**.

These results were discussed with DPIE and Council, and it was resolved to proceed with Scenario 3 – applying an IFD zone – specific ARF to each zone.

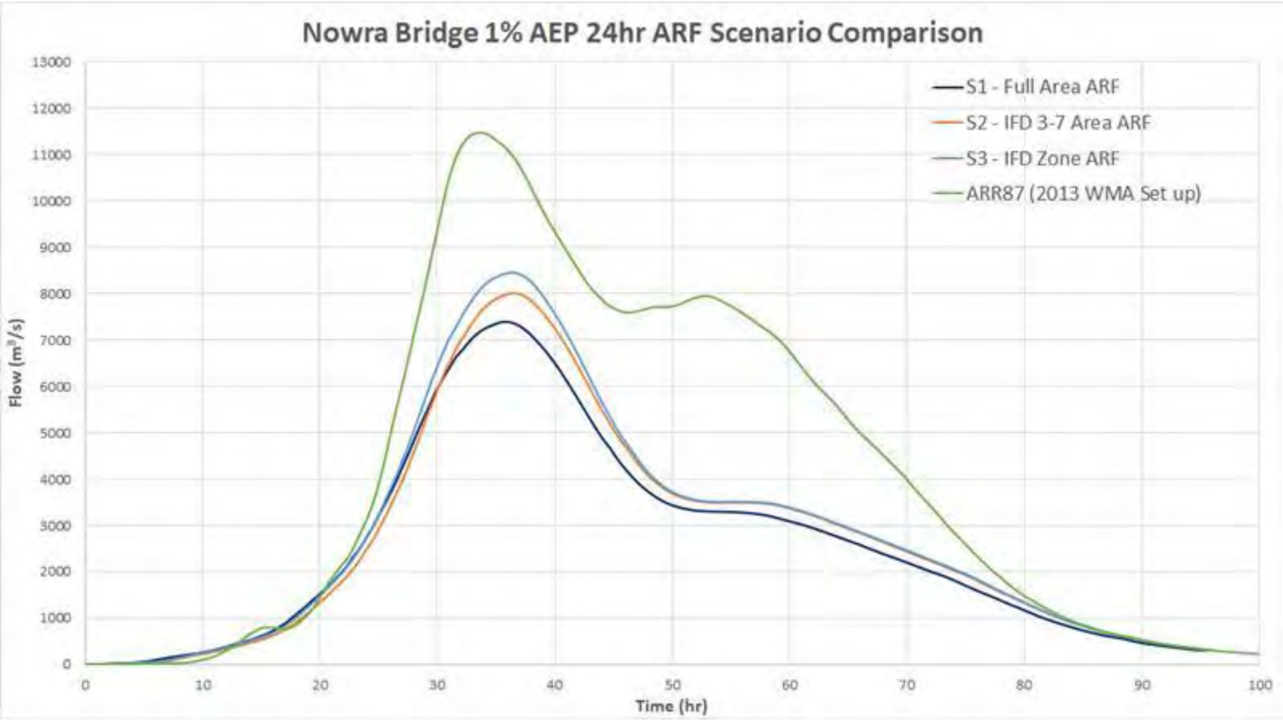


Figure 4-2 ARF sensitivity comparison at Nowra Bridge for 1% AEP 24 hour duration event

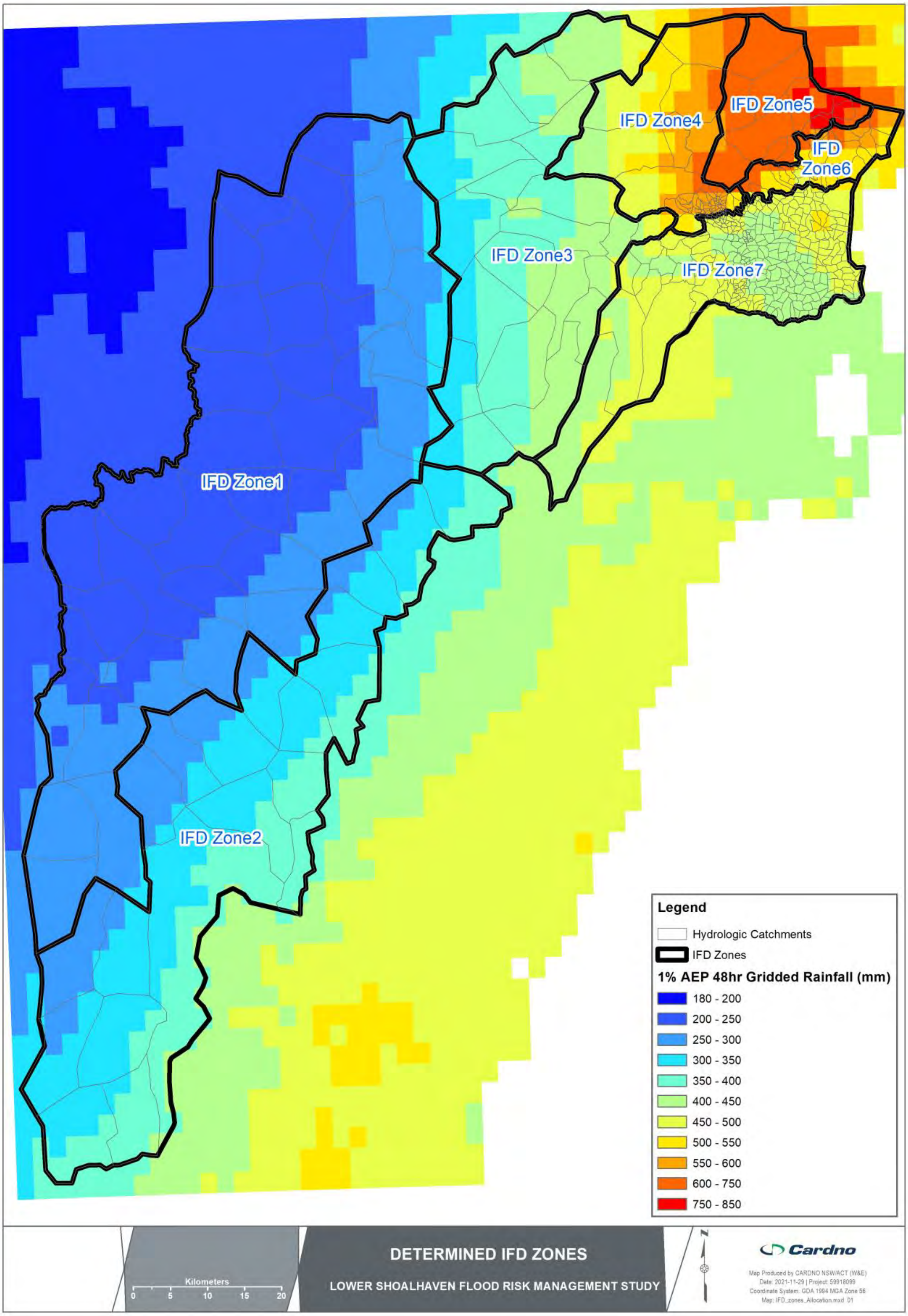


Figure 4-3 Determined IFD Zones

4.5 Selection of Temporal Pattern

In accordance with ARR2019, an ensemble of ten temporal patterns for each storm duration were run using StormInjector. The adopted critical duration was 18 hours (which had the highest mean flow), with the adopted temporal pattern being the one closest to the mean flow, with a bias to those above the mean, and bias factor of 2. The distribution of peak flows for each temporal pattern was investigated to determine if another temporal pattern may produce a peak flow closer to the FFA derived flow. Looking at the 1% AEP, 18 hour event (with a continuing loss of 0 mm/hr), we can see in **Figure 4-4** that the maximum flow produced for the 18 hour duration is 13,819 m^3/s, which is some 610m^3/s higher than the mean flow (13,209 m^3/s). This tells us that even the highest flow produced by the ensemble of ten temporal patterns falls short of the FFA derived estimates (over 14,000 m^3/s). It is noted that selection of the highest temporal pattern would typically not be supported by ARR2019 guidelines. **Figure 4-5** shows the box plots of flow estimates for the ensemble of temporal patterns for a range of durations. The biggest flow produced was for a temporal pattern in the 48 hour duration. Given that the temporal and spatial distribution of rainfall that produced historical event peak flows/levels is unknown, it is possible that it is a ‘worst case’ temporal pattern rather than the mean temporal pattern occurred to produce the historical events.

4.6 At-Site IFD

When the ARR2019 design flood estimates do not provide a good correlation with the FFA, it is possible that the rainfall IFD obtained from the Bureau of Meteorology (BoM) is not representative of the catchment depending on the rainfall gauges being used to derive the IFD. In such cases, and At-Site IFD can be generated to compare with the BoM IFD and utilised if deemed more representative.

For the Shoalhaven River catchment, there is insufficient pluviometer gauges, both spatially, and with a continuous record to provide a good record for at-site IFD generation. There is a large number of daily read gauges which can be used for comparison, however, this can only be used in 24 hour duration intervals and is only for 9am to 9am periods. Hence, these could also miss the peak 24 hour rainfall if it occurred from 6pm to 6pm for example. As such, this was not examined further and the BoM IFD is the most suitable to use for the catchment.

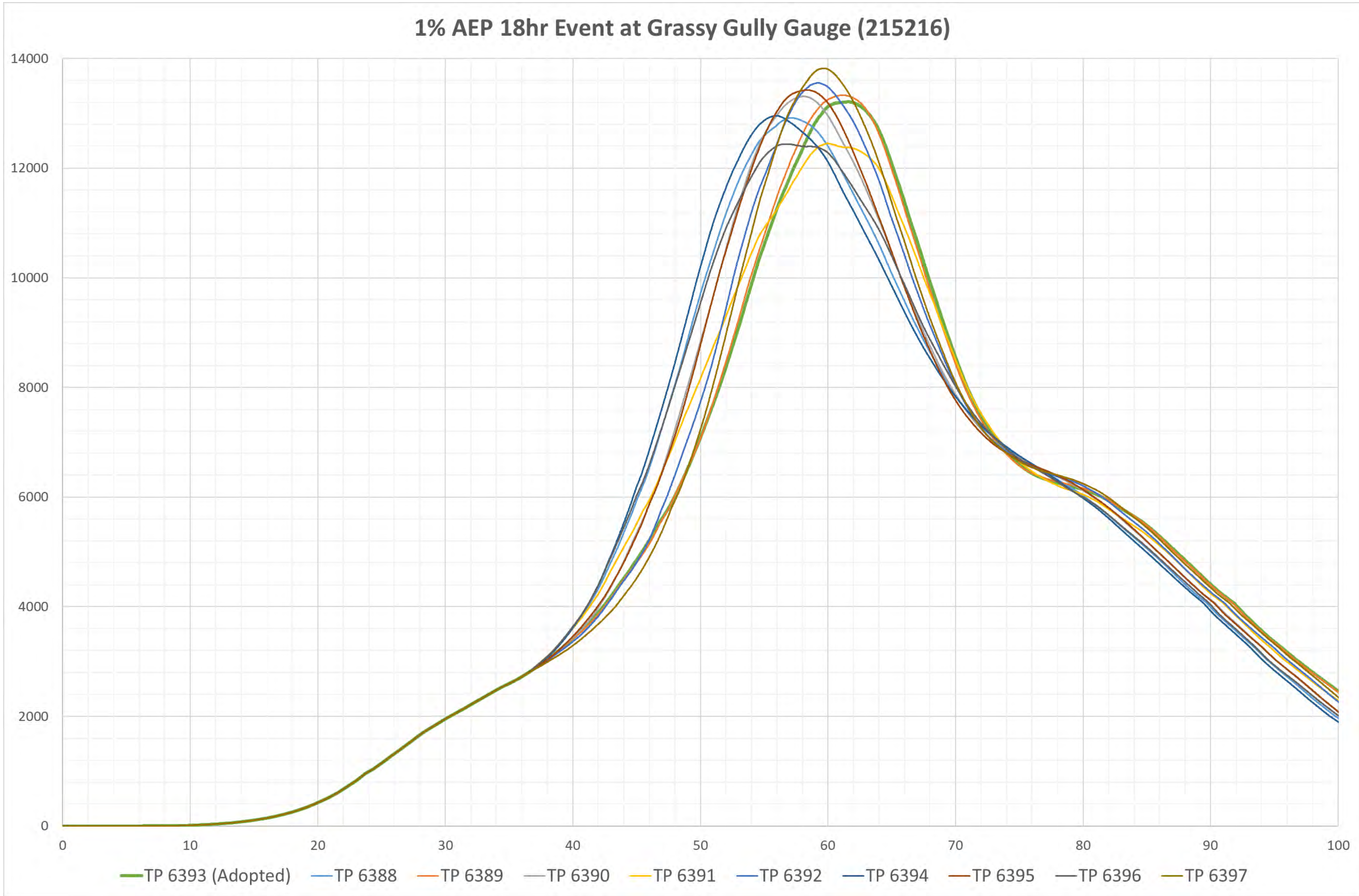


Figure 4-4 1% AEP Temporal Patterns at Grassy Gully Gauge (215216)

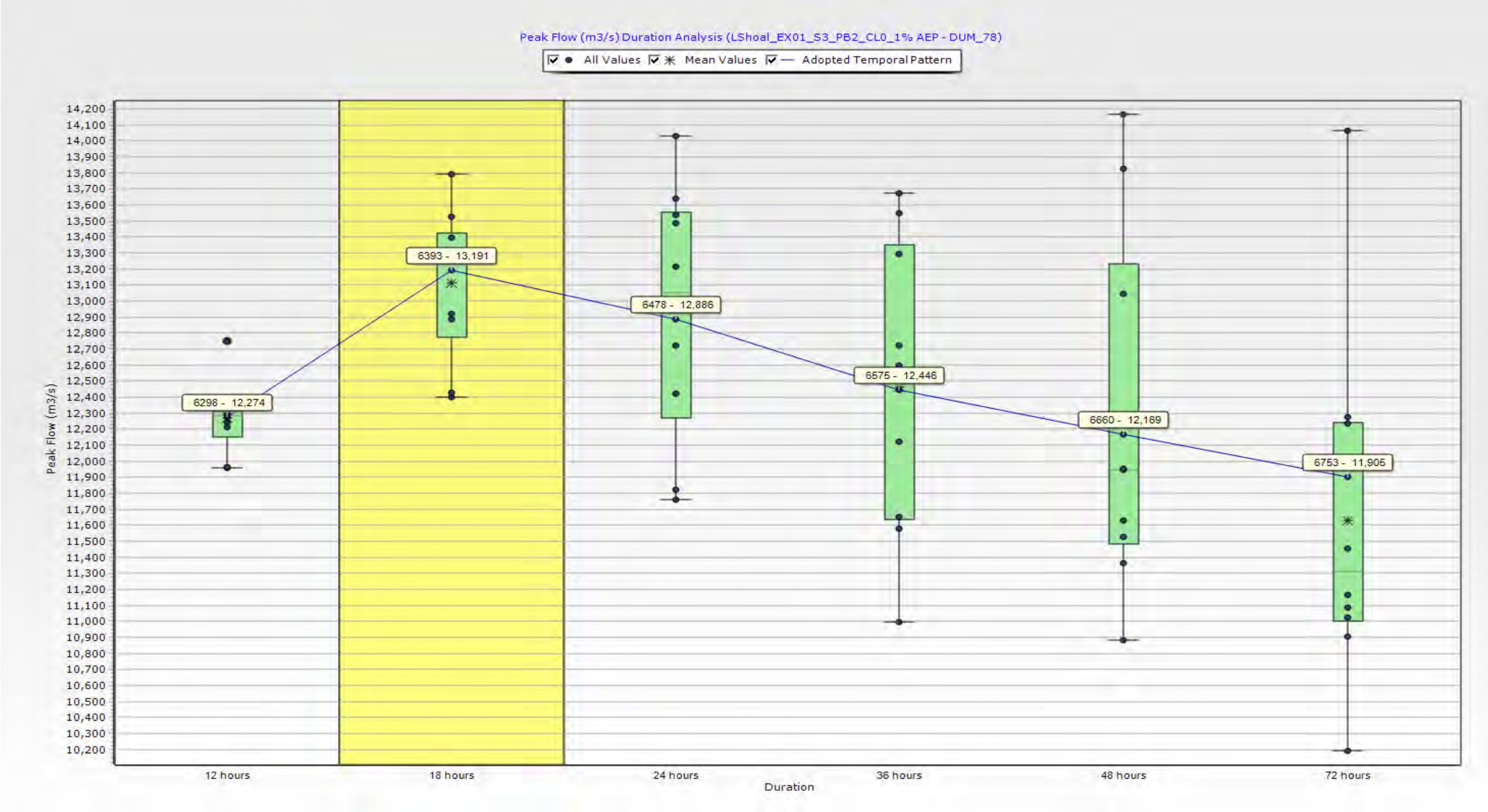


Figure 4-5 1% AEP Event Box Plots at Grassy Gully Gauge (215216)

5 Outcomes and Recommendations

Following the extensive investigations documented in this technical memorandum, we can conclude the following:

> Flood Frequency analyses were undertaken at Shoalhaven River at Warri and Kangaroo River at Hampden Bridge gauges. The FFA at both gauges did not provide a good fit to historical events at the right hand tail (for rare event AEPs) and FFA estimates appear conservatively high. However, the ARR2019 design event flows do plot well with the historical event AEP plotting positions. It was considered that further effort to review and revise the rating curves or extend the AMS record at these two gauges was not warranted. As this study is concerned with the Lower Shoalhaven River and due to the long records available at Nowra Bridge, effort was focussed on assessment of flows at Shoalhaven River at Grassy Gully II gauge described in the following sections.

> The presented Flood Frequency Analysis results are considered to be the best possible given the available information, and significant effort has been made to reduce uncertainties (particularly at Grassy Gully II) and make the most of available historic data at Nowra Bridge.

> The ARR2019 design estimate validation against the FFA demonstrates that the application of a single set of loss values across the range of design events produces design flood estimates with a flatter gradient to the FFA fit.

> Validation of ARR2019 design flood estimates using the calibrated losses with the FFA produces flows that are well correlated at around the 1 in 10 to 1 in 20 AEP, but underestimates flows for rarer events and overestimates flows for more frequent events.

> The FFA results have been presented with an envelope of initial and continuing loss scenarios to understand the possibility of adjusting losses to obtain a better match to the FFA. Across the three sites the application of a continuing loss of 0 mm/hr produces flows that approach the historical values and the FFA, however, are still potentially lower than the FFA estimate.

> For events more frequent than the 1% AEP event, however, it appears that adjusting (increasing) continuing losses does assist with producing a flow that is a better match to the FFA at each location.

> The hydrologic model is reasonably well calibrated to historical events given the available data, and sensitivity using zero continuing loss shows that flows are still slightly underestimated compared to FFA estimates. It appears there may be insufficient design rainfall being applied to the model with the ARR2019 IFD values.

> Following investigation of all ARR2019 inputs and methodologies, the use of varying continuing loss across the range of recurrence intervals is able to produce the most reliable design flood estimates that correlate reasonably well with the historical events and the adopted FFA fit. It is recommended that variable continuing losses similar to the following table be applied to the hydrologic model for the design events peak flood estimation:

Table 5-1 Recommended Variable Continuing Losses

AEP Event	Continuing Loss (mm/hr)
50%	3.5
20%	2
10%	1
5%	0.5
2%	0
1%	0
<1 %	0

> The application of ARR2019 methodologies is acknowledged to have necessarily departed from the standard guidelines due to the catchment size and topographic variation. The reasoning behind each variation has been discussed at length with Council and DPIE and is documented in **Section 4**.

6 References

Cardno, August 2020, Lower Shoalhaven River Flood Study Update and FRMSP Stage 3 Progress Report – Model Setup, Calibration and Validation

Condon, J, (1986) Shoalhaven River Flood History - Compendium

NSW Government (Office of Environment and Heritage), 2019, Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies

Public Works Department, April 1990, Lower Shoalhaven River Flood Study

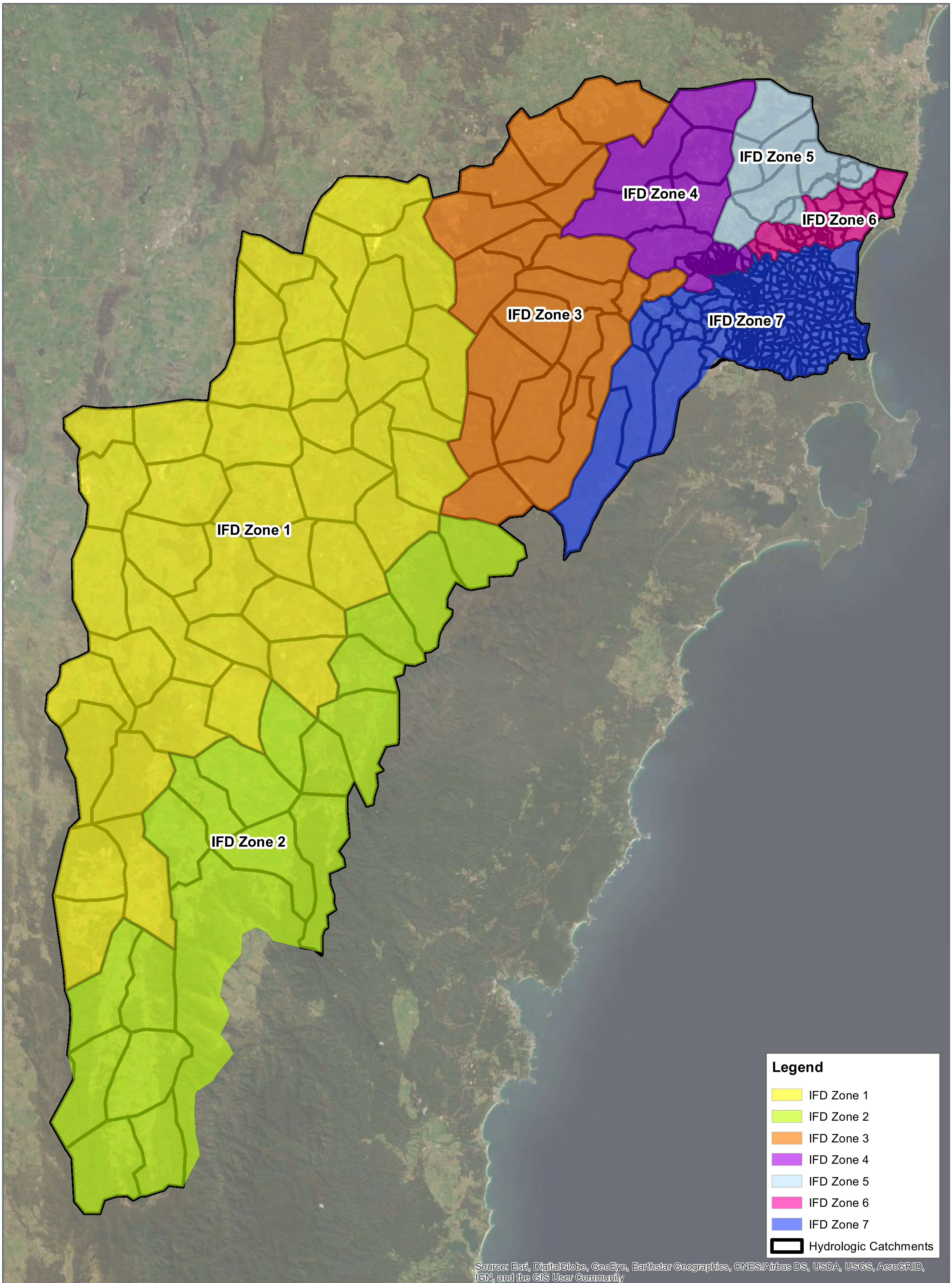
WMAwater, March 2013, Shoalhaven River Flood Study, Shoalhaven Starches

APPENDIX

F

ARR IFD AND DATA HUB RECORD

Cardno



Kilometers
0 5 10 15 20

APPLIED IFD ZONES

LOWER SHOALHAVEN FLOOD RISK MANAGEMENT STUDY

N

Cardno

Map Produced by CARDNO NSW/ACT (W&E)
Date: 2019-08-02 | Project: 59918099
Coordinate System: GDA 1994 MGA Zone 56
Map: IFD_zones.mxd 01

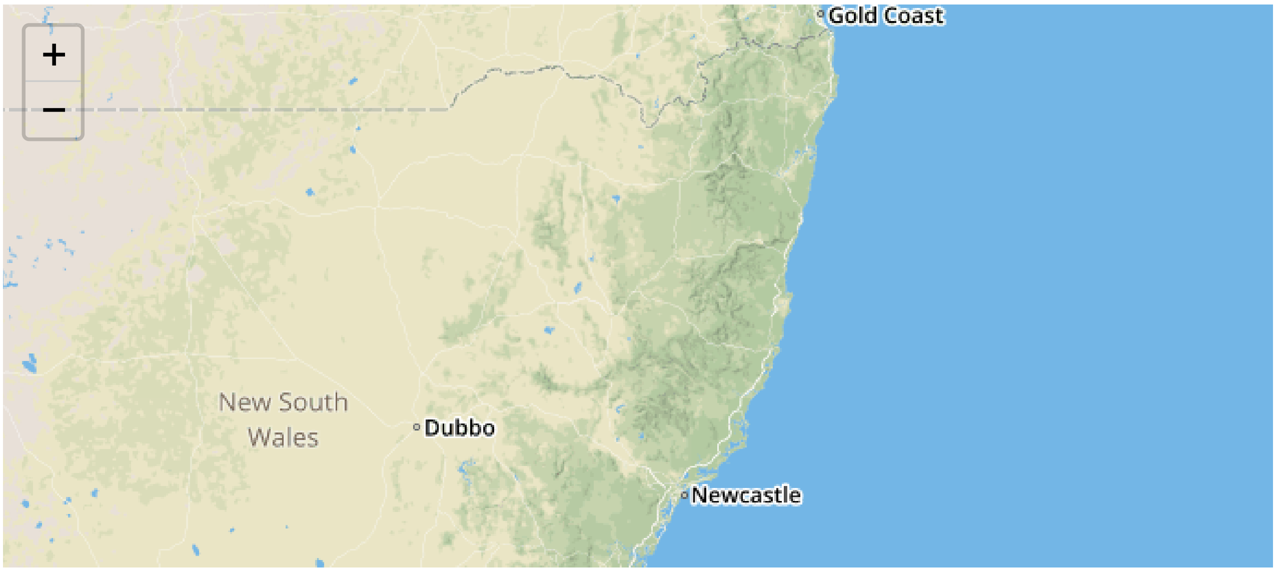
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 1

Longitude	149.823
Latitude	-35.129
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show



Data

River Region

Division	South East Coast (NSW)
River Number	15
River Name	Shoalhaven River

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	11321.0
Storm Initial Losses (mm)	22.0
Storm Continuing Losses (mm/h)	3.3

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-35.129&longitude=149.823&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:31PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.8 (0.092)	1.3 (0.046)	0.9 (0.027)	0.5 (0.013)	0.7 (0.016)	0.9 (0.018)
90 (1.5)	2.8 (0.121)	2.0 (0.065)	1.5 (0.042)	1.0 (0.024)	0.8 (0.016)	0.6 (0.012)
120 (2.0)	1.3 (0.053)	1.2 (0.036)	1.1 (0.028)	1.0 (0.022)	0.6 (0.011)	0.3 (0.005)
180 (3.0)	1.7 (0.058)	1.3 (0.035)	1.1 (0.024)	0.9 (0.017)	0.4 (0.007)	0.1 (0.001)
360 (6.0)	1.6 (0.044)	0.9 (0.019)	0.5 (0.009)	0.1 (0.001)	0.5 (0.006)	0.8 (0.009)
720 (12.0)	1.2 (0.025)	2.0 (0.031)	2.5 (0.033)	3.0 (0.035)	7.6 (0.074)	11.1 (0.095)
1080 (18.0)	0.0 (0.000)	2.5 (0.034)	4.2 (0.047)	5.9 (0.056)	9.6 (0.077)	12.3 (0.087)
1440 (24.0)	0.0 (0.000)	0.5 (0.006)	0.8 (0.008)	1.1 (0.010)	3.8 (0.027)	5.8 (0.036)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.6 (0.004)	1.1 (0.006)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.0 (0.595)	10.2 (0.373)	9.0 (0.279)	7.8 (0.211)	12.2 (0.281)	15.5 (0.320)
90 (1.5)	11.8 (0.512)	10.7 (0.348)	10.0 (0.277)	9.3 (0.225)	11.5 (0.237)	13.1 (0.243)
120 (2.0)	11.4 (0.450)	12.6 (0.377)	13.5 (0.343)	14.2 (0.317)	11.4 (0.218)	9.3 (0.160)
180 (3.0)	13.6 (0.467)	13.2 (0.346)	12.9 (0.291)	12.7 (0.250)	12.5 (0.210)	12.3 (0.186)
360 (6.0)	10.7 (0.285)	13.0 (0.266)	14.5 (0.255)	16.0 (0.246)	23.0 (0.300)	28.3 (0.329)
720 (12.0)	9.1 (0.188)	13.3 (0.207)	16.0 (0.213)	18.7 (0.215)	33.4 (0.322)	44.5 (0.380)
1080 (18.0)	1.9 (0.034)	9.1 (0.121)	13.9 (0.155)	18.4 (0.177)	30.4 (0.244)	39.4 (0.278)
1440 (24.0)	0.6 (0.010)	4.6 (0.055)	7.2 (0.072)	9.7 (0.082)	19.9 (0.140)	27.5 (0.170)
2160 (36.0)	0.0 (0.000)	1.6 (0.017)	2.7 (0.023)	3.7 (0.027)	8.8 (0.052)	12.6 (0.065)
2880 (48.0)	0.0 (0.000)	1.5 (0.014)	2.4 (0.019)	3.4 (0.022)	7.7 (0.041)	10.9 (0.051)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.6 (0.003)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	20.5 (1.017)	20.7 (0.759)	20.8 (0.647)	20.9 (0.565)	26.5 (0.611)	30.6 (0.635)
90 (1.5)	25.0 (1.086)	26.6 (0.866)	27.7 (0.767)	28.7 (0.694)	31.6 (0.655)	33.9 (0.630)
120 (2.0)	24.6 (0.969)	28.2 (0.840)	30.6 (0.780)	32.9 (0.733)	40.7 (0.777)	46.6 (0.800)
180 (3.0)	23.3 (0.800)	26.7 (0.699)	28.9 (0.650)	31.1 (0.612)	35.8 (0.603)	39.3 (0.595)
360 (6.0)	27.5 (0.735)	36.2 (0.741)	41.9 (0.736)	47.4 (0.728)	55.5 (0.724)	61.5 (0.717)
720 (12.0)	19.0 (0.393)	34.9 (0.546)	45.5 (0.604)	55.6 (0.639)	73.6 (0.710)	87.1 (0.744)
1080 (18.0)	21.3 (0.382)	28.4 (0.379)	33.1 (0.372)	37.7 (0.362)	61.1 (0.490)	78.6 (0.555)
1440 (24.0)	19.2 (0.313)	24.1 (0.288)	27.3 (0.273)	30.4 (0.259)	42.3 (0.298)	51.2 (0.317)
2160 (36.0)	10.2 (0.148)	11.9 (0.124)	13.1 (0.112)	14.1 (0.102)	25.7 (0.153)	34.3 (0.179)
2880 (48.0)	4.0 (0.054)	8.9 (0.084)	12.1 (0.094)	15.2 (0.099)	38.9 (0.208)	56.6 (0.265)
4320 (72.0)	0.4 (0.005)	5.2 (0.045)	8.4 (0.058)	11.4 (0.066)	14.4 (0.069)	16.7 (0.069)

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	11.5	8.1	7.6	8.5	7.0	4.8
90 (1.5)	11.0	7.8	7.4	8.1	7.0	4.9
120 (2.0)	11.4	7.9	7.4	8.0	7.1	4.8
180 (3.0)	11.2	8.0	7.9	8.3	7.8	5.4
360 (6.0)	11.6	8.4	8.5	8.2	7.6	4.3
720 (12.0)	12.6	9.0	9.0	8.4	7.0	2.1
1080 (18.0)	14.1	10.1	10.0	8.5	8.0	2.1
1440 (24.0)	14.9	11.9	11.9	12.0	9.0	4.0
2160 (36.0)	16.3	14.2	14.9	16.4	12.4	7.8
2880 (48.0)	17.7	15.1	15.0	17.1	12.3	8.2
4320 (72.0)	18.8	16.5	16.6	18.4	14.9	11.1

Layer Info

Time Accessed	02 August 2019 03:31PM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	10620
Area (km2)	601.548544
Catchment Number	10695
Volume Factor	1.230835
Peak Factor	0.161812

Layer Info

Time Accessed	02 August 2019 03:31PM
Version	2016_v1

Download TXT (downloads/a02bd1ff-f3df-4c15-bed6-be6015b12901.txt)

Download JSON (downloads/88aa9629-8059-405b-9a20-db70872881a1.json)

Generating PDF... (downloads/b547a457-94d9-45fd-8200-cacf64c96521.pdf)

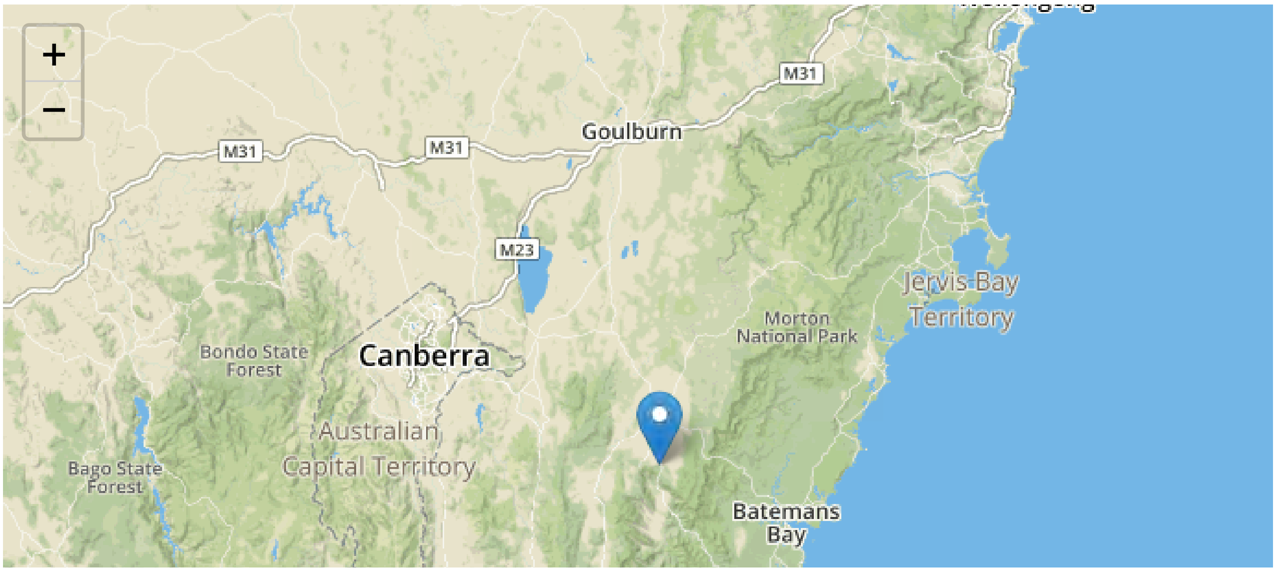
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 2

Longitude	149.797
Latitude	-35.566
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show



Data

River Region

Division	South East Coast (NSW)
River Number	17
River Name	Moruya River

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right) Duration^{-d} + eArea^{f} Duration^{g} \left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}} \left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	5222.0
Storm Initial Losses (mm)	31.0
Storm Continuing Losses (mm/h)	7.0

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-35.566&longitude=149.797&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:32PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.6 (0.079)	1.2 (0.043)	0.9 (0.028)	0.6 (0.016)	0.7 (0.016)	0.8 (0.016)
90 (1.5)	0.7 (0.030)	0.7 (0.021)	0.6 (0.017)	0.6 (0.014)	0.6 (0.013)	0.7 (0.012)
120 (2.0)	1.5 (0.057)	1.1 (0.033)	0.9 (0.022)	0.7 (0.015)	0.4 (0.007)	0.1 (0.002)
180 (3.0)	1.5 (0.047)	1.4 (0.034)	1.3 (0.028)	1.3 (0.024)	1.4 (0.022)	1.5 (0.021)
360 (6.0)	3.5 (0.080)	4.1 (0.071)	4.4 (0.066)	4.8 (0.063)	9.4 (0.105)	12.8 (0.128)
720 (12.0)	3.3 (0.055)	12.4 (0.150)	18.4 (0.188)	24.2 (0.214)	18.8 (0.140)	14.7 (0.097)
1080 (18.0)	0.6 (0.008)	8.2 (0.079)	13.2 (0.107)	18.0 (0.126)	16.1 (0.094)	14.7 (0.075)
1440 (24.0)	0.5 (0.006)	3.1 (0.026)	4.9 (0.034)	6.5 (0.039)	9.6 (0.047)	12.0 (0.052)
2160 (36.0)	0.0 (0.000)	0.6 (0.004)	1.0 (0.006)	1.4 (0.007)	2.3 (0.009)	3.0 (0.010)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.2 (0.001)	0.3 (0.001)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	1.5 (0.018)	2.5 (0.026)	3.5 (0.031)	1.5 (0.011)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	15.5 (0.757)	13.3 (0.490)	11.8 (0.374)	10.4 (0.289)	13.8 (0.330)	16.4 (0.353)
90 (1.5)	10.7 (0.450)	10.0 (0.320)	9.6 (0.263)	9.1 (0.221)	10.2 (0.213)	11.0 (0.209)
120 (2.0)	14.5 (0.549)	15.1 (0.433)	15.4 (0.381)	15.7 (0.342)	11.6 (0.218)	8.5 (0.145)
180 (3.0)	14.1 (0.450)	16.8 (0.407)	18.5 (0.387)	20.2 (0.371)	26.1 (0.414)	30.5 (0.438)
360 (6.0)	23.2 (0.533)	36.1 (0.628)	44.6 (0.666)	52.8 (0.691)	62.3 (0.697)	69.4 (0.698)
720 (12.0)	25.3 (0.413)	40.2 (0.484)	50.0 (0.510)	59.5 (0.526)	53.5 (0.398)	49.0 (0.324)
1080 (18.0)	8.3 (0.112)	23.7 (0.230)	33.8 (0.275)	43.5 (0.304)	41.7 (0.242)	40.3 (0.207)
1440 (24.0)	12.8 (0.152)	17.4 (0.146)	20.4 (0.142)	23.2 (0.138)	30.2 (0.148)	35.4 (0.153)
2160 (36.0)	5.5 (0.055)	9.3 (0.065)	11.8 (0.068)	14.2 (0.069)	17.7 (0.070)	20.2 (0.070)
2880 (48.0)	1.4 (0.013)	4.5 (0.028)	6.5 (0.033)	8.5 (0.036)	12.9 (0.045)	16.2 (0.049)
4320 (72.0)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)	0.2 (0.001)	1.3 (0.004)	2.1 (0.005)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	36.7 (1.798)	30.2 (1.114)	25.9 (0.817)	21.7 (0.601)	27.9 (0.665)	32.5 (0.701)
90 (1.5)	35.1 (1.480)	30.7 (0.983)	27.8 (0.765)	25.1 (0.605)	28.3 (0.590)	30.7 (0.580)
120 (2.0)	32.2 (1.216)	32.2 (0.925)	32.2 (0.796)	32.2 (0.700)	50.6 (0.950)	64.4 (1.095)
180 (3.0)	38.6 (1.230)	55.6 (1.351)	66.9 (1.398)	77.7 (1.428)	83.4 (1.323)	87.7 (1.259)
360 (6.0)	51.6 (1.189)	63.1 (1.099)	70.6 (1.055)	77.9 (1.020)	104.0 (1.164)	123.5 (1.243)
720 (12.0)	46.0 (0.749)	73.1 (0.881)	91.0 (0.929)	108.2 (0.957)	115.0 (0.857)	120.1 (0.795)
1080 (18.0)	31.6 (0.423)	51.2 (0.498)	64.2 (0.522)	76.6 (0.535)	86.8 (0.505)	94.3 (0.484)
1440 (24.0)	30.0 (0.354)	42.3 (0.357)	50.5 (0.353)	58.4 (0.347)	70.7 (0.347)	79.9 (0.345)
2160 (36.0)	35.5 (0.358)	39.3 (0.277)	41.9 (0.241)	44.3 (0.214)	50.3 (0.199)	54.7 (0.189)
2880 (48.0)	12.8 (0.118)	20.7 (0.130)	25.8 (0.132)	30.8 (0.131)	36.9 (0.128)	41.4 (0.125)
4320 (72.0)	12.9 (0.107)	13.5 (0.076)	13.9 (0.062)	14.2 (0.052)	23.7 (0.071)	30.7 (0.080)

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	20.9	12.0	11.3	12.0	11.2	10.4
90 (1.5)	24.0	13.6	12.6	13.3	12.5	11.5
120 (2.0)	23.3	13.4	12.4	12.8	12.3	9.5
180 (3.0)	22.3	13.3	11.7	11.2	9.9	6.3
360 (6.0)	19.2	12.7	11.5	9.8	7.8	4.4
720 (12.0)	20.0	12.6	10.9	10.5	10.4	6.0
1080 (18.0)	25.3	17.3	15.6	13.8	14.7	6.6
1440 (24.0)	25.9	20.4	20.0	19.0	17.4	6.3
2160 (36.0)	27.4	23.8	23.6	25.7	19.6	14.1
2880 (48.0)	31.3	26.9	27.2	29.9	24.1	18.3
4320 (72.0)	32.4	29.4	30.8	35.2	28.5	19.5

Layer Info

Time Accessed	02 August 2019 03:32PM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	0
Area (km2)	1444.098816
Catchment Number	10860
Volume Factor	0.287219
Peak Factor	0.078249

Layer Info

Time Accessed	02 August 2019 03:32PM
Version	2016_v1

Download TXT (downloads/878ac4e9-c2ad-474a-b758-2ba041ba18c8.txt)

Download JSON (downloads/9394437d-d8dc-42a5-8ad6-b11a24058410.json)

Generating PDF... (downloads/a5f98a1a-ee44-414c-b876-970e1a0c234e.pdf)

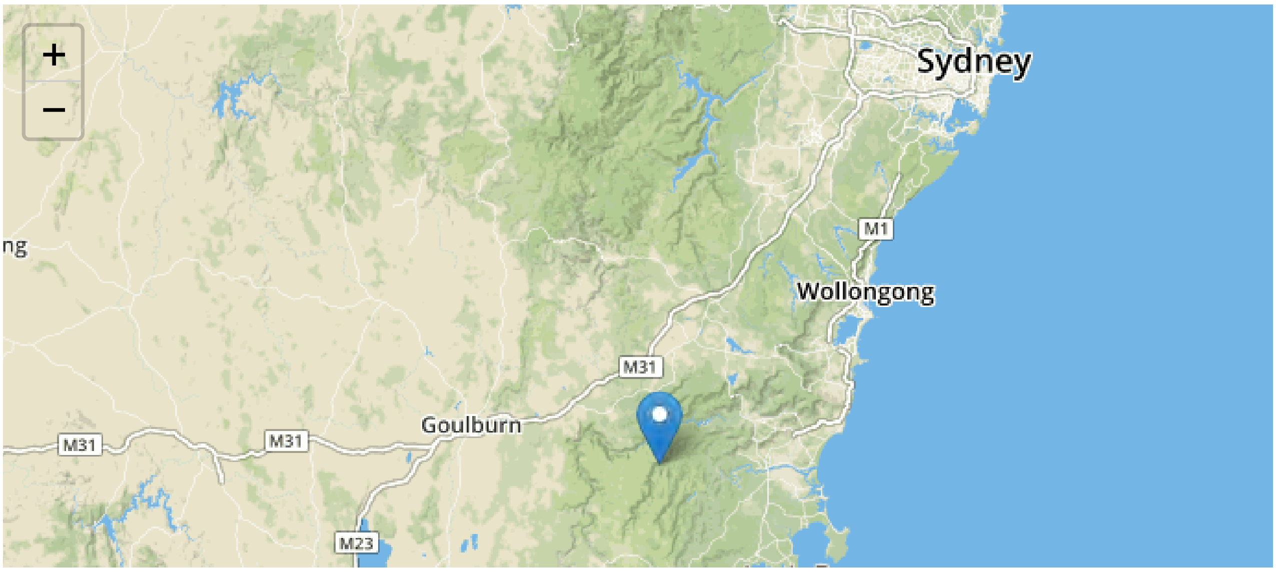
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

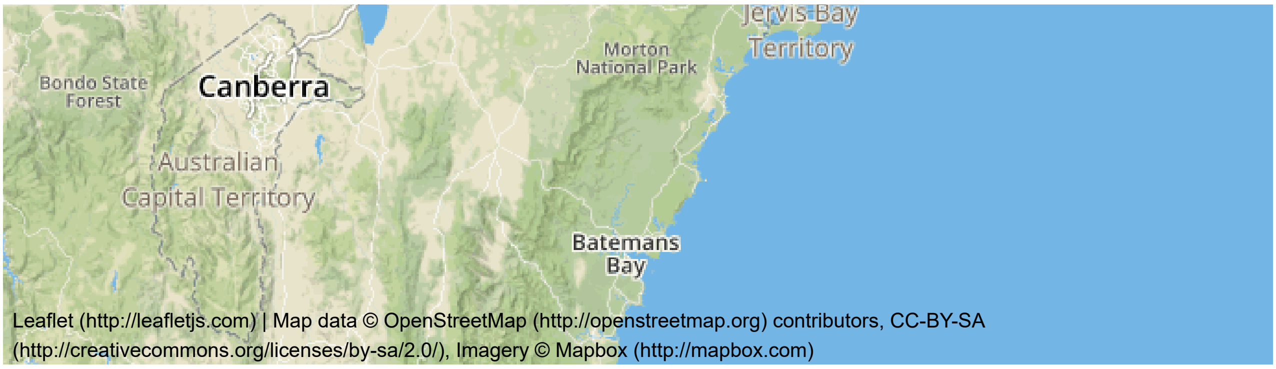
Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 3

Longitude	150.276
Latitude	-34.855
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (NSW)
River Number	15
River Name	Shoalhaven River

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	18715.0
Storm Initial Losses (mm)	29.0
Storm Continuing Losses (mm/h)	4.8

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.855&longitude=150.276&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:33PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.0 (0.043)	1.5 (0.045)	1.7 (0.045)	2.0 (0.045)	1.5 (0.027)	1.1 (0.017)
90 (1.5)	2.8 (0.098)	2.2 (0.058)	1.9 (0.041)	1.5 (0.029)	1.4 (0.022)	1.2 (0.017)
120 (2.0)	0.5 (0.017)	1.1 (0.025)	1.5 (0.029)	1.8 (0.031)	2.4 (0.034)	2.9 (0.036)
180 (3.0)	1.1 (0.028)	1.8 (0.035)	2.2 (0.037)	2.7 (0.038)	3.4 (0.040)	3.9 (0.041)
360 (6.0)	5.8 (0.111)	13.7 (0.190)	18.9 (0.220)	23.9 (0.241)	19.7 (0.167)	16.5 (0.125)
720 (12.0)	6.9 (0.093)	13.5 (0.130)	17.9 (0.144)	22.2 (0.152)	24.5 (0.142)	26.2 (0.135)
1080 (18.0)	4.3 (0.049)	7.2 (0.057)	9.1 (0.059)	10.9 (0.060)	20.4 (0.095)	27.4 (0.114)
1440 (24.0)	3.2 (0.032)	7.1 (0.049)	9.7 (0.055)	12.2 (0.058)	16.1 (0.065)	19.0 (0.068)
2160 (36.0)	0.3 (0.002)	2.2 (0.013)	3.4 (0.016)	4.7 (0.019)	6.7 (0.022)	8.2 (0.024)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.8 (0.002)	1.5 (0.004)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.8 (0.004)	1.4 (0.006)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	13.3 (0.557)	14.5 (0.445)	15.3 (0.393)	16.1 (0.354)	14.3 (0.262)	13.0 (0.210)
90 (1.5)	30.1 (1.072)	24.2 (0.637)	20.4 (0.451)	16.7 (0.317)	17.2 (0.274)	17.7 (0.248)
120 (2.0)	12.9 (0.408)	23.3 (0.545)	30.2 (0.596)	36.9 (0.626)	35.9 (0.511)	35.2 (0.443)
180 (3.0)	20.9 (0.553)	39.8 (0.778)	52.3 (0.863)	64.4 (0.916)	52.8 (0.632)	44.1 (0.468)
360 (6.0)	38.4 (0.730)	55.5 (0.768)	66.8 (0.778)	77.7 (0.780)	82.1 (0.697)	85.4 (0.646)
720 (12.0)	28.7 (0.388)	42.7 (0.411)	52.0 (0.417)	61.0 (0.418)	68.6 (0.398)	74.4 (0.385)
1080 (18.0)	33.4 (0.375)	43.9 (0.345)	50.9 (0.330)	57.6 (0.318)	69.5 (0.323)	78.4 (0.325)
1440 (24.0)	24.4 (0.244)	30.9 (0.212)	35.1 (0.198)	39.2 (0.188)	50.7 (0.203)	59.2 (0.212)
2160 (36.0)	11.8 (0.103)	21.7 (0.127)	28.2 (0.135)	34.5 (0.138)	32.4 (0.108)	30.9 (0.092)
2880 (48.0)	2.2 (0.017)	6.8 (0.036)	9.8 (0.042)	12.7 (0.046)	16.8 (0.050)	19.9 (0.053)
4320 (72.0)	0.0 (0.000)	0.2 (0.001)	0.4 (0.001)	0.5 (0.002)	17.6 (0.047)	30.3 (0.071)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	63.4 (2.648)	68.8 (2.111)	72.4 (1.862)	75.9 (1.672)	65.2 (1.196)	57.2 (0.924)
90 (1.5)	66.7 (2.379)	98.8 (2.599)	120.1 (2.656)	140.5 (2.672)	107.5 (1.709)	82.7 (1.161)
120 (2.0)	53.0 (1.679)	90.2 (2.110)	114.8 (2.263)	138.5 (2.351)	124.0 (1.765)	113.2 (1.426)
180 (3.0)	52.4 (1.388)	91.6 (1.789)	117.5 (1.936)	142.4 (2.026)	130.6 (1.564)	121.8 (1.295)
360 (6.0)	78.9 (1.503)	103.9 (1.439)	120.4 (1.402)	136.3 (1.369)	141.2 (1.199)	145.0 (1.098)
720 (12.0)	63.9 (0.865)	86.4 (0.830)	101.3 (0.811)	115.6 (0.793)	128.9 (0.747)	138.9 (0.719)
1080 (18.0)	64.7 (0.728)	85.0 (0.667)	98.4 (0.637)	111.2 (0.614)	129.7 (0.603)	143.6 (0.595)
1440 (24.0)	63.7 (0.636)	71.6 (0.493)	76.8 (0.434)	81.8 (0.391)	104.2 (0.418)	121.0 (0.432)
2160 (36.0)	39.4 (0.341)	47.5 (0.279)	52.8 (0.252)	57.9 (0.232)	89.4 (0.299)	113.0 (0.335)
2880 (48.0)	17.7 (0.142)	28.3 (0.152)	35.4 (0.153)	42.1 (0.152)	67.9 (0.204)	87.3 (0.232)
4320 (72.0)	10.1 (0.074)	13.4 (0.065)	15.5 (0.061)	17.6 (0.057)	70.2 (0.187)	109.7 (0.258)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	24.8	16.7	14.7	15.3	15.2	13.6
90 (1.5)	29.1	15.1	13.8	15.0	14.0	12.9
120 (2.0)	32.8	17.8	15.0	14.5	12.7	11.2
180 (3.0)	35.0	18.2	14.5	13.8	12.9	9.8
360 (6.0)	28.7	17.5	15.6	14.5	12.1	7.2
720 (12.0)	32.2	23.1	21.6	19.0	15.7	9.8
1080 (18.0)	33.6	26.4	25.8	23.2	20.3	8.7
1440 (24.0)	36.3	29.5	29.5	28.4	25.6	15.7
2160 (36.0)	42.9	35.5	35.6	35.5	32.3	16.6
2880 (48.0)	48.7	41.3	41.5	46.0	37.6	21.9
4320 (72.0)	51.1	46.3	46.2	53.6	38.4	22.4

Layer Info

Time Accessed	02 August 2019 03:33PM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	10619
Area (km2)	697.854656
Catchment Number	10661
Volume Factor	0.0
Peak Factor	0.042398

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

Download TXT (downloads/d1dac216-0d6f-4def-a517-26f55439c2b4.txt)

Download JSON (downloads/a61a769a-e181-48f1-bbd2-1982e509940e.json)

Generating PDF... (downloads/5cbf48a3-38f2-49d8-89fd-98144fadf788.pdf)

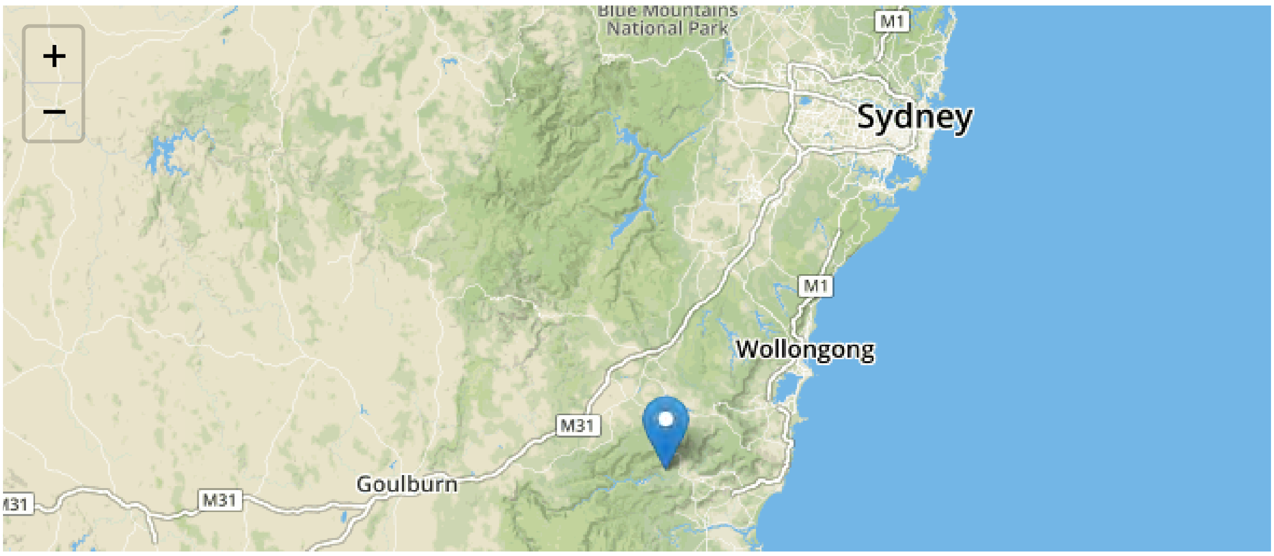
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

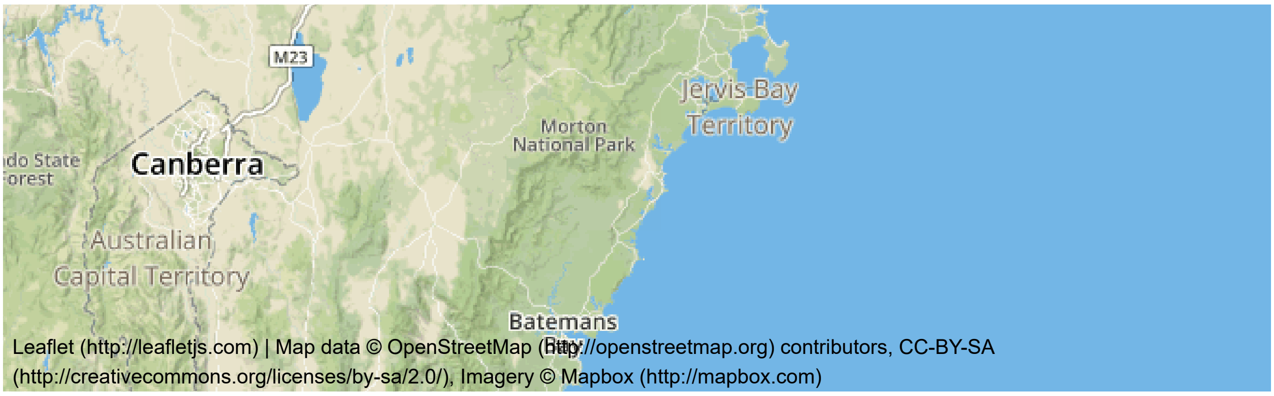
Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 4

Longitude	150.48
Latitude	-34.722
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (NSW)
River Number	15
River Name	Shoalhaven River

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	12329.0
Storm Initial Losses (mm)	37.0
Storm Continuing Losses (mm/h)	4.8

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.722&longitude=150.48&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:33PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.3 (0.084)	2.1 (0.056)	2.0 (0.044)	1.9 (0.035)	1.3 (0.020)	0.9 (0.011)
90 (1.5)	4.7 (0.143)	5.2 (0.113)	5.4 (0.099)	5.7 (0.088)	3.1 (0.039)	1.2 (0.013)
120 (2.0)	12.0 (0.315)	10.2 (0.196)	9.1 (0.145)	8.0 (0.108)	5.1 (0.057)	2.9 (0.029)
180 (3.0)	8.3 (0.178)	10.4 (0.162)	11.8 (0.153)	13.2 (0.146)	10.0 (0.092)	7.6 (0.061)
360 (6.0)	12.0 (0.176)	18.3 (0.192)	22.4 (0.196)	26.4 (0.197)	20.2 (0.126)	15.5 (0.086)
720 (12.0)	17.2 (0.171)	21.4 (0.149)	24.1 (0.138)	26.7 (0.131)	40.3 (0.166)	50.5 (0.185)
1080 (18.0)	6.8 (0.055)	15.9 (0.088)	21.9 (0.100)	27.7 (0.107)	25.1 (0.081)	23.1 (0.067)
1440 (24.0)	4.2 (0.030)	11.3 (0.055)	16.1 (0.063)	20.6 (0.068)	26.2 (0.073)	30.4 (0.076)
2160 (36.0)	1.6 (0.010)	3.8 (0.016)	5.3 (0.017)	6.7 (0.018)	20.7 (0.047)	31.1 (0.063)
2880 (48.0)	0.0 (0.000)	0.6 (0.002)	1.0 (0.003)	1.4 (0.003)	15.5 (0.032)	26.0 (0.047)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	4.7 (0.008)	8.2 (0.013)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.3 (0.006)	0.5 (0.009)	0.8 (0.010)	0.3 (0.004)	0.0 (0.000)
180 (3.0)	0.1 (0.003)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	2.3 (0.023)	1.3 (0.009)	0.6 (0.004)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)	0.3 (0.001)	0.1 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.7 (0.002)	1.3 (0.003)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.6 (0.001)	1.0 (0.002)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	36.7 (1.317)	29.4 (0.766)	24.5 (0.531)	19.9 (0.365)	22.4 (0.338)	24.4 (0.319)
90 (1.5)	39.0 (1.172)	39.9 (0.874)	40.6 (0.739)	41.2 (0.638)	39.9 (0.507)	38.9 (0.431)
120 (2.0)	44.1 (1.159)	45.6 (0.872)	46.6 (0.742)	47.5 (0.645)	45.8 (0.512)	44.5 (0.434)
180 (3.0)	51.8 (1.109)	52.7 (0.819)	53.2 (0.691)	53.8 (0.596)	68.5 (0.628)	79.5 (0.639)
360 (6.0)	45.8 (0.670)	72.1 (0.757)	89.6 (0.782)	106.3 (0.794)	112.1 (0.699)	116.3 (0.642)
720 (12.0)	53.5 (0.531)	62.6 (0.435)	68.6 (0.394)	74.3 (0.363)	96.9 (0.399)	113.8 (0.418)
1080 (18.0)	38.6 (0.311)	54.6 (0.303)	65.2 (0.297)	75.3 (0.290)	86.2 (0.280)	94.4 (0.274)
1440 (24.0)	27.5 (0.194)	40.6 (0.195)	49.3 (0.193)	57.6 (0.190)	76.7 (0.213)	91.0 (0.226)
2160 (36.0)	19.7 (0.118)	21.7 (0.088)	23.0 (0.075)	24.3 (0.066)	86.0 (0.197)	132.3 (0.270)
2880 (48.0)	7.8 (0.043)	18.5 (0.068)	25.5 (0.075)	32.3 (0.079)	82.0 (0.167)	119.1 (0.216)
4320 (72.0)	0.1 (0.000)	10.7 (0.035)	17.8 (0.047)	24.6 (0.053)	45.3 (0.081)	60.9 (0.096)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	74.7 (2.682)	71.6 (1.868)	69.6 (1.507)	67.6 (1.242)	90.6 (1.364)	107.9 (1.411)
90 (1.5)	73.5 (2.209)	94.9 (2.077)	109.0 (1.986)	122.6 (1.899)	127.5 (1.623)	131.2 (1.455)
120 (2.0)	97.3 (2.557)	130.0 (2.486)	151.6 (2.416)	172.3 (2.340)	158.5 (1.774)	148.2 (1.448)
180 (3.0)	95.2 (2.038)	136.2 (2.118)	163.3 (2.119)	189.4 (2.097)	187.2 (1.716)	185.5 (1.492)
360 (6.0)	105.5 (1.544)	140.8 (1.476)	164.1 (1.433)	186.5 (1.392)	195.7 (1.221)	202.7 (1.118)
720 (12.0)	101.4 (1.007)	132.4 (0.921)	153.0 (0.879)	172.7 (0.845)	211.3 (0.870)	240.2 (0.882)
1080 (18.0)	74.5 (0.600)	118.3 (0.657)	147.4 (0.671)	175.2 (0.676)	187.3 (0.608)	196.3 (0.570)
1440 (24.0)	59.7 (0.421)	95.8 (0.461)	119.8 (0.469)	142.7 (0.471)	161.2 (0.448)	175.0 (0.435)
2160 (36.0)	53.2 (0.320)	90.1 (0.364)	114.5 (0.374)	138.0 (0.376)	173.7 (0.397)	200.5 (0.409)
2880 (48.0)	37.7 (0.207)	68.5 (0.251)	88.9 (0.261)	108.4 (0.264)	131.1 (0.267)	148.2 (0.268)
4320 (72.0)	8.5 (0.042)	39.8 (0.131)	60.4 (0.159)	80.3 (0.173)	98.6 (0.176)	112.3 (0.178)

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	21.7	11.8	12.3	13.8	13.3	10.9
90 (1.5)	19.9	11.8	11.8	12.2	11.8	9.7
120 (2.0)	16.9	11.5	11.9	11.6	12.8	9.3
180 (3.0)	17.6	12.0	12.9	12.1	10.9	7.3
360 (6.0)	18.5	13.1	12.6	10.8	11.5	5.7
720 (12.0)	19.1	15.4	16.3	13.7	14.7	3.7
1080 (18.0)	24.3	17.8	18.4	15.4	18.0	4.8
1440 (24.0)	27.2	21.4	21.0	18.5	18.8	6.9
2160 (36.0)	30.9	24.7	25.0	24.9	20.1	6.7
2880 (48.0)	34.7	27.4	26.9	25.0	18.9	7.8
4320 (72.0)	39.8	31.2	30.6	30.1	29.7	11.5

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	10649
Area (km2)	880.297152
Catchment Number	10580
Volume Factor	0.193861
Peak Factor	0.053471

Layer Info

Time Accessed	02 August 2019 03:33PM
Version	2016_v1

Download TXT (downloads/ff750e13-9e20-416d-9aaf-233e5ed7593c.txt)

Download JSON (downloads/091f88c0-b781-4ce1-bec2-1ba7d9534a97.json)

Generating PDF... (downloads/4e966af9-8f8a-4dd4-b5ab-1136ab856307.pdf)

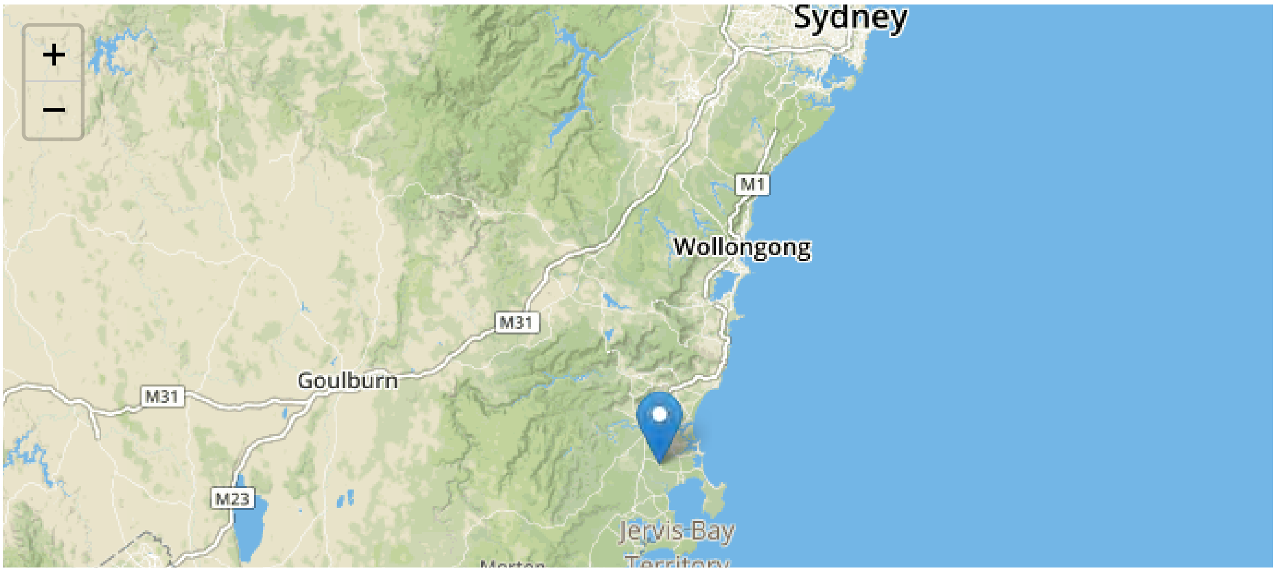
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

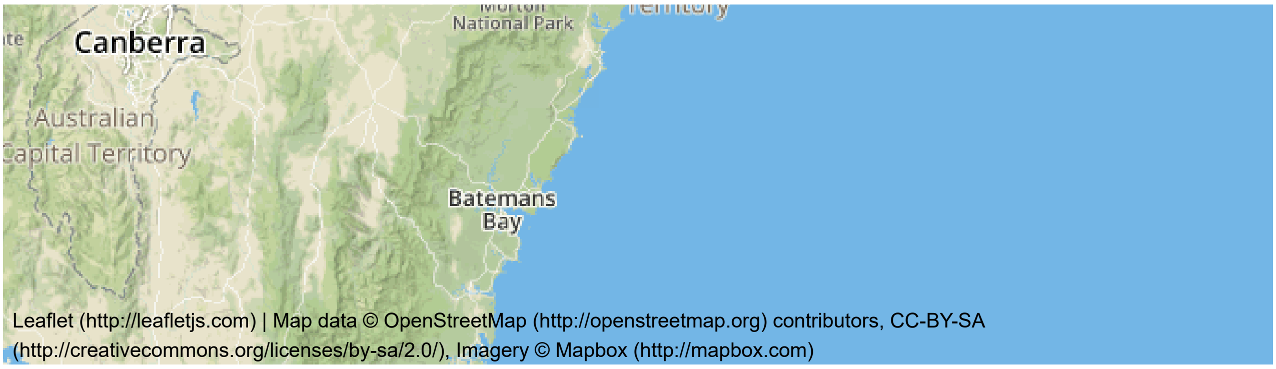
Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 5

Longitude	150.644
Latitude	-34.963
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (NSW)
River Number	16
River Name	Clyde River-Jervis Bay

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	14817.0
Storm Initial Losses (mm)	26.0
Storm Continuing Losses (mm/h)	4.0

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.963&longitude=150.644&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:34PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.7 (0.098)	2.5 (0.067)	2.4 (0.053)	2.3 (0.043)	1.1 (0.017)	0.2 (0.002)
90 (1.5)	1.7 (0.053)	3.8 (0.084)	5.2 (0.095)	6.5 (0.102)	3.8 (0.049)	1.8 (0.020)
120 (2.0)	5.5 (0.148)	6.4 (0.126)	7.1 (0.115)	7.7 (0.107)	5.4 (0.062)	3.6 (0.037)
180 (3.0)	13.1 (0.291)	10.8 (0.175)	9.3 (0.127)	7.9 (0.092)	8.3 (0.081)	8.6 (0.074)
360 (6.0)	11.3 (0.178)	20.4 (0.232)	26.4 (0.252)	32.2 (0.264)	23.3 (0.161)	16.6 (0.102)
720 (12.0)	5.1 (0.056)	12.7 (0.100)	17.8 (0.117)	22.7 (0.129)	29.4 (0.141)	34.4 (0.148)
1080 (18.0)	6.7 (0.061)	10.2 (0.066)	12.5 (0.067)	14.7 (0.068)	23.9 (0.093)	30.8 (0.107)
1440 (24.0)	1.2 (0.010)	6.1 (0.034)	9.3 (0.043)	12.4 (0.050)	18.8 (0.064)	23.7 (0.072)
2160 (36.0)	0.0 (0.000)	1.8 (0.009)	3.0 (0.012)	4.2 (0.014)	7.0 (0.020)	9.2 (0.023)
2880 (48.0)	0.0 (0.000)	0.2 (0.001)	0.3 (0.001)	0.4 (0.001)	1.8 (0.005)	2.9 (0.006)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.5 (0.011)	0.3 (0.005)	0.1 (0.002)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.4 (0.007)	0.6 (0.007)	0.7 (0.007)	0.8 (0.007)	0.4 (0.002)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.7 (0.007)	3.0 (0.010)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	31.5 (1.145)	26.0 (0.681)	22.3 (0.485)	18.9 (0.348)	21.5 (0.326)	23.5 (0.311)
90 (1.5)	49.0 (1.500)	50.0 (1.108)	50.7 (0.935)	51.3 (0.806)	38.7 (0.503)	29.3 (0.333)
120 (2.0)	42.1 (1.134)	51.4 (1.005)	57.5 (0.938)	63.4 (0.884)	51.2 (0.592)	42.1 (0.428)
180 (3.0)	47.7 (1.062)	54.9 (0.889)	59.7 (0.808)	64.3 (0.746)	67.4 (0.652)	69.7 (0.596)
360 (6.0)	46.3 (0.728)	67.7 (0.770)	81.8 (0.780)	95.3 (0.783)	98.1 (0.678)	100.1 (0.616)
720 (12.0)	22.9 (0.252)	42.6 (0.337)	55.7 (0.368)	68.3 (0.388)	84.0 (0.403)	95.7 (0.411)
1080 (18.0)	23.4 (0.214)	35.8 (0.231)	43.9 (0.236)	51.8 (0.238)	64.9 (0.252)	74.7 (0.260)
1440 (24.0)	15.3 (0.124)	25.5 (0.144)	32.2 (0.151)	38.6 (0.155)	50.8 (0.172)	59.8 (0.181)
2160 (36.0)	9.3 (0.065)	20.8 (0.100)	28.4 (0.113)	35.7 (0.120)	41.6 (0.118)	46.1 (0.116)
2880 (48.0)	4.7 (0.030)	9.4 (0.041)	12.5 (0.045)	15.4 (0.047)	19.6 (0.050)	22.8 (0.051)
4320 (72.0)	0.0 (0.000)	1.2 (0.005)	1.9 (0.006)	2.7 (0.007)	22.0 (0.049)	36.6 (0.072)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	73.6 (2.679)	67.0 (1.757)	62.7 (1.362)	58.5 (1.079)	92.0 (1.395)	117.1 (1.548)
90 (1.5)	107.6 (3.296)	129.7 (2.875)	144.2 (2.661)	158.2 (2.487)	135.8 (1.763)	118.9 (1.351)
120 (2.0)	94.7 (2.550)	125.6 (2.456)	146.1 (2.384)	165.8 (2.311)	152.9 (1.768)	143.3 (1.454)
180 (3.0)	107.6 (2.396)	131.4 (2.126)	147.1 (1.992)	162.2 (1.883)	156.6 (1.517)	152.4 (1.303)
360 (6.0)	88.3 (1.388)	119.6 (1.360)	140.2 (1.337)	160.1 (1.314)	173.5 (1.199)	183.6 (1.129)
720 (12.0)	66.8 (0.738)	95.1 (0.751)	113.8 (0.751)	131.8 (0.748)	162.5 (0.780)	185.6 (0.797)
1080 (18.0)	61.8 (0.564)	85.1 (0.549)	100.6 (0.540)	115.4 (0.531)	145.8 (0.567)	168.6 (0.587)
1440 (24.0)	61.3 (0.494)	72.7 (0.411)	80.3 (0.376)	87.5 (0.351)	110.5 (0.373)	127.7 (0.386)
2160 (36.0)	54.0 (0.374)	58.6 (0.282)	61.6 (0.244)	64.5 (0.218)	83.2 (0.235)	97.2 (0.245)
2880 (48.0)	21.8 (0.138)	37.8 (0.165)	48.4 (0.174)	58.5 (0.178)	73.0 (0.185)	83.8 (0.188)
4320 (72.0)	9.7 (0.056)	18.8 (0.074)	24.8 (0.080)	30.6 (0.082)	78.6 (0.175)	114.6 (0.225)

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	13.2	9.5	9.7	10.6	9.8	6.9
90 (1.5)	11.9	8.4	8.9	8.9	9.0	5.6
120 (2.0)	12.1	8.6	8.7	8.5	8.5	5.4
180 (3.0)	10.9	8.6	9.0	8.8	8.8	4.0
360 (6.0)	12.1	8.1	8.5	8.1	8.8	2.8
720 (12.0)	16.3	11.3	11.6	9.3	10.1	3.0
1080 (18.0)	17.1	13.0	13.7	11.3	11.7	3.7
1440 (24.0)	19.9	15.5	15.6	13.5	14.5	4.5
2160 (36.0)	22.0	17.1	17.4	15.6	17.2	8.2
2880 (48.0)	25.0	20.7	19.8	21.0	20.3	10.3
4320 (72.0)	27.5	24.4	24.6	24.4	23.2	7.6

Layer Info

Time Accessed	02 August 2019 03:34PM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	0
Area (km2)	838.345984
Catchment Number	10707
Volume Factor	0.245158
Peak Factor	0.102911

Layer Info

Time Accessed	02 August 2019 03:34PM
Version	2016_v1

Download TXT (downloads/d506ce5e-d274-4767-a1b8-f9c4726f00d2.txt)

Download JSON (downloads/3a5fc89d-fbe8-47c7-899f-7936a935773c.json)

Generating PDF... (downloads/5db368b8-dc51-45f1-91f5-dc9b41d9bbbb.pdf)

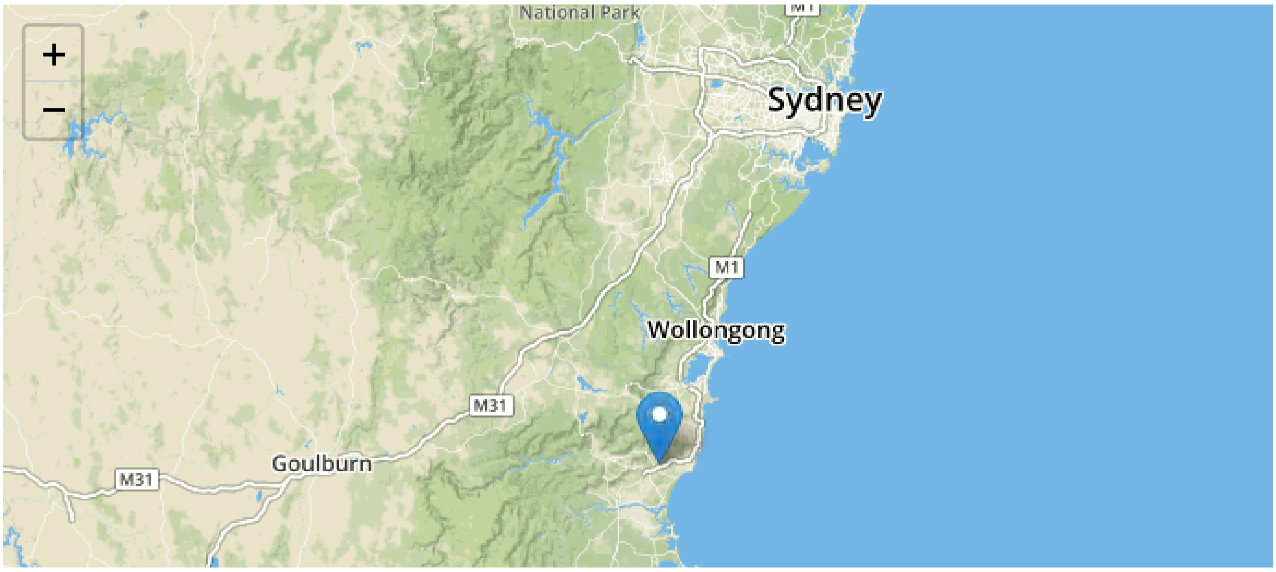
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

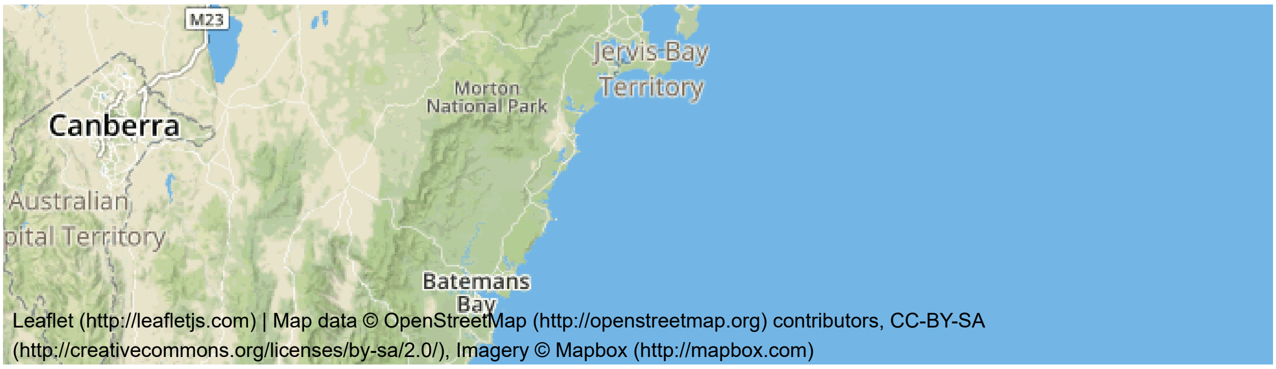
Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 6

Longitude	150.723
Latitude	-34.759
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (NSW)
River Number	15
River Name	Shoalhaven River

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	25987.0
Storm Initial Losses (mm)	51.0
Storm Continuing Losses (mm/h)	4.4

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.759&longitude=150.723&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:35PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	3.7 (0.127)	3.6 (0.088)	3.6 (0.071)	3.5 (0.059)	1.9 (0.026)	0.6 (0.008)
90 (1.5)	14.6 (0.419)	10.8 (0.221)	8.3 (0.141)	5.9 (0.085)	3.9 (0.046)	2.4 (0.025)
120 (2.0)	13.2 (0.330)	12.3 (0.221)	11.7 (0.175)	11.1 (0.141)	6.2 (0.065)	2.5 (0.023)
180 (3.0)	10.7 (0.220)	12.8 (0.190)	14.2 (0.176)	15.6 (0.165)	10.5 (0.092)	6.7 (0.052)
360 (6.0)	15.5 (0.221)	20.2 (0.208)	23.3 (0.201)	26.2 (0.195)	21.3 (0.134)	17.6 (0.098)
720 (12.0)	16.7 (0.165)	20.1 (0.142)	22.3 (0.132)	24.4 (0.125)	26.9 (0.117)	28.8 (0.112)
1080 (18.0)	7.4 (0.059)	12.9 (0.074)	16.6 (0.079)	20.1 (0.083)	28.2 (0.098)	34.2 (0.107)
1440 (24.0)	4.7 (0.033)	10.6 (0.053)	14.5 (0.060)	18.3 (0.065)	21.9 (0.066)	24.6 (0.066)
2160 (36.0)	0.5 (0.003)	2.1 (0.009)	3.2 (0.011)	4.2 (0.012)	8.2 (0.020)	11.2 (0.025)
2880 (48.0)	0.0 (0.000)	0.6 (0.002)	0.9 (0.003)	1.3 (0.003)	4.7 (0.010)	7.3 (0.014)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.3 (0.002)	2.3 (0.004)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.3 (0.008)	0.2 (0.003)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.4 (0.009)	0.2 (0.003)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.5 (0.007)	0.3 (0.003)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	2.0 (0.019)	1.1 (0.008)	0.5 (0.003)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.2 (0.000)	0.3 (0.001)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	42.7 (1.460)	39.4 (0.954)	37.1 (0.741)	35.0 (0.590)	33.8 (0.466)	32.8 (0.394)
90 (1.5)	49.4 (1.414)	42.6 (0.870)	38.1 (0.644)	33.8 (0.484)	37.8 (0.445)	40.8 (0.420)
120 (2.0)	58.1 (1.458)	60.3 (1.085)	61.8 (0.922)	63.2 (0.802)	56.1 (0.589)	50.8 (0.467)
180 (3.0)	50.3 (1.034)	57.8 (0.856)	62.8 (0.775)	67.5 (0.713)	72.7 (0.639)	76.6 (0.593)
360 (6.0)	46.7 (0.667)	72.4 (0.747)	89.5 (0.773)	105.8 (0.787)	107.6 (0.674)	108.9 (0.608)
720 (12.0)	55.1 (0.542)	61.8 (0.437)	66.3 (0.392)	70.6 (0.360)	80.4 (0.348)	87.7 (0.340)
1080 (18.0)	37.6 (0.302)	51.7 (0.296)	61.1 (0.292)	70.1 (0.288)	79.7 (0.277)	86.9 (0.271)
1440 (24.0)	27.1 (0.191)	39.3 (0.195)	47.3 (0.196)	55.1 (0.196)	68.3 (0.205)	78.2 (0.210)
2160 (36.0)	16.4 (0.099)	18.9 (0.079)	20.6 (0.071)	22.2 (0.066)	47.3 (0.117)	66.1 (0.146)
2880 (48.0)	6.7 (0.036)	17.5 (0.066)	24.7 (0.077)	31.5 (0.083)	60.1 (0.132)	81.6 (0.159)
4320 (72.0)	0.1 (0.000)	7.1 (0.024)	11.8 (0.033)	16.3 (0.038)	28.5 (0.054)	37.6 (0.063)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	122.2 (4.180)	119.3 (2.893)	117.3 (2.343)	115.5 (1.947)	119.7 (1.651)	122.8 (1.474)
90 (1.5)	138.5 (3.966)	141.4 (2.891)	143.4 (2.424)	145.3 (2.082)	140.2 (1.654)	136.5 (1.405)
120 (2.0)	138.3 (3.467)	160.2 (2.880)	174.8 (2.606)	188.7 (2.395)	160.7 (1.686)	139.8 (1.284)
180 (3.0)	124.9 (2.568)	156.0 (2.311)	176.6 (2.180)	196.3 (2.072)	192.1 (1.688)	188.9 (1.463)
360 (6.0)	115.1 (1.643)	145.7 (1.503)	166.0 (1.435)	185.5 (1.380)	192.6 (1.207)	198.0 (1.105)
720 (12.0)	102.3 (1.007)	122.2 (0.863)	135.3 (0.801)	147.9 (0.755)	156.4 (0.677)	162.7 (0.631)
1080 (18.0)	74.3 (0.596)	111.8 (0.639)	136.7 (0.652)	160.5 (0.660)	187.9 (0.654)	208.4 (0.651)
1440 (24.0)	59.2 (0.417)	87.7 (0.436)	106.6 (0.441)	124.7 (0.443)	146.3 (0.439)	162.5 (0.437)
2160 (36.0)	52.6 (0.315)	73.4 (0.307)	87.1 (0.301)	100.3 (0.296)	132.4 (0.328)	156.4 (0.345)
2880 (48.0)	33.1 (0.181)	63.7 (0.241)	84.0 (0.261)	103.4 (0.273)	117.4 (0.258)	127.9 (0.249)
4320 (72.0)	8.3 (0.041)	35.8 (0.121)	53.9 (0.148)	71.4 (0.165)	88.3 (0.169)	101.0 (0.170)

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50**	**20**	**10**	**5**	**2**	**1**
60 (1.0)	29.1	14.1	13.7	15.1	14.3	13.6
90 (1.5)	25.8	14.1	14.4	15.5	15.9	12.0
120 (2.0)	24.2	14.0	14.1	13.6	14.4	11.7
180 (3.0)	25.8	16.0	15.7	14.2	14.2	10.0
360 (6.0)	26.4	17.1	17.2	15.0	13.6	9.1
720 (12.0)	29.0	21.9	21.0	20.5	18.4	8.9
1080 (18.0)	34.7	26.9	24.8	22.8	21.2	8.2
1440 (24.0)	39.0	30.1	28.2	26.6	25.9	15.1
2160 (36.0)	44.0	36.9	36.5	36.1	31.4	13.1
2880 (48.0)	48.0	39.7	37.3	37.2	31.1	15.4
4320 (72.0)	54.2	44.6	43.6	46.9	34.6	23.1

Layer Info

Time Accessed	02 August 2019 03:35PM

Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	0
Area (km2)	7068.868064
Catchment Number	10619
Volume Factor	0.200273
Peak Factor	0.048426

Layer Info

Time Accessed	02 August 2019 03:35PM
Version	2016_v1

Download TXT (downloads/4e2e6822-05a1-43d6-81f4-979efbdfbef6.txt)

Download JSON (downloads/c918d029-1d24-4c1d-8fab-96b422d0d503.json)

Generating PDF... (downloads/b1ceb615-f6e5-4c3e-8f41-9f17cc39dd35.pdf)

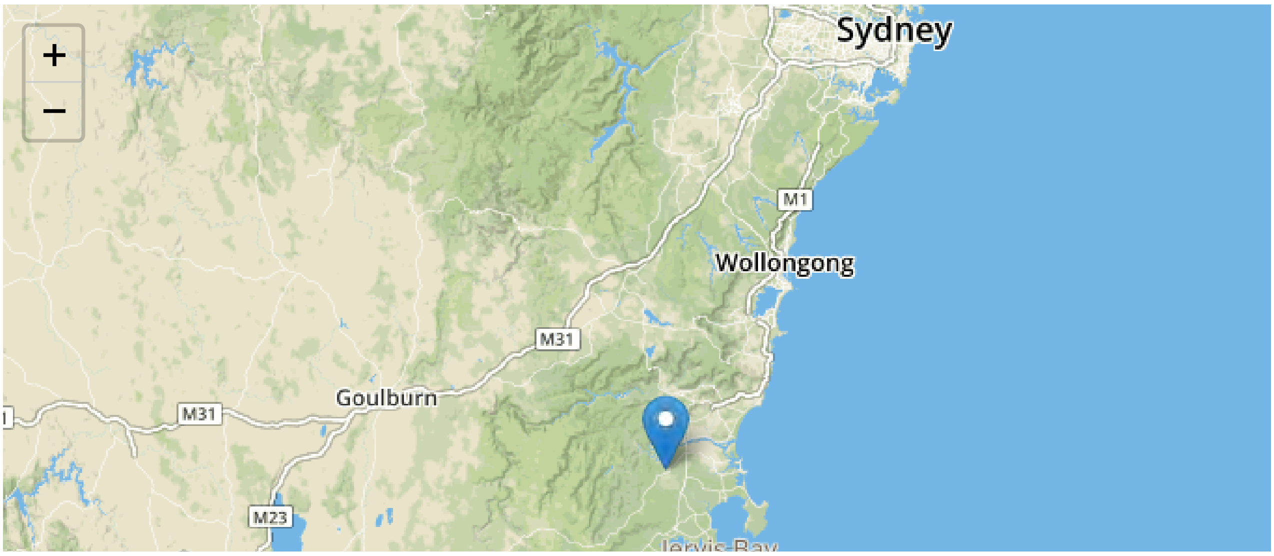
ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

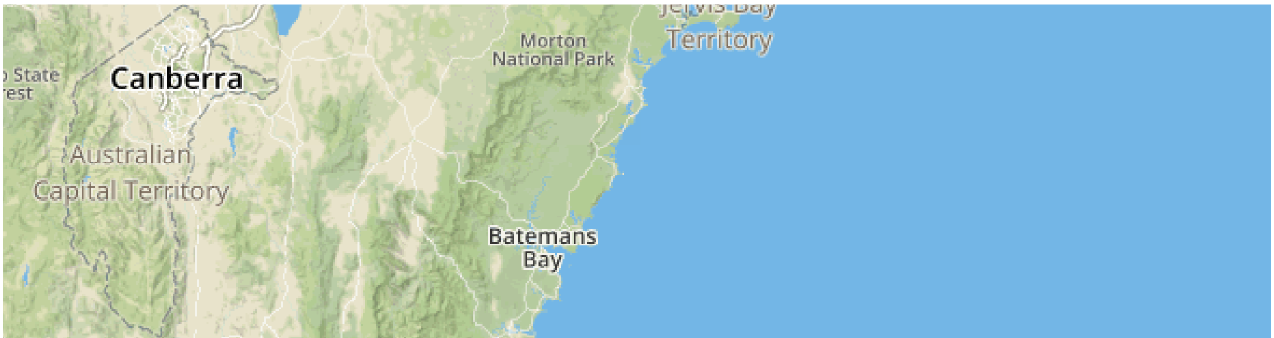
Australian Rainfall & Runoff Data Hub - Results

Input Data

IFD ZONE 7

Longitude	150.538
Latitude	-34.93
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show
Baseflow Factors	show





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Data

River Region

Division	South East Coast (NSW)
River Number	15
River Name	Shoalhaven River

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	10346.0
Storm Initial Losses (mm)	37.0
Storm Continuing Losses (mm/h)	4.5

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.93&longitude=150.538&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	02 August 2019 03:36PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.6 (0.024)	0.8 (0.021)	0.9 (0.019)	1.0 (0.018)	1.0 (0.015)	1.0 (0.013)
90 (1.5)	2.2 (0.068)	2.7 (0.061)	3.1 (0.058)	3.4 (0.055)	3.3 (0.044)	3.2 (0.037)
120 (2.0)	2.7 (0.076)	3.8 (0.076)	4.5 (0.075)	5.2 (0.073)	3.7 (0.044)	2.6 (0.027)
180 (3.0)	5.2 (0.118)	5.6 (0.092)	5.9 (0.081)	6.1 (0.072)	5.8 (0.057)	5.6 (0.048)
360 (6.0)	8.6 (0.136)	16.6 (0.189)	21.9 (0.208)	26.9 (0.220)	21.9 (0.150)	18.1 (0.110)
720 (12.0)	5.2 (0.057)	13.5 (0.104)	19.0 (0.122)	24.2 (0.134)	29.2 (0.136)	32.9 (0.137)
1080 (18.0)	7.4 (0.066)	10.6 (0.066)	12.7 (0.066)	14.7 (0.065)	23.9 (0.089)	30.8 (0.102)
1440 (24.0)	1.8 (0.015)	6.5 (0.035)	9.6 (0.043)	12.5 (0.048)	18.0 (0.058)	22.1 (0.063)
2160 (36.0)	0.0 (0.000)	2.3 (0.010)	3.7 (0.014)	5.1 (0.016)	7.8 (0.021)	9.9 (0.023)
2880 (48.0)	0.0 (0.000)	0.4 (0.002)	0.7 (0.002)	0.9 (0.003)	2.3 (0.005)	3.2 (0.007)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.7 (0.008)	1.1 (0.011)	1.6 (0.013)	0.7 (0.005)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.1 (0.001)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	1.7 (0.006)	3.0 (0.010)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	16.6 (0.618)	18.4 (0.494)	19.6 (0.437)	20.8 (0.393)	19.2 (0.298)	18.0 (0.244)
90 (1.5)	23.0 (0.722)	32.9 (0.747)	39.5 (0.745)	45.8 (0.736)	35.3 (0.468)	27.4 (0.318)
120 (2.0)	37.4 (1.031)	37.7 (0.753)	37.9 (0.631)	38.1 (0.542)	36.7 (0.432)	35.6 (0.368)
180 (3.0)	48.8 (1.108)	52.3 (0.860)	54.7 (0.750)	56.9 (0.669)	58.0 (0.568)	58.8 (0.508)
360 (6.0)	40.8 (0.645)	58.8 (0.669)	70.8 (0.673)	82.3 (0.672)	88.3 (0.606)	92.9 (0.566)
720 (12.0)	26.3 (0.288)	44.9 (0.347)	57.1 (0.368)	68.9 (0.380)	81.9 (0.381)	91.6 (0.381)
1080 (18.0)	23.8 (0.213)	36.0 (0.225)	44.0 (0.228)	51.8 (0.229)	64.9 (0.242)	74.7 (0.249)
1440 (24.0)	18.2 (0.143)	29.0 (0.158)	36.2 (0.162)	43.0 (0.164)	53.0 (0.170)	60.5 (0.173)
2160 (36.0)	9.3 (0.063)	21.6 (0.099)	29.7 (0.112)	37.5 (0.119)	50.0 (0.133)	59.3 (0.140)
2880 (48.0)	4.7 (0.029)	9.7 (0.040)	13.0 (0.044)	16.2 (0.046)	22.9 (0.054)	28.0 (0.059)
4320 (72.0)	0.0 (0.000)	1.2 (0.004)	2.0 (0.006)	2.7 (0.007)	26.6 (0.055)	44.4 (0.081)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	82.2 (3.066)	82.1 (2.203)	82.0 (1.825)	81.9 (1.547)	75.5 (1.172)	70.7 (0.957)
90 (1.5)	89.7 (2.813)	115.5 (2.620)	132.6 (2.502)	149.0 (2.395)	130.4 (1.731)	116.5 (1.353)
120 (2.0)	112.7 (3.105)	121.4 (2.422)	127.1 (2.115)	132.7 (1.885)	132.5 (1.559)	132.3 (1.367)
180 (3.0)	114.0 (2.585)	122.4 (2.011)	128.1 (1.757)	133.4 (1.568)	129.5 (1.269)	126.6 (1.094)
360 (6.0)	81.5 (1.290)	108.5 (1.234)	126.3 (1.201)	143.4 (1.171)	162.1 (1.112)	176.1 (1.074)
720 (12.0)	79.2 (0.866)	100.6 (0.779)	114.8 (0.739)	128.5 (0.709)	153.7 (0.715)	172.6 (0.718)
1080 (18.0)	70.0 (0.626)	89.7 (0.561)	102.8 (0.532)	115.4 (0.510)	145.8 (0.543)	168.6 (0.561)
1440 (24.0)	69.4 (0.545)	77.7 (0.423)	83.2 (0.373)	88.5 (0.337)	105.5 (0.338)	118.2 (0.339)
2160 (36.0)	54.1 (0.363)	67.8 (0.311)	76.9 (0.289)	85.6 (0.272)	104.6 (0.278)	118.8 (0.281)
2880 (48.0)	21.9 (0.134)	38.5 (0.160)	49.4 (0.167)	59.9 (0.171)	75.3 (0.178)	86.8 (0.182)
4320 (72.0)	9.7 (0.054)	23.7 (0.089)	33.0 (0.100)	41.9 (0.105)	91.5 (0.190)	128.8 (0.236)

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	25.1	12.5	12.3	12.6	12.1	11.7
90 (1.5)	22.8	12.0	10.9	10.8	10.6	8.7
120 (2.0)	20.1	11.9	11.7	11.9	10.8	8.6
180 (3.0)	18.4	12.0	12.4	11.4	11.0	7.8
360 (6.0)	19.7	13.0	12.3	10.8	10.3	4.8
720 (12.0)	23.8	17.3	15.6	13.8	12.9	3.8
1080 (18.0)	25.1	20.2	18.9	16.9	15.8	5.0
1440 (24.0)	28.1	23.1	21.6	20.0	21.7	8.8
2160 (36.0)	31.3	26.0	25.0	24.2	22.2	9.2
2880 (48.0)	35.9	30.5	29.4	33.2	25.5	15.7
4320 (72.0)	39.3	34.9	33.7	35.5	28.1	12.6

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Baseflow Factors

Downstream	0
Area (km2)	7068.868064
Catchment Number	10619
Volume Factor	0.200273
Peak Factor	0.048426

Layer Info

Time Accessed	02 August 2019 03:36PM
Version	2016_v1

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Download JSON (downloads/22730d97-28c9-44da-bded-6506fbb67bdc.json)

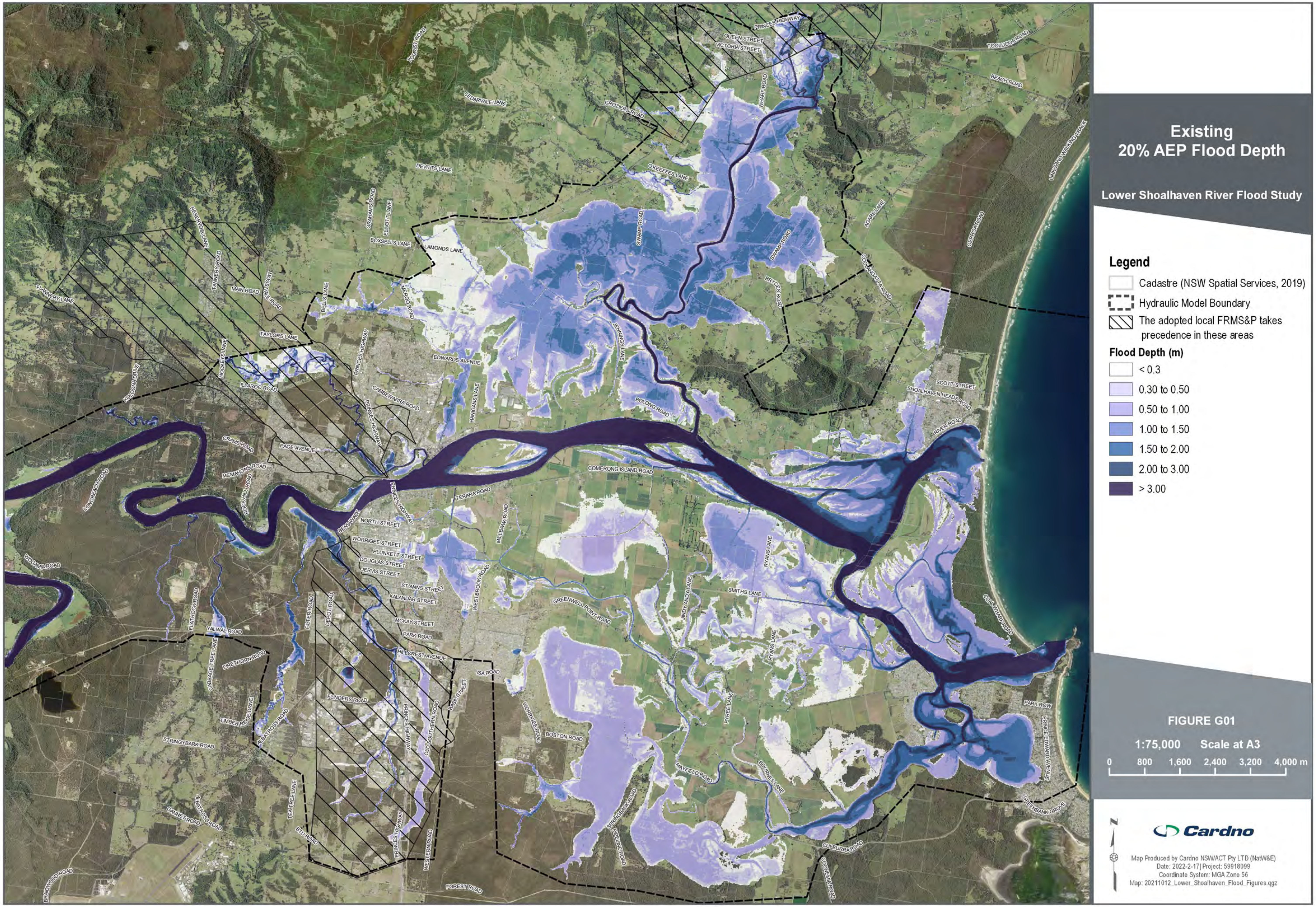
Generating PDF... (downloads/228ecce9-c831-434b-a9b3-c968c0ecbd55.pdf)

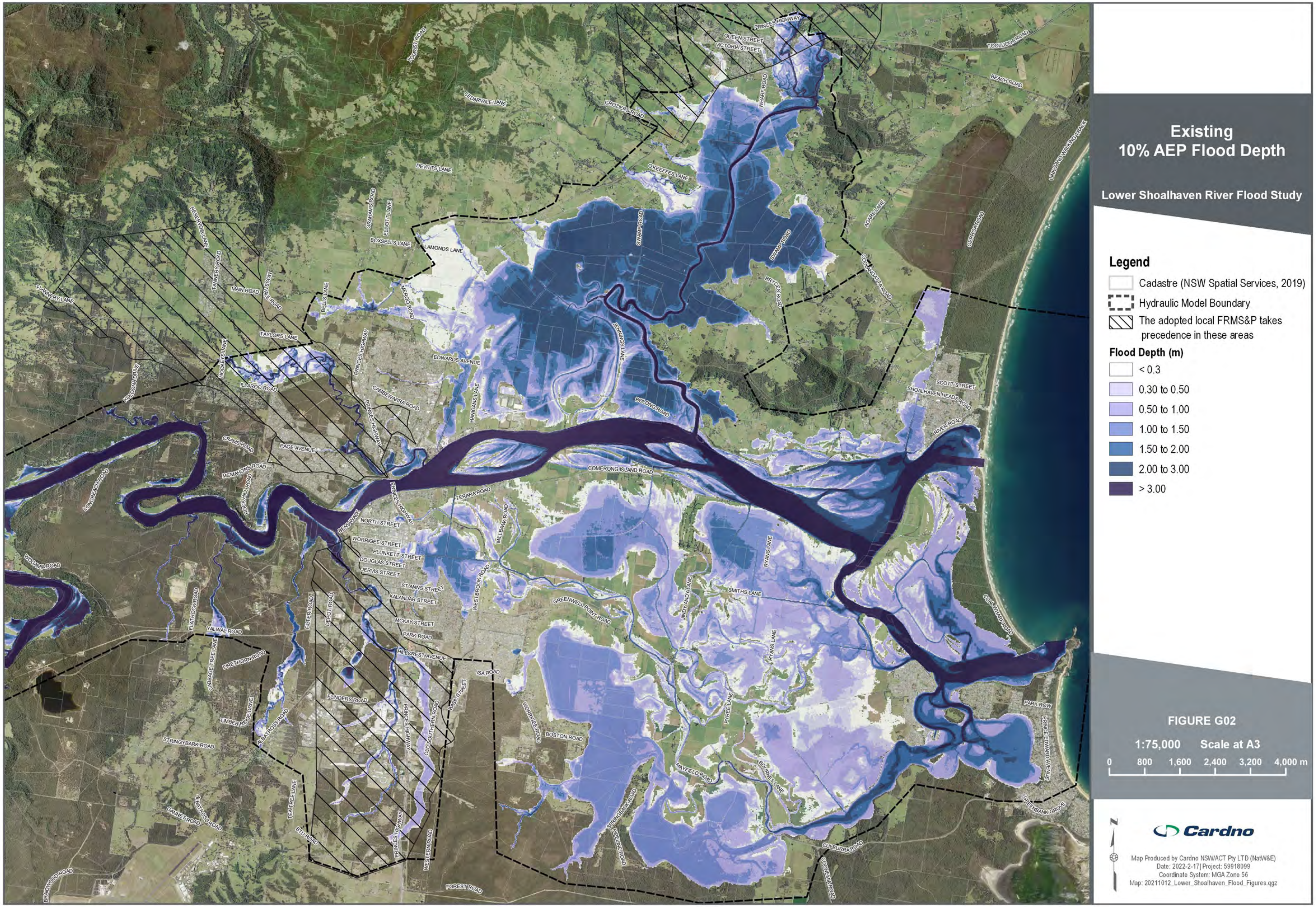
APPENDIX

G

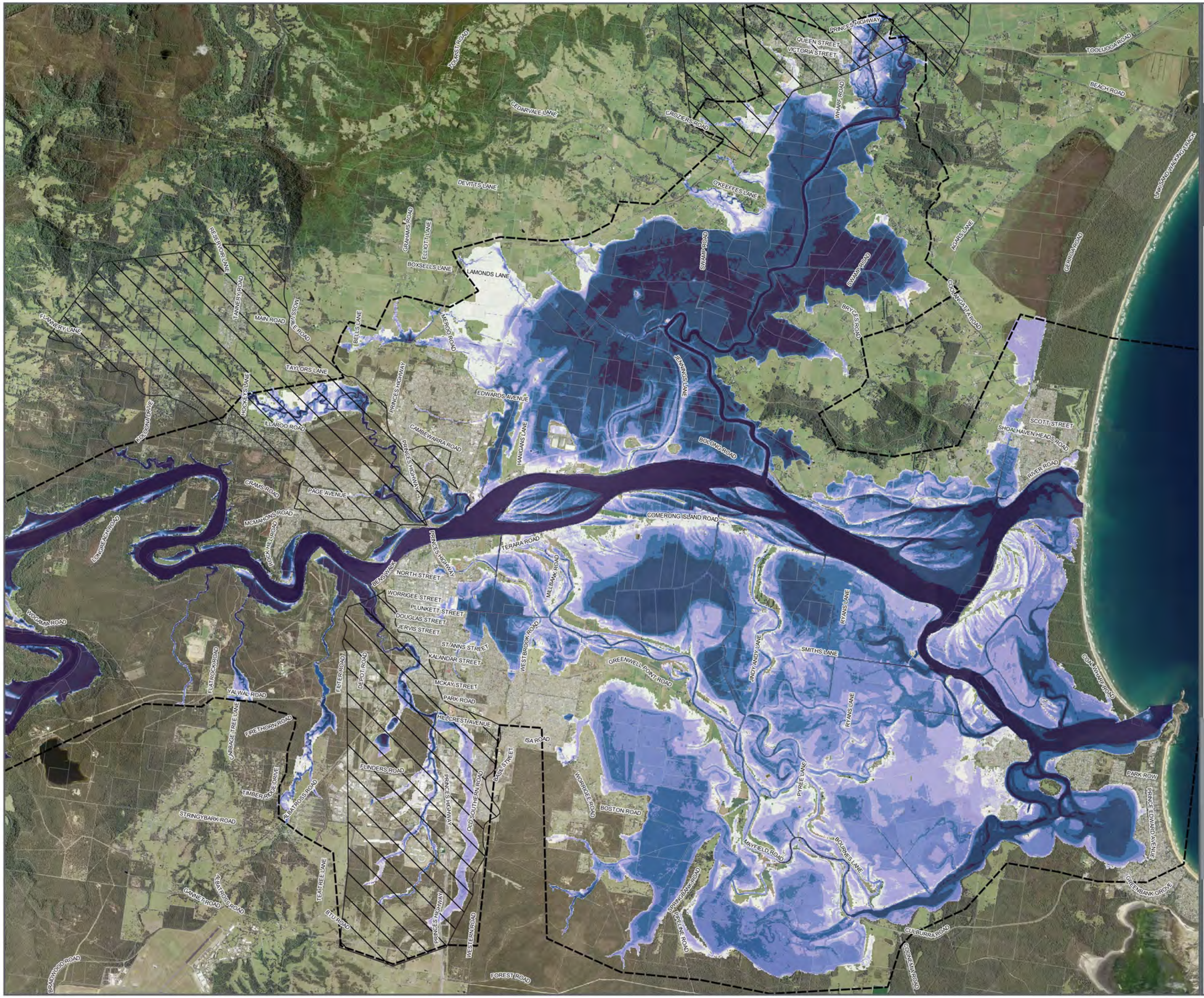
DESIGN EVENT FLOOD MAPS

Figure List:


Existing
20% AEP Flood Depth
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE G01
1:75,000
Scale at A3
0
800
1,600
2,400
3,200
4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
10% AEP Flood Depth
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE G02
1:75,000
Scale at A3
0
800
1,600
2,400
3,200
4,000 m
N
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz
COMERONG ISLAND ROAD
PRINCES HIGHWAY
BOLONG ROAD
GREENWELL POINT ROAD



Existing 5% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

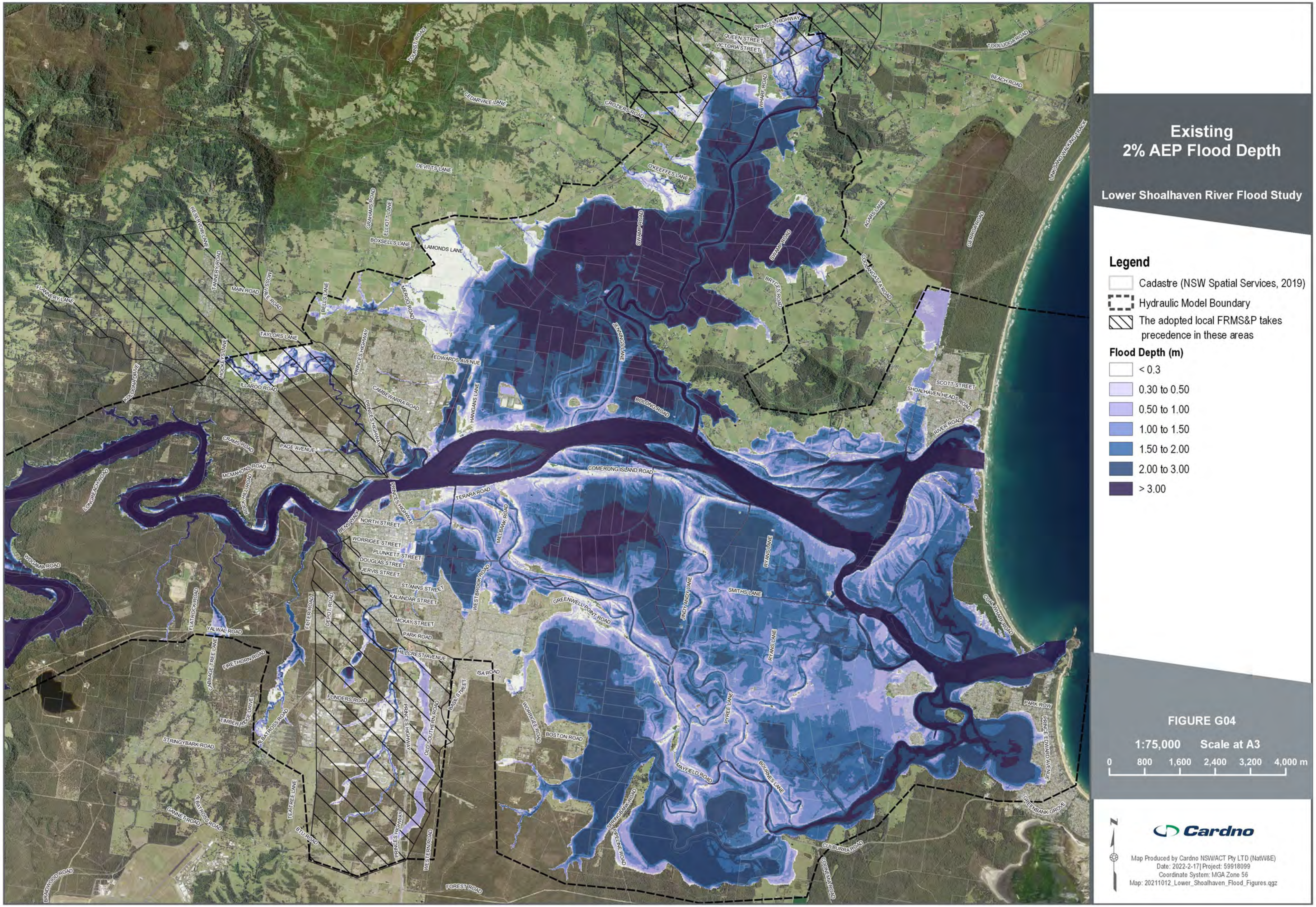
FIGURE G03

1:75,000 Scale at A3

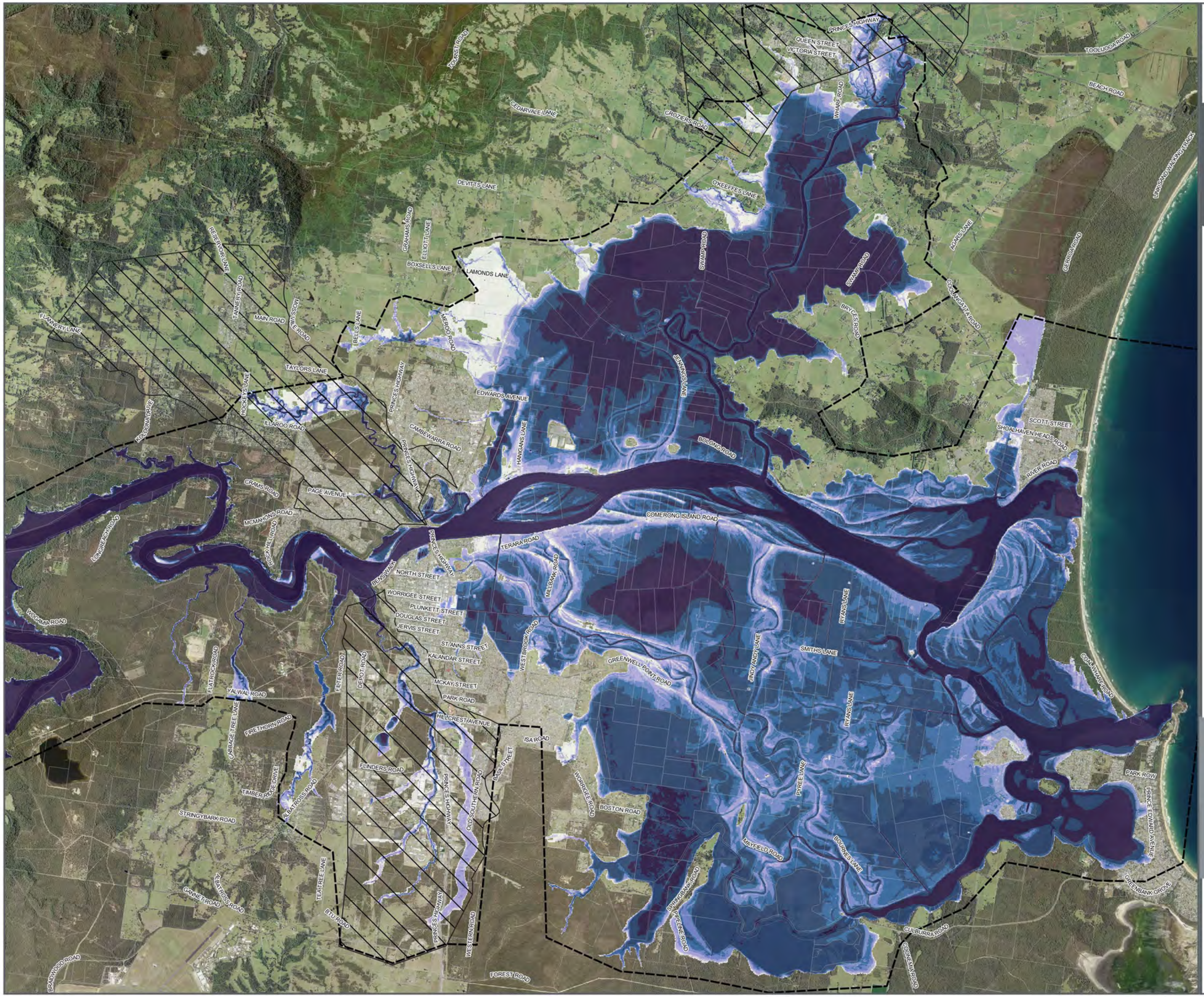
0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
2% AEP Flood Depth
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE G04
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

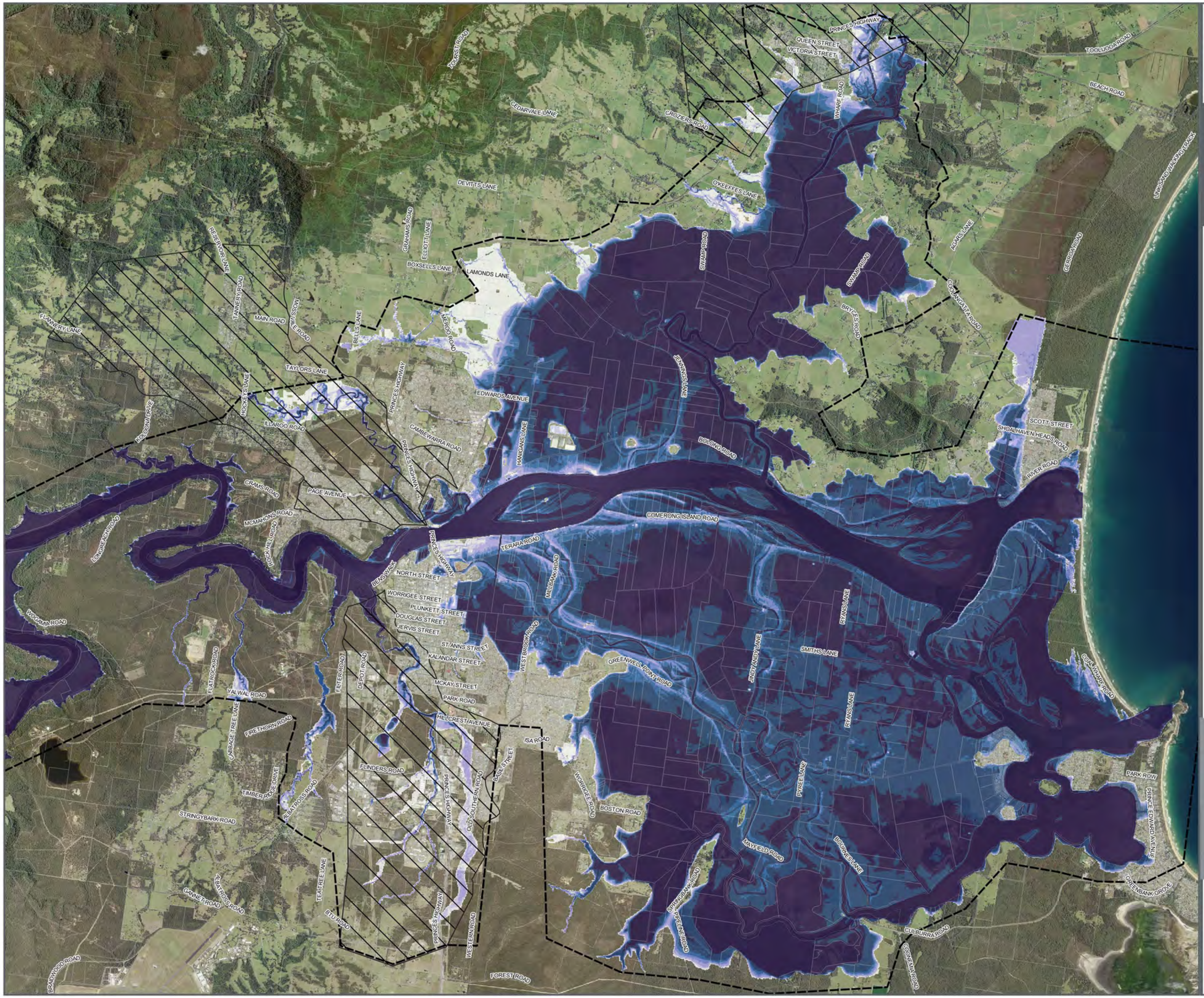
FIGURE G05

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
0.2% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

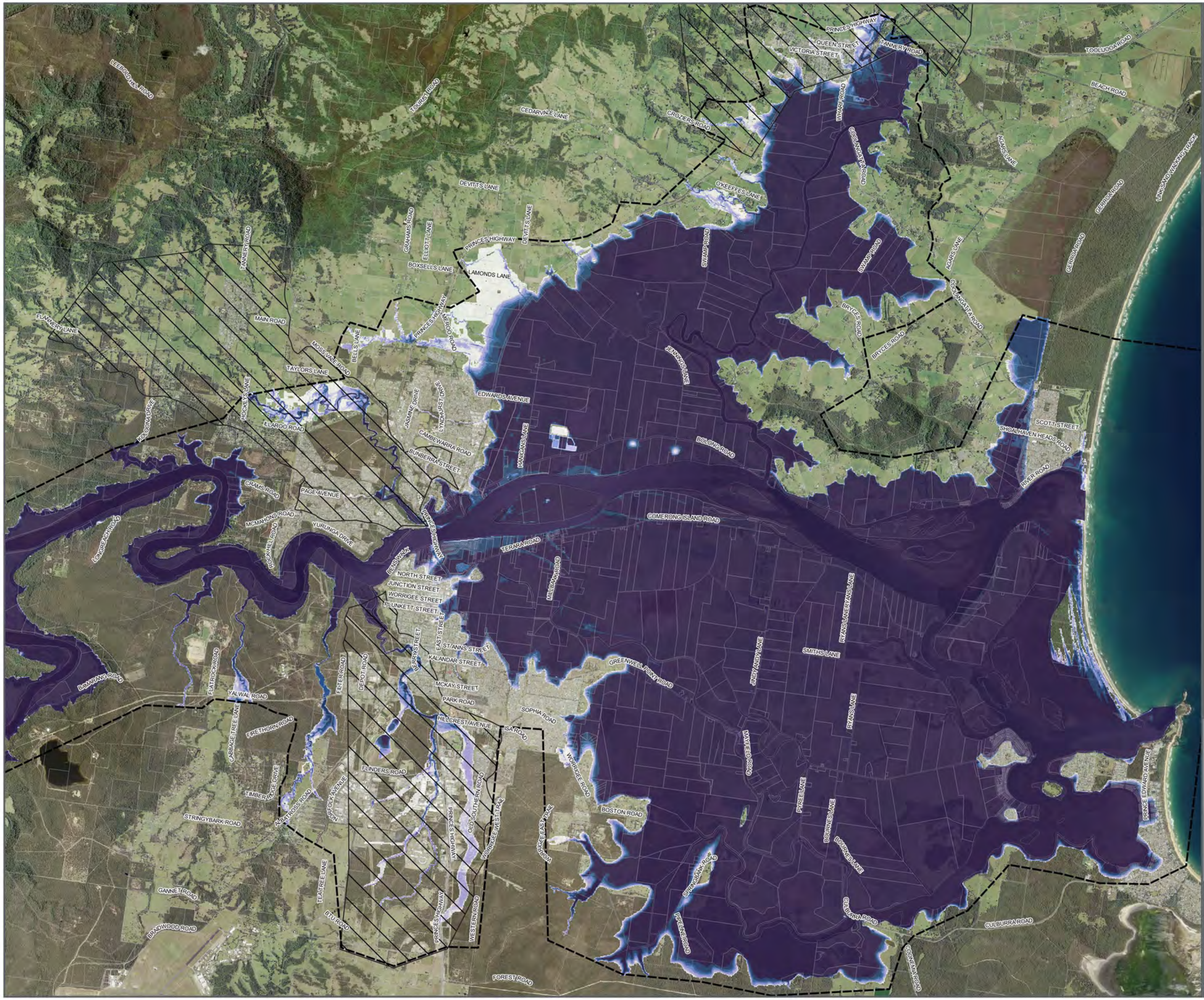
FIGURE G06

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

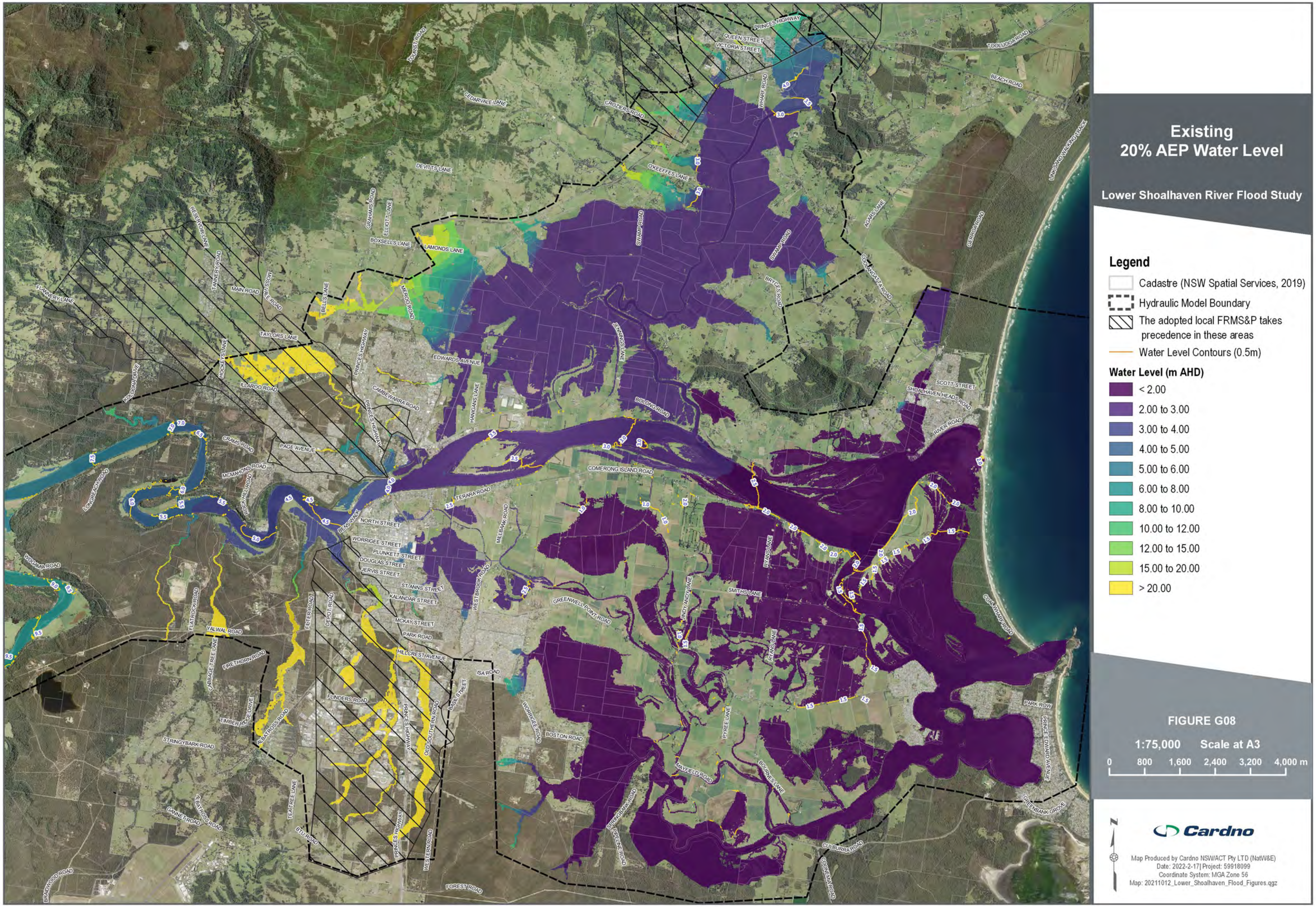
FIGURE G07

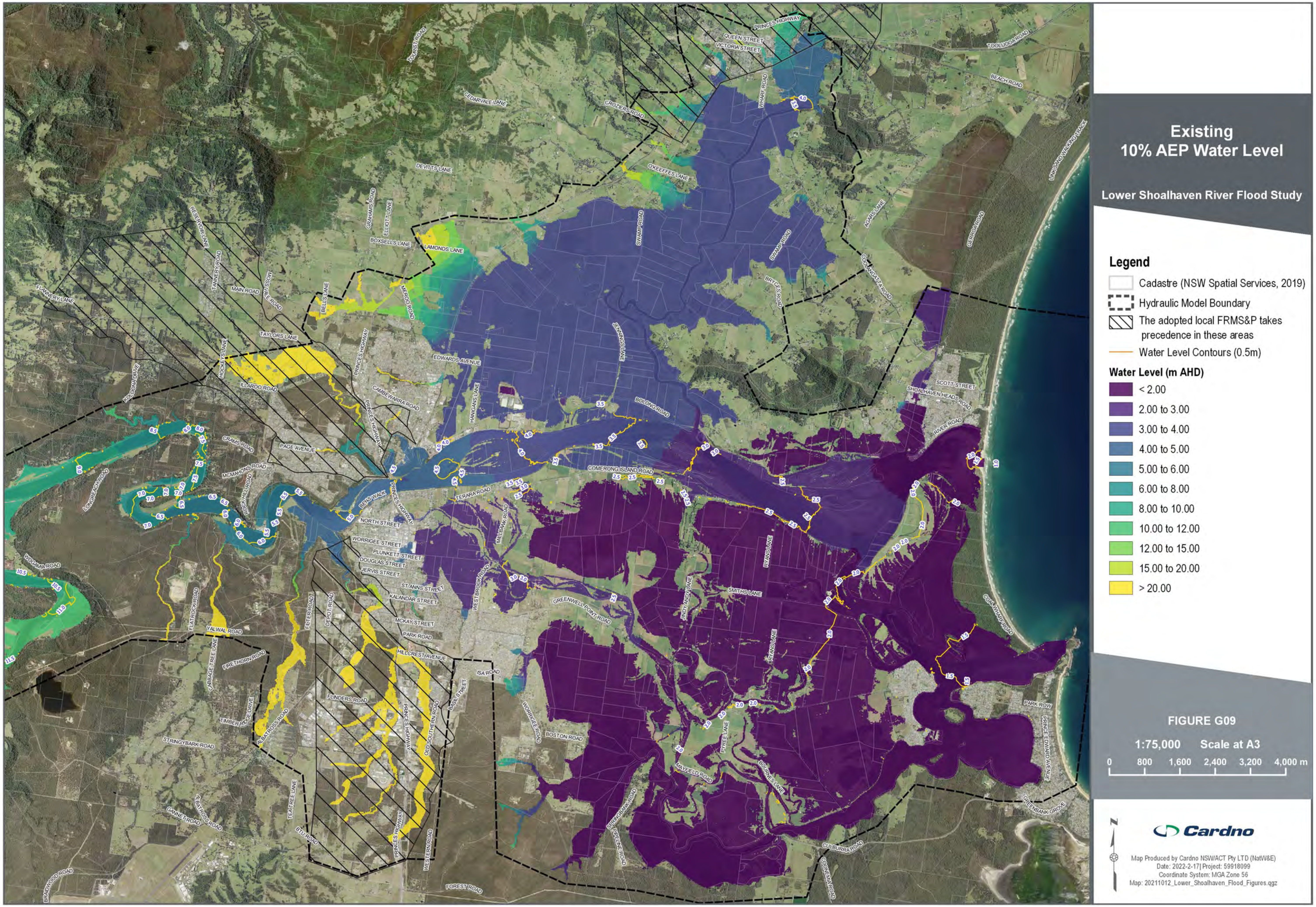
1:75,000 Scale at A3

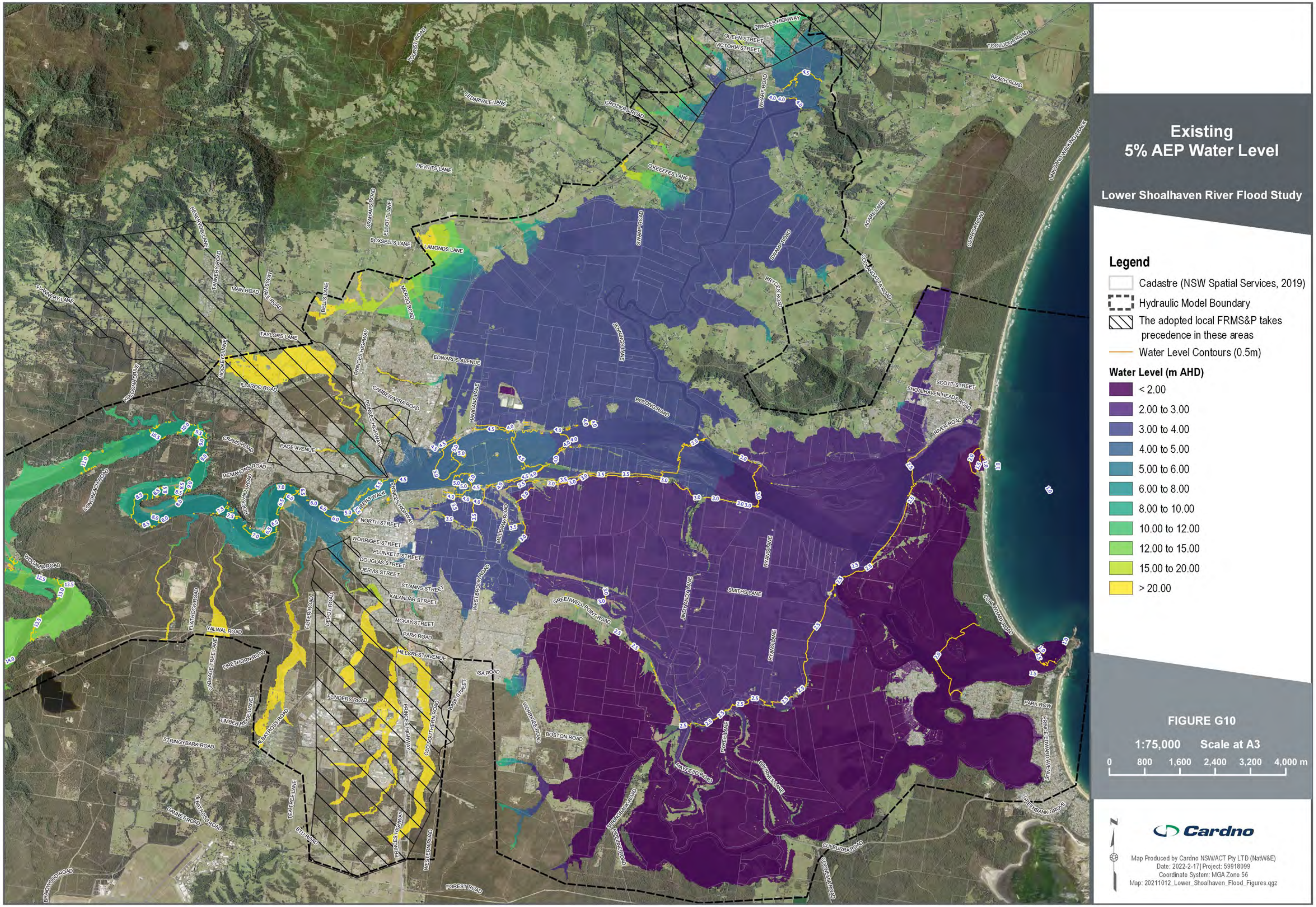
0 800 1,600 2,400 3,200 4,000 m

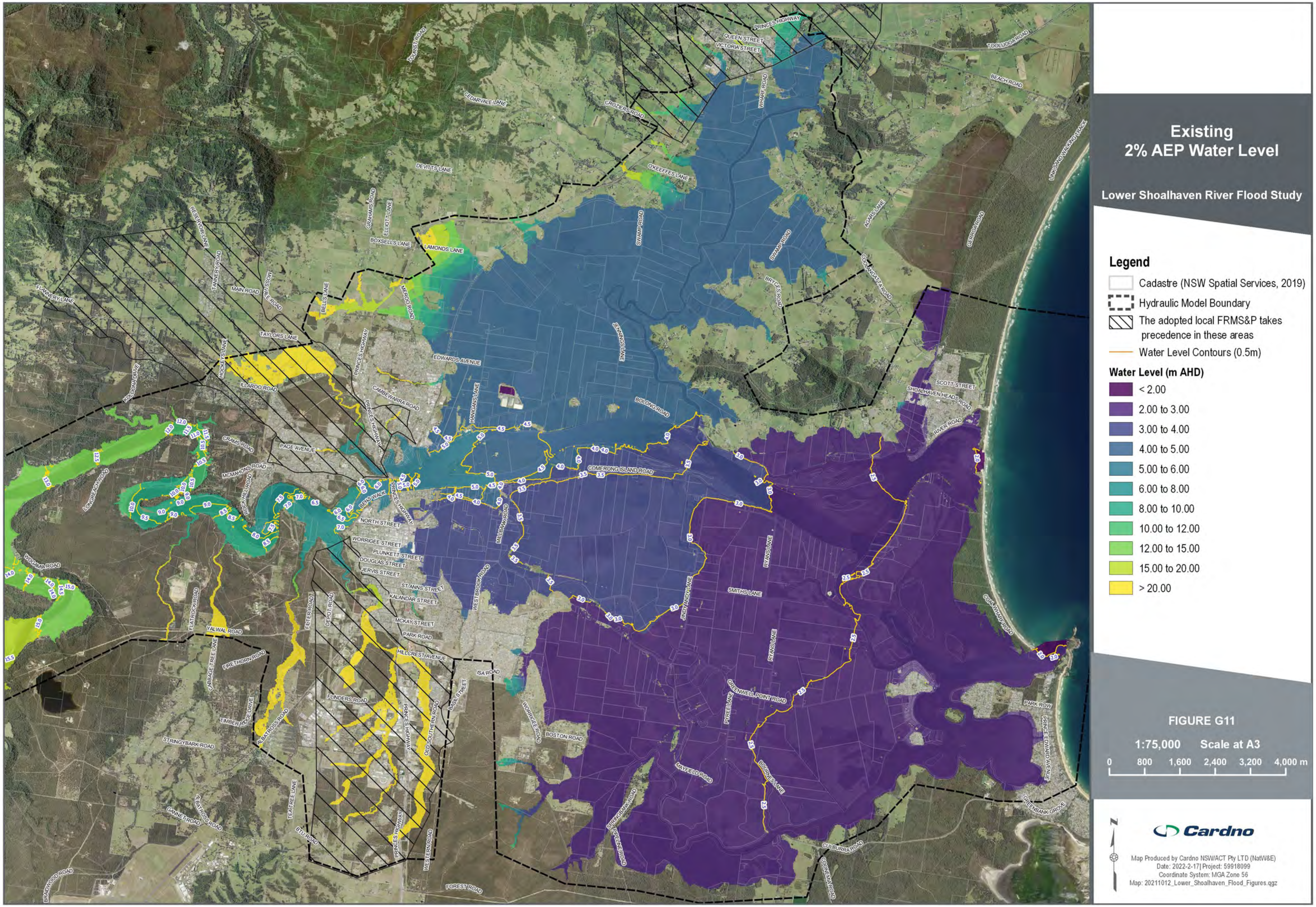
Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

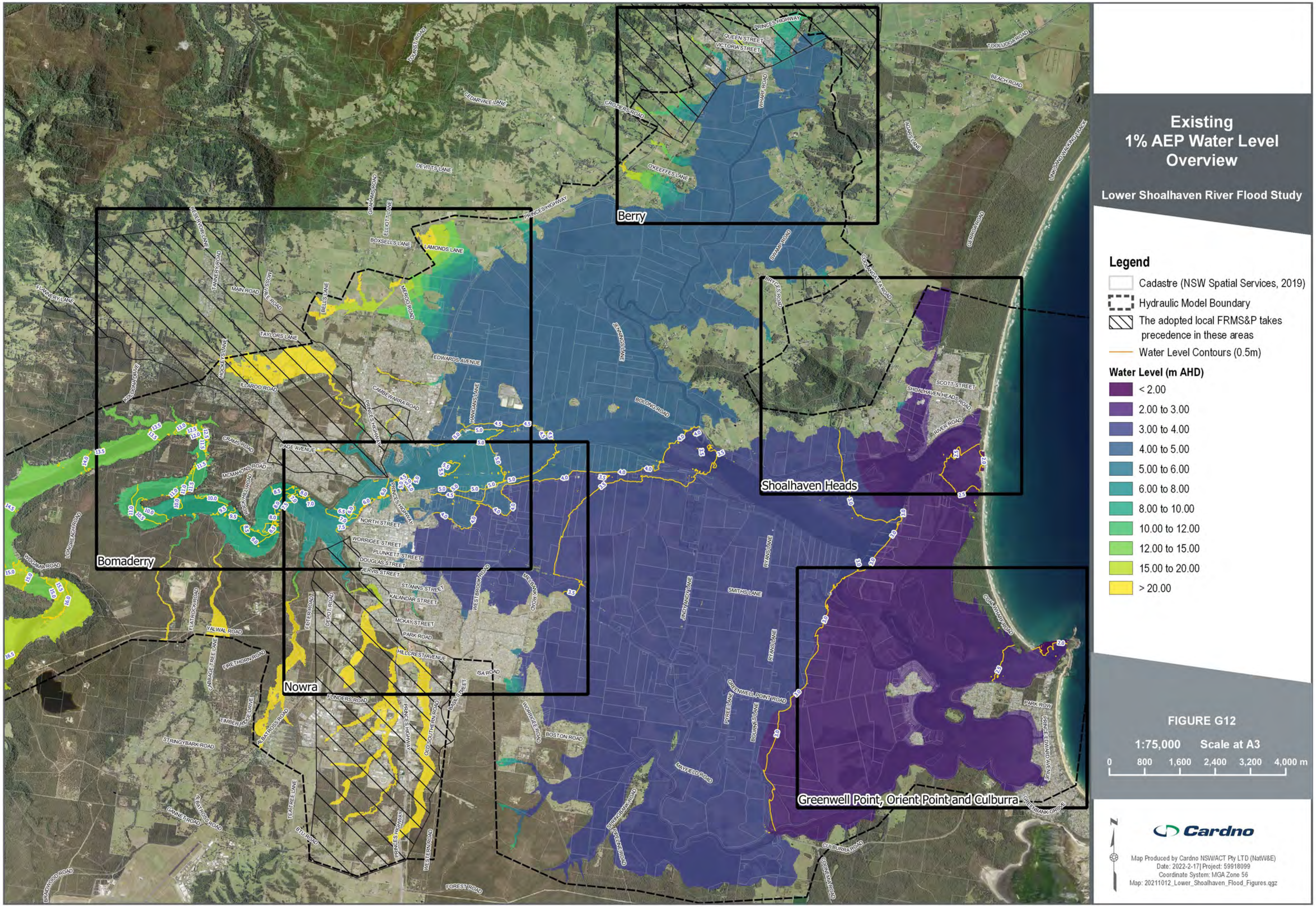

Existing
20% AEP Water Level
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G08
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Existing
10% AEP Water Level
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G09
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Existing
5% AEP Water Level
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G10
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

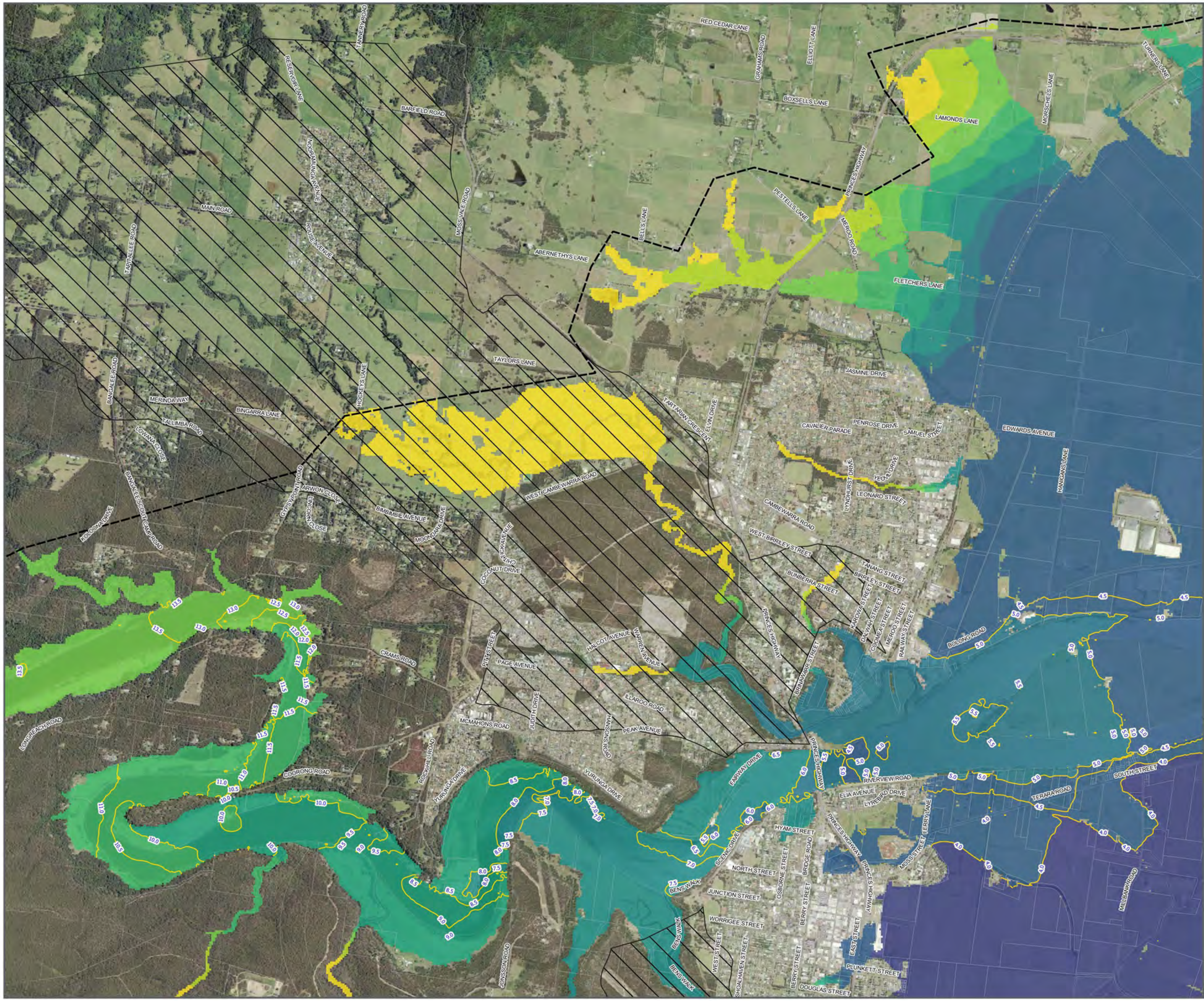


Existing
2% AEP Water Level
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G11
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
1% AEP Water Level
Overview
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G12
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz
Berry
Bomaderry
Nowra
Shoalhaven Heads
Greenwell Point, Orient Point and Culburra

Existing
1% AEP Water Level
Nowra
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G12.1
1:21,000 Scale at A3
0 200 400 600 800 1,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
1% AEP Water Level
Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G12.2

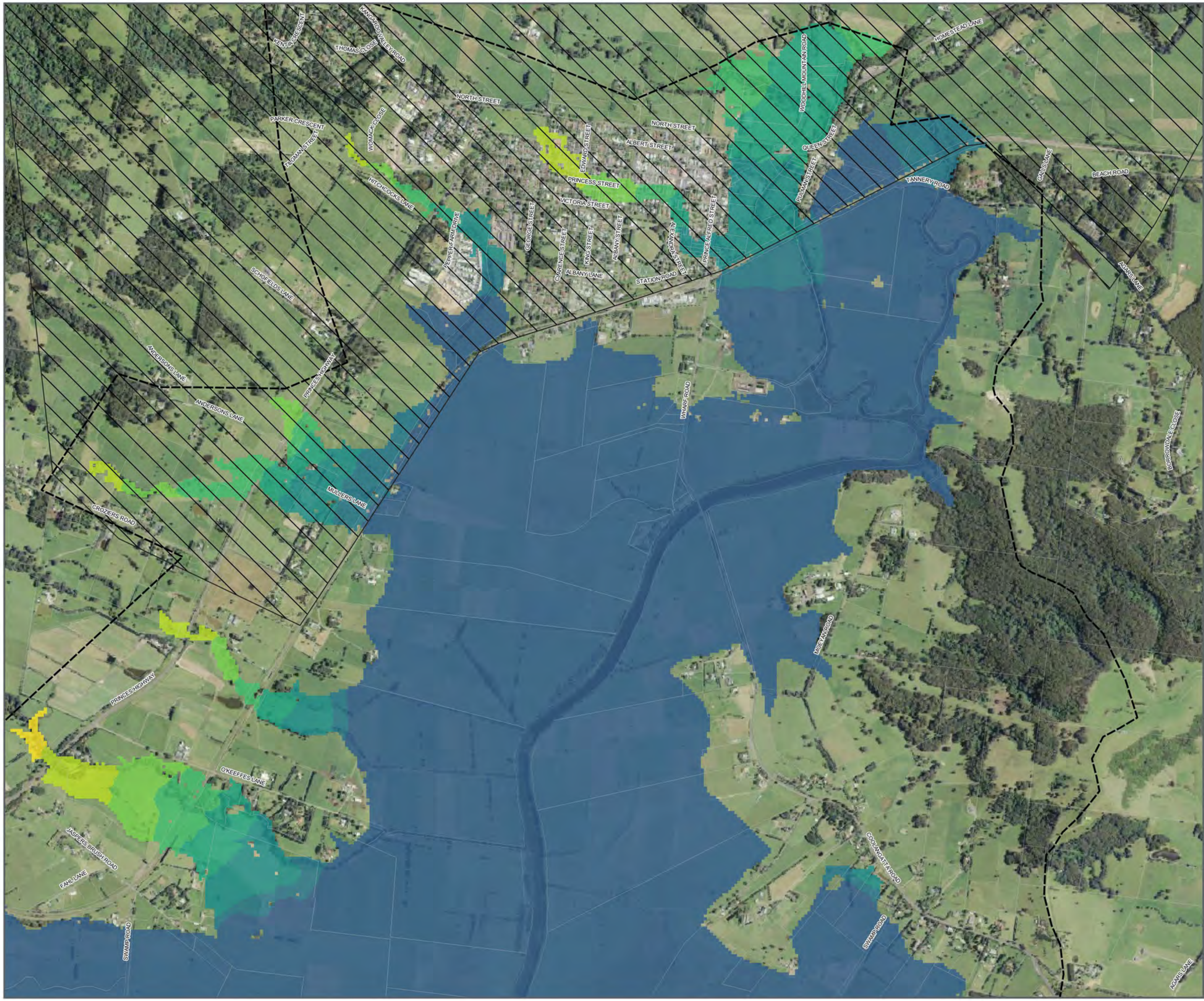
1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Water Level Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

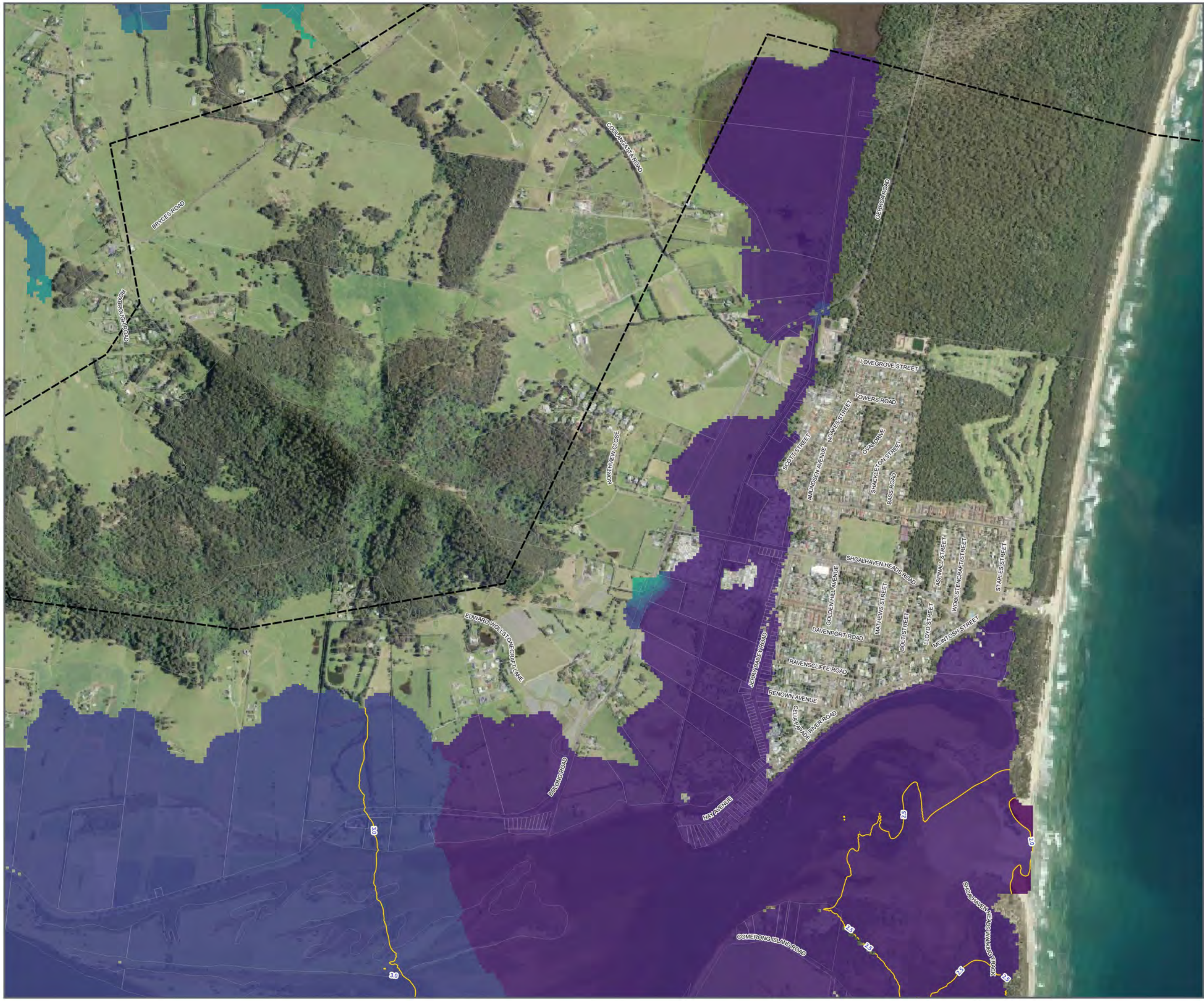
FIGURE G12.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Water Level Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

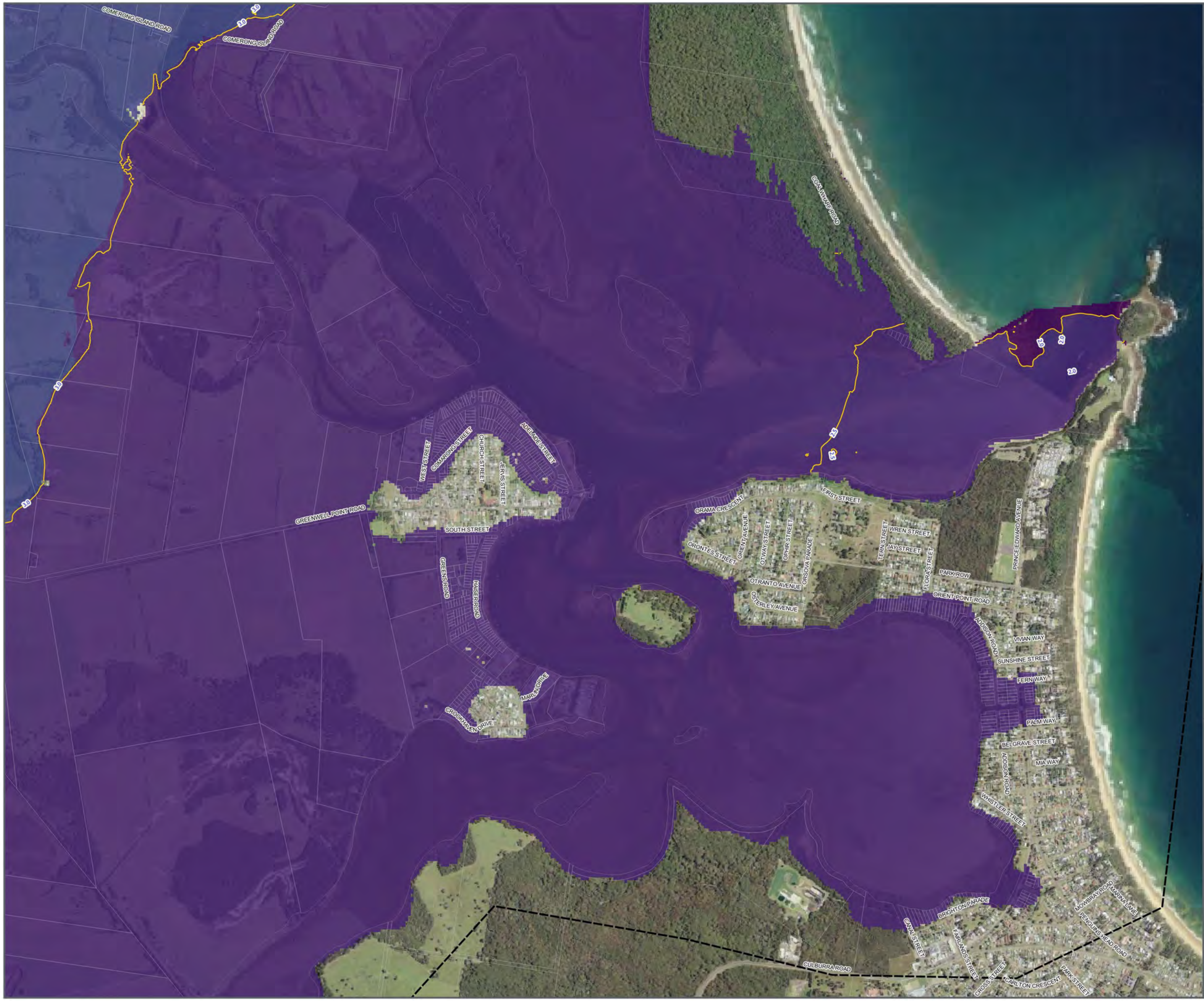
FIGURE G12.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Water Level Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

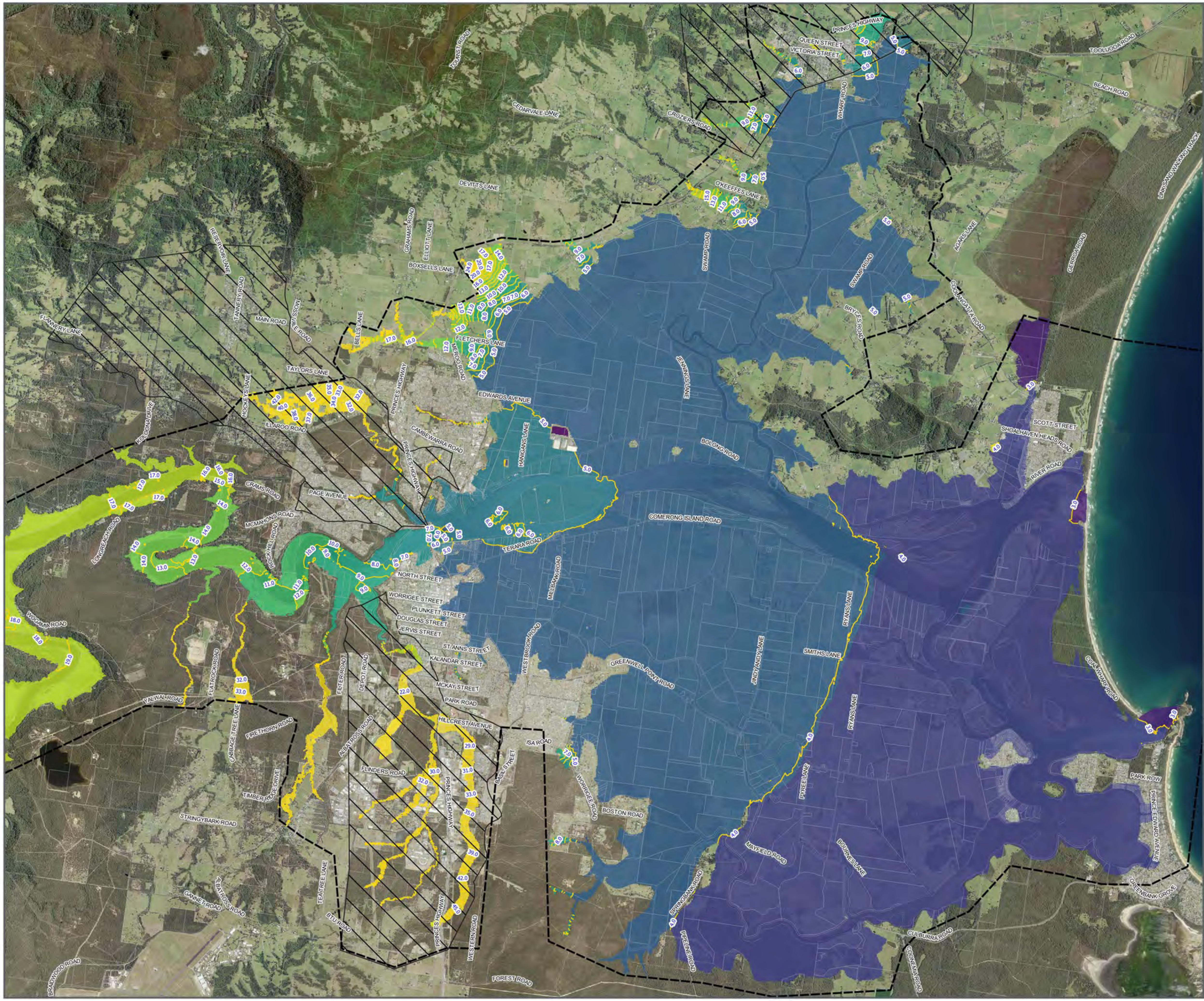
FIGURE G12.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 0.2% AEP Water Level

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

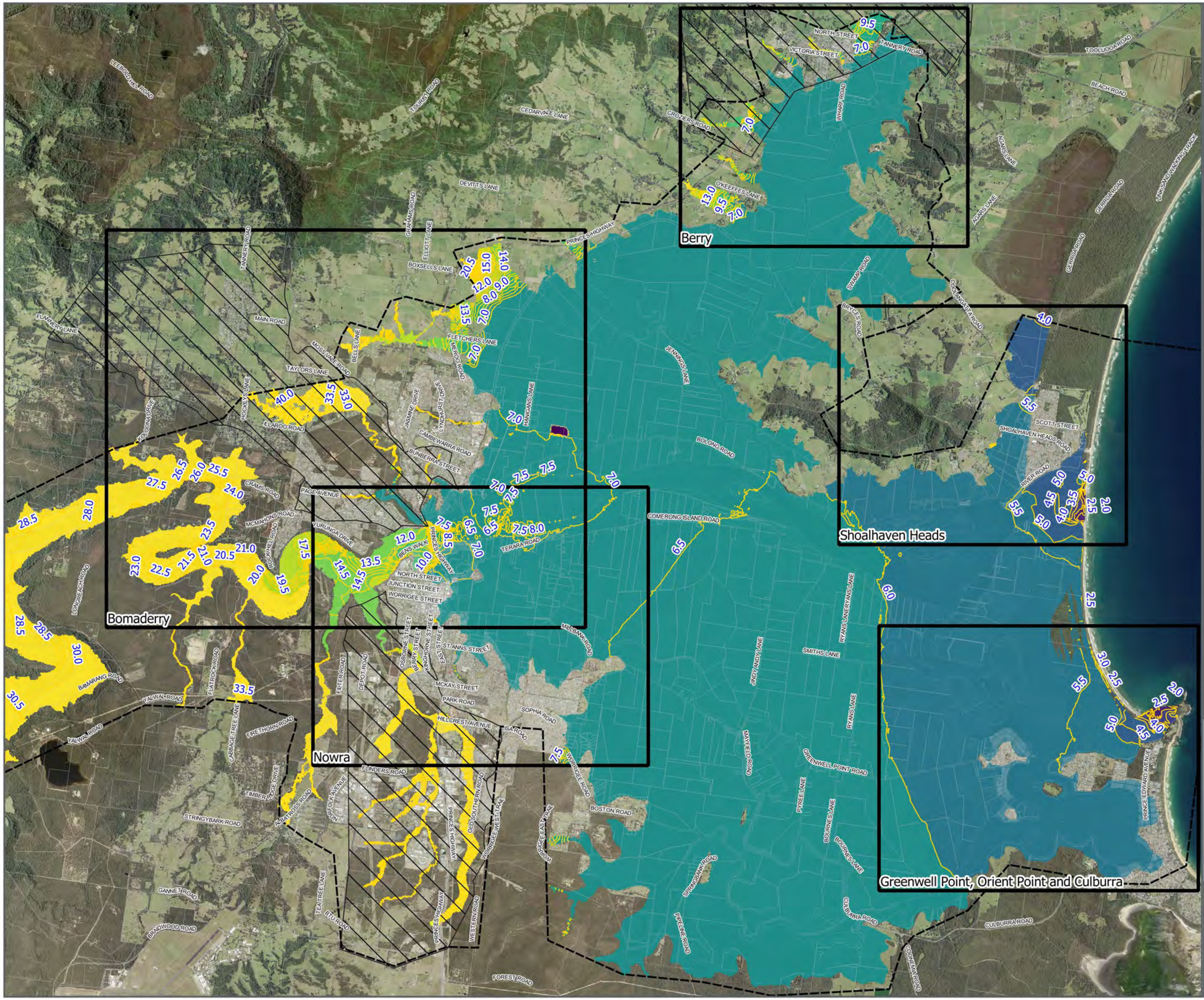
FIGURE G13

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Water Level Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

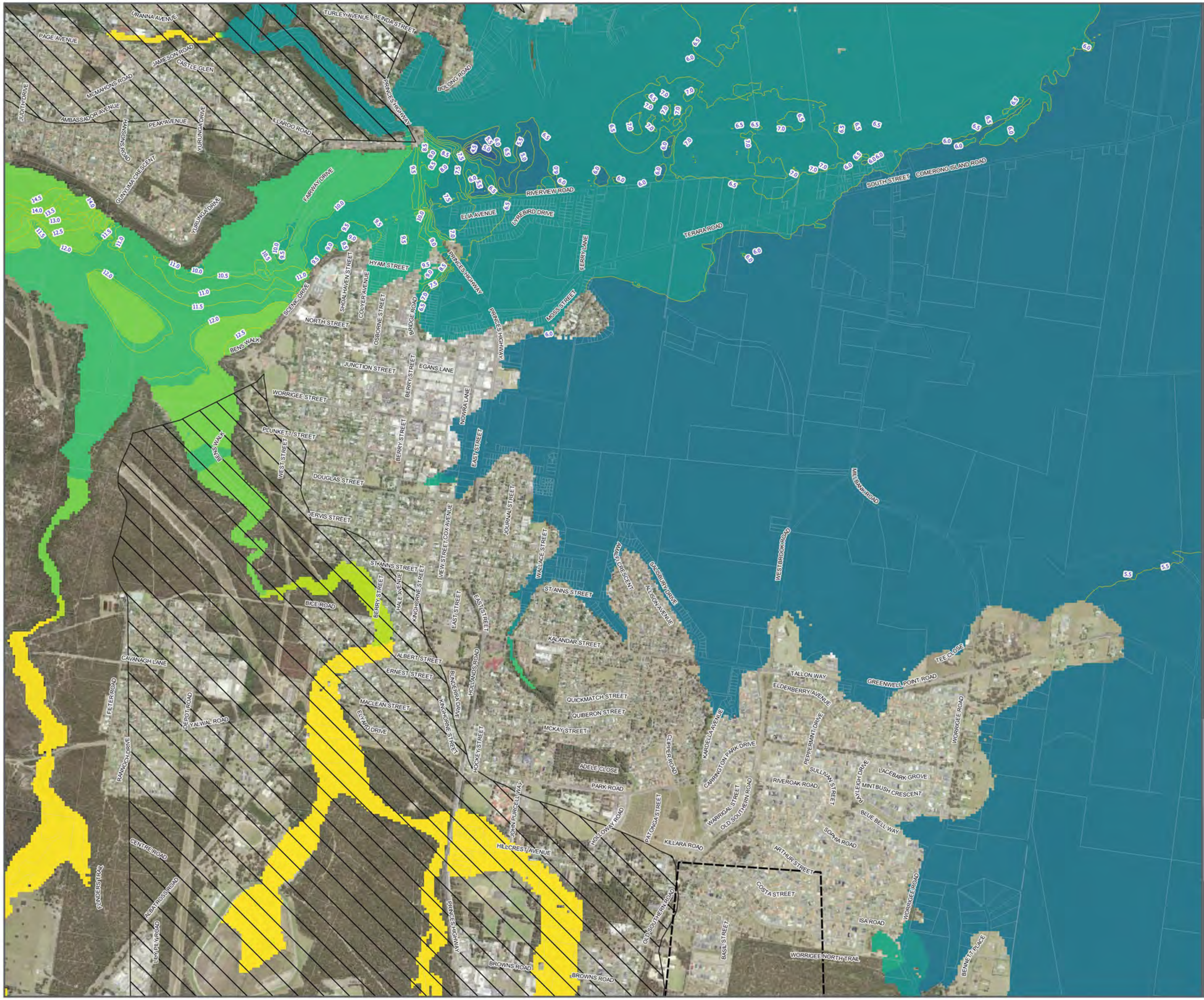
FIGURE G14

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Water Level Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

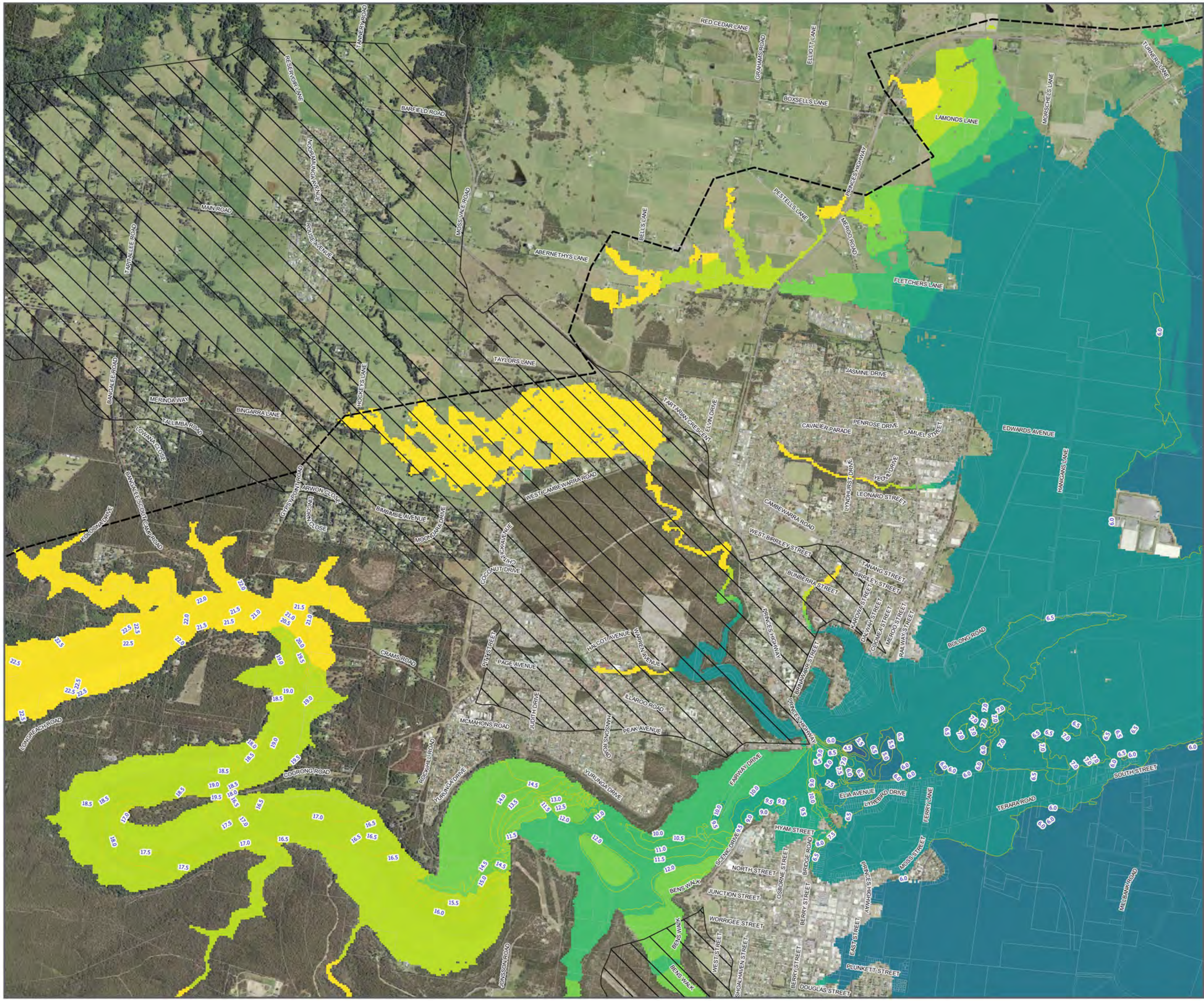
FIGURE G14.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Water Level Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

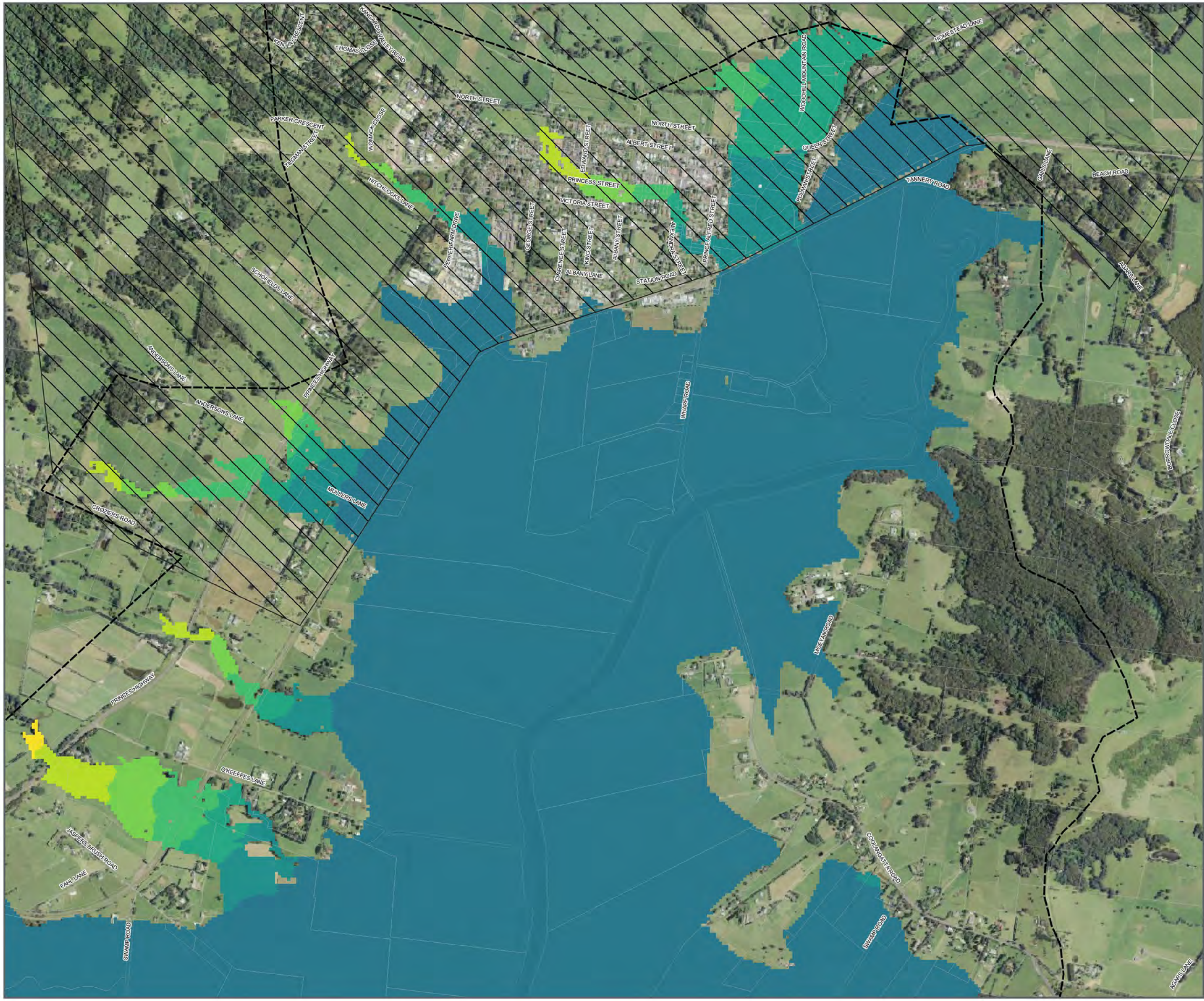
FIGURE G14.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Water Level Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G14.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Existing PMF Water Level Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

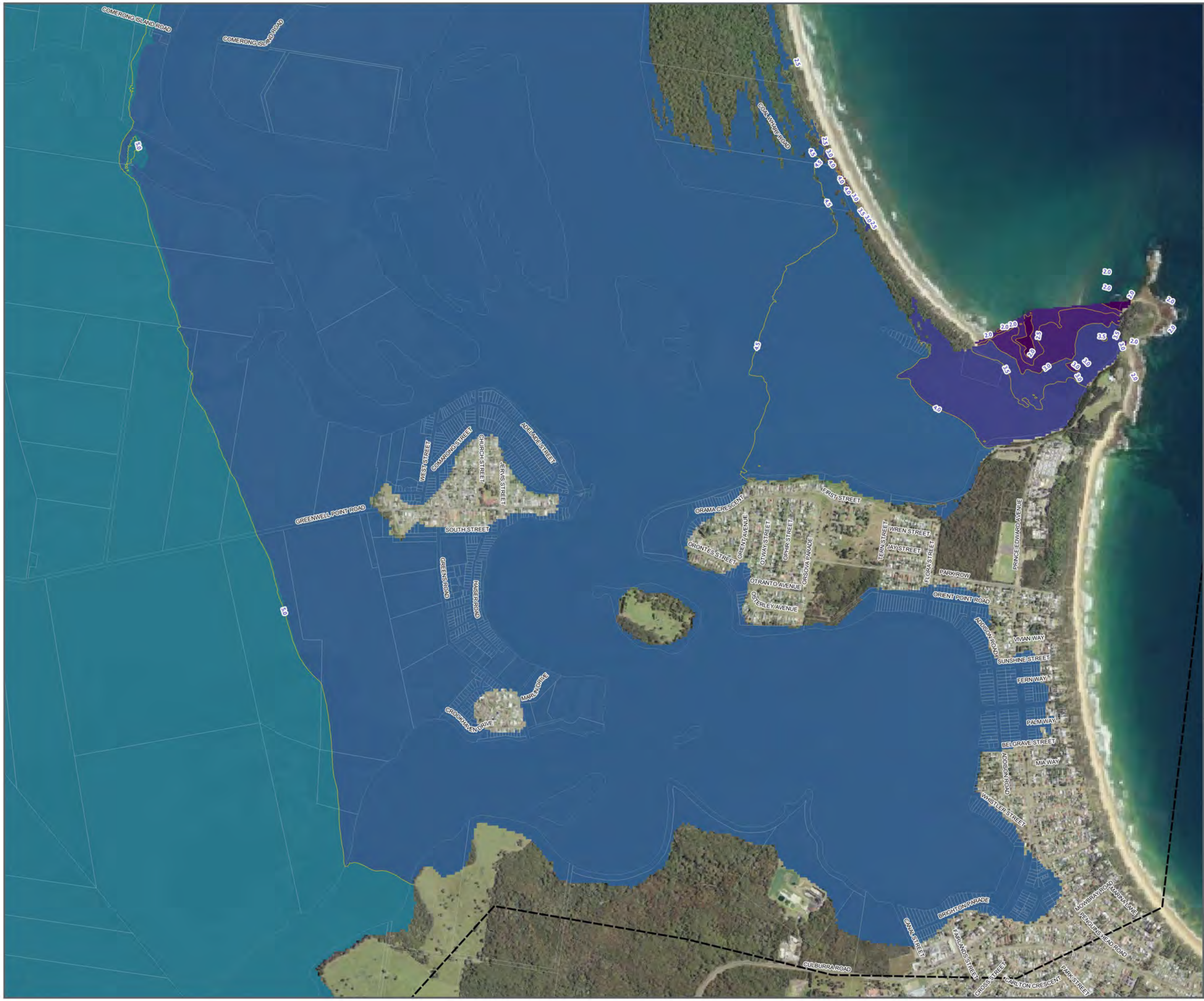
FIGURE G14.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Water Level Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

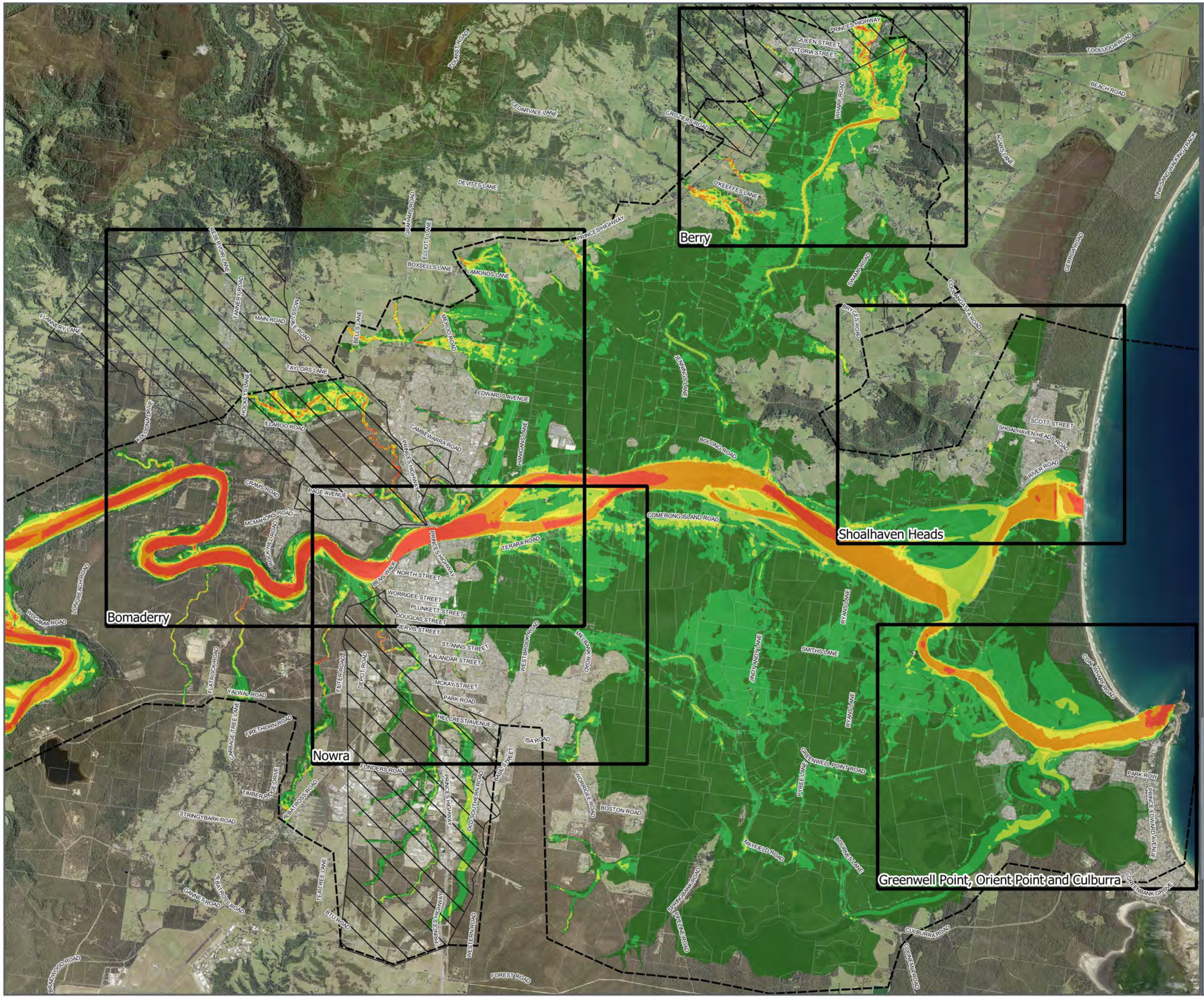
FIGURE G14.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Velocity Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

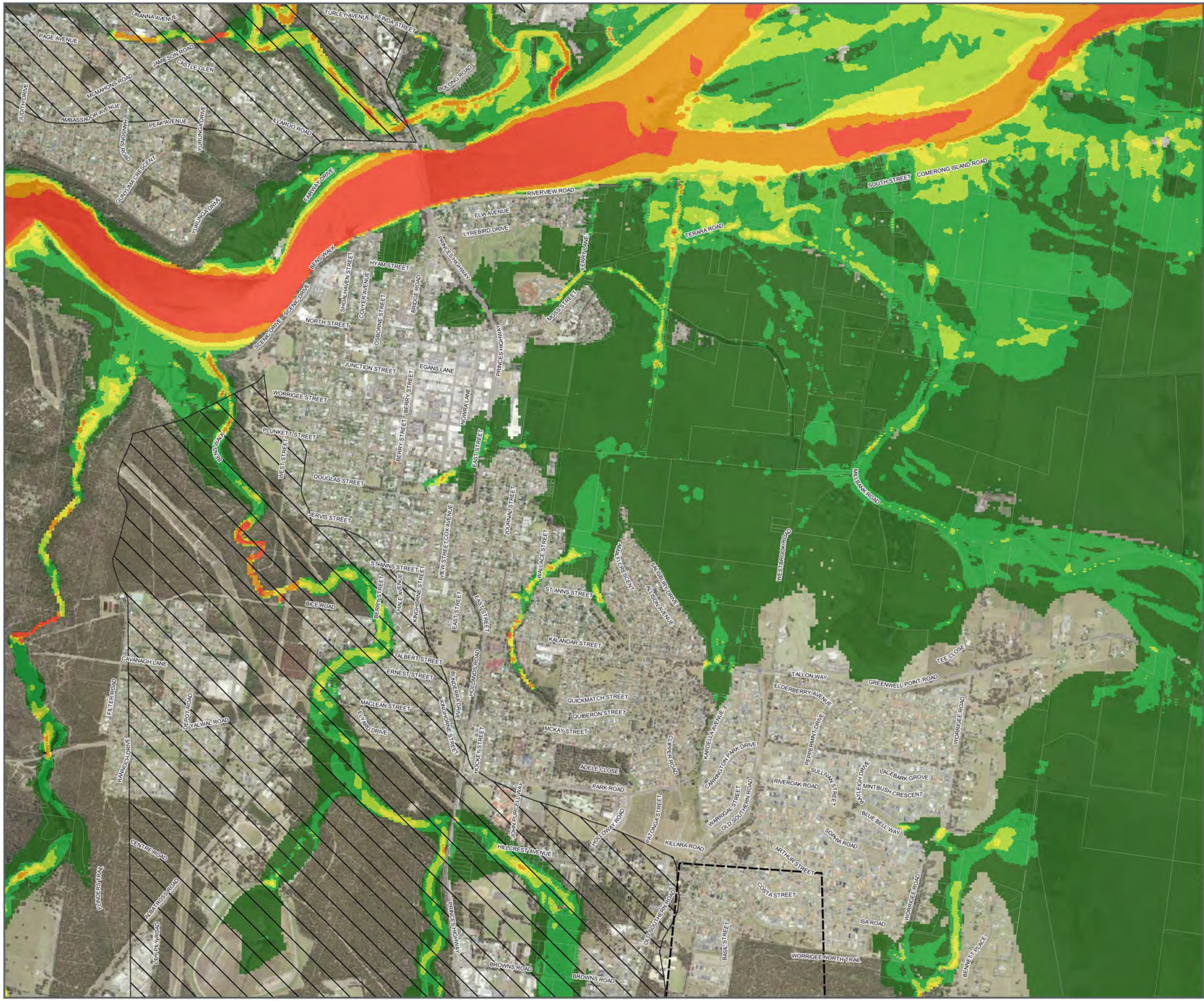
- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G15

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Velocity Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

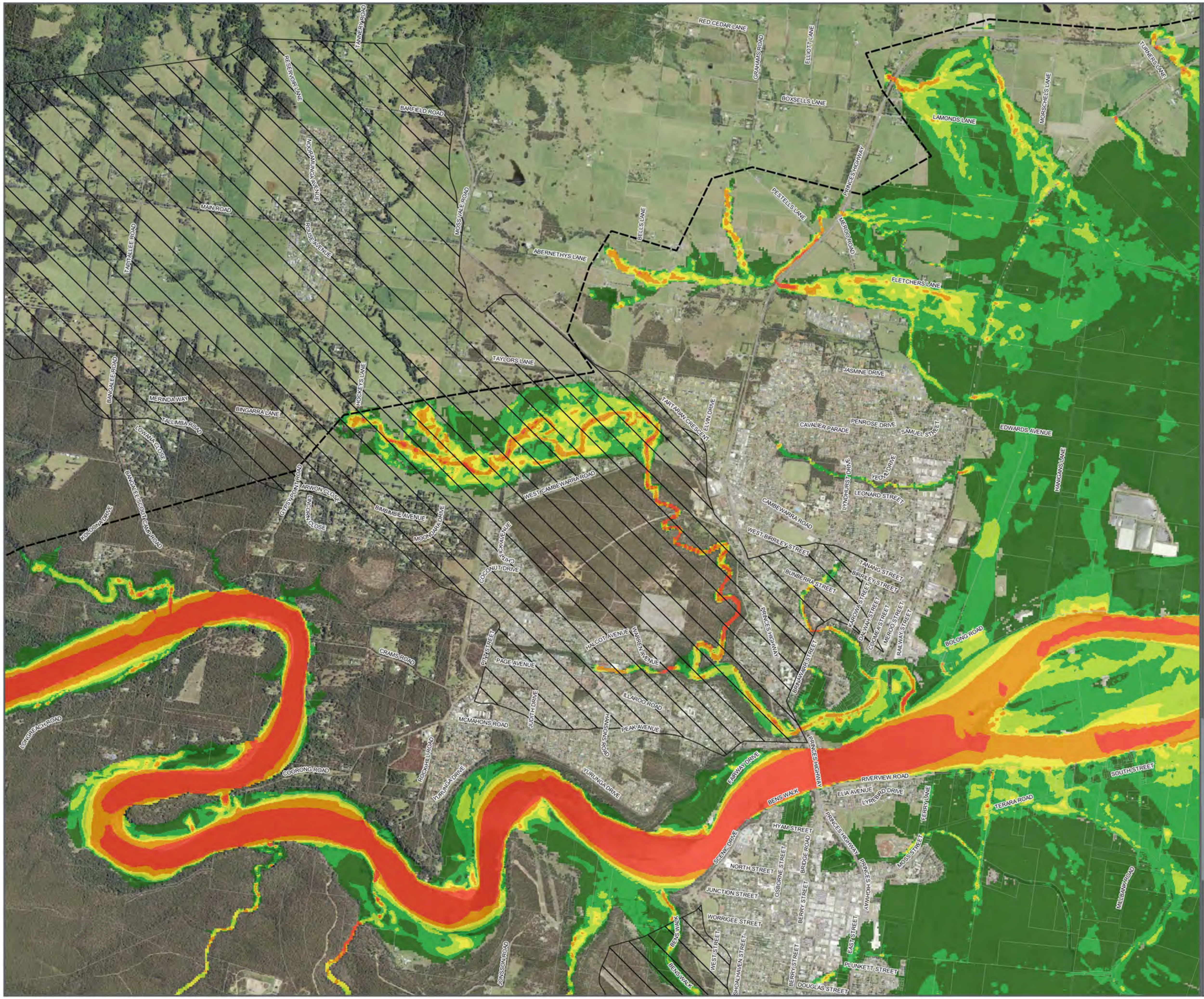
FIGURE G15.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Velocity Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

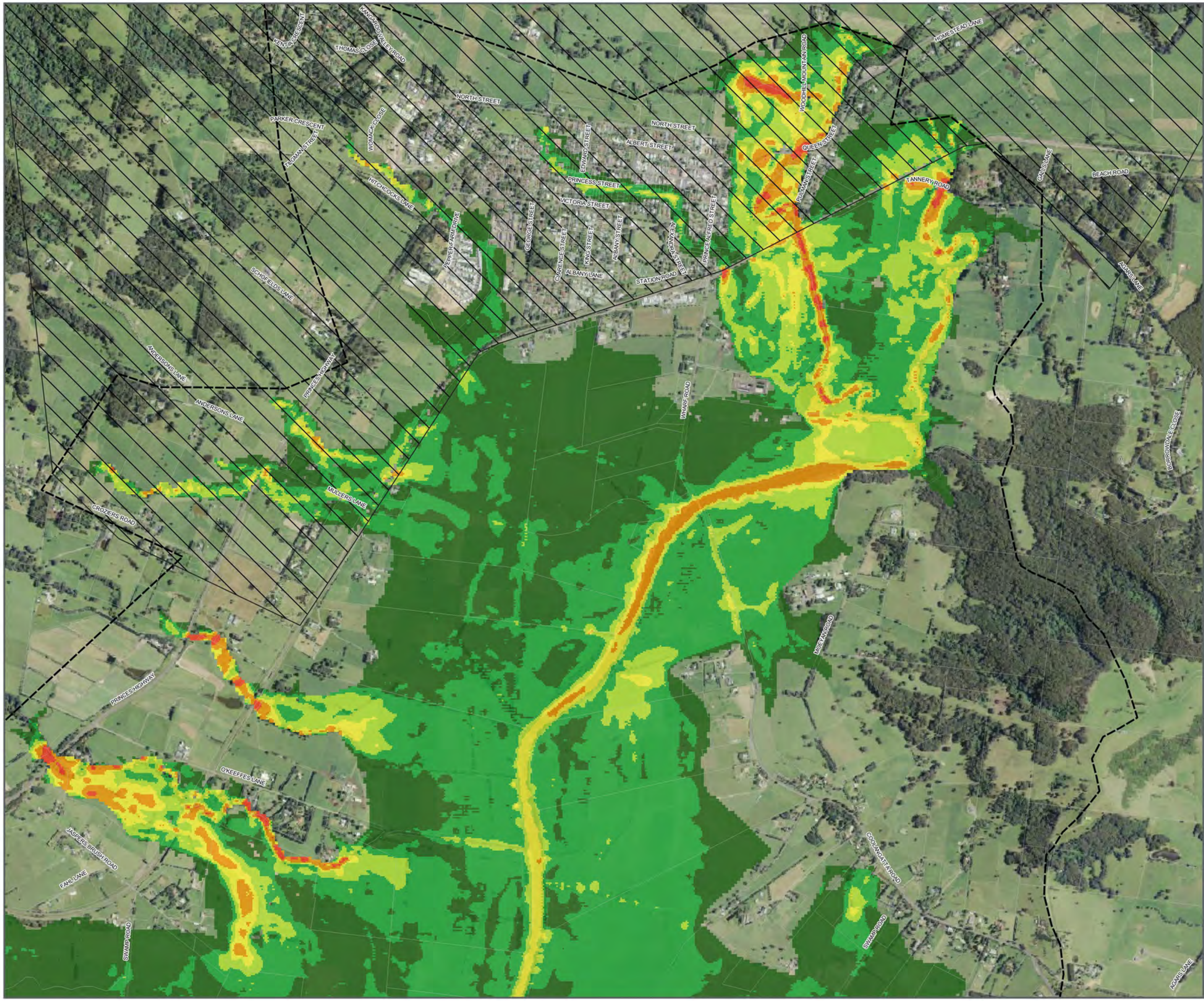
FIGURE G15.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Velocity Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

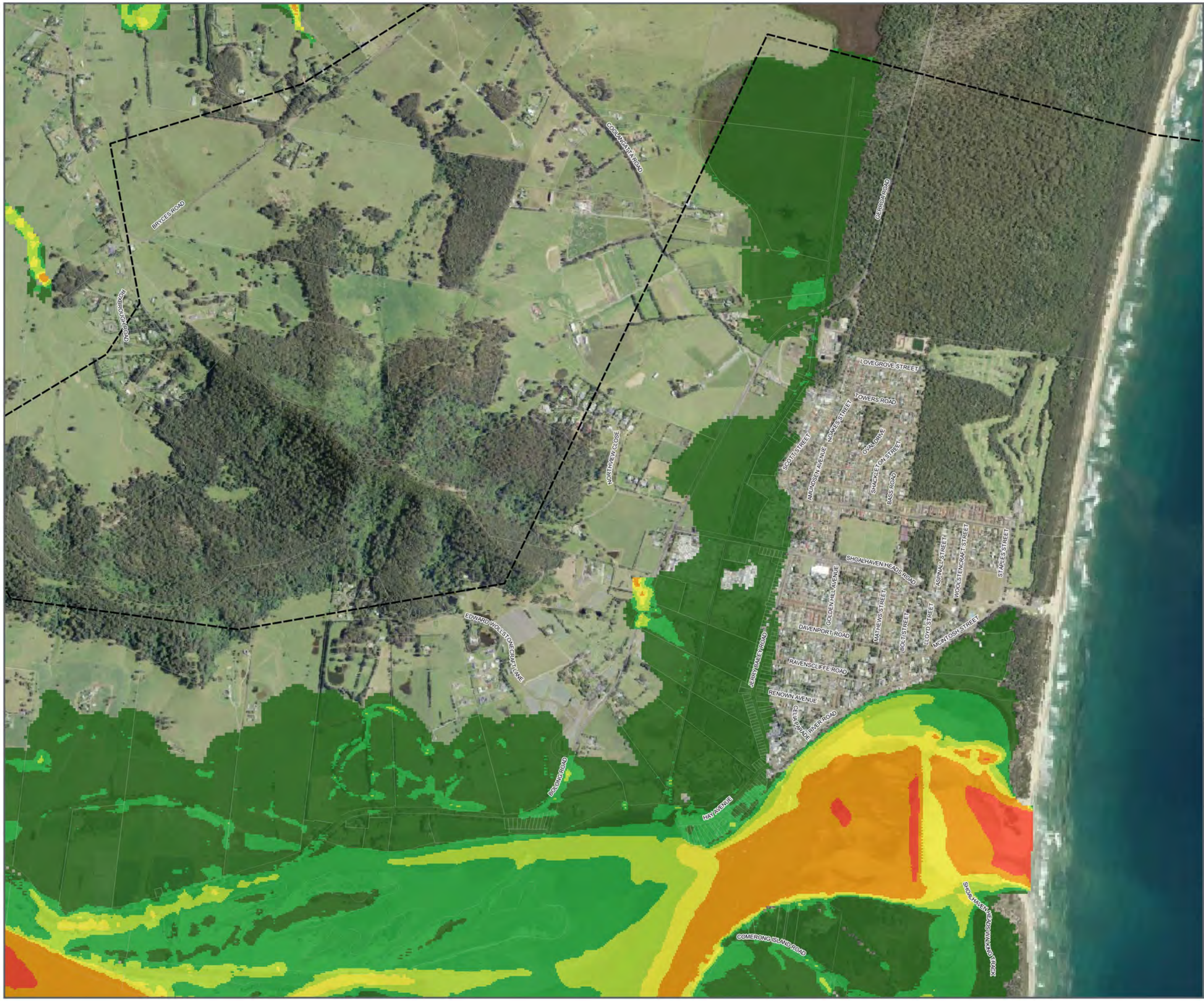
FIGURE G15.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Velocity Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G15.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Existing 1% AEP Velocity Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

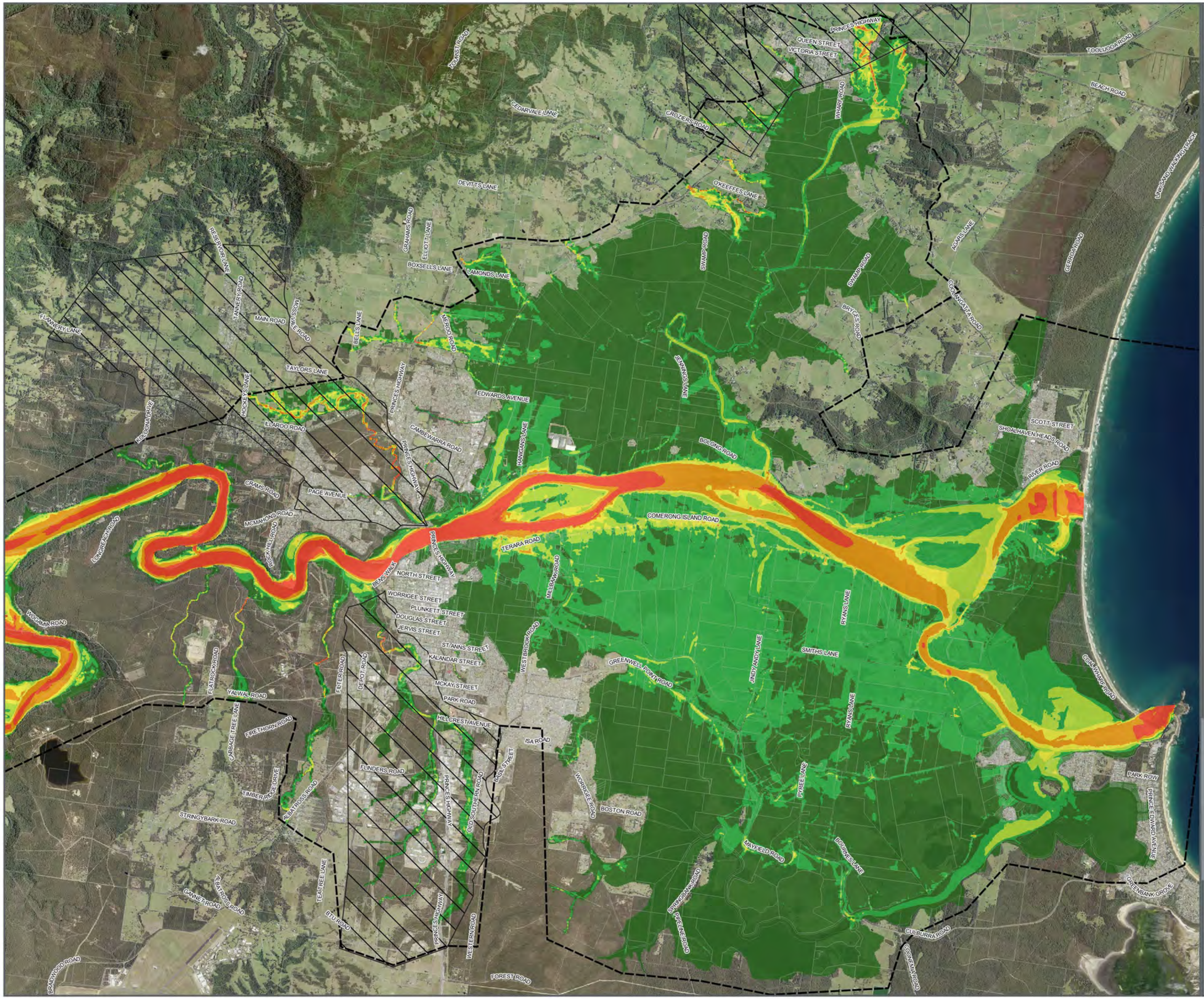
FIGURE G15.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 0.2% AEP Velocity

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G16

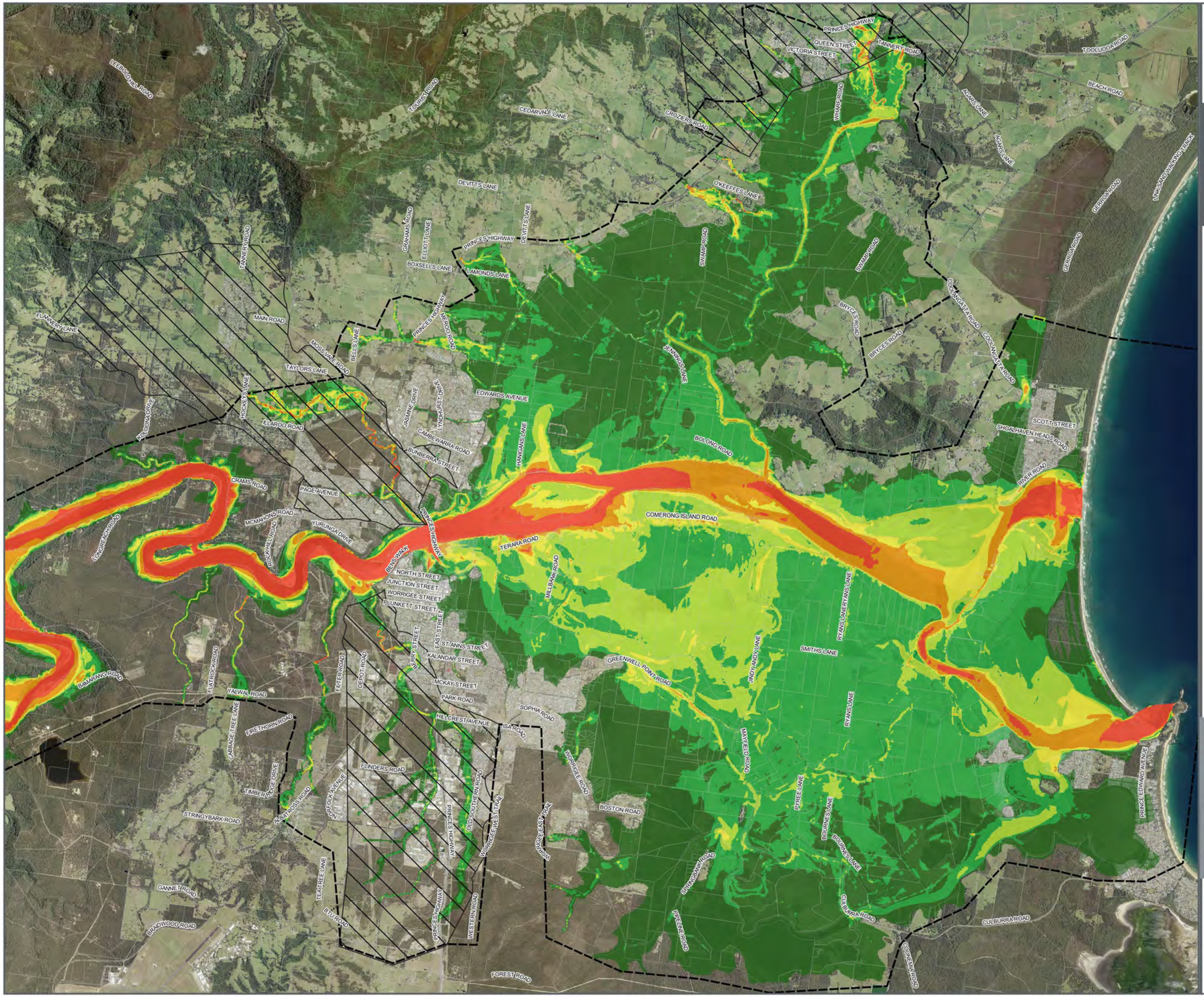
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Velocity

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

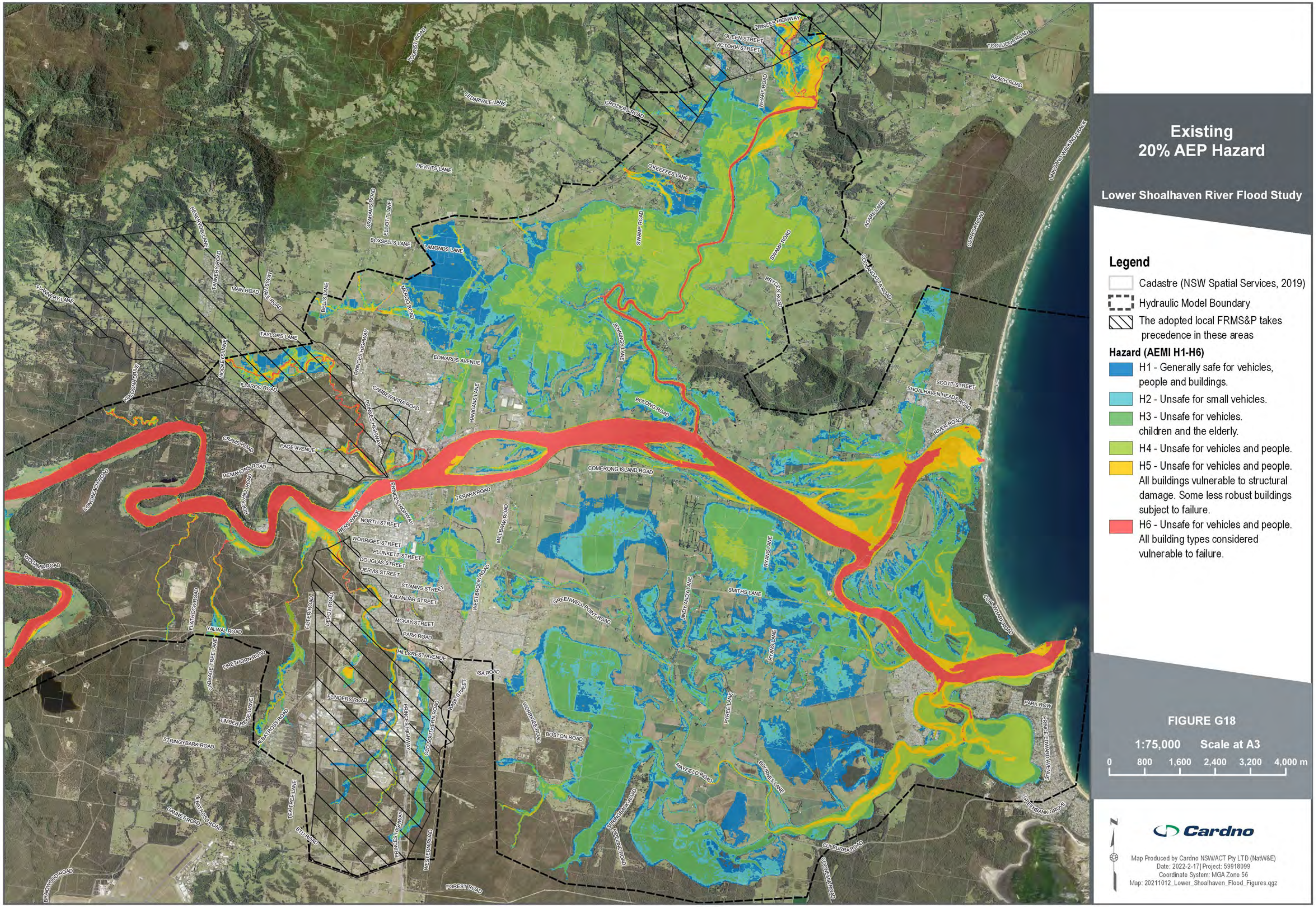
FIGURE G17

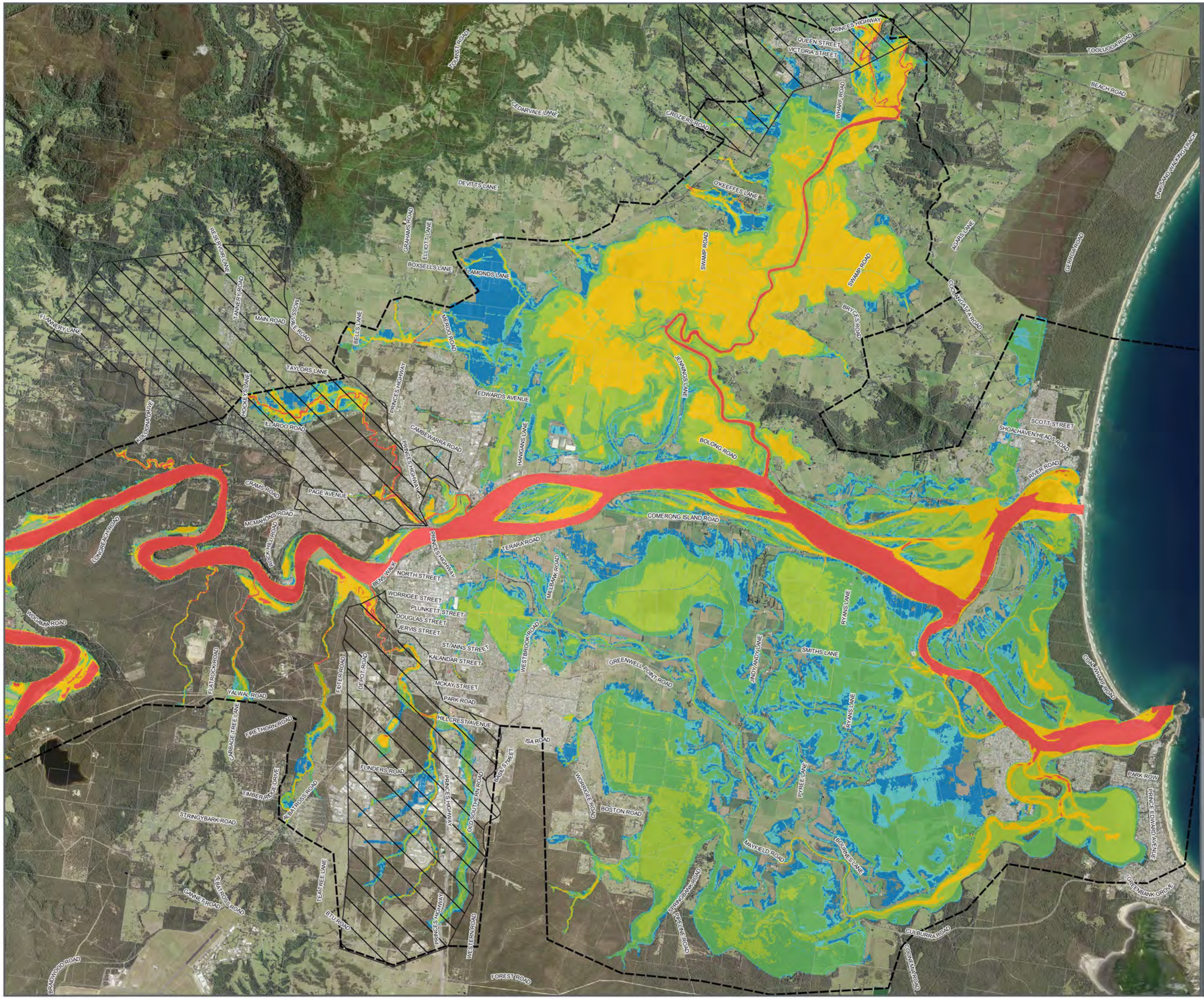
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Existing
20% AEP Hazard
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Hazard (AEMI H1-H6)
H1 - Generally safe for vehicles, people and buildings.
H2 - Unsafe for small vehicles.
H3 - Unsafe for vehicles. children and the elderly.
H4 - Unsafe for vehicles and people.
H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.
FIGURE G18
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 10% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

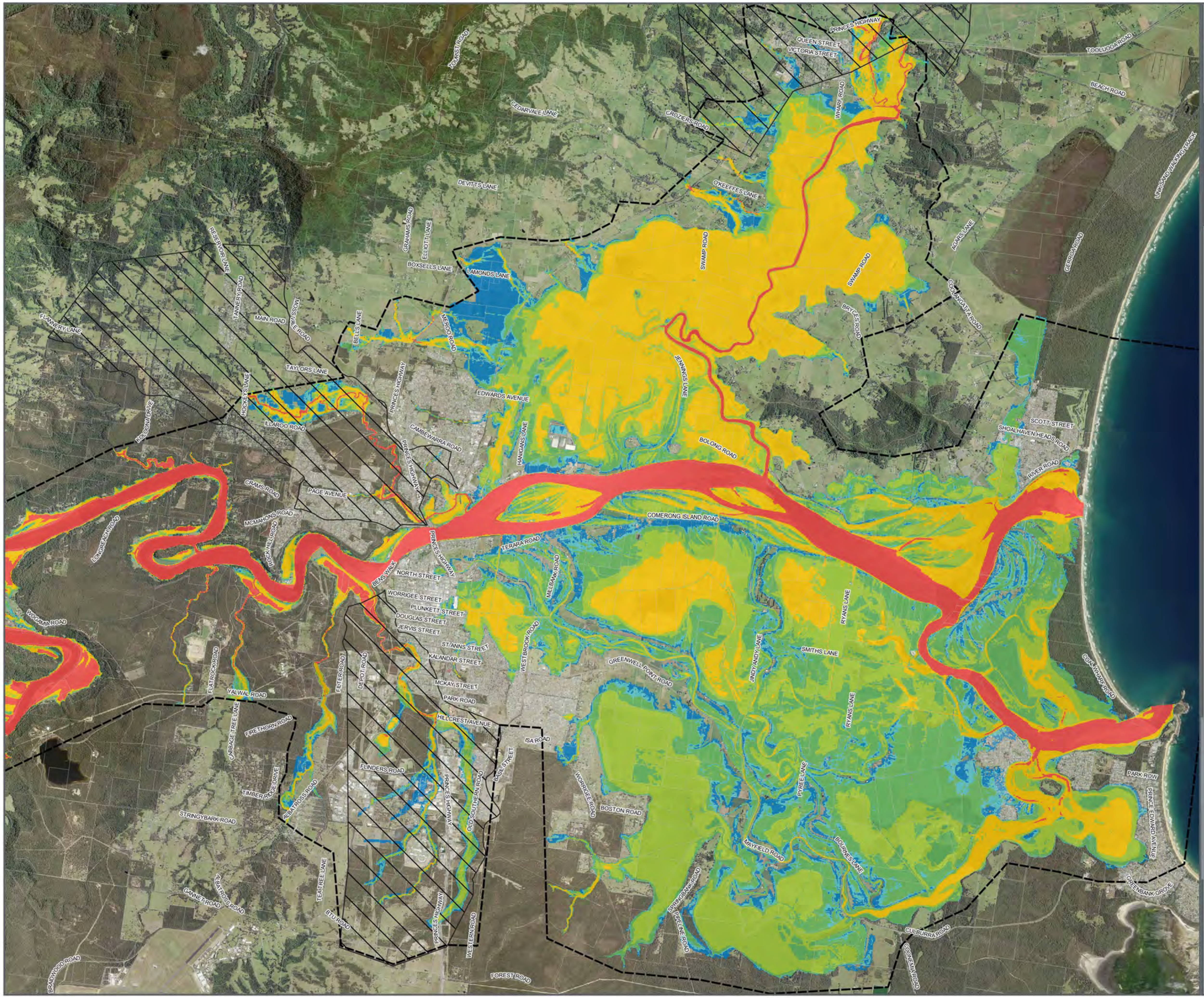
FIGURE G19

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 5% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

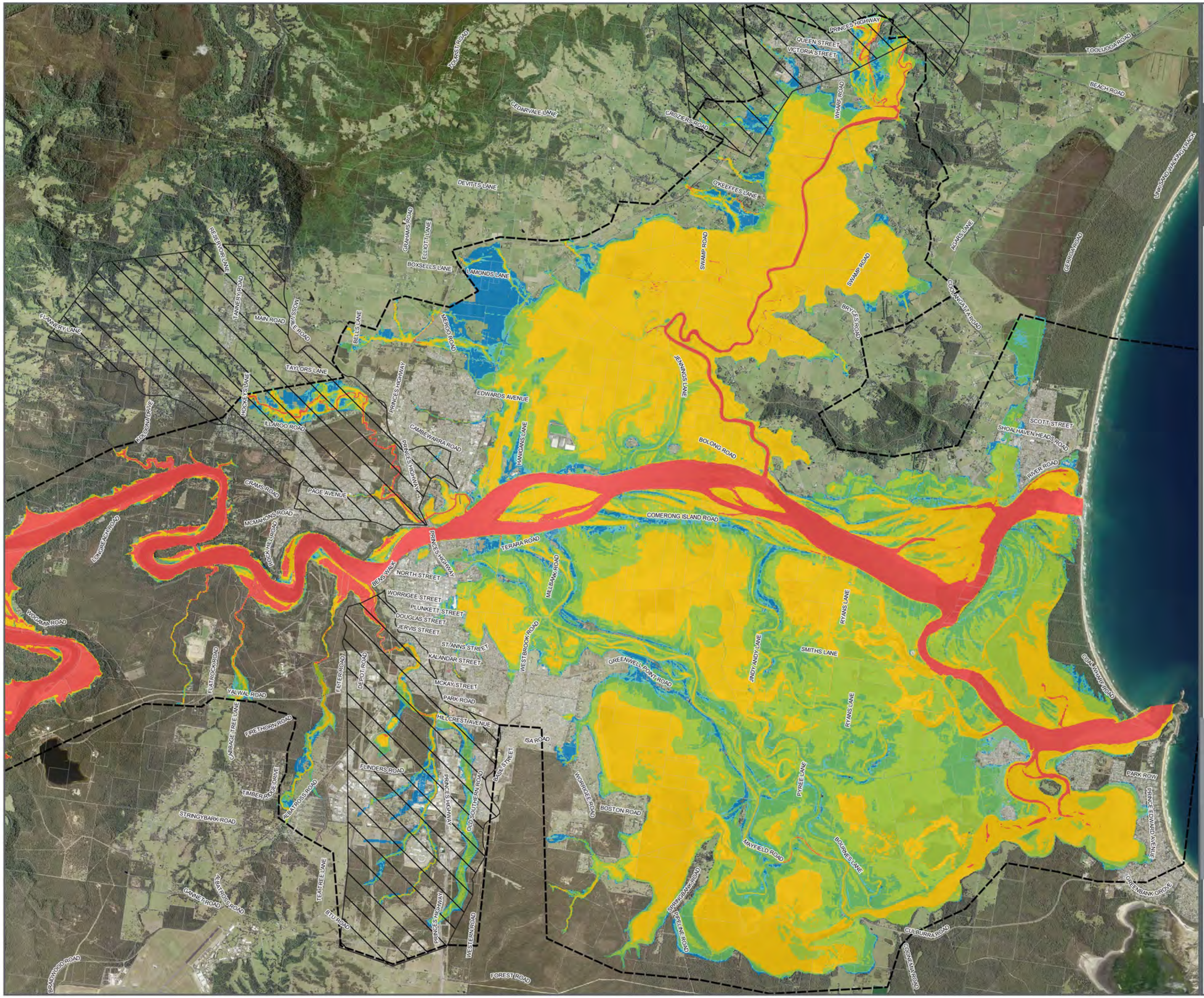
FIGURE G20

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 2% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G21

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

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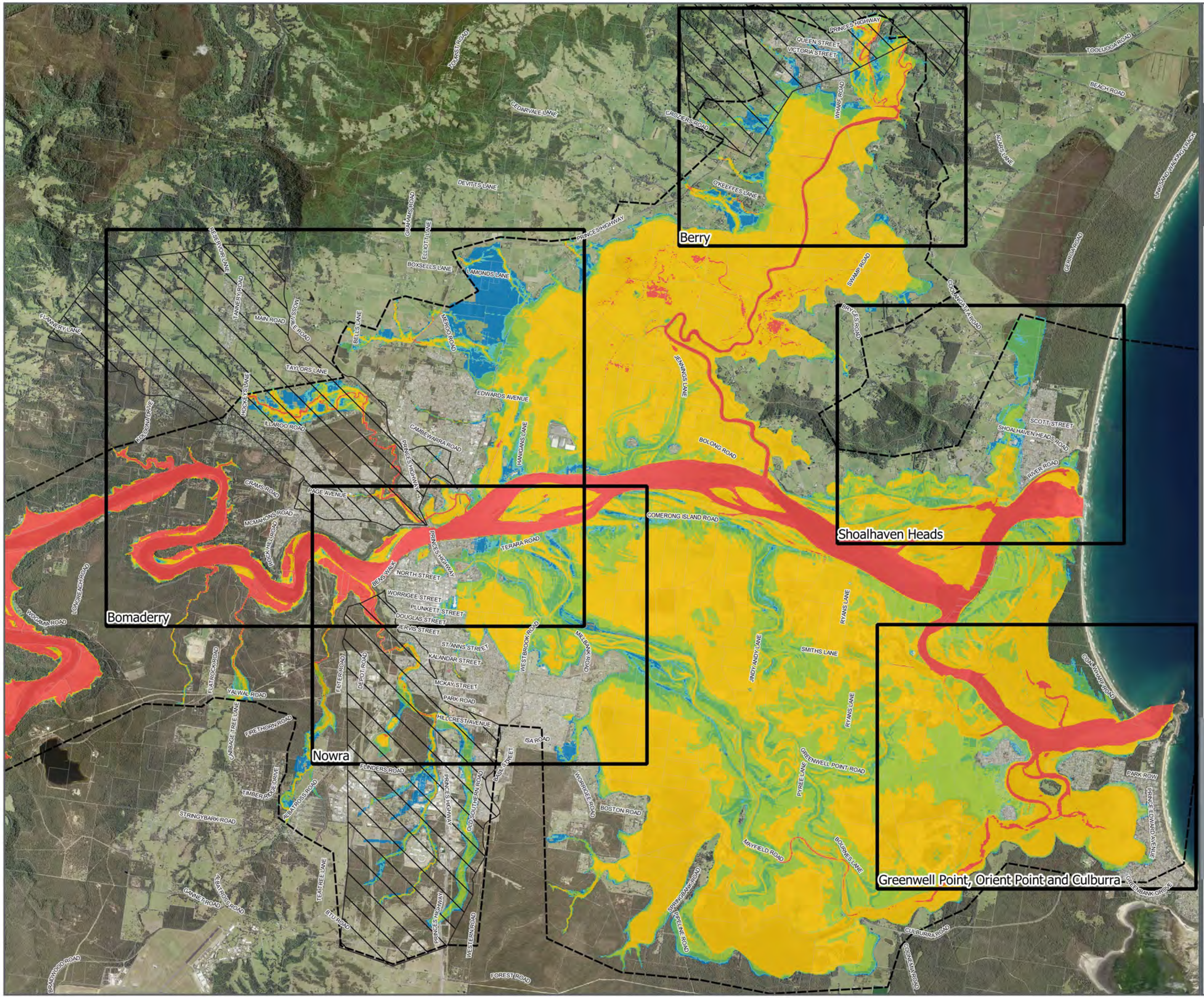
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hazard Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G22

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

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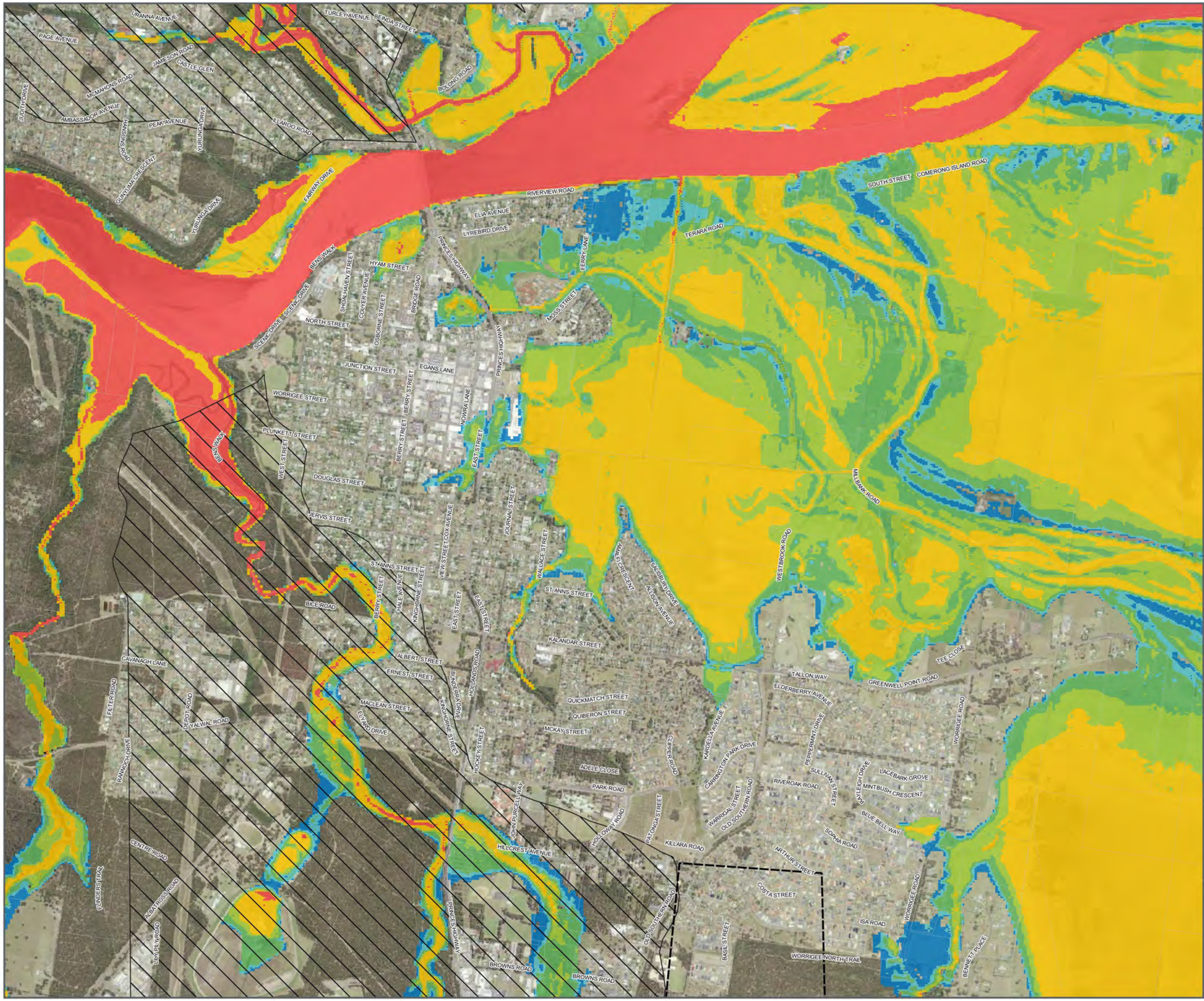
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hazard Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G22.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

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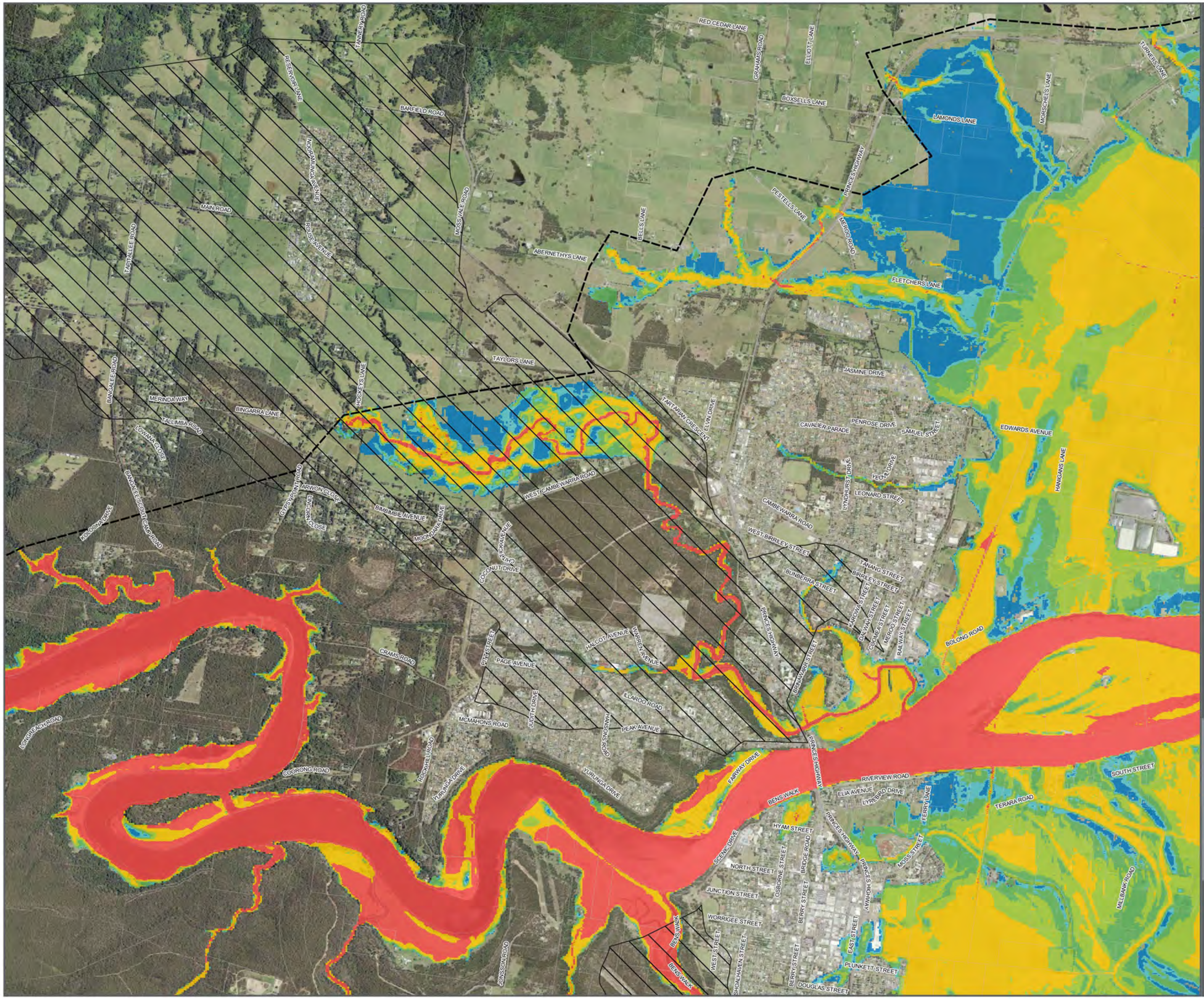
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hazard Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G22.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

N

Cardno

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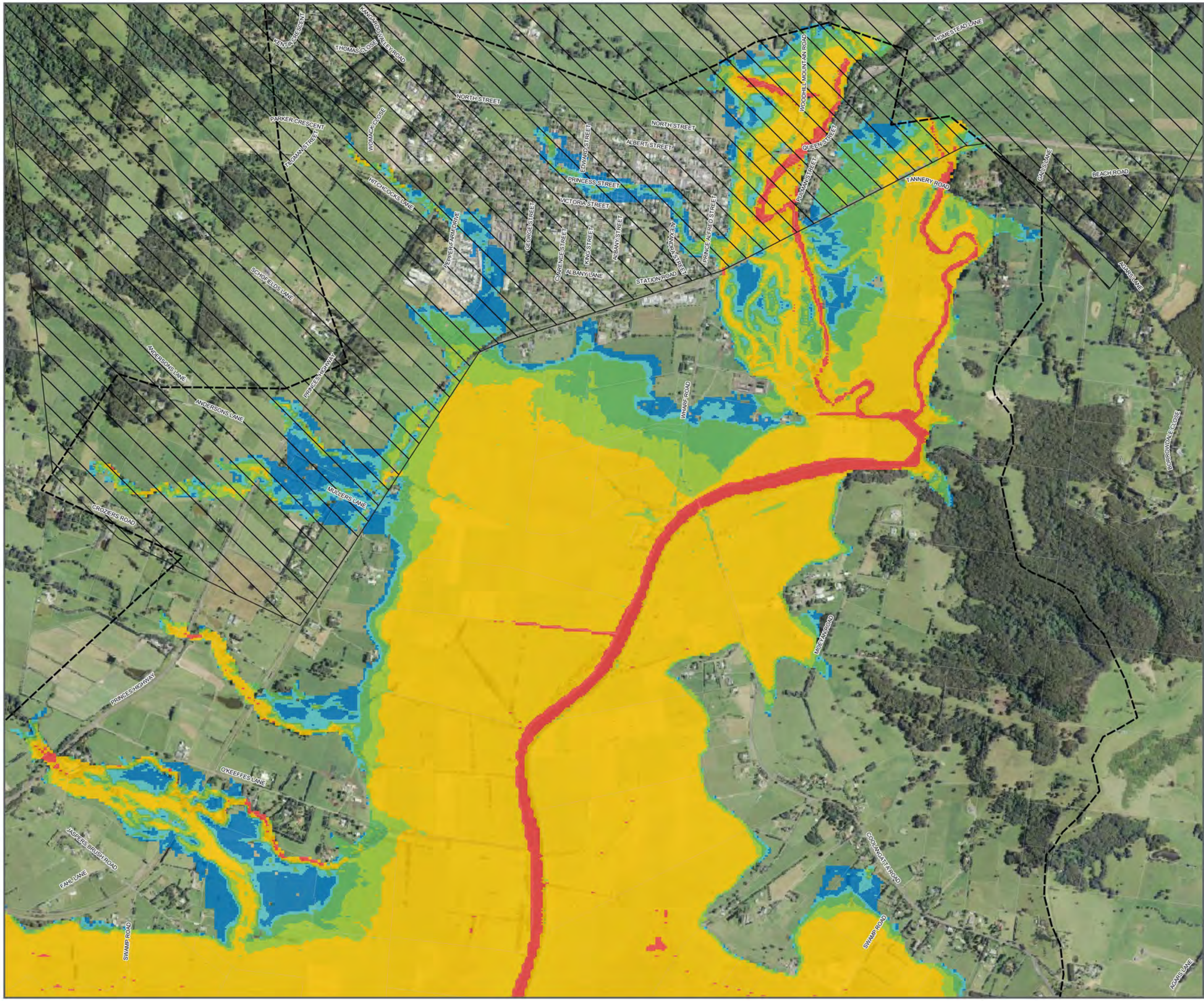
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hazard Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G22.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

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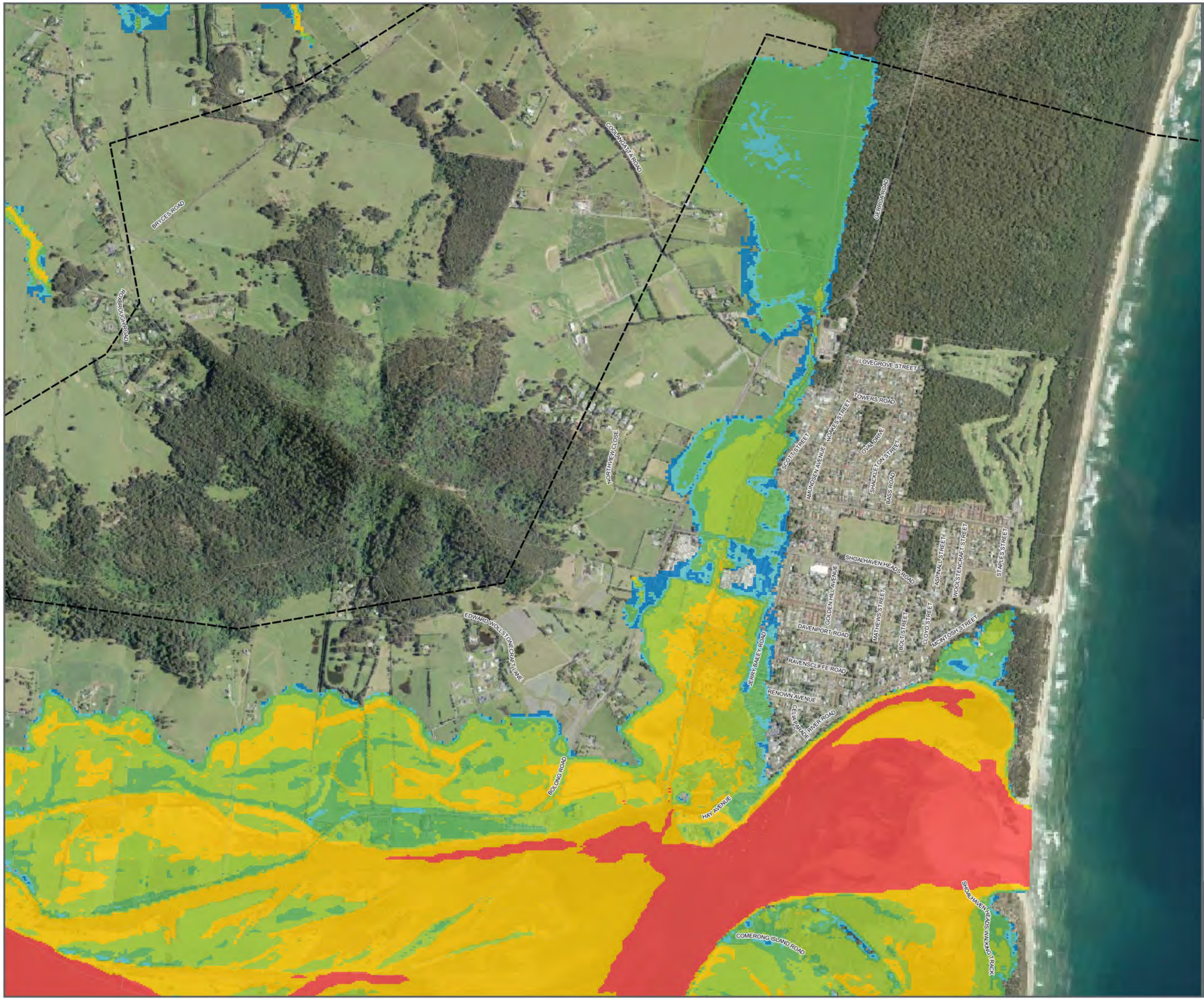
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hazard Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G22.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

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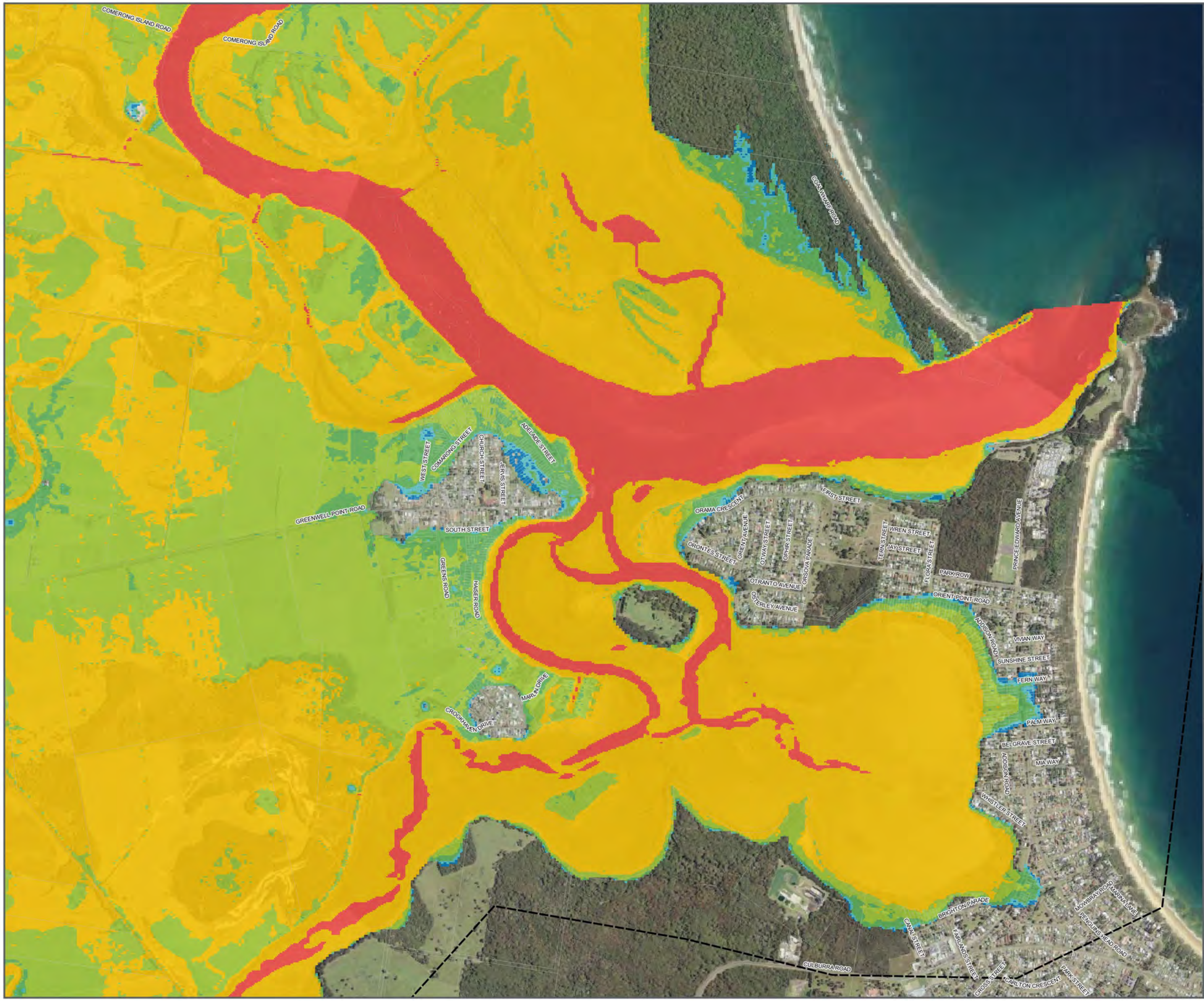
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hazard Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G22.5

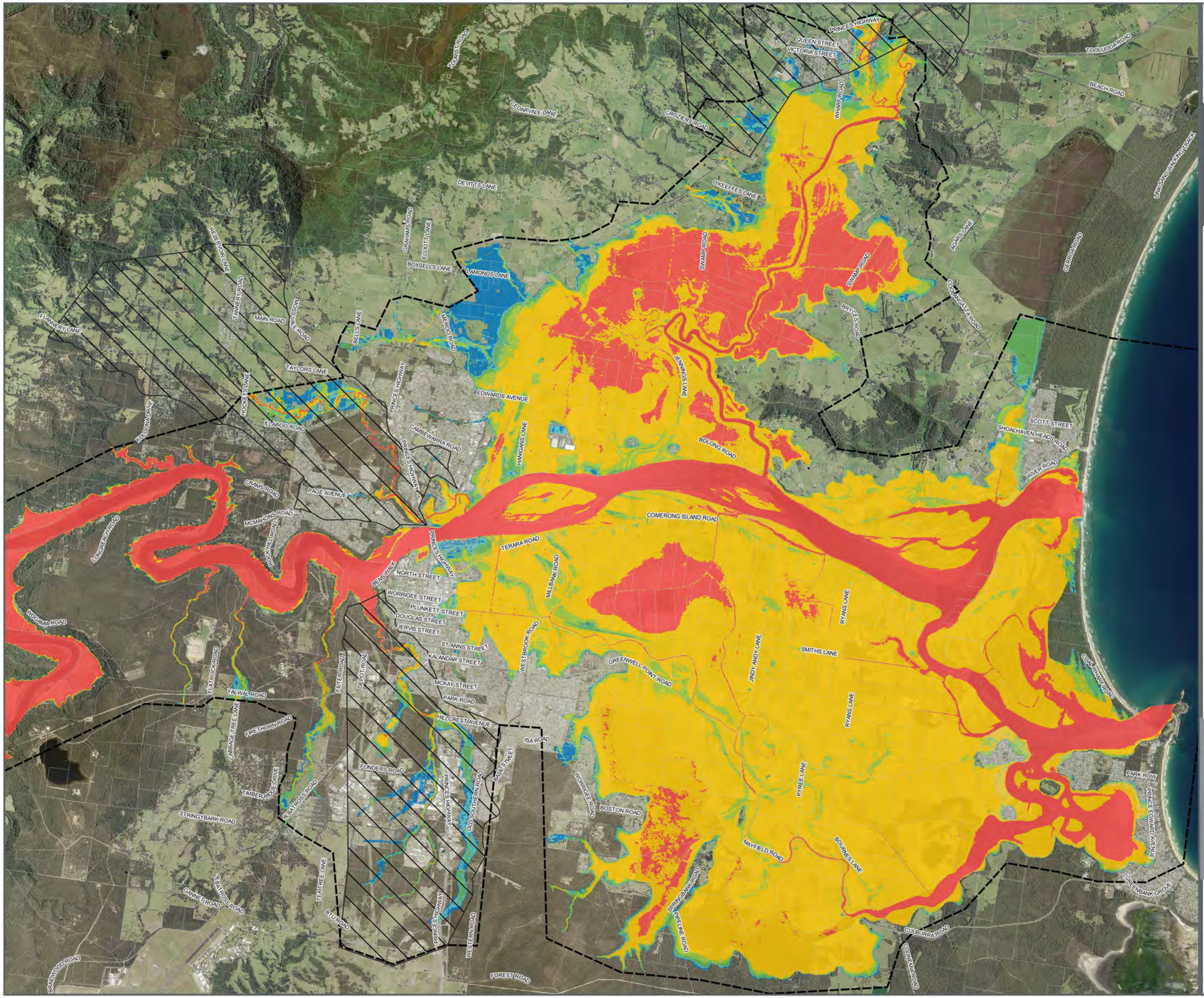
1:20,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 0.2% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G23

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

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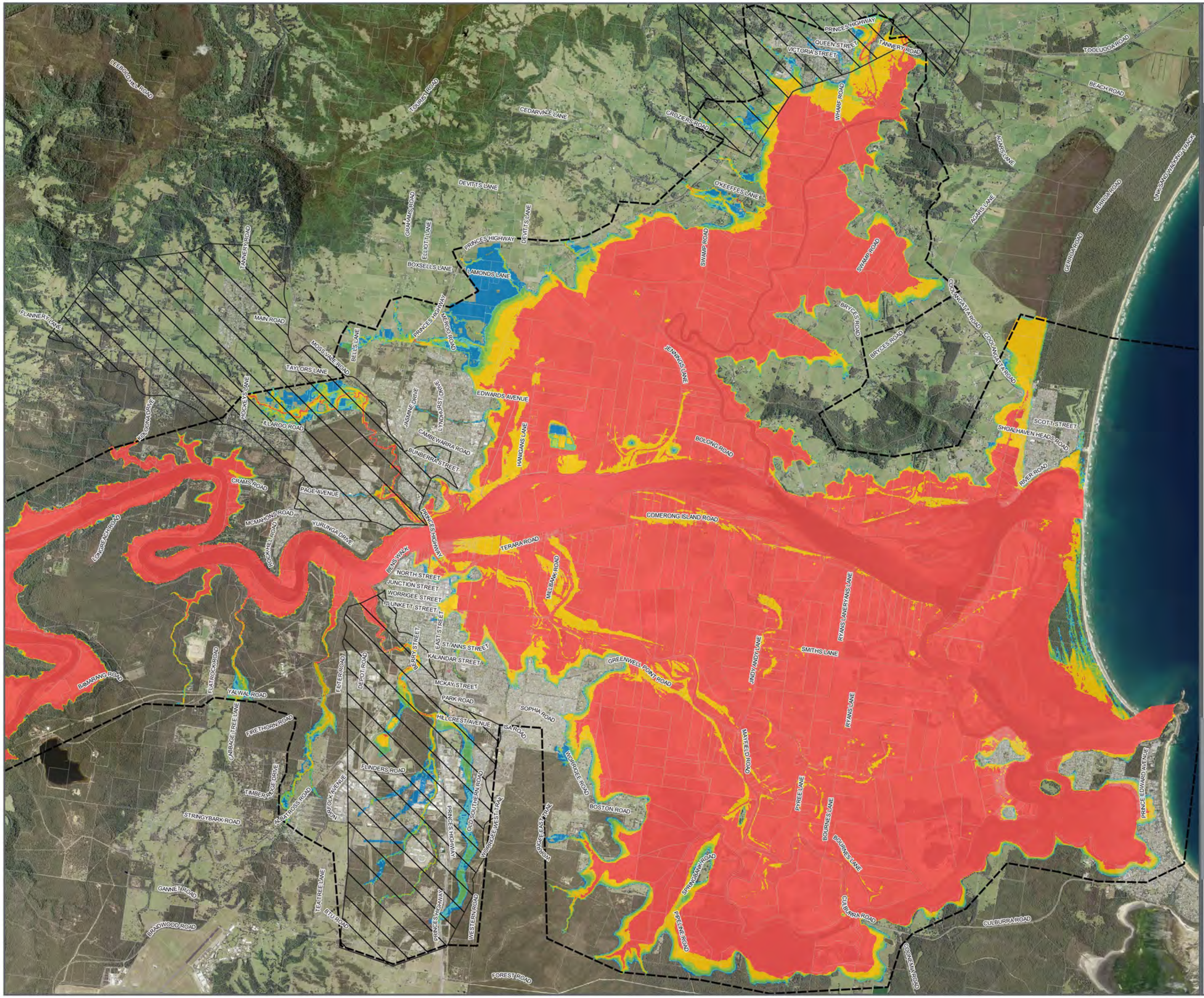
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G24

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

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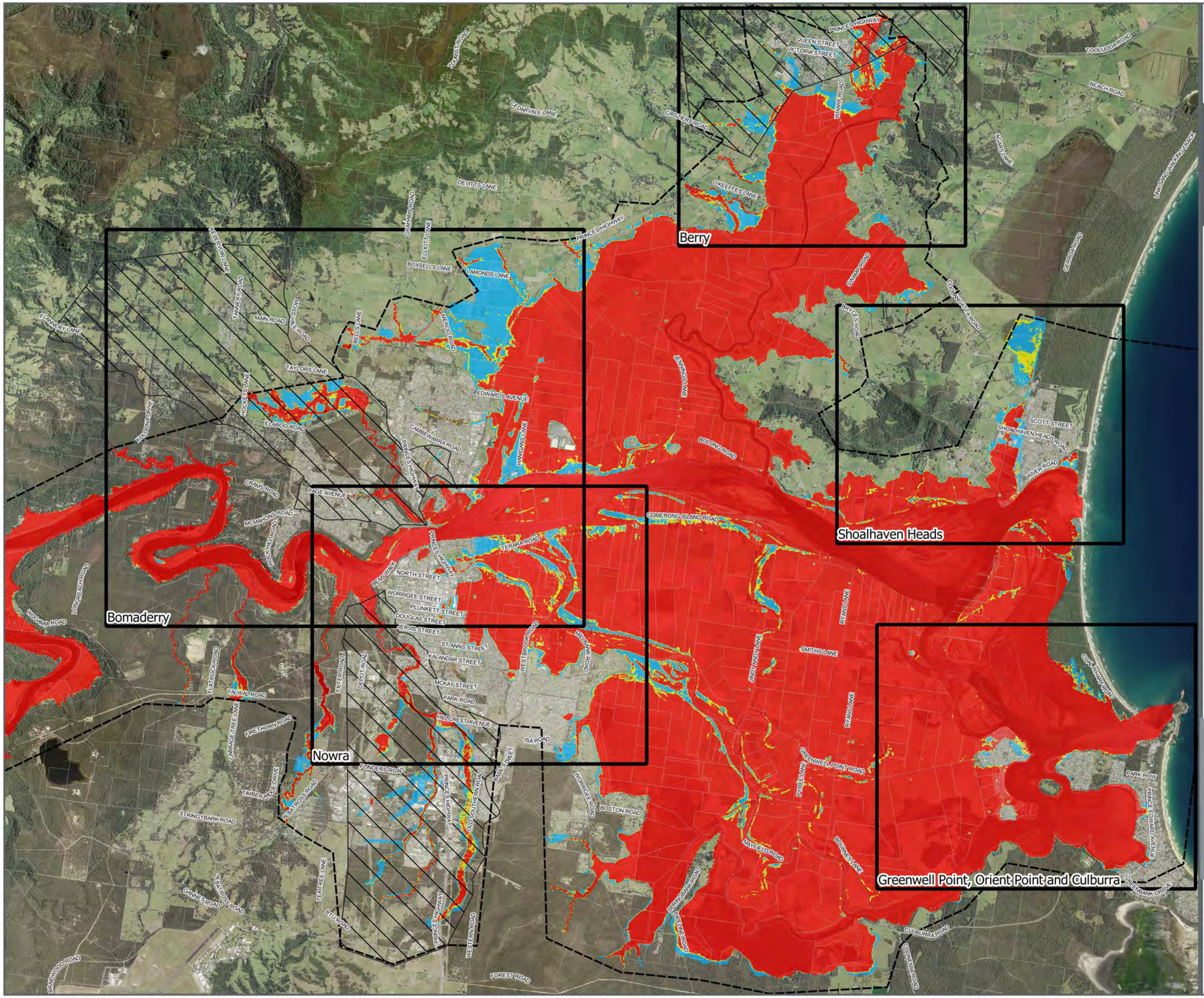
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Provisional Hazard Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

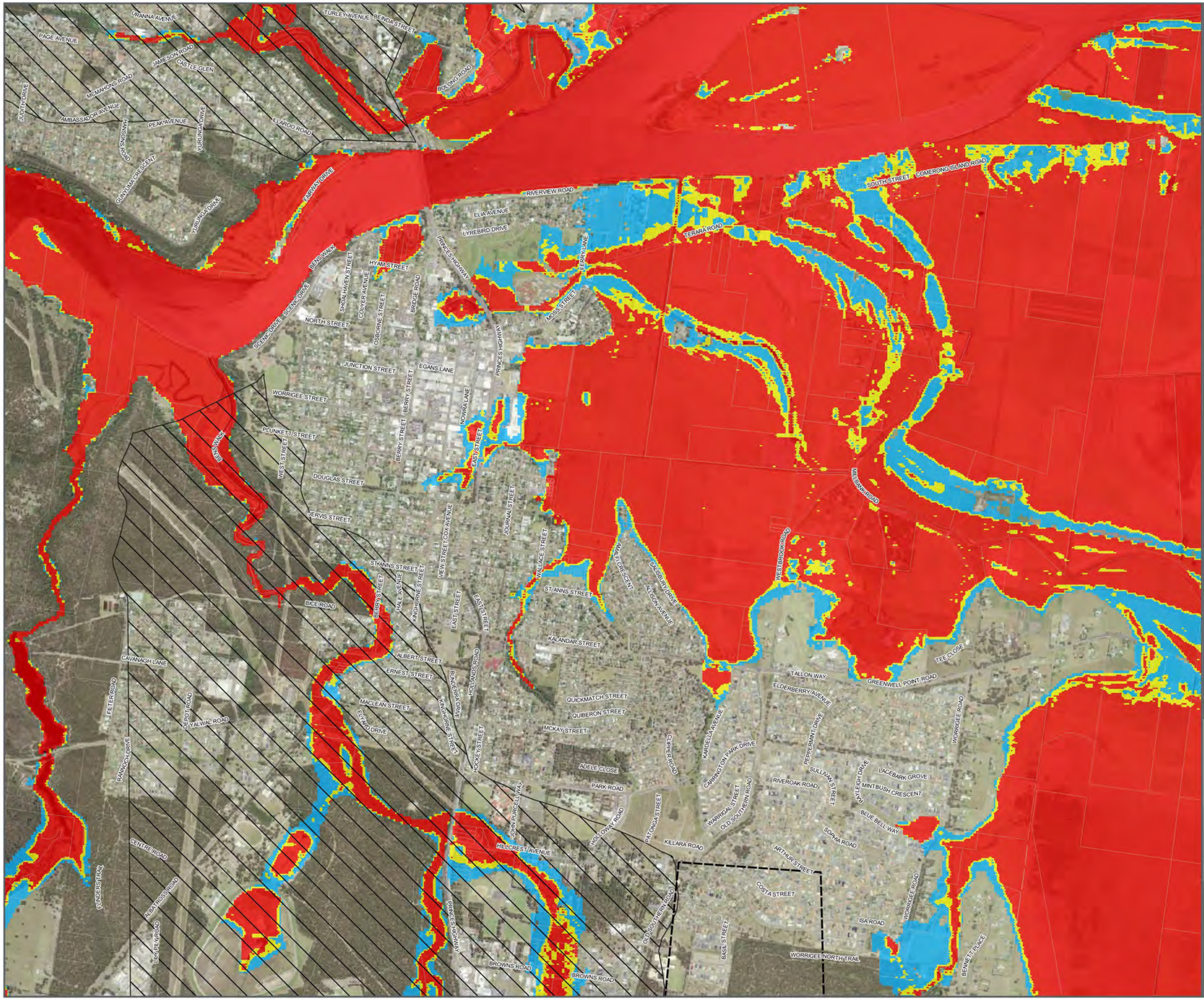
FIGURE G25

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Provisional Hazard Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

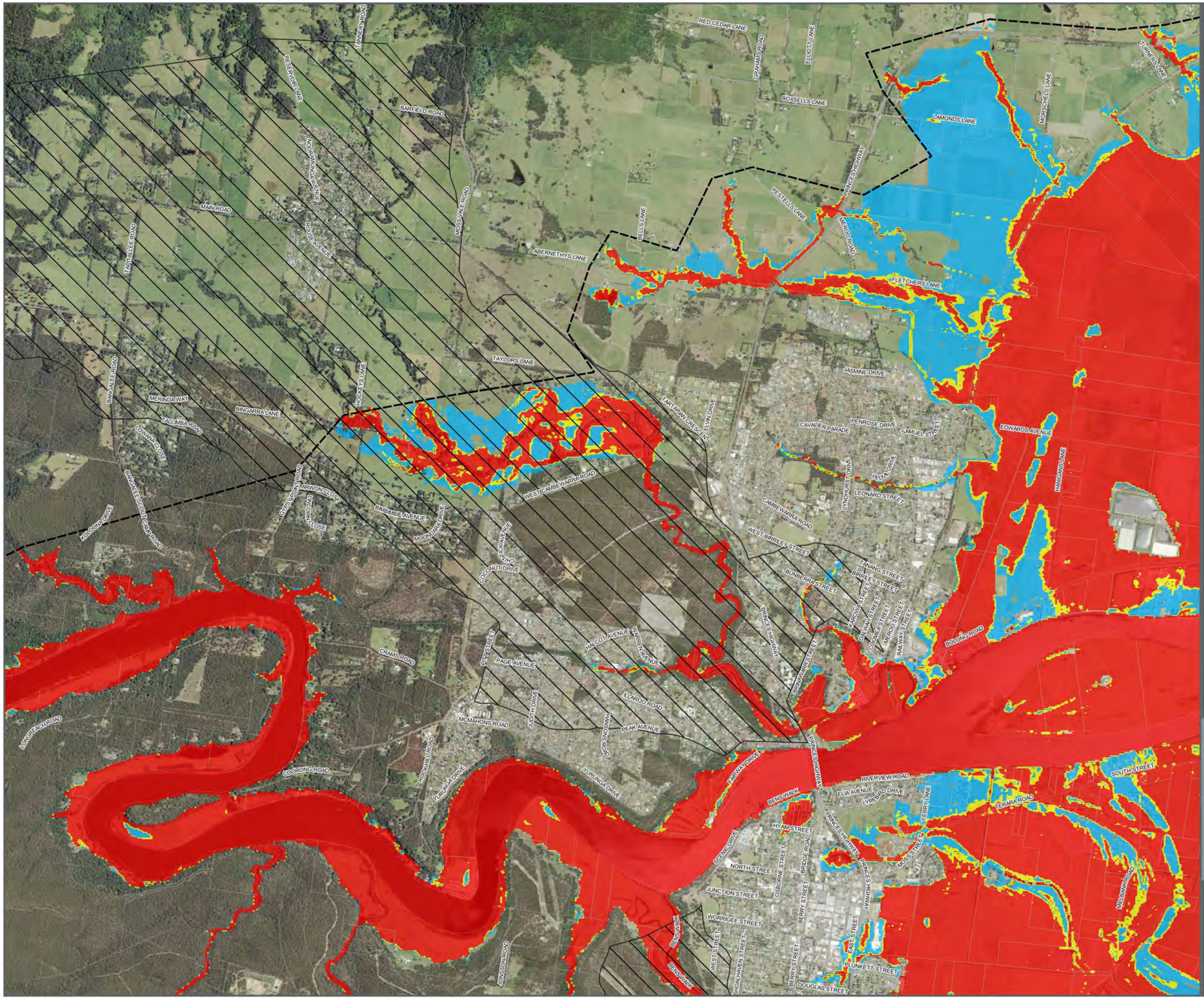
FIGURE G25.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Provisional Hazard Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

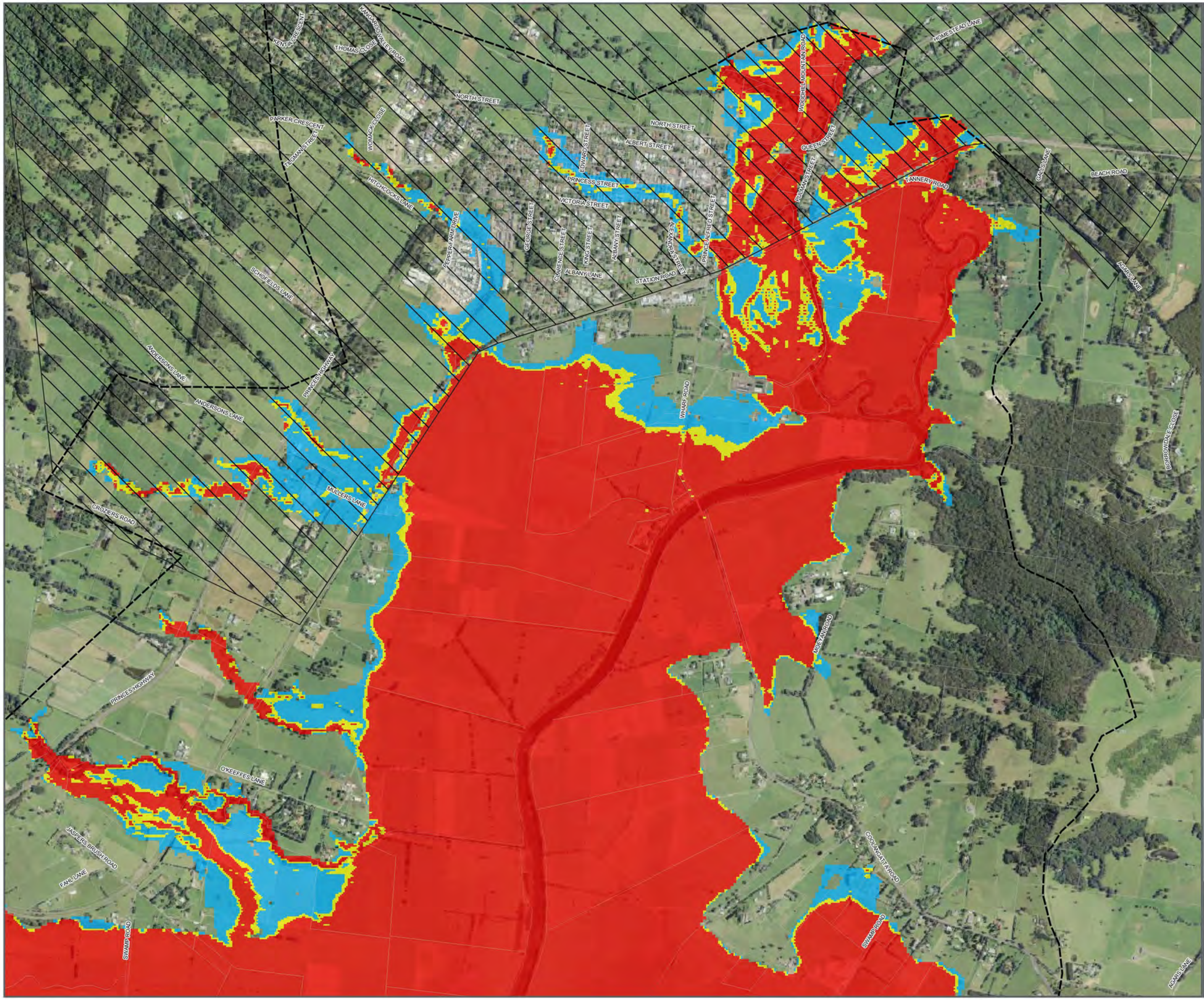
FIGURE G25.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Provisional Hazard Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

FIGURE G25.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

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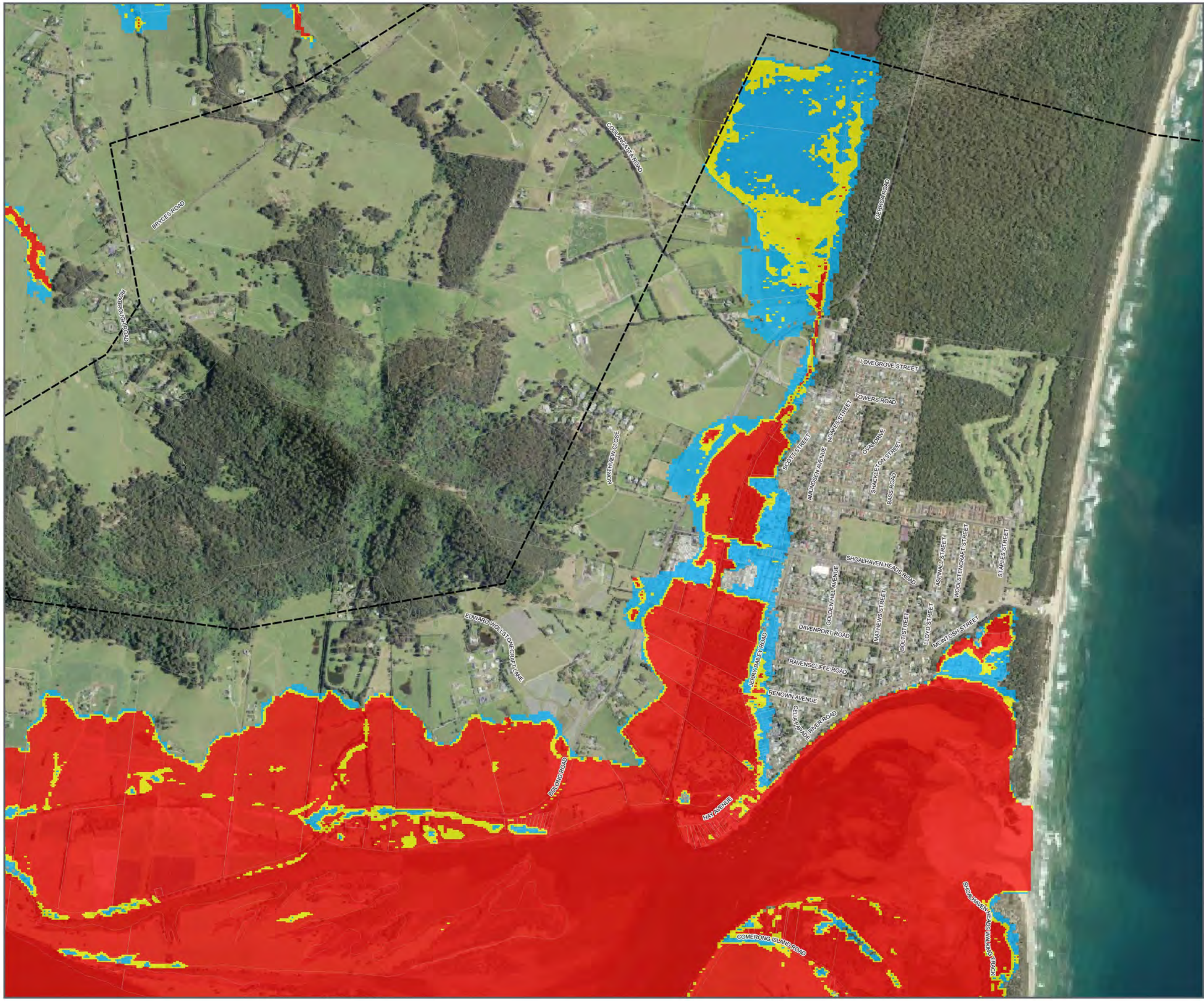
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Provisional Hazard Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

Cadastre (NSW Spatial Services, 2019)

Hydraulic Model Boundary

The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

FIGURE G25.4

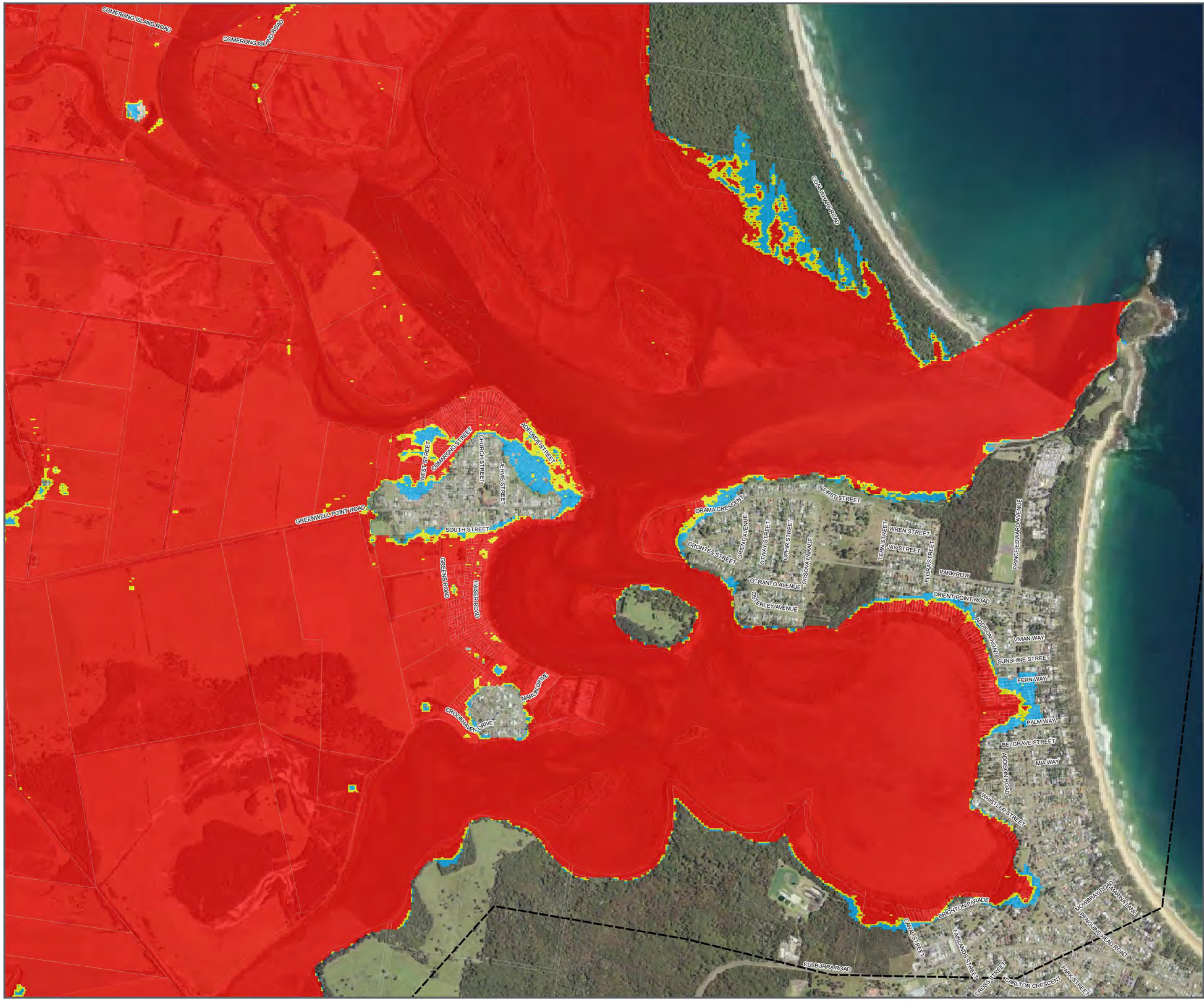
1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Provisional Hazard Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

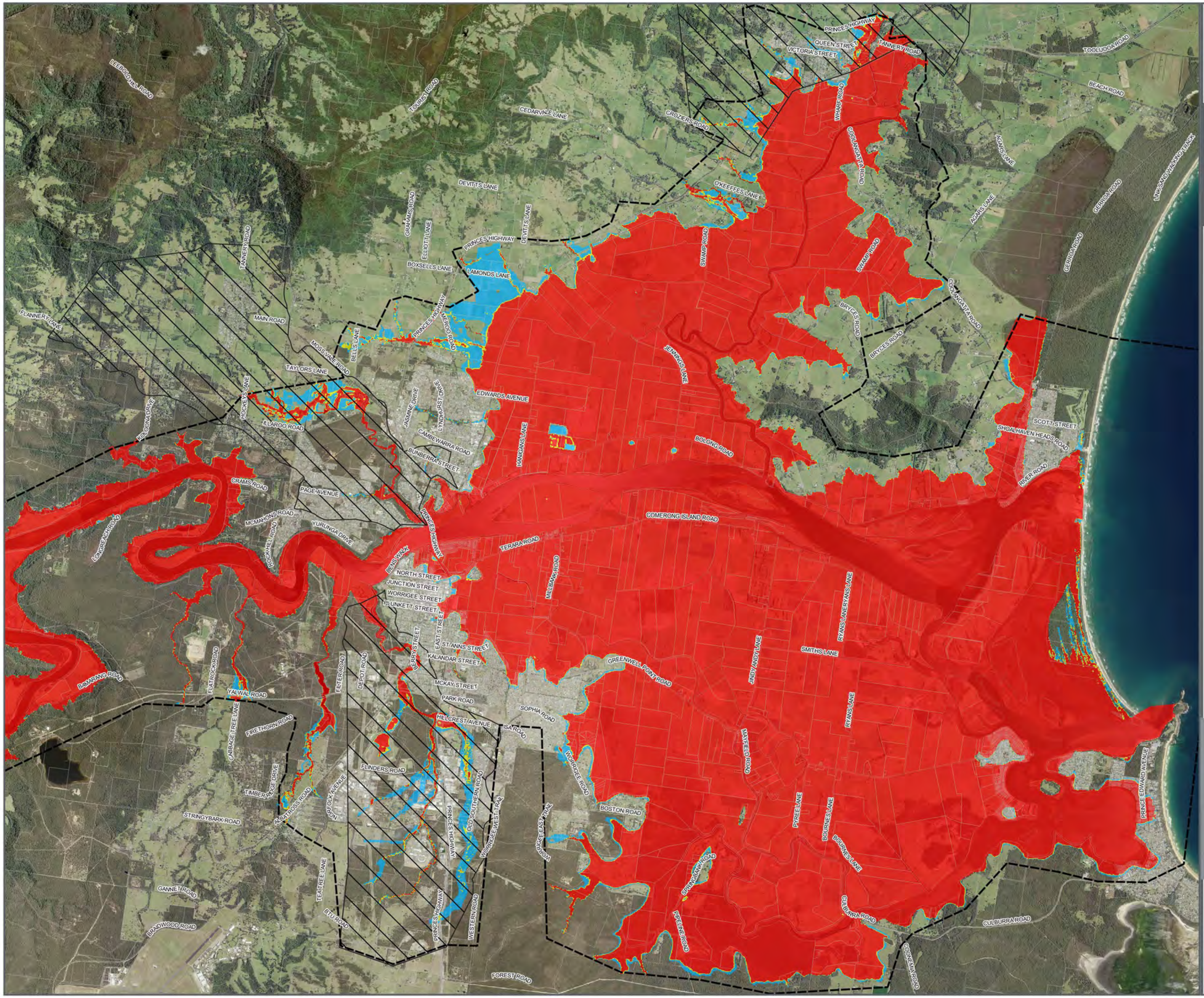
FIGURE G25.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Provisional Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

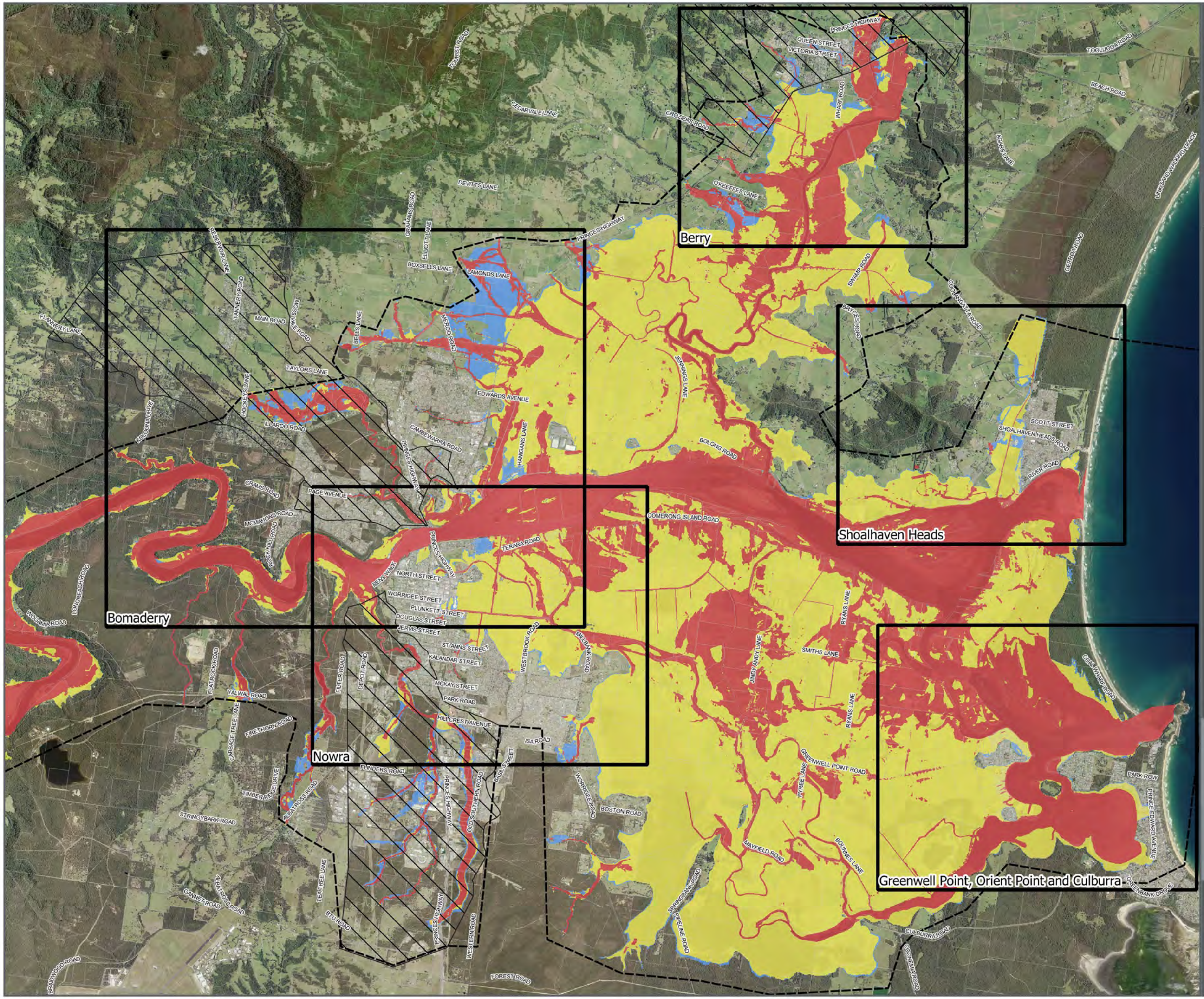
FIGURE G26

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hydraulic Categories Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

FIGURE G27

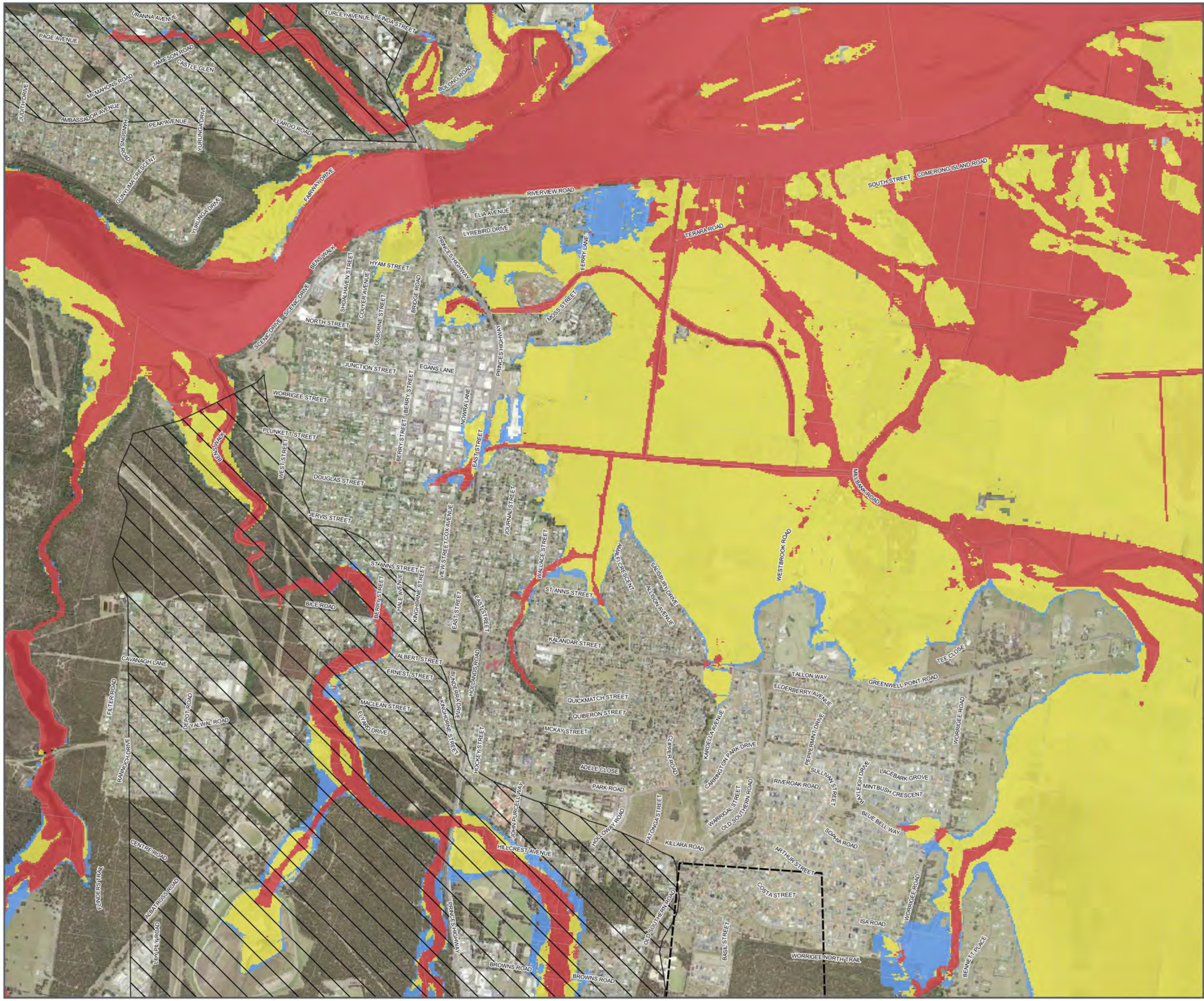
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hydraulic Categories Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

FIGURE G27.1

1:21,000 Scale at A3

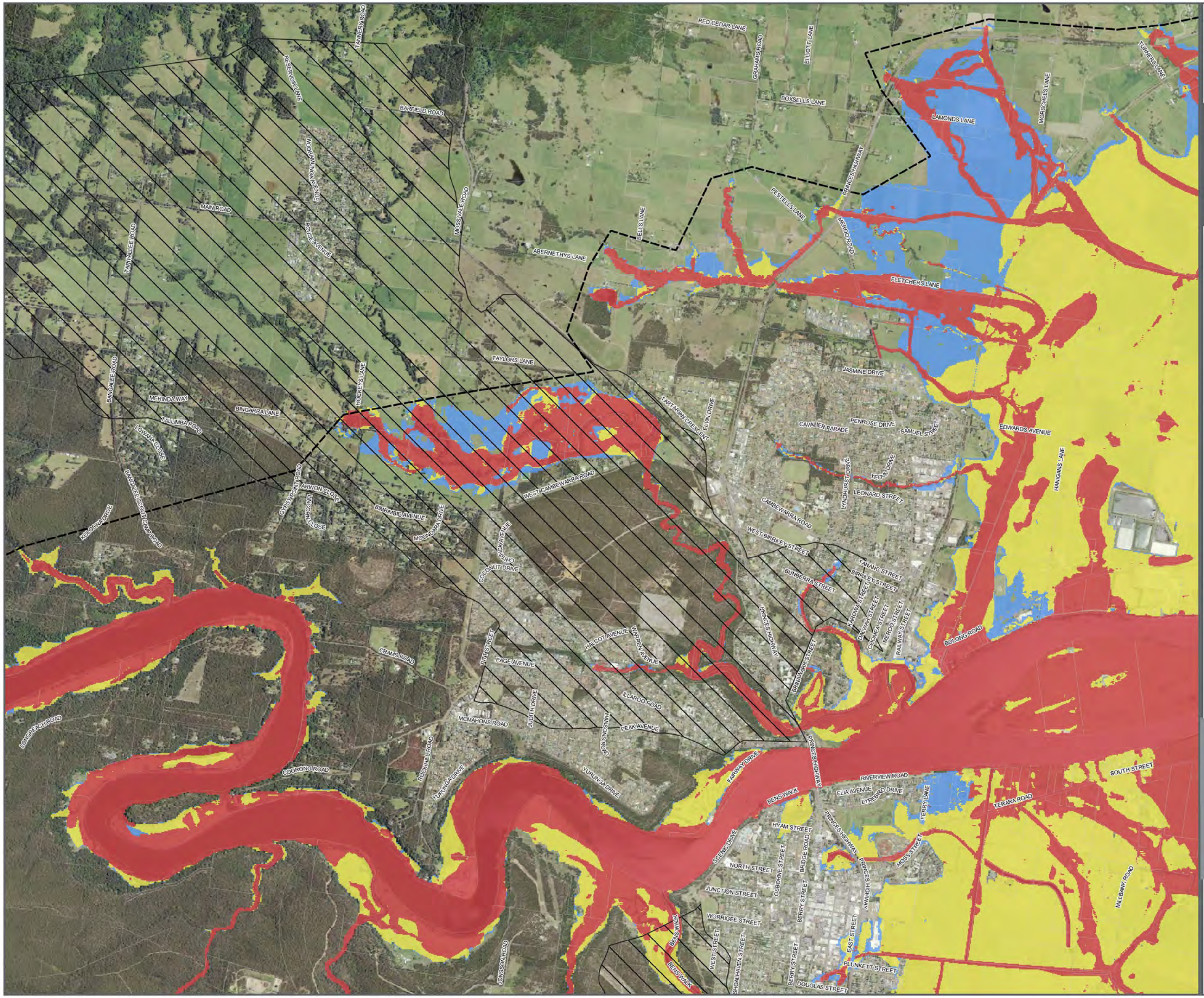
0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Existing 1% AEP Hydraulic Categories Bomaderry

Lower Shoalhaven River Flood Study



Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

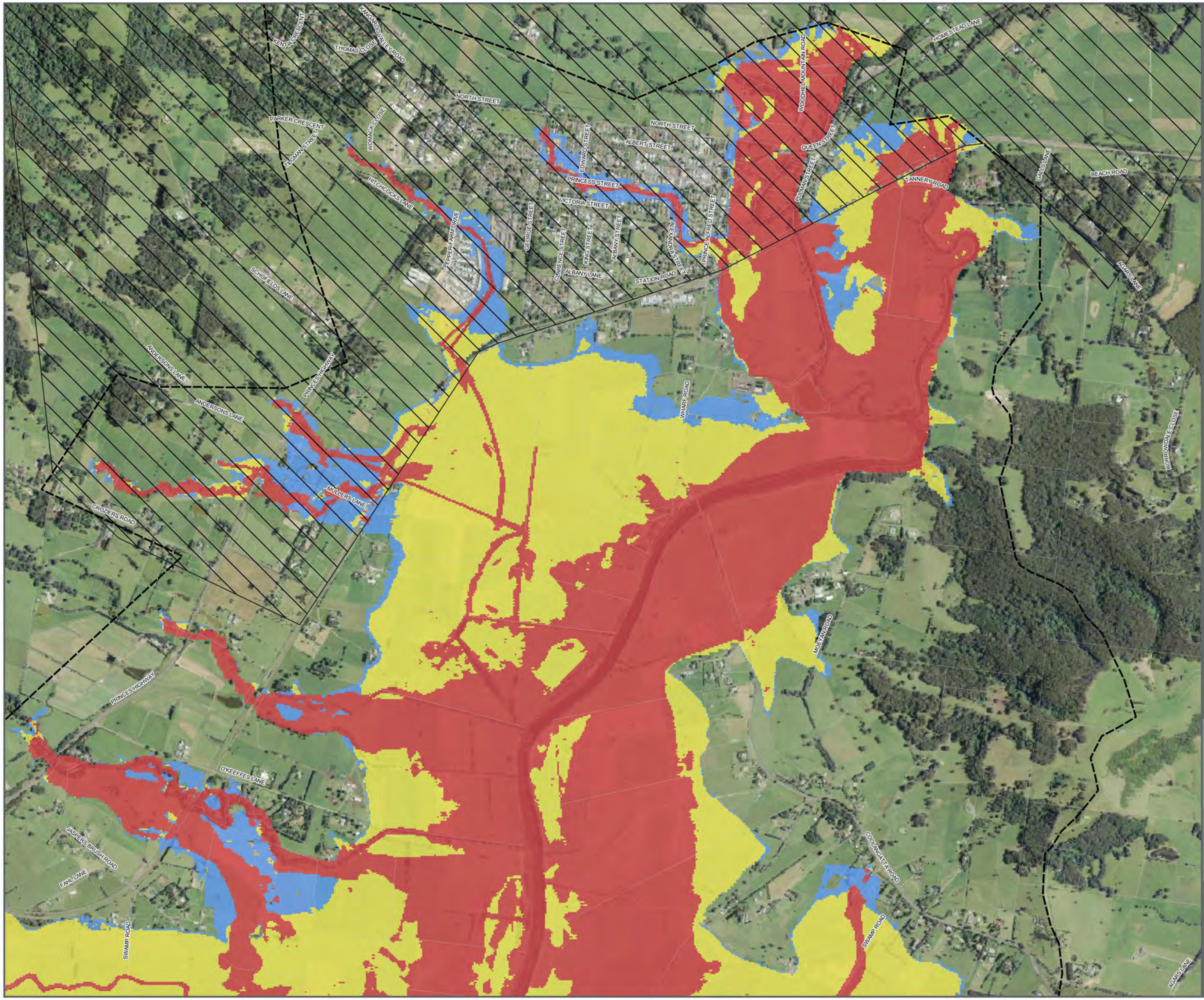
FIGURE G27.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hydraulic Categories Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

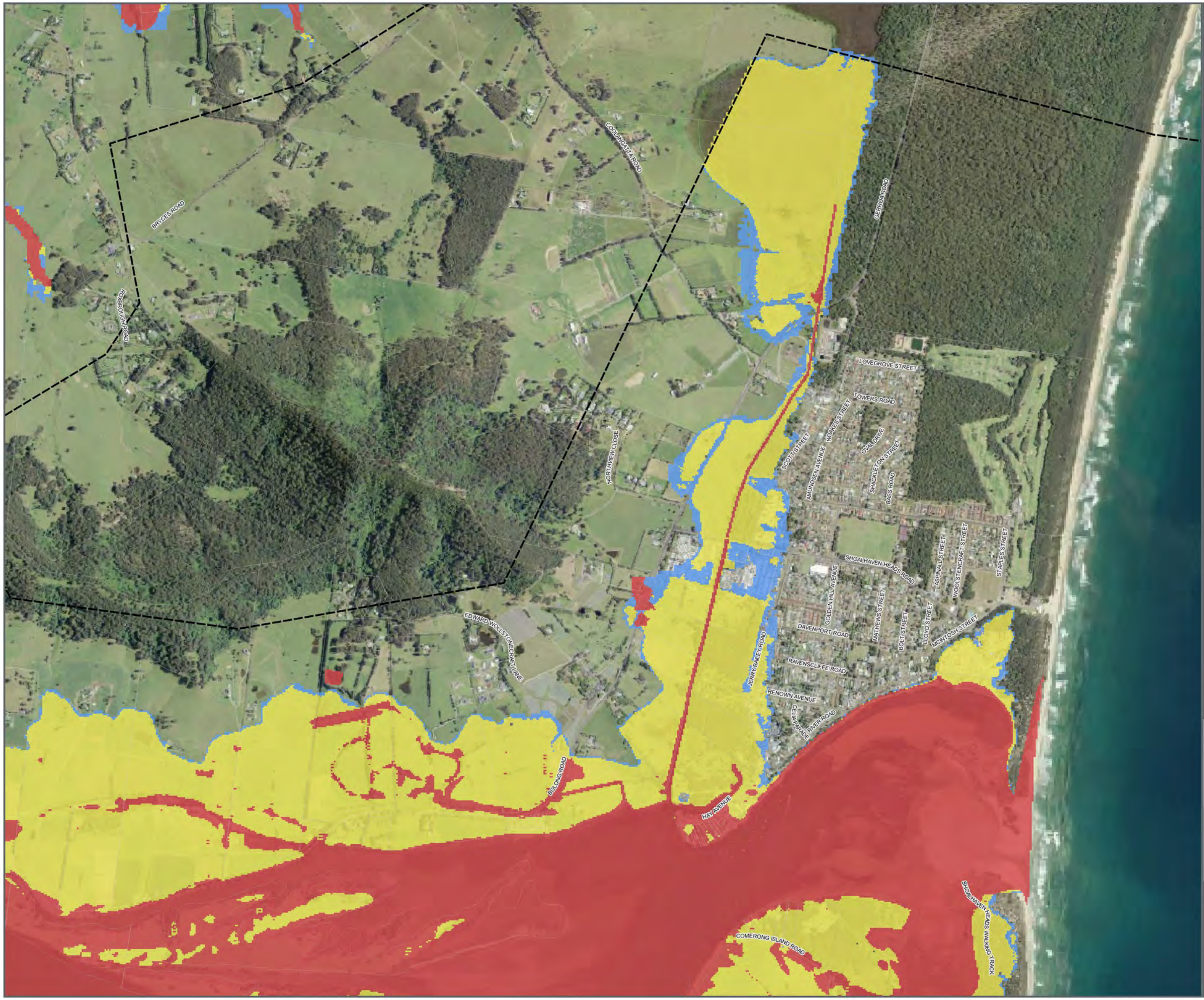
FIGURE G27.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hydraulic Categories Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

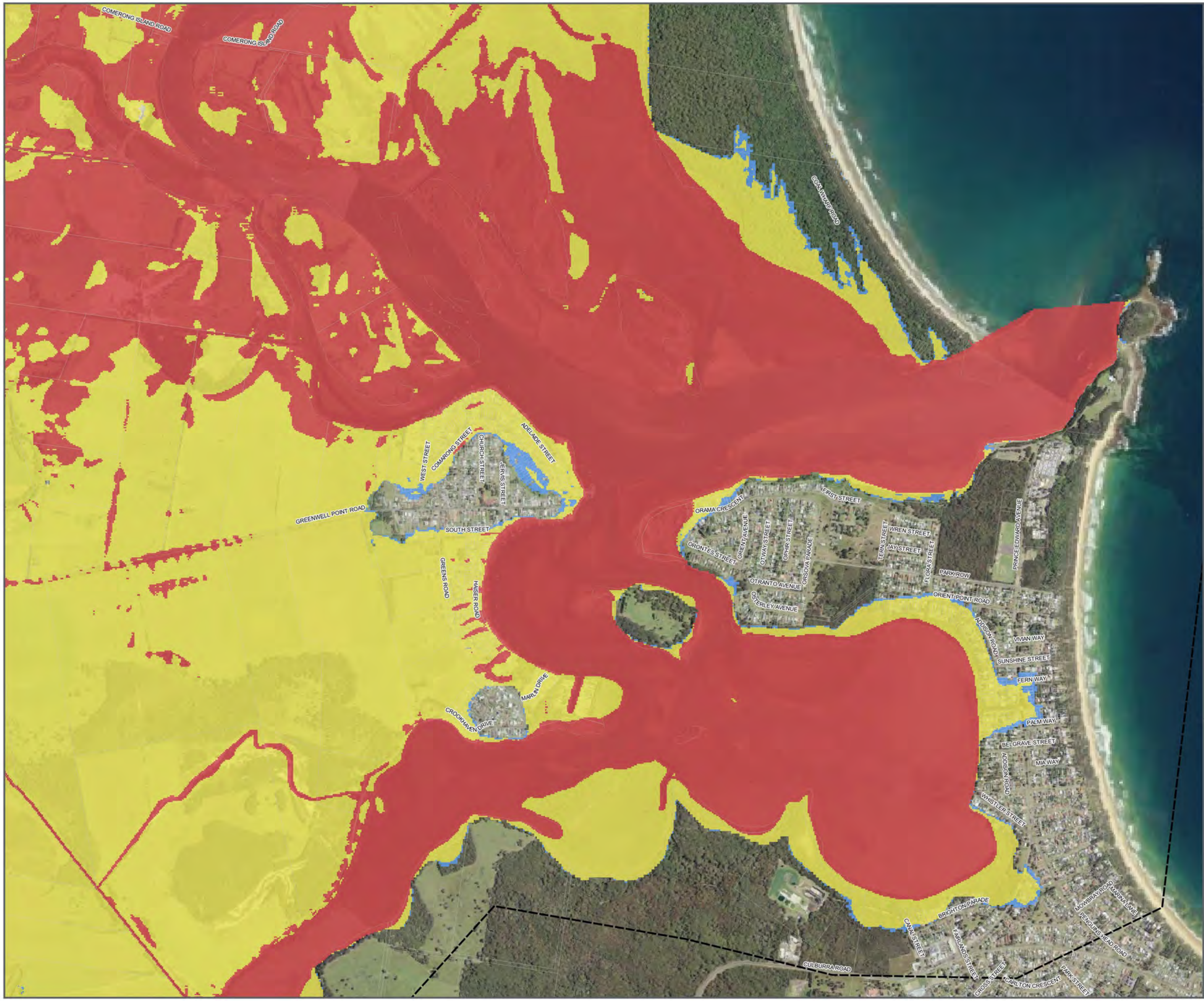
FIGURE G27.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Hydraulic Categories Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

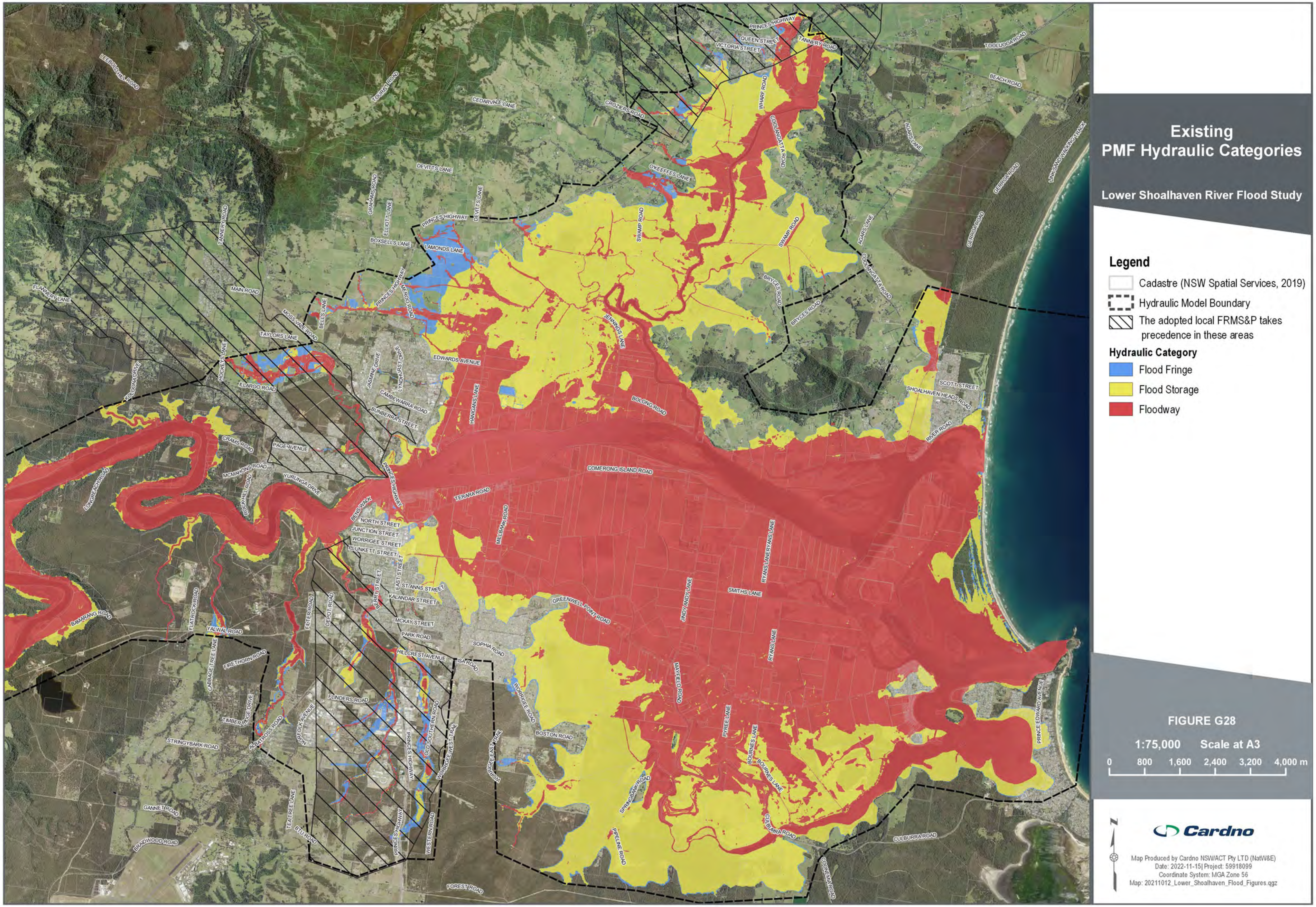
FIGURE G27.5

1:20,000 Scale at A3

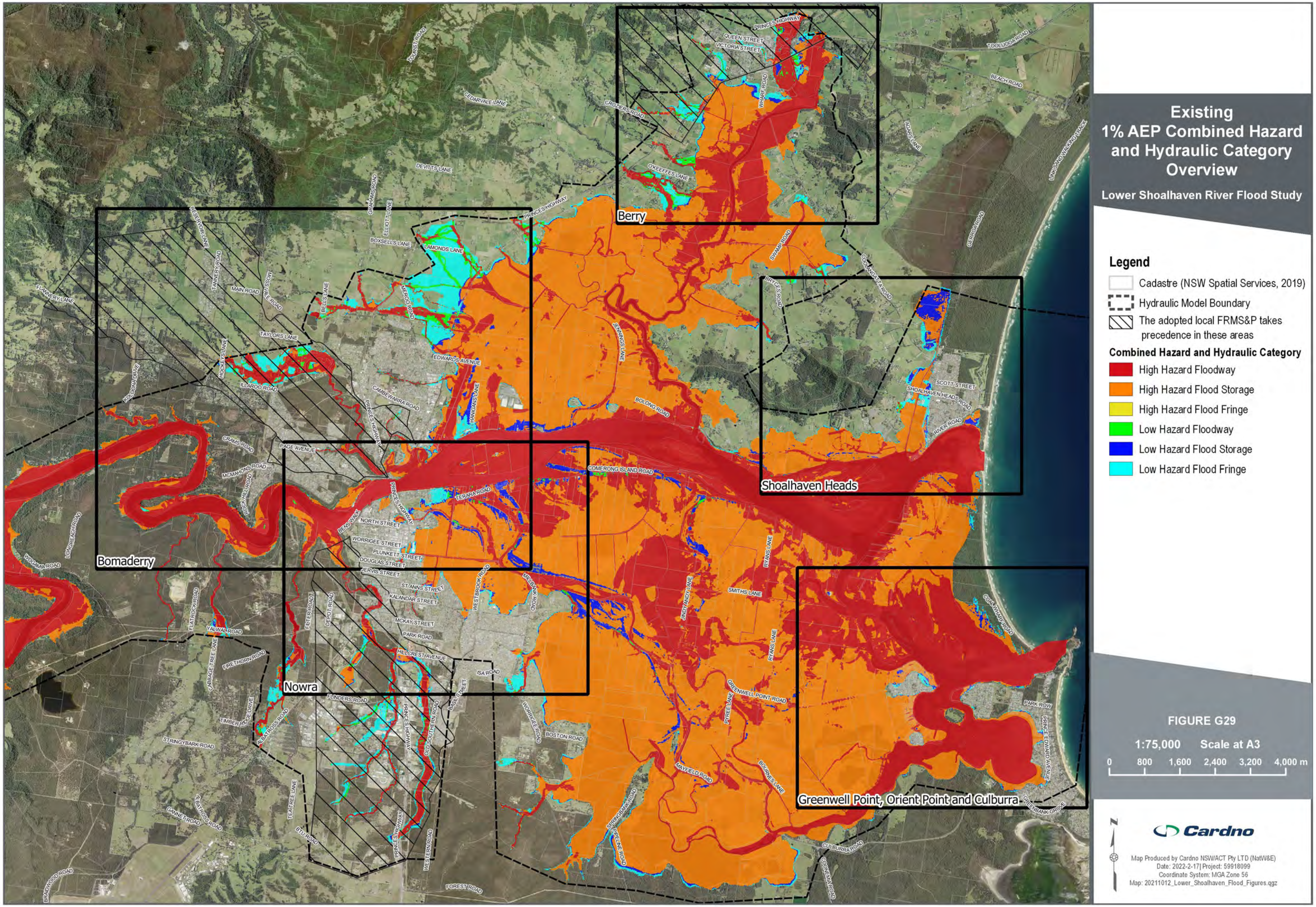
0 200 400 600 800 1,000 m

Cardno

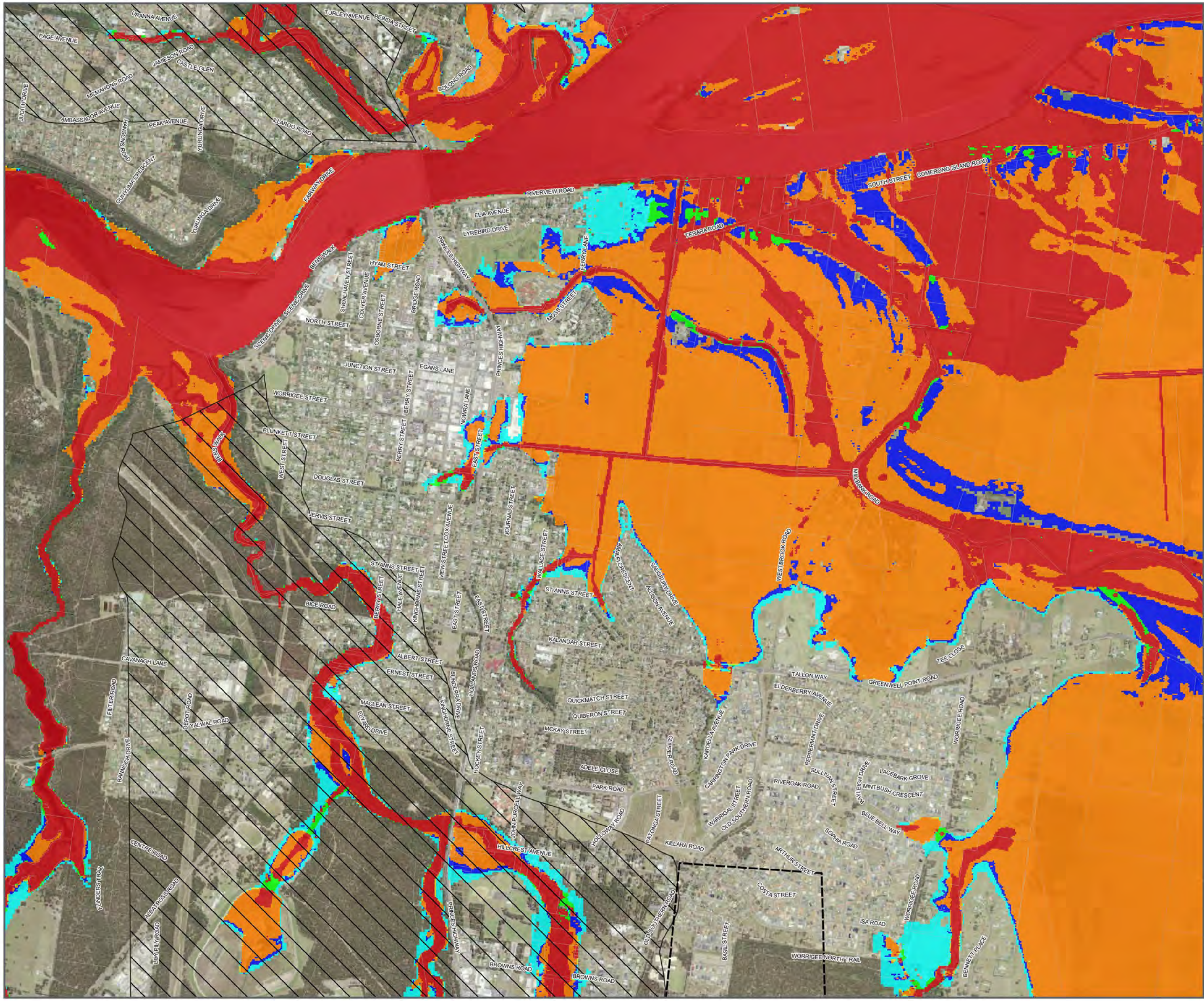
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
PMF Hydraulic Categories
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Hydraulic Category
Flood Fringe
Flood Storage
Floodway
FIGURE G28
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
1% AEP Combined Hazard and Hydraulic Category Overview
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Combined Hazard and Hydraulic Category
High Hazard Floodway
High Hazard Flood Storage
High Hazard Flood Fringe
Low Hazard Floodway
Low Hazard Flood Storage
Low Hazard Flood Fringe
Berry
Bomaderry
Nowra
Shoalhaven Heads
Greenwell Point, Orient Point and Culburra
FIGURE G29
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
1% AEP Combined Hazard and Hydraulic Category Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

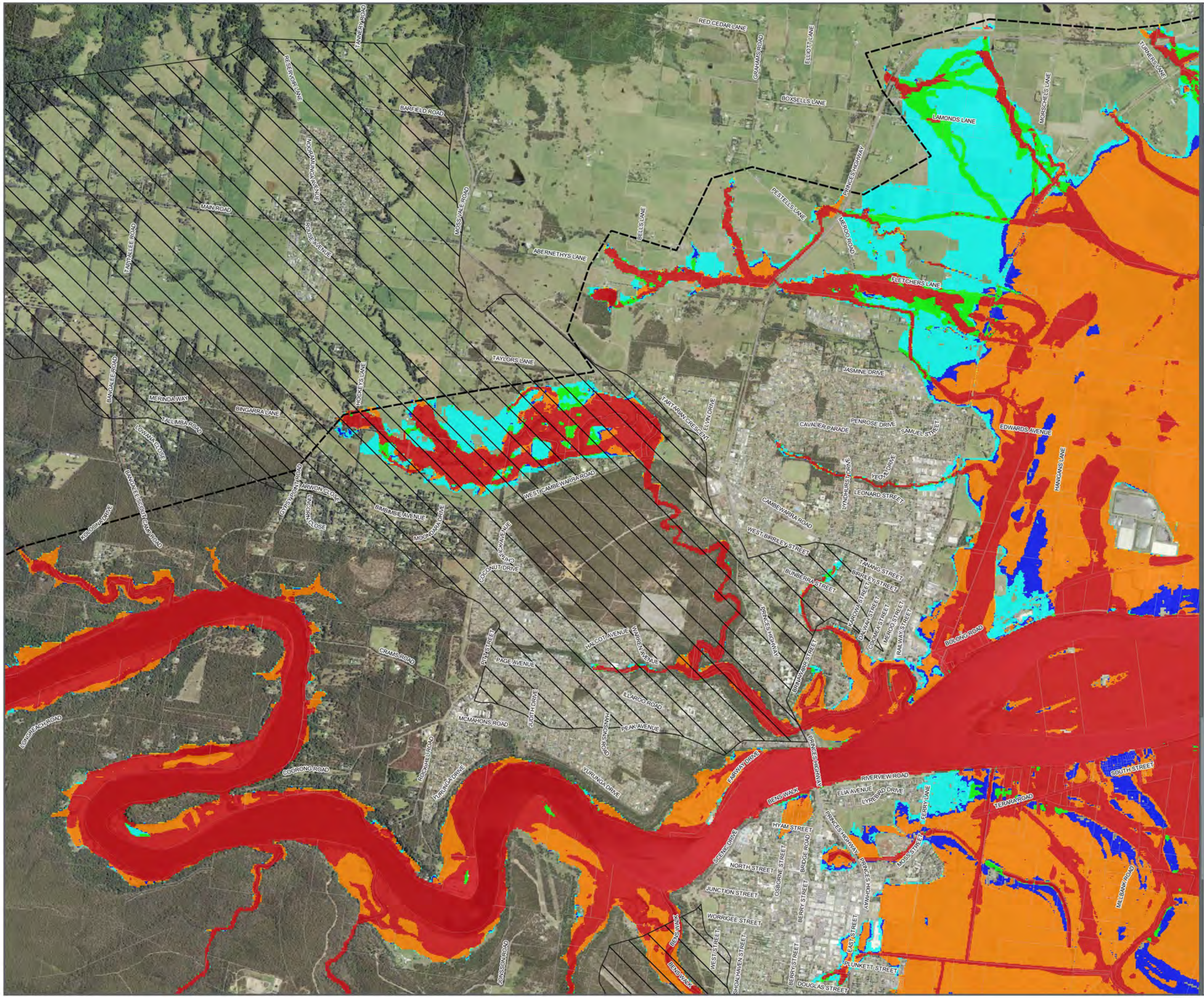
FIGURE G29.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Combined Hazard and Hydraulic Category Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

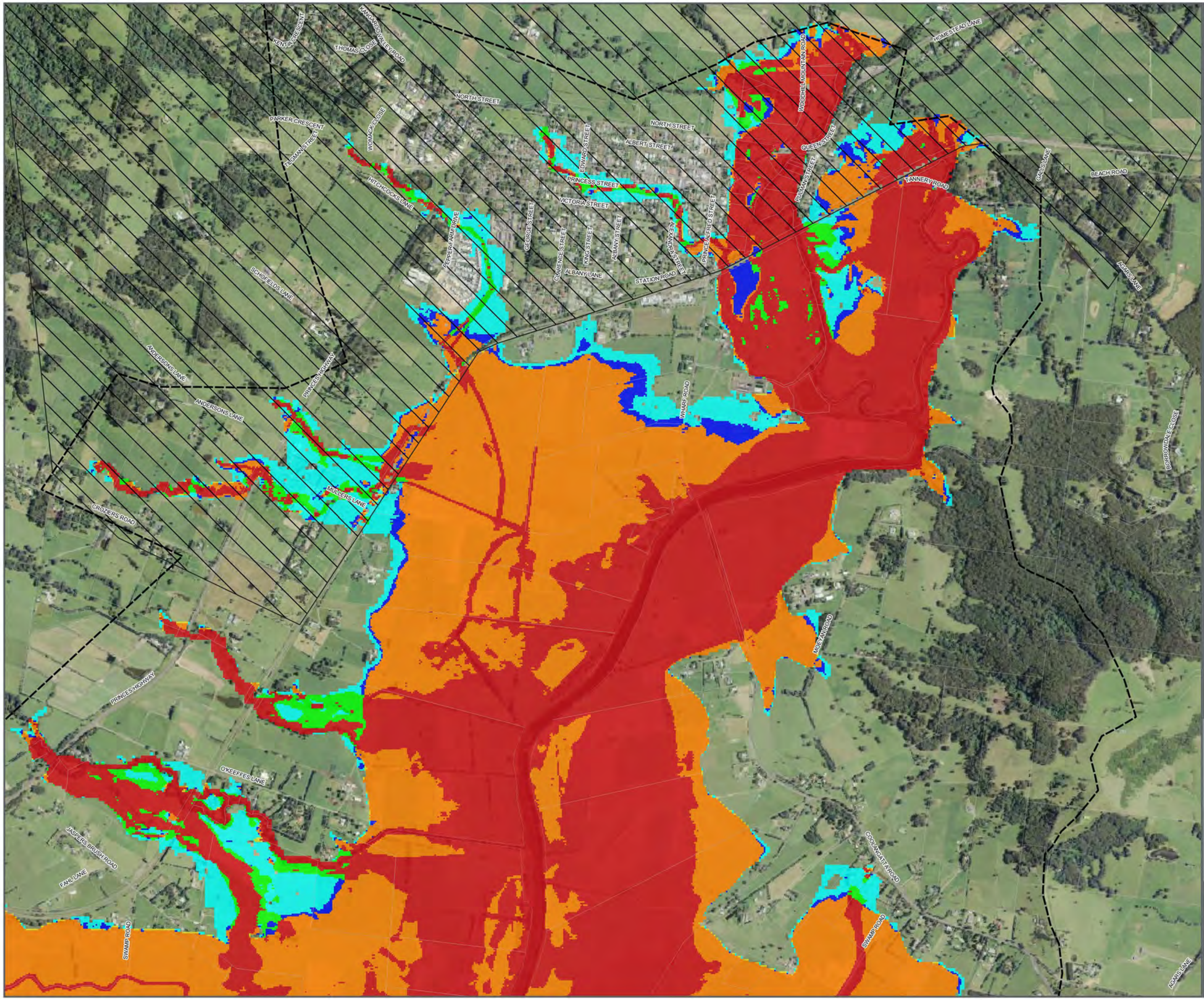
FIGURE G29.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Combined Hazard and Hydraulic Category Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

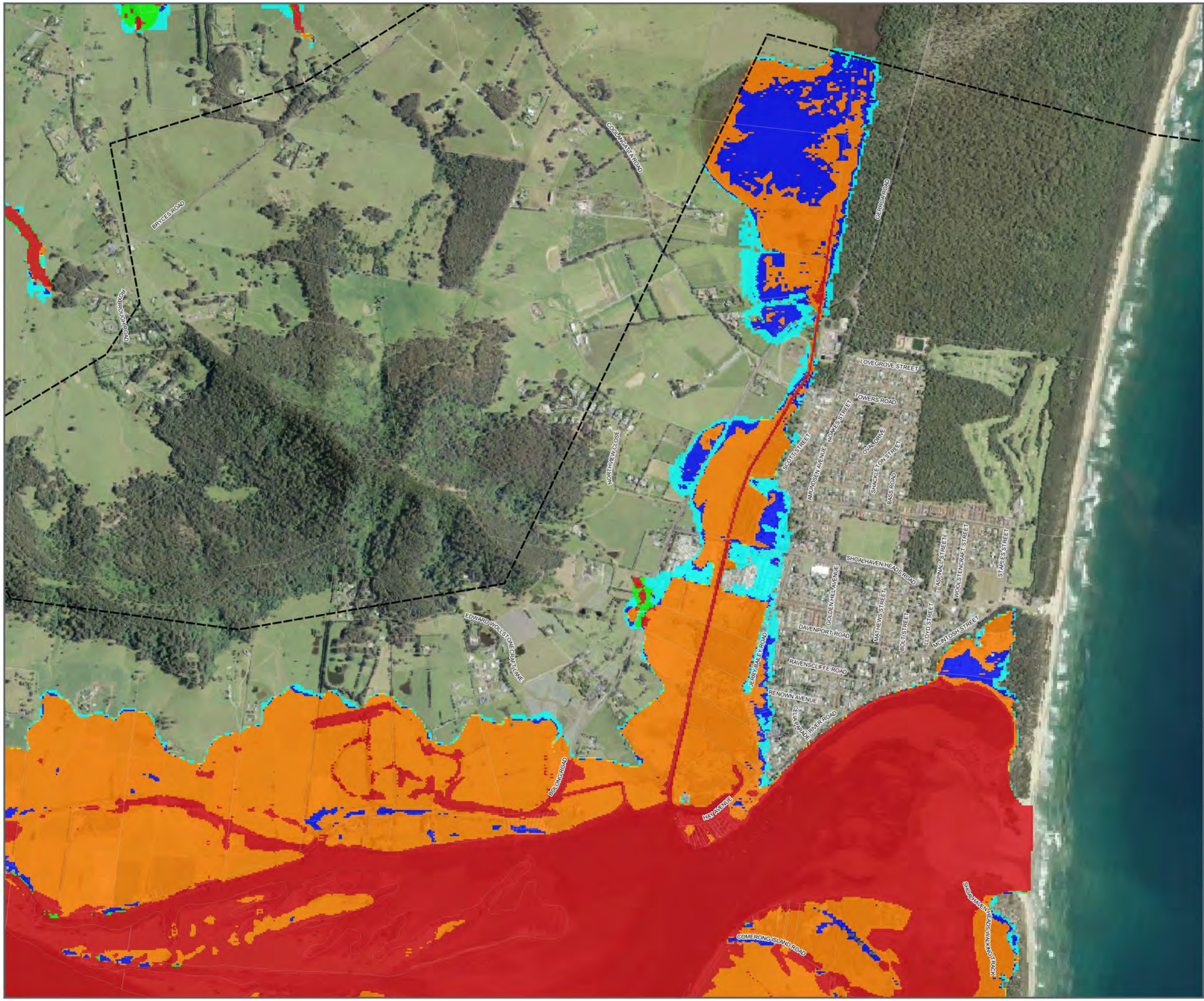
FIGURE G29.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing 1% AEP Combined Hazard and Hydraulic Category Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

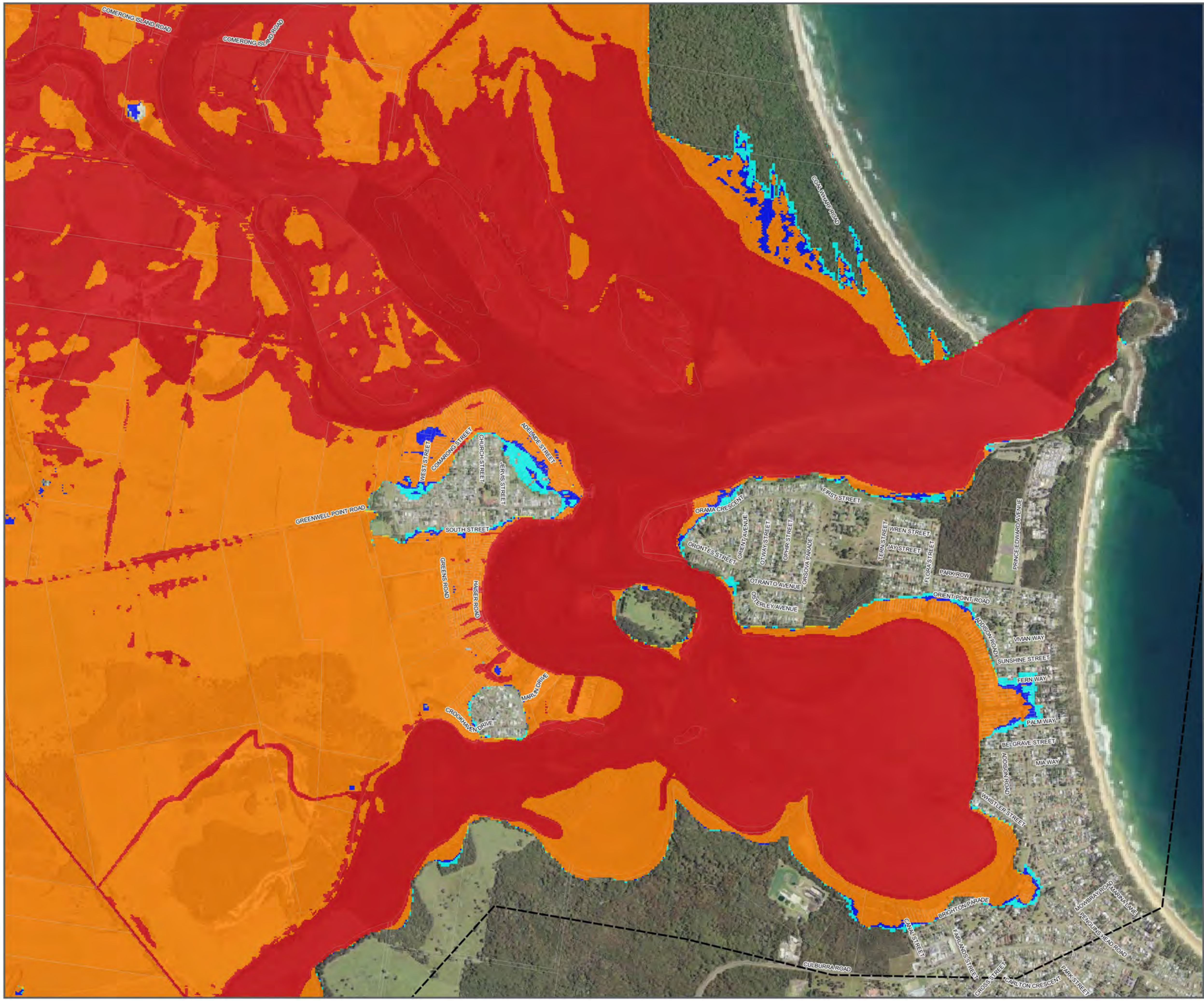
FIGURE G29.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
1% AEP Combined Hazard and Hydraulic Category Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

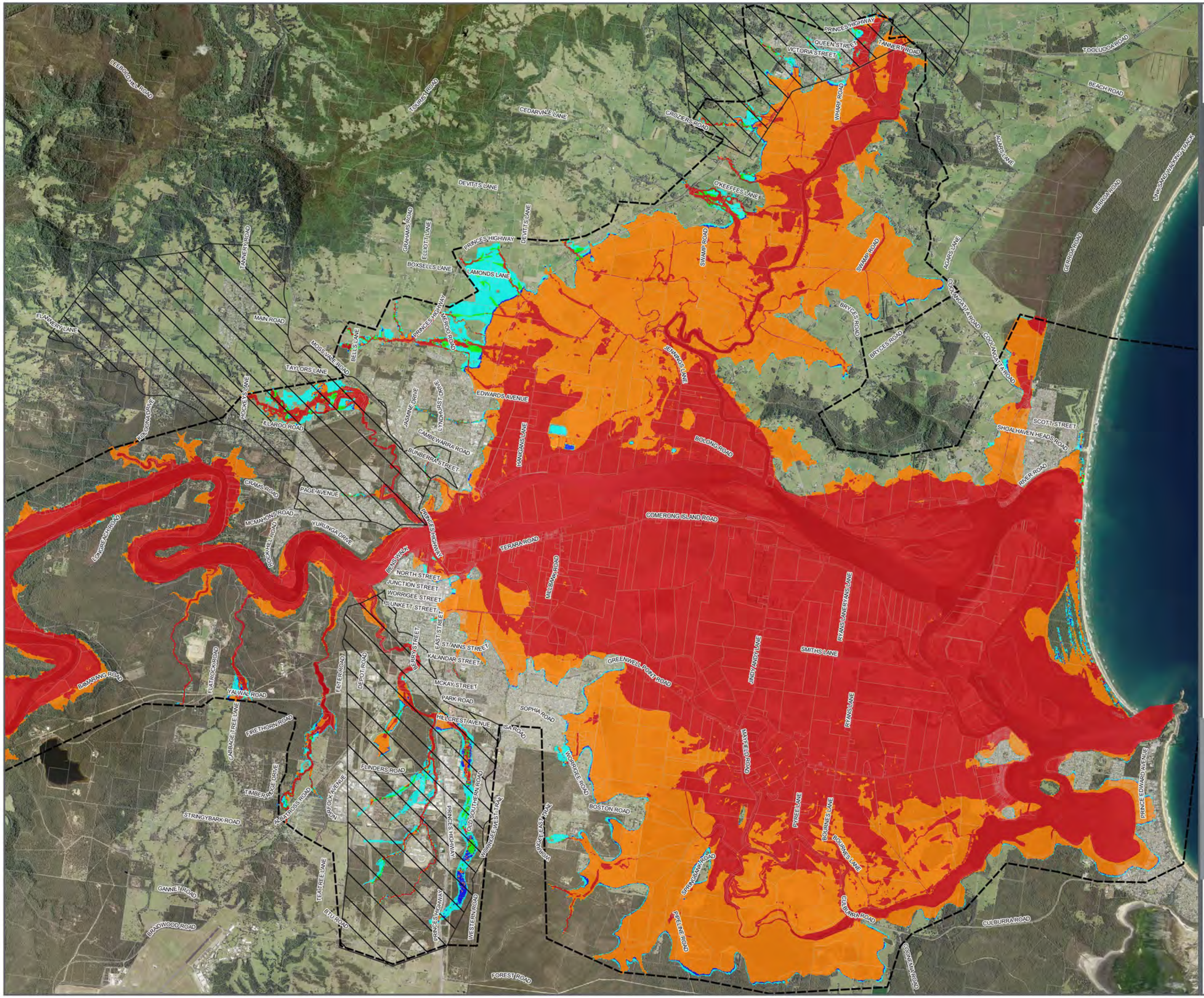
FIGURE G29.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing PMF Combined Hazard and Hydraulic Category

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

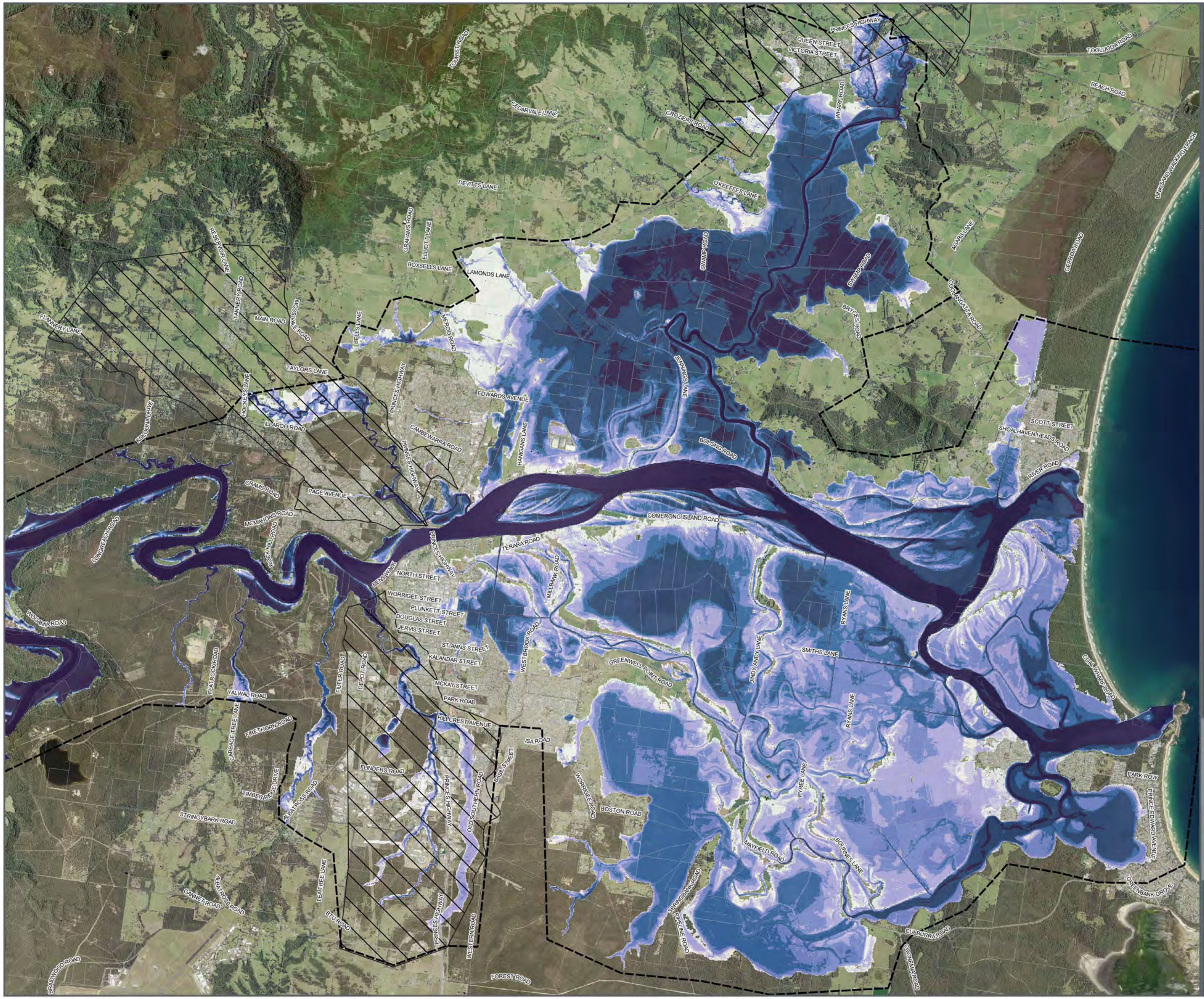
FIGURE G30

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
5% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

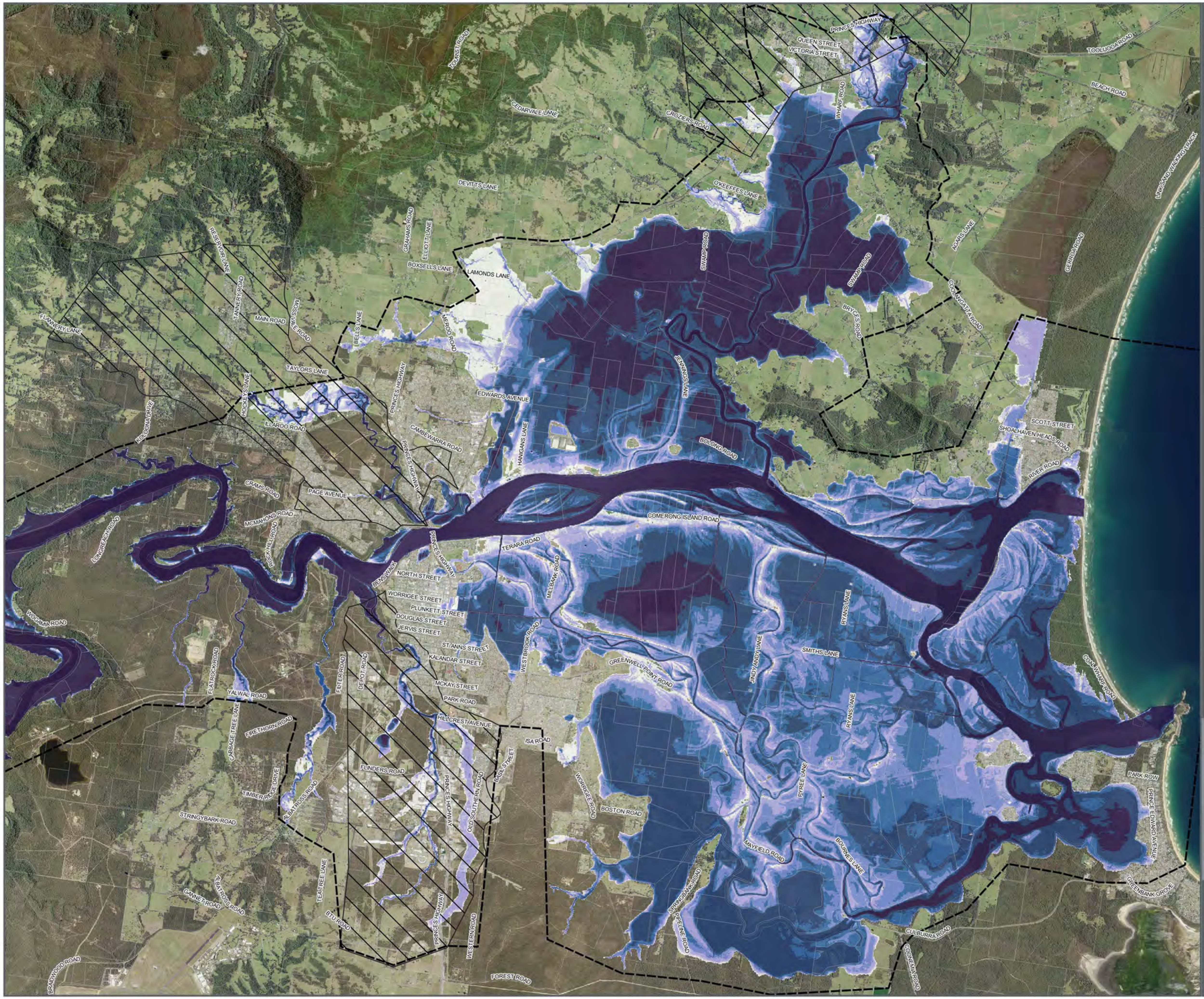
FIGURE G31

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 2% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

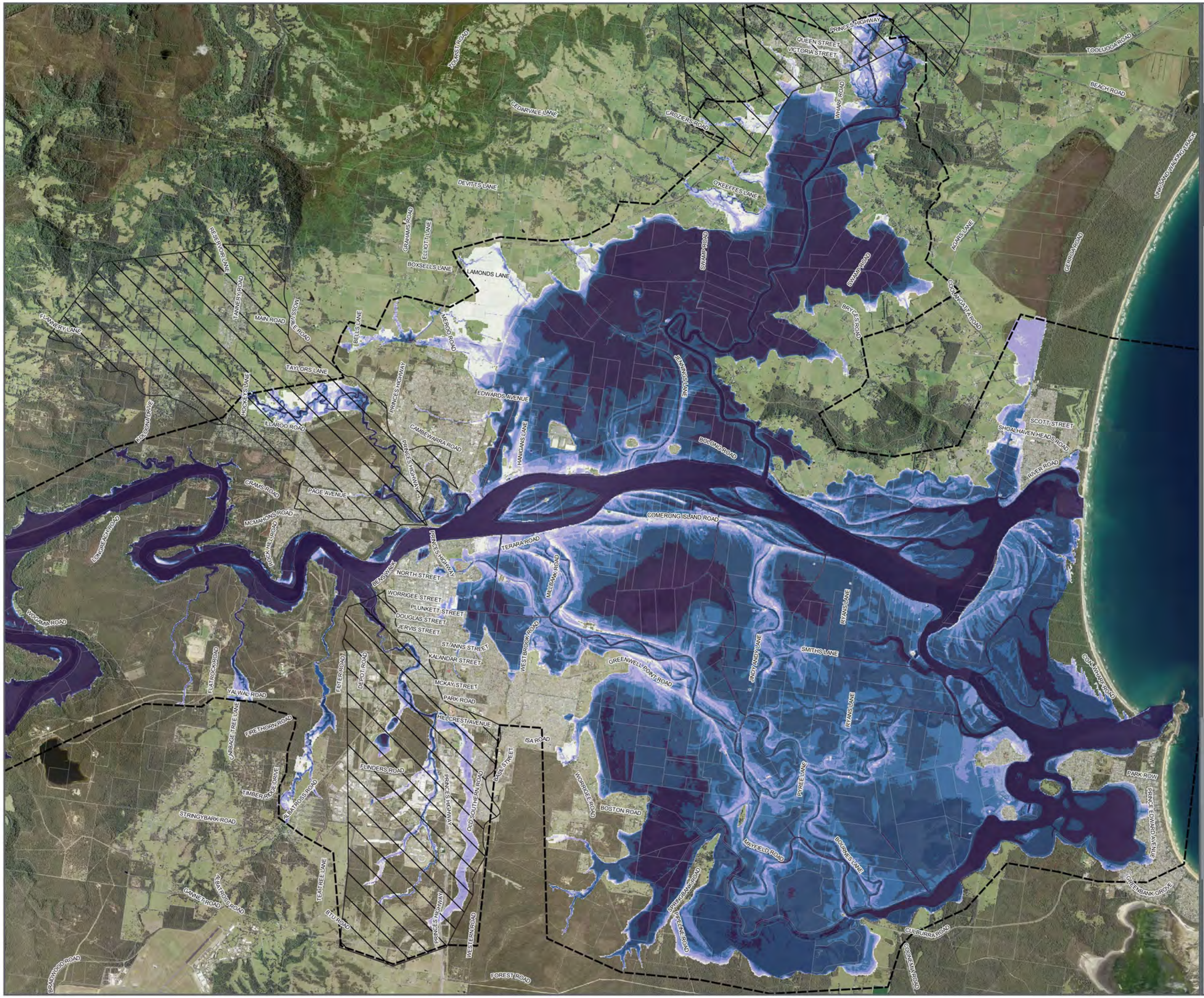
FIGURE G32

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

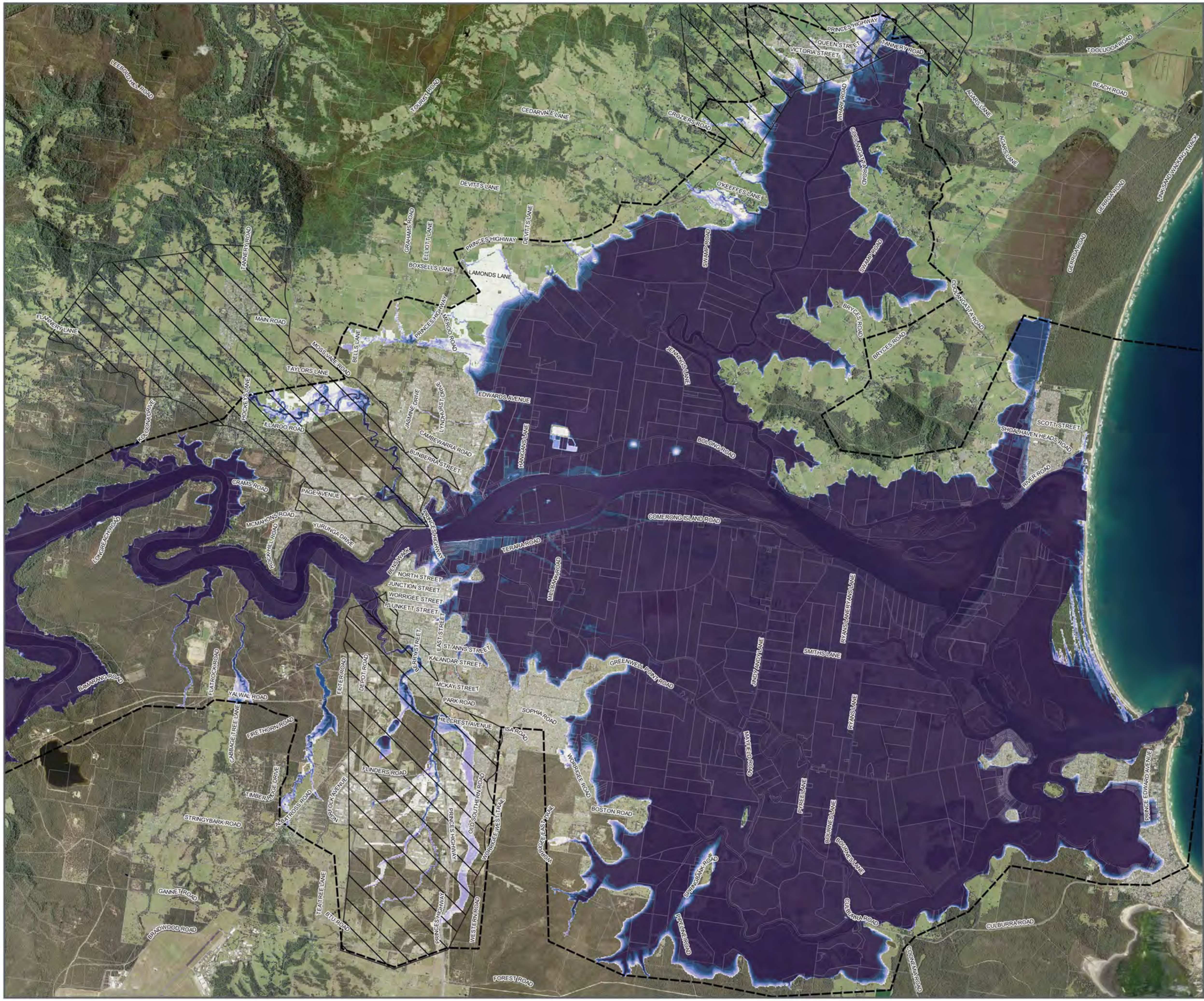
FIGURE G33

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

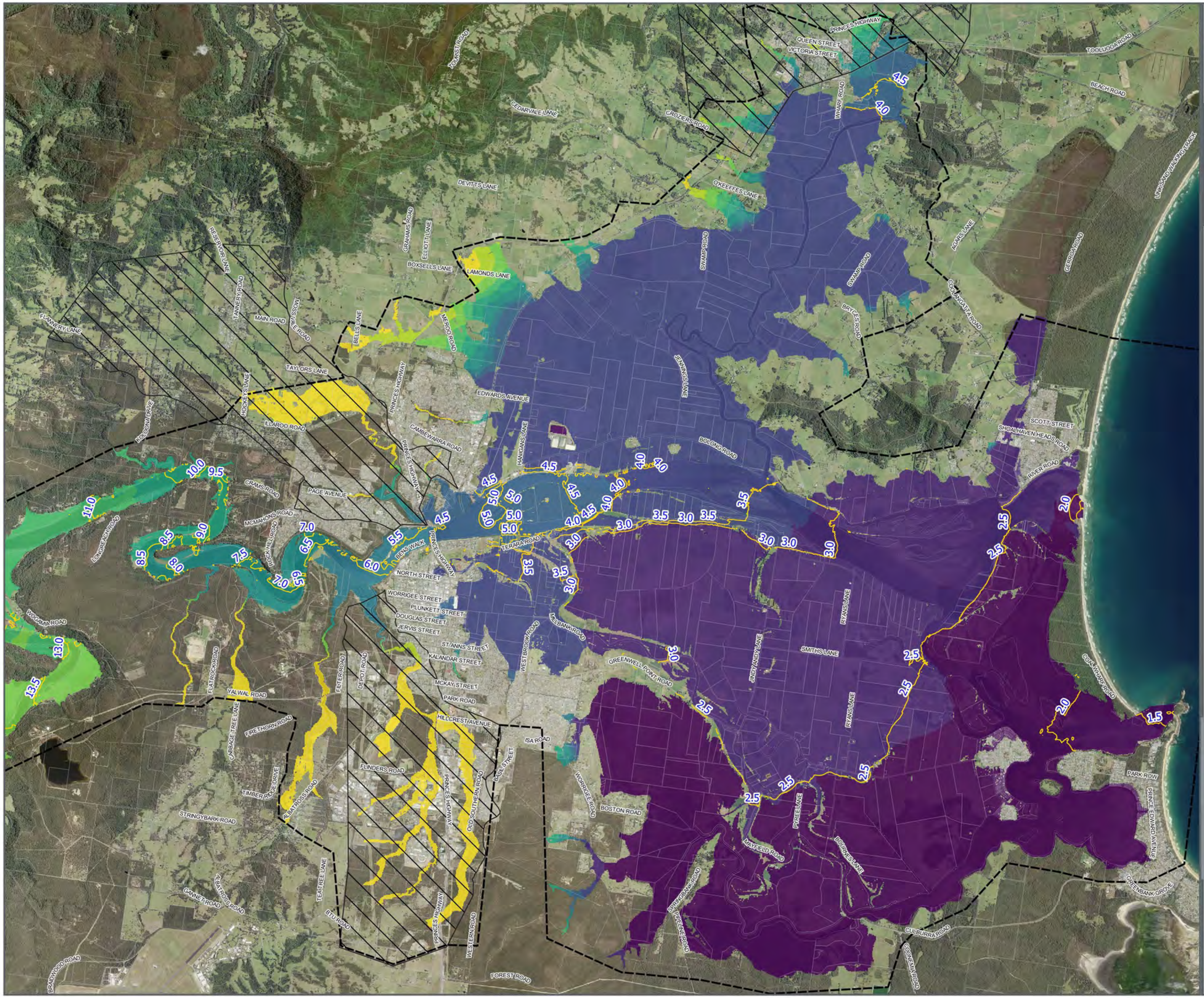
- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G34

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 5% AEP Water Level

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

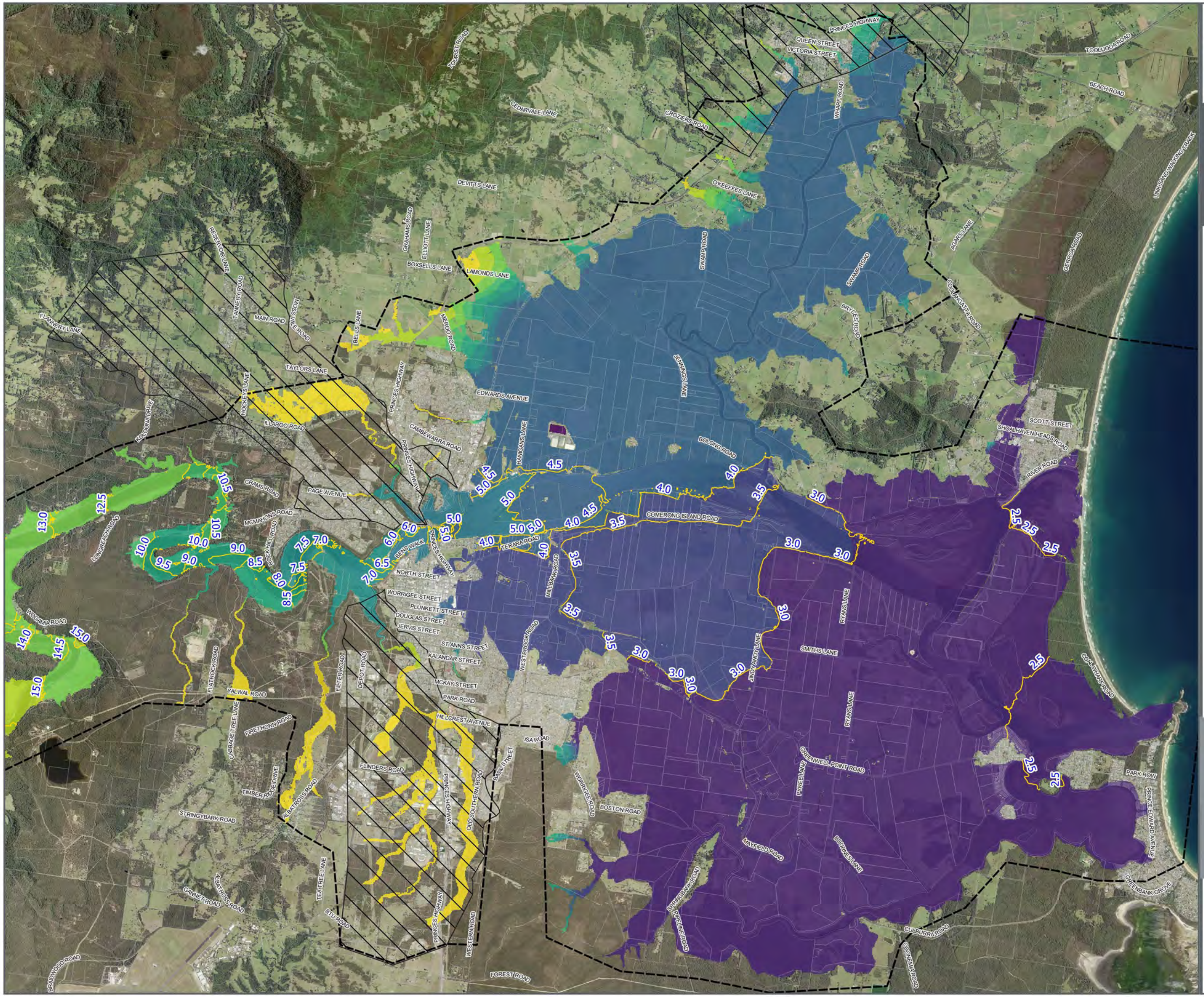
FIGURE G35

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
2% AEP Water Level

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

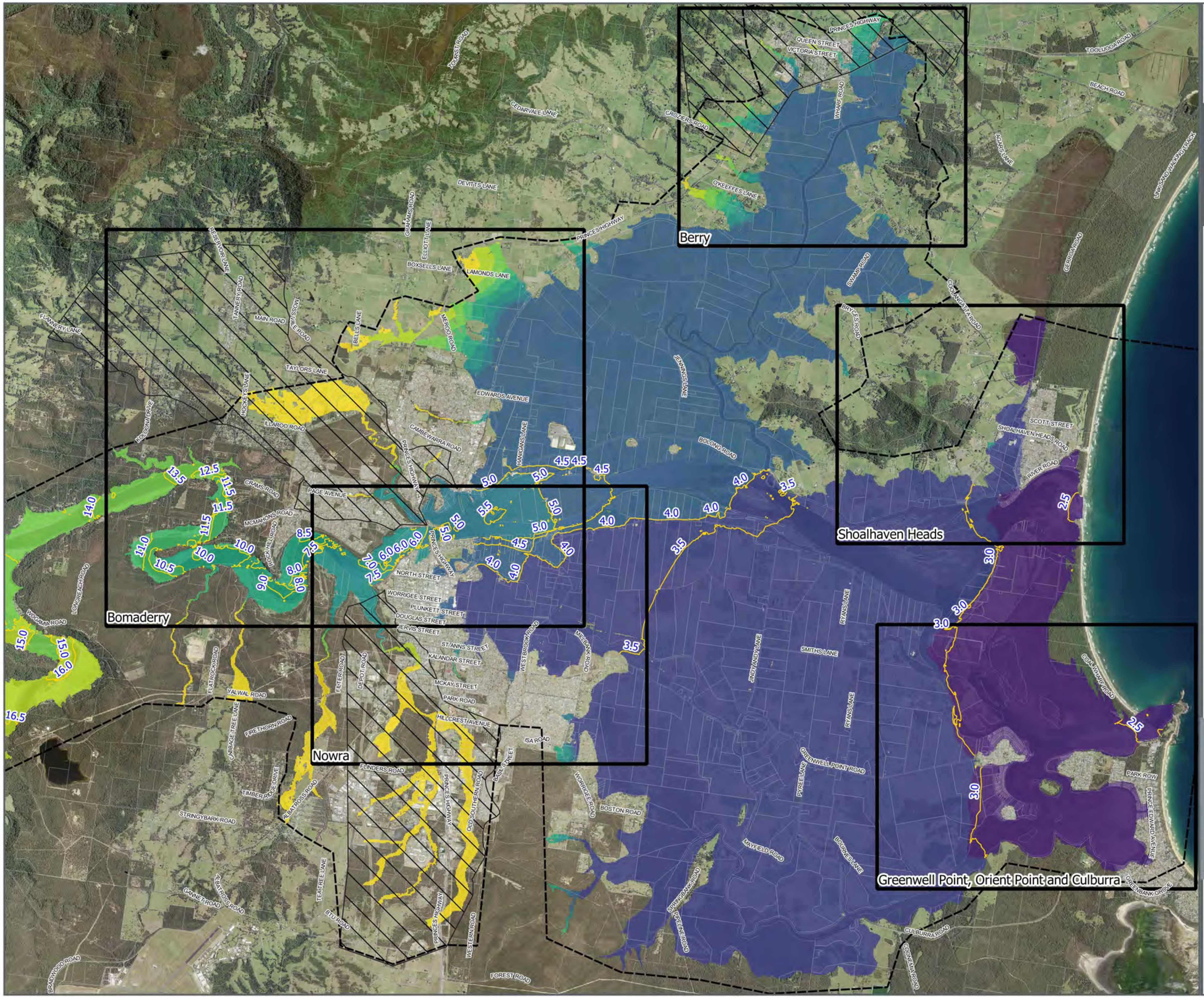
FIGURE G36

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Water Level Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G37

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 1% AEP Water Level Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

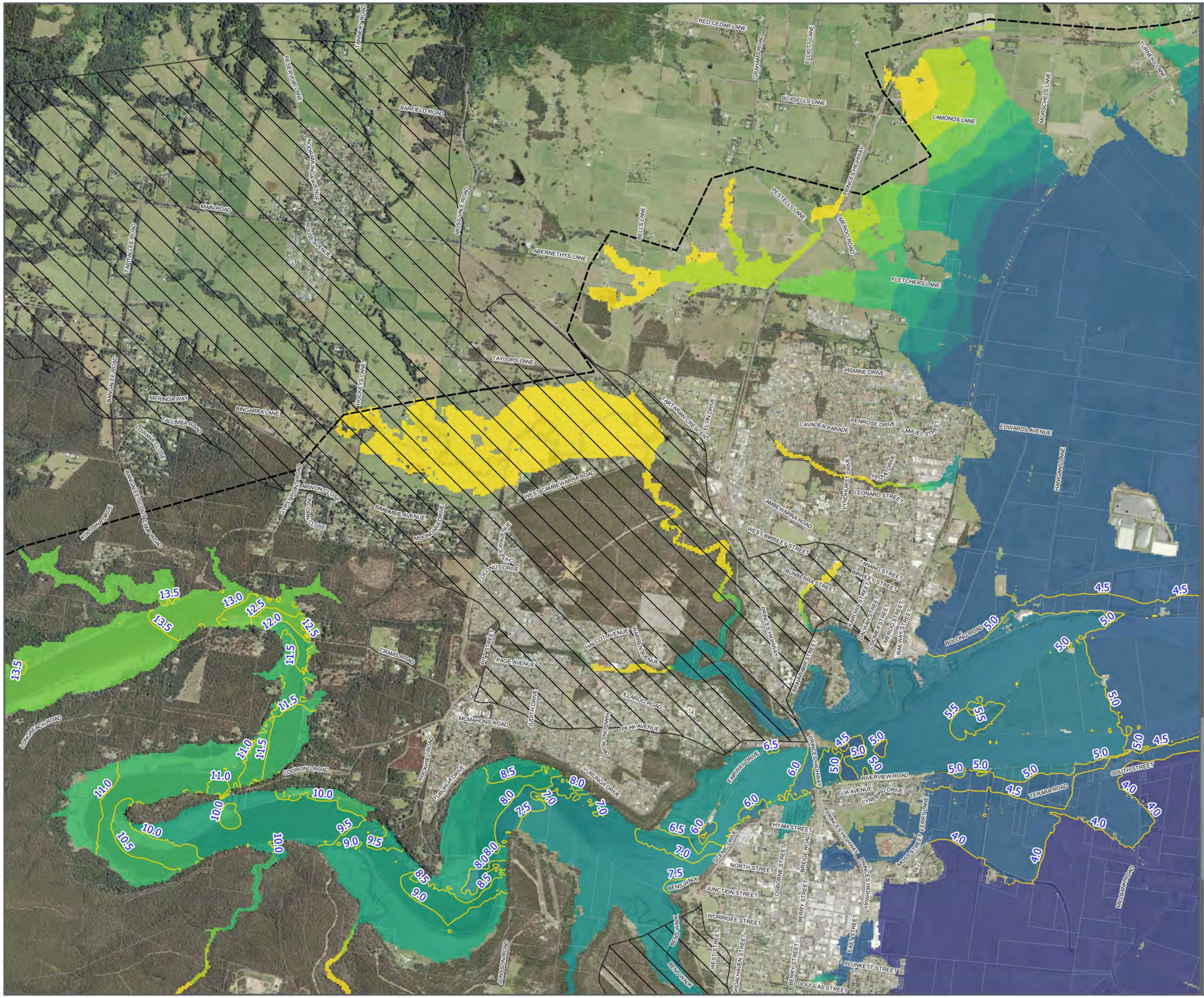
FIGURE G37.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Water Level
Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

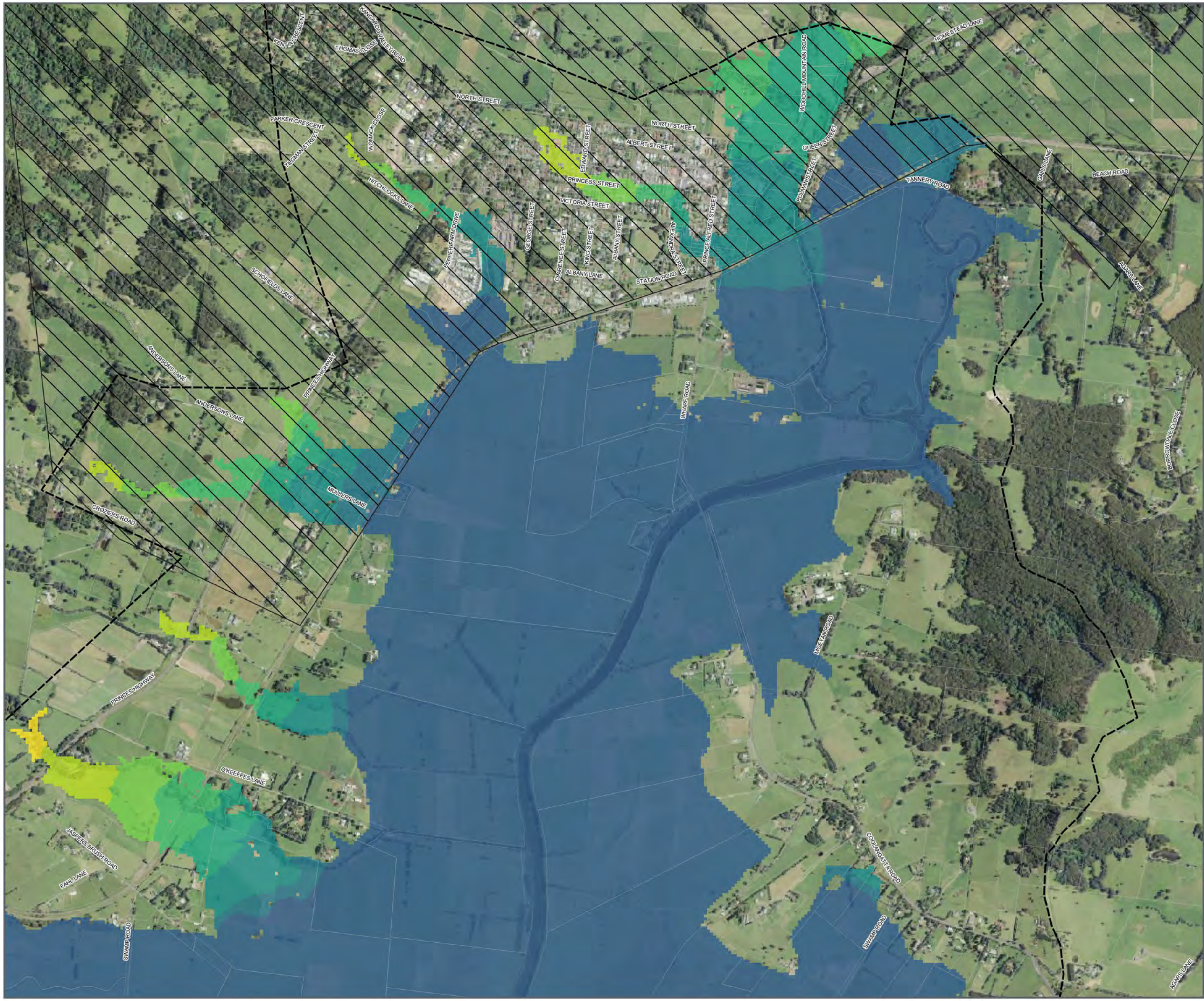
FIGURE G37.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Water Level Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G37.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050
1% AEP Water Level
Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G37.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 1% AEP Water Level Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

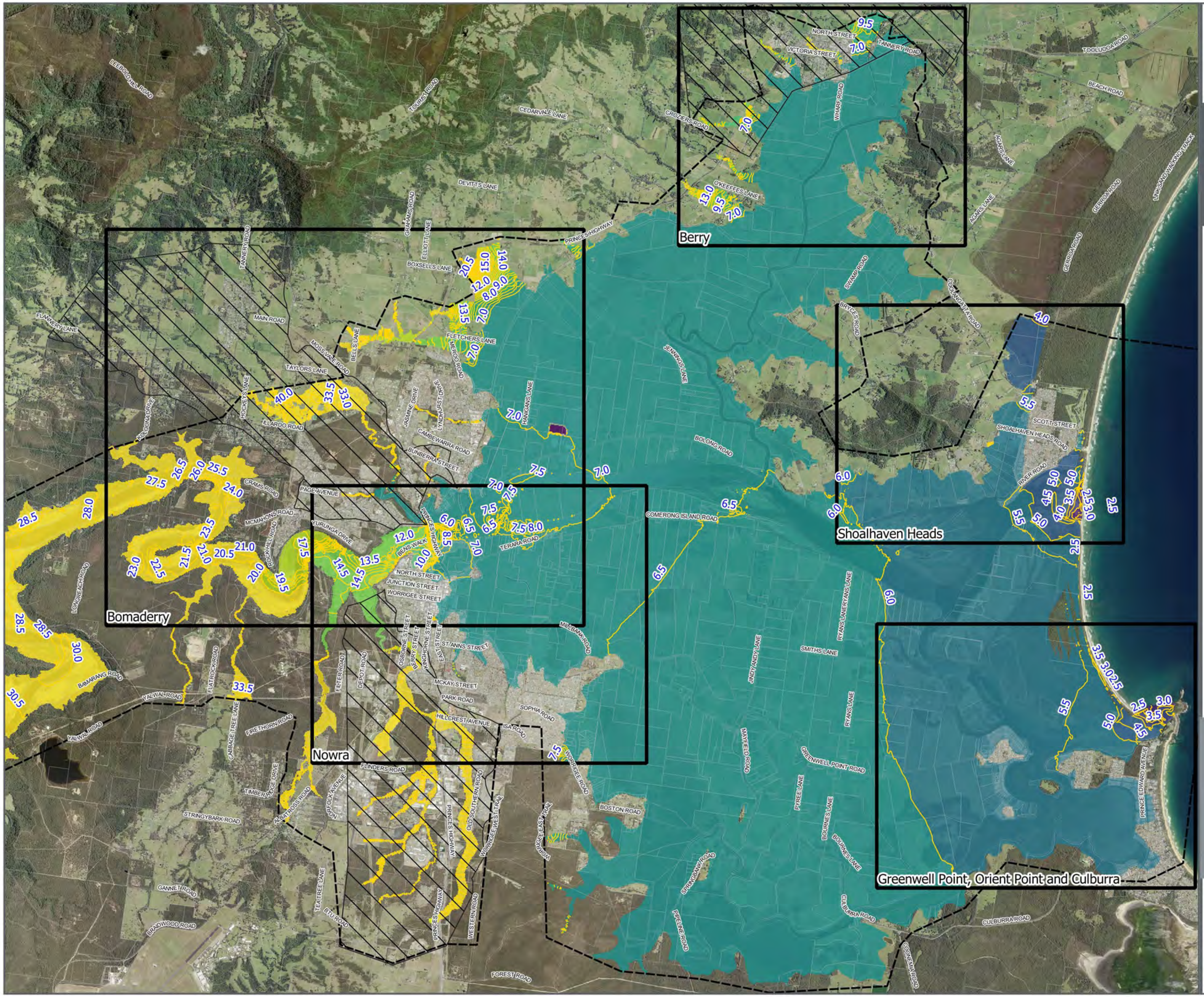
FIGURE G37.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Water Level Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G38

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 PMF Water Level Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

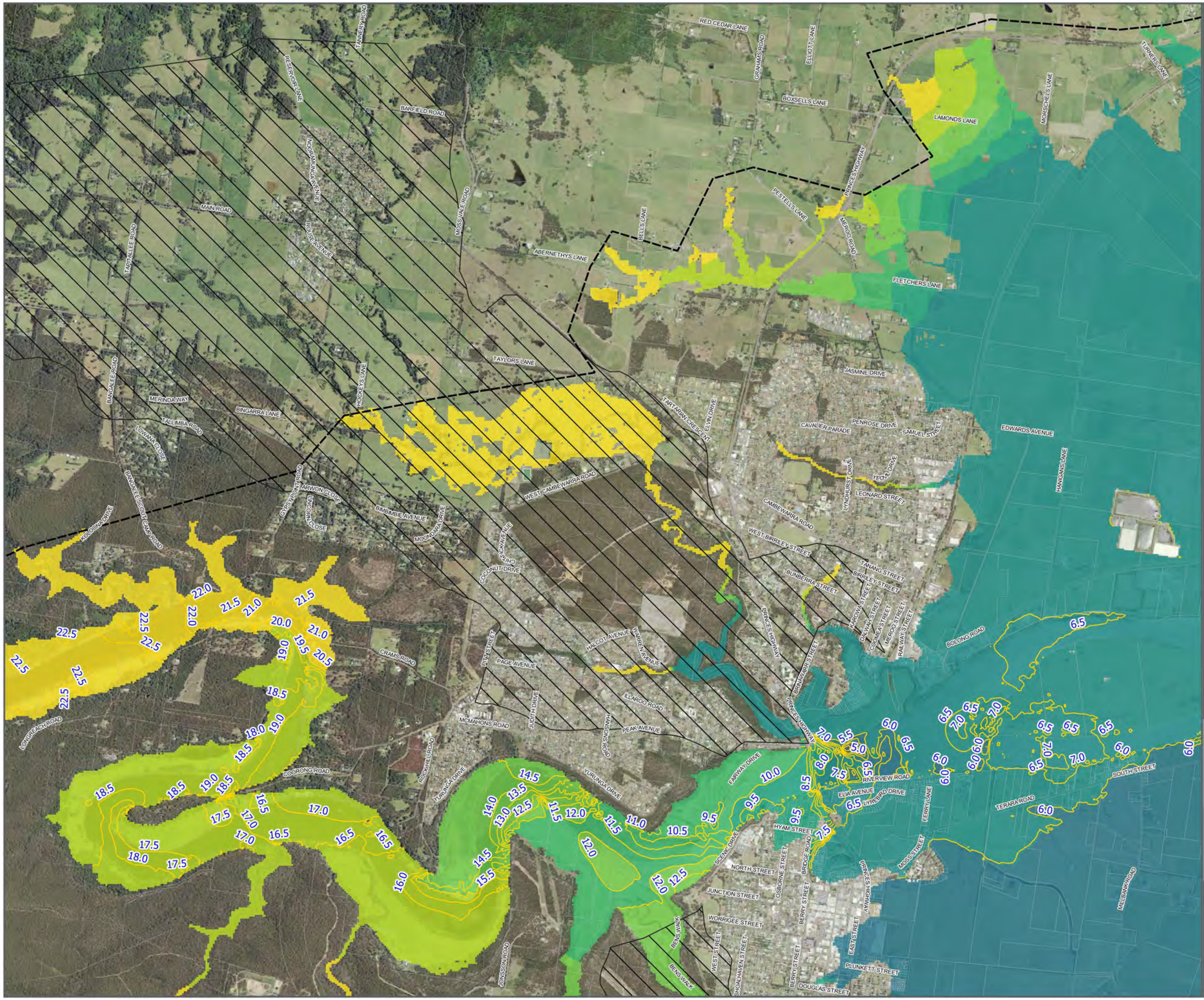
FIGURE G38.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Water Level Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

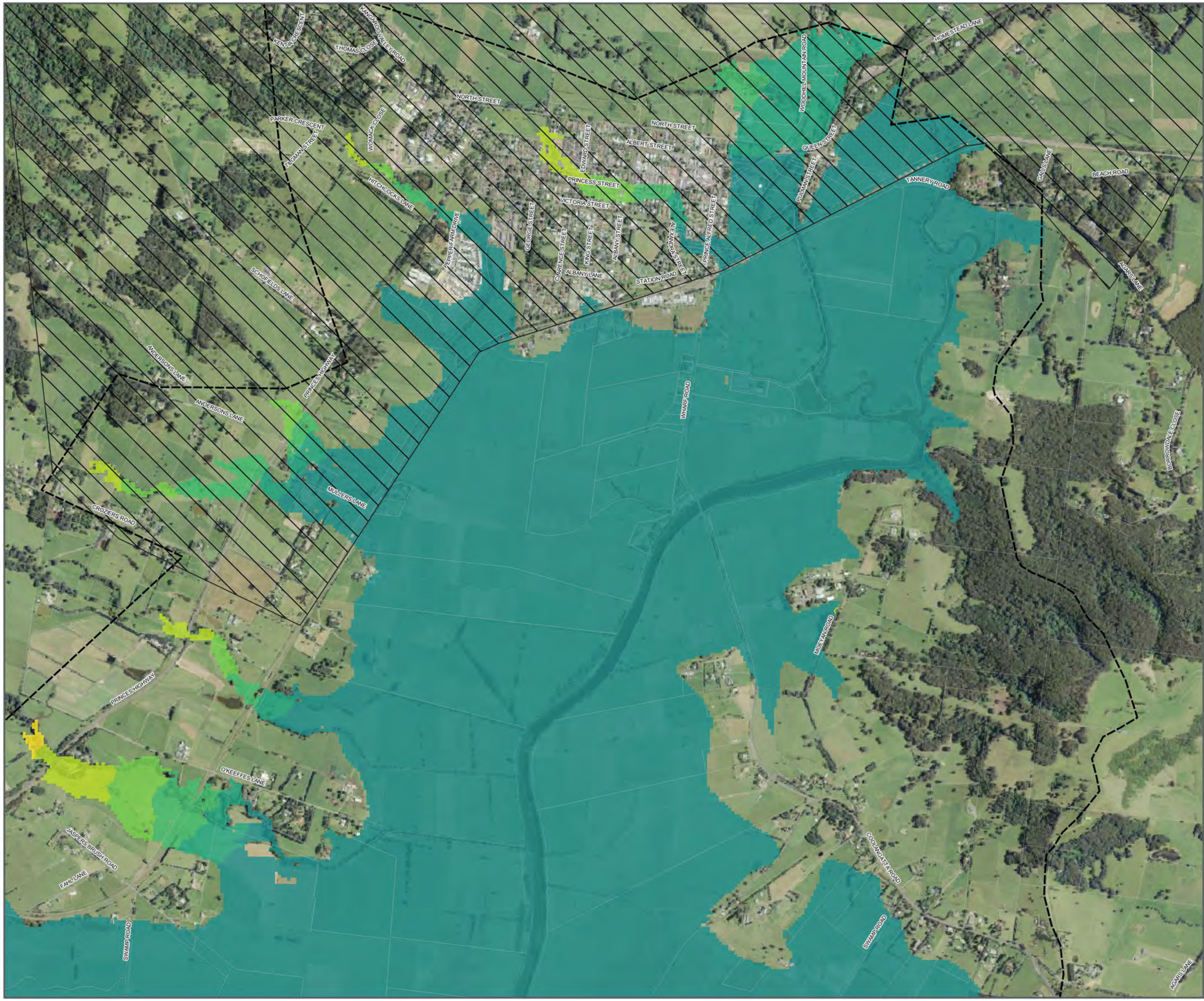
FIGURE G38.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Water Level Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G38.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 PMF Water Level Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

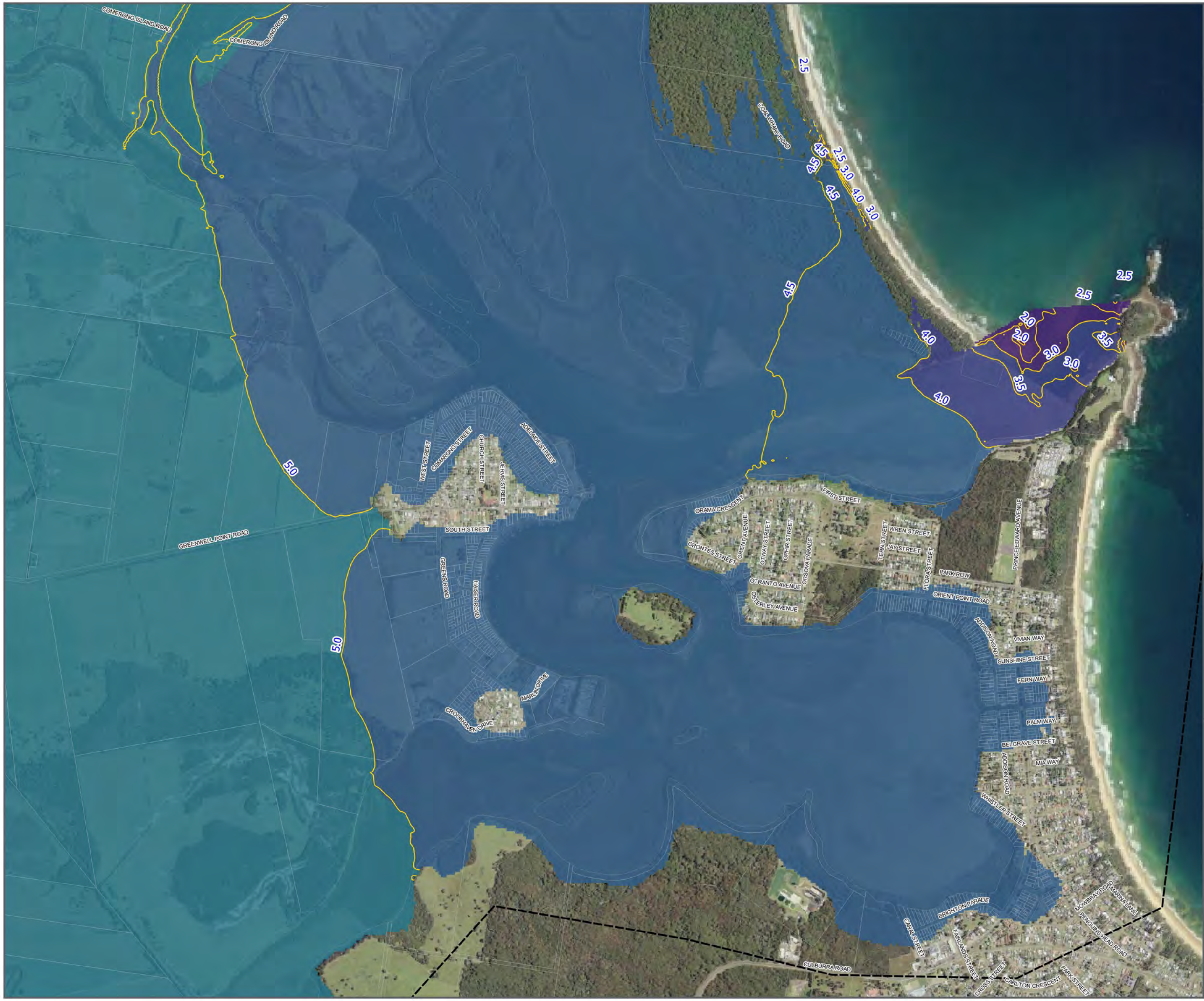
FIGURE G38.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Water Level Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G38.5

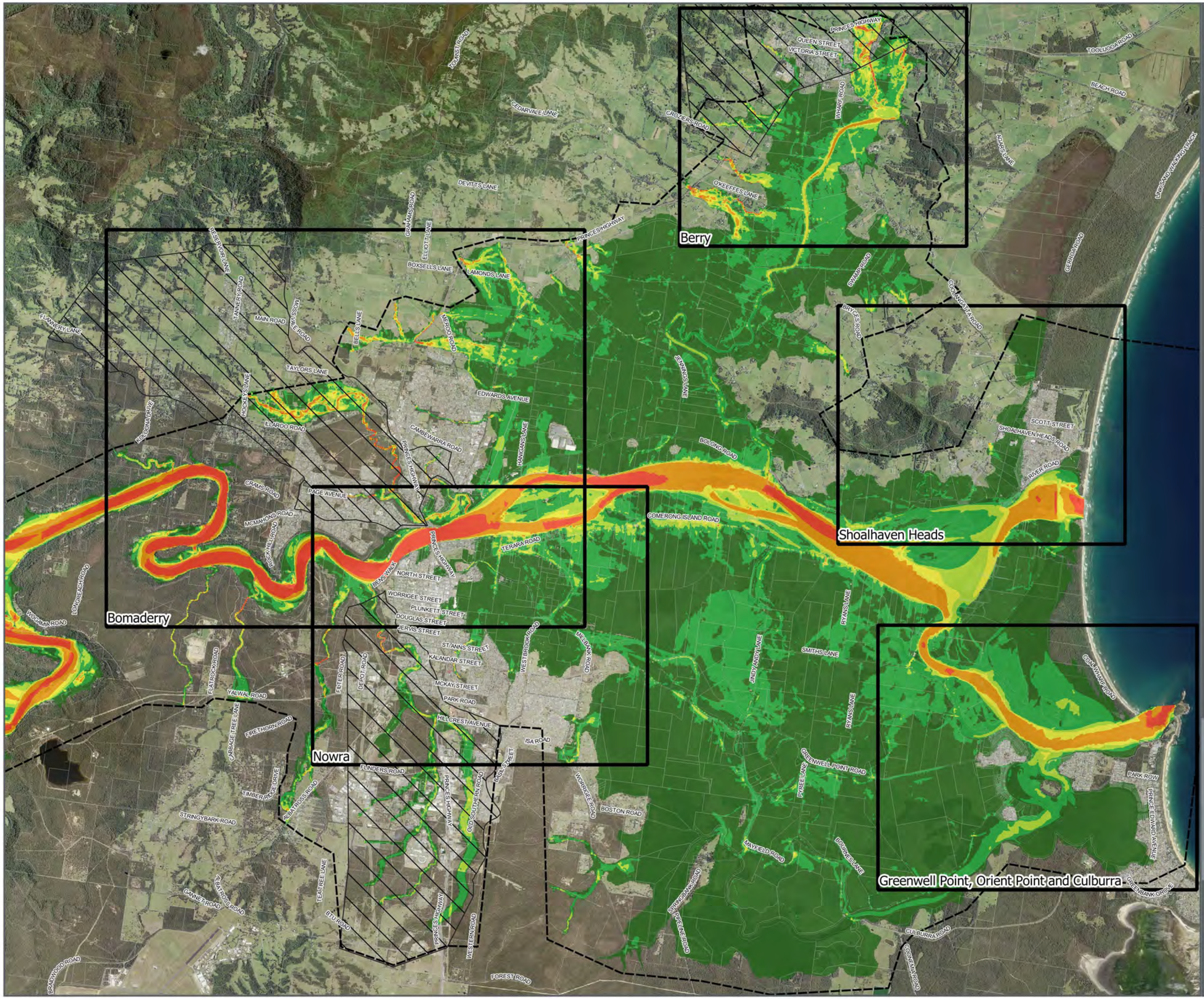
1:20,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Velocity Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

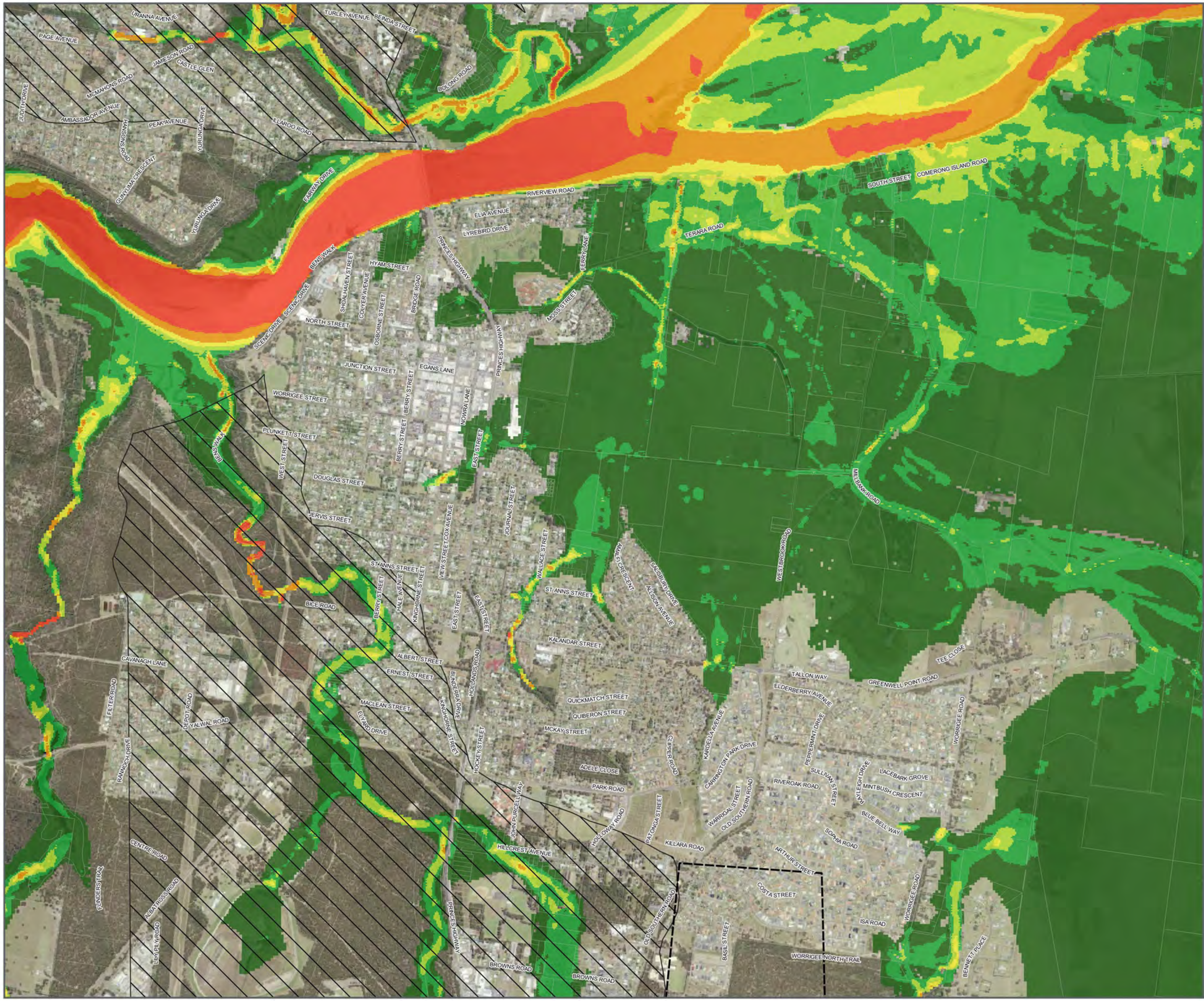
FIGURE G39

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Velocity
Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

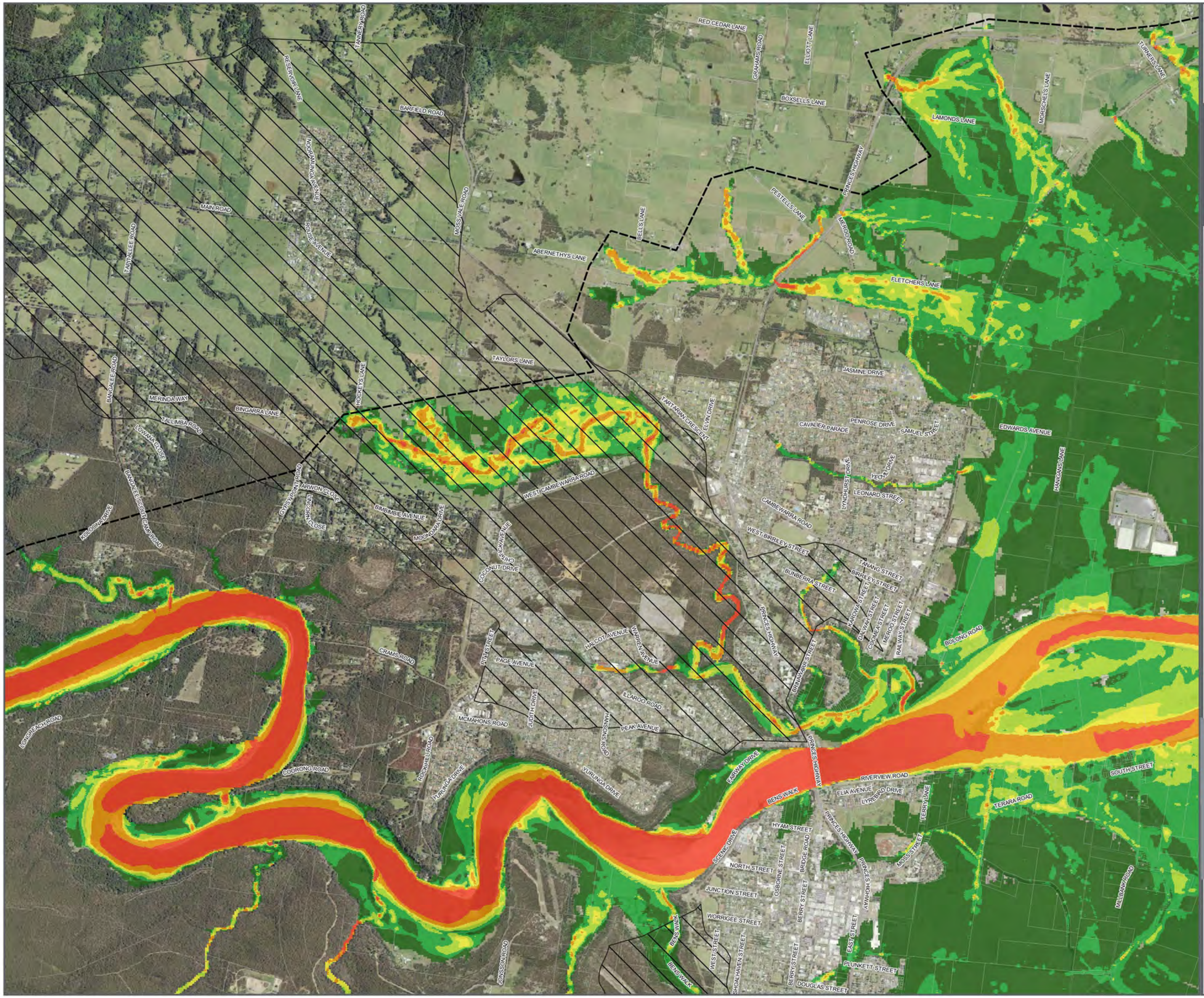
FIGURE G39.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Velocity Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

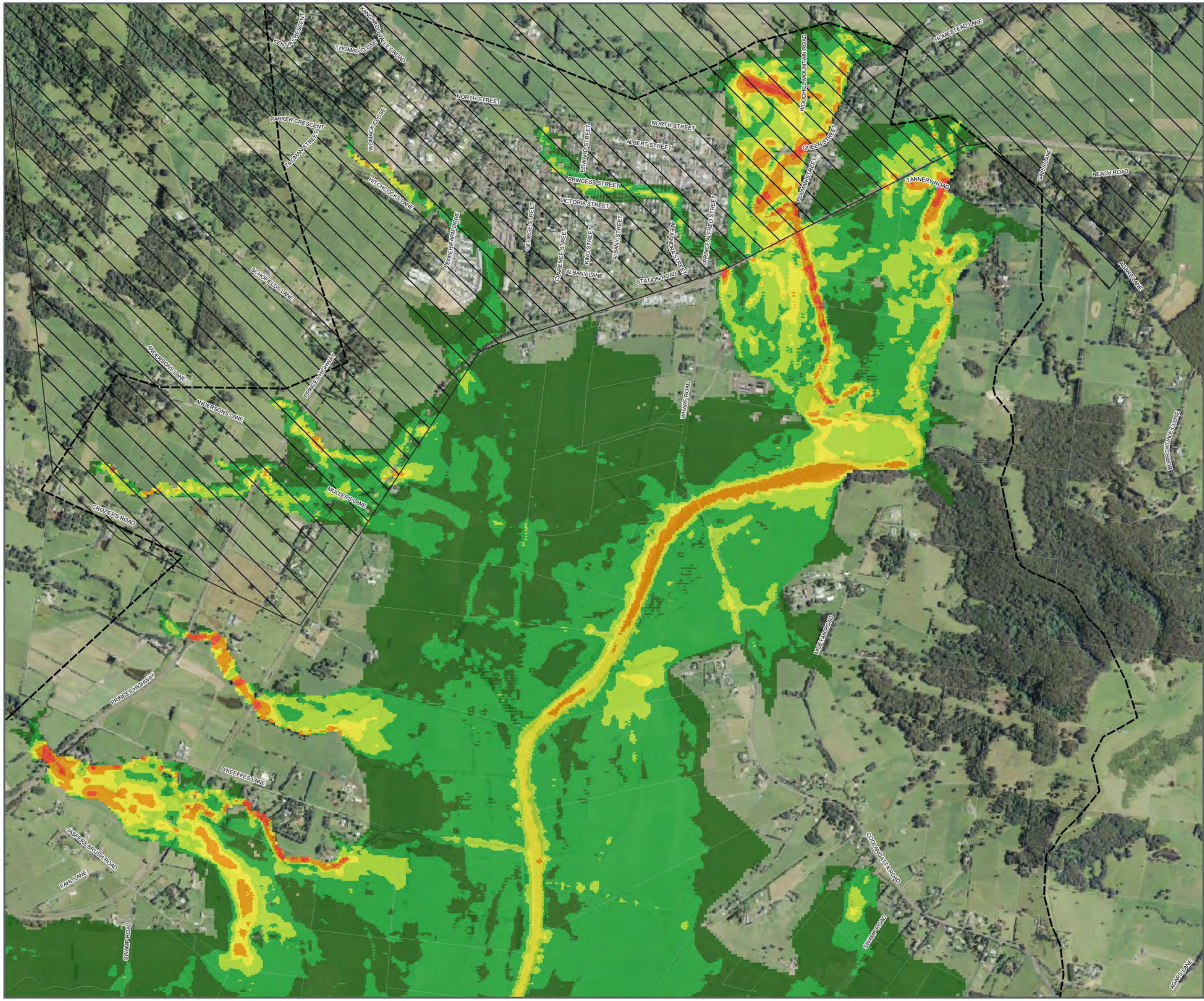
FIGURE G39.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Velocity Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

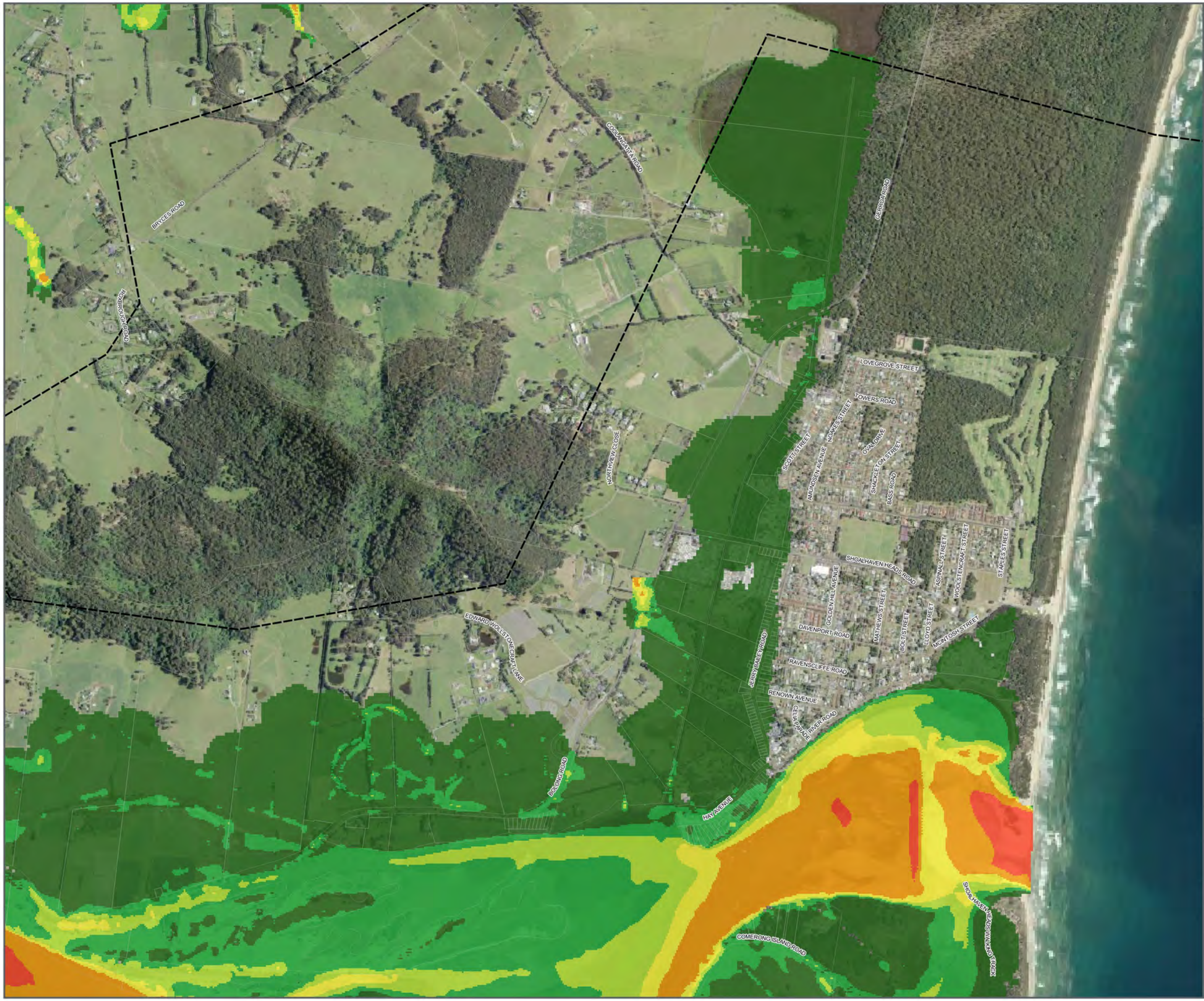
FIGURE G39.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Velocity Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G39.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 1% AEP Velocity Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

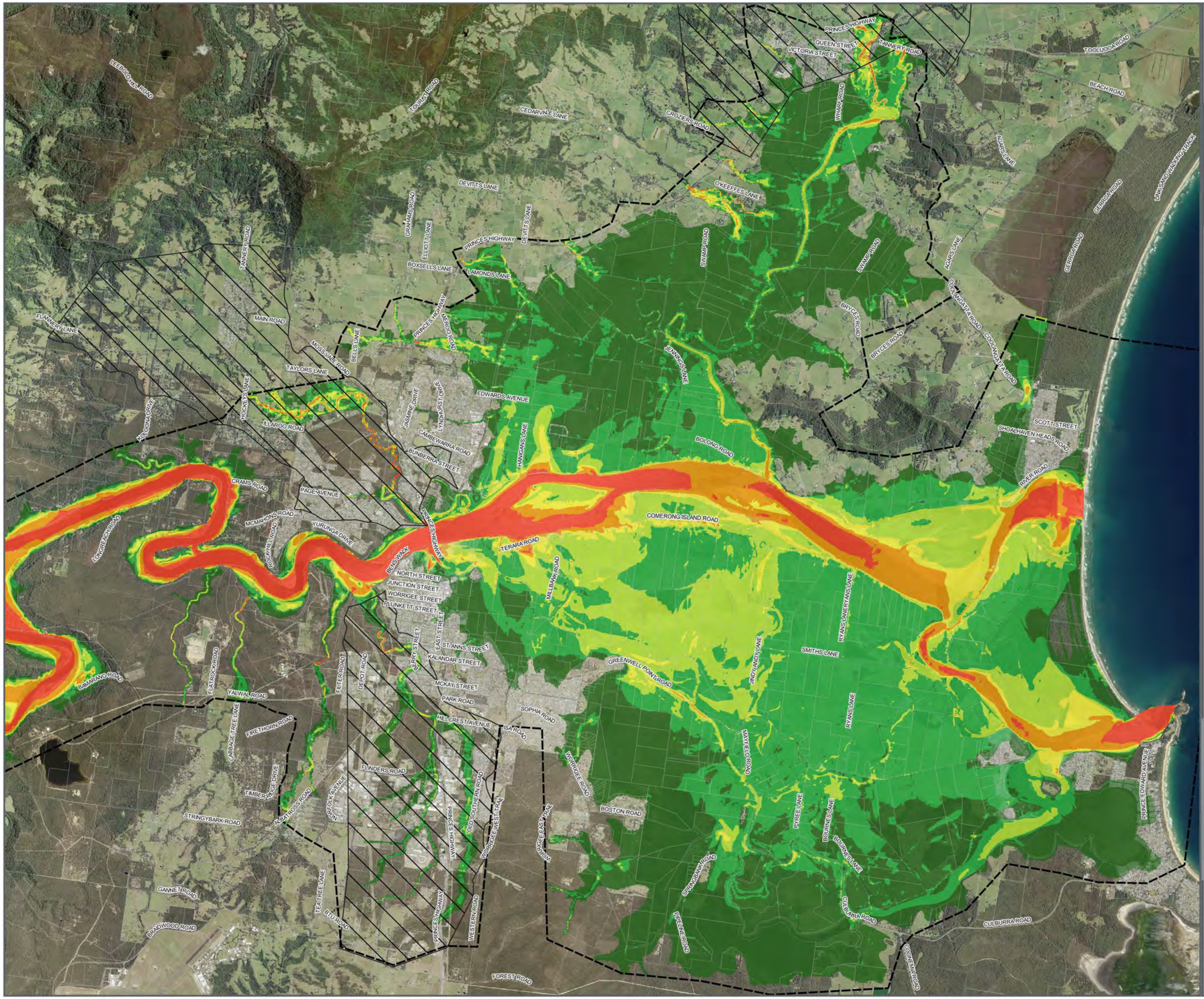
FIGURE G39.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Velocity

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

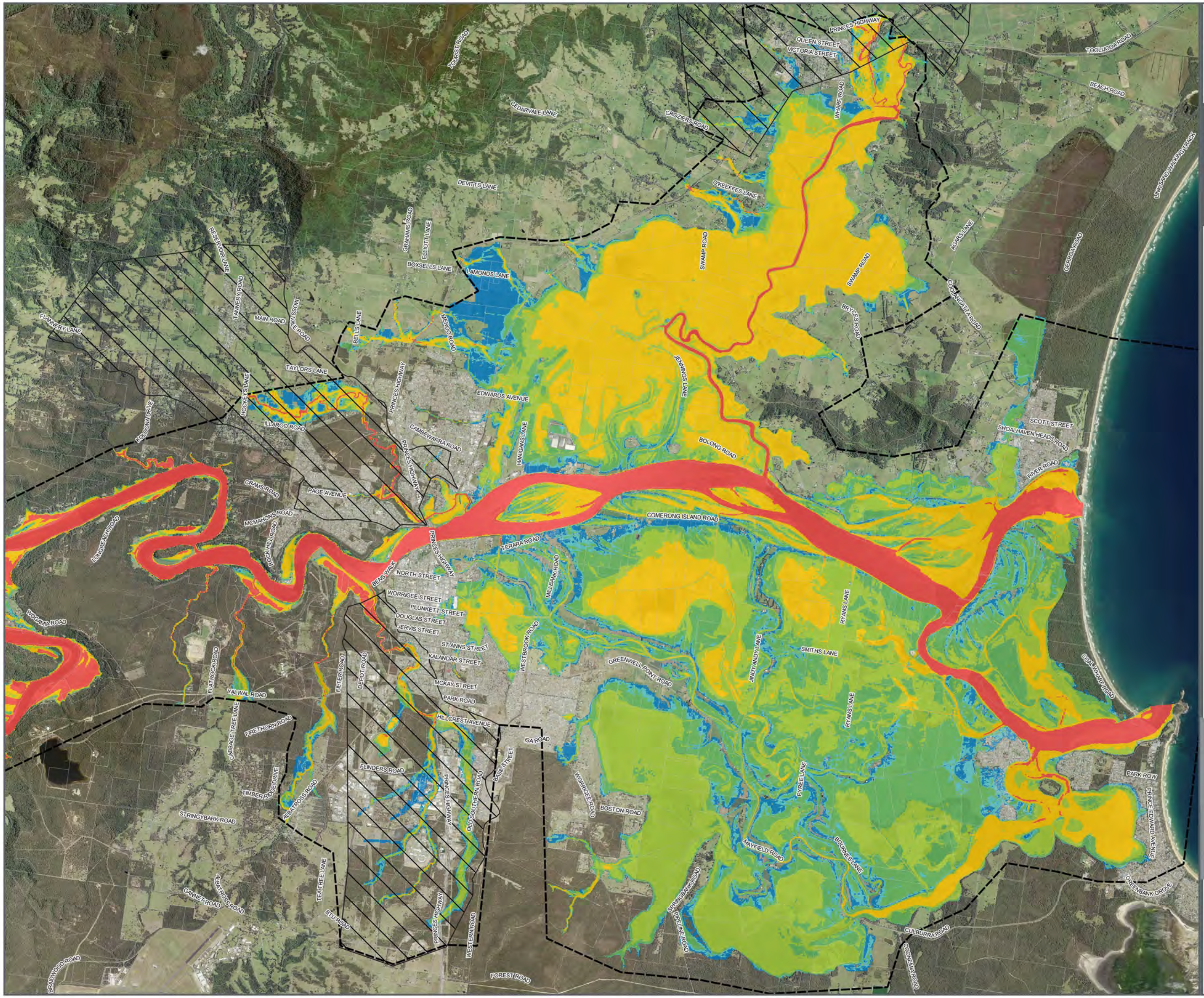
- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G40

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 5% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

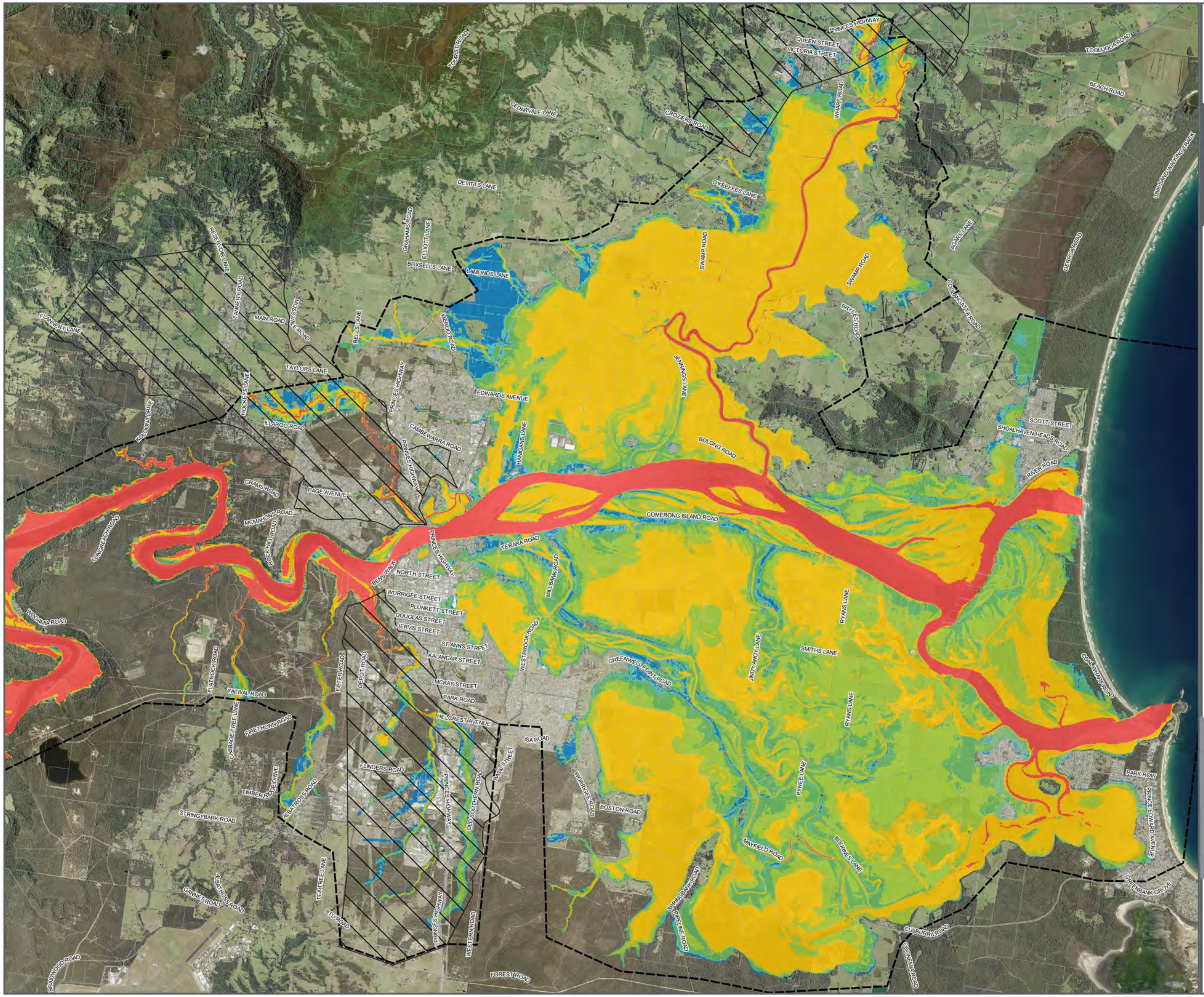
FIGURE G41

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
2% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

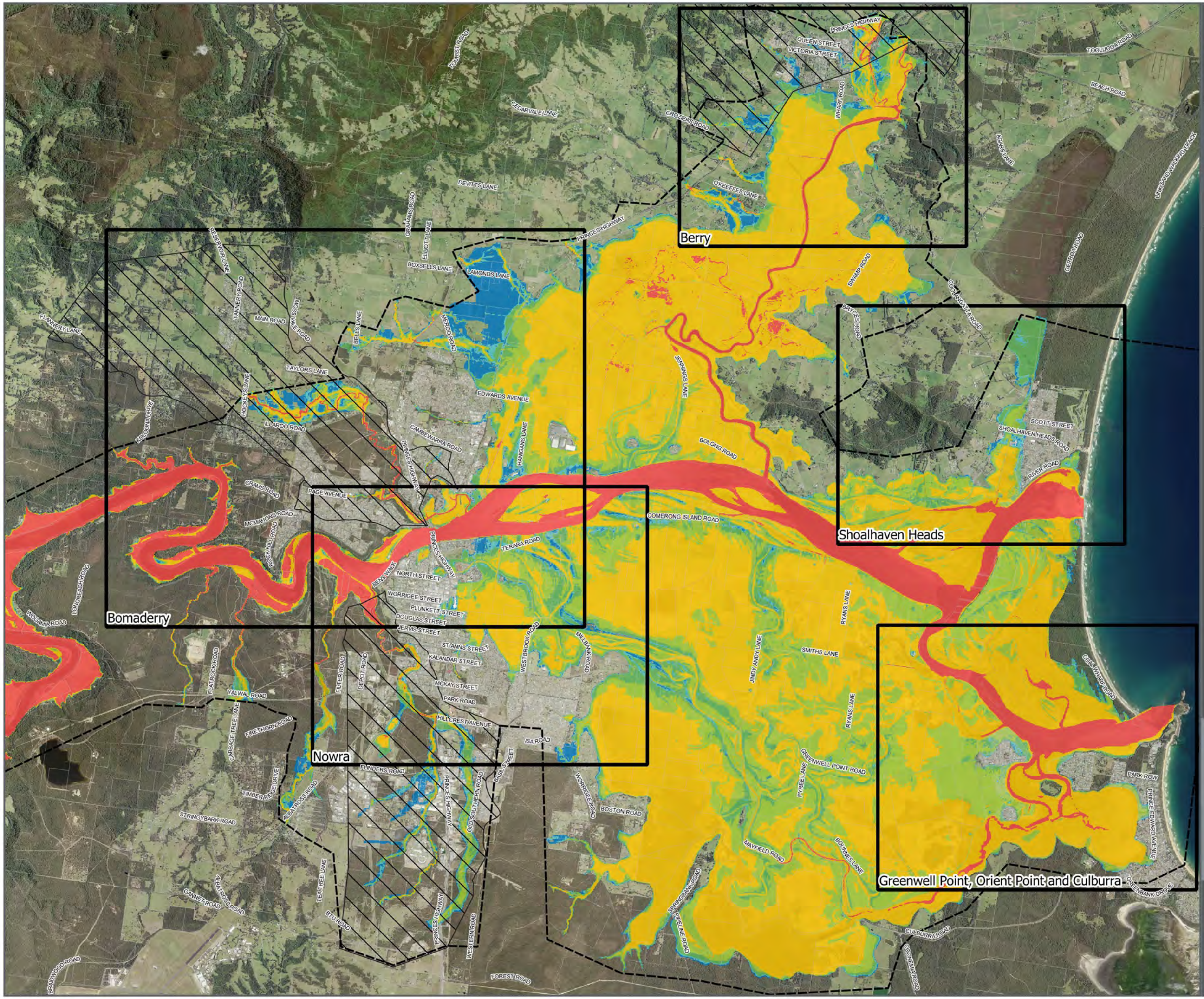
FIGURE G42

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Hazard Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

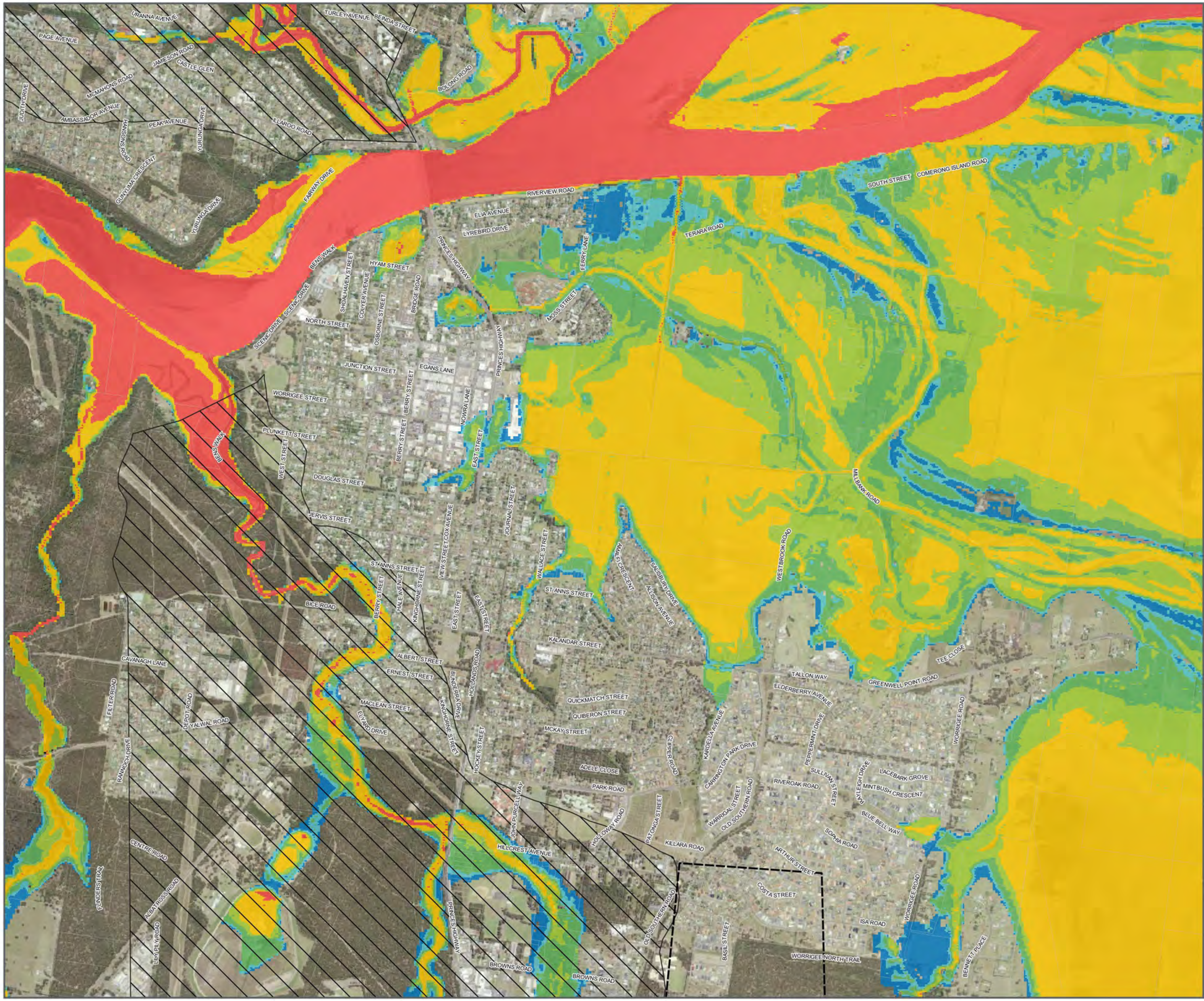
FIGURE G43

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Hazard Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G43.1

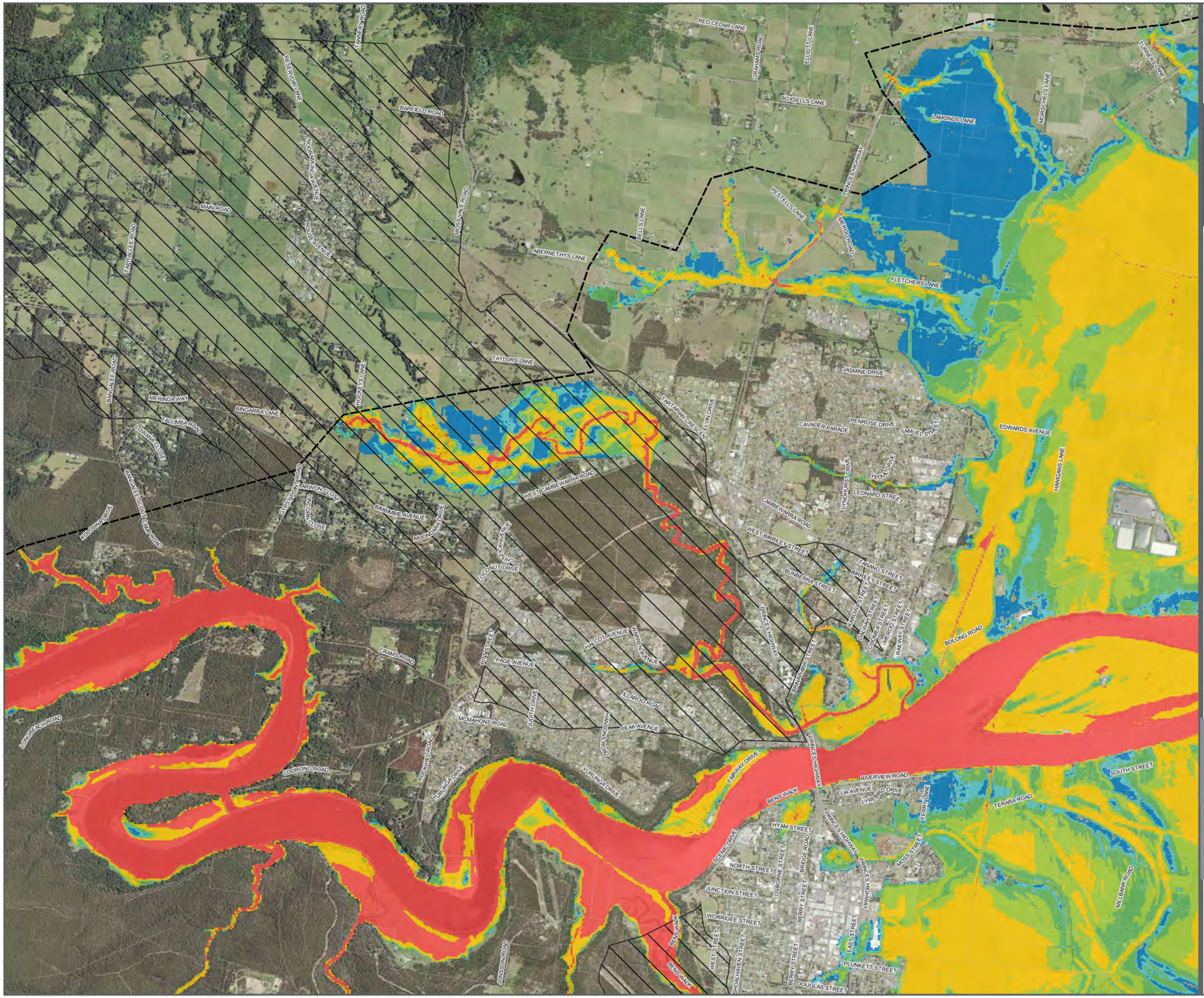
1:21,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Hazard
Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G43.2

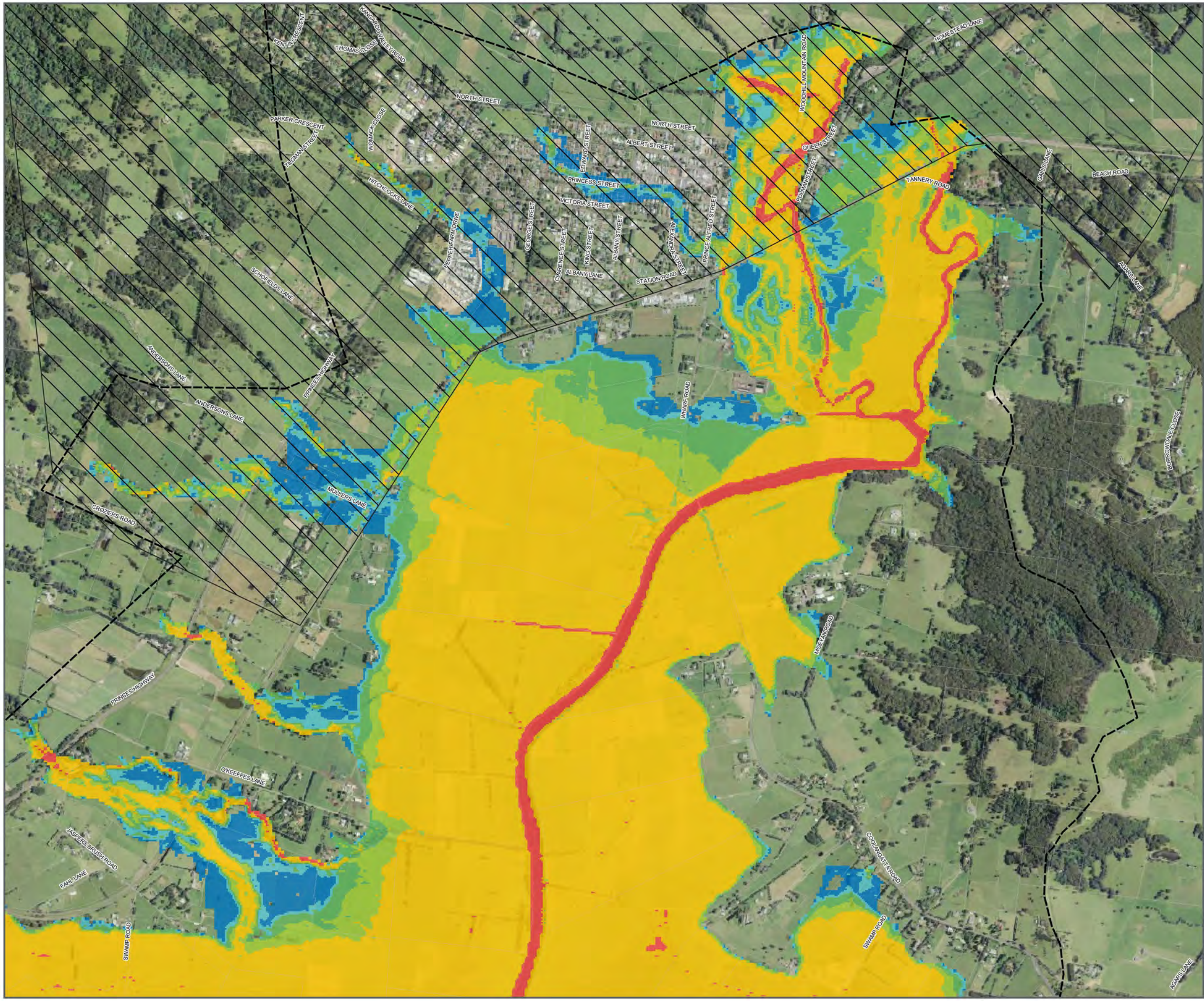
1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Hazard
Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

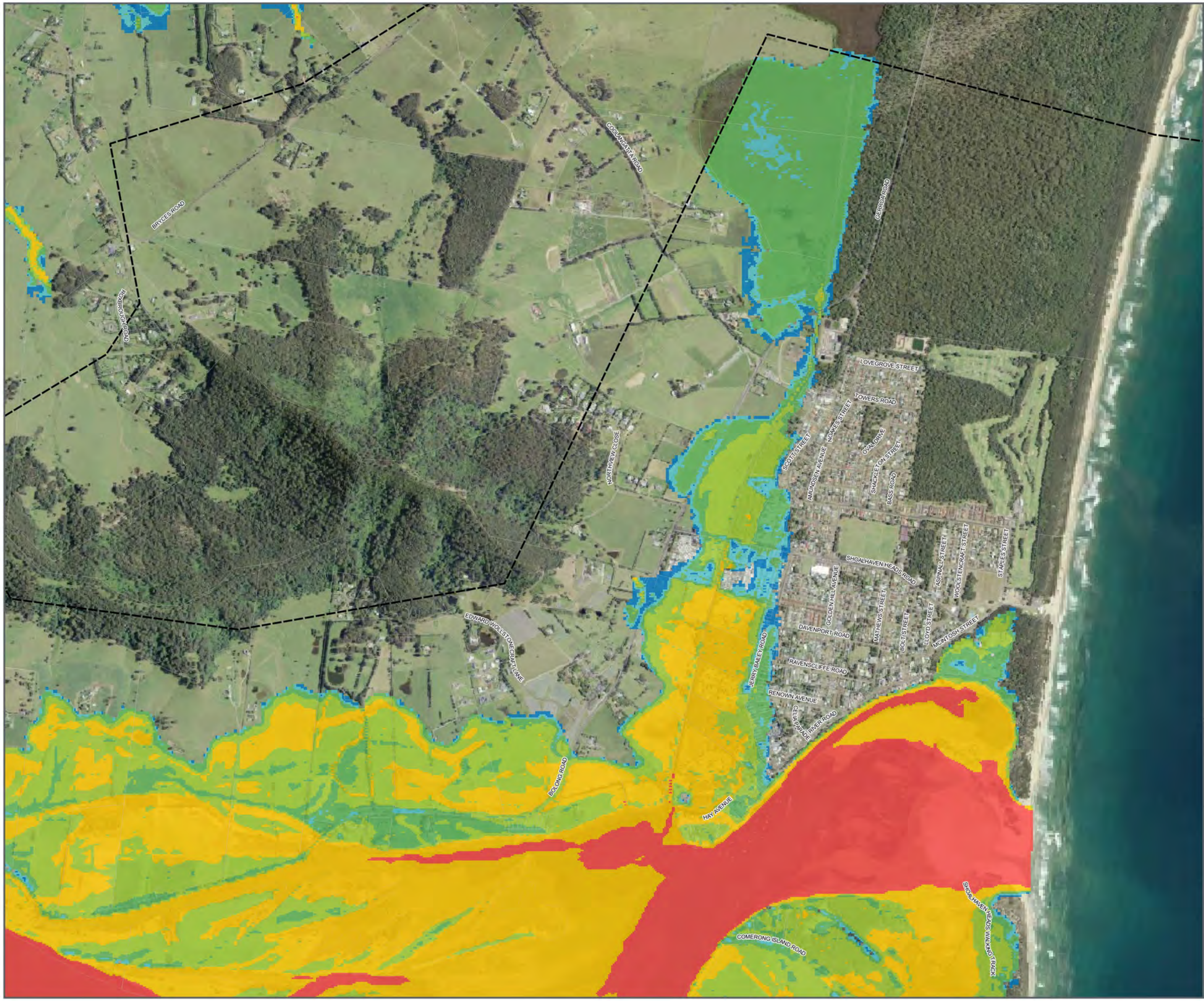
FIGURE G43.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Hazard Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

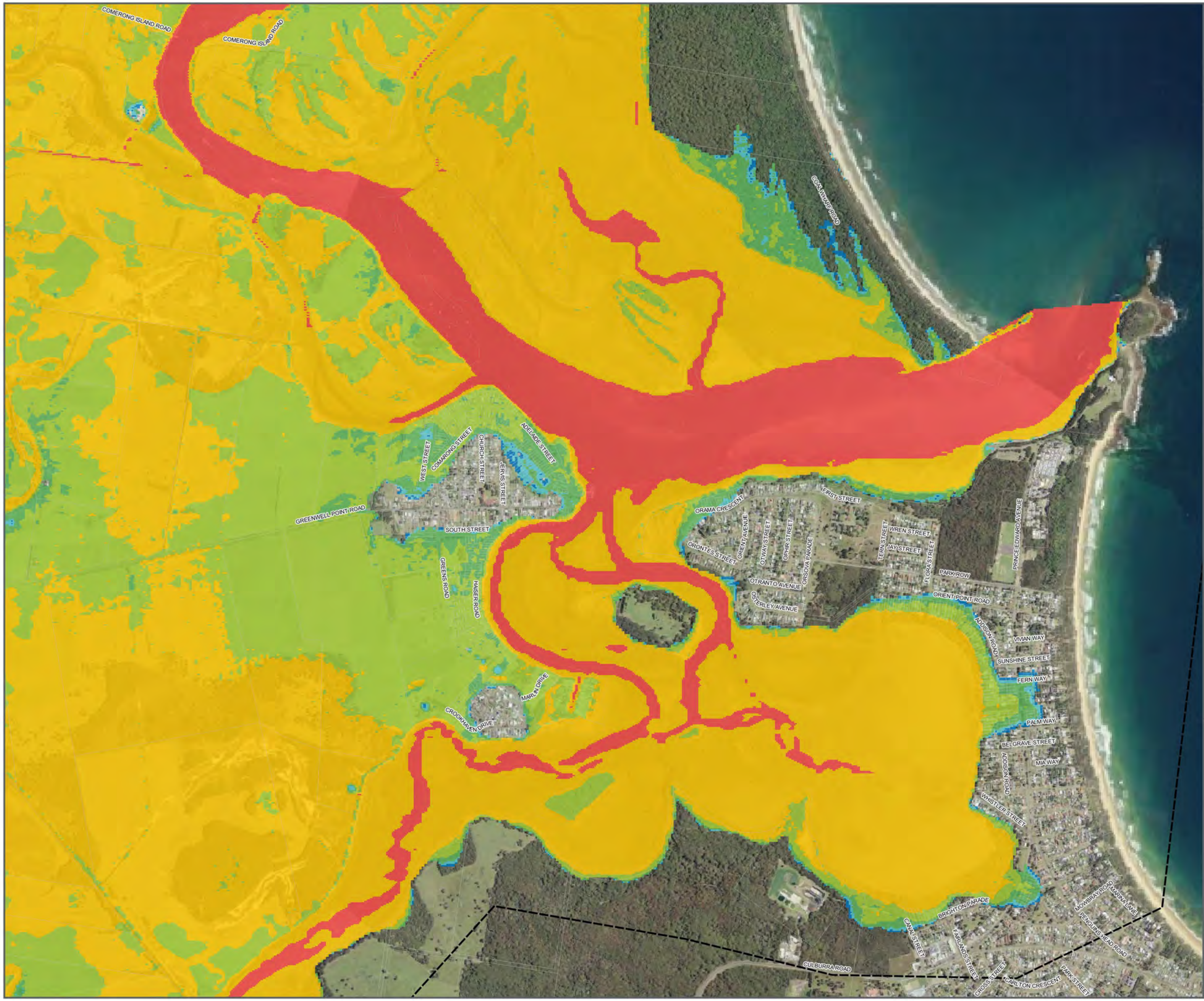
FIGURE G43.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Hazard Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

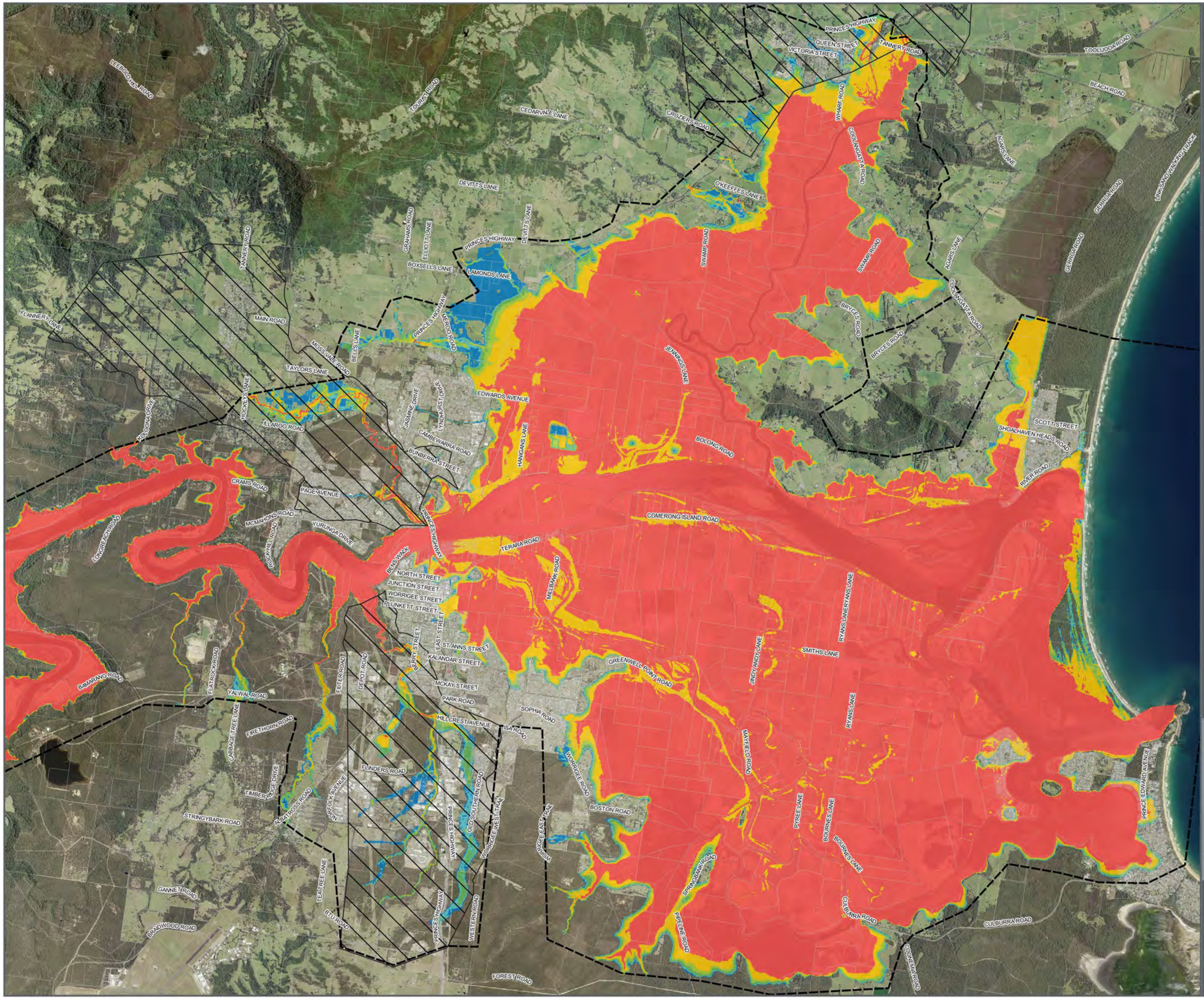
FIGURE G43.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

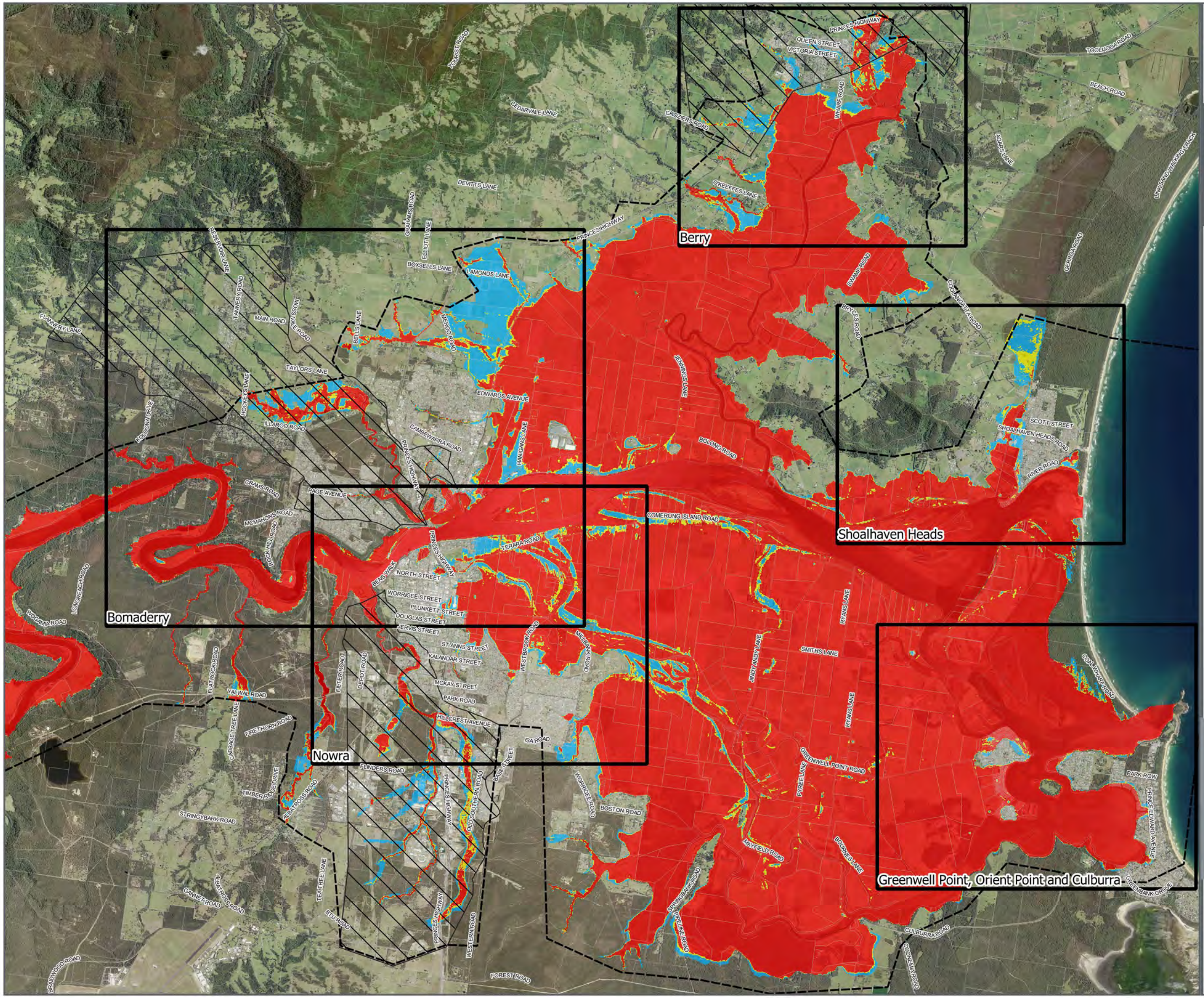
FIGURE G44

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Provisional Hazard Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

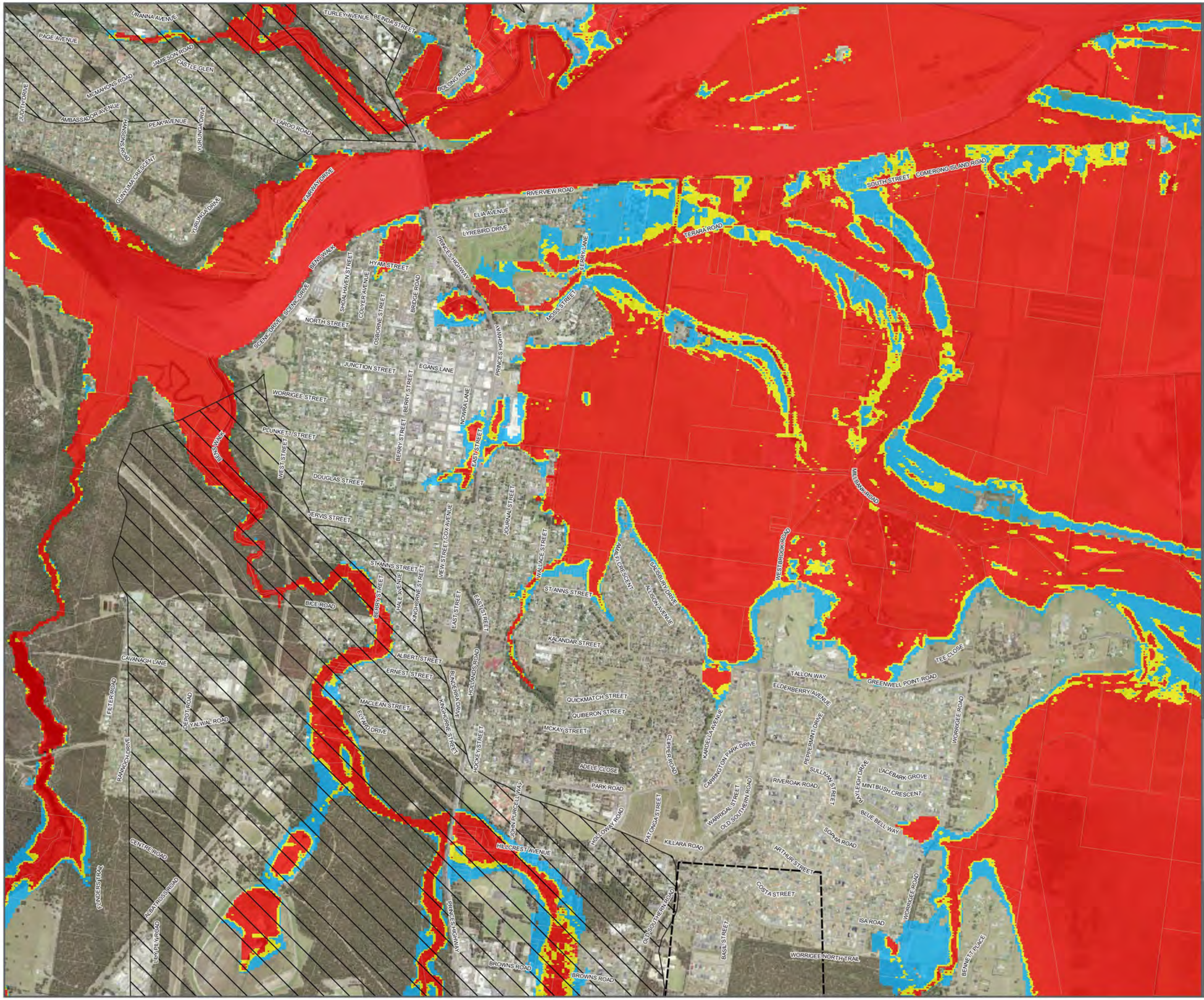
FIGURE G45

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Provisional Hazard
Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

FIGURE G45.1

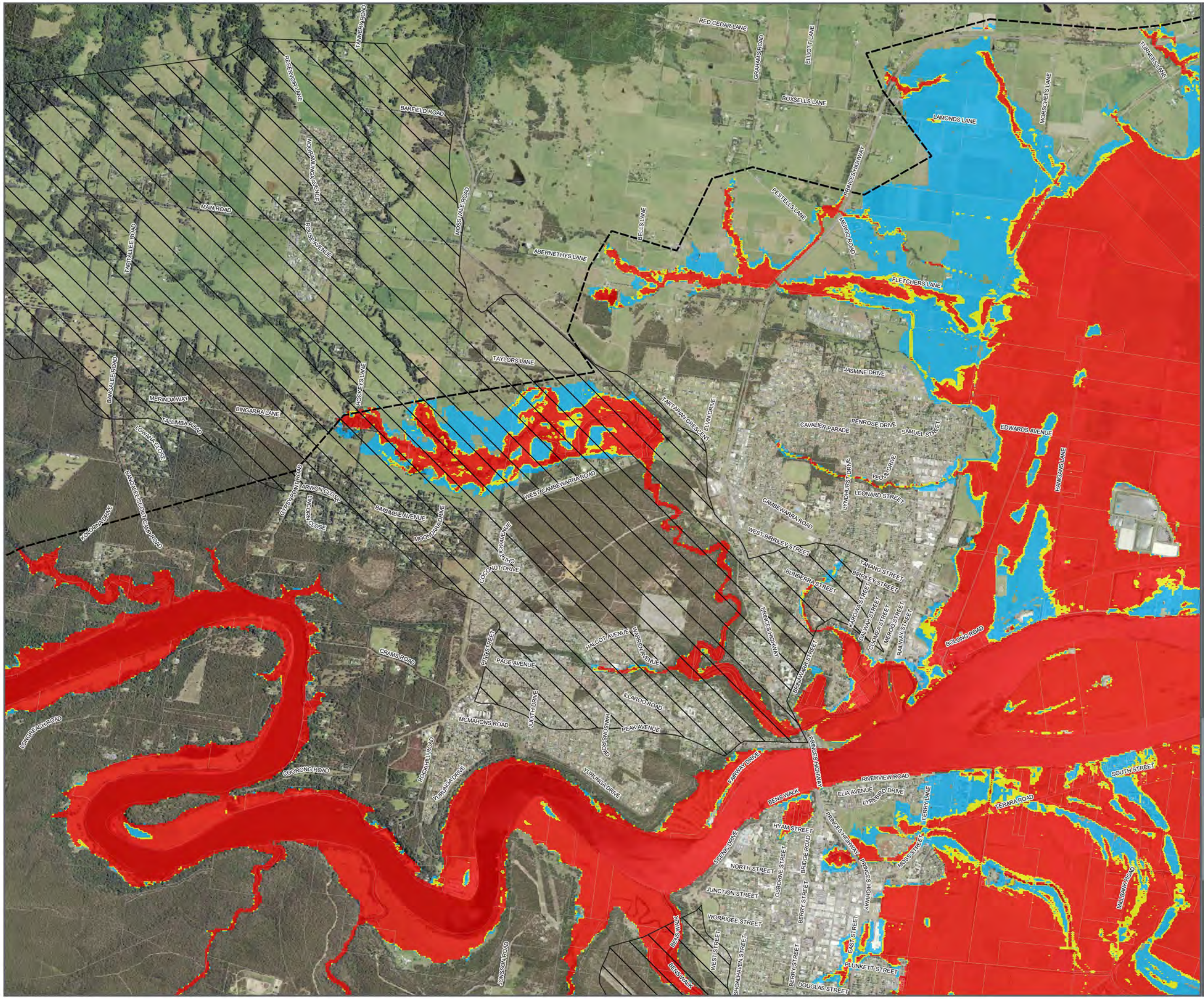
1:21,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Provisional Hazard Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

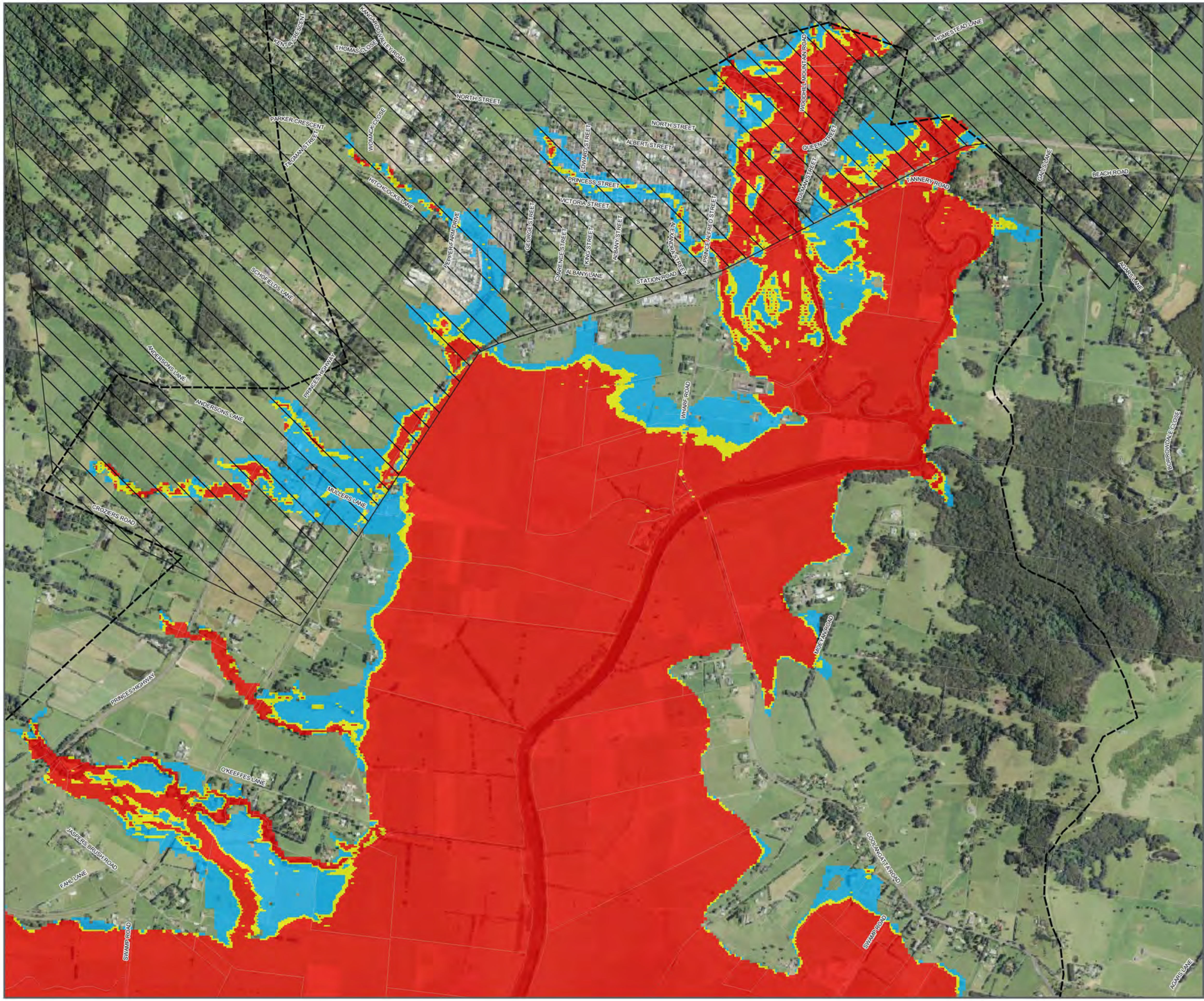
FIGURE G45.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Provisional Hazard Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

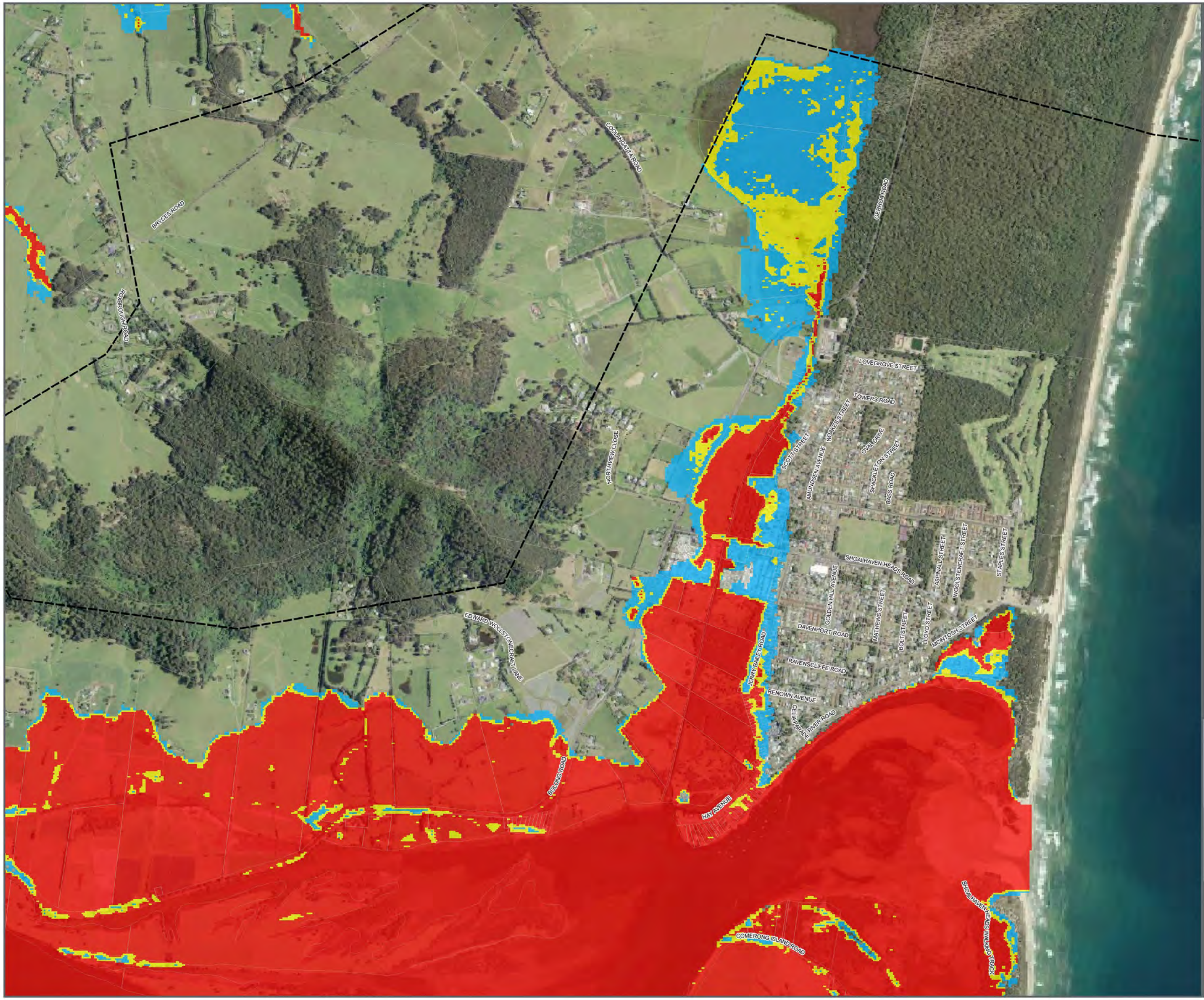
FIGURE G45.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Provisional Hazard Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

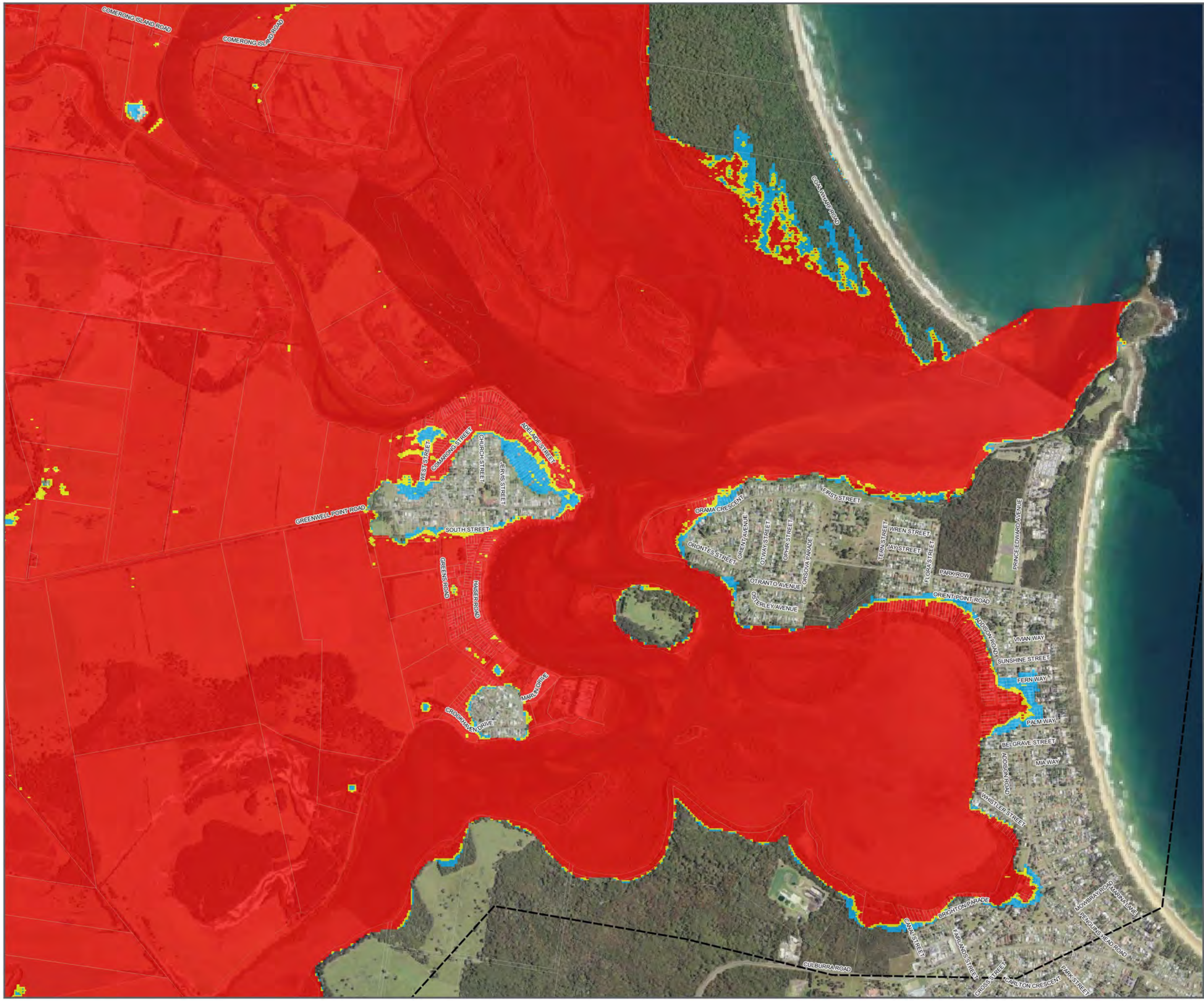
FIGURE G45.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Provisional Hazard Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

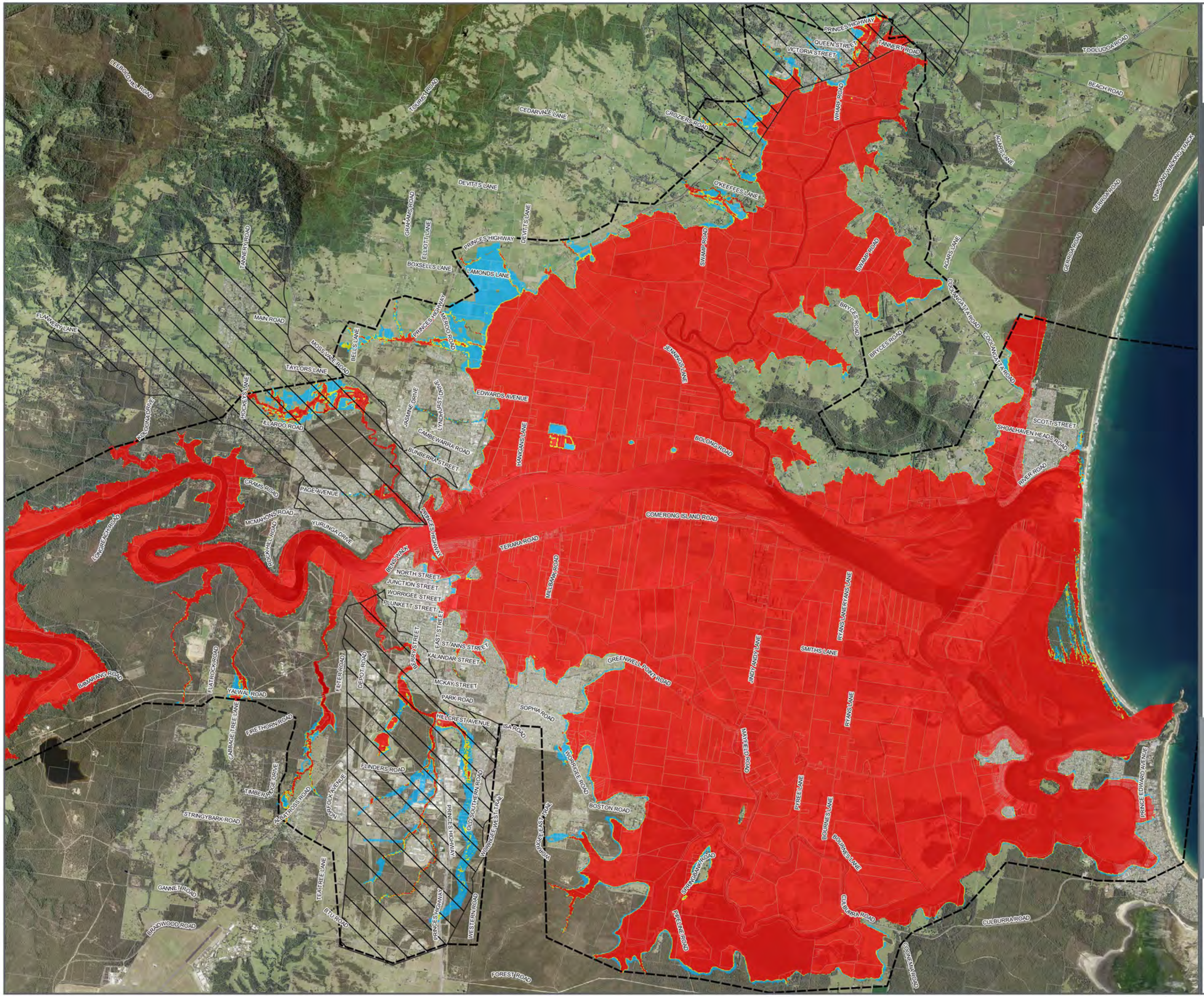
FIGURE G45.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Provisional Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

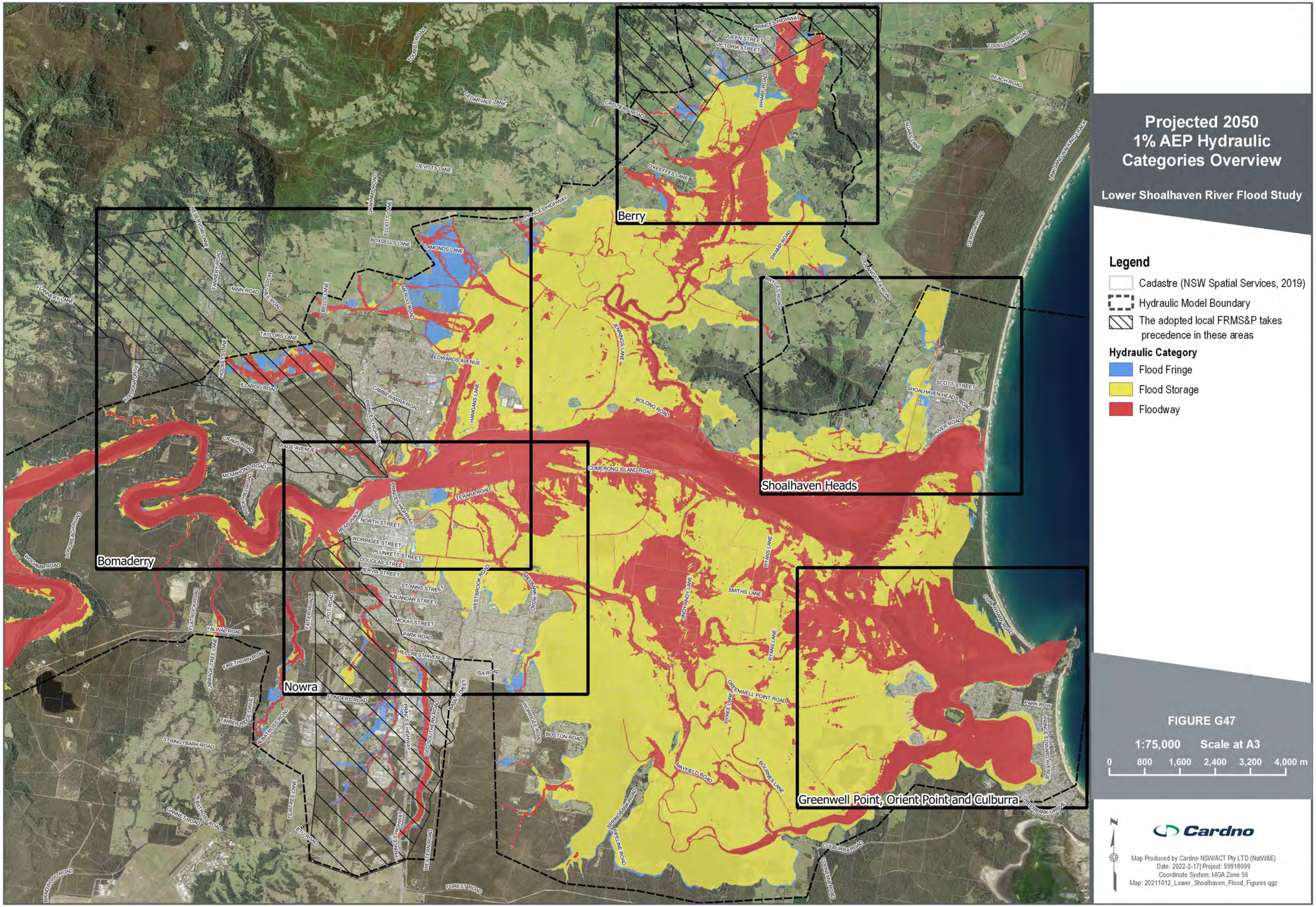
FIGURE G46

1:75,000 Scale at A3

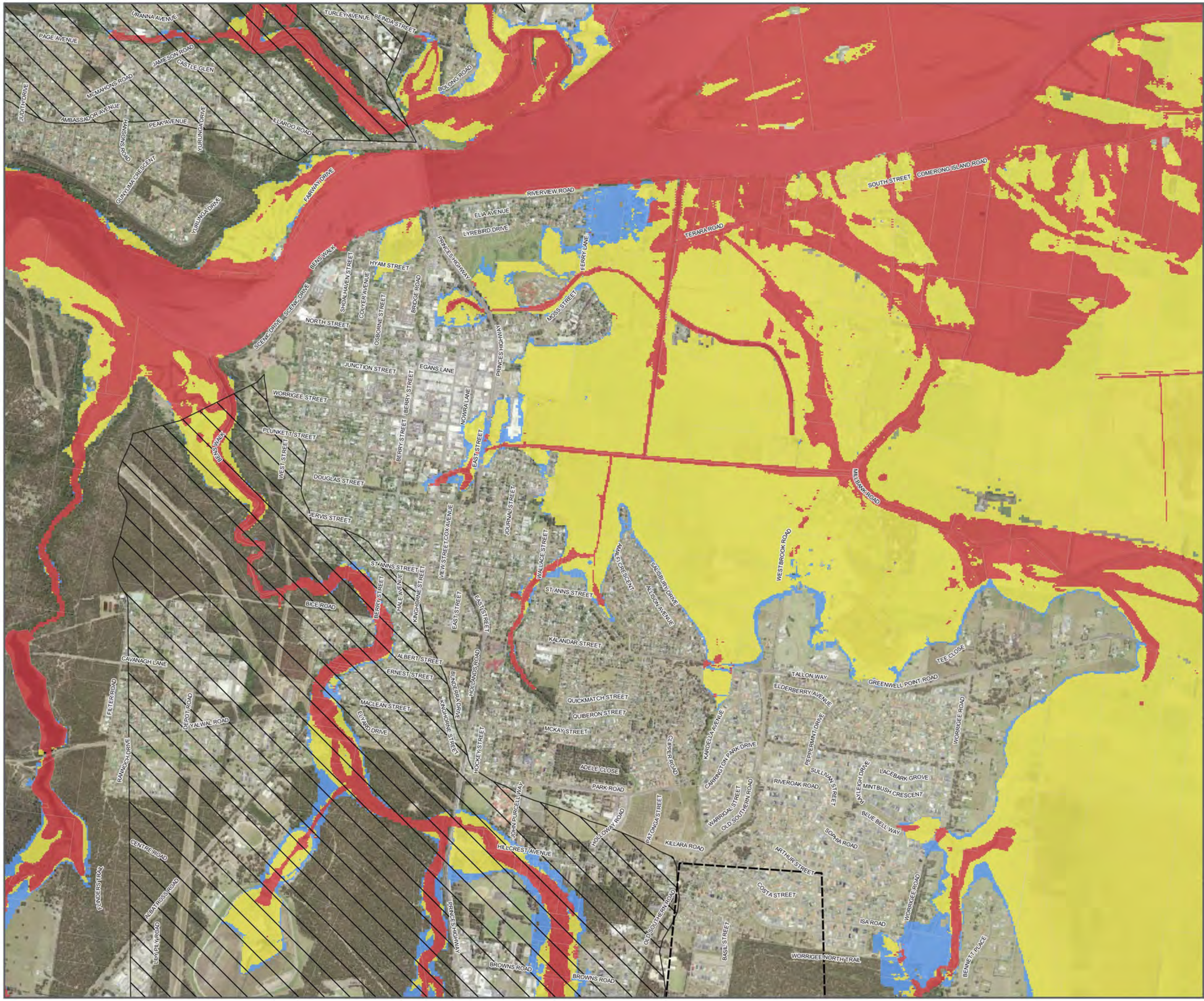
0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Hydraulic
Categories Overview
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Hydraulic Category
Flood Fringe
Flood Storage
Floodway
FIGURE G47
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz
Berry
Bomaderry
Nowra
Shoalhaven Heads
Greenwell Point, Orient Point and Culburra



Projected 2050 1% AEP Hydraulic Categories Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

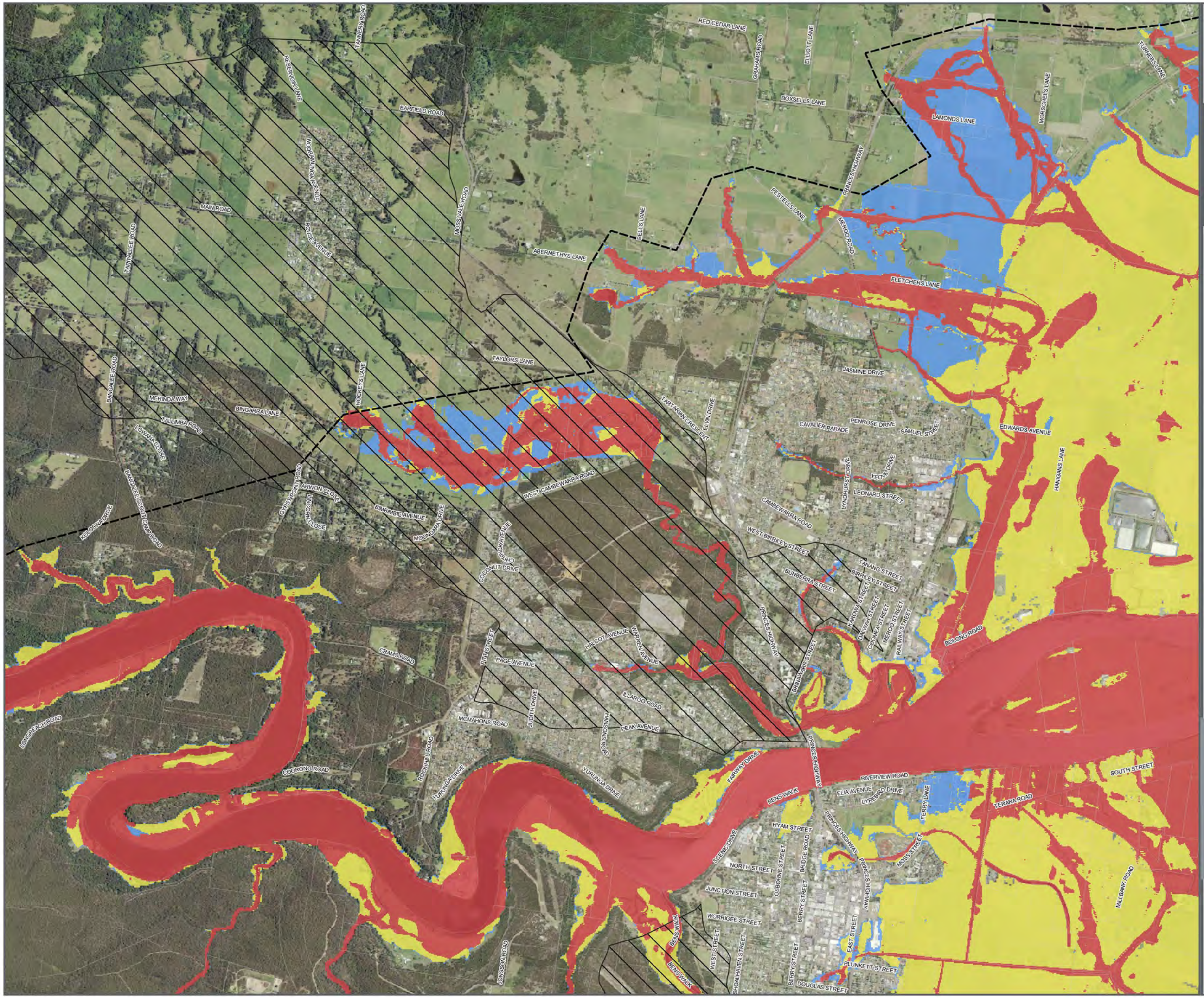
FIGURE G47.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Hydraulic Categories Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

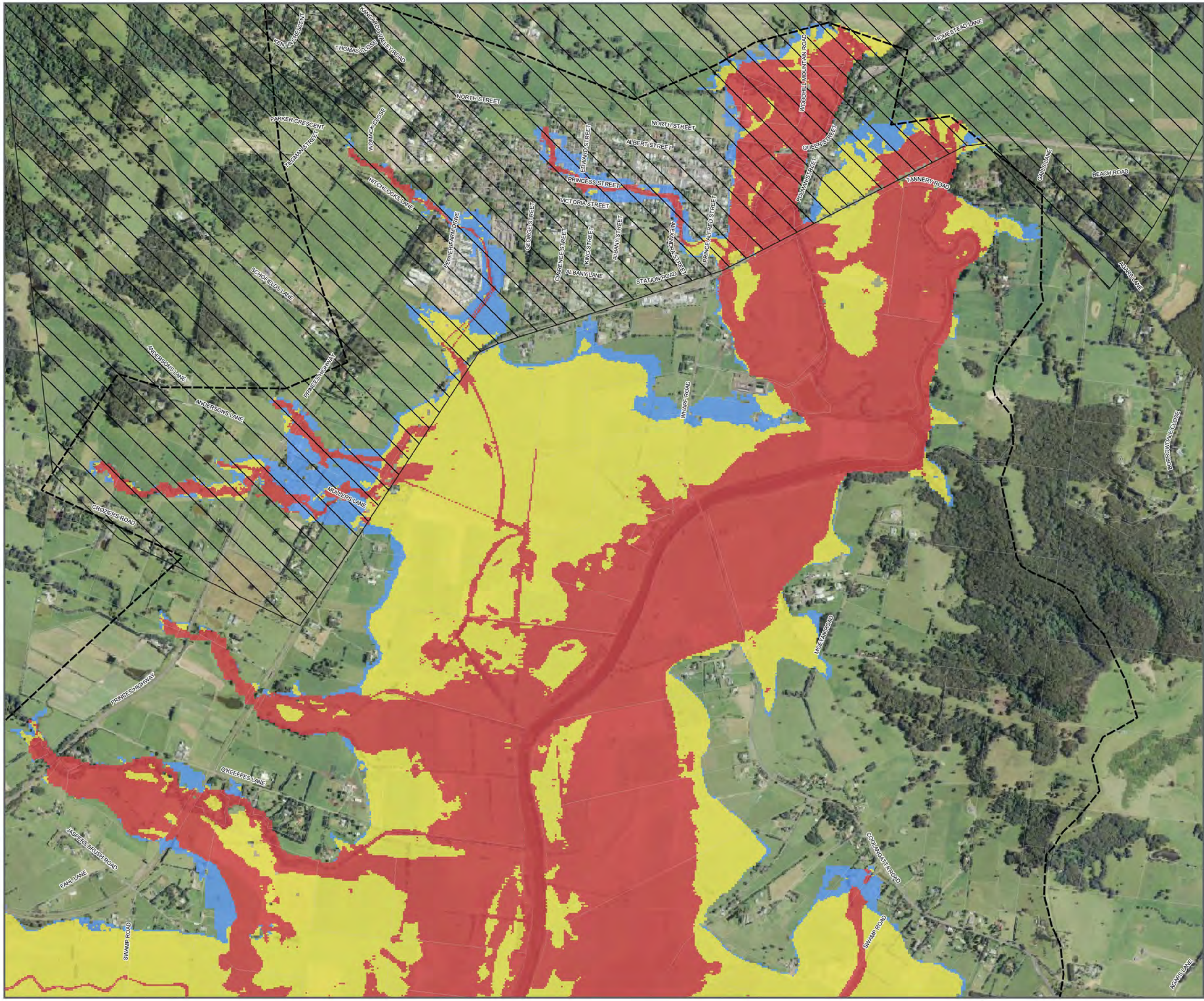
FIGURE G47.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Hydraulic Categories Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

FIGURE G47.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 1% AEP Hydraulic Categories Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

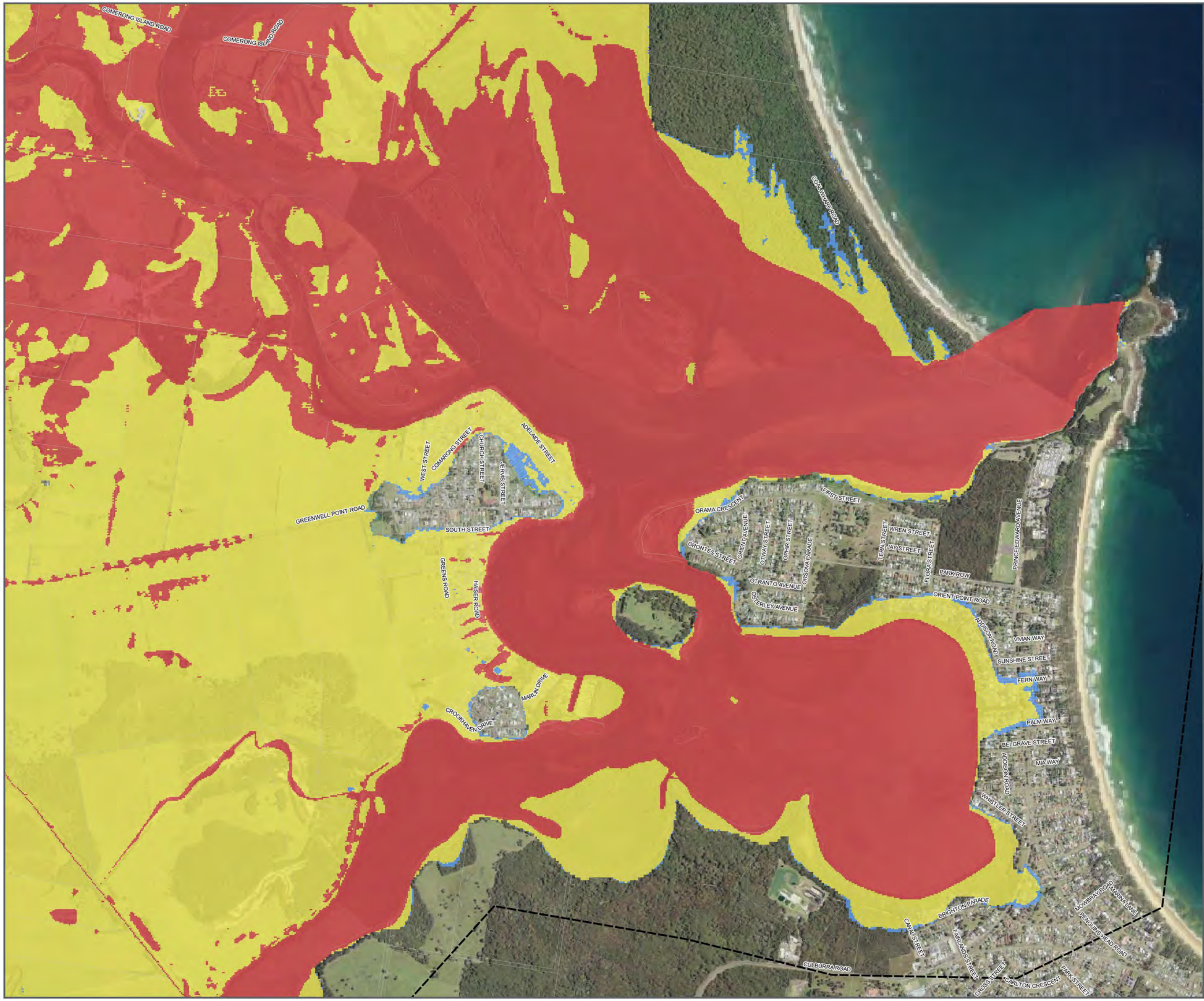
FIGURE G47.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Hydraulic Categories Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

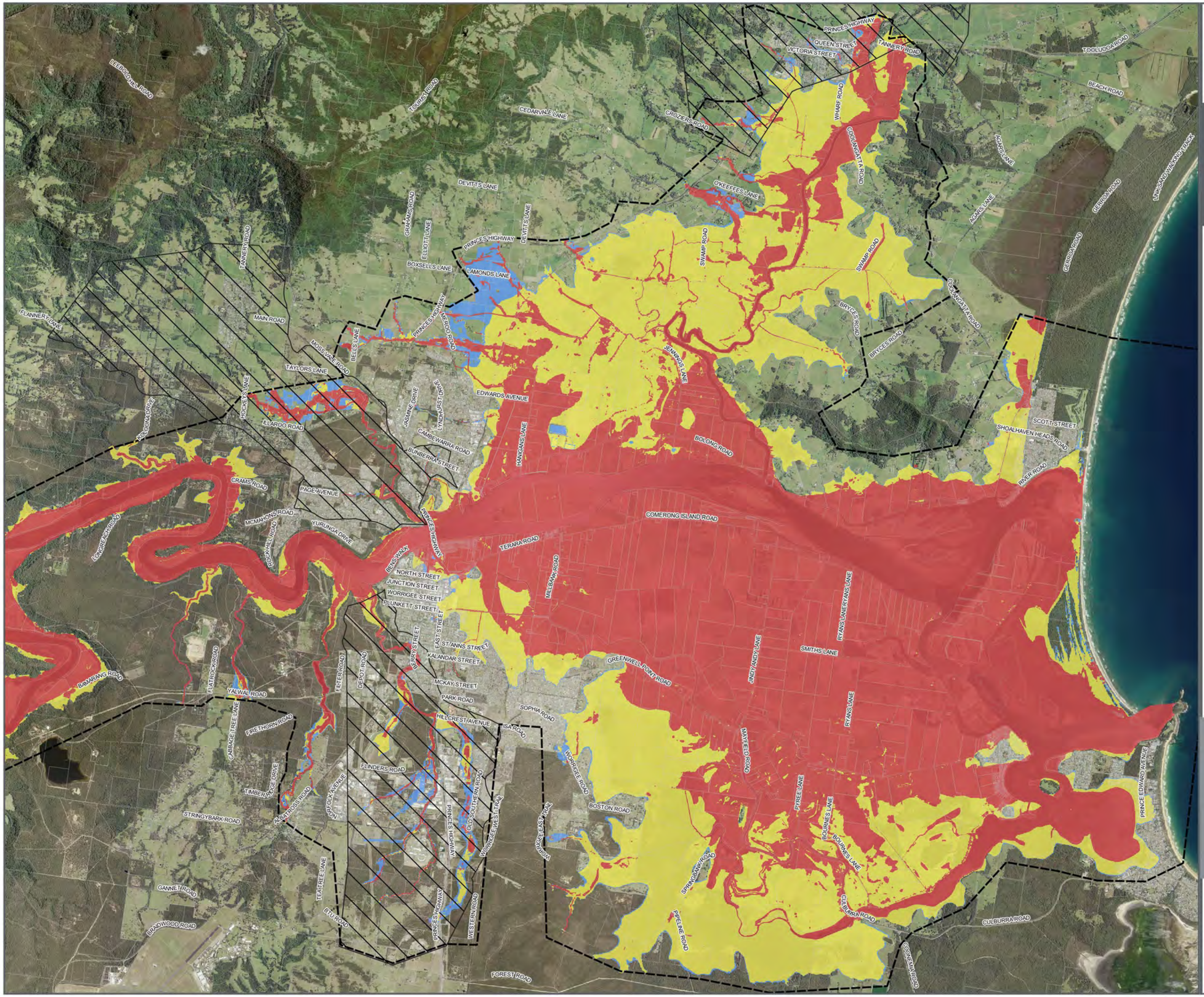
FIGURE G47.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Hydraulic Categories

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

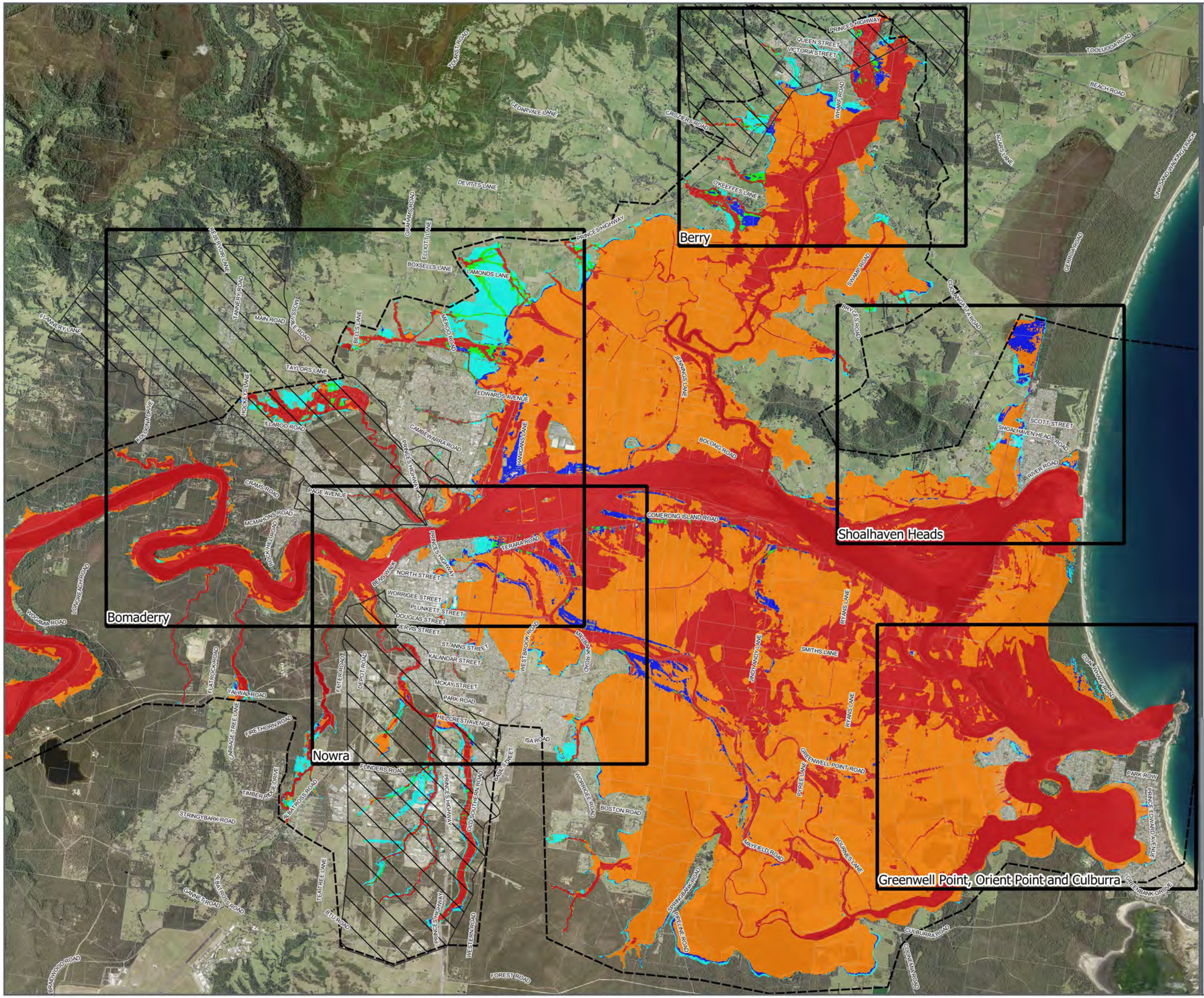
FIGURE G48

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Combined Hazard and Hydraulic Category Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

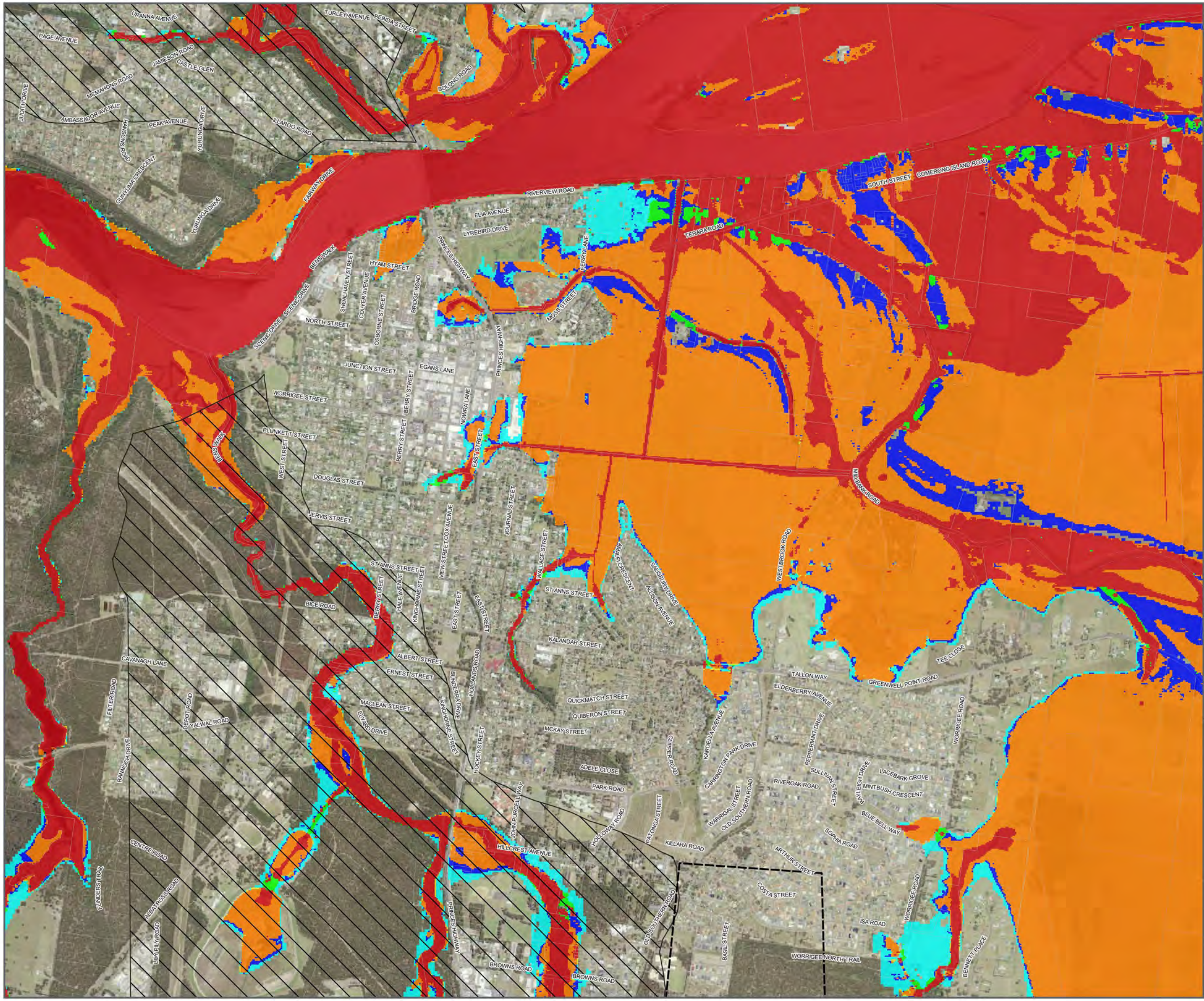
- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

FIGURE G49

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050
1% AEP Combined Hazard and Hydraulic Category
Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

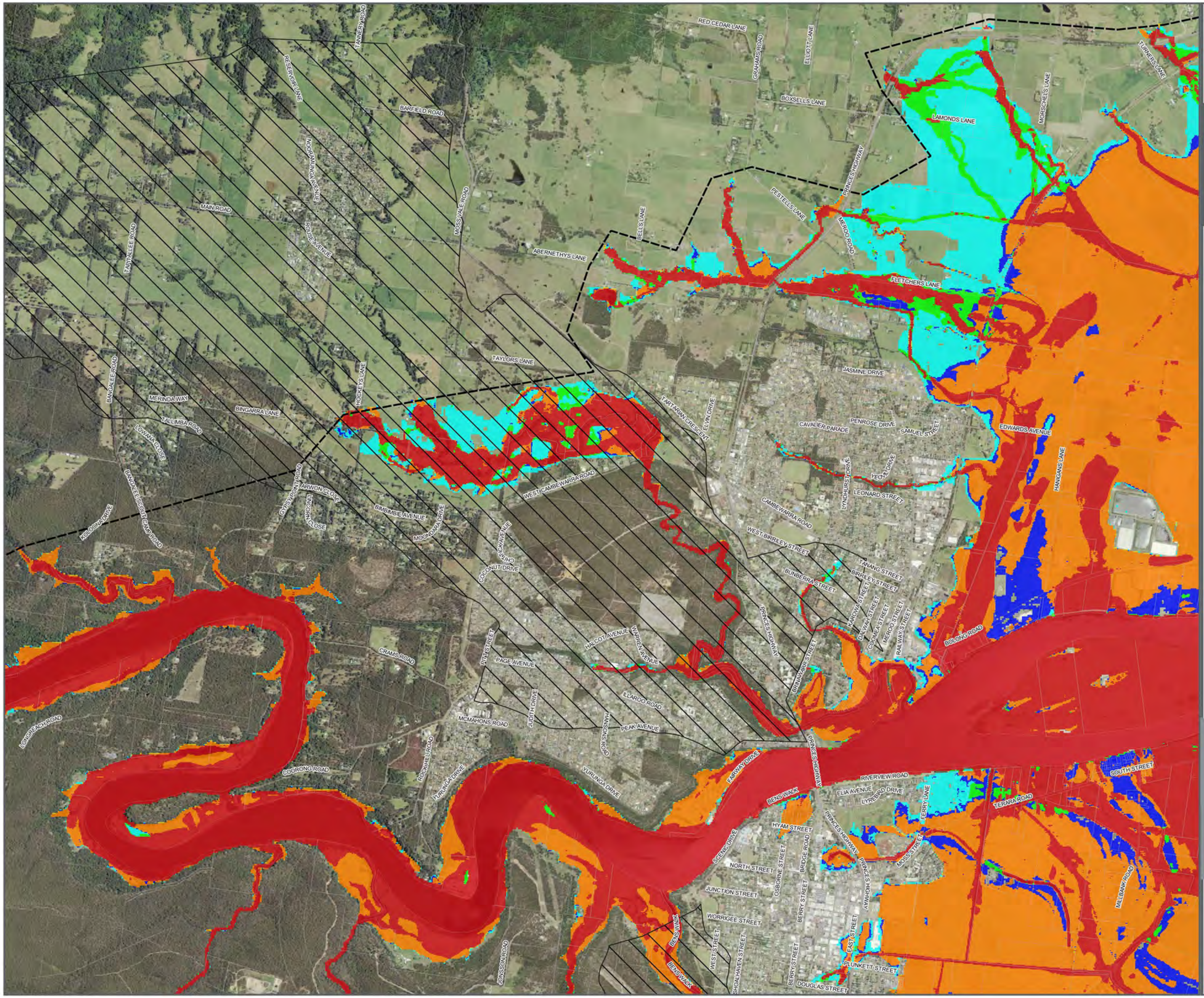
FIGURE G49.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Combined Hazard and Hydraulic Category Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

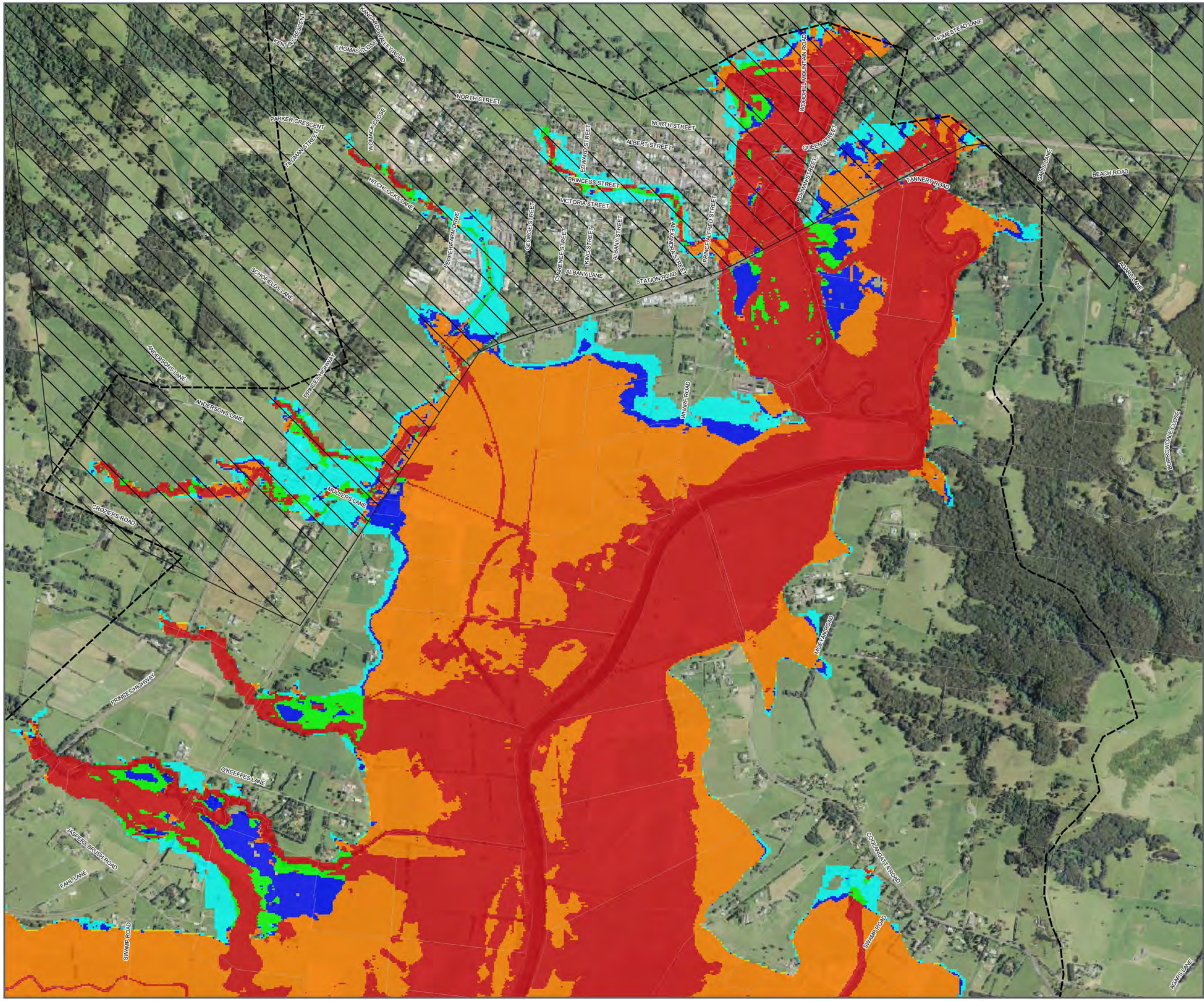
FIGURE G49.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Combined Hazard and Hydraulic Category Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

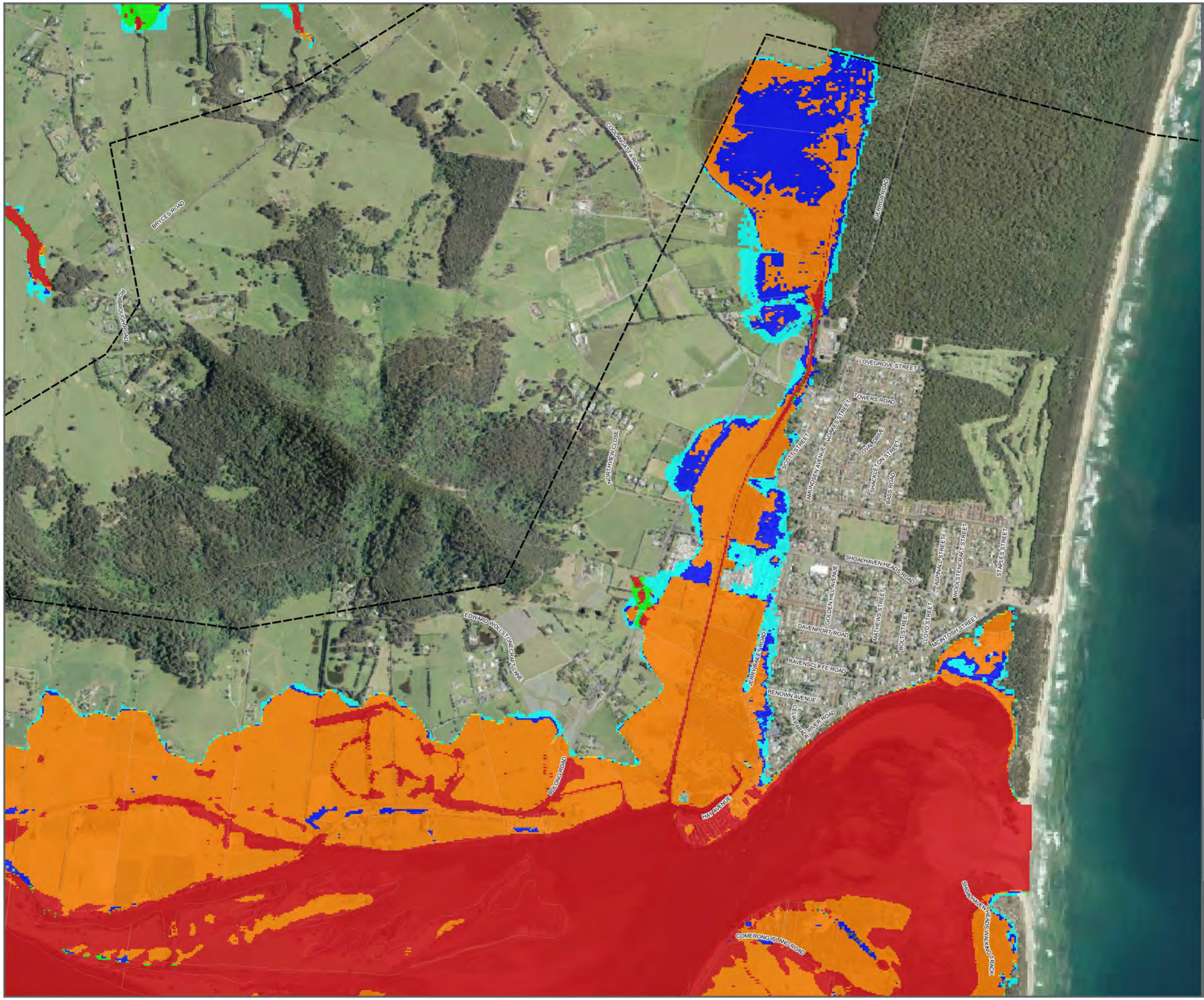
FIGURE G49.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Combined Hazard and Hydraulic Category Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

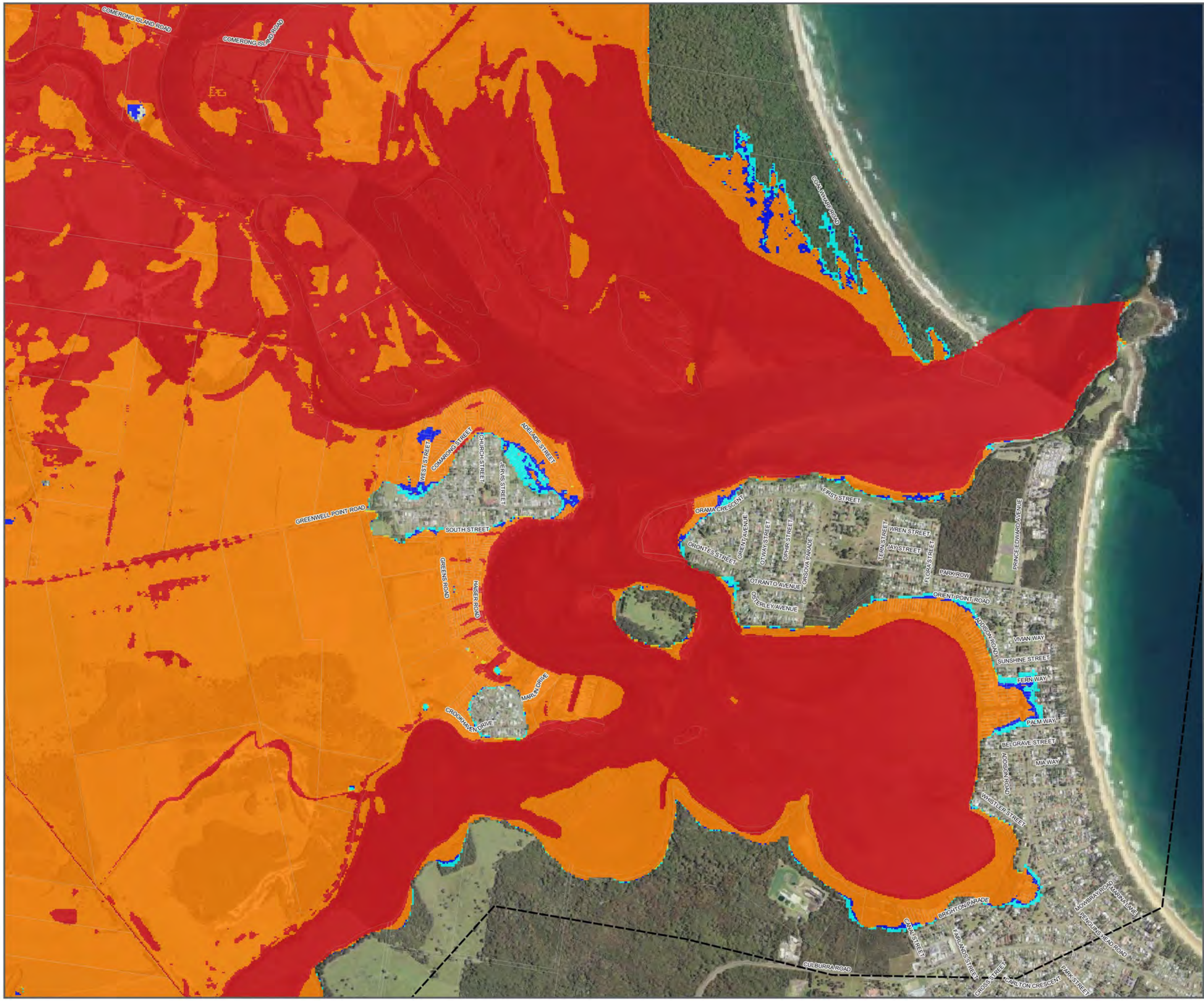
FIGURE G49.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Combined Hazard and Hydraulic Category Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

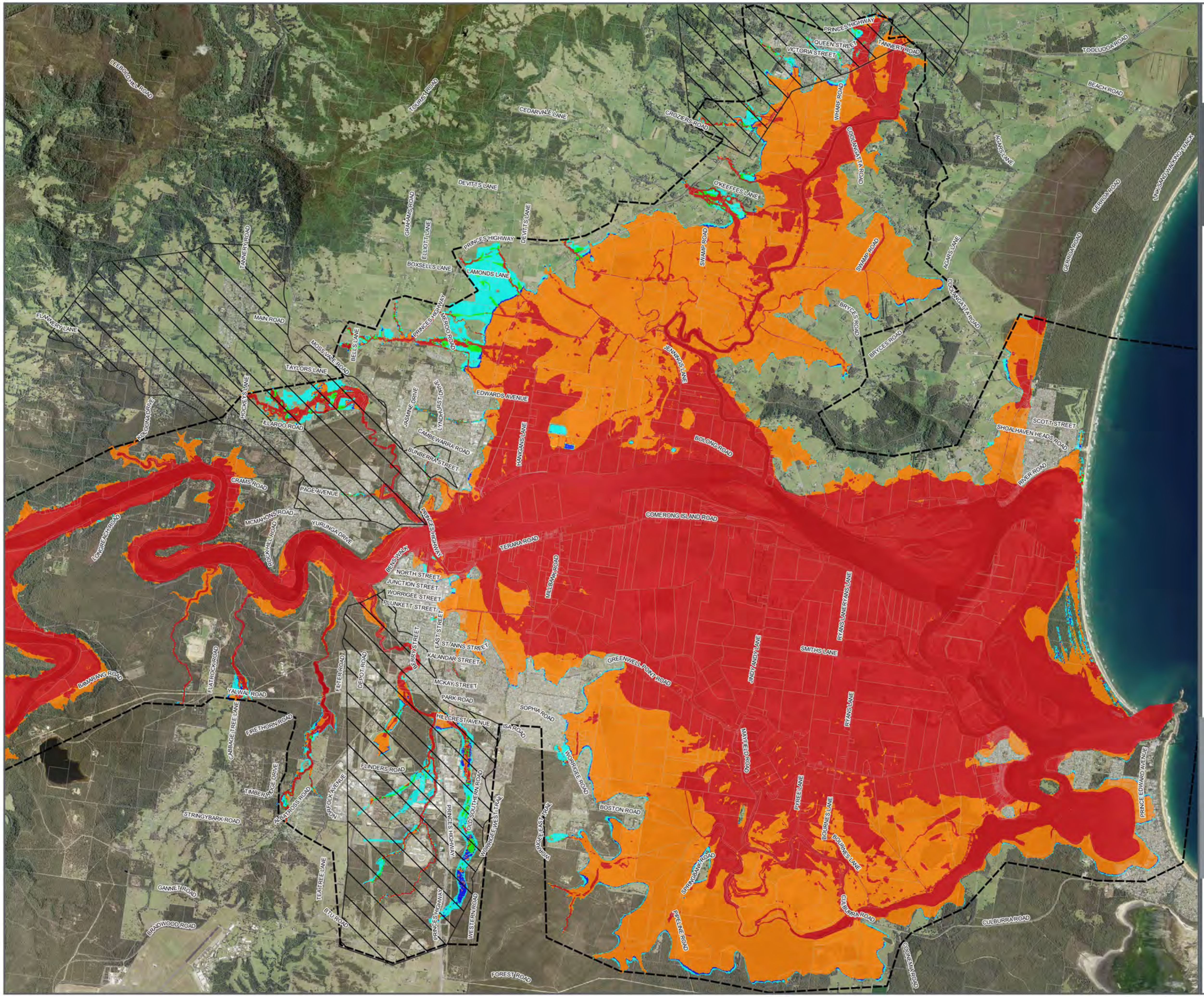
FIGURE G49.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 PMF Combined Hazard and Hydraulic Category

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

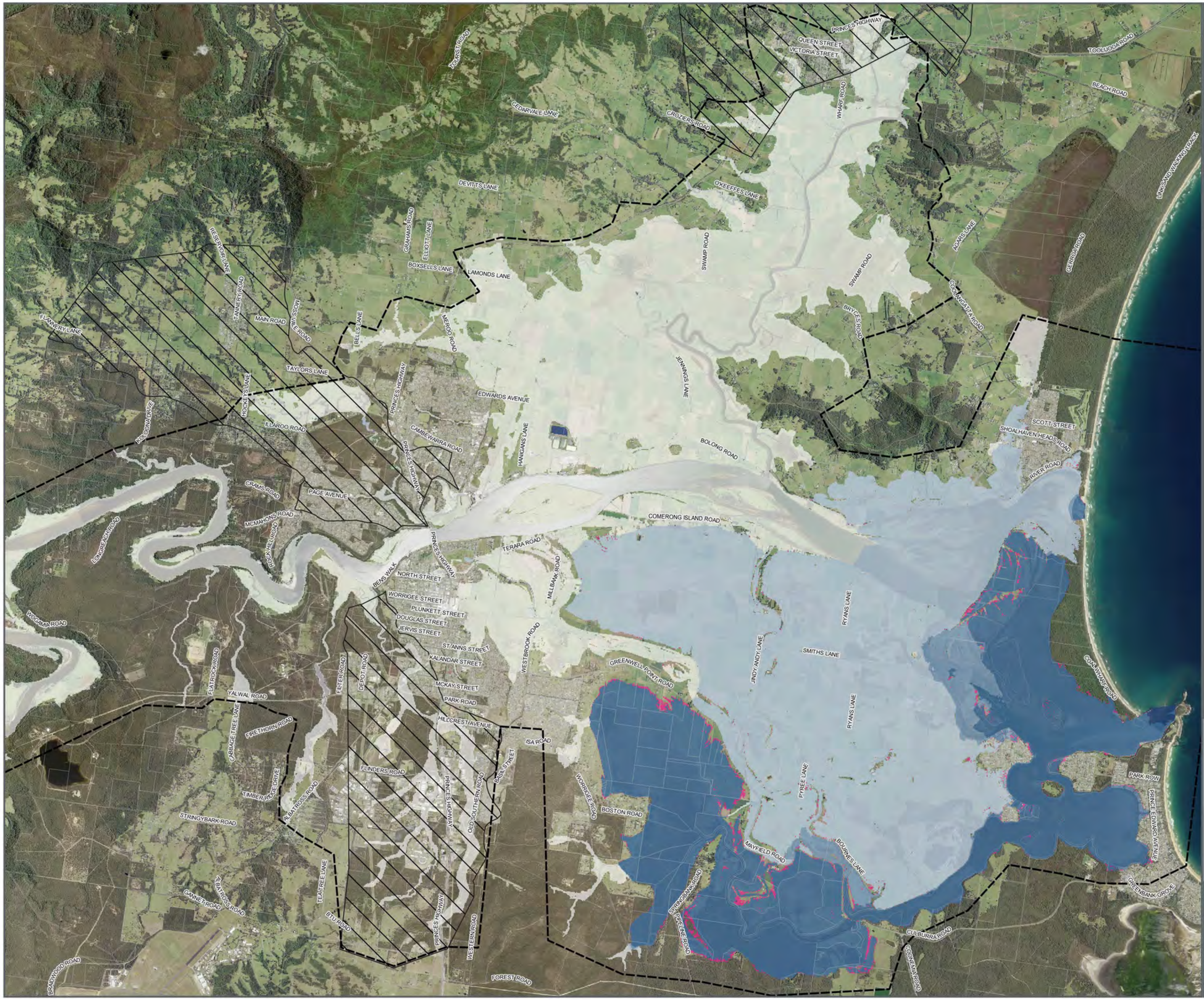
FIGURE G50

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

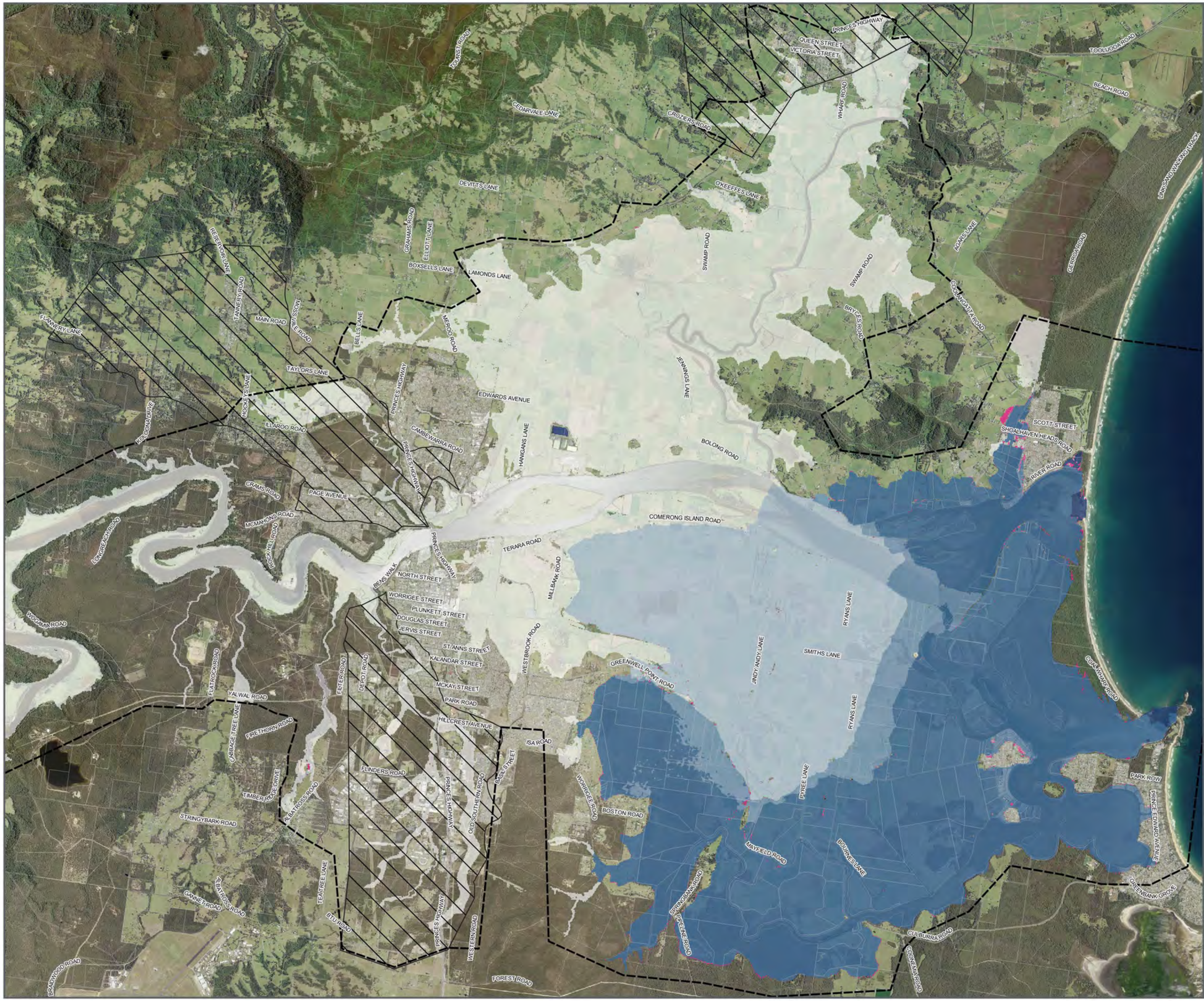
FIGURE G51

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 2% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE G52

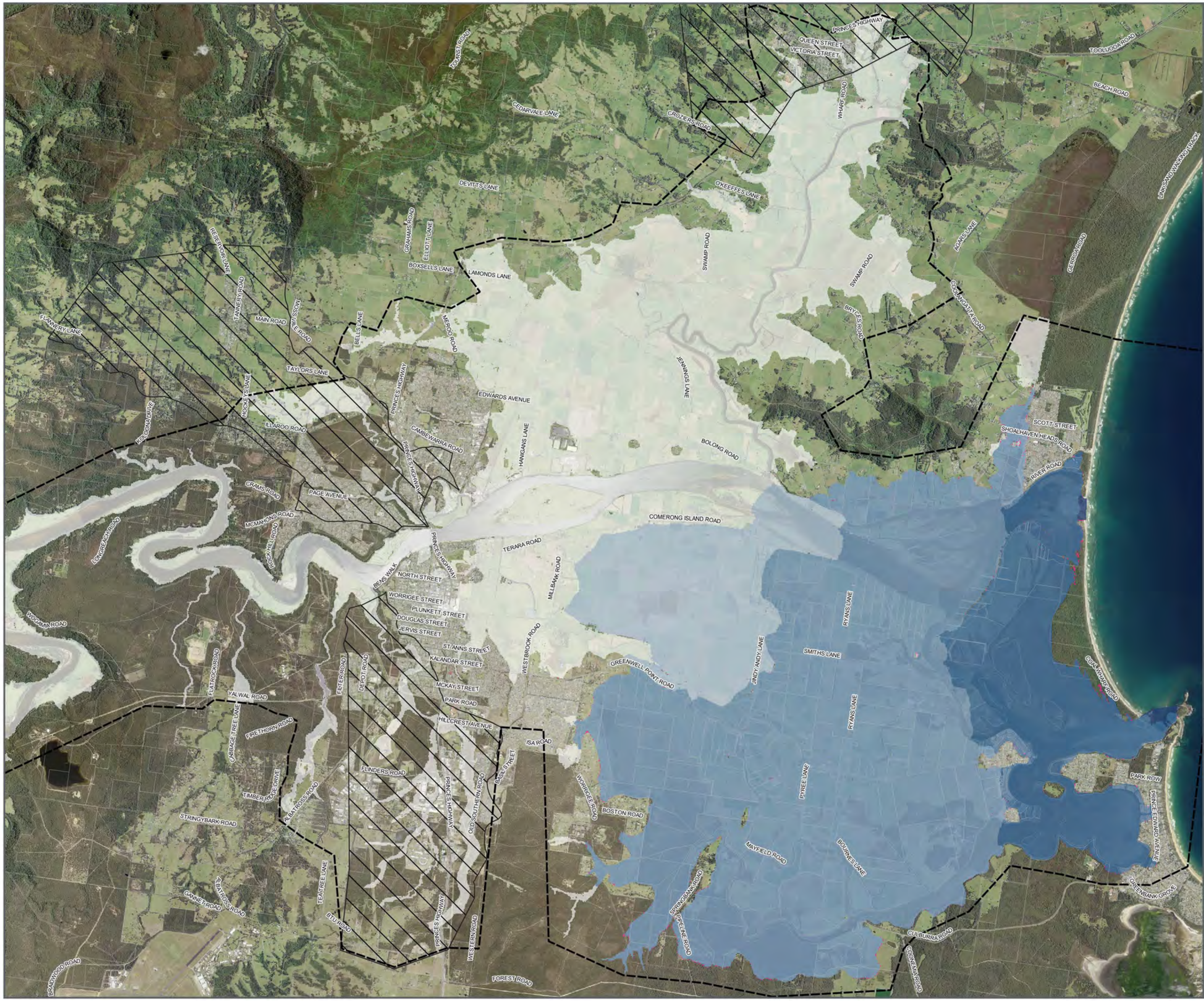
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE G53

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 PMF Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE G54

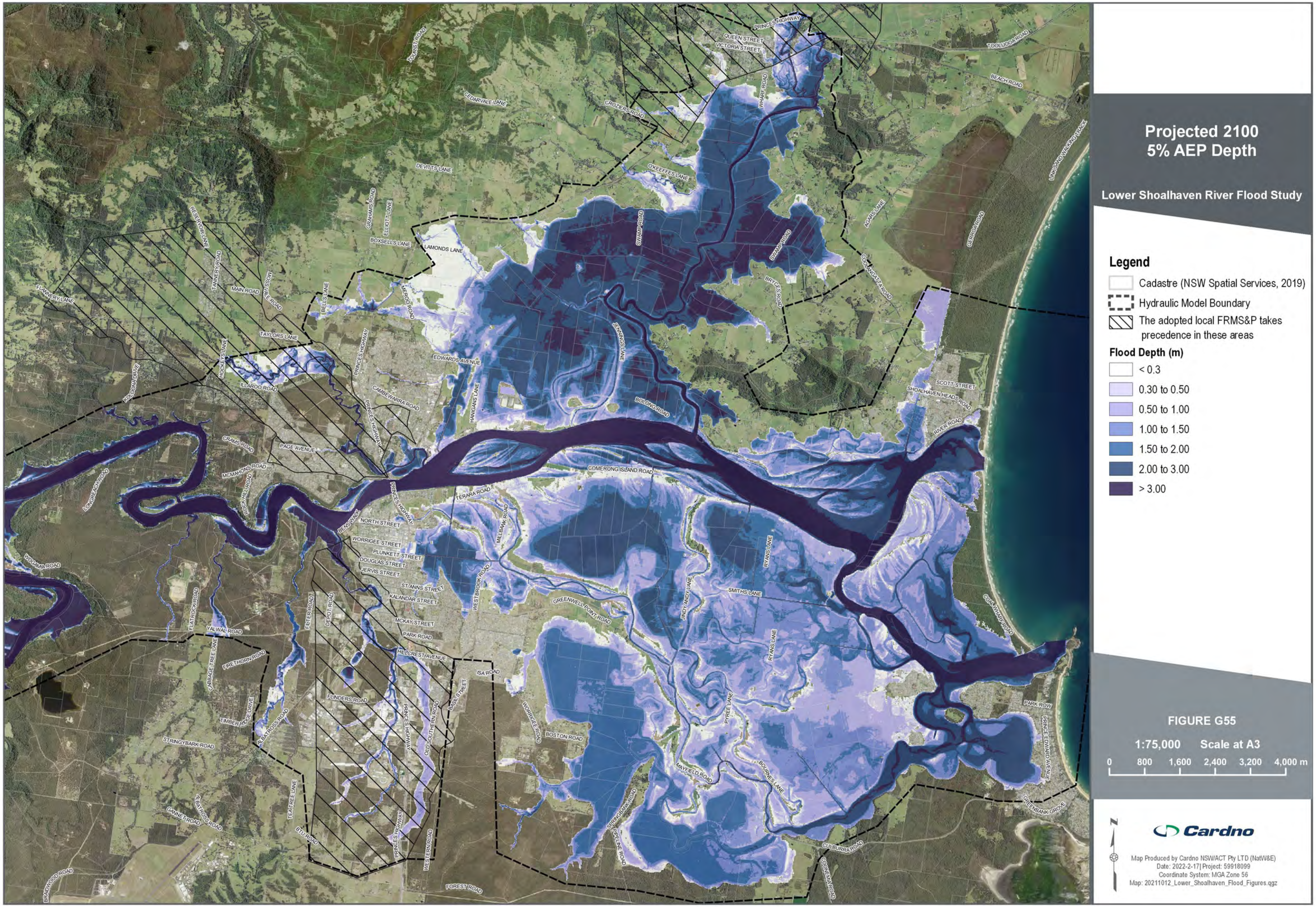
1:75,000 Scale at A3

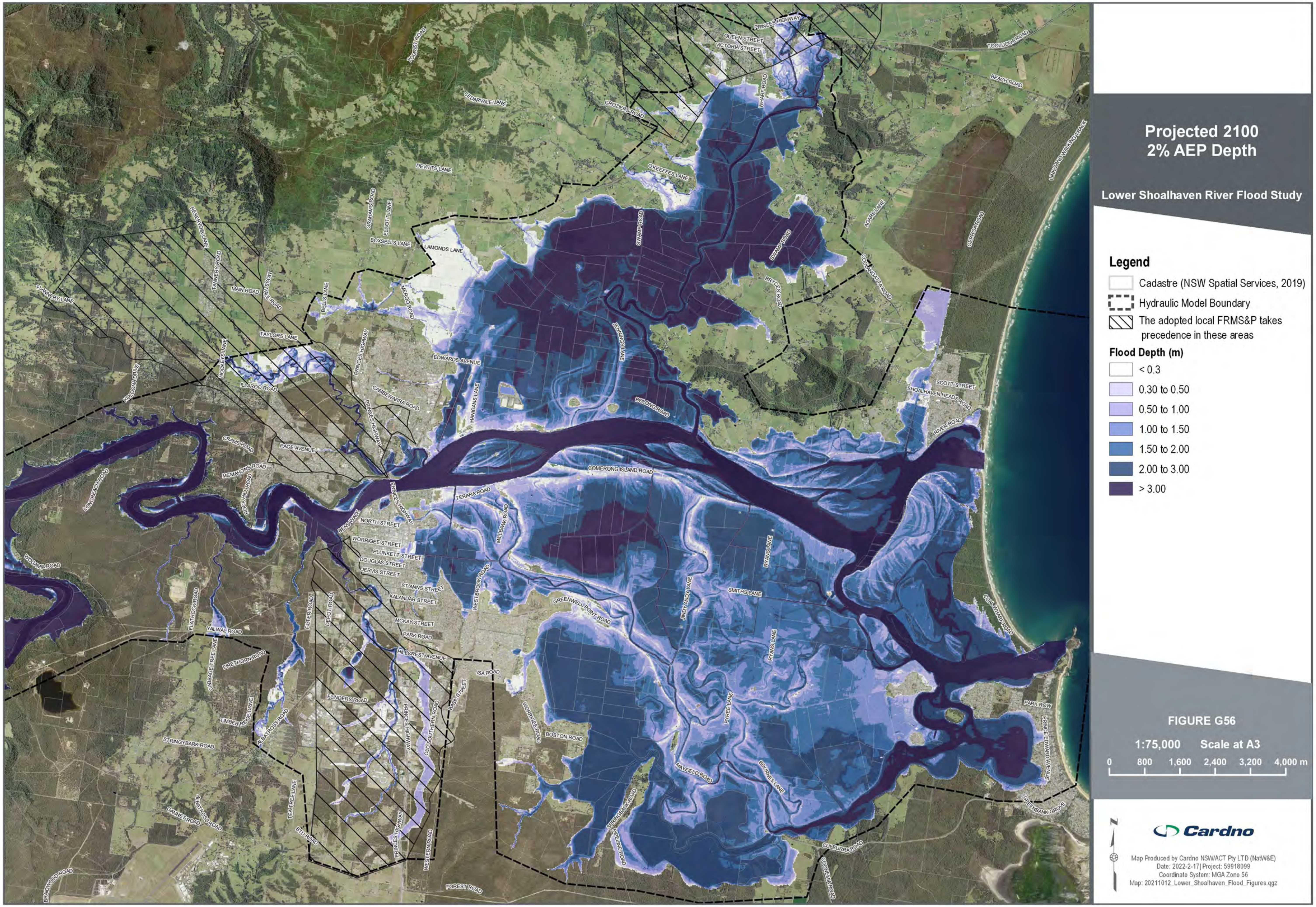
0 800 1,600 2,400 3,200 4,000 m

N

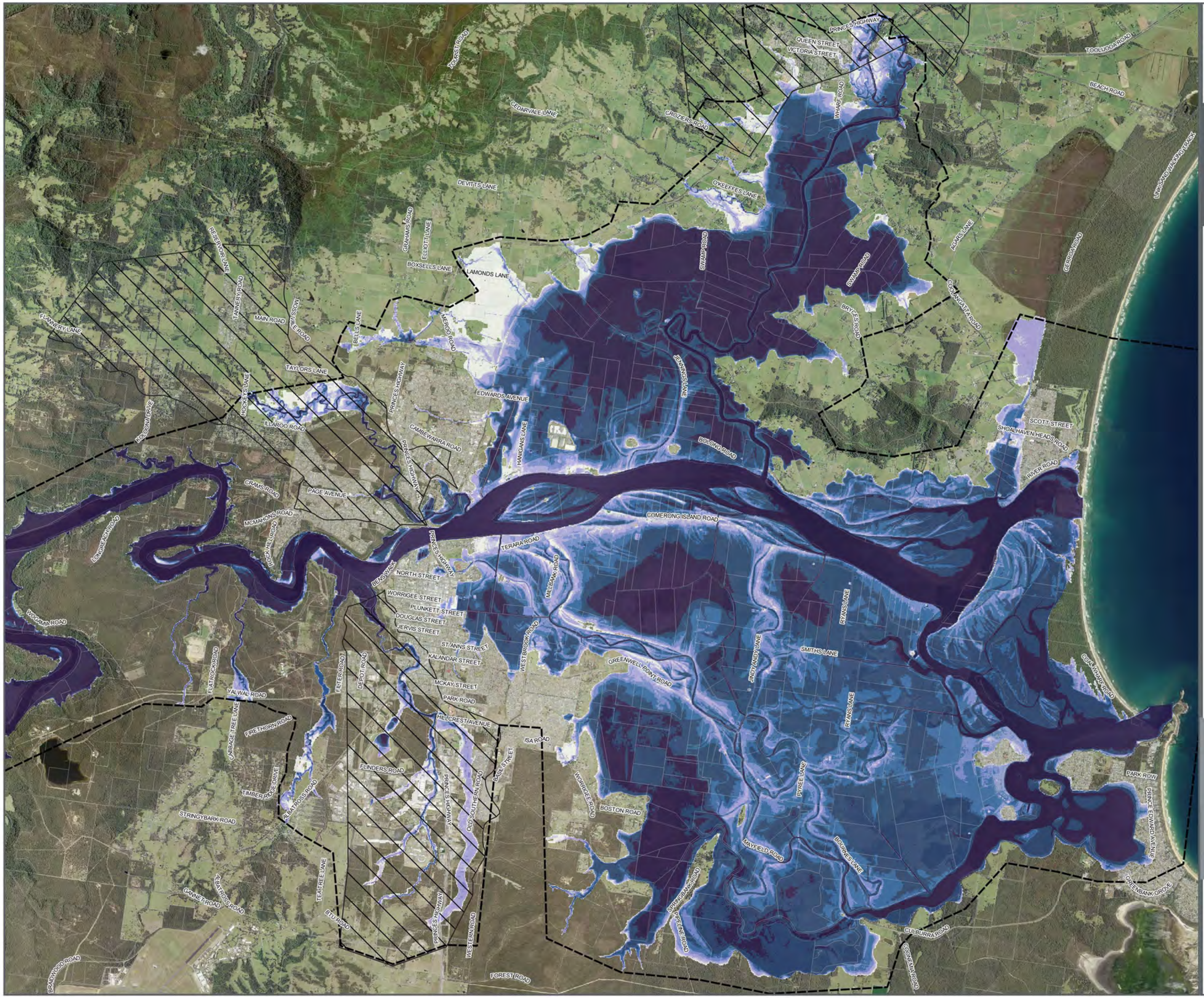
Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Projected 2100
5% AEP Depth
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE G55
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
2% AEP Depth
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE G56
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

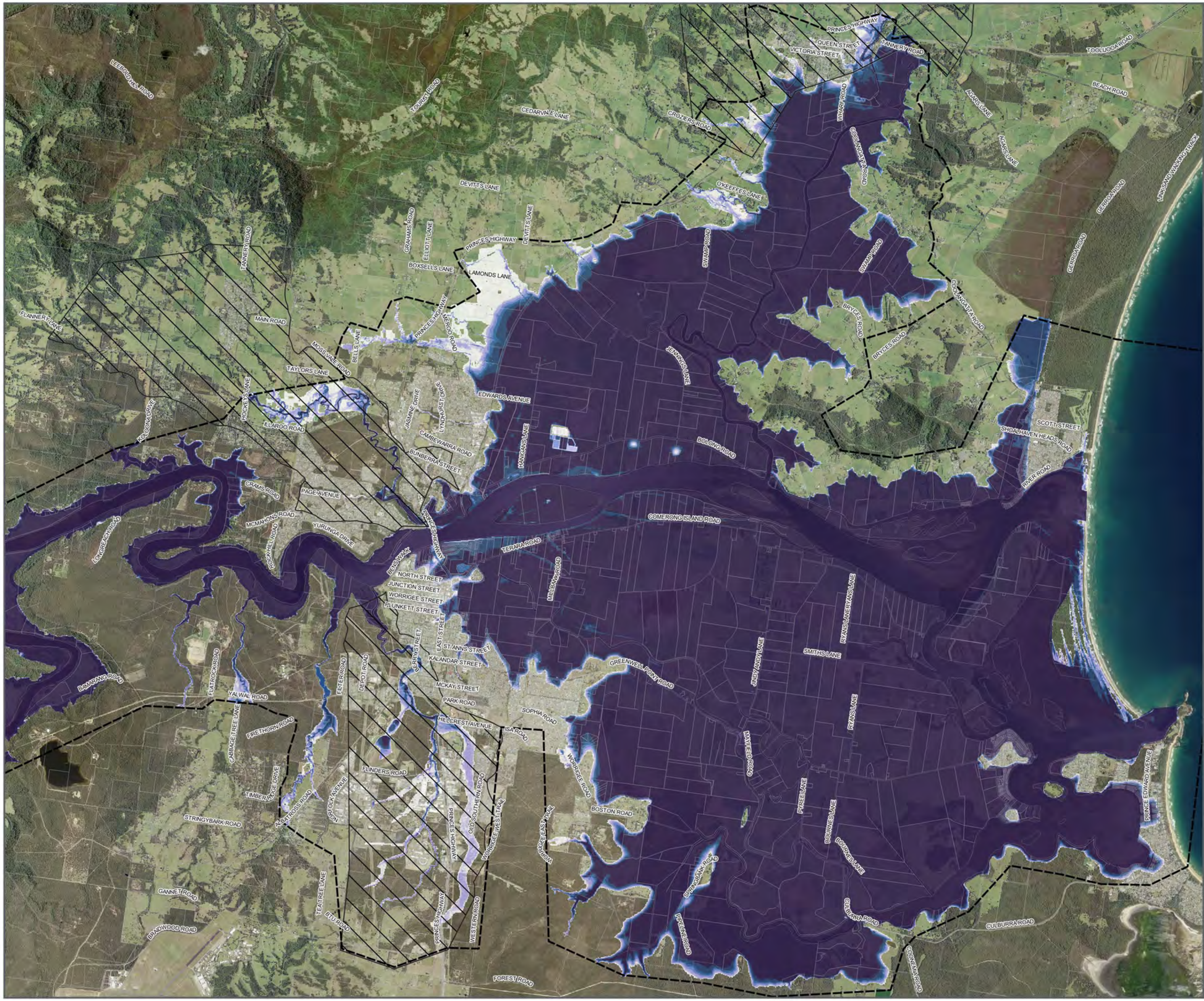
FIGURE G57

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

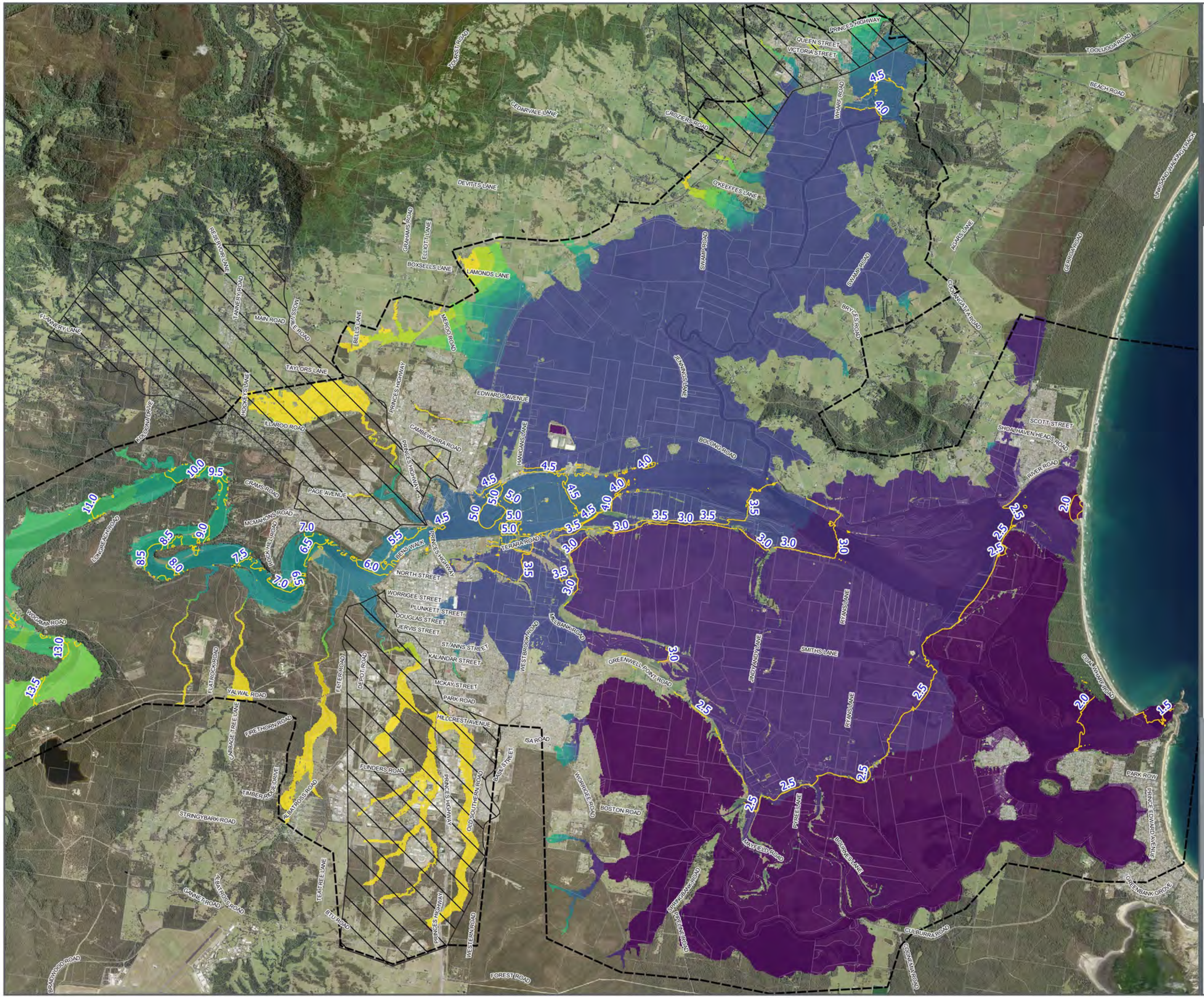
FIGURE G58

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 5% AEP Water Level

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

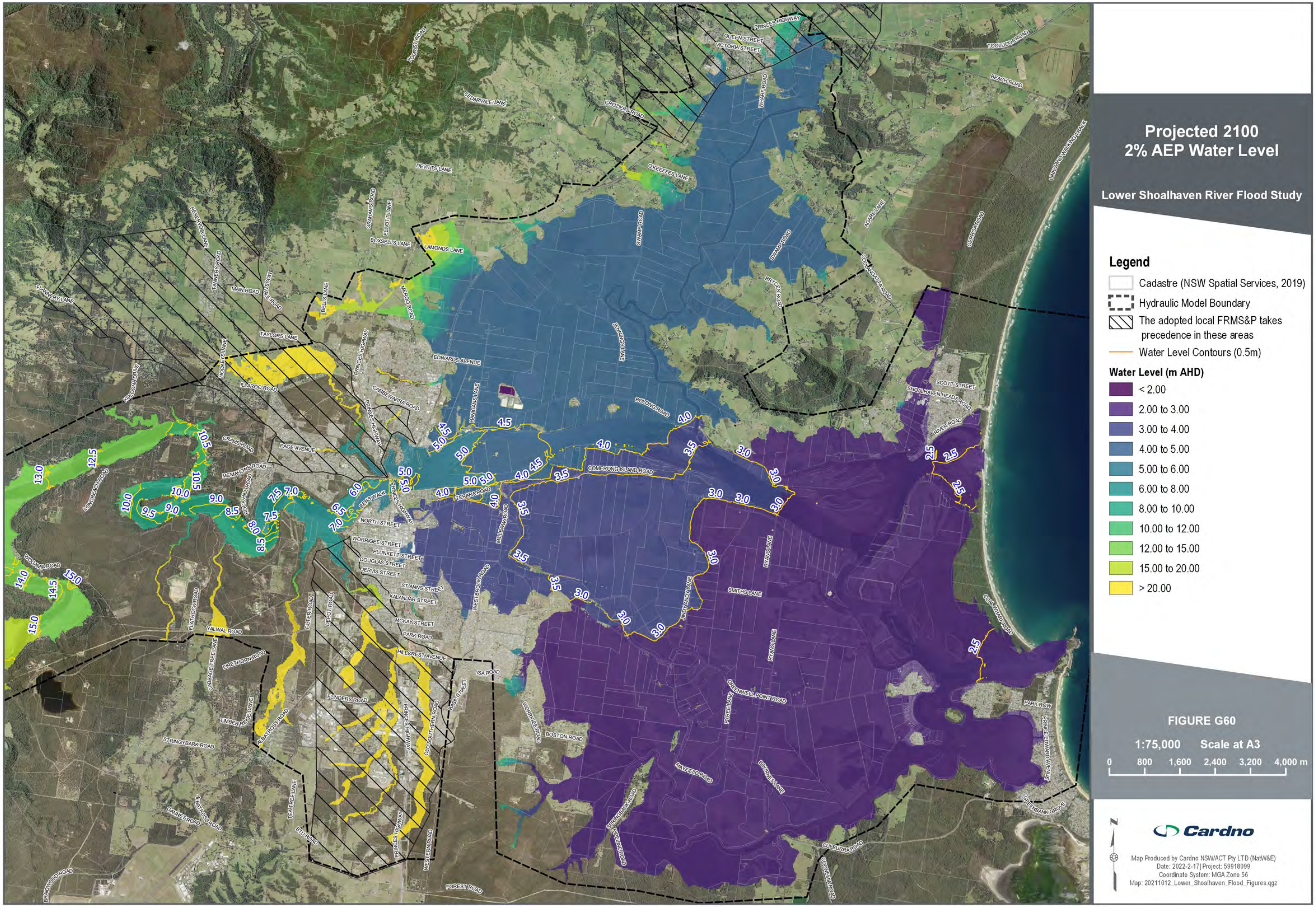
FIGURE G59

1:75,000 Scale at A3

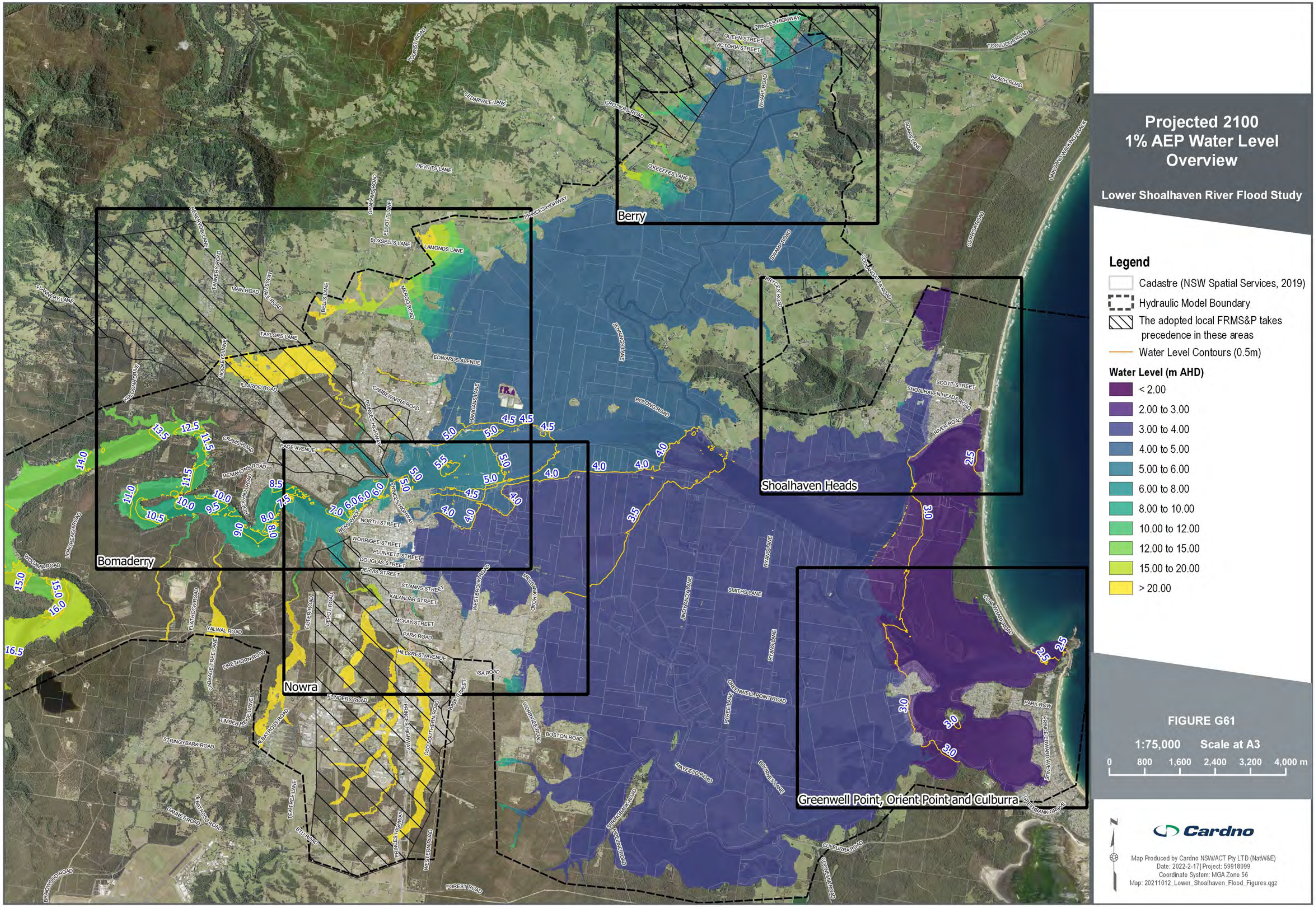
0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
2% AEP Water Level
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G60
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Water Level
Overview
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Water Level (m AHD)
< 2.00
2.00 to 3.00
3.00 to 4.00
4.00 to 5.00
5.00 to 6.00
6.00 to 8.00
8.00 to 10.00
10.00 to 12.00
12.00 to 15.00
15.00 to 20.00
> 20.00
FIGURE G61
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz
Berry
Bomaderry
Nowra
Shoalhaven Heads
Greenwell Point, Orient Point and Culburra

Projected 2100 1% AEP Water Level Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

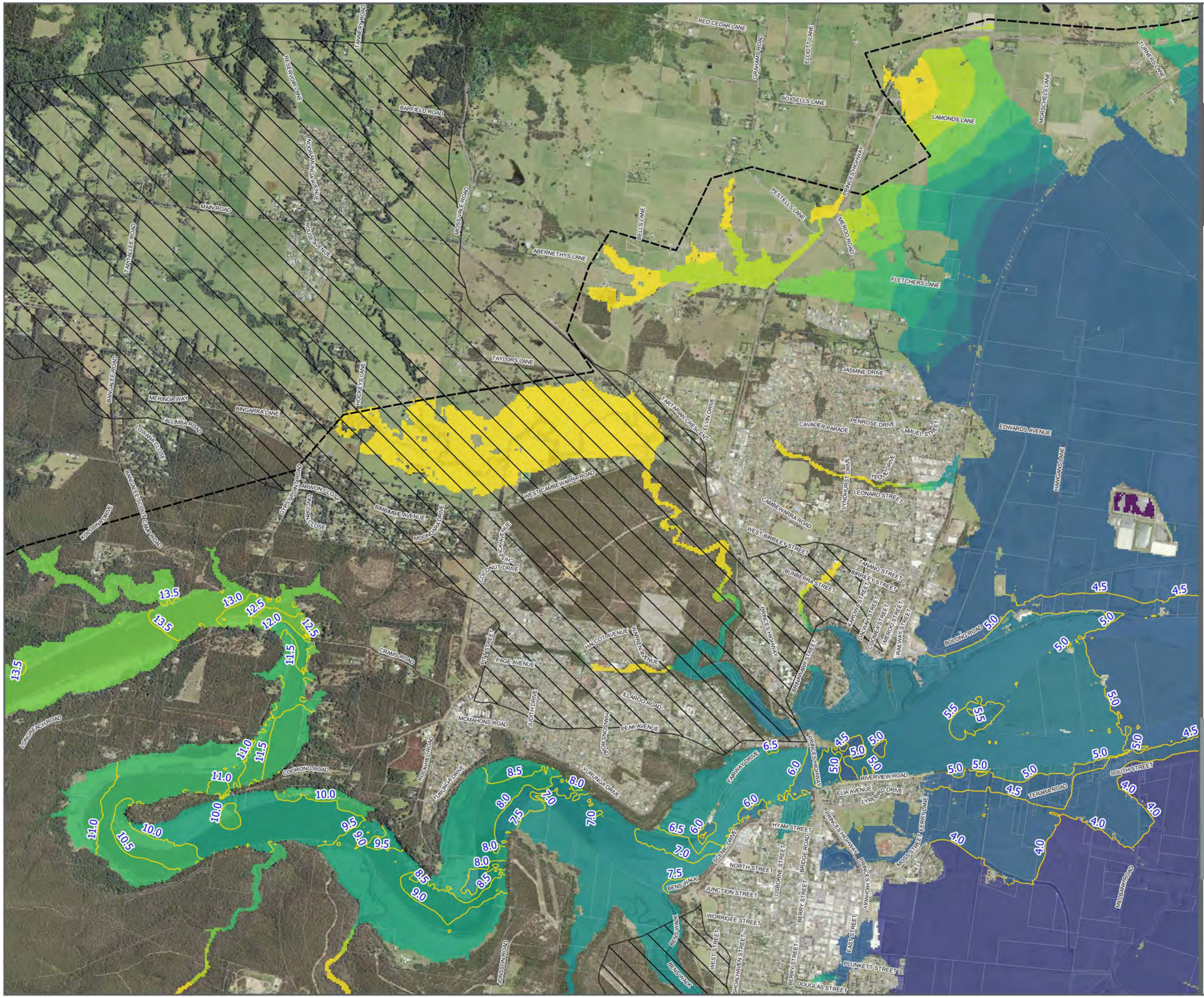
FIGURE G61.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Water Level Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

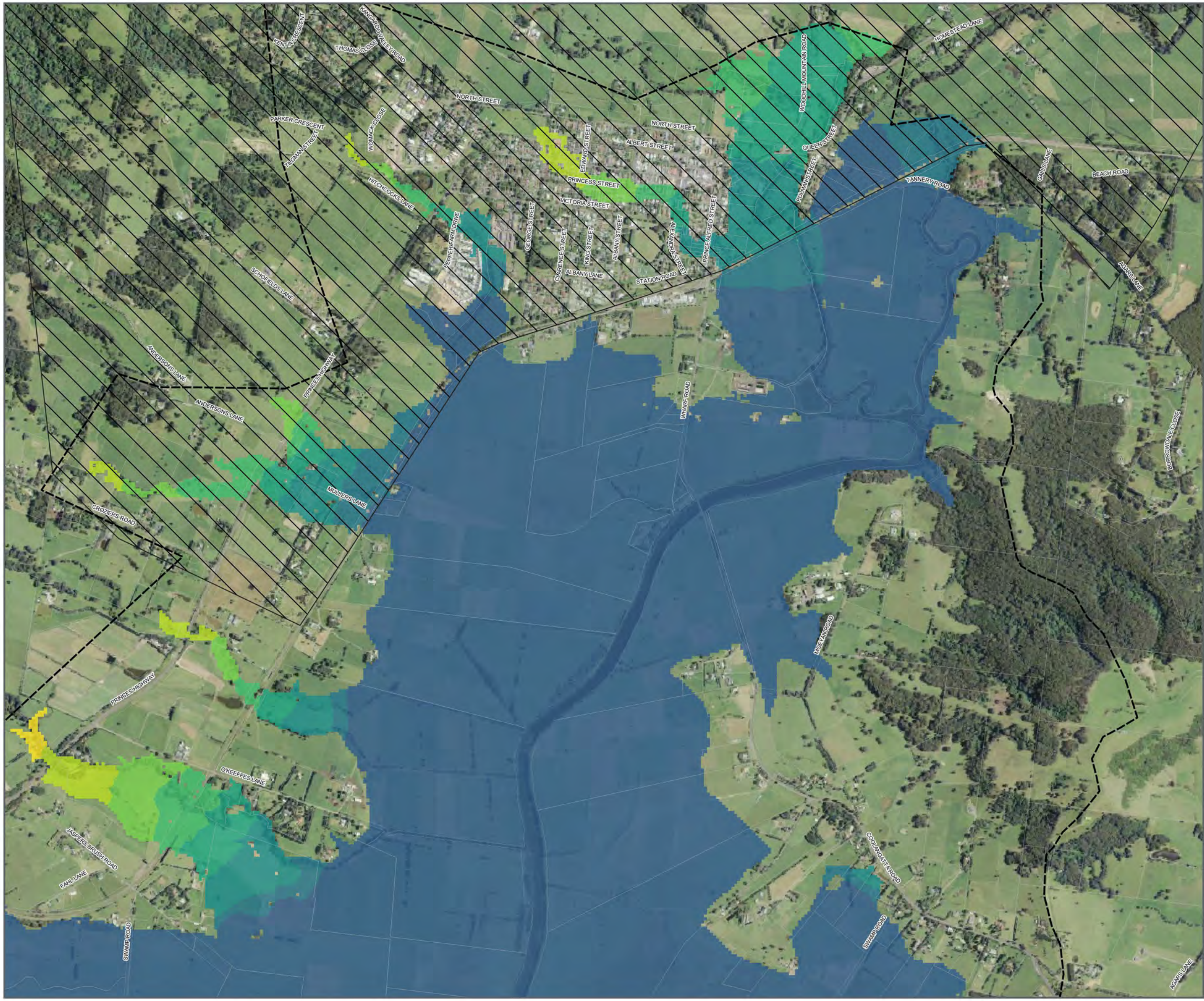
FIGURE G61.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Water Level Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G61.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 1% AEP Water Level Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G61.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 1% AEP Water Level Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

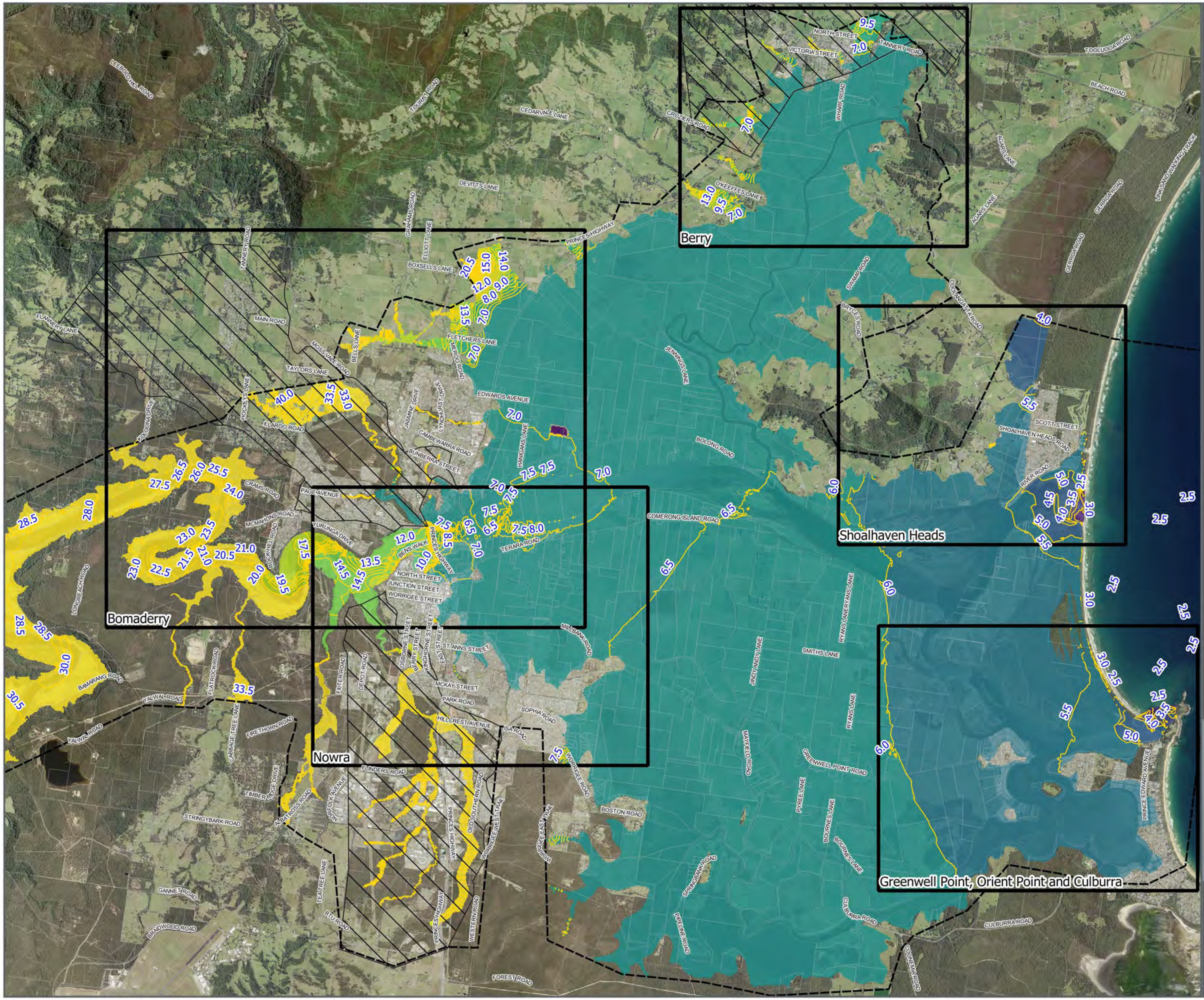
FIGURE G61.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Water Level Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G62

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 PMF Water Level Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

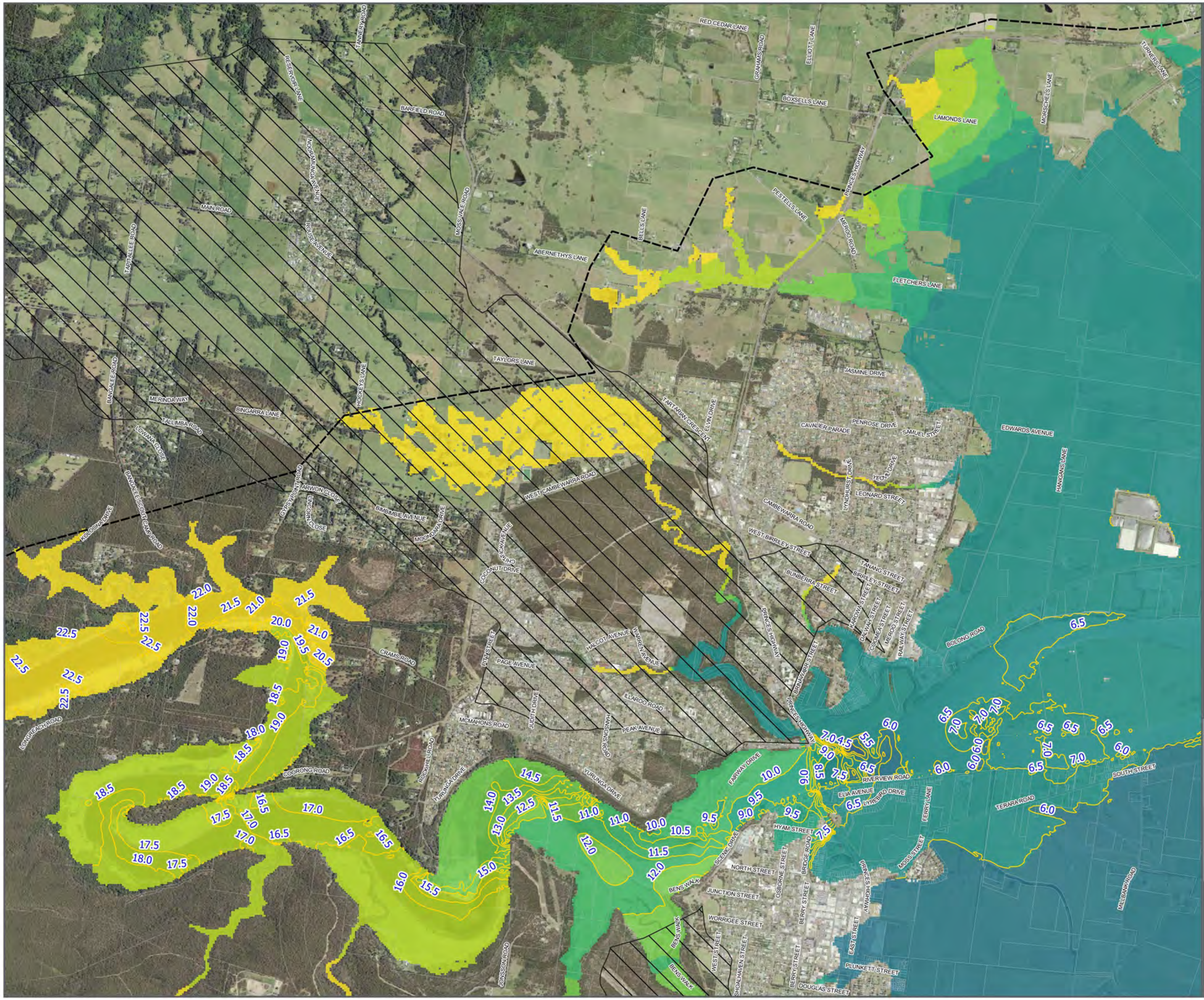
FIGURE G62.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Water Level Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

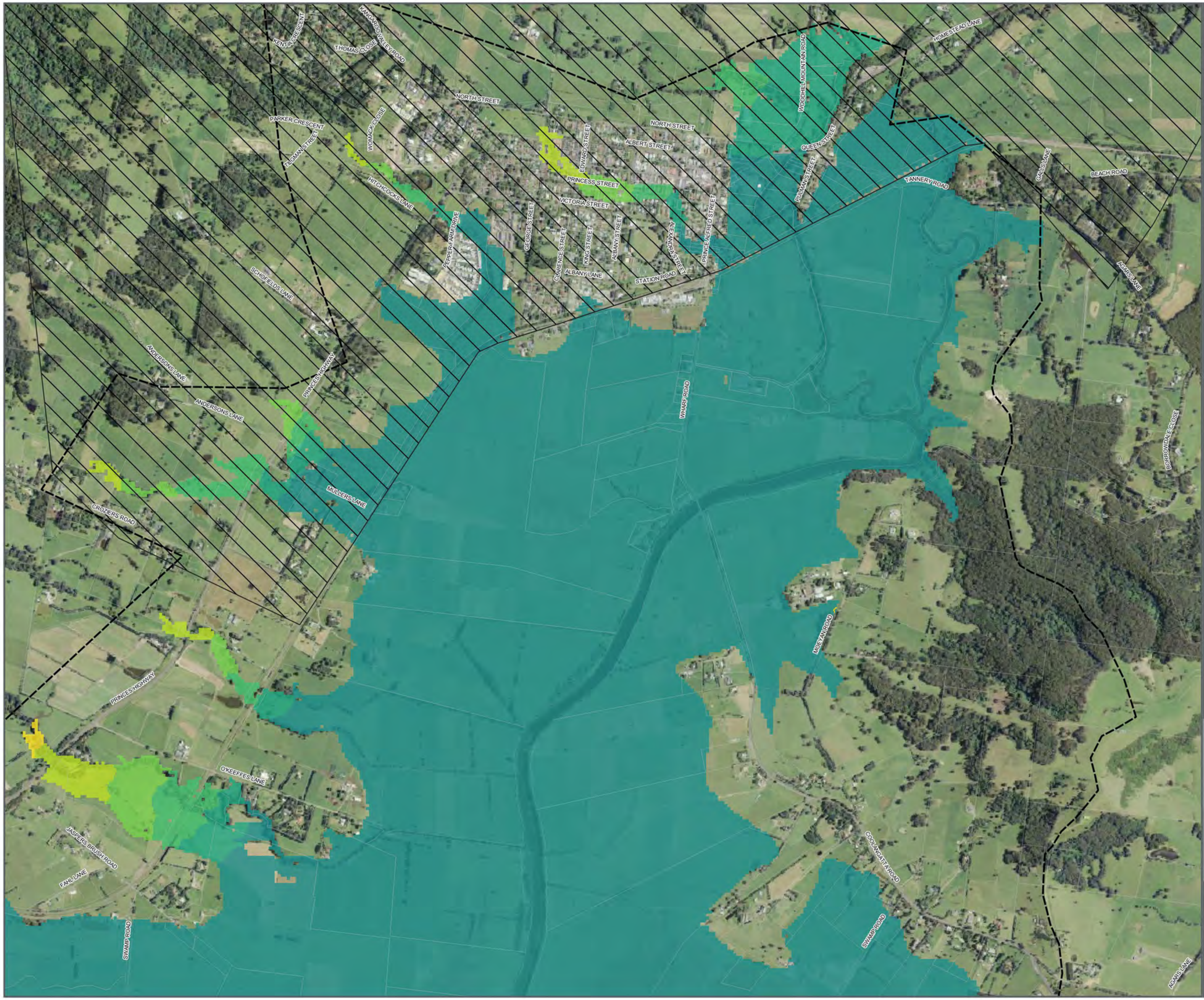
FIGURE G62.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Water Level Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G62.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 PMF Water Level Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

FIGURE G62.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 PMF Water Level Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Water Level (m AHD)

- < 2.00
- 2.00 to 3.00
- 3.00 to 4.00
- 4.00 to 5.00
- 5.00 to 6.00
- 6.00 to 8.00
- 8.00 to 10.00
- 10.00 to 12.00
- 12.00 to 15.00
- 15.00 to 20.00
- > 20.00

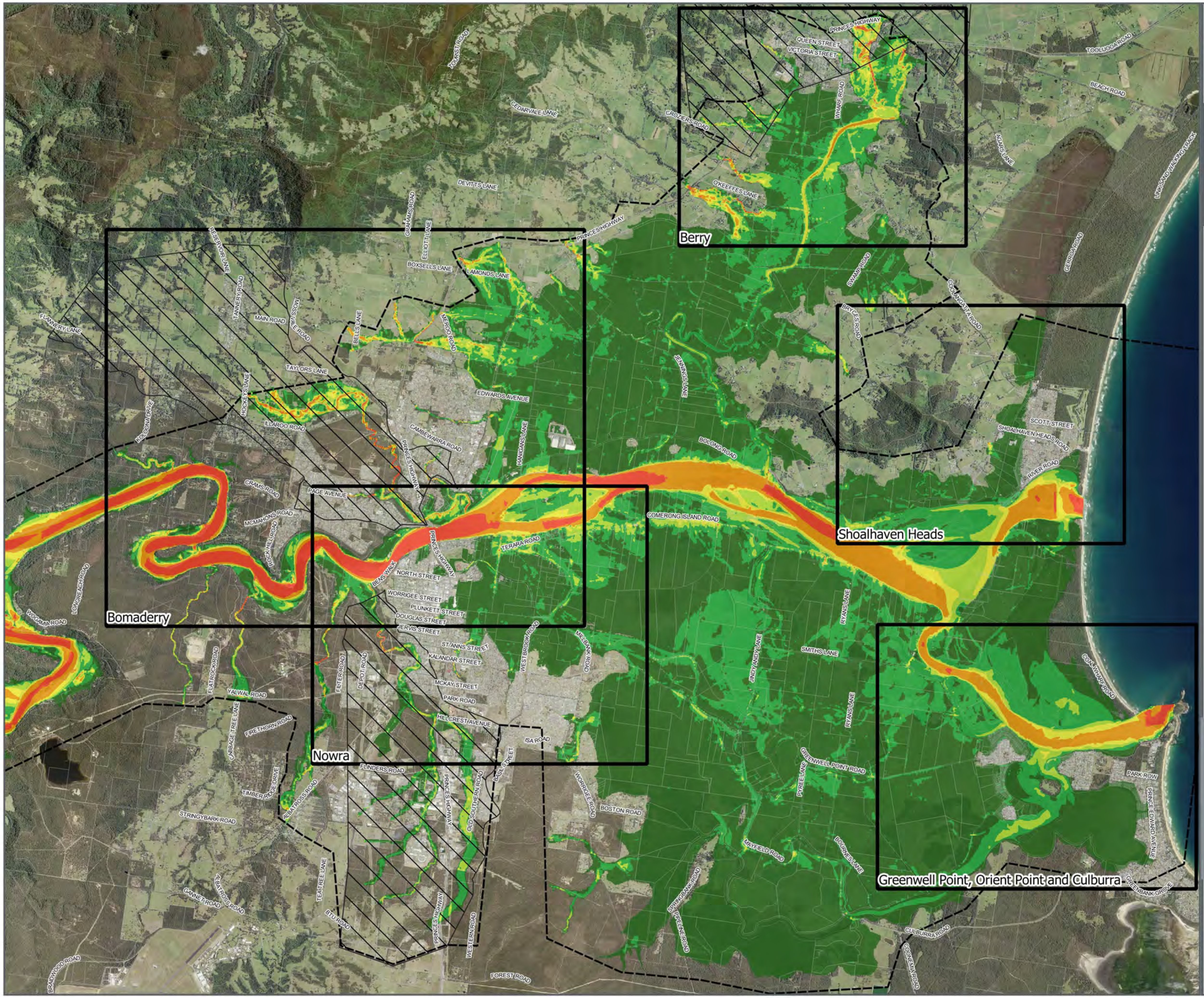
FIGURE G62.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Velocity Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

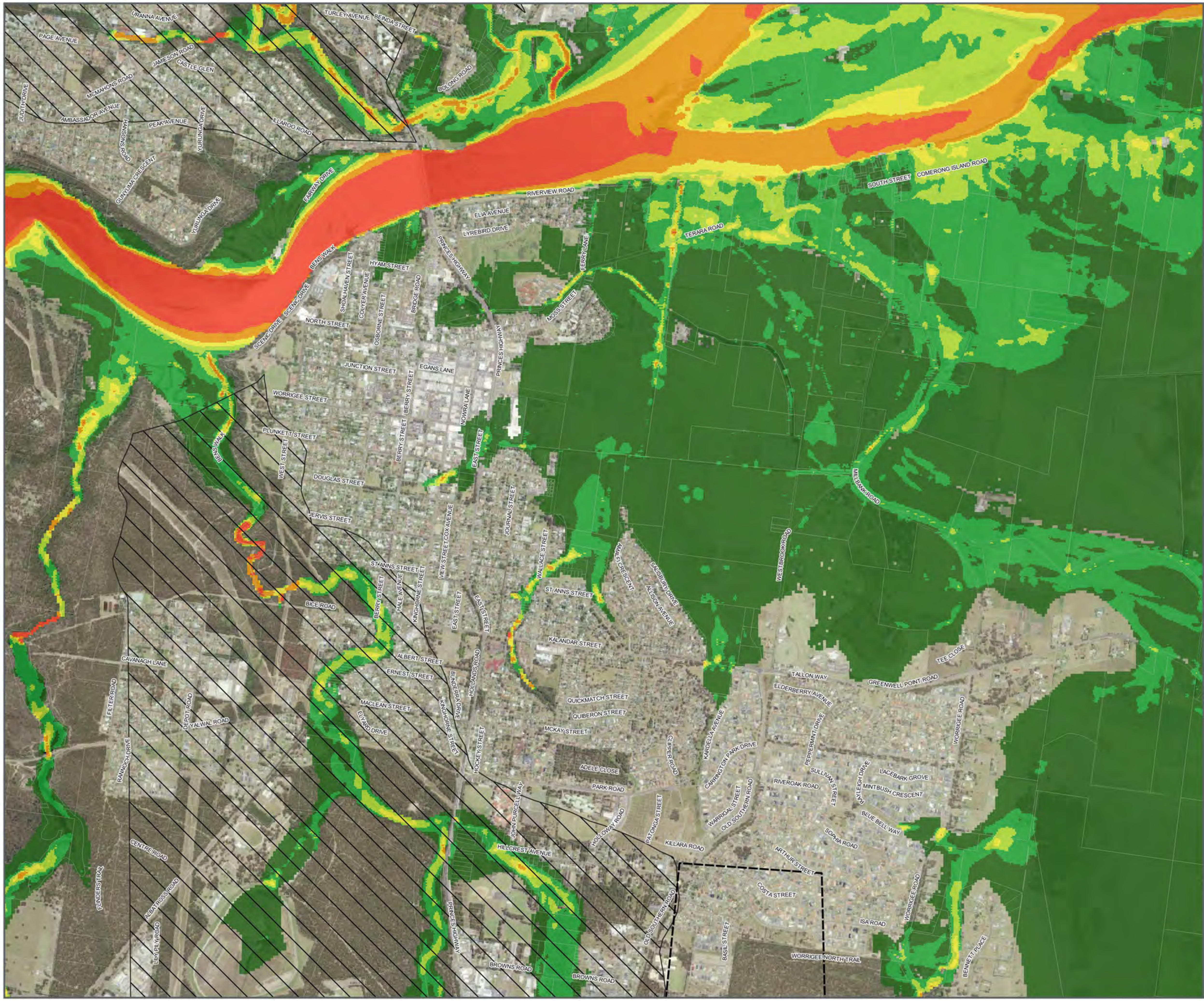
FIGURE G63

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Velocity
Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

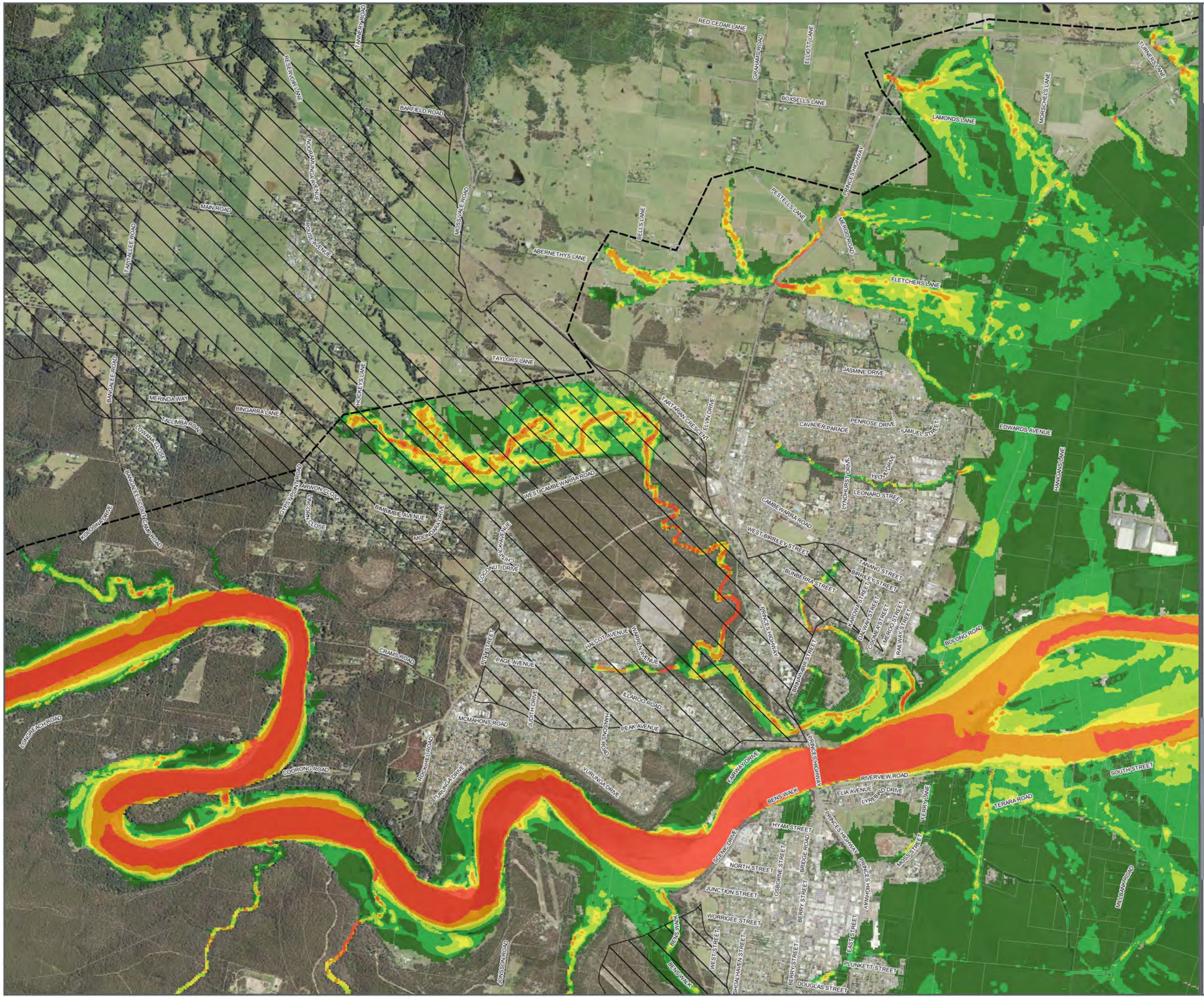
FIGURE G63.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Velocity Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

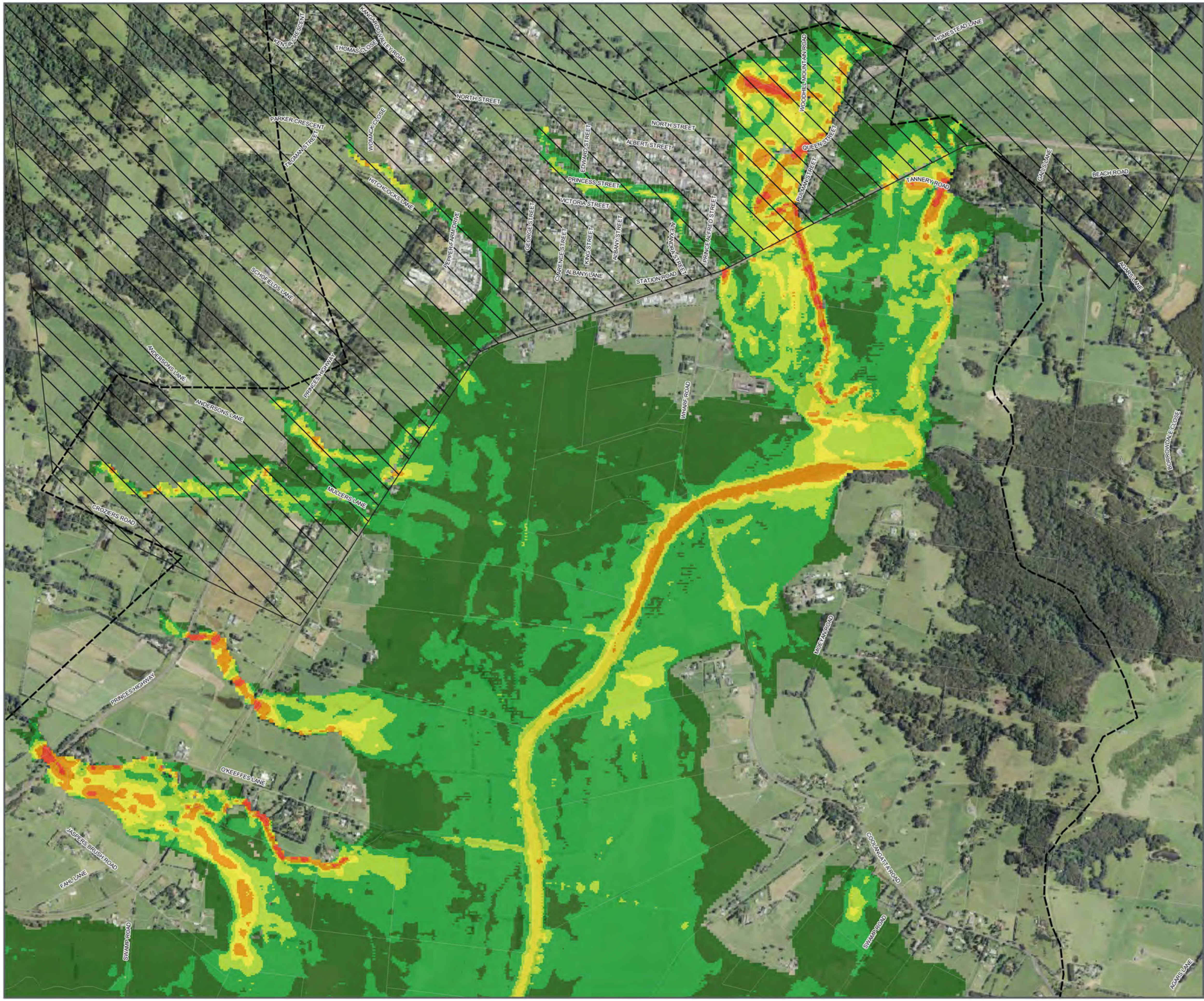
FIGURE G63.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Velocity Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

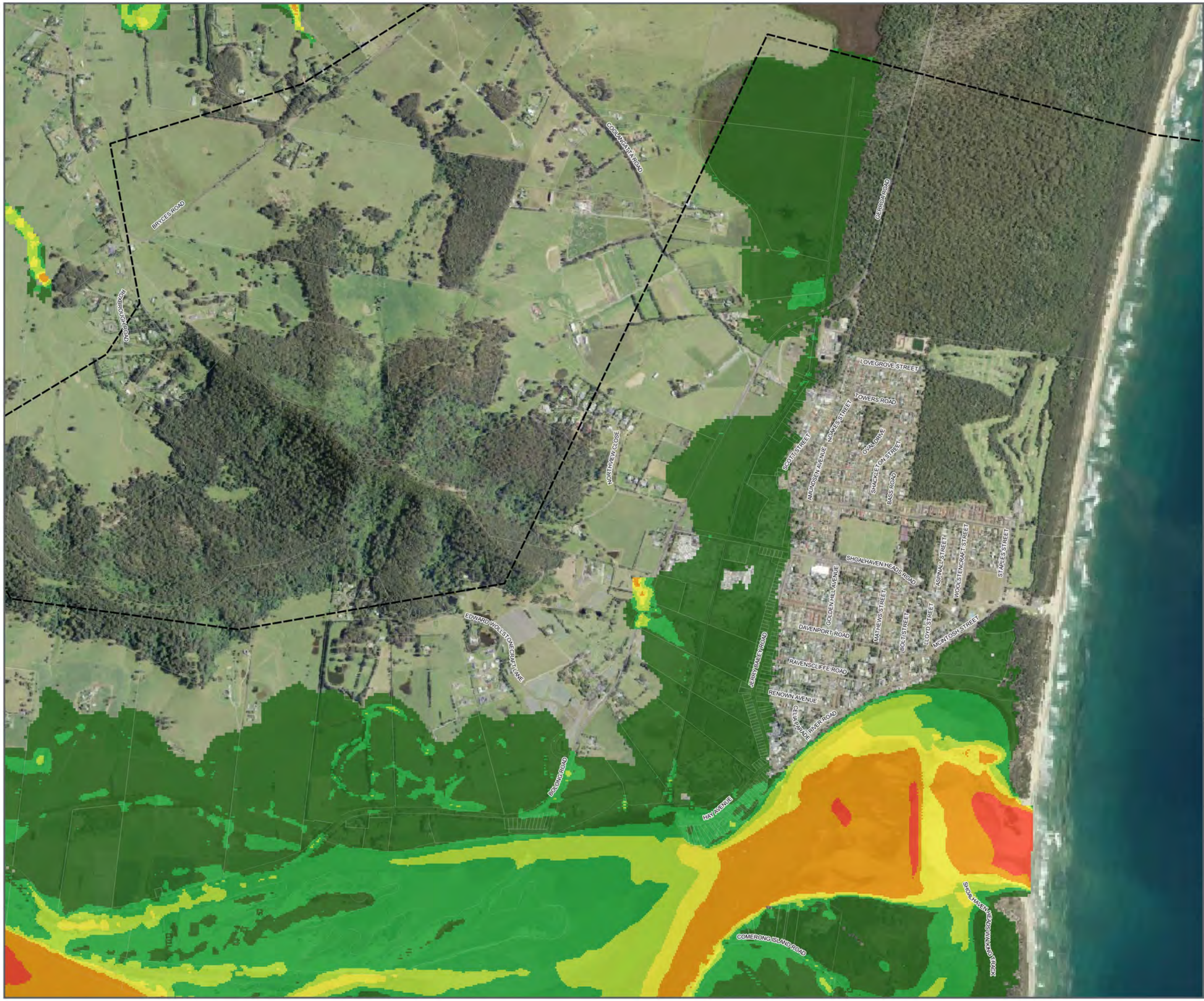
FIGURE G63.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Velocity Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G63.4

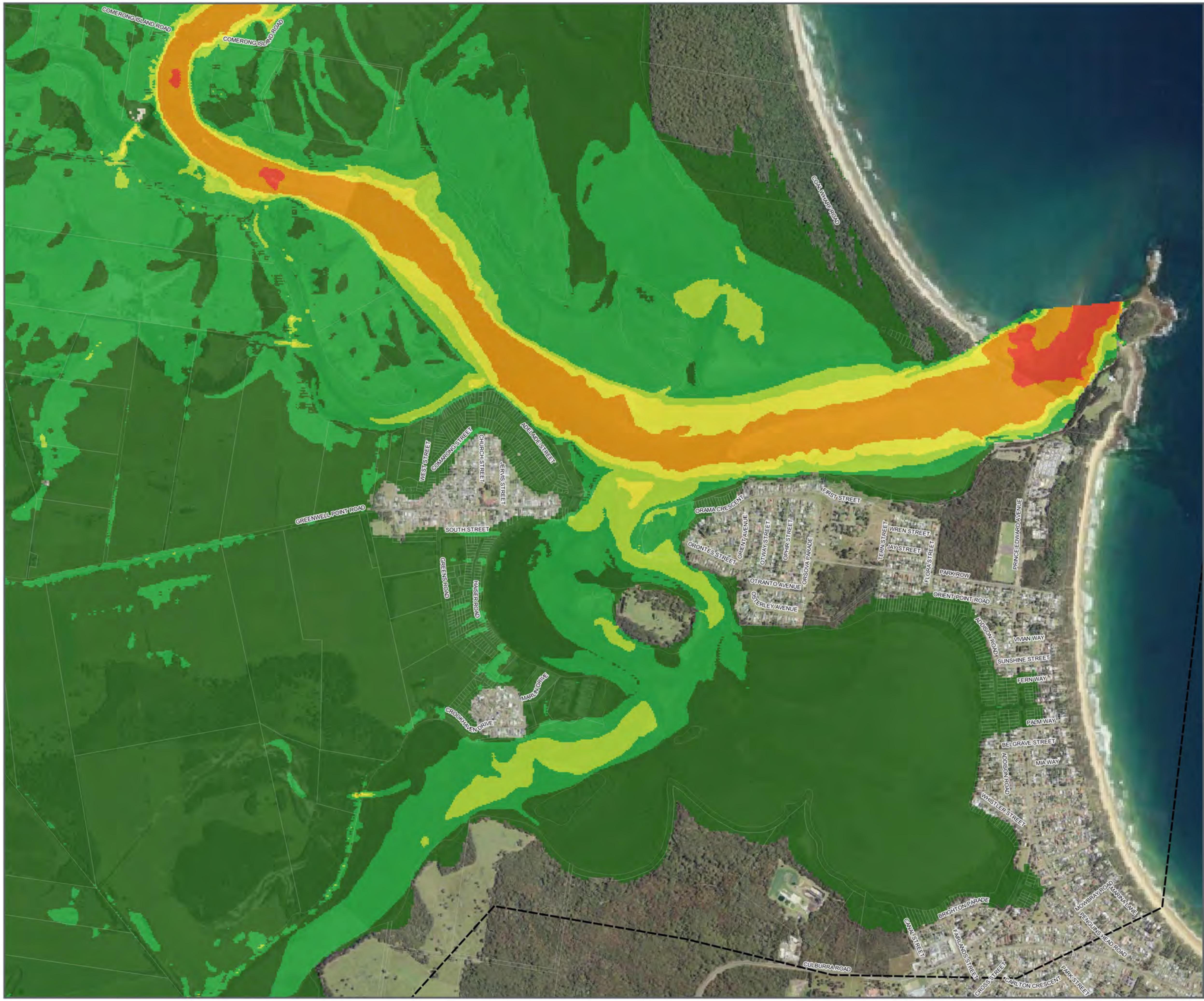
1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Velocity Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

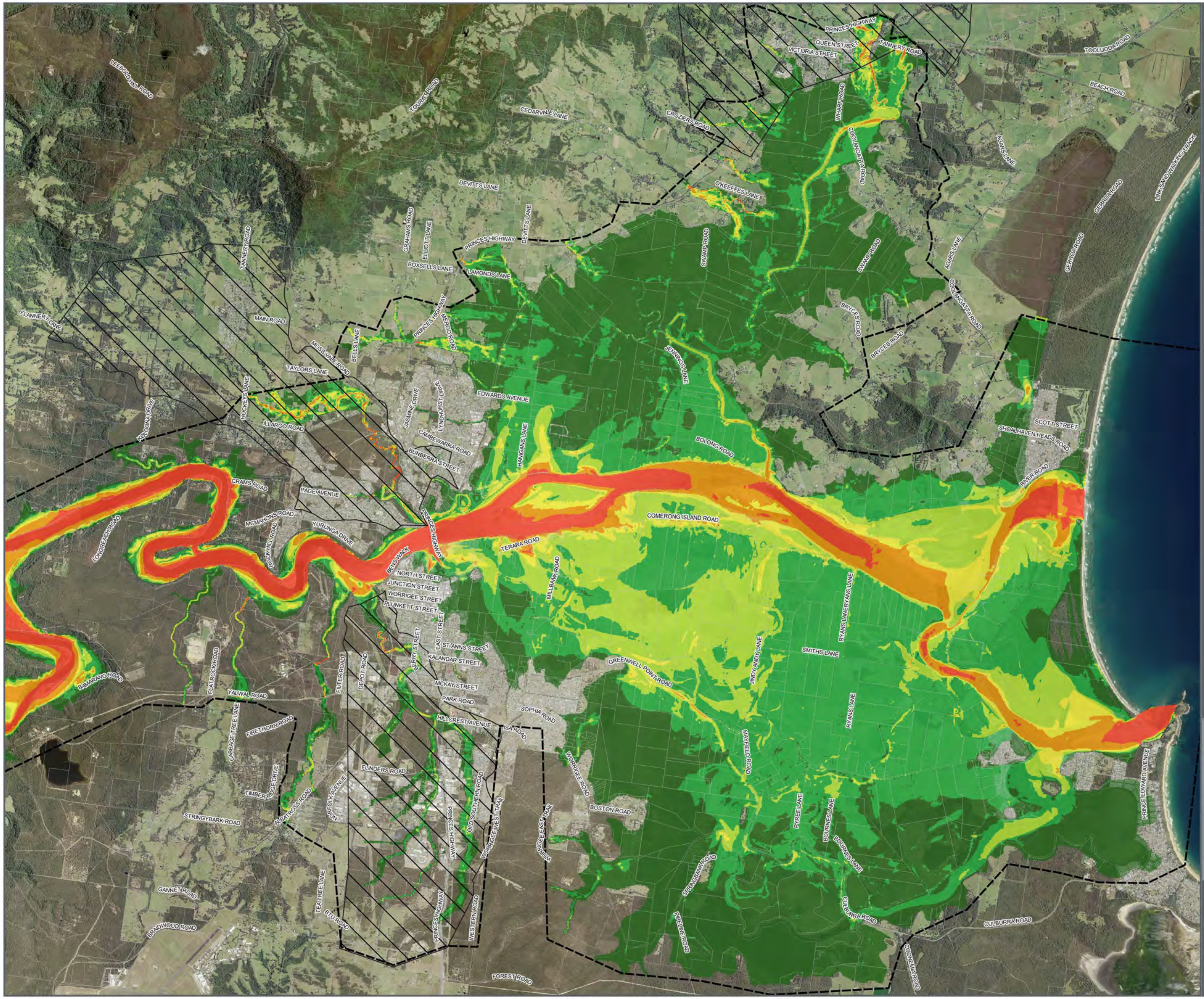
FIGURE G63.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Velocity

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

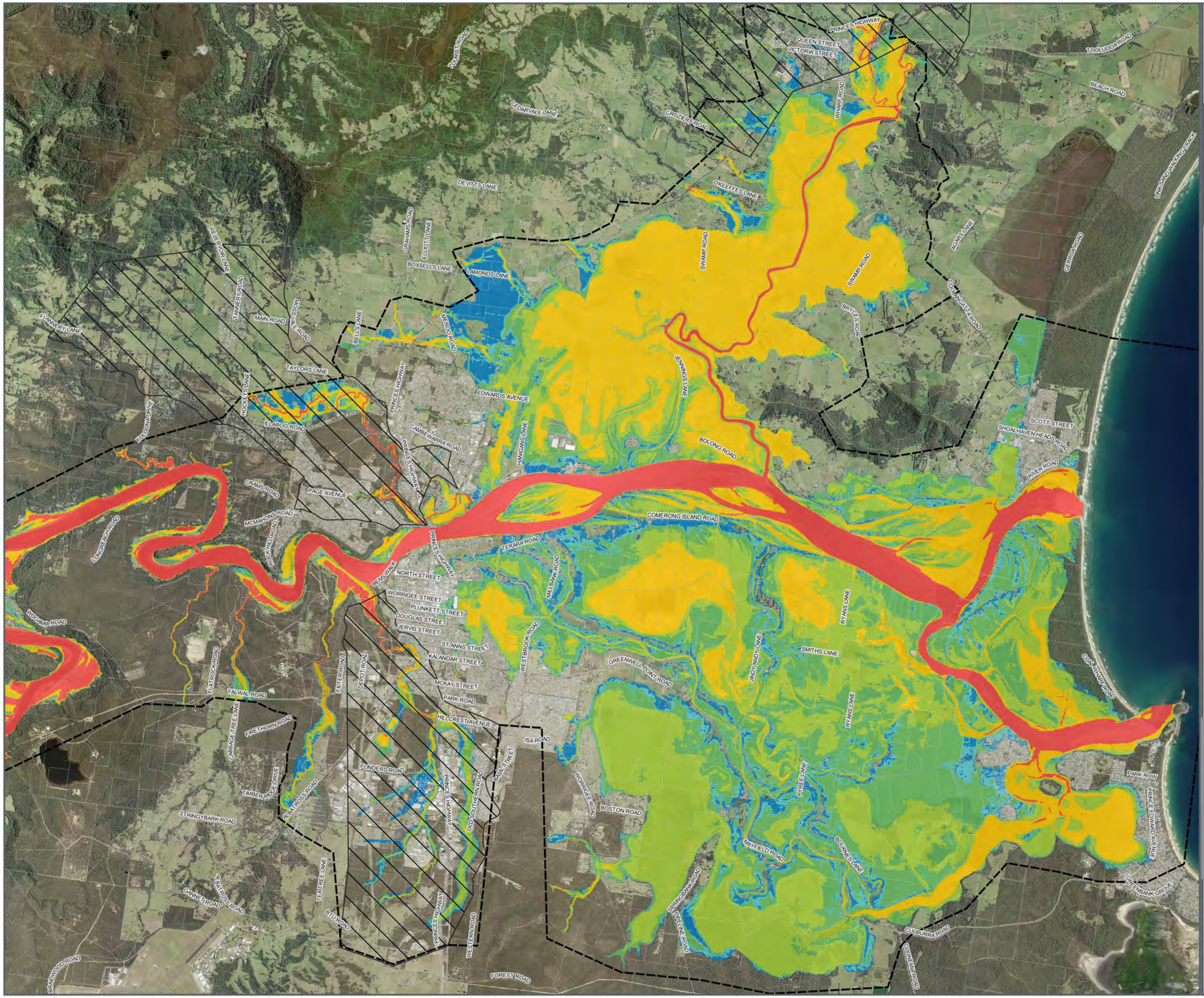
FIGURE G64

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
5% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

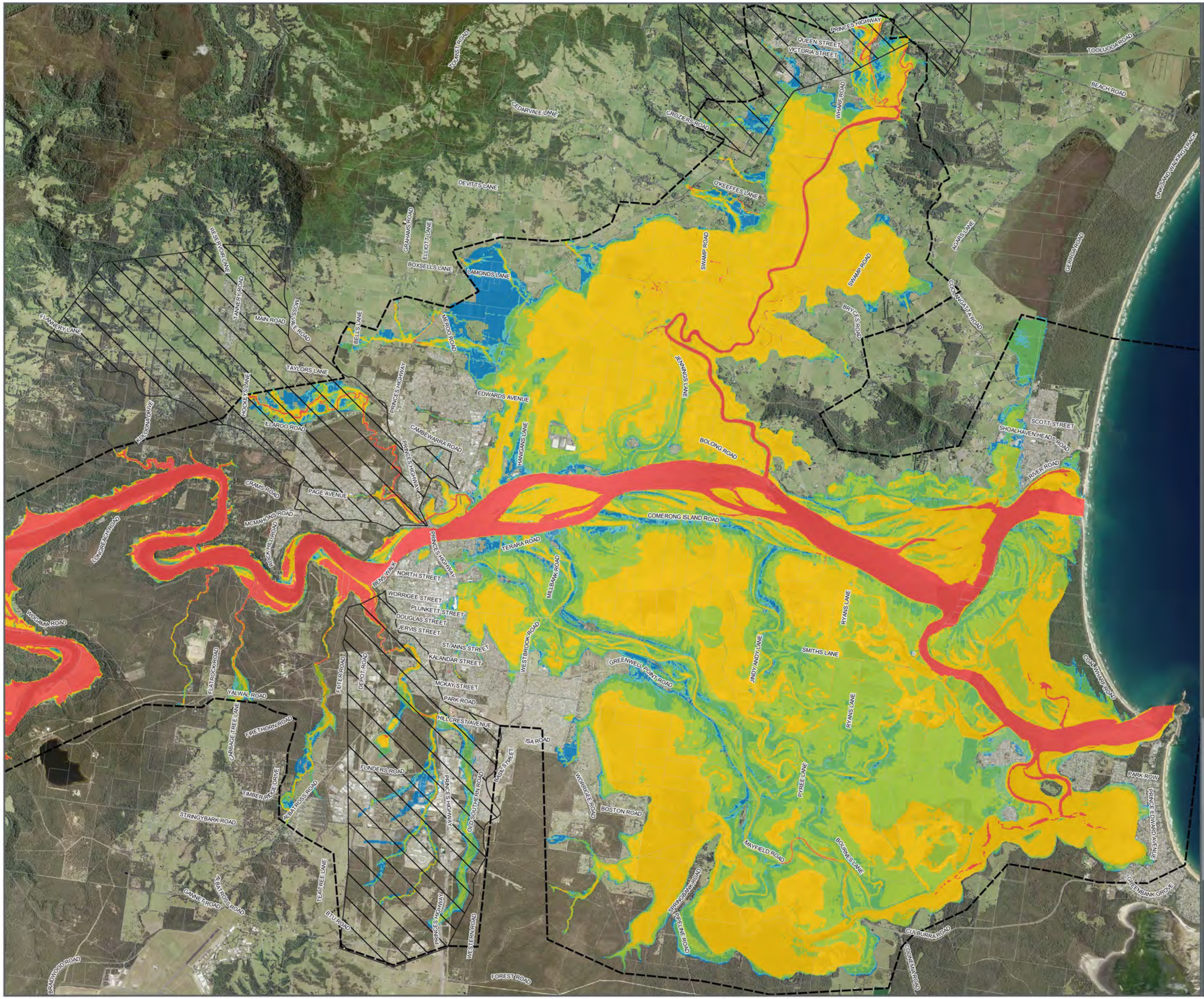
FIGURE G65

1:75,000 **Scale at A3**

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
2% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G66

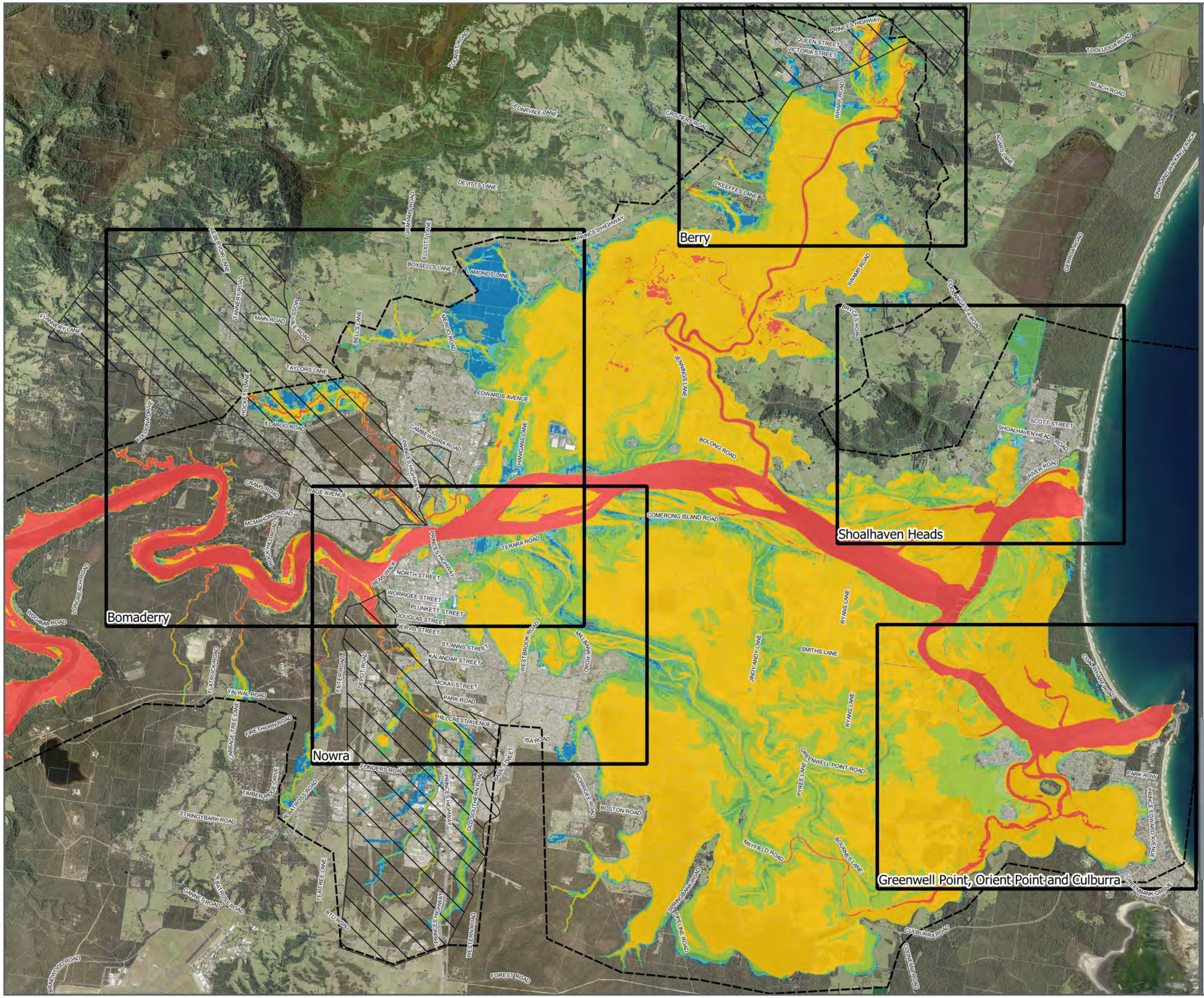
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hazard Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

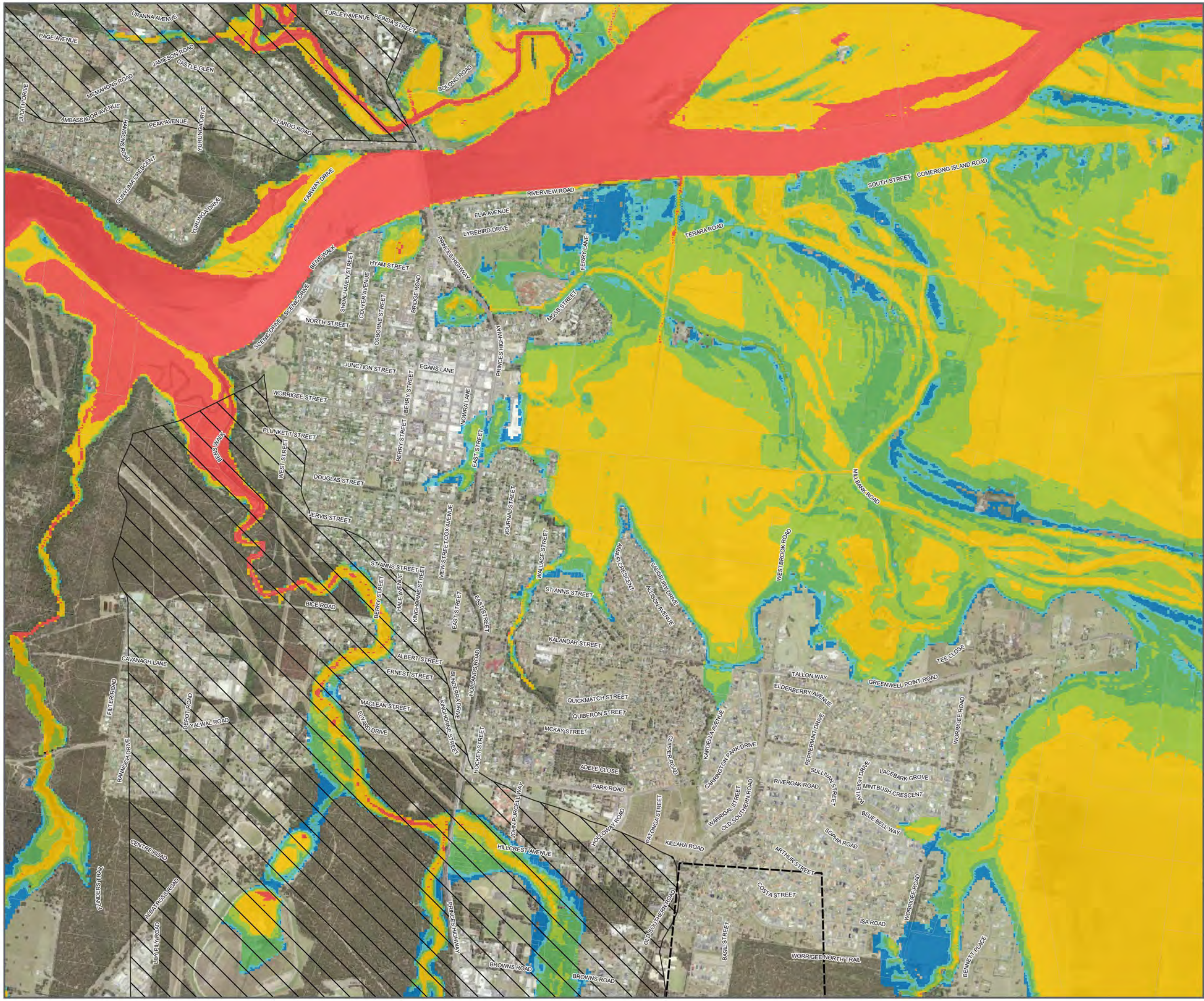
FIGURE G67

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Hazard
Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

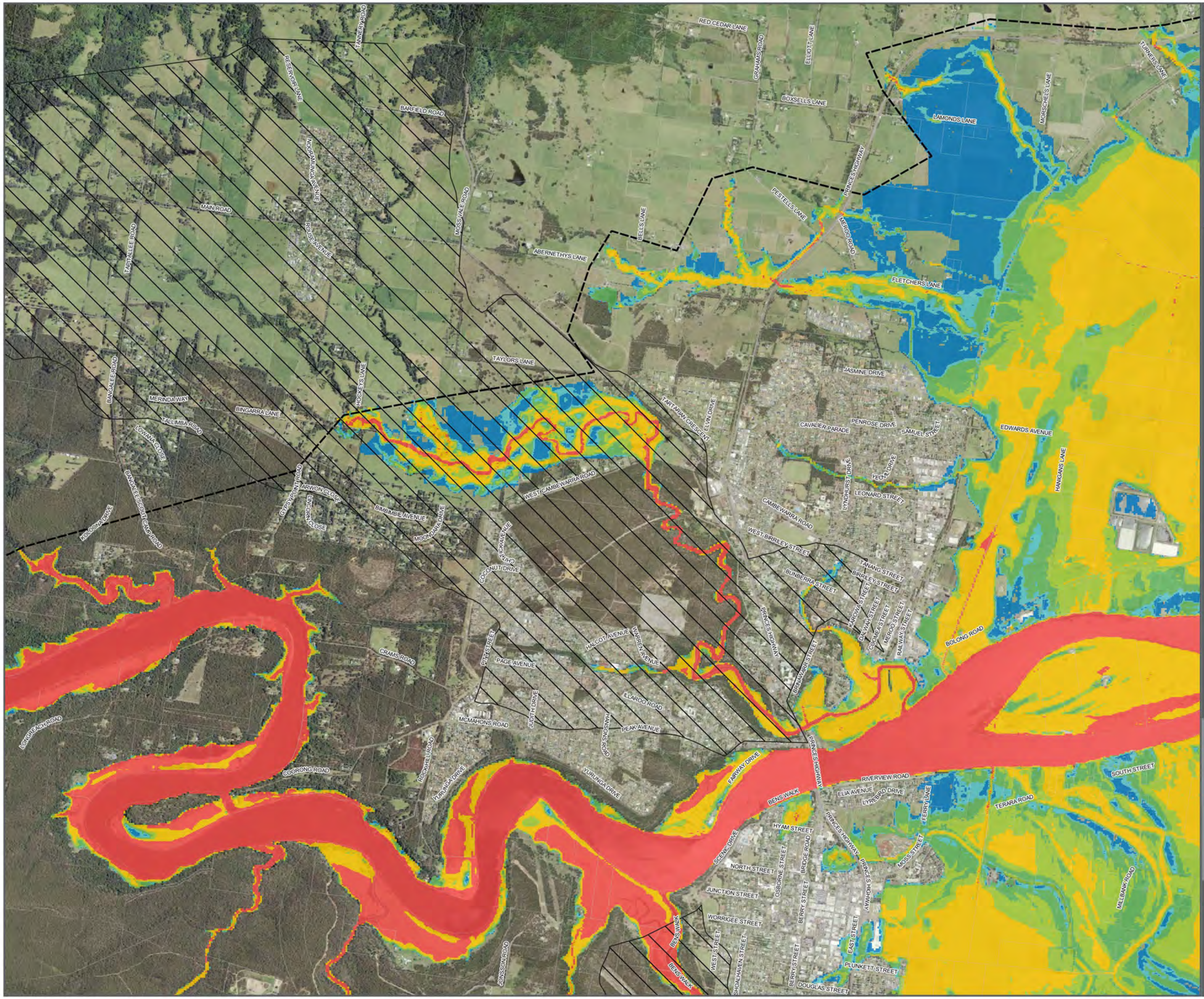
FIGURE G67.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hazard Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

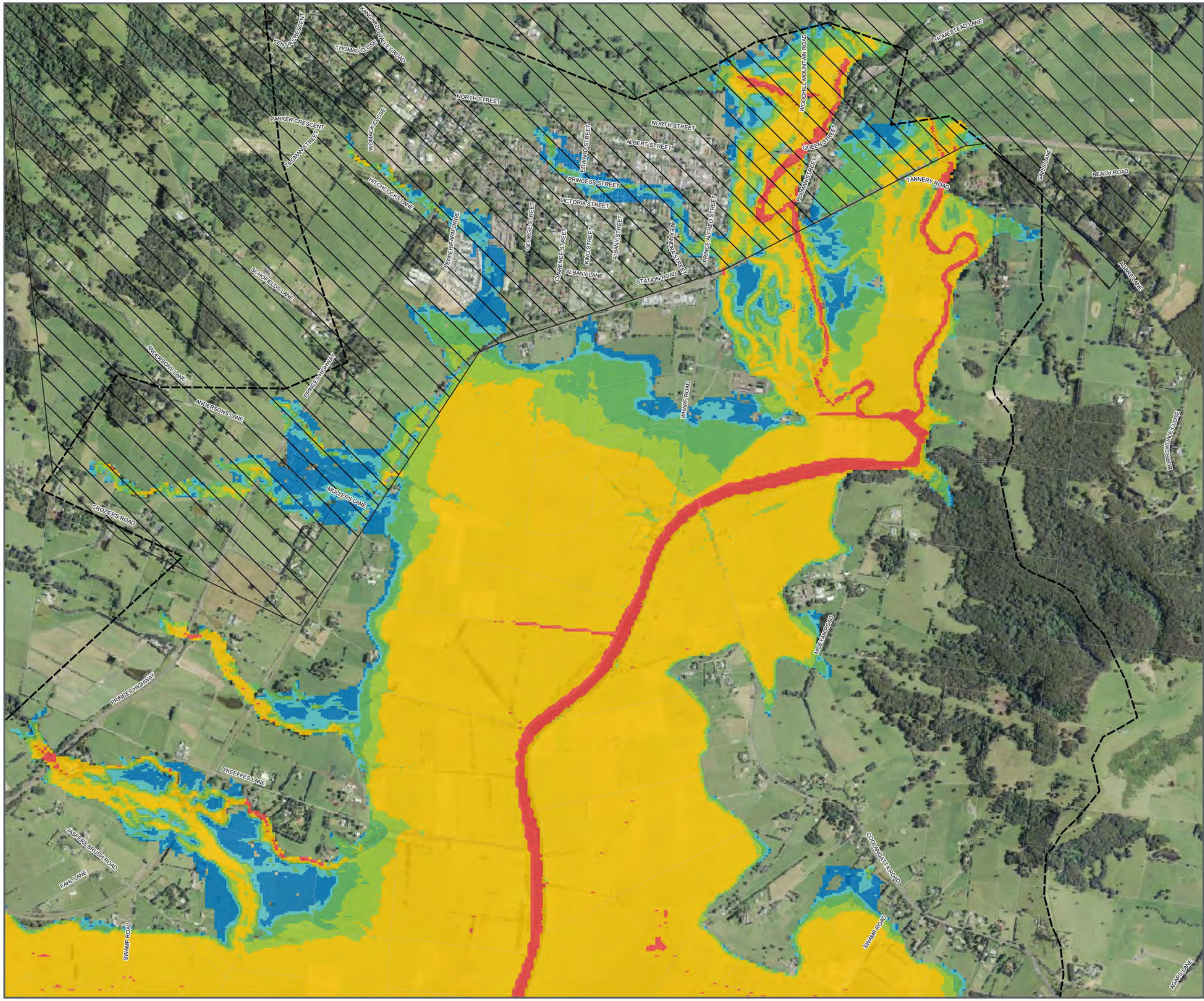
FIGURE G67.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Hazard
Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

FIGURE G67.3

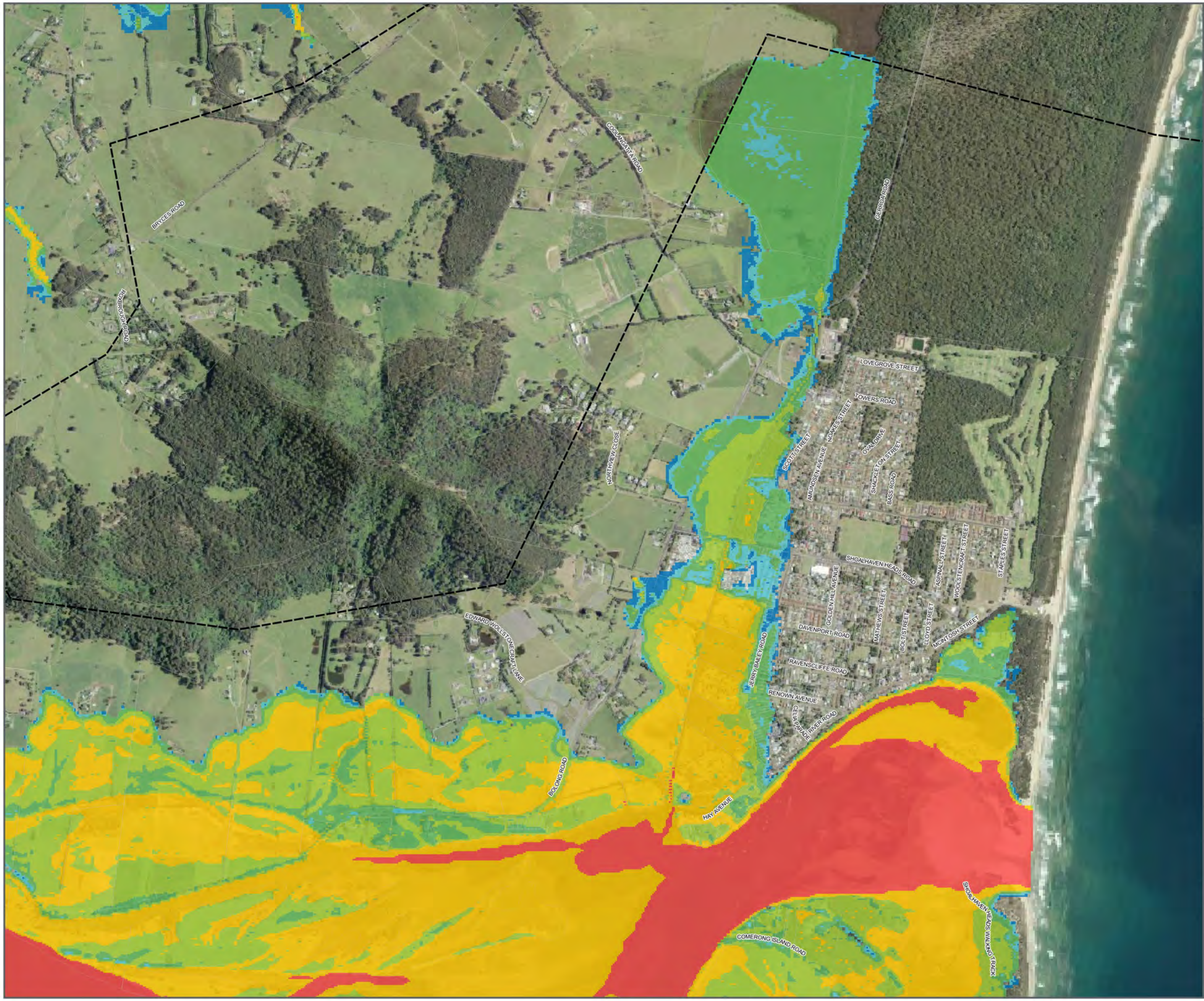
1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hazard Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

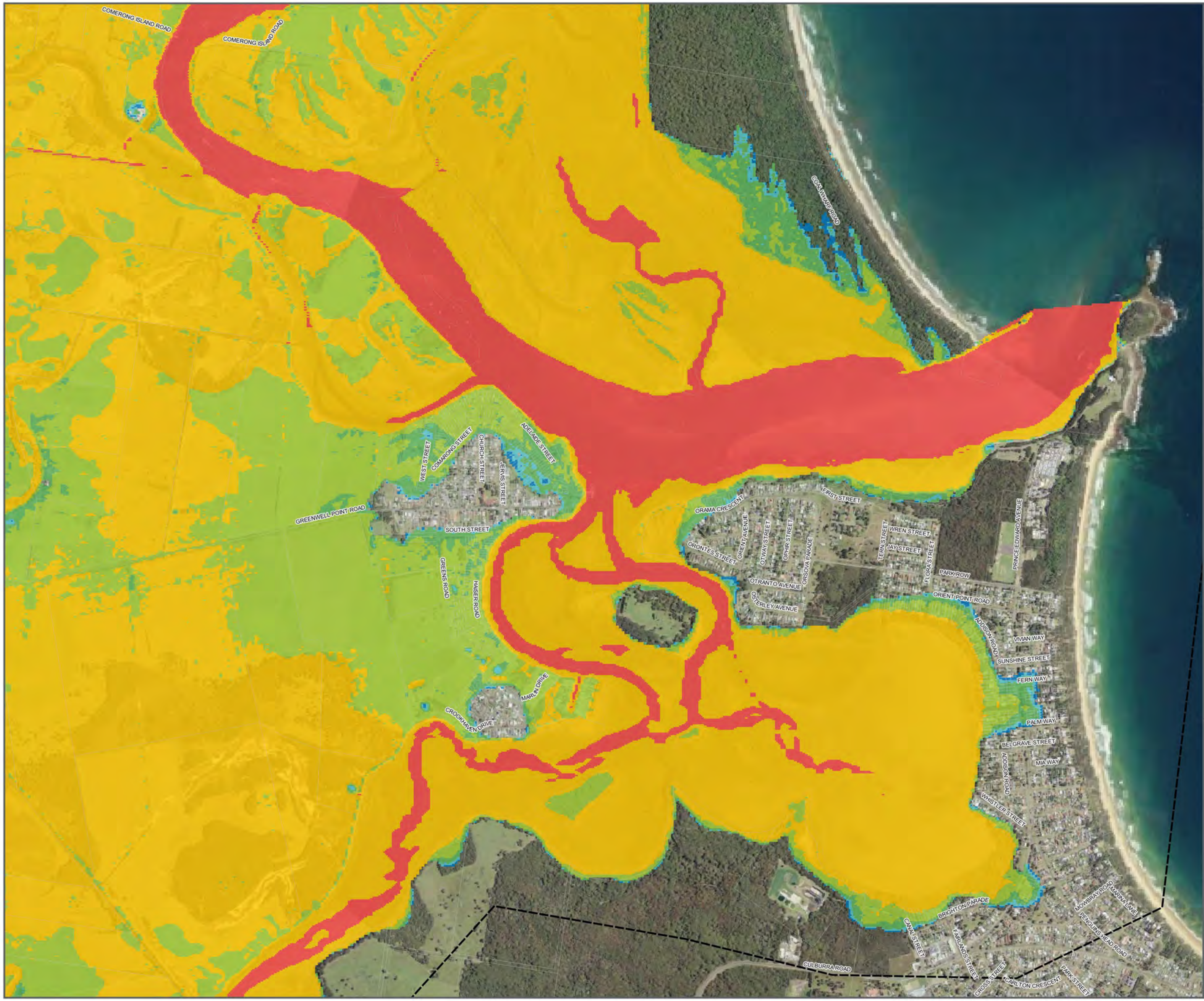
FIGURE G67.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hazard Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

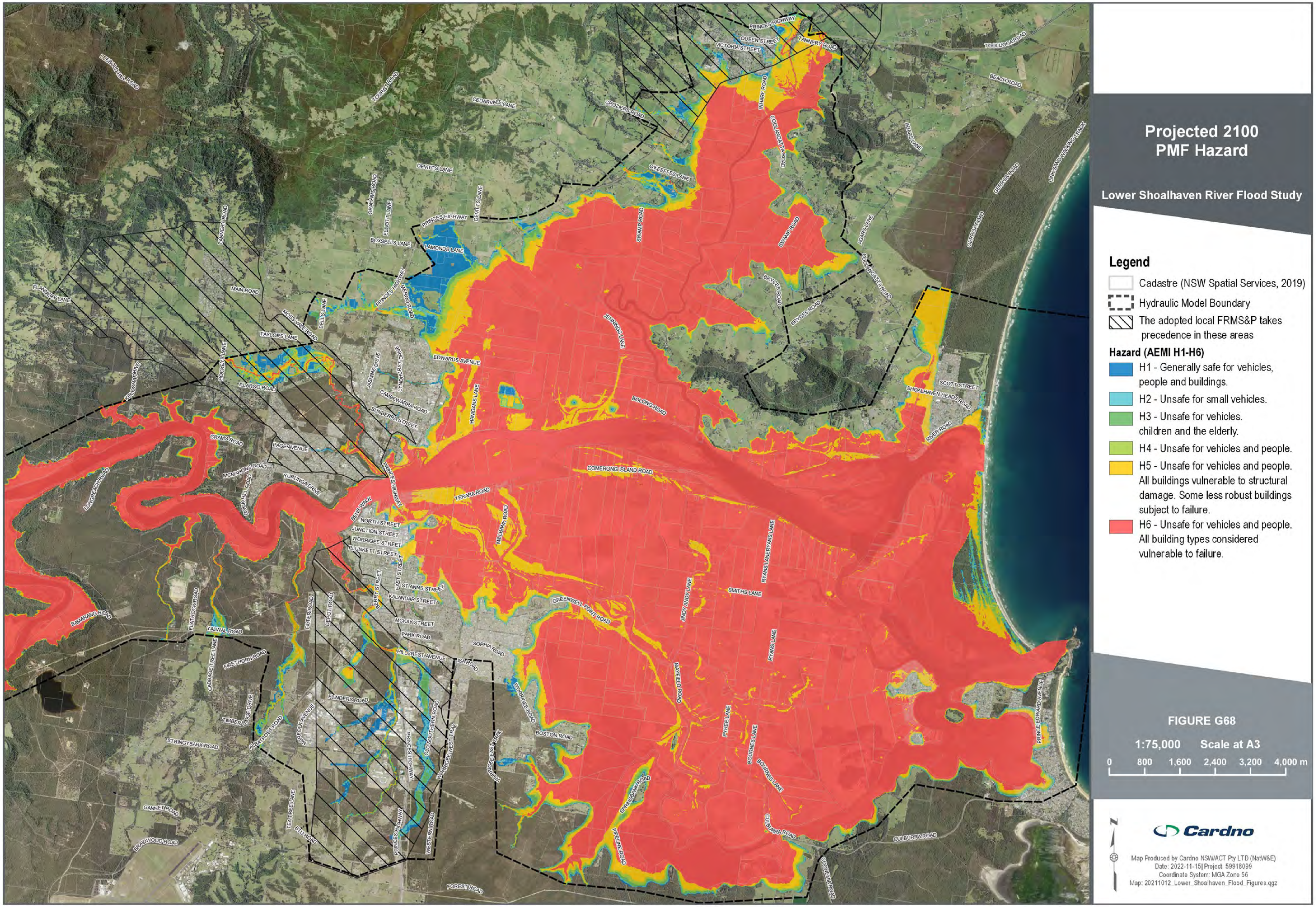
FIGURE G67.5

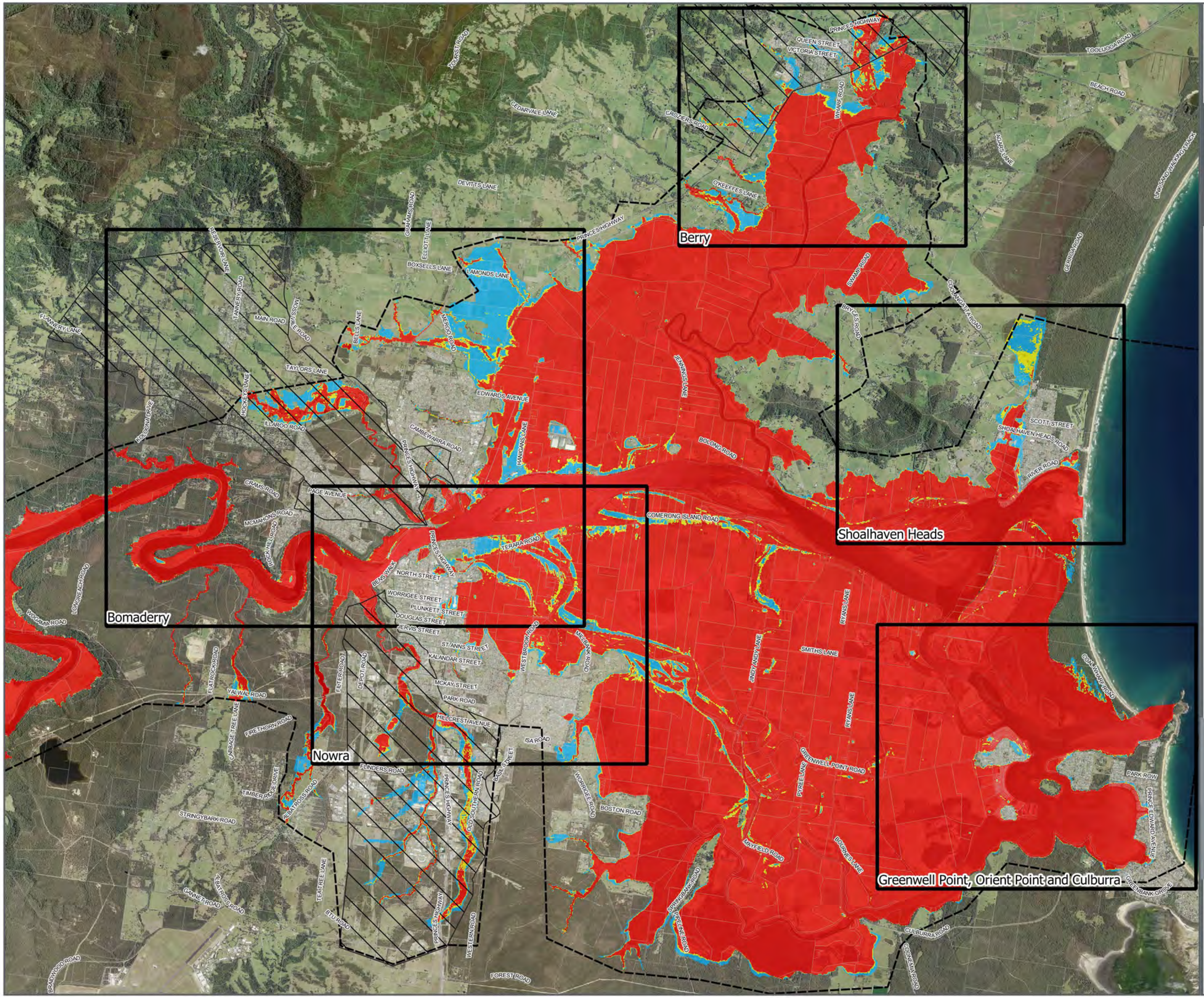
1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Projected 2100
PMF Hazard
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Hazard (AEMI H1-H6)
H1 - Generally safe for vehicles, people and buildings.
H2 - Unsafe for small vehicles.
H3 - Unsafe for vehicles. children and the elderly.
H4 - Unsafe for vehicles and people.
H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.
FIGURE G68
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Provisional Hazard Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

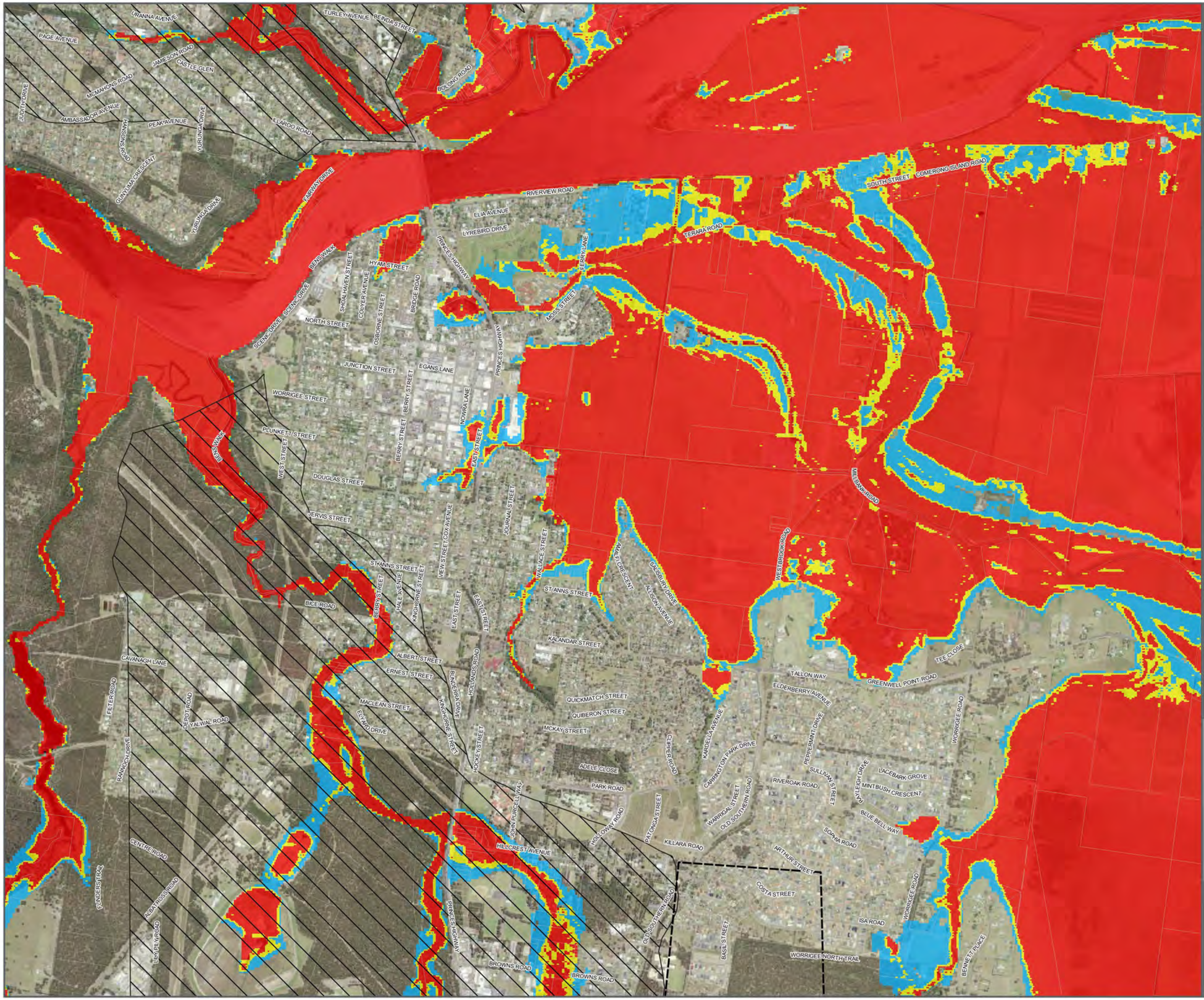
FIGURE G69

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Provisional Hazard
Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

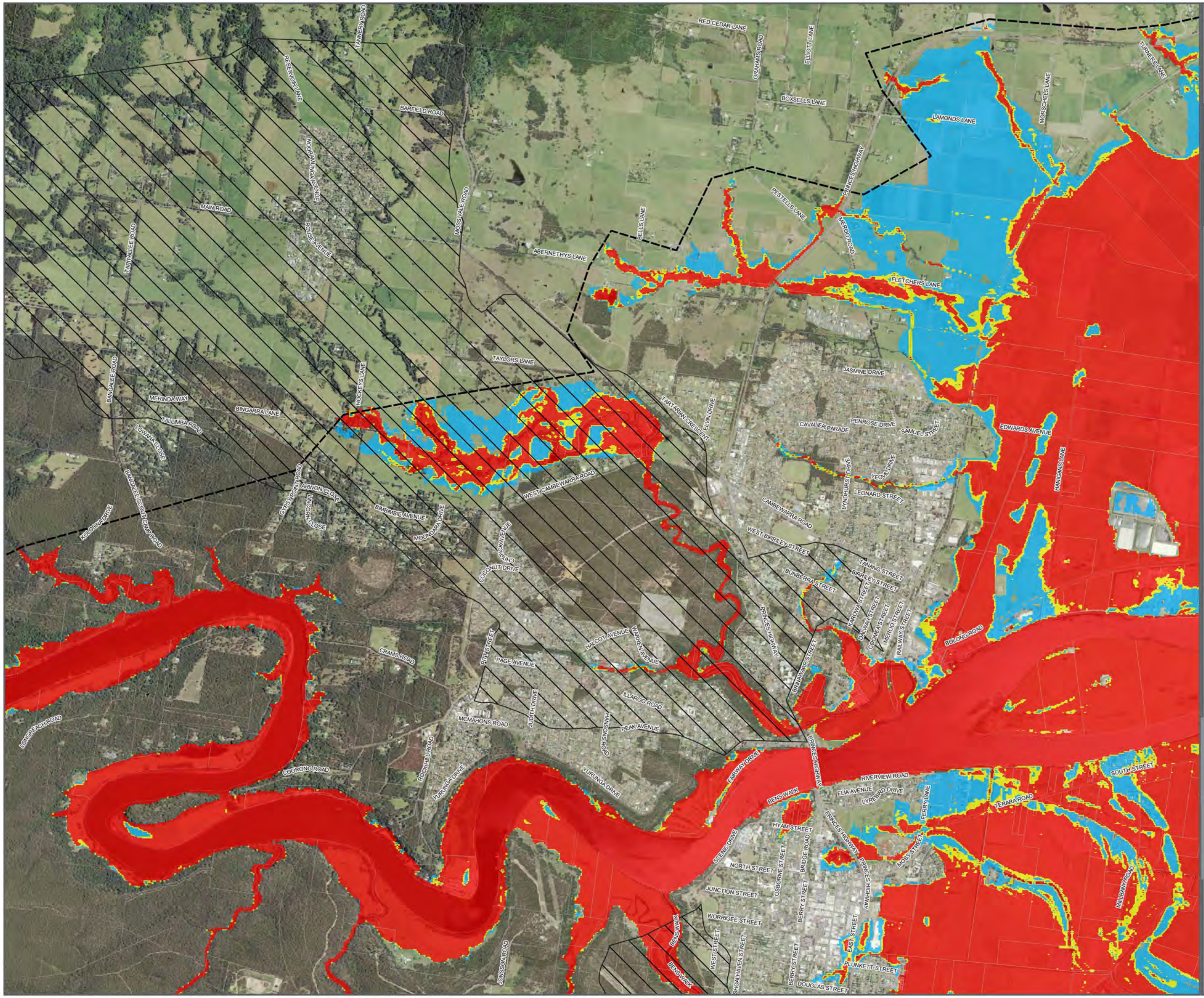
FIGURE G69.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Provisional Hazard Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

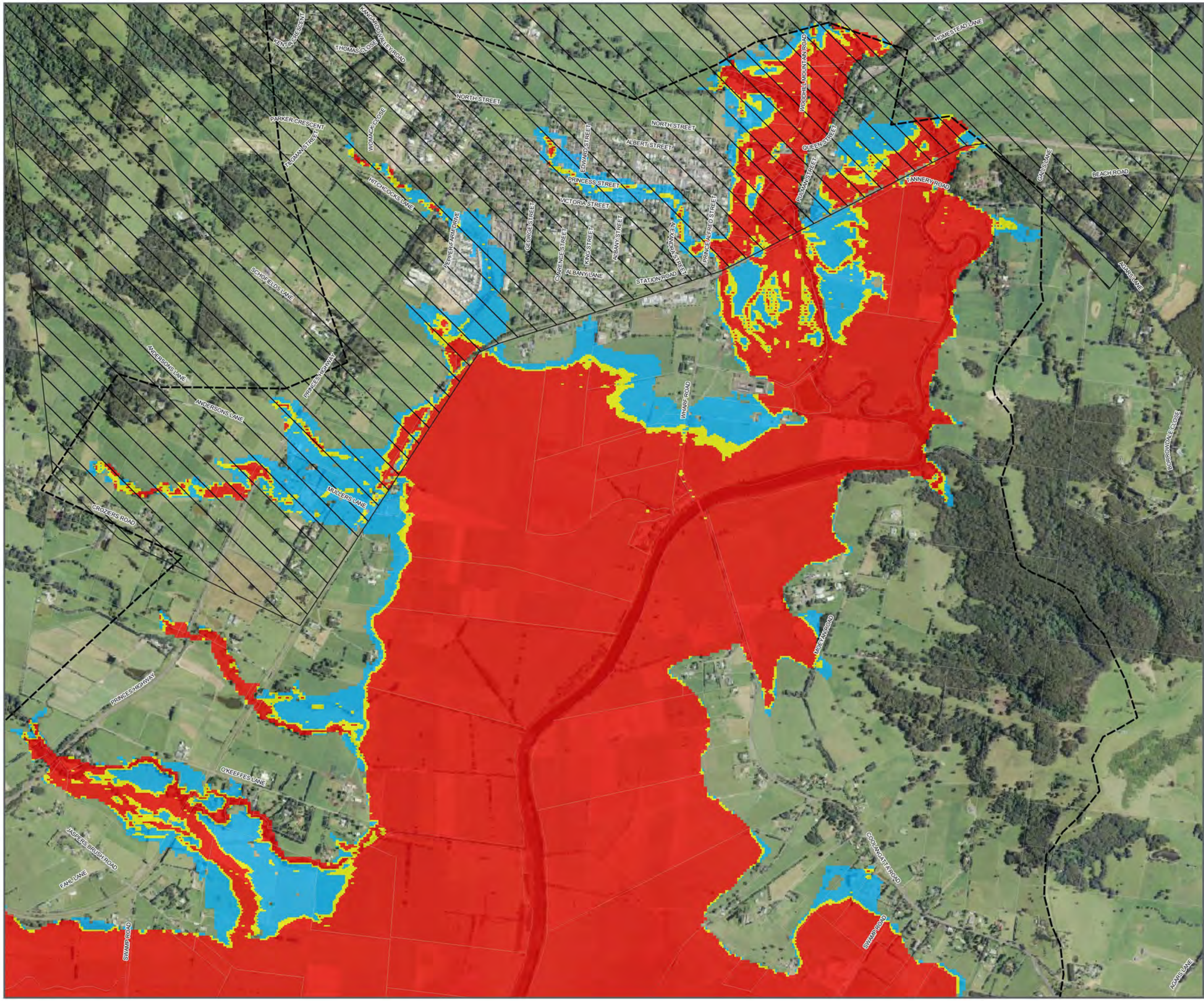
FIGURE G69.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Provisional Hazard Berry

Lower Shoalhaven River Flood Study

Legend

Cadastre (NSW Spatial Services, 2019)

Hydraulic Model Boundary

The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

Low

Transitional

High

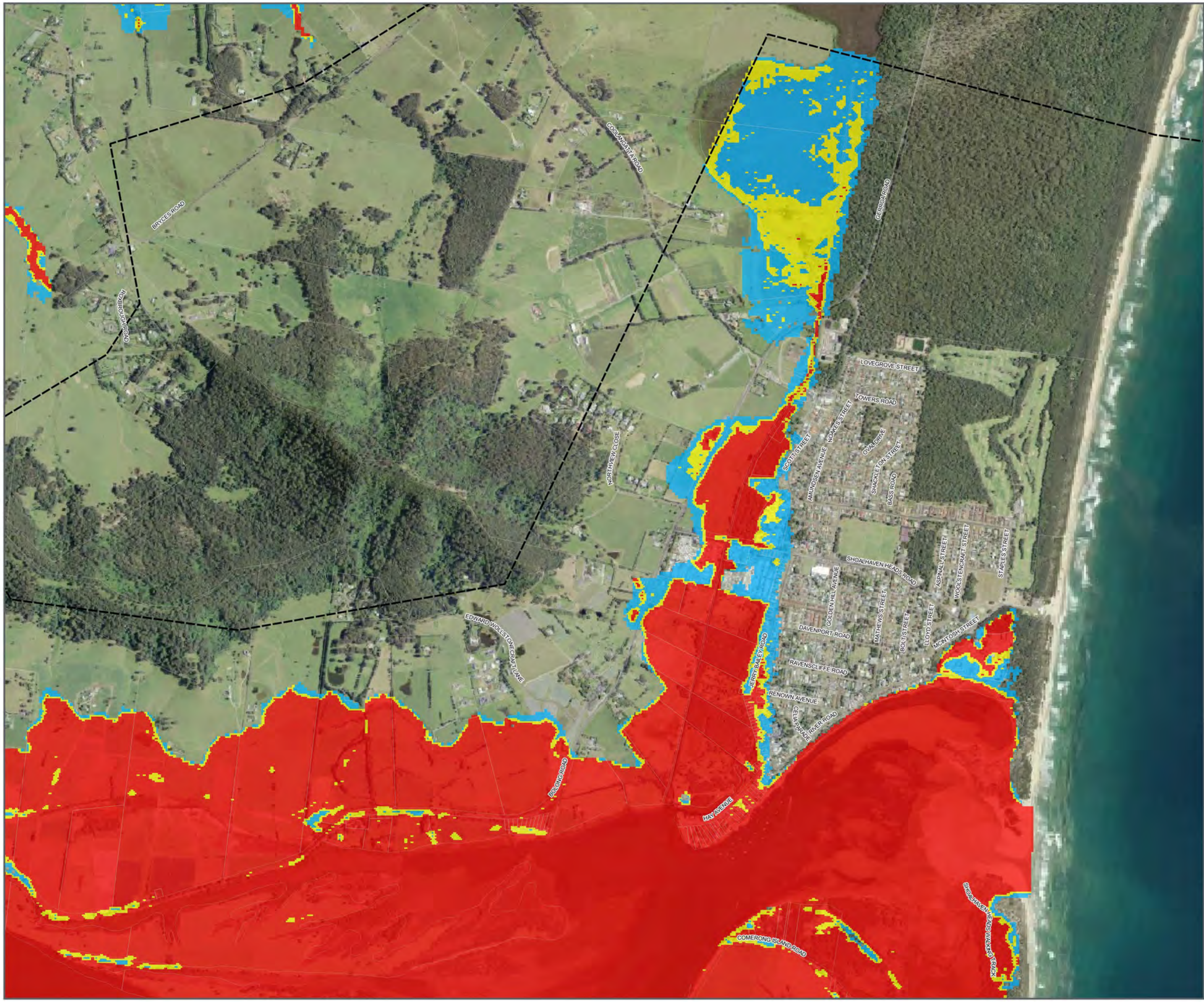
FIGURE G69.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Provisional Hazard Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

FIGURE G69.4

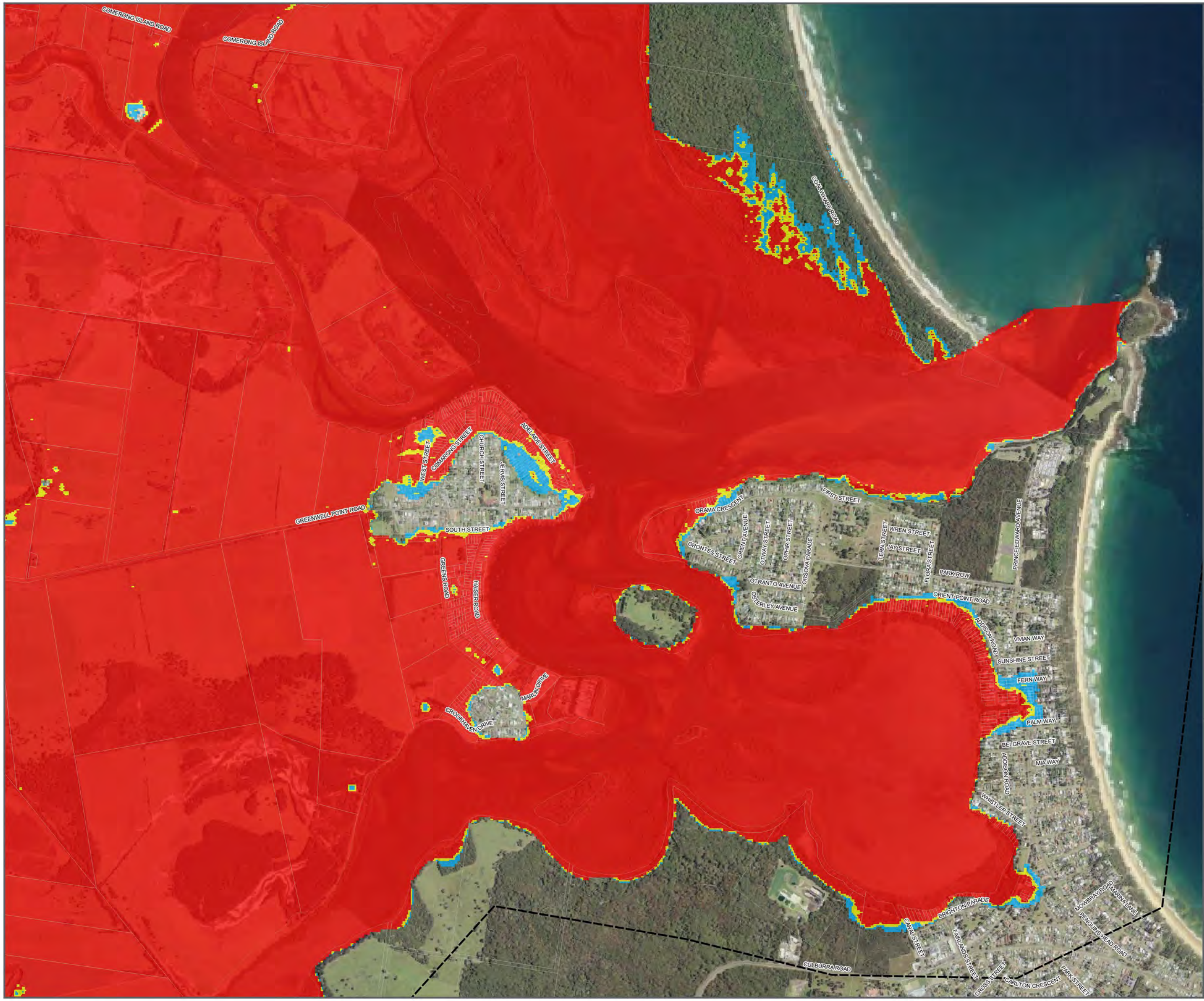
1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Provisional Hazard Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

- Low
- Transitional
- High

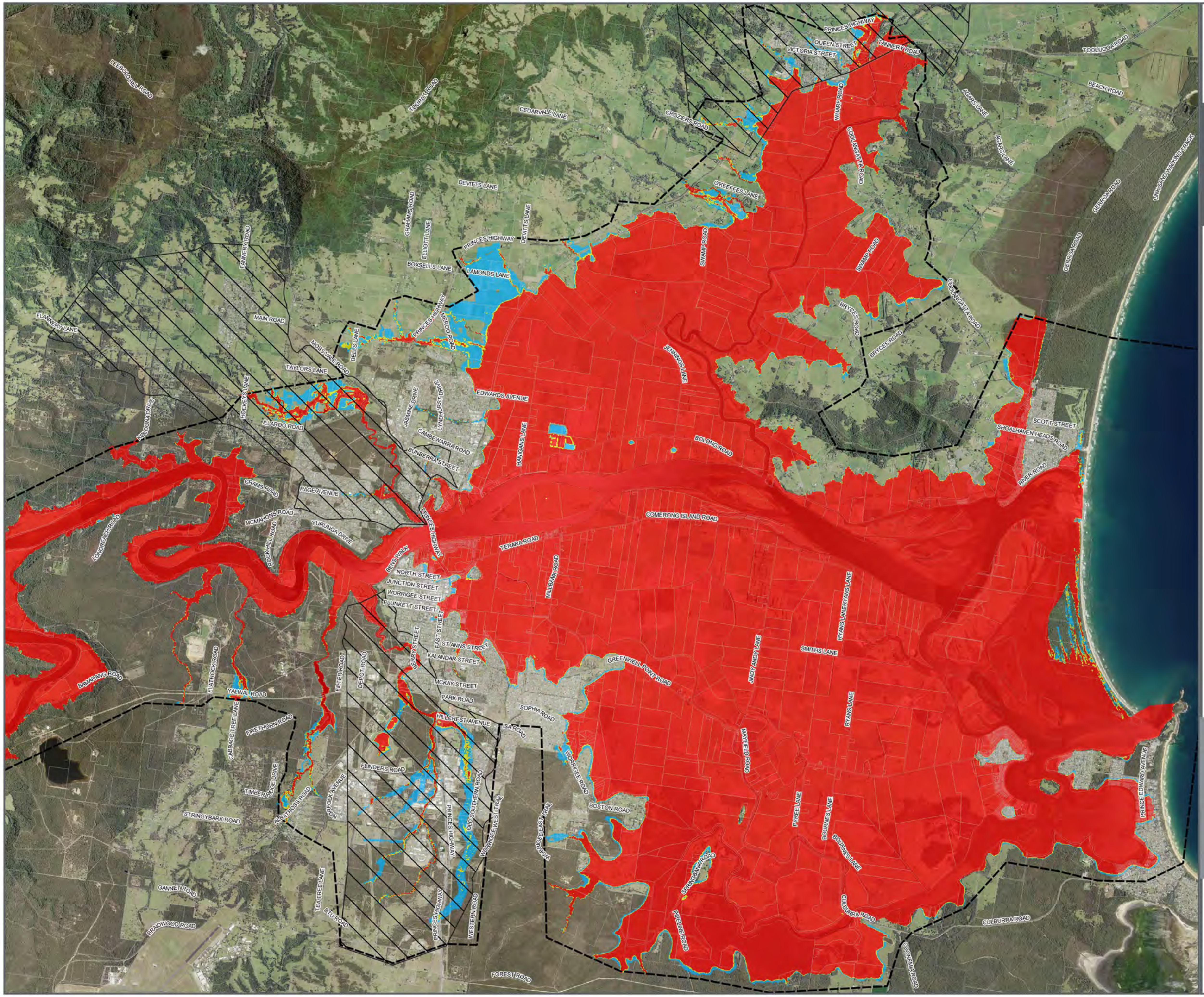
FIGURE G69.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Provisional Hazard

Lower Shoalhaven River Flood Study

Legend

Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas

Hazard (FDM)

Low
Transitional
High

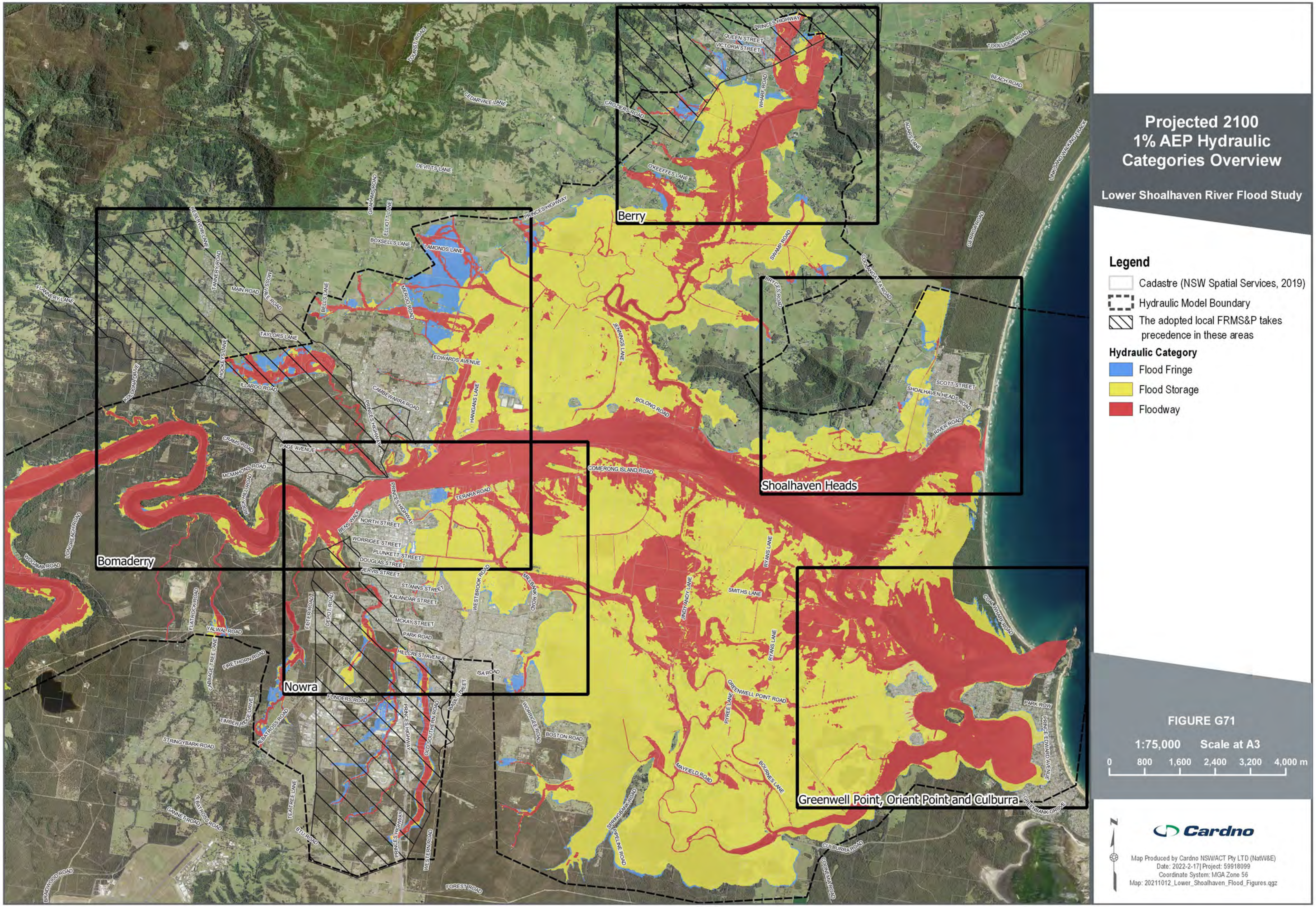
FIGURE G70

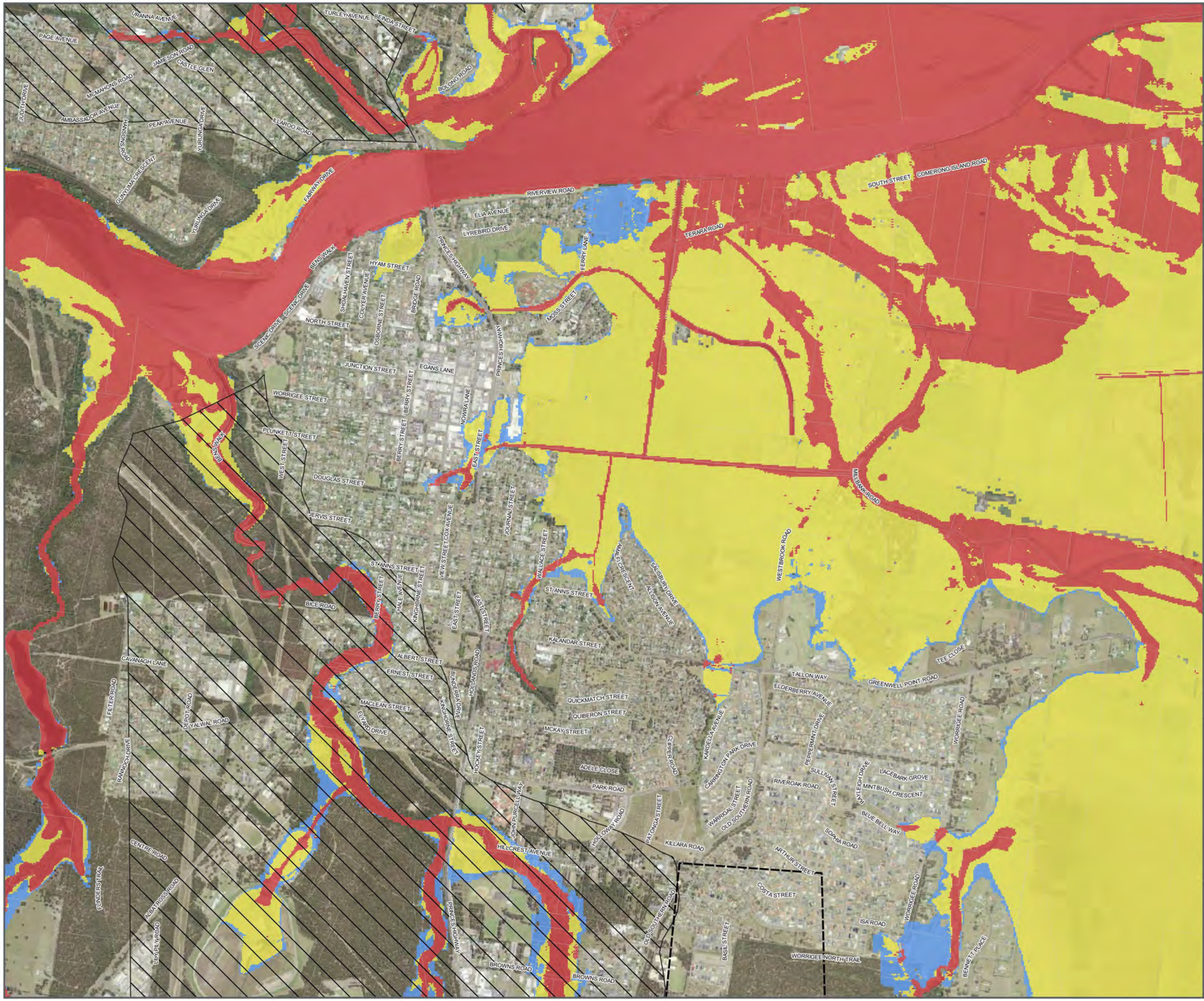
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Projected 2100
1% AEP Hydraulic
Categories Overview
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Hydraulic Category
Flood Fringe
Flood Storage
Floodway
Berry
Bomaderry
Nowra
Shoalhaven Heads
Greenwell Point, Orient Point and Culburra
FIGURE G71
1:75,000
Scale at A3
0
800
1,600
2,400
3,200
4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hydraulic Categories Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

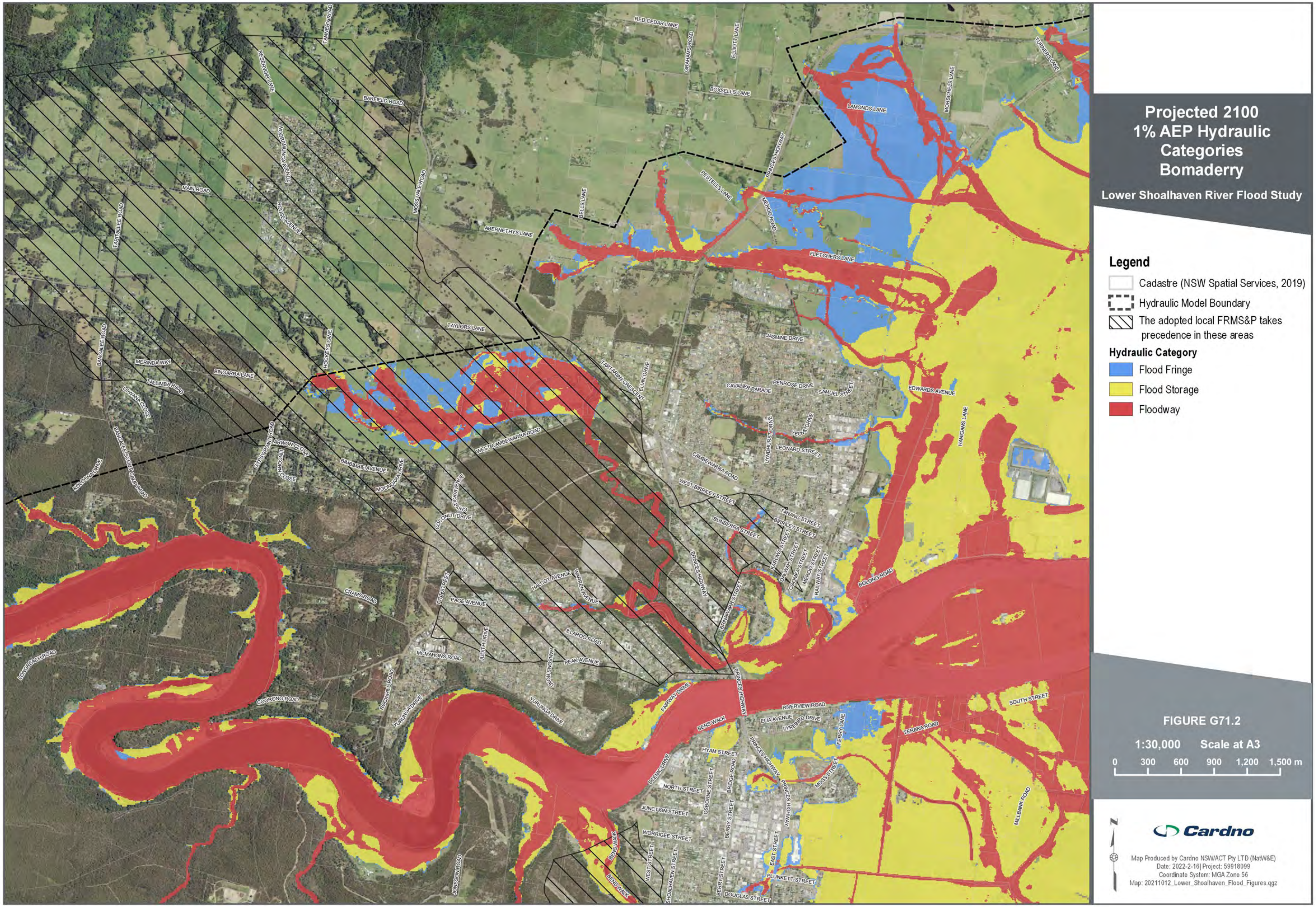
FIGURE G71.1

1:21,000 Scale at A3

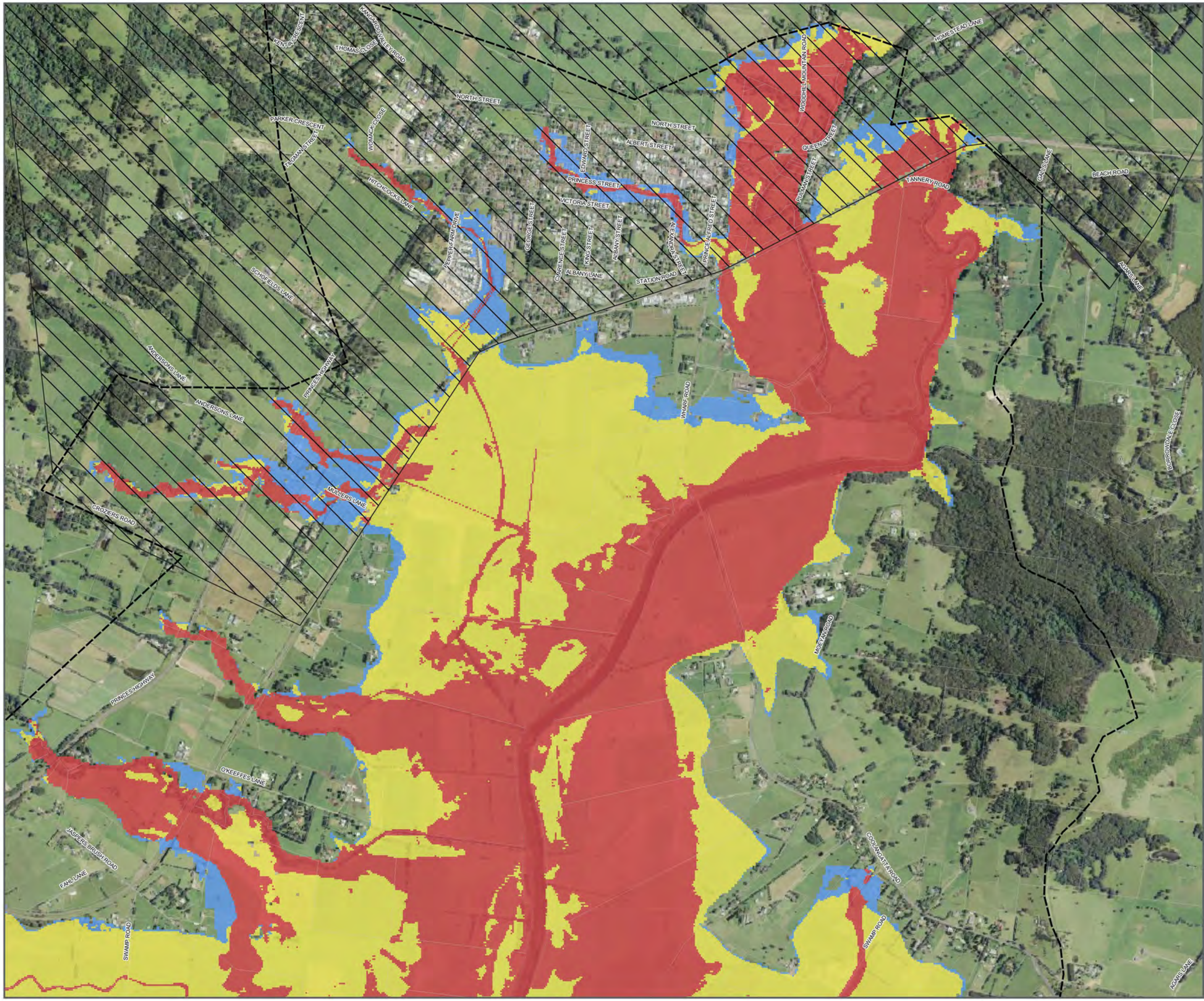
0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Hydraulic
Categories
Bomaderry
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Hydraulic Category
Flood Fringe
Flood Storage
Floodway
FIGURE G71.2
1:30,000 Scale at A3
0 300 600 900 1,200 1,500 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hydraulic Categories Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

FIGURE G71.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 1% AEP Hydraulic Categories Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

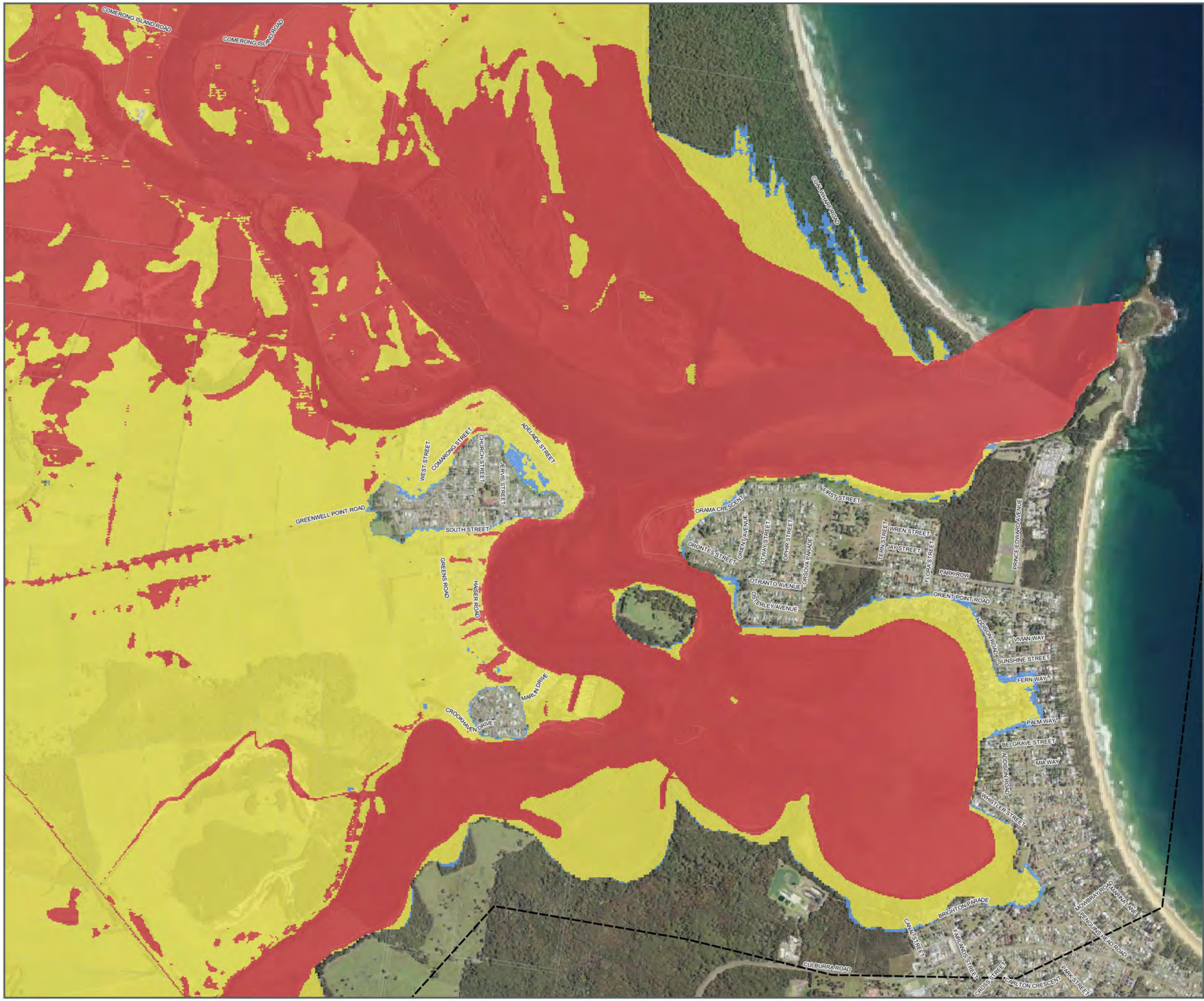
FIGURE G71.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Hydraulic Categories Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

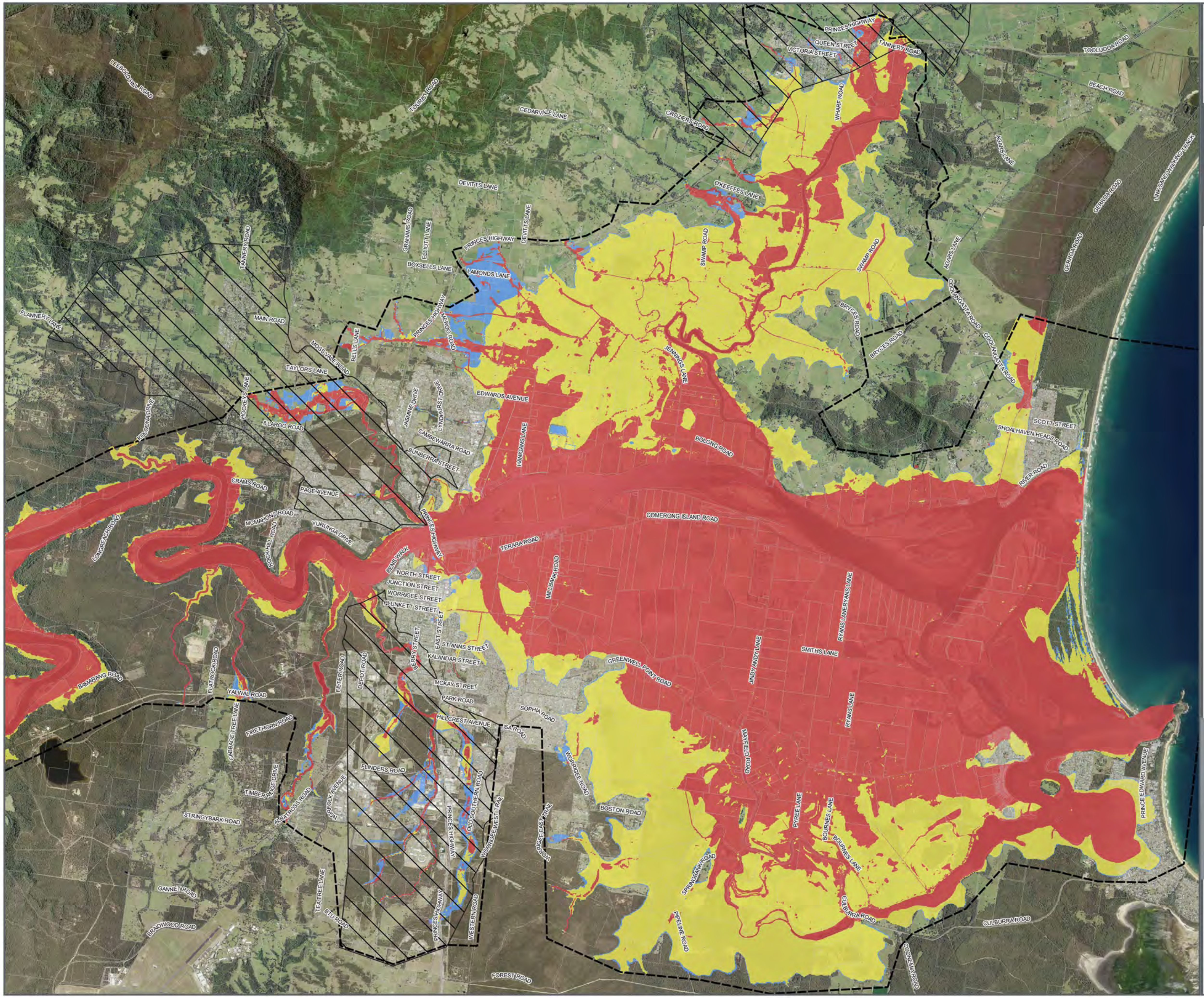
FIGURE G71.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Hydraulic Categories

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

FIGURE G72

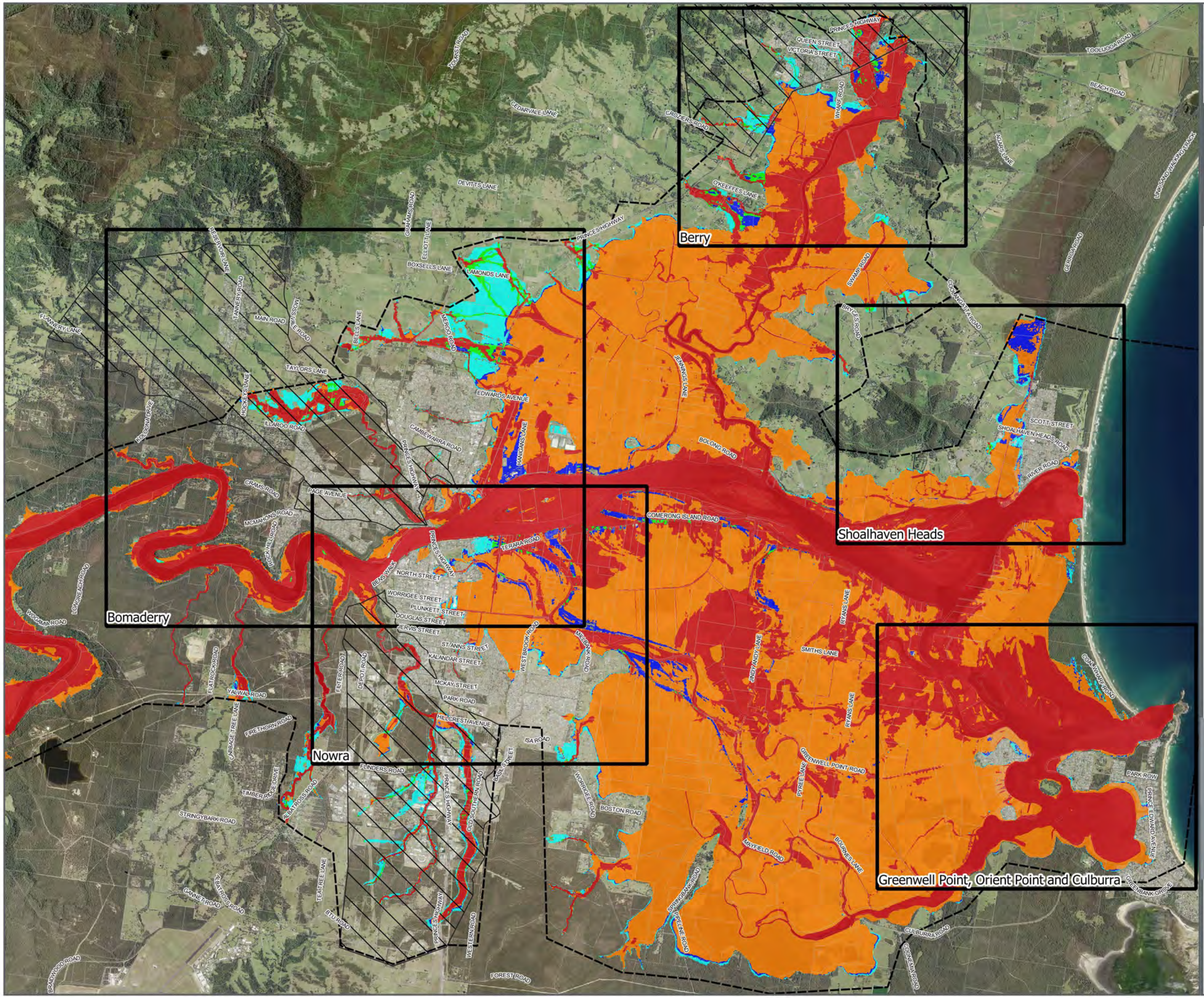
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Combined Hazard and Hydraulic Category Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

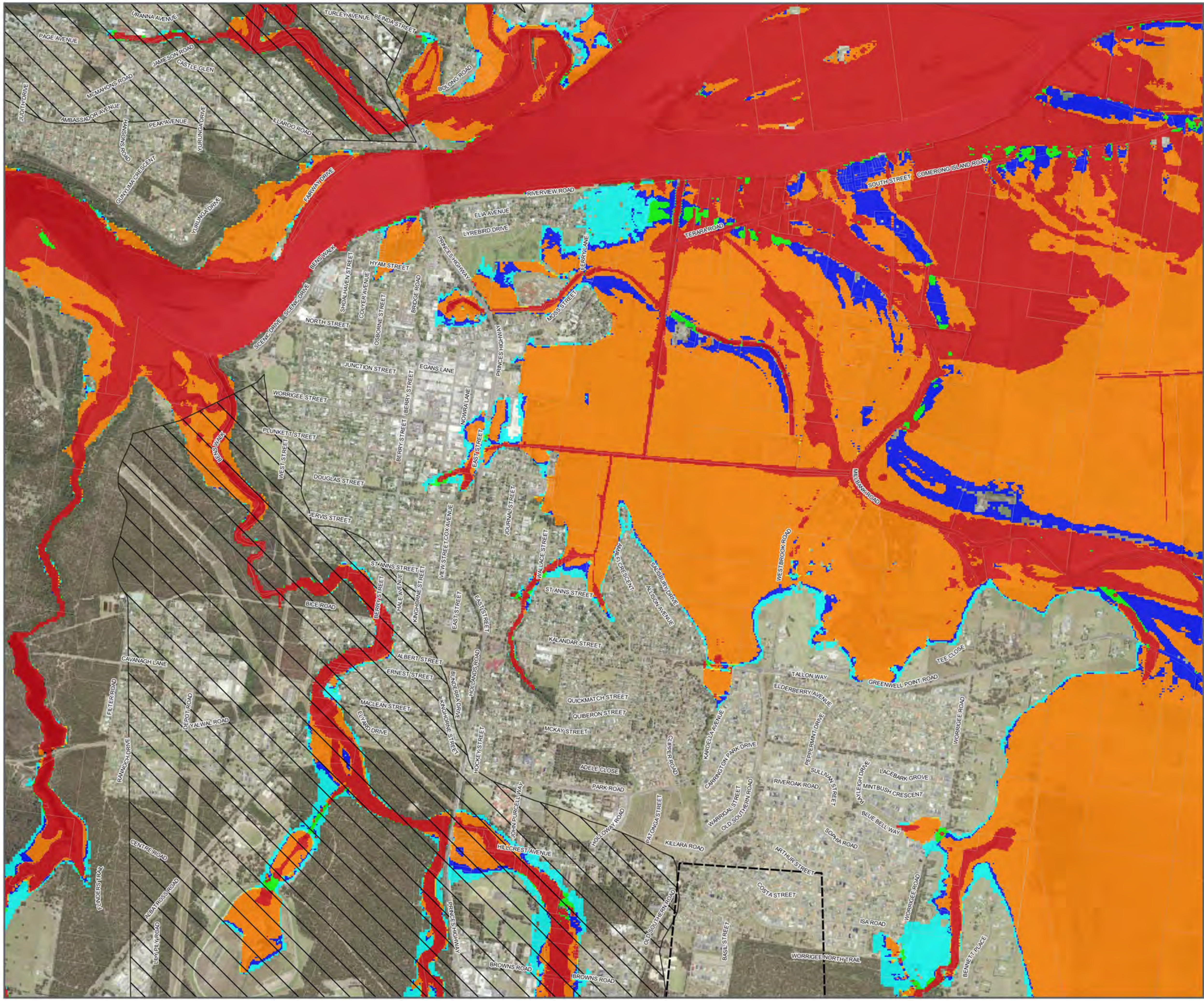
FIGURE G73

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Combined Hazard and Hydraulic Category Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

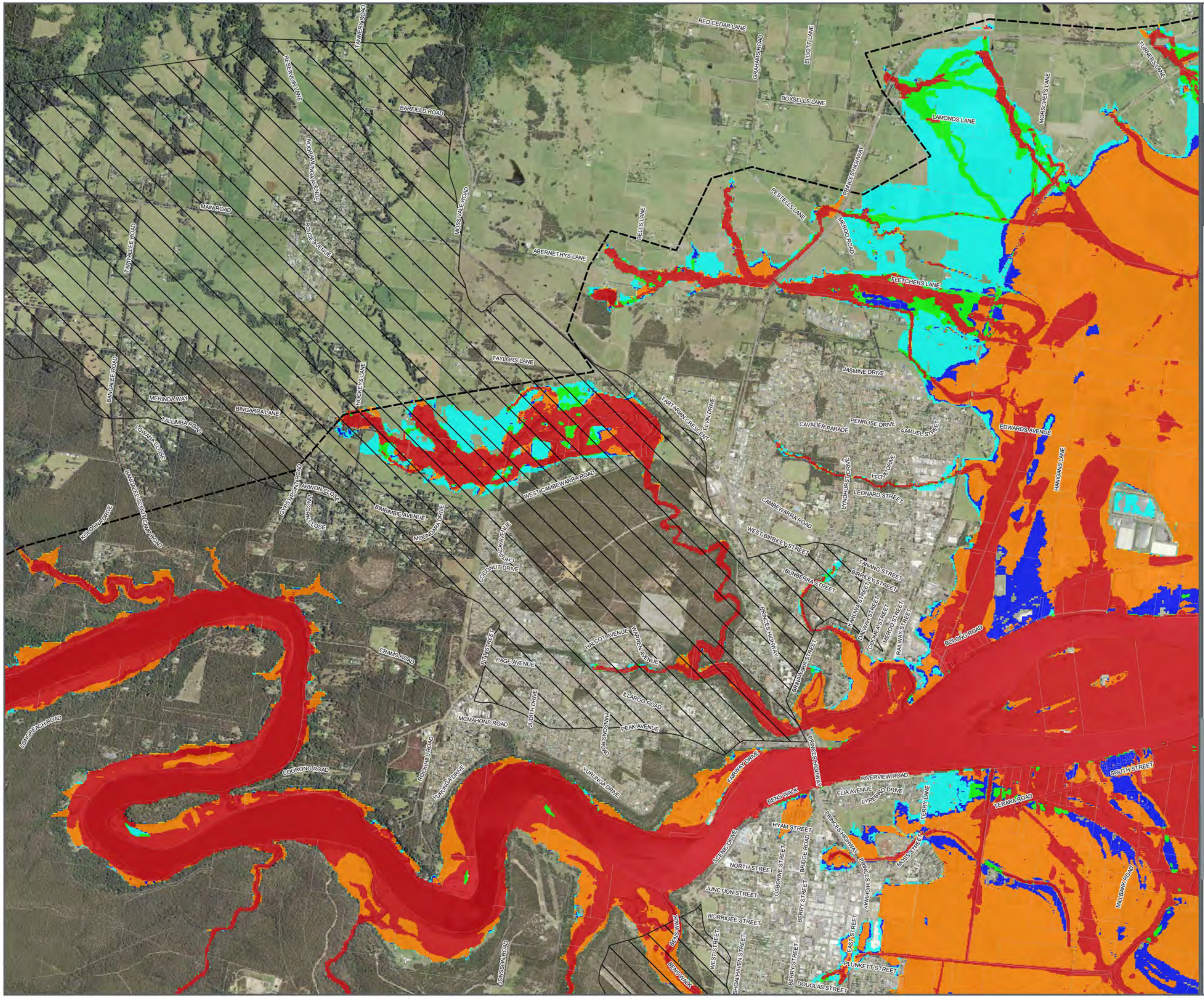
FIGURE G73.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Combined Hazard and Hydraulic Category Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

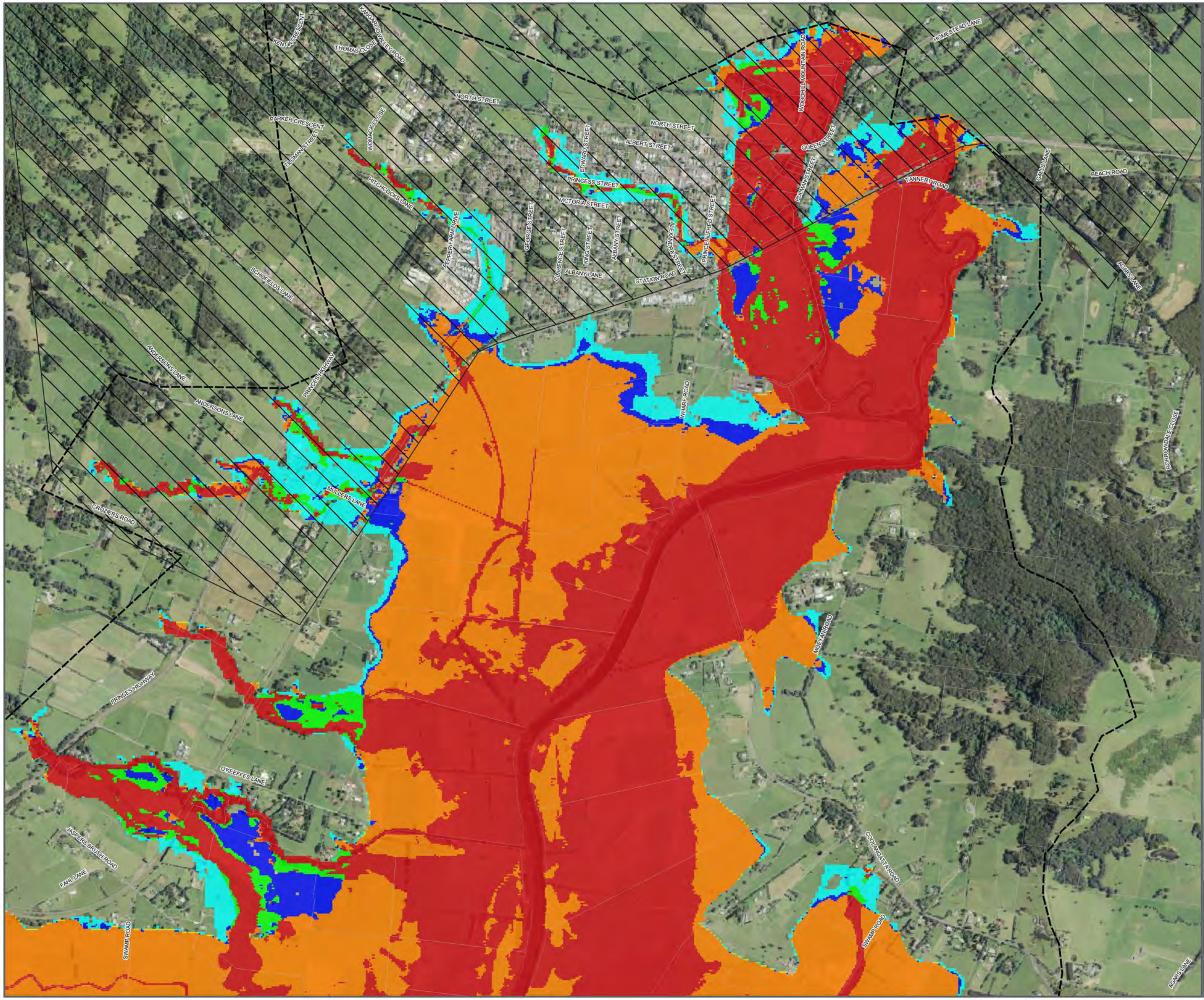
FIGURE G73.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Combined Hazard and Hydraulic Category Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

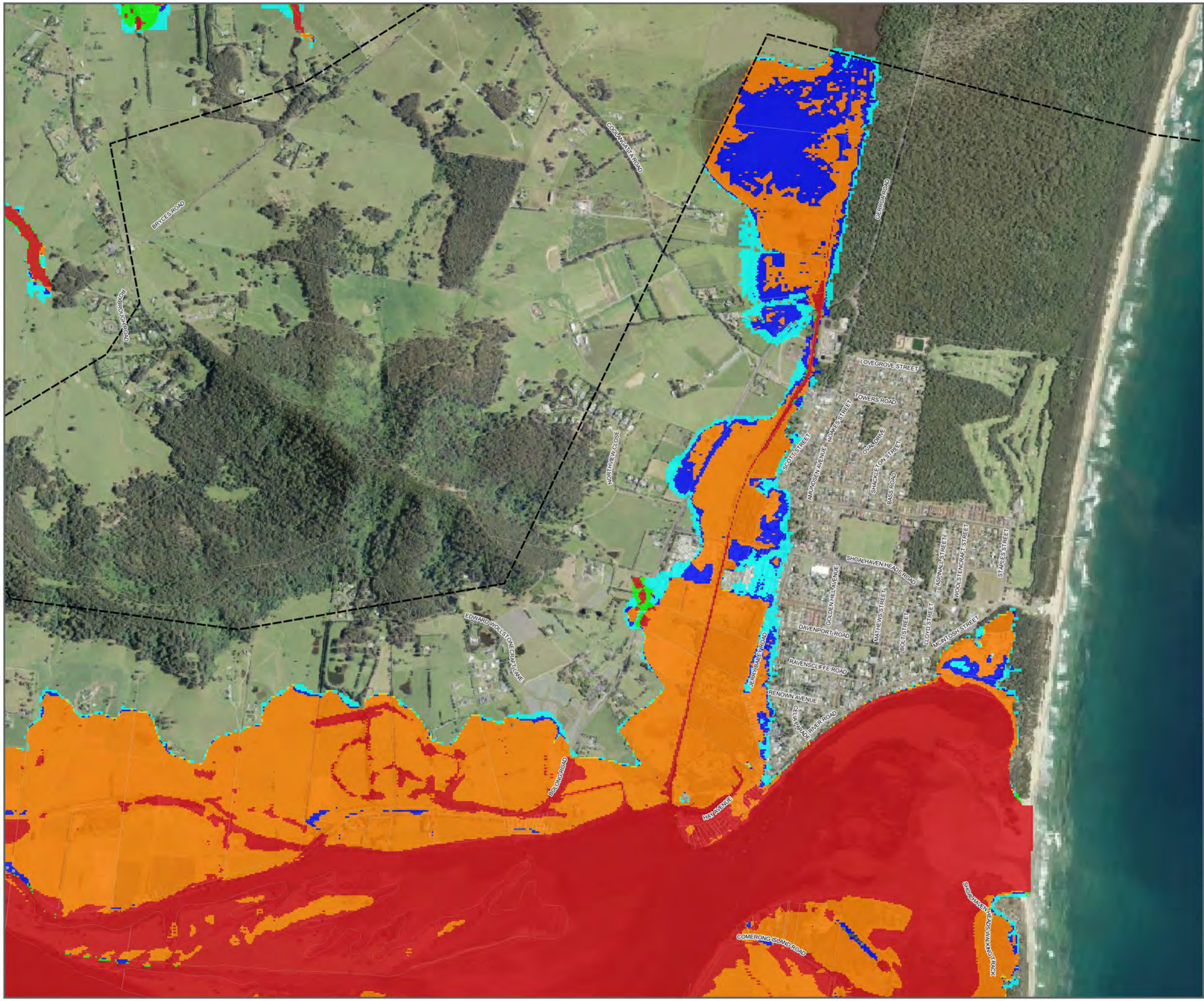
FIGURE G73.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Combined Hazard and Hydraulic Category Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

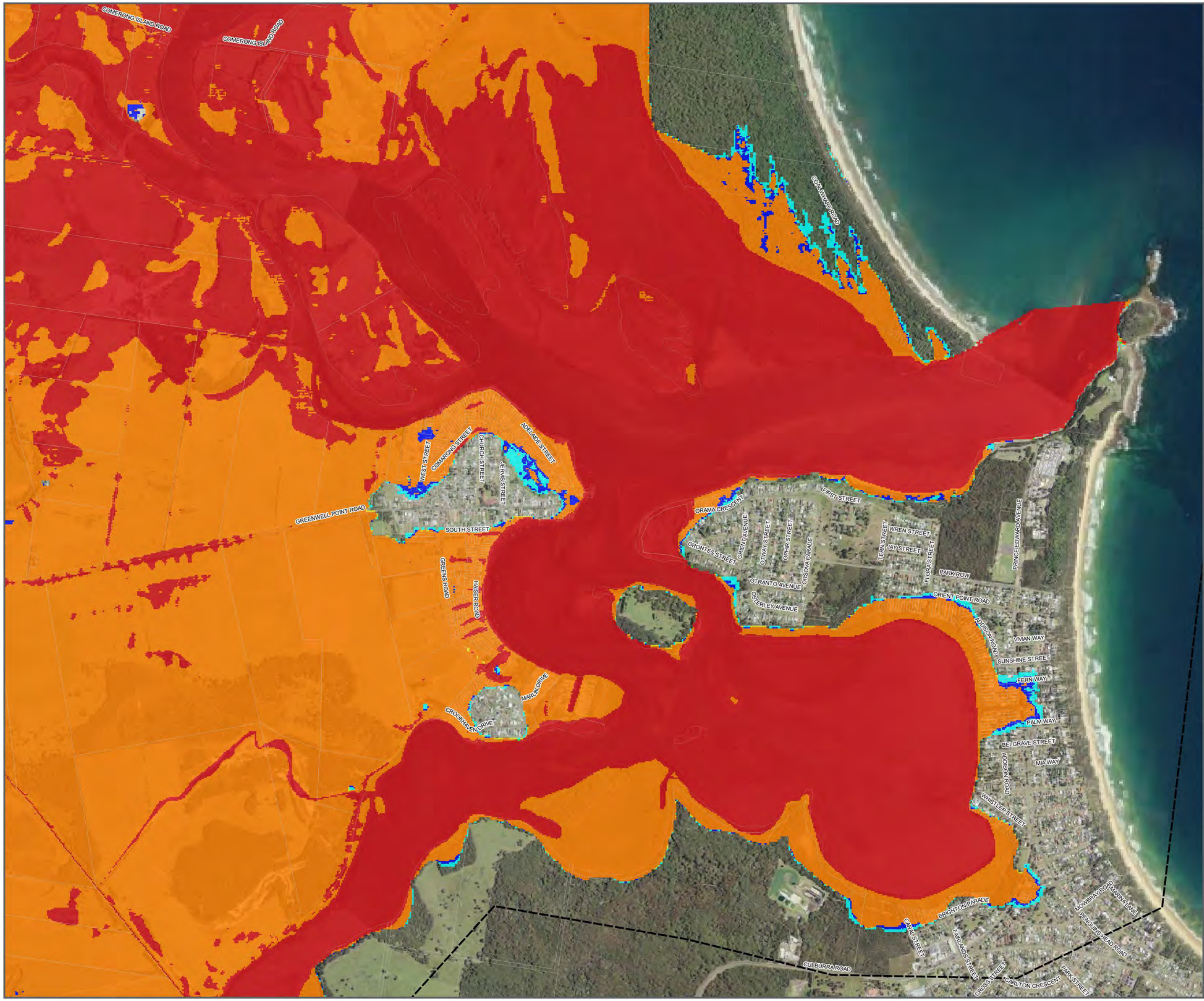
FIGURE G73.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100
1% AEP Combined Hazard and Hydraulic Category Greenwell Point, Orient Point and Culburra Beach
Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

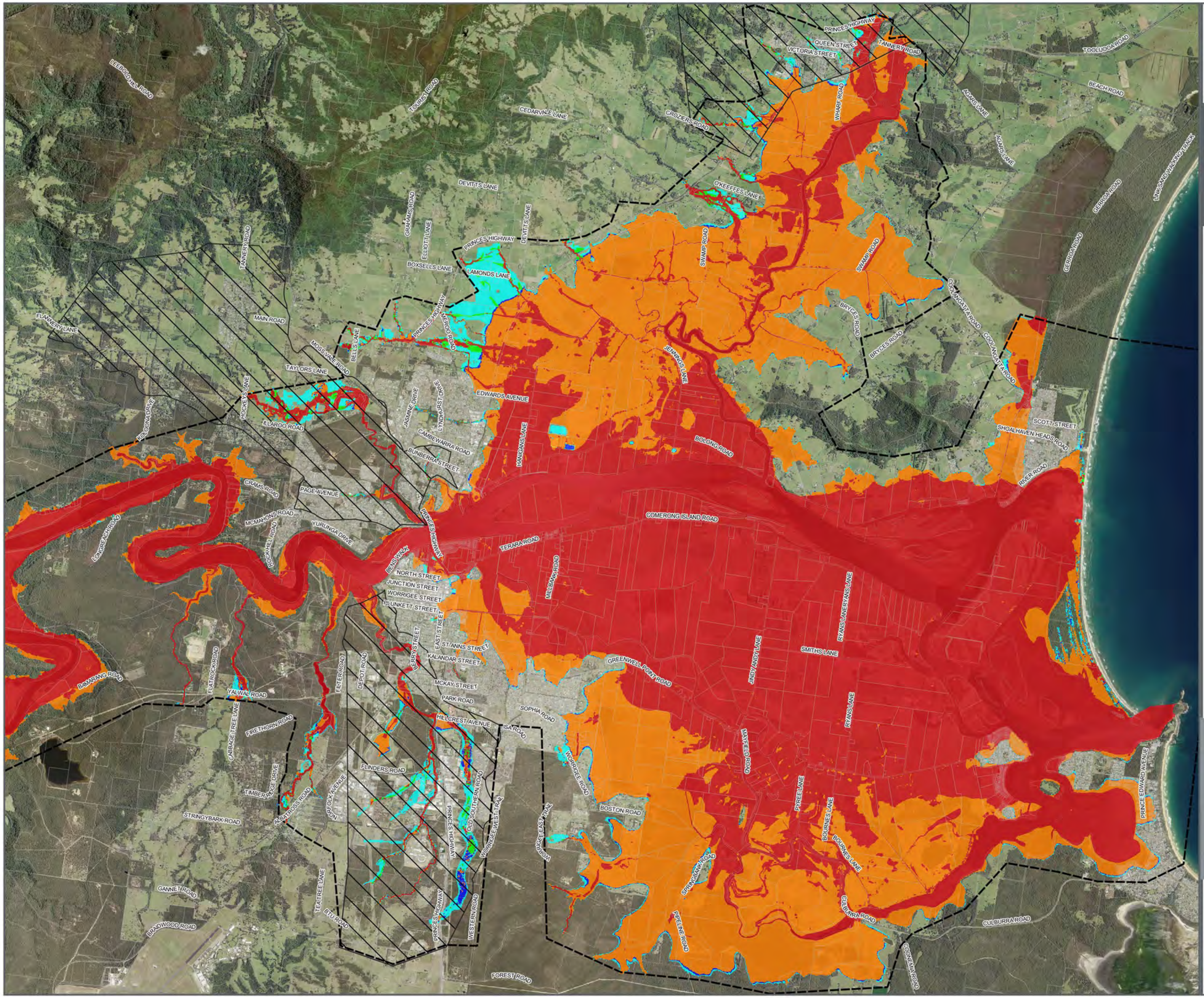
FIGURE G73.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Combined Hazard and Hydraulic Category

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Combined Hazard and Hydraulic Category

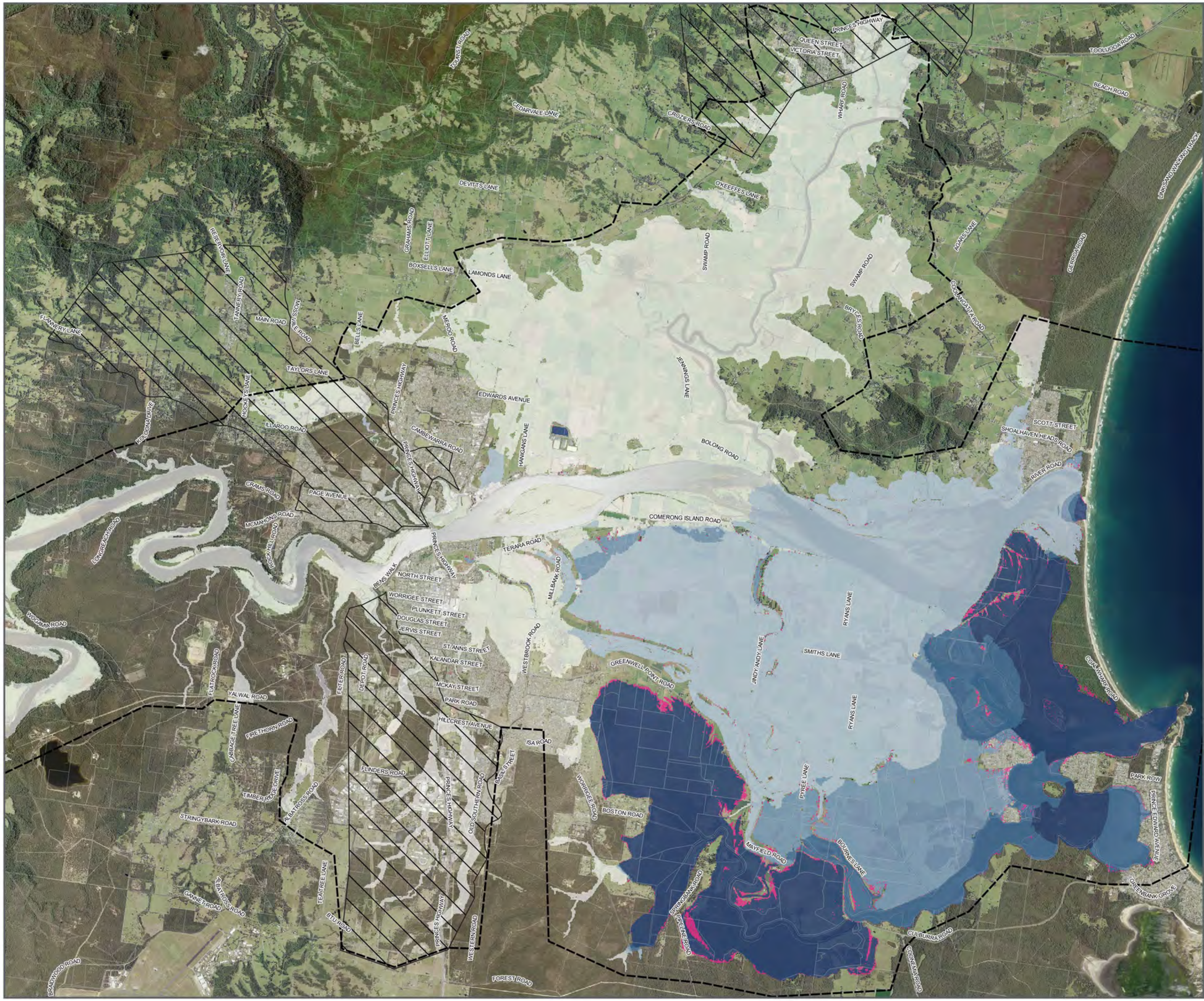
- High Hazard Floodway
- High Hazard Flood Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

FIGURE G74

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE G75

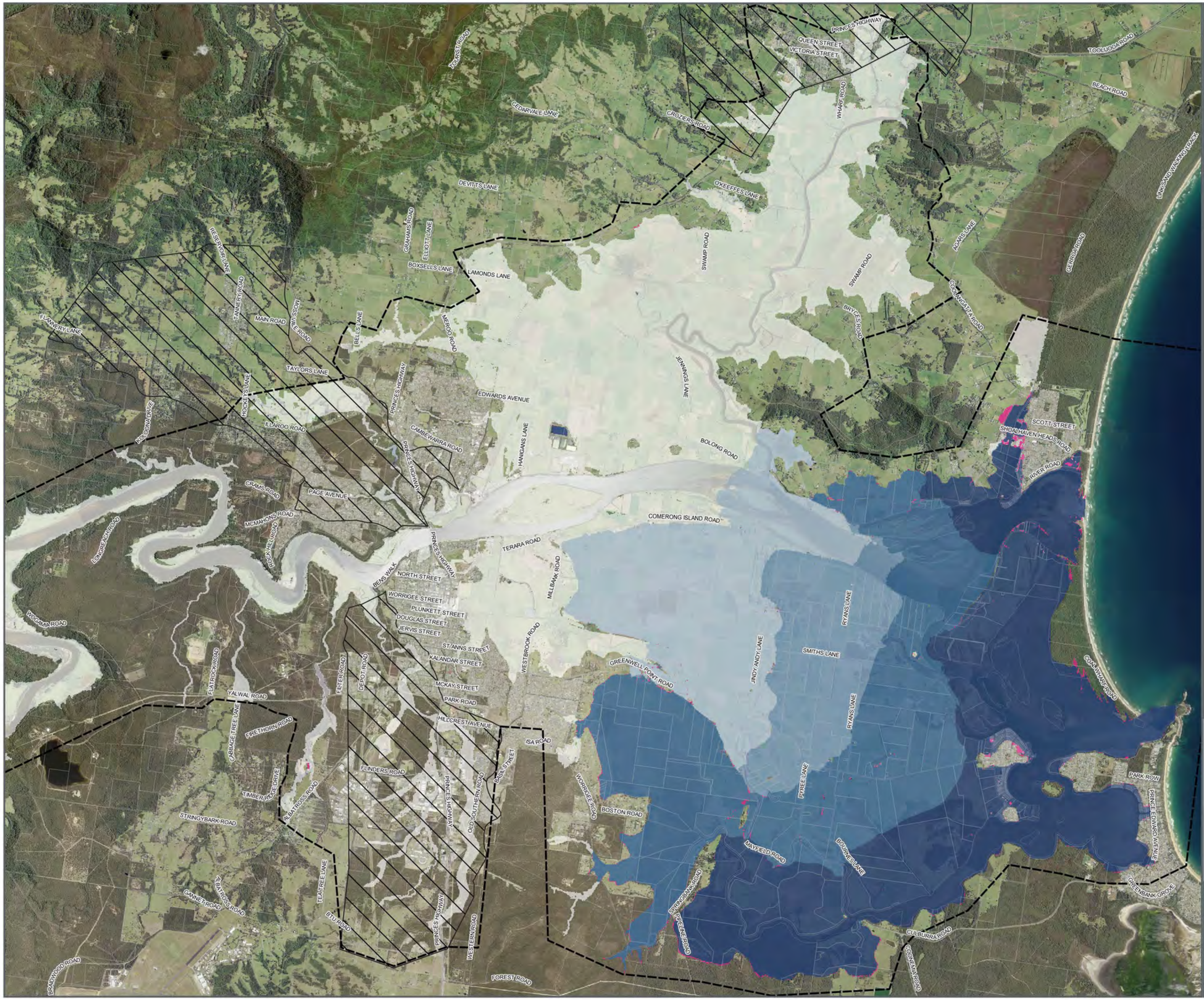
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 2% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

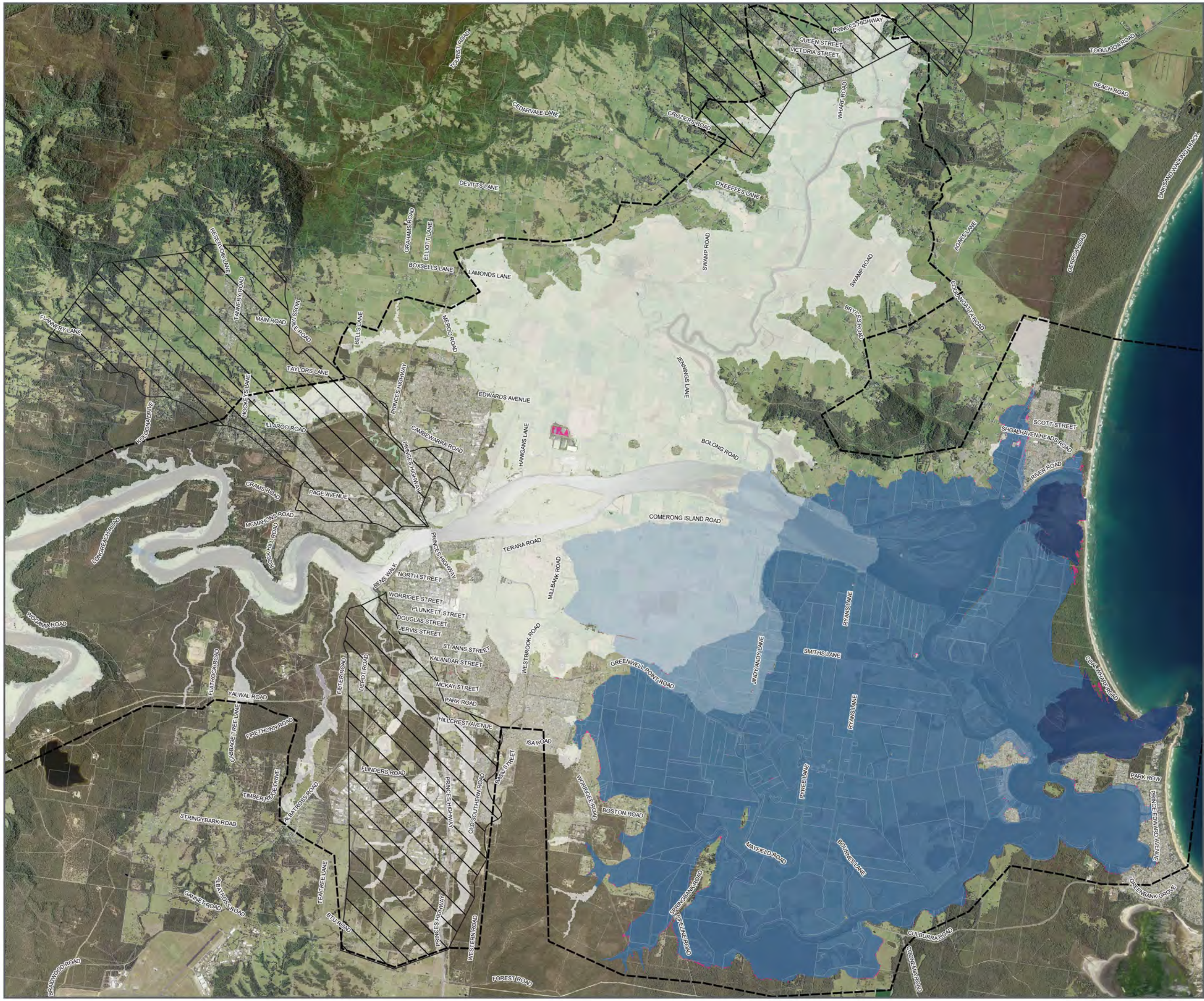
FIGURE G76

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

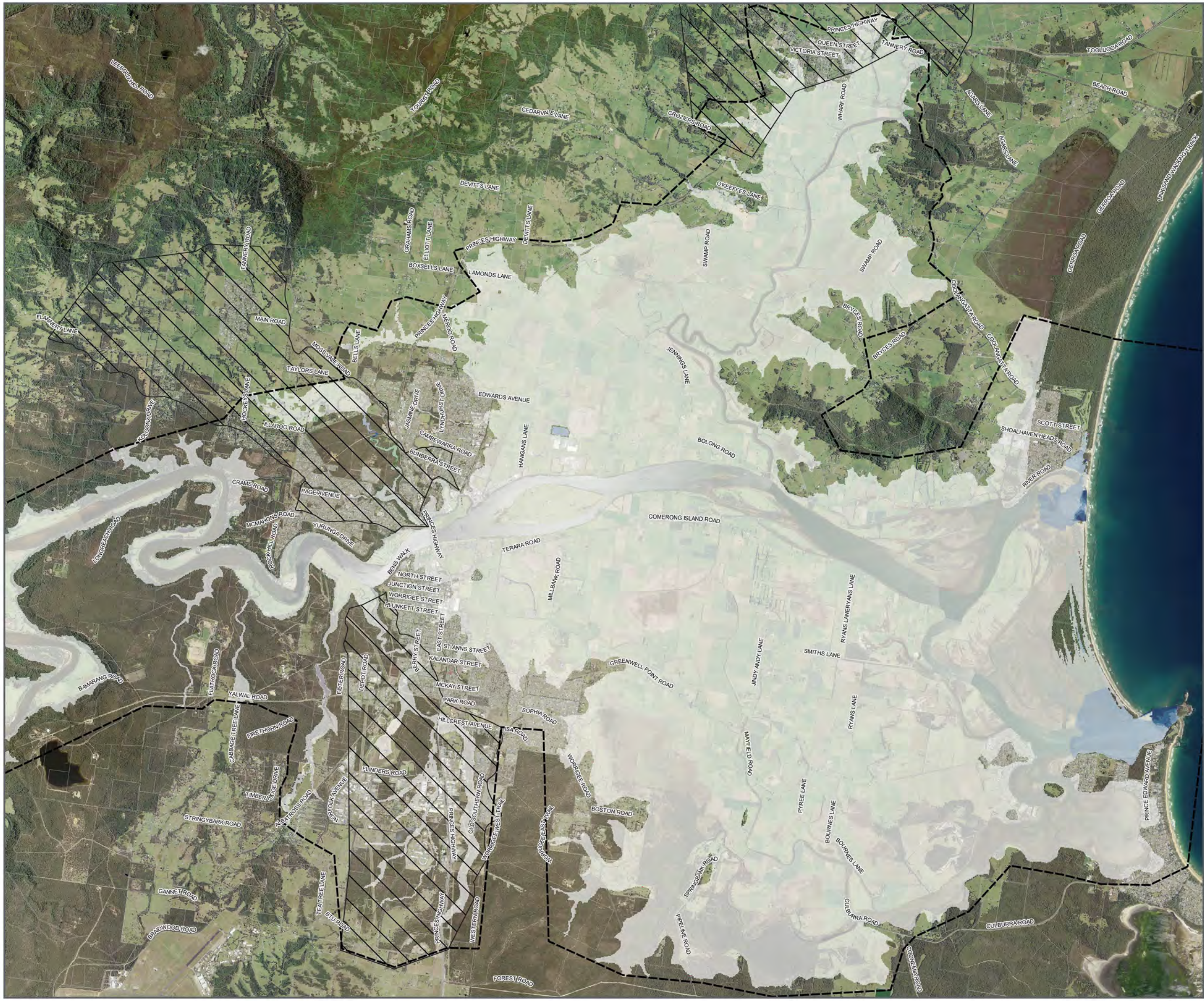
FIGURE G77

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 PMF Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE G78

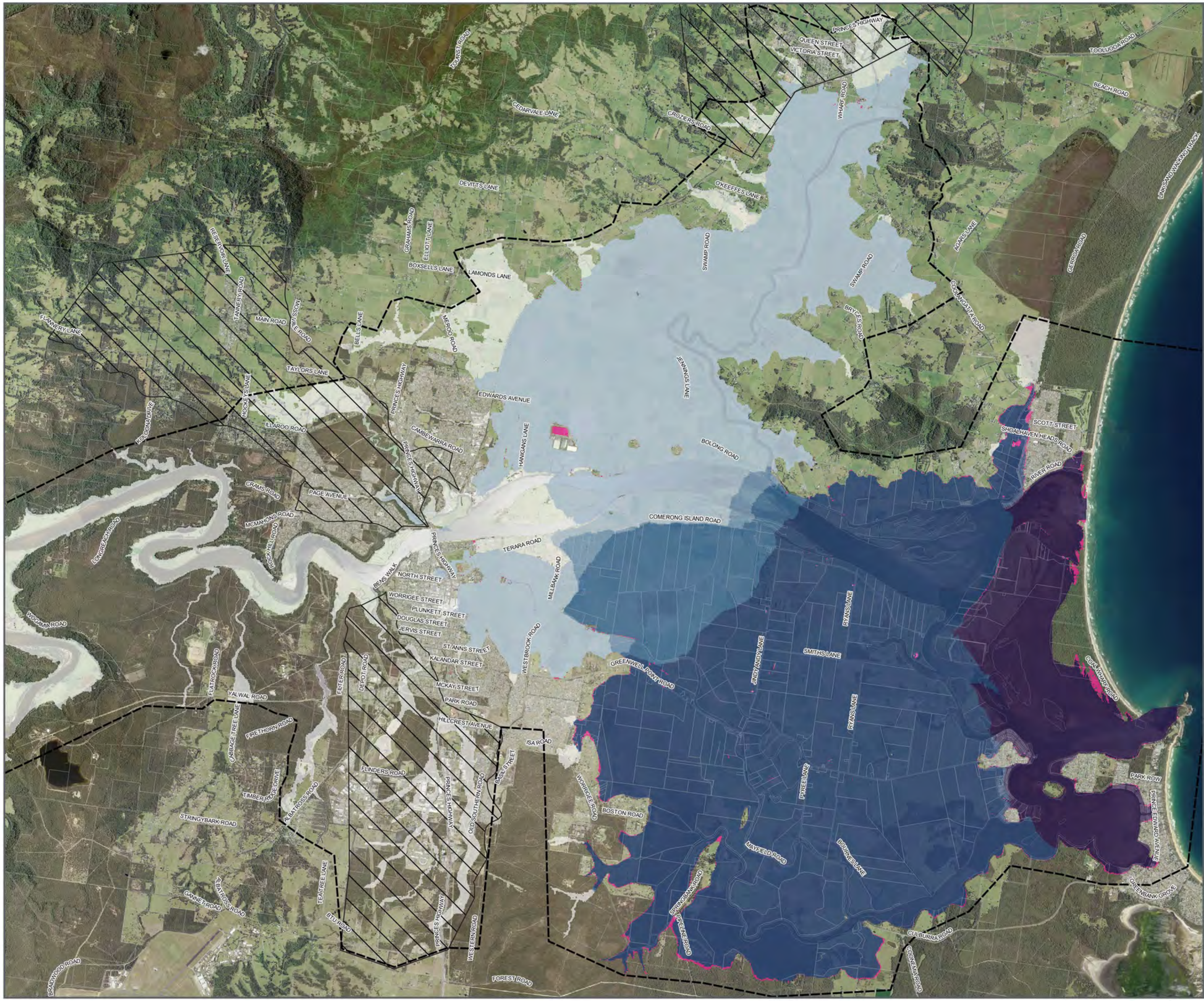
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



NSW Projected 2100 Sea Level Rise (+0.90m) 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

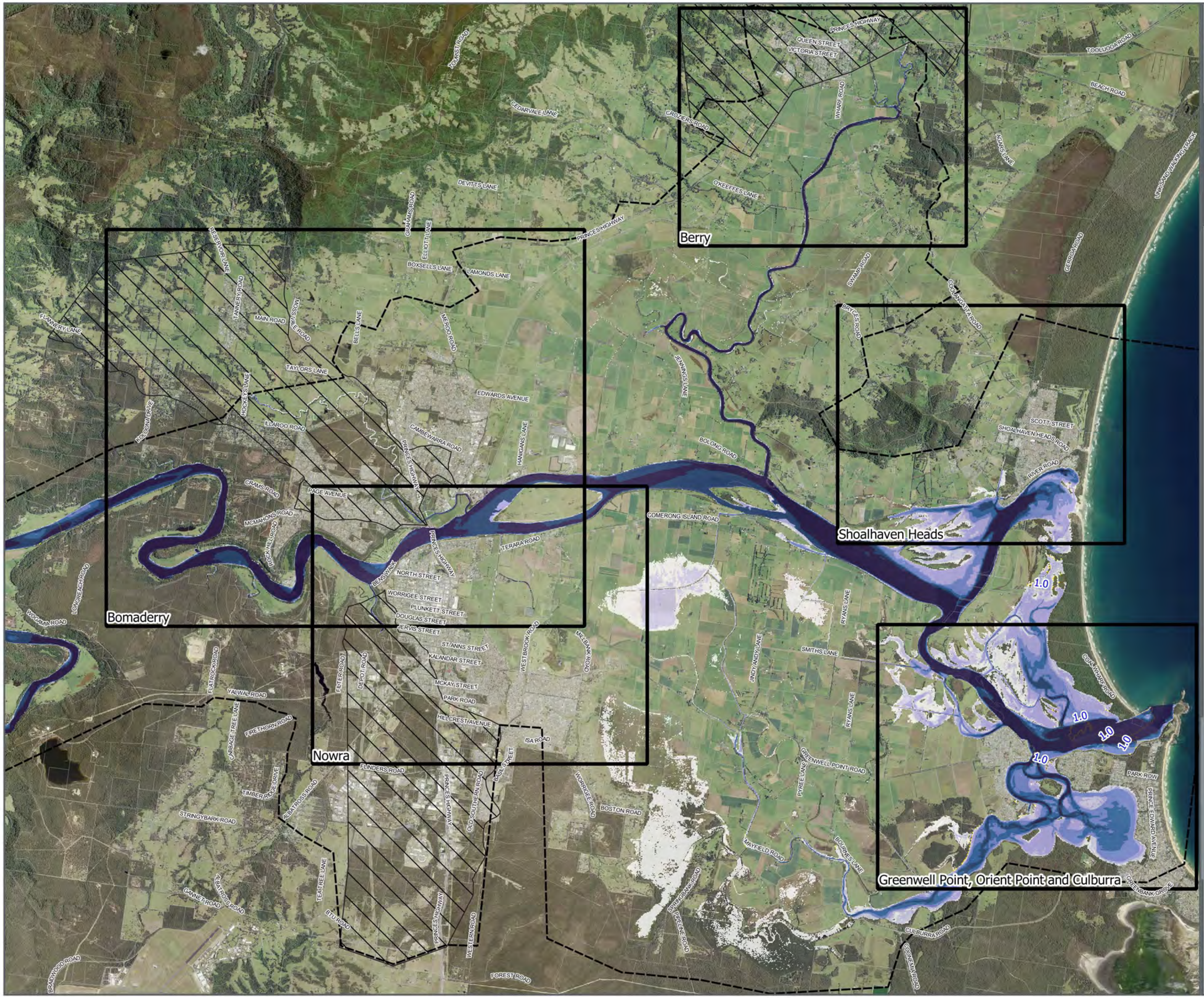
FIGURE G79

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tidal Inundation Flood Depth and Water Level Contours Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G80

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Flood Depth and Water Level Contours Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G80.1

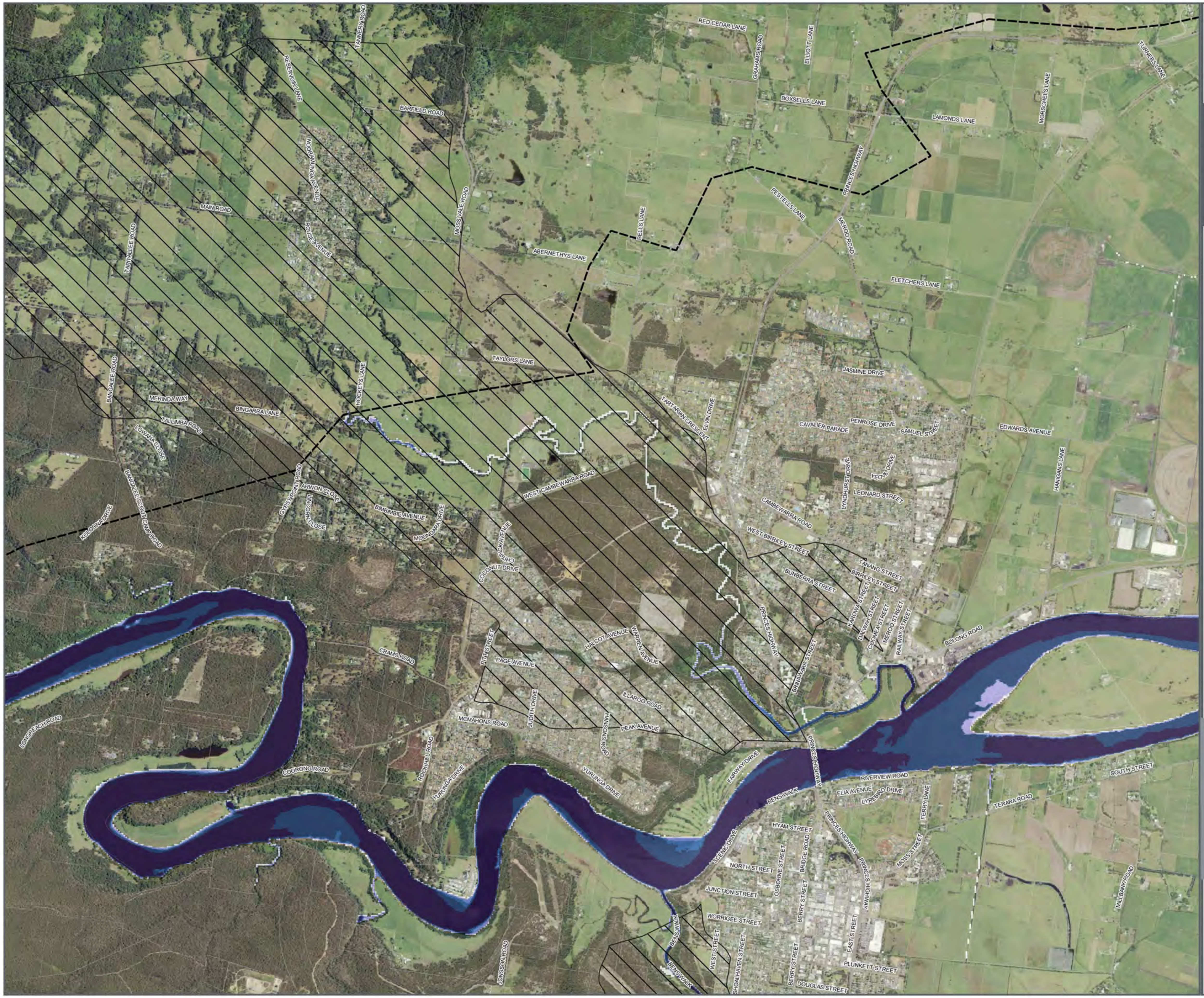
1:21,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tidal Inundation Flood Depth and Water Level Contours Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G80.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Flood Depth and Water Level Contours Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G80.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Flood Depth and Water Level Contours Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G80.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Flood Depth and Water Level Contours Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

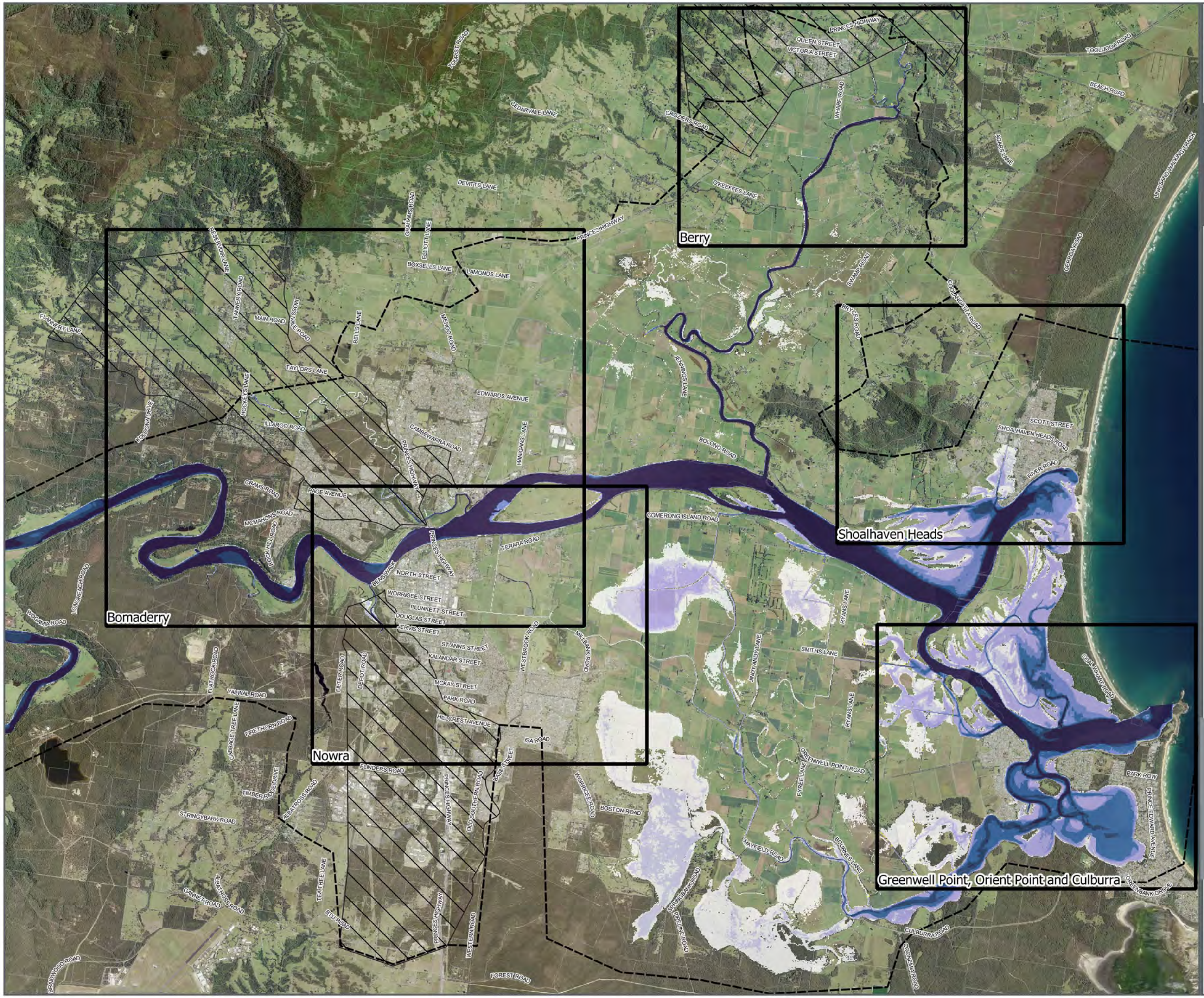
FIGURE G80.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tidal Inundation Projected 2050 Flood Depth and Water Level Contours Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G81

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2050 Flood Depth and Water Level Contours Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

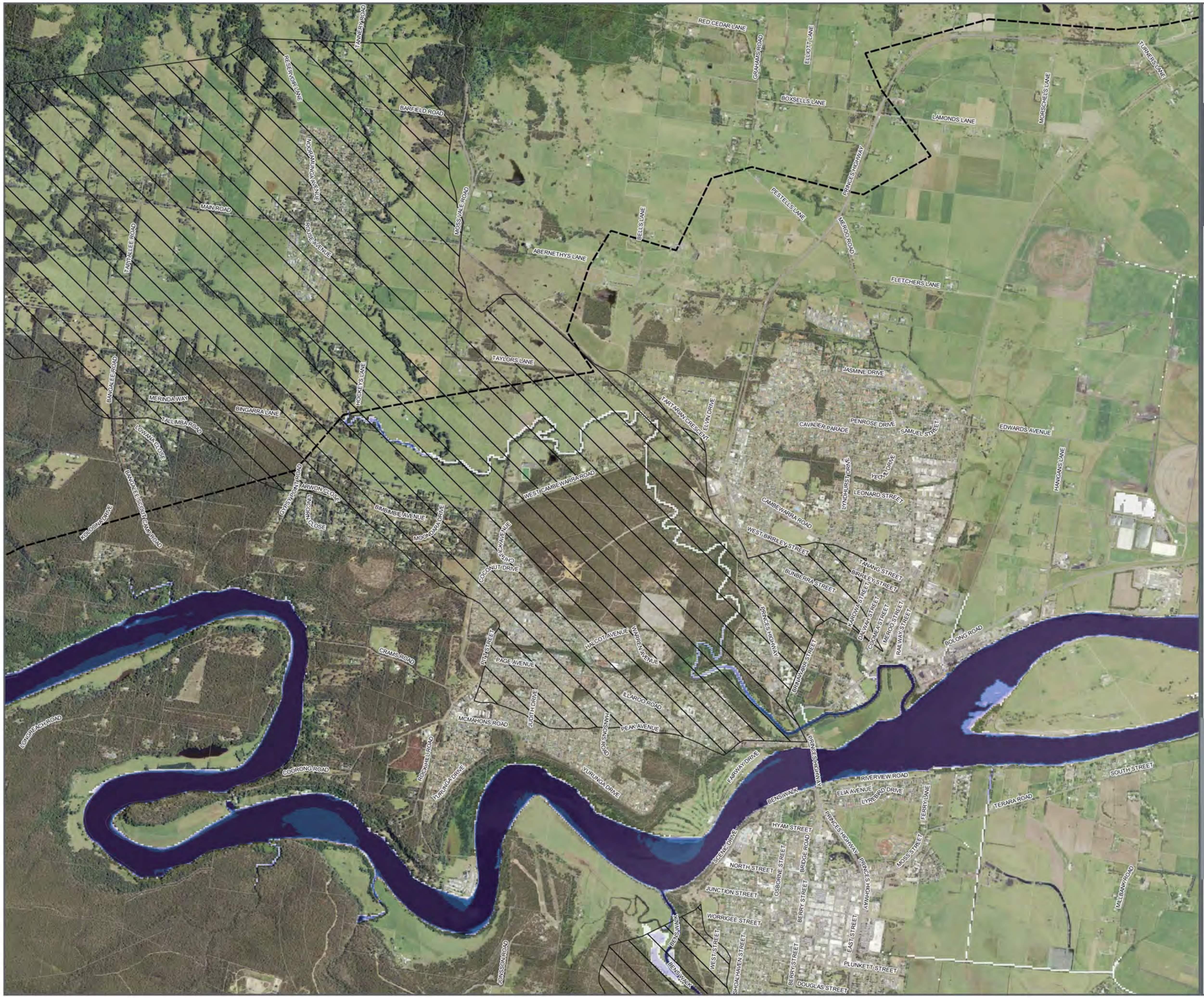
FIGURE G81.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tidal Inundation Projected 2050 Flood Depth and Water Level Contours Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G81.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2050 Flood Depth and Water Level Contours Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G81.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2050 Flood Depth and Water Level Contours Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G81.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2050 Flood Depth and Water Level Contours Greenwell Point, Orient

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

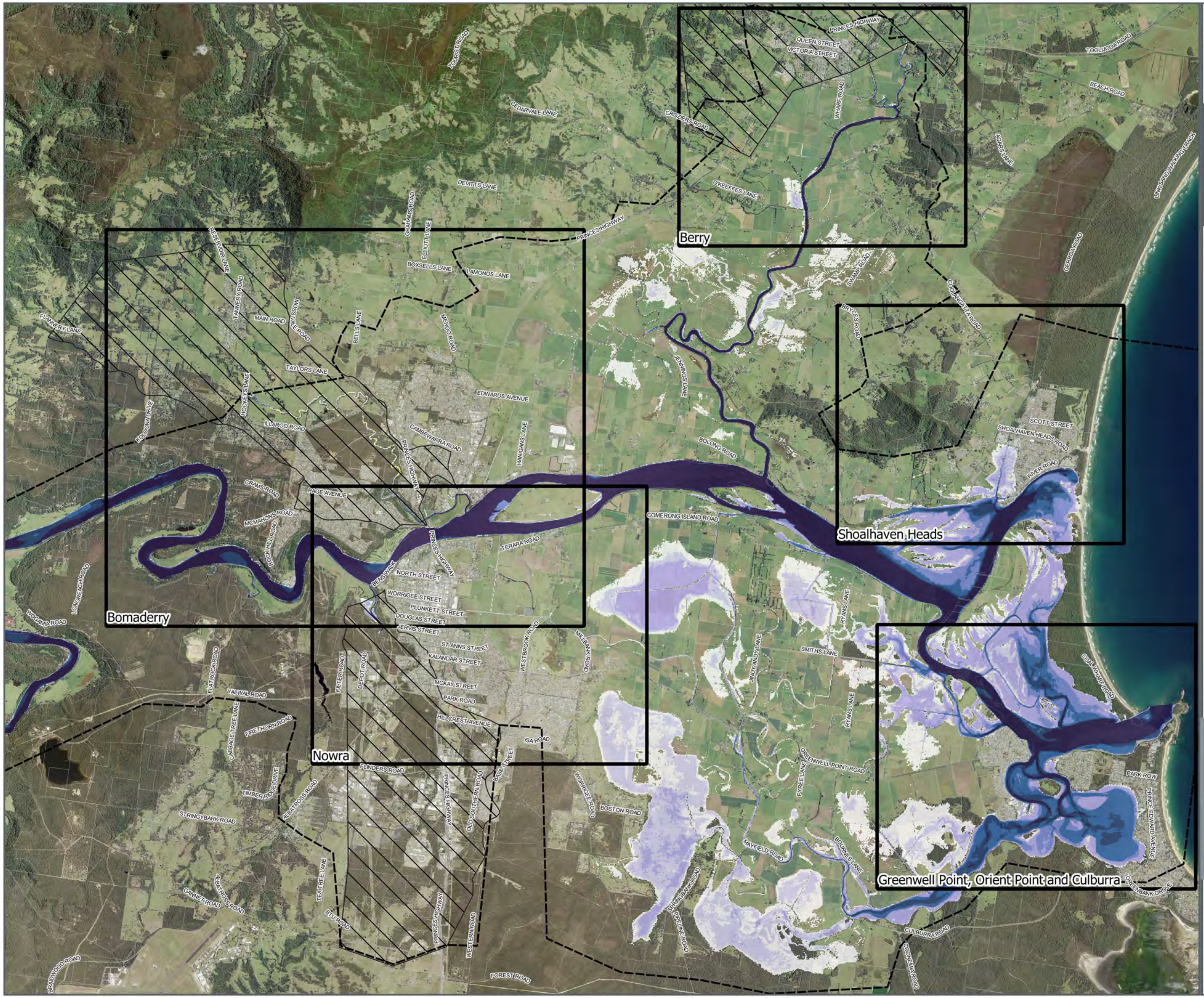
FIGURE G81.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tidal Inundation Projected 2100 Flood Depth and Water Level Contours Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G82

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2100
Flood Depth and Water Level Contours
Nowra
Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

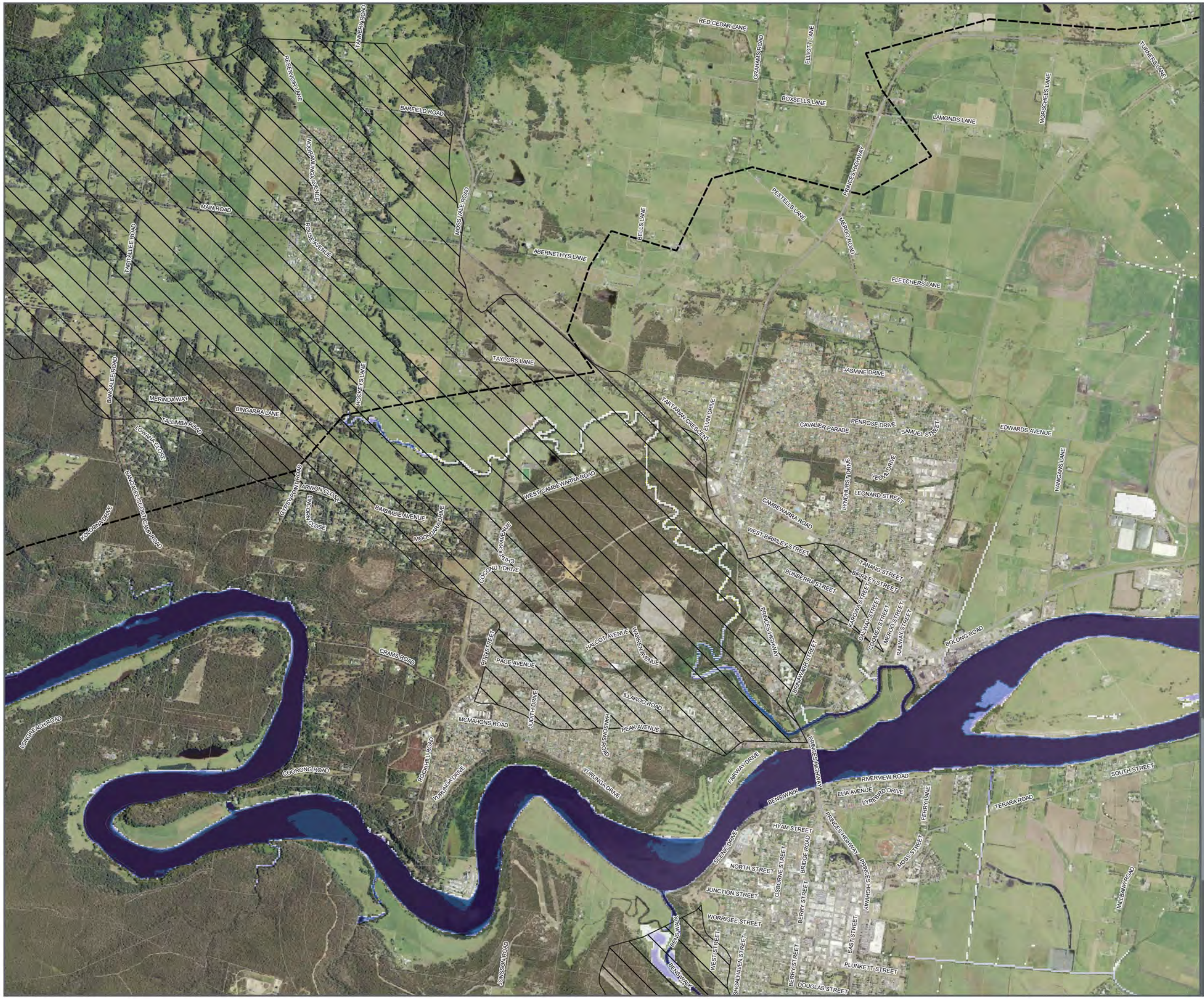
FIGURE G82.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tidal Inundation Projected 2100 Flood Depth and Water Level Contours Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G82.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2100
Flood Depth and Water Level Contours
Berry
Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G82.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2100 Flood Depth and Water Level Contours Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G82.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Tidal Inundation Projected 2100 Flood Depth and Water Level Contours Greenwell Point, Orient

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

FIGURE G82.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

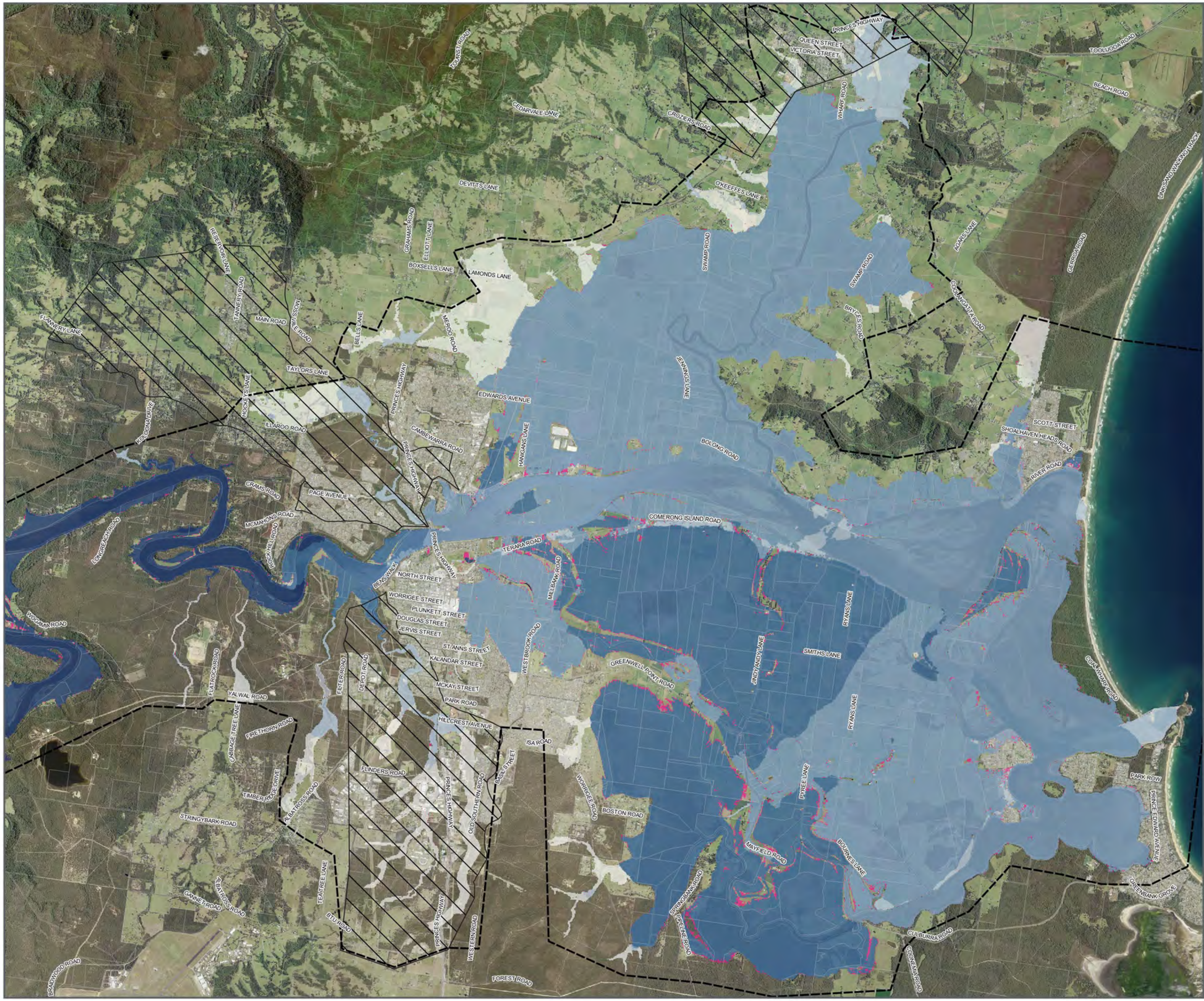
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

APPENDIX

H

SENSITIVITY FLOOD MAPS

Figure List:



Climate Change 2050 RCP 4.5
5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H1

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Climate Change 2050 RCP 4.5 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

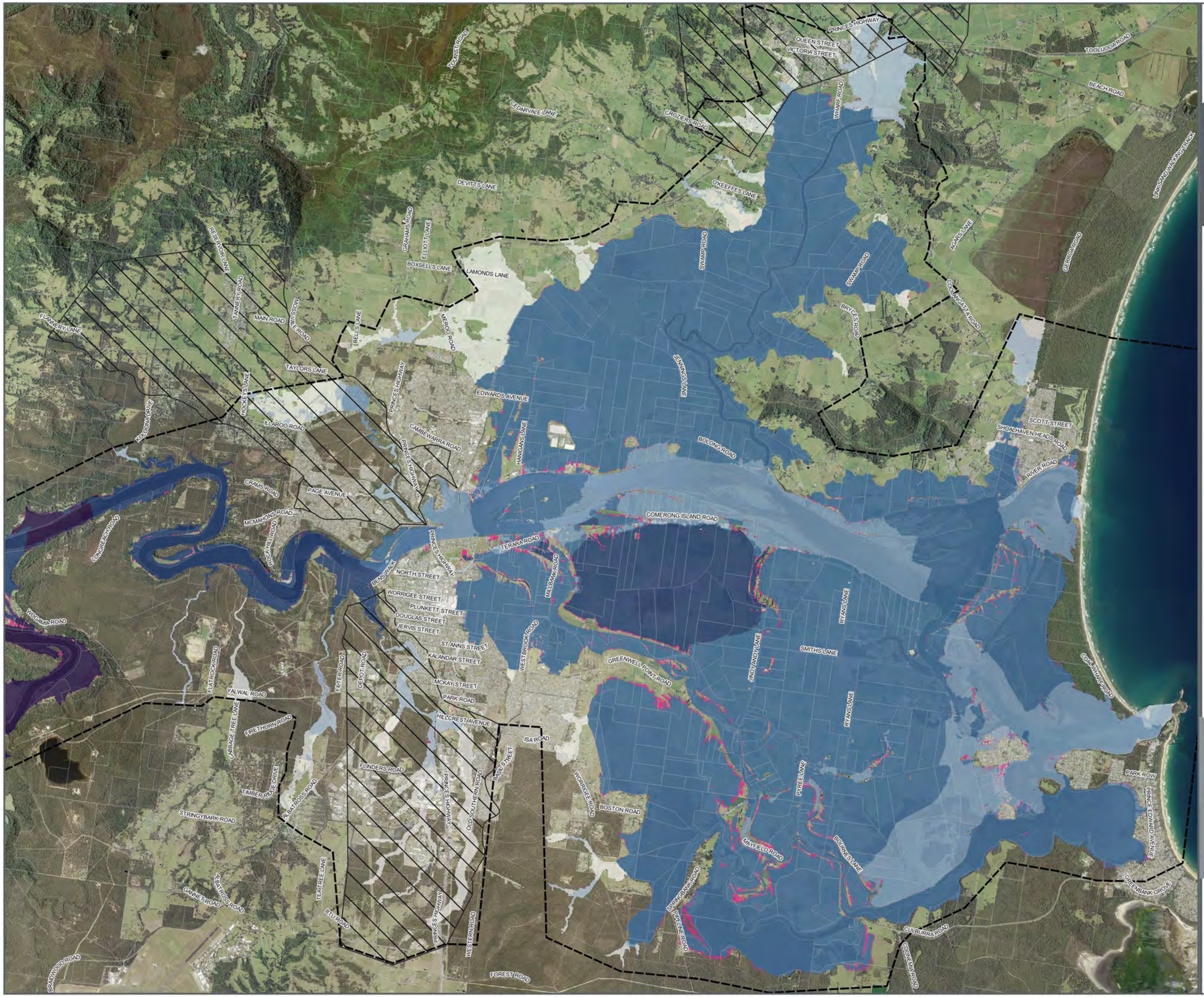
FIGURE H2

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2050 RCP 8.5
5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

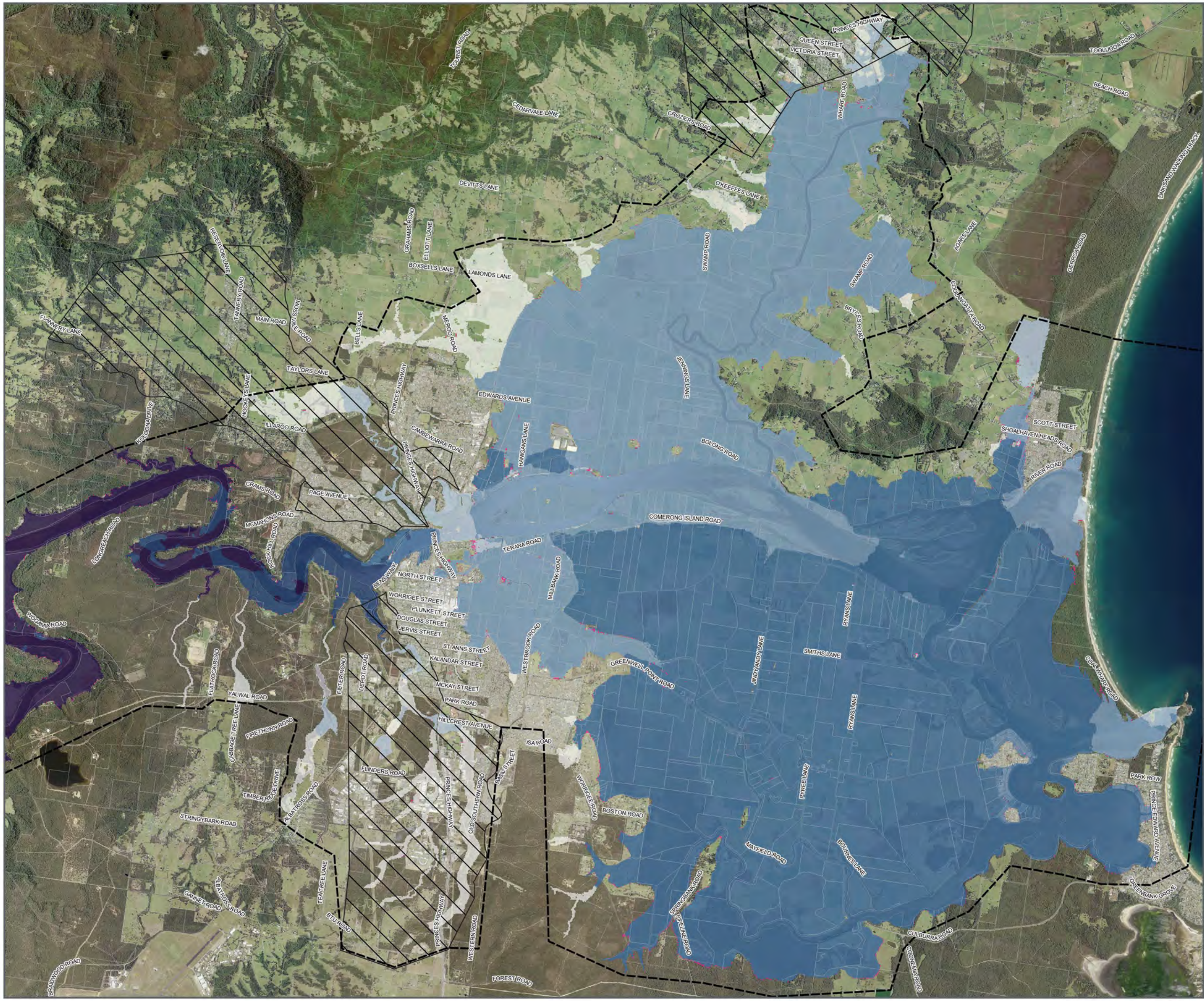
FIGURE H3

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2050 RCP 8.5 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

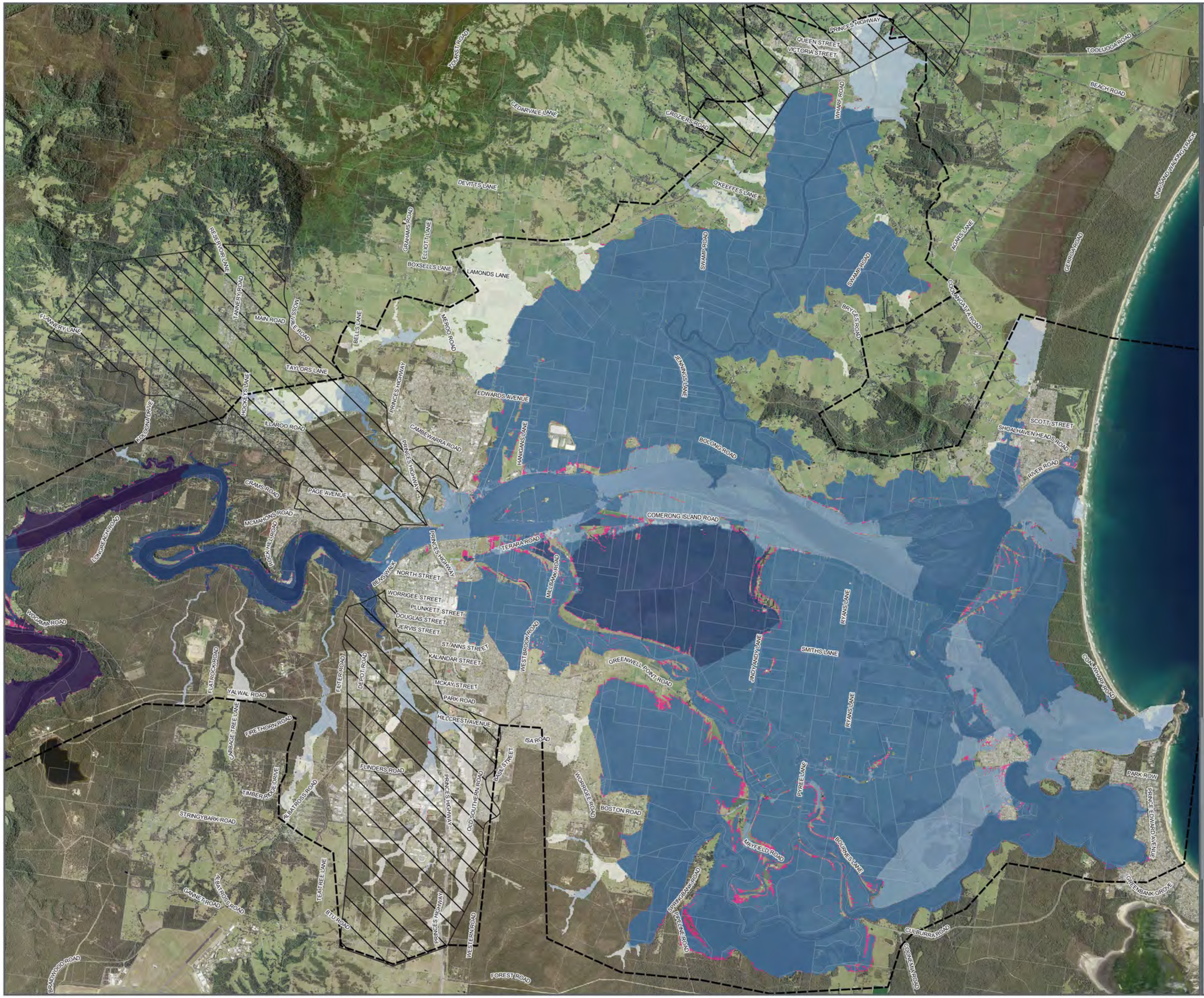
FIGURE H4

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2100 RCP 4.5
5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

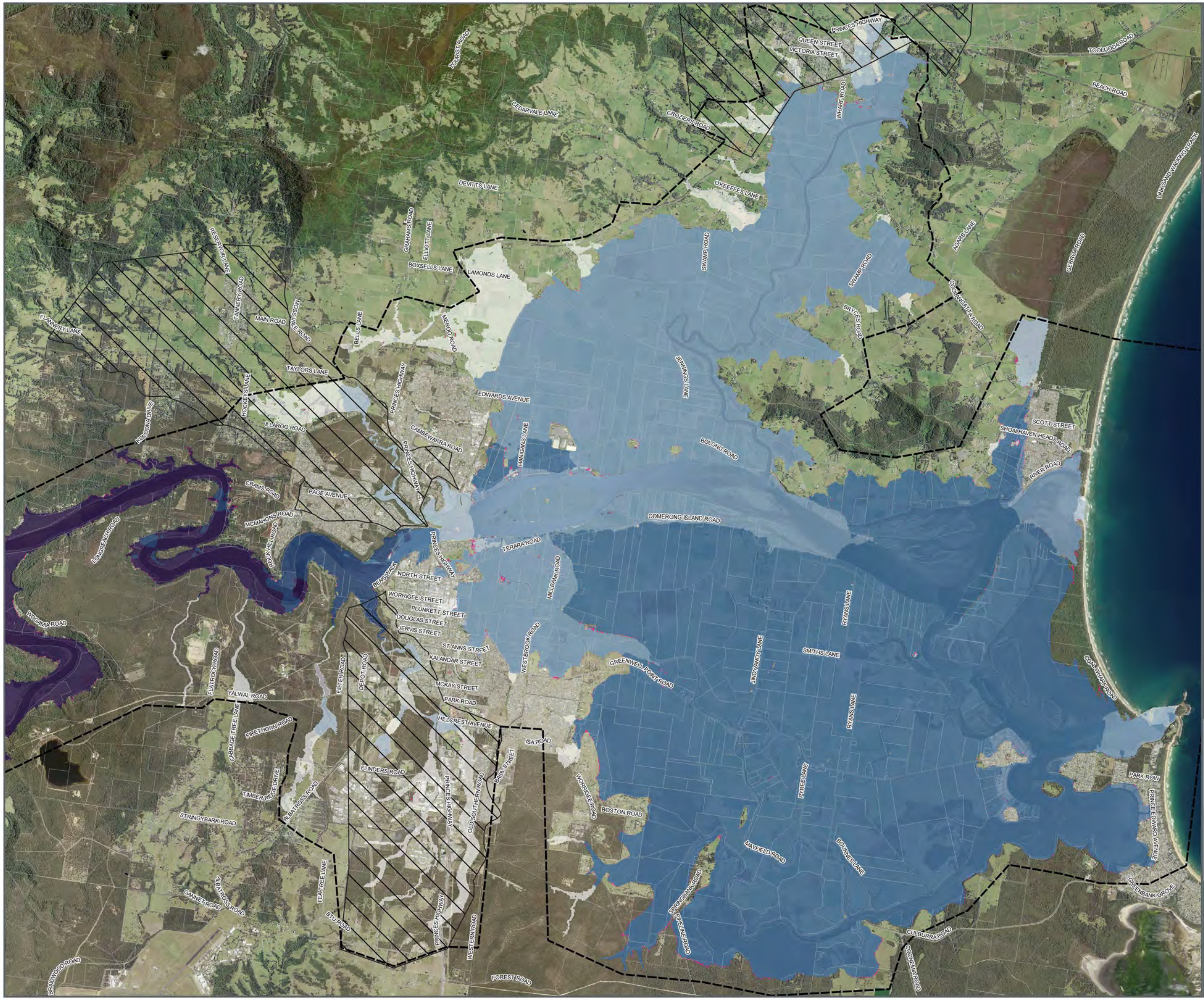
FIGURE H5

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2100 RCP 4.5 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

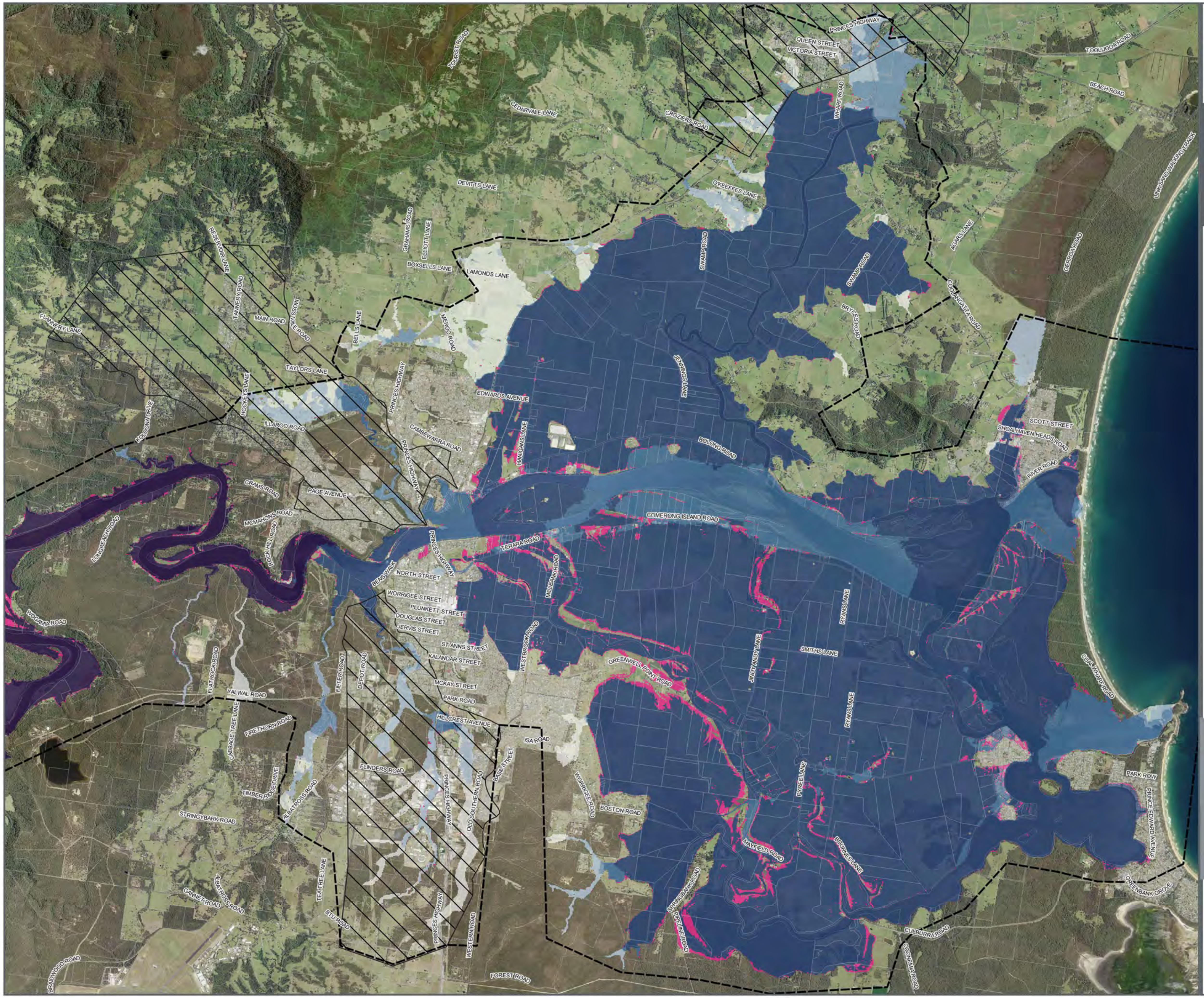
FIGURE H6

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2100 RCP 8.5 5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

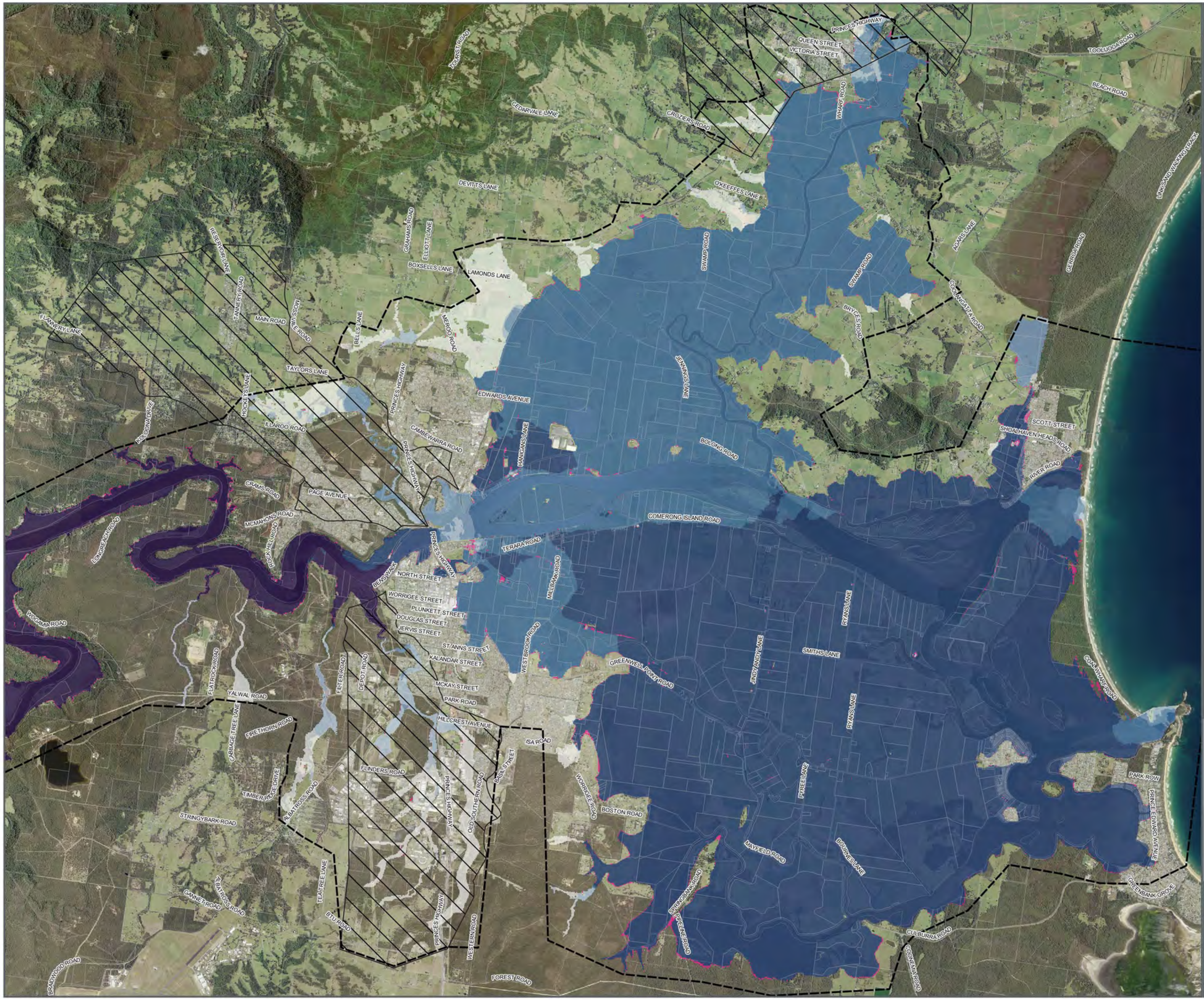
FIGURE H7

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2100 RCP 8.5
1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H8

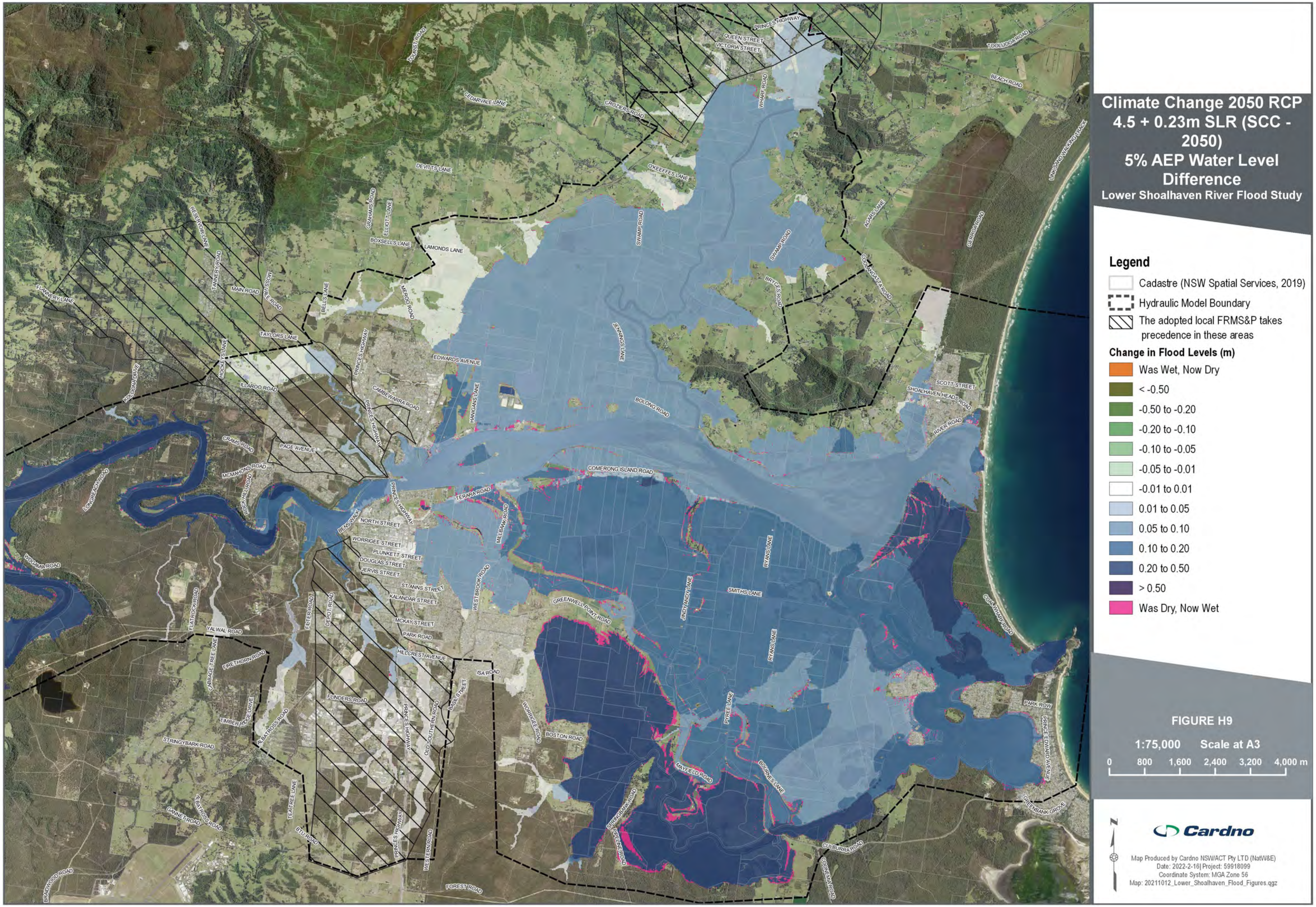
1:75,000 Scale at A3

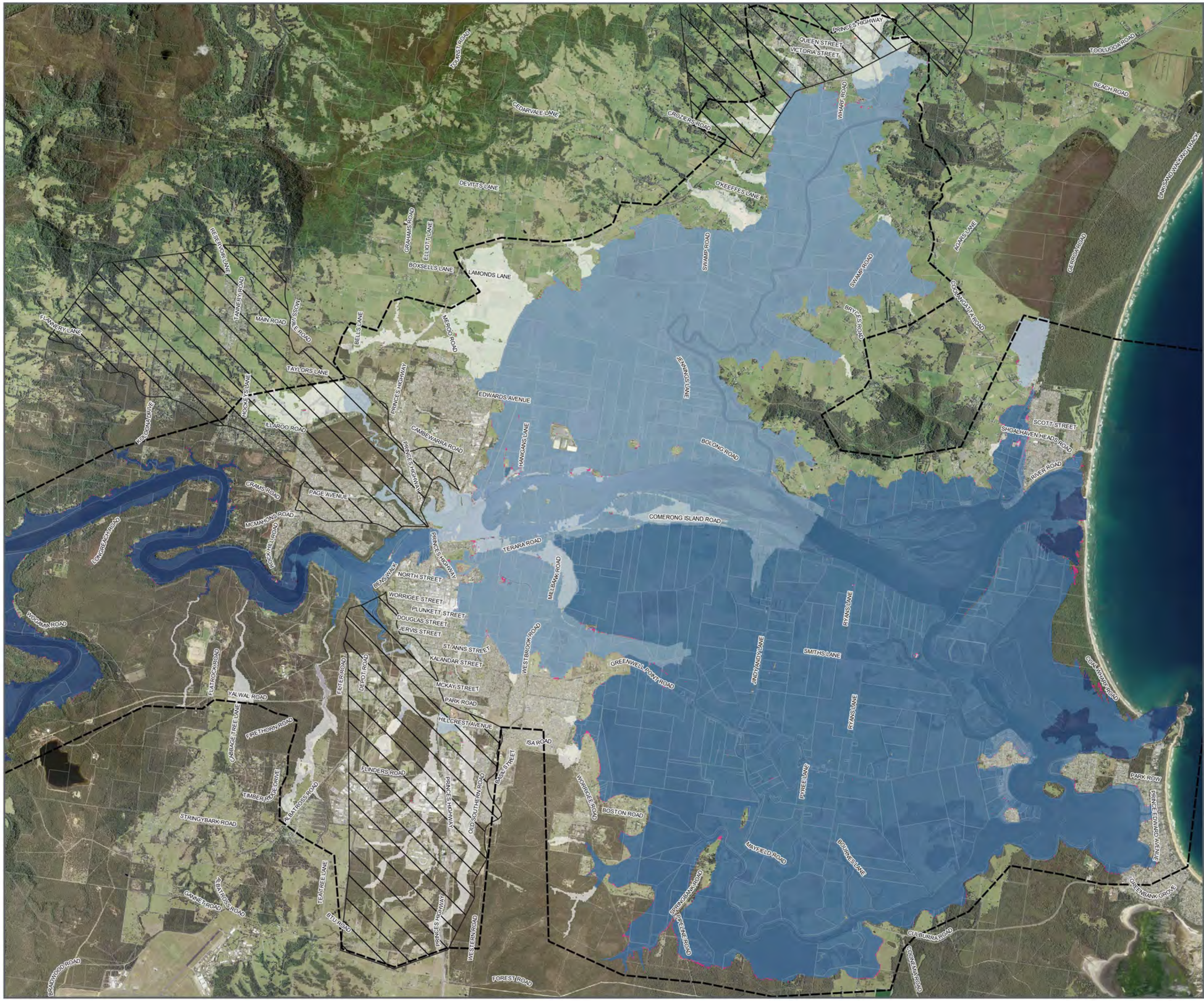
0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Climate Change 2050 RCP 4.5 + 0.23m SLR (SCC - 2050)
5% AEP Water Level Difference
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Change in Flood Levels (m)
Was Wet, Now Dry
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.50
> 0.50
Was Dry, Now Wet
FIGURE H9
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-16| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2050 RCP 4.5 + 0.23m SLR (SCC - 2050)

1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

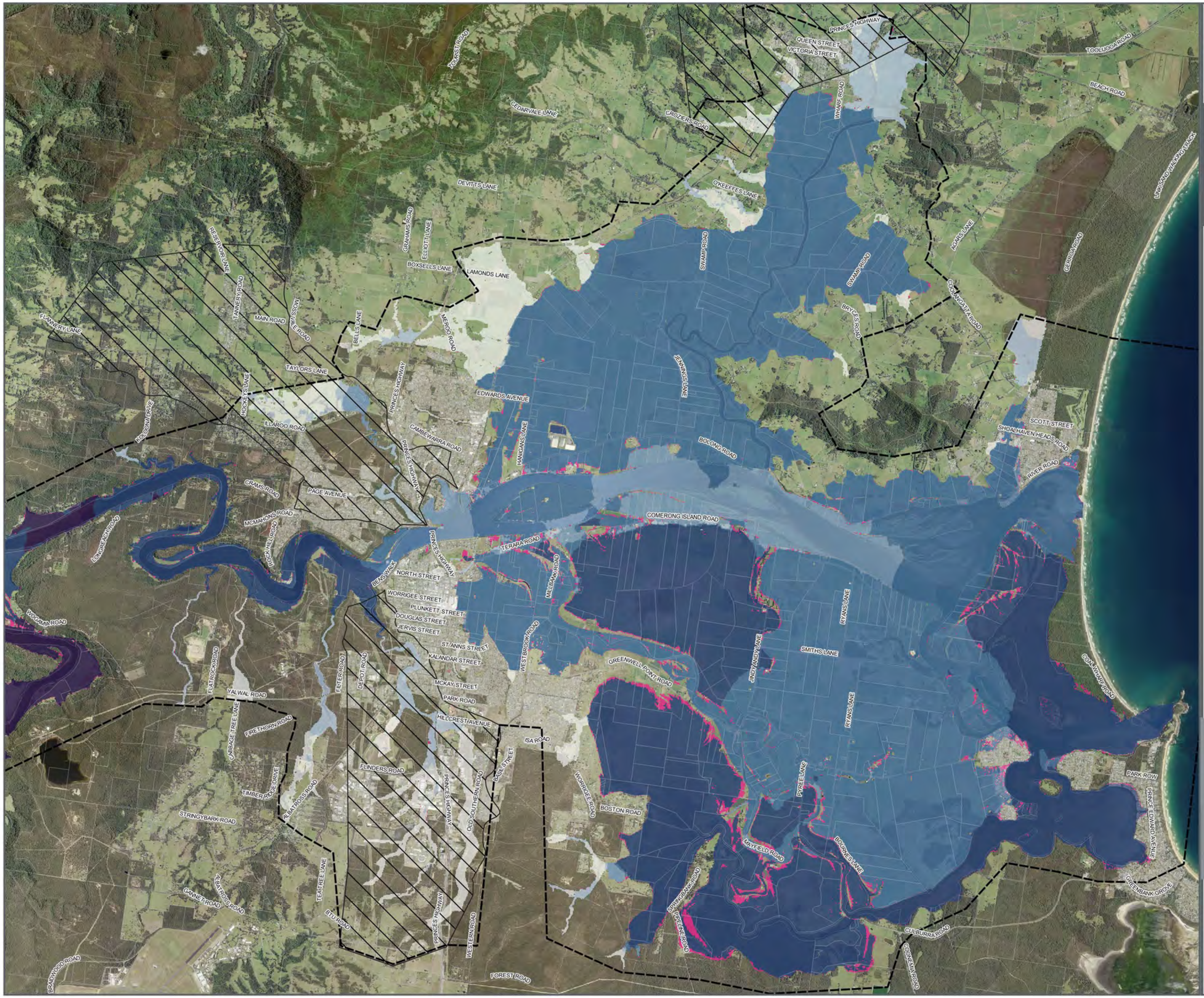
FIGURE H10

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2050 RCP 8.5 + 0.23m SLR (SCC - 2050)
5% AEP Water Level Difference
Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

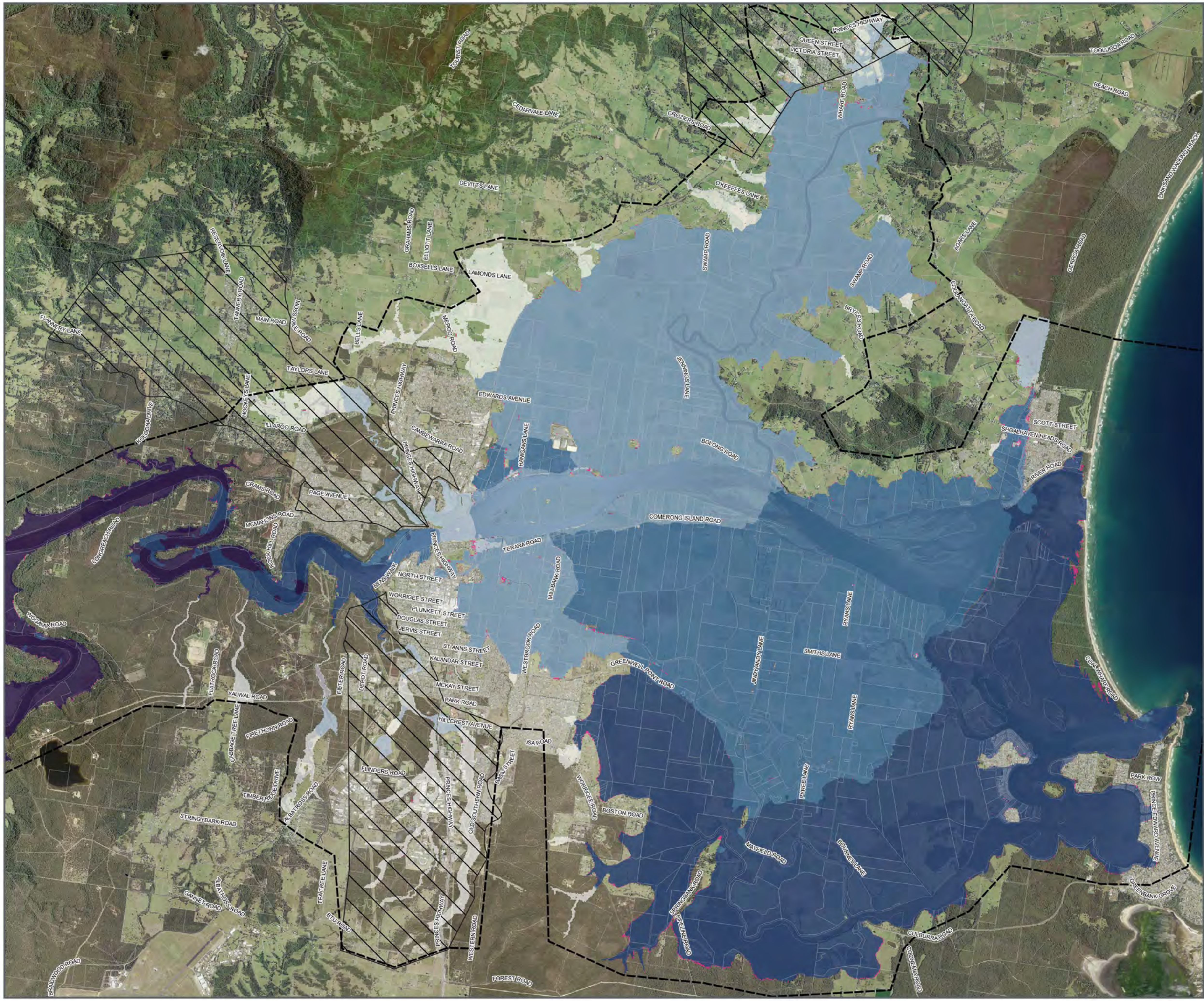
- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H11

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2050 RCP 8.5 + 0.23m SLR (SCC - 2050)
1% AEP Water Level Difference
Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

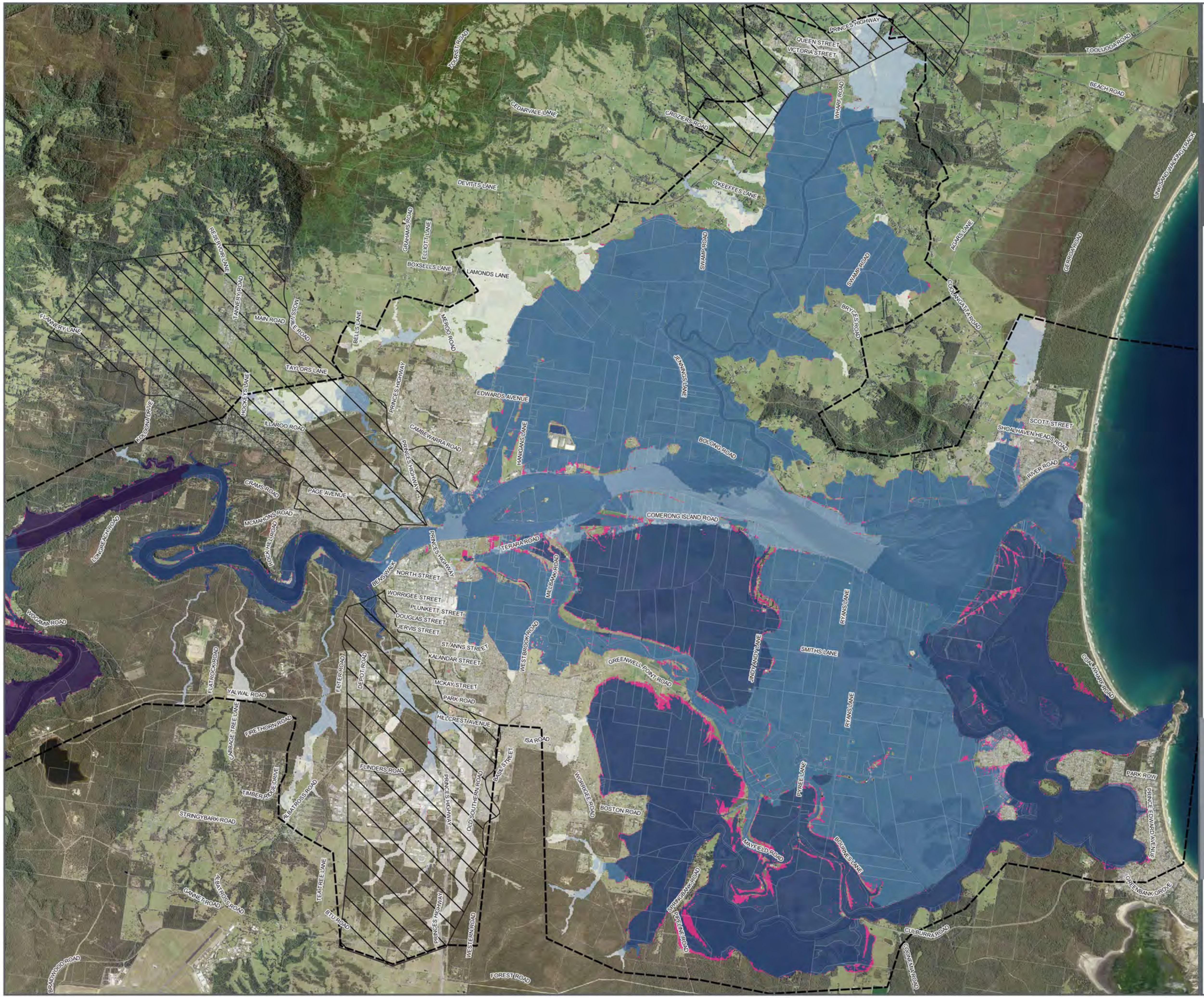
FIGURE H12

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2090 RCP 4.5 + 0.36m SLR (SCC - 2100) 5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H13

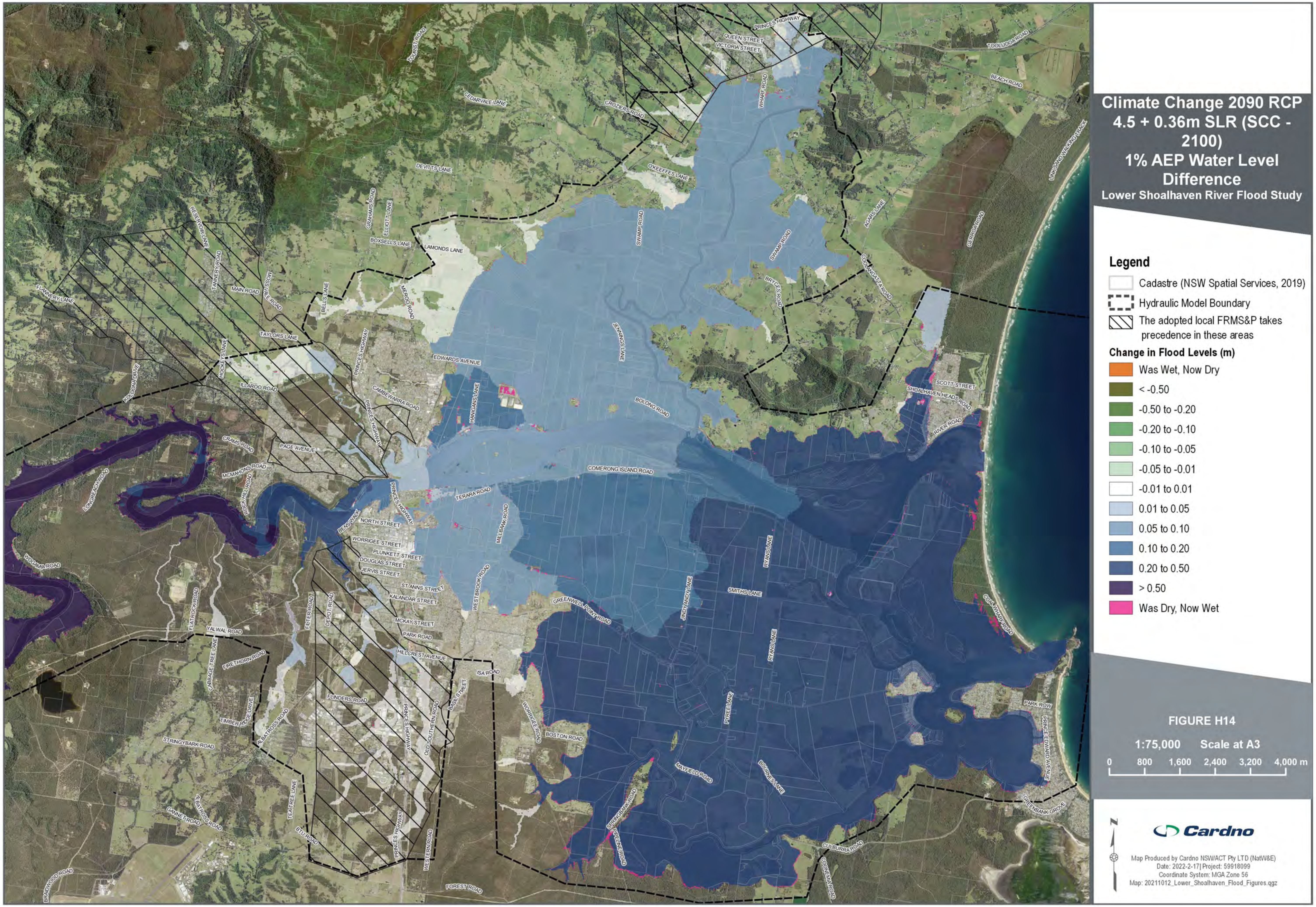
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

N

Cardno

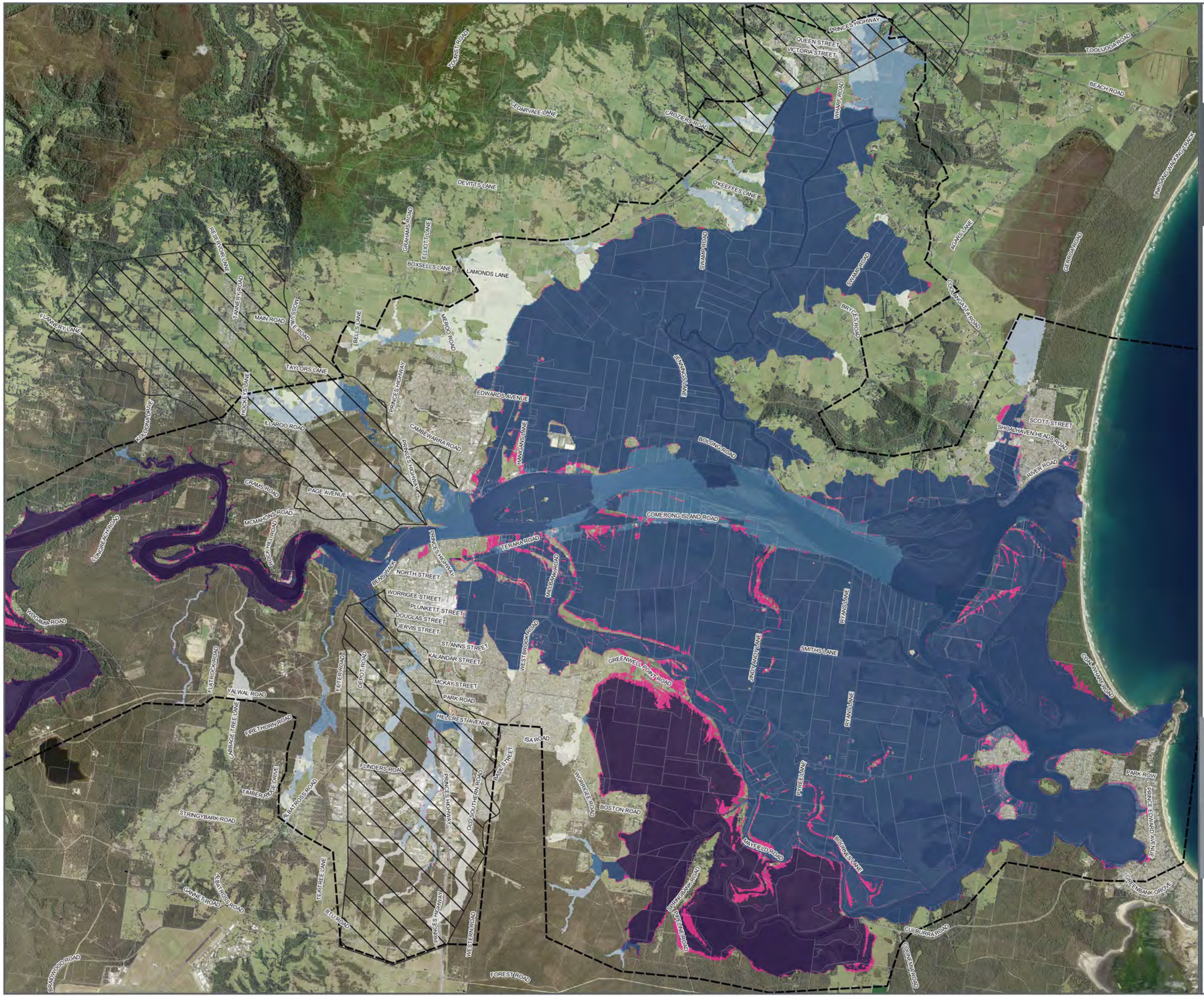
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2090 RCP 4.5 + 0.36m SLR (SCC - 2100)
1% AEP Water Level Difference
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Change in Flood Levels (m)
Was Wet, Now Dry
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.50
> 0.50
Was Dry, Now Wet
FIGURE H14
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Climate Change 2090 RCP 8.5 + 0.36m SLR (SCC - 2100) 5% AEP Water Level Difference

Lower Shoalhaven River Flood Study



Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

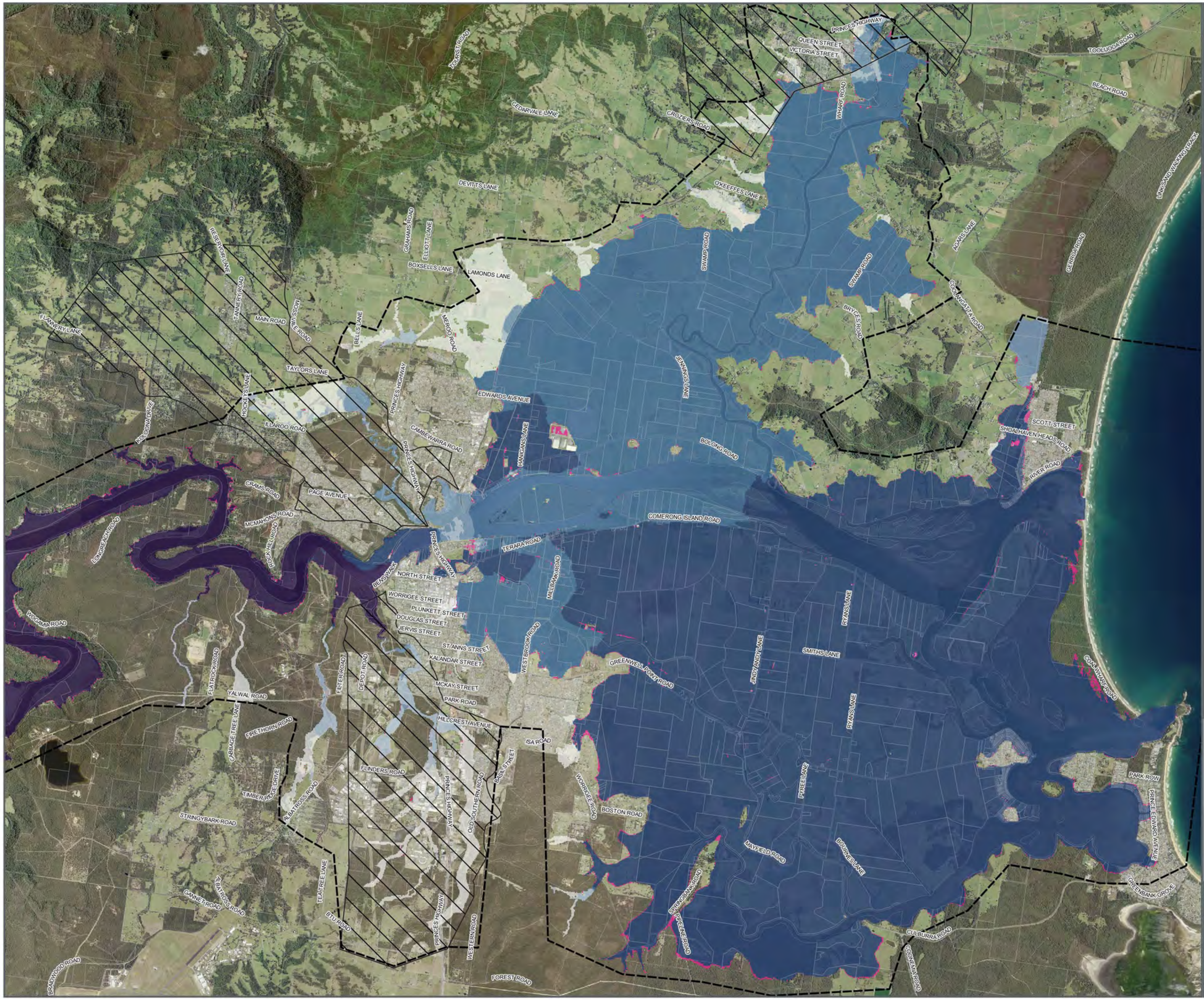
FIGURE H15

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Climate Change 2090 RCP 8.5 + 0.36m SLR (SCC - 2100) 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

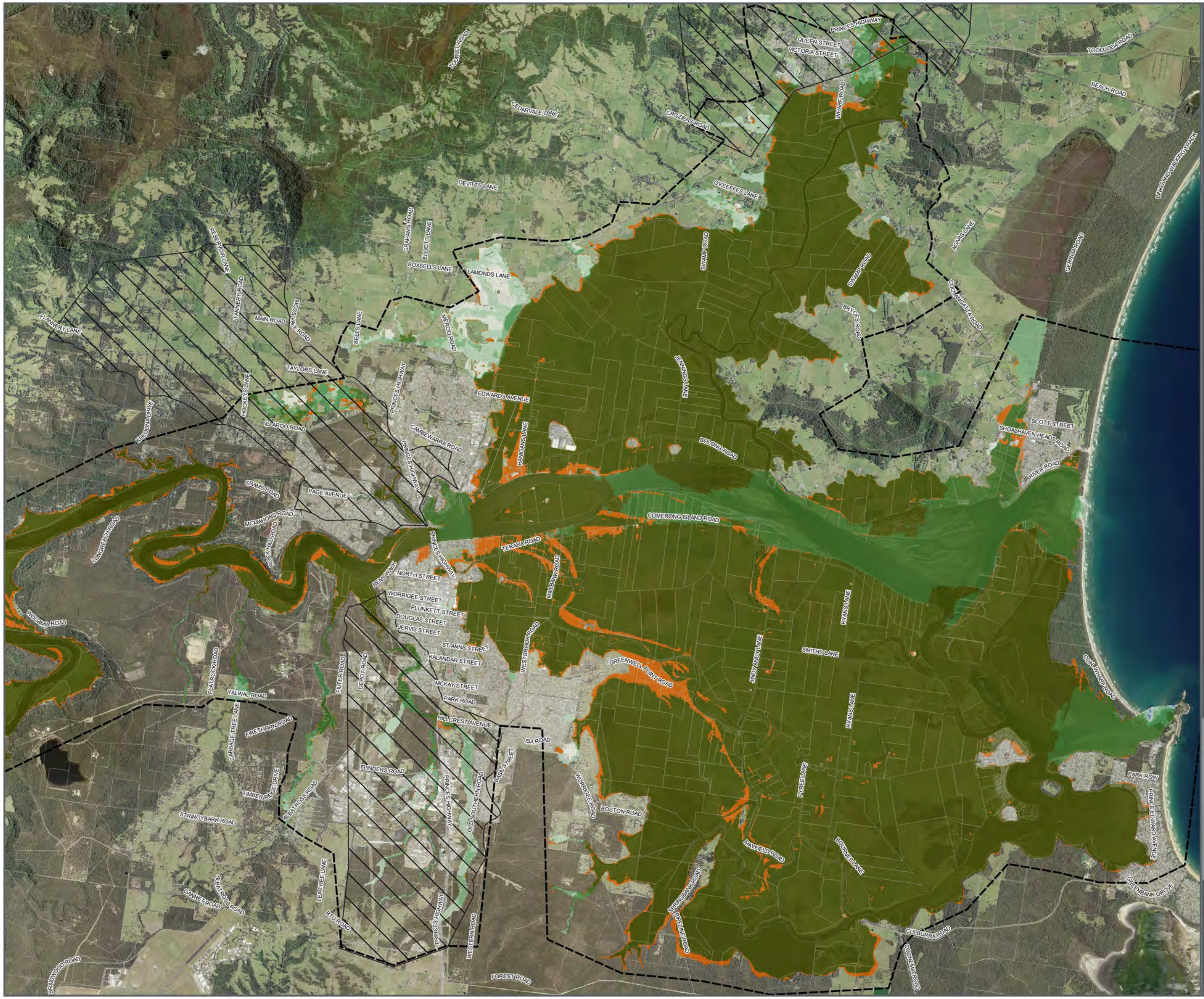
FIGURE H16

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Flow Sensitivity - Lag + 50%
1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

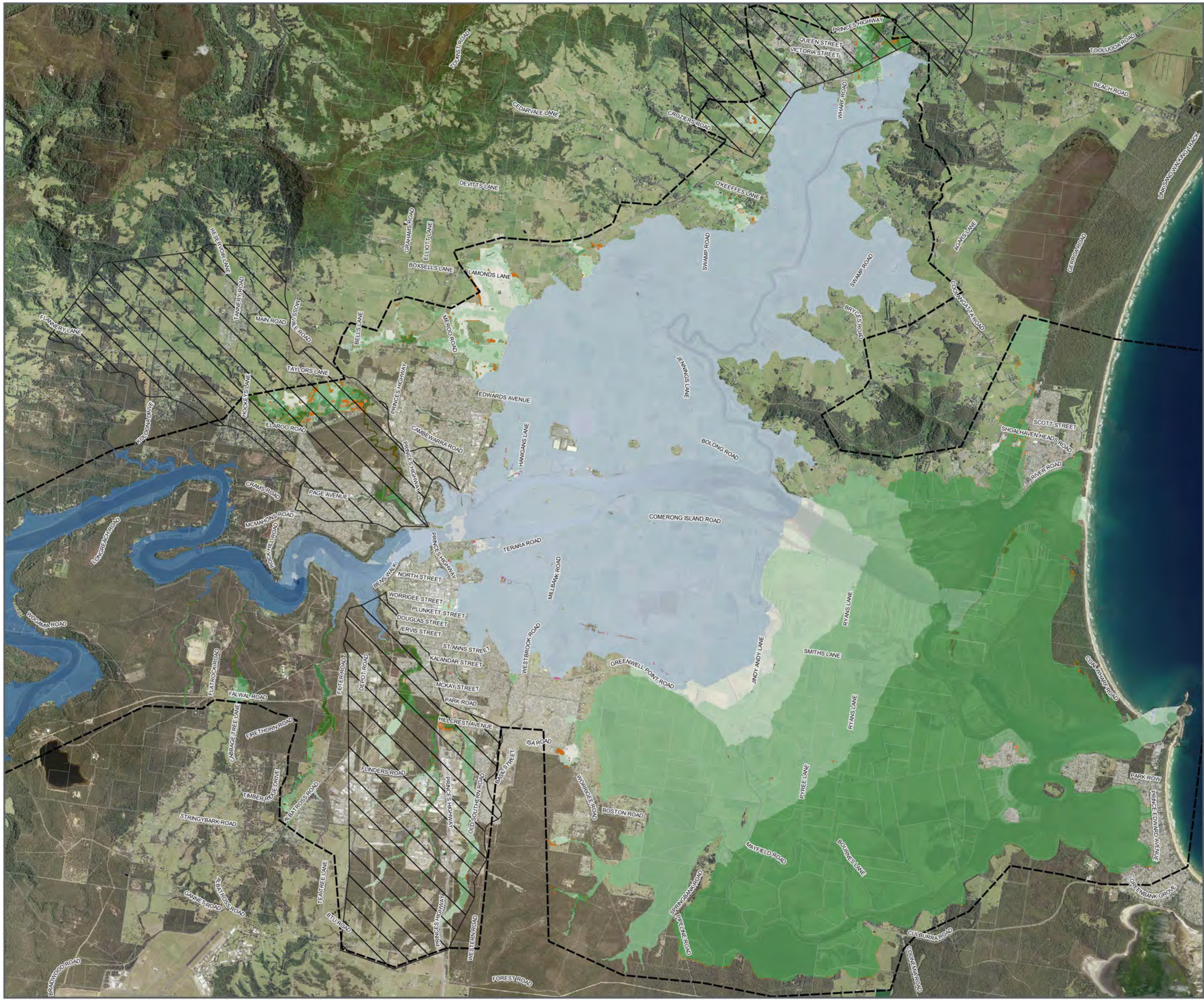
FIGURE H17

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Flow Sensitivity - Lag - 50% 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

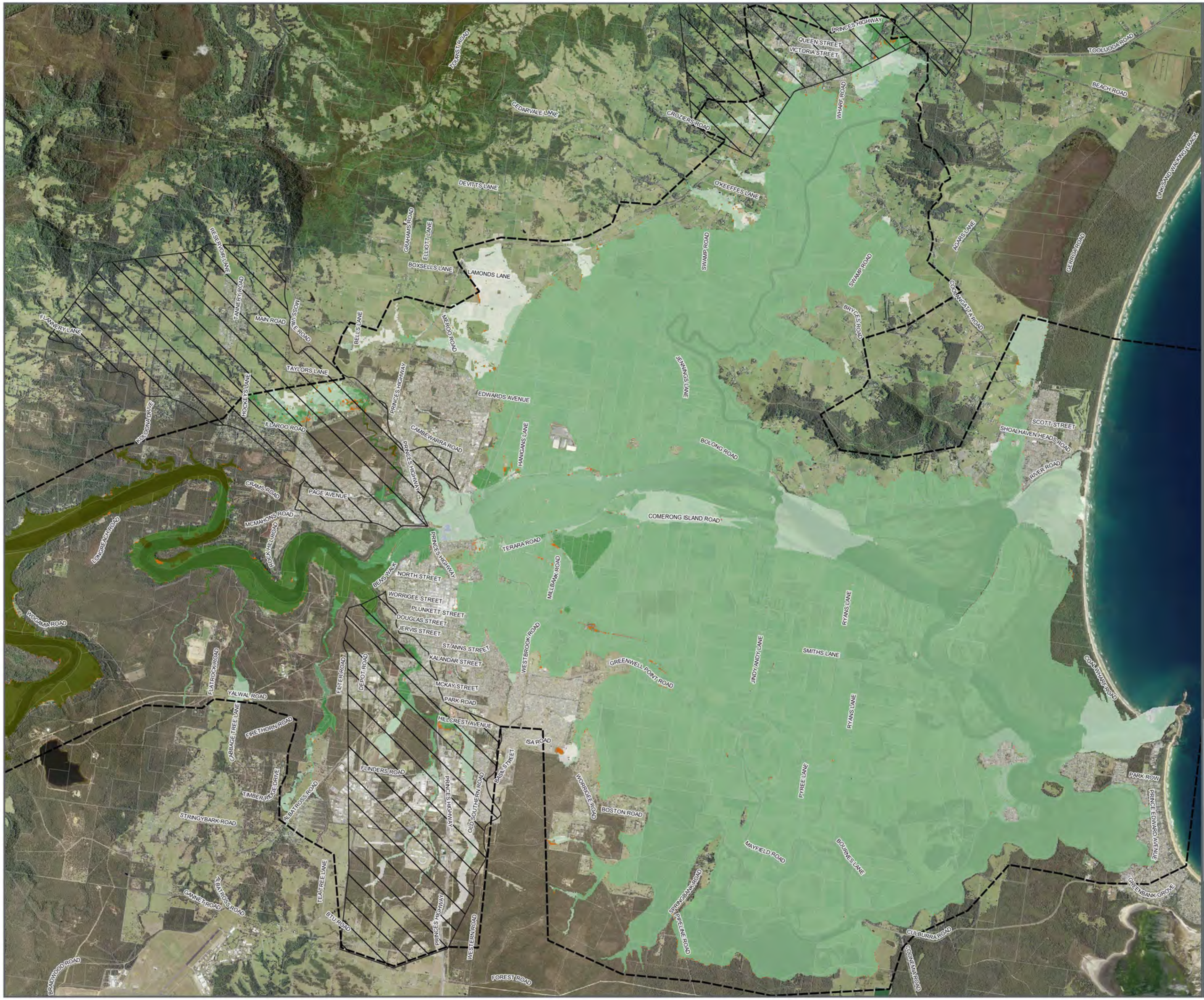
FIGURE H18

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Flow Sensitivity - Minimum Temporal Pattern 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H19

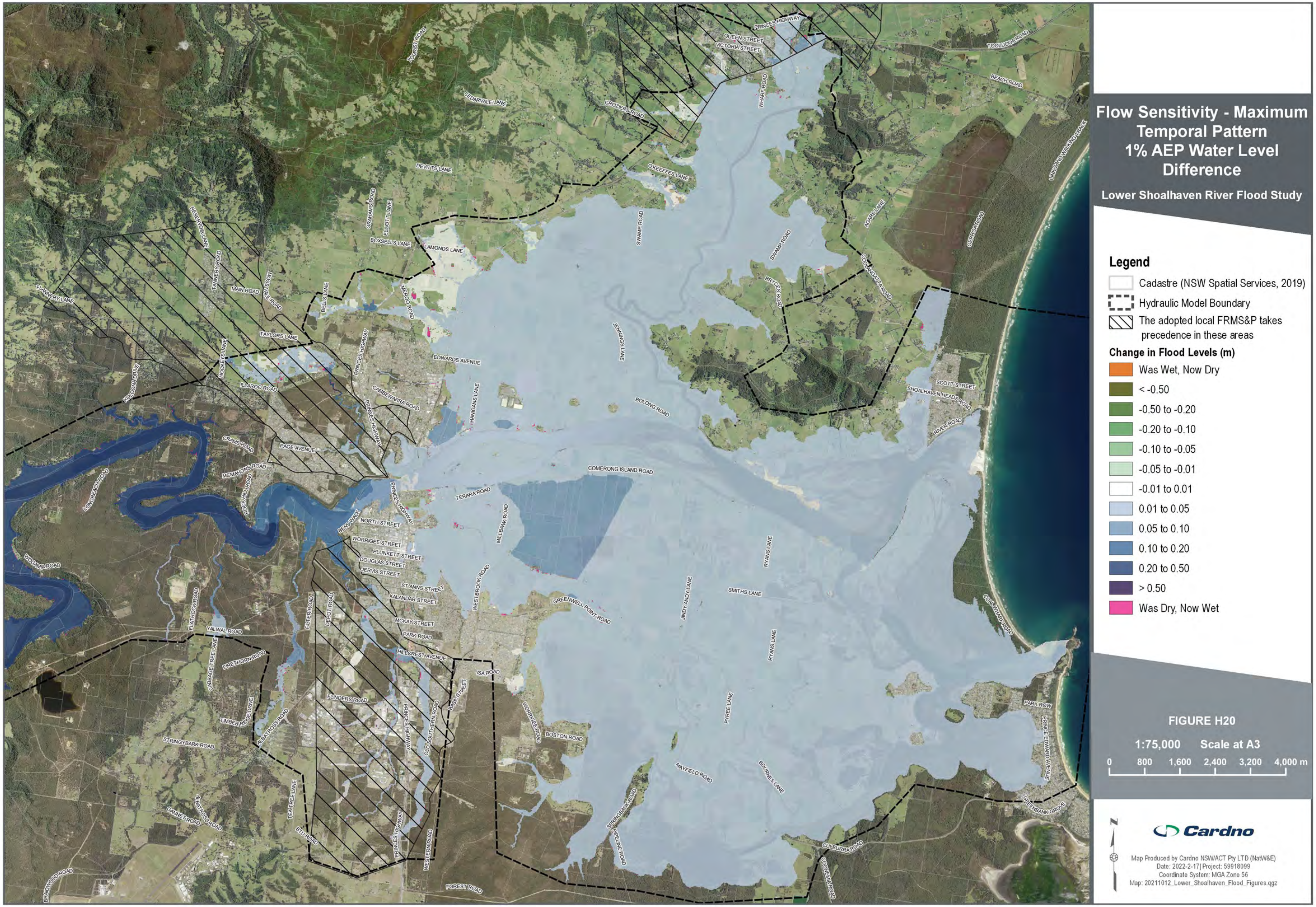
1:75,000 Scale at A3

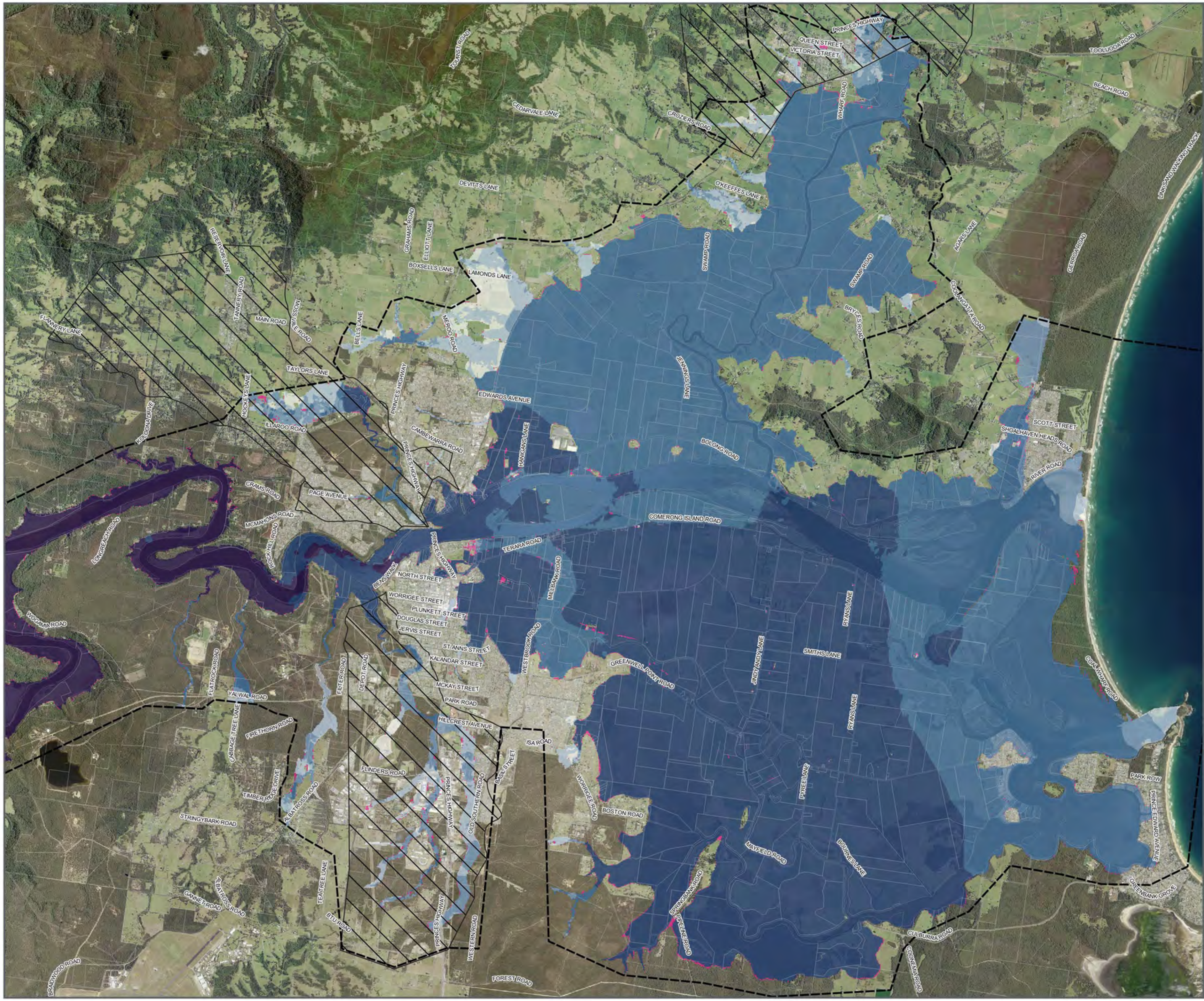
0 800 1,600 2,400 3,200 4,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Flow Sensitivity - Maximum Temporal Pattern 1% AEP Water Level Difference
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Change in Flood Levels (m)
Was Wet, Now Dry
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.50
> 0.50
Was Dry, Now Wet
FIGURE H20
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz
PRINCES HIGHWAY
QUEEN STREET
VICTORIA STREET
CEDARVALE LANE
CROZIERS ROAD
WHARF ROAD
TOOLIJOOA ROAD
BEACH ROAD
DEVITTS LANE
OKEEFFES LANE
SWAMP ROAD
AGARS LANE
BOXSELLS LANE
LAMONDS LANE
MAIN ROAD
TAYLORS LANE
BELLS LANE
MERCO ROAD
EDWARDS AVENUE
JENNINGS LANE
BRYCES ROAD
COOLANGATTA ROAD
FLANNERY LANE
ILLAROO ROAD
CAMBEWARRA ROAD
HANIGANS LANE
BOLONG ROAD
SCOTT STREET
SHOALHAVEN HEADS ROAD
RIVER ROAD
CRAMS ROAD
PAGE AVENUE
MCMAHONS ROAD
COMERONG ISLAND ROAD
TERARA ROAD
NORTH STREET
WORRIGEE STREET
PLUNKETT STREET
DOUGLAS STREET
JERVIS STREET
ST ANNS STREET
KALANDAR STREET
MCKAY STREET
PARK ROAD
HILLCREST AVENUE
MILLBANK ROAD
WESTBROOK ROAD
GREENWELL POINT ROAD
SMITHS LANE
RYANS LANE
YALWAL ROAD
FIRETHORN ROAD
FLINDERS ROAD
ISA ROAD
BOSTON ROAD
WORRIGEE ROAD
PYREE LANE
MAYFIELD ROAD
BOURNES LANE
PARK ROW
PRINCE EDWARD AVENUE
GREENBANK GROVE
STRINGYBARK ROAD
ALBATROSS ROAD
TEATREE LANE
GANNET ROAD
BTU ROAD
WESTERN ROAD
FOREST ROAD
CULBURRA ROAD
BRAIDWOOD ROAD
WOGAMIA ROAD



Manning's +20% Sensitivity 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

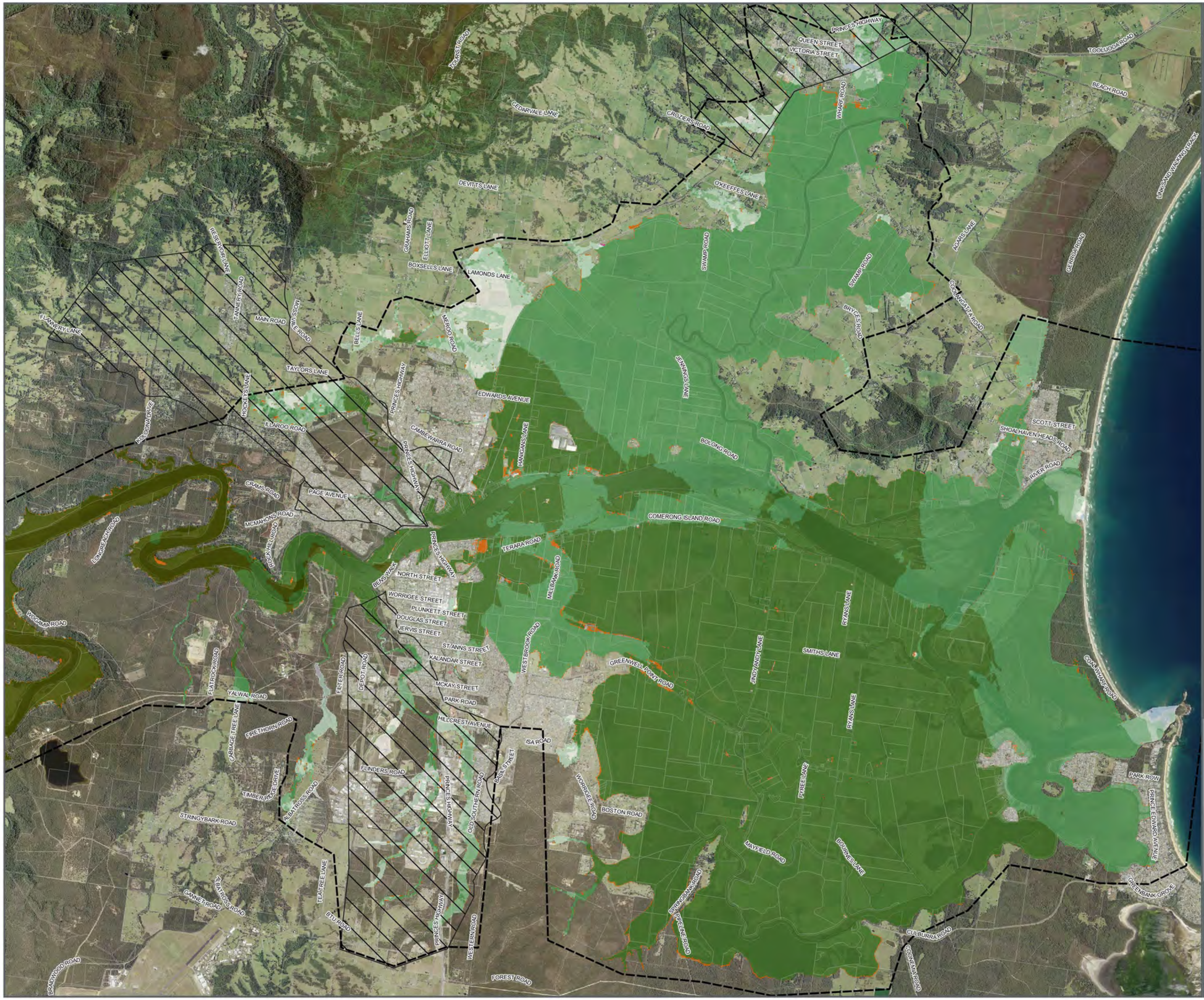
FIGURE H21

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Manning's -20% Sensitivity 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H22

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

50% Blockage of Hydraulic Structures 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H23

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

100% Blockage of Hydraulic Structures 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H24

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Closed Shoalhaven Heads Entrance 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

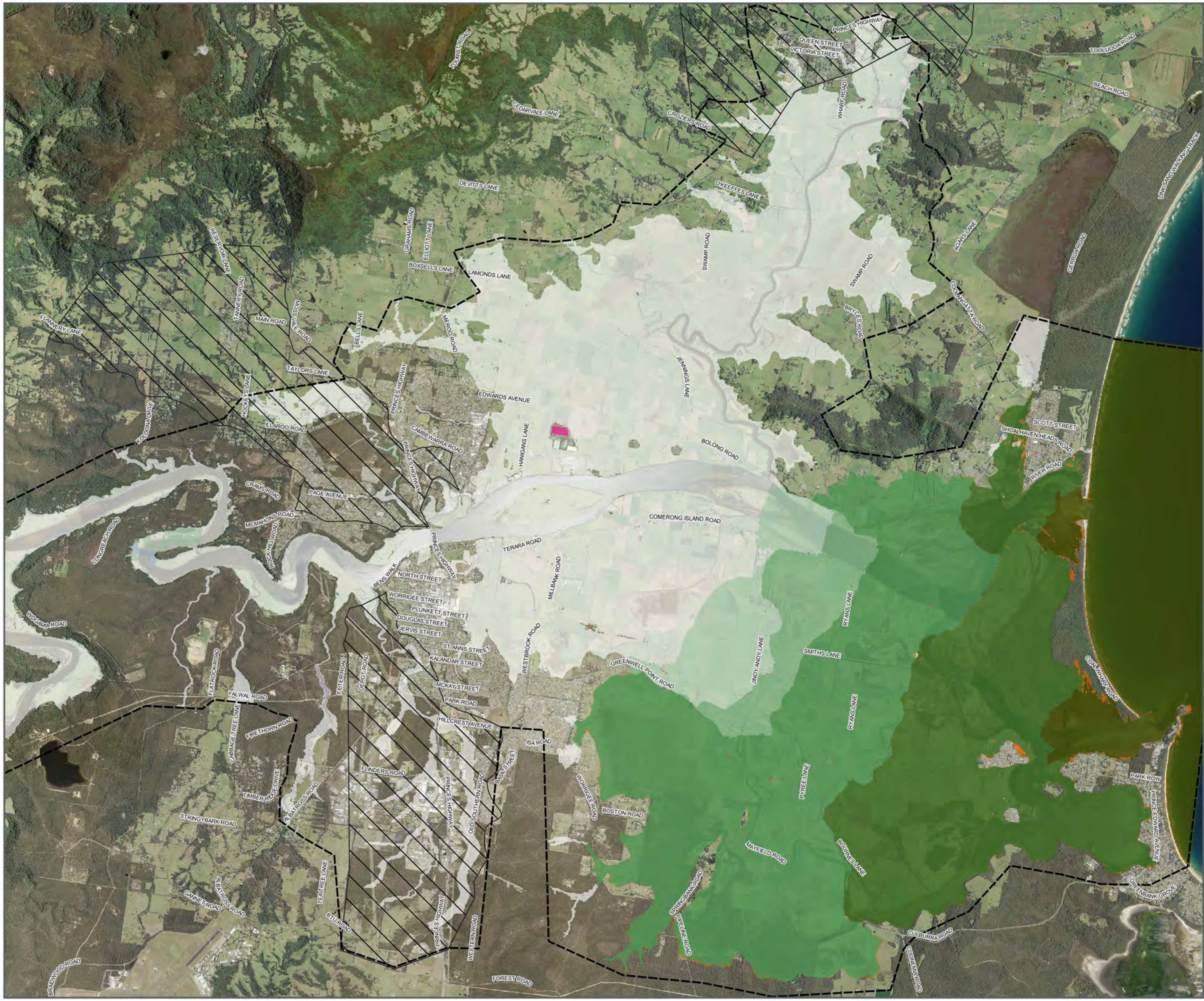
FIGURE H25

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Tailwater Sensitivity - HHWSS 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

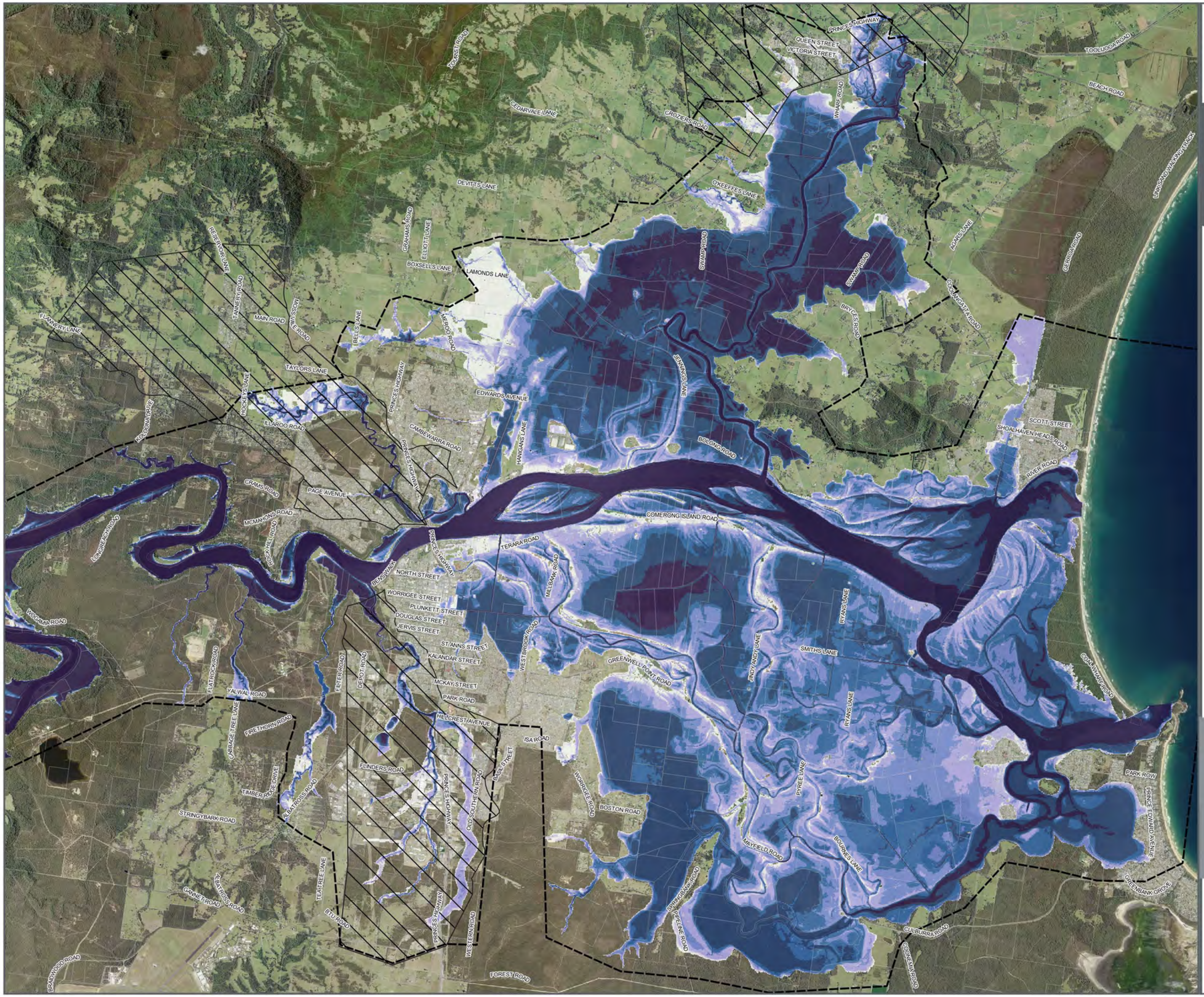
FIGURE H26

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Levee Removal Sensitivity 5% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

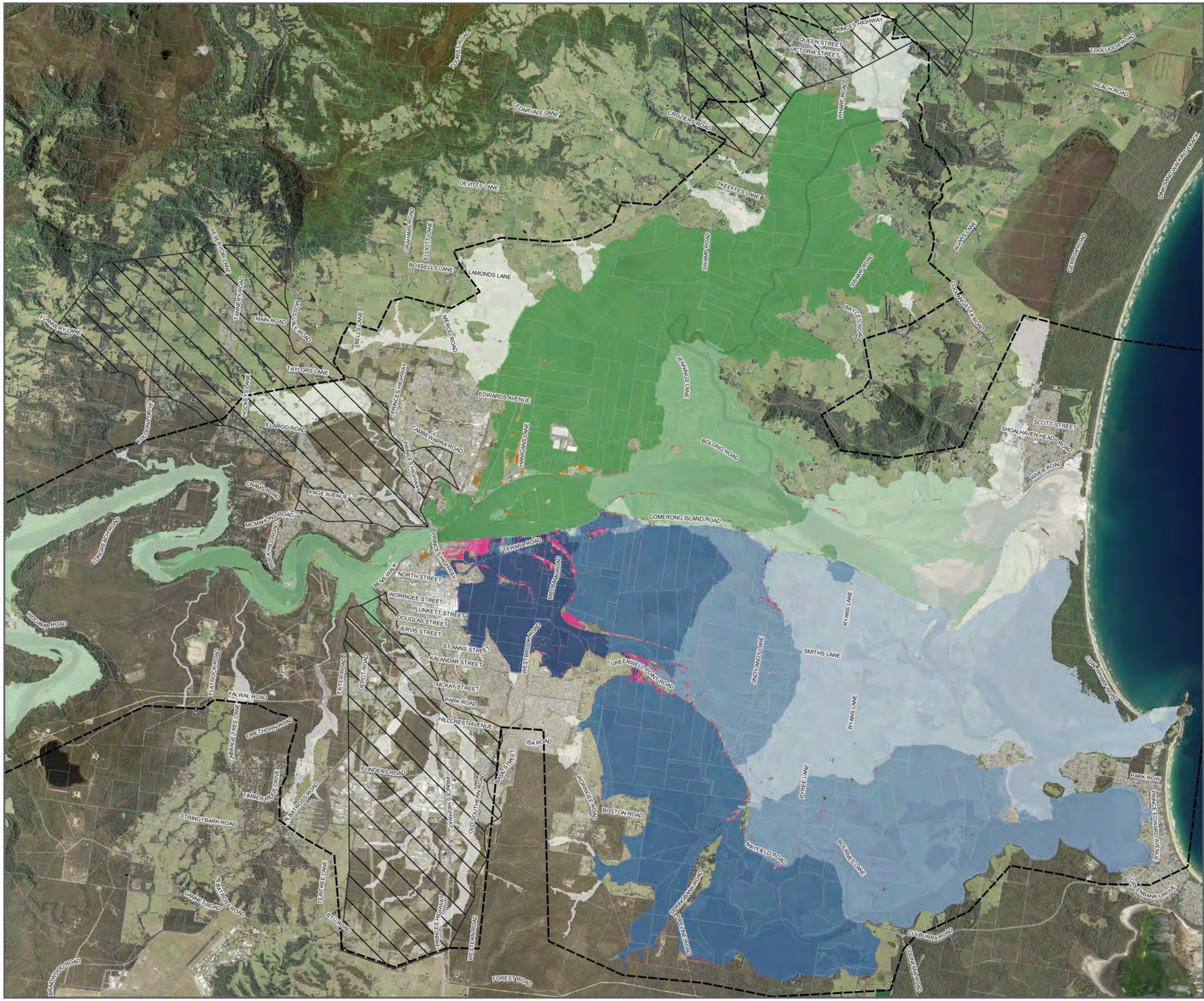
FIGURE H27

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Levee Removal Sensitivity 5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

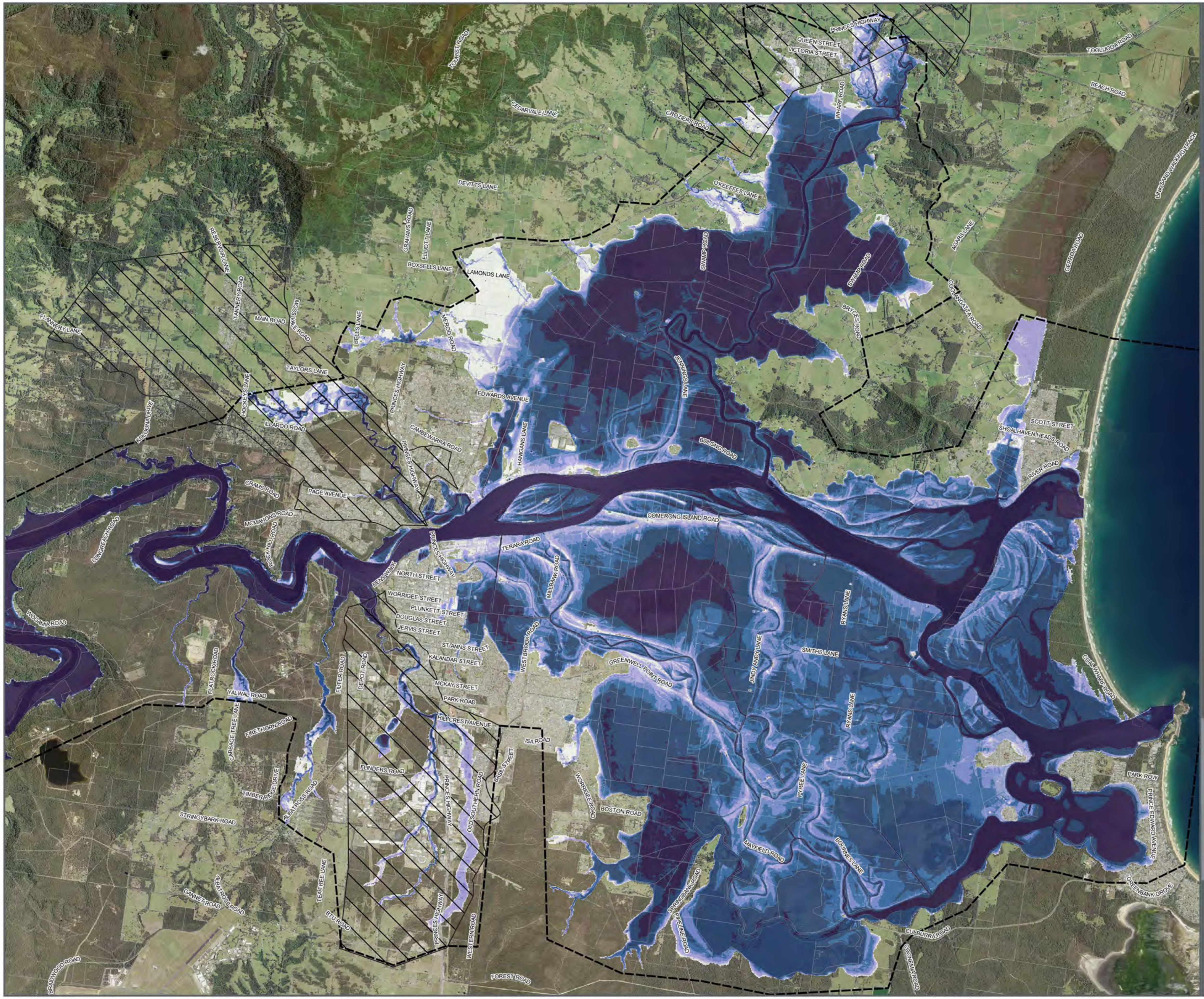
FIGURE H28

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Levee Removal Sensitivity 1% AEP Flood Depth

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

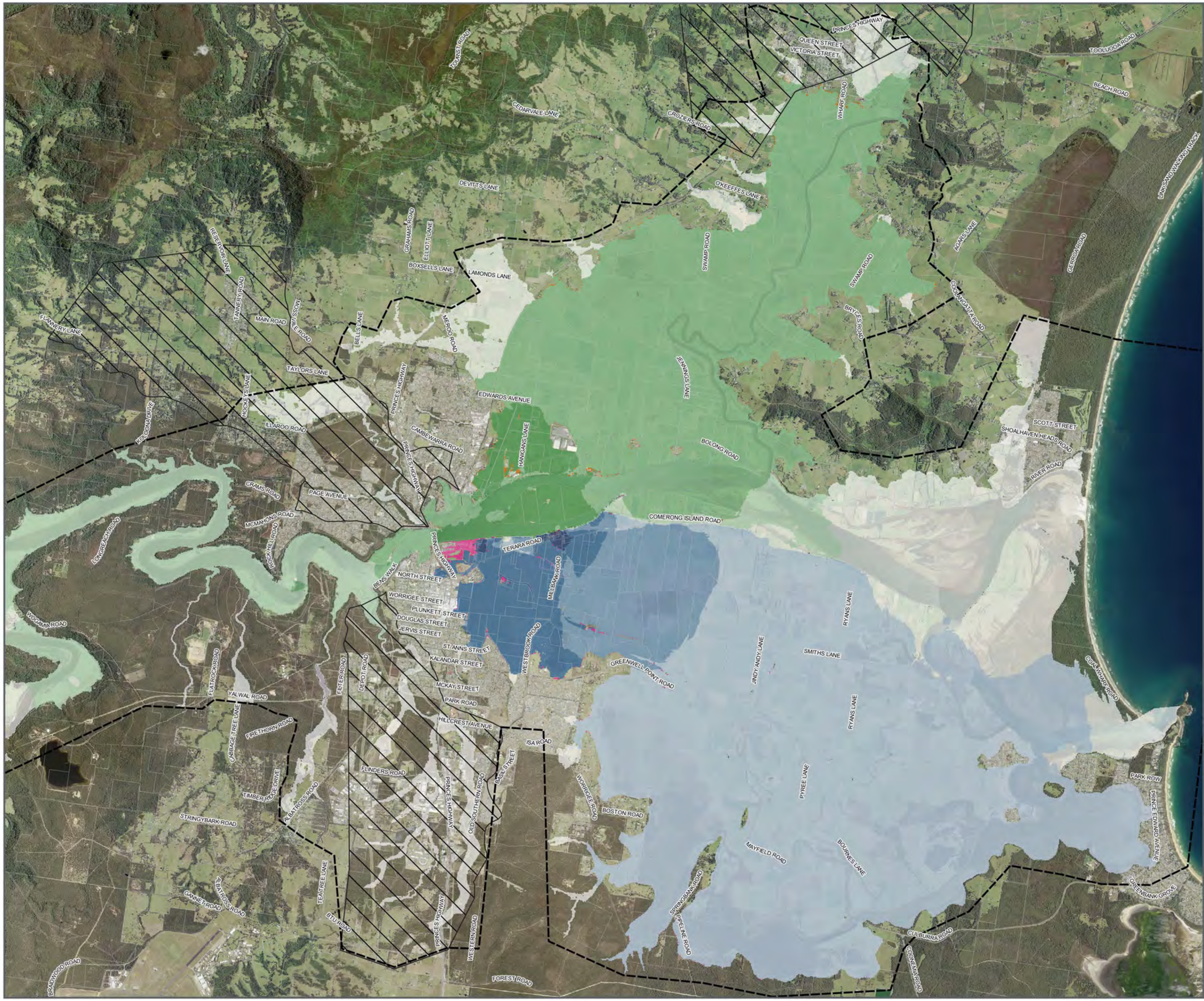
FIGURE H29

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Levee Removal Sensitivity 1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

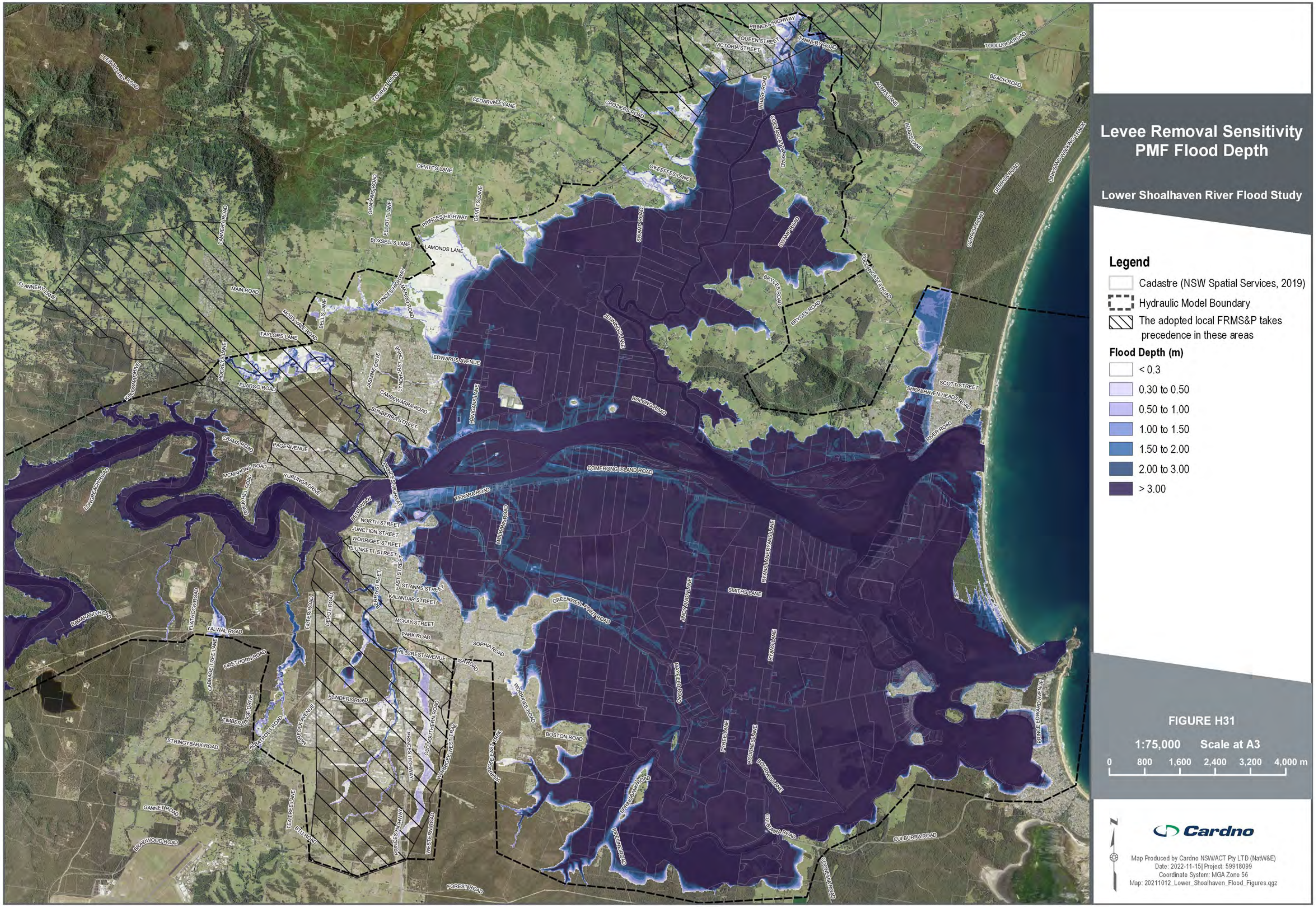
FIGURE H30

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


Levee Removal Sensitivity
PMF Flood Depth
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE H31
1:75,000 Scale at A3
0 800 1,600 2,400 3,200 4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Levee Removal Sensitivity PMF Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

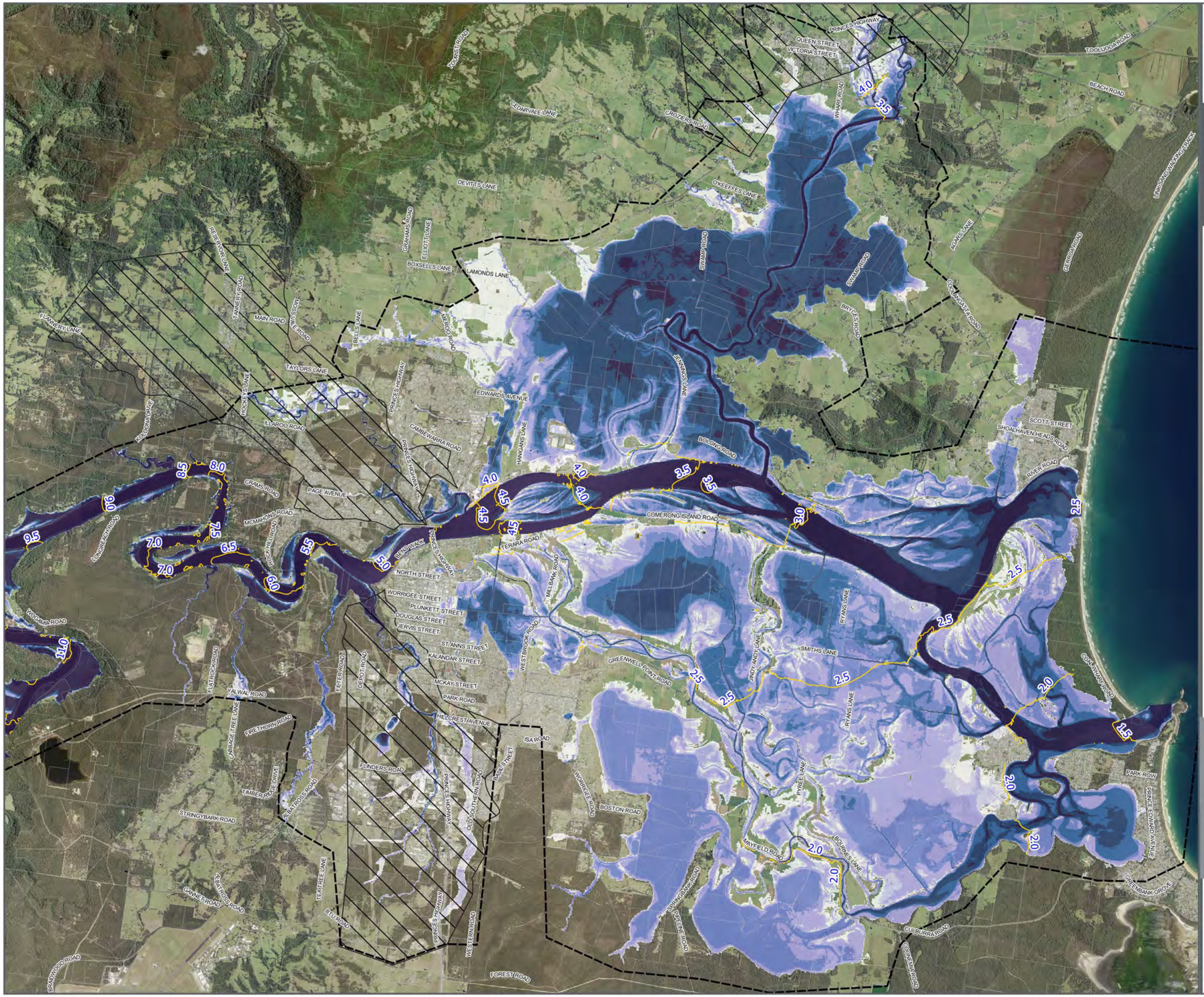
FIGURE H32

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987 5% AEP Flood Depth and Water Level Contours

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Water Level Contours (0.5m)

Flood Depth (m)

- < 0.3
- 0.30 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

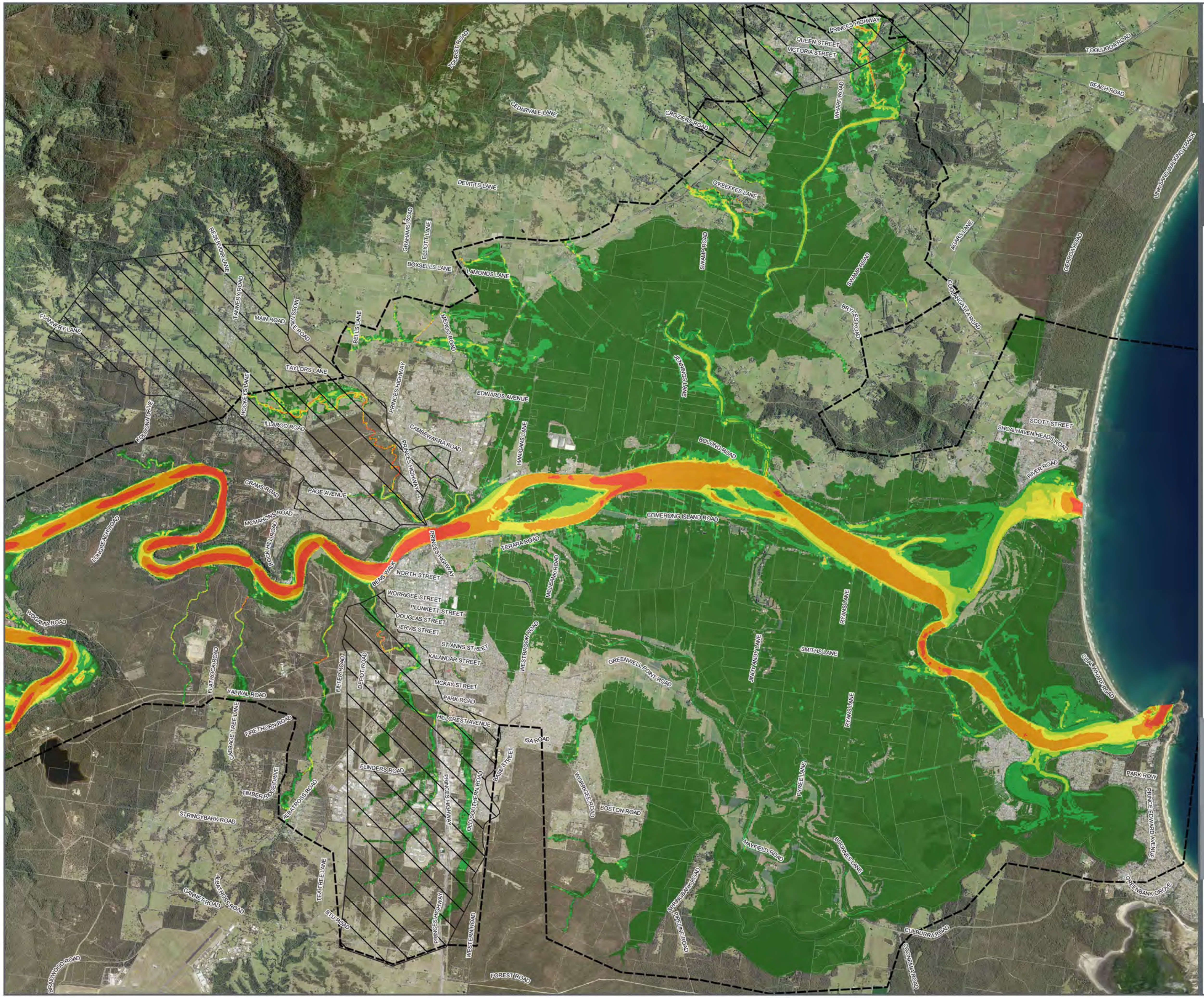
FIGURE H33

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987
5% AEP Velocity

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

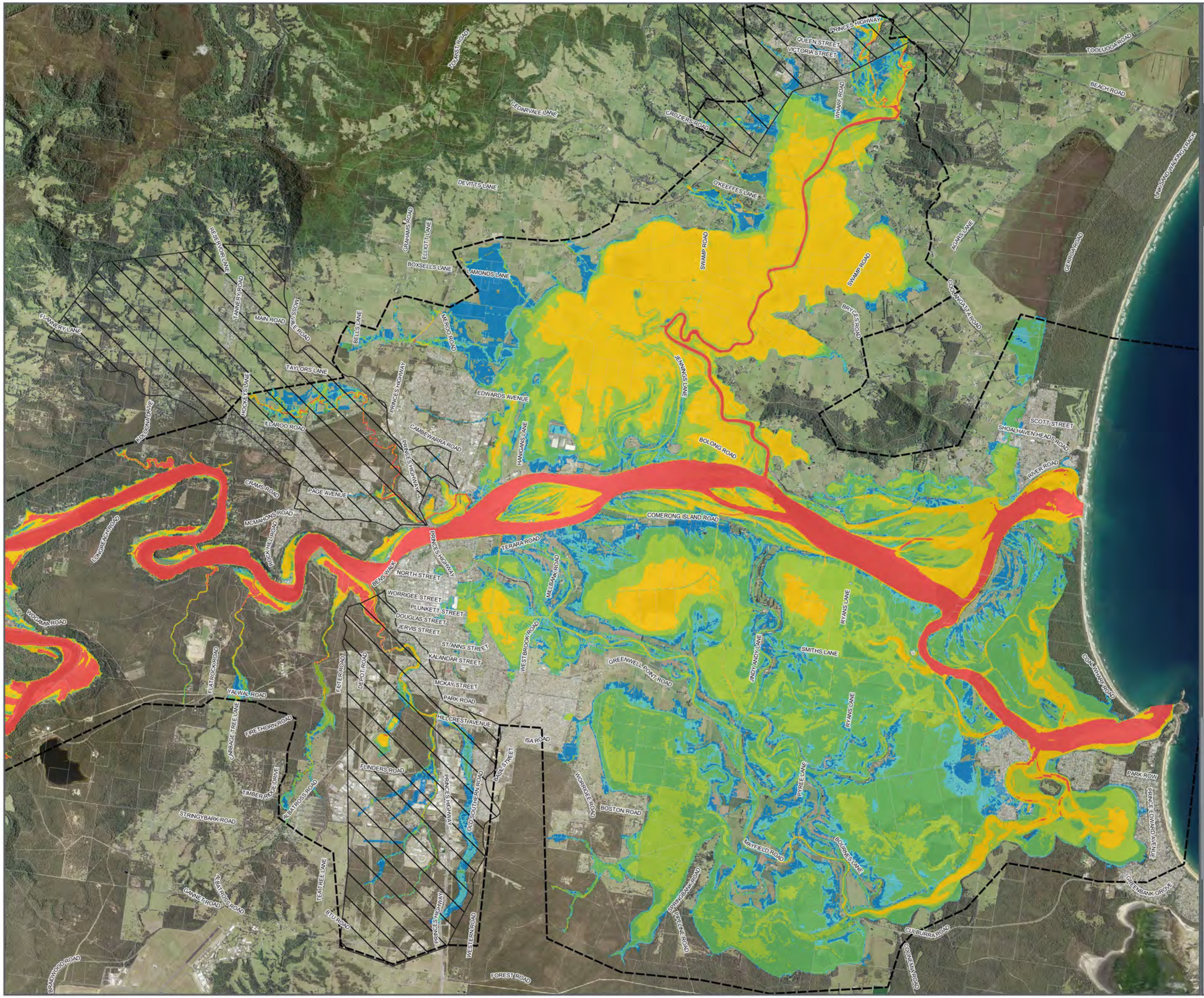
FIGURE H34

1:75,000 **Scale at A3**

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987
5% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

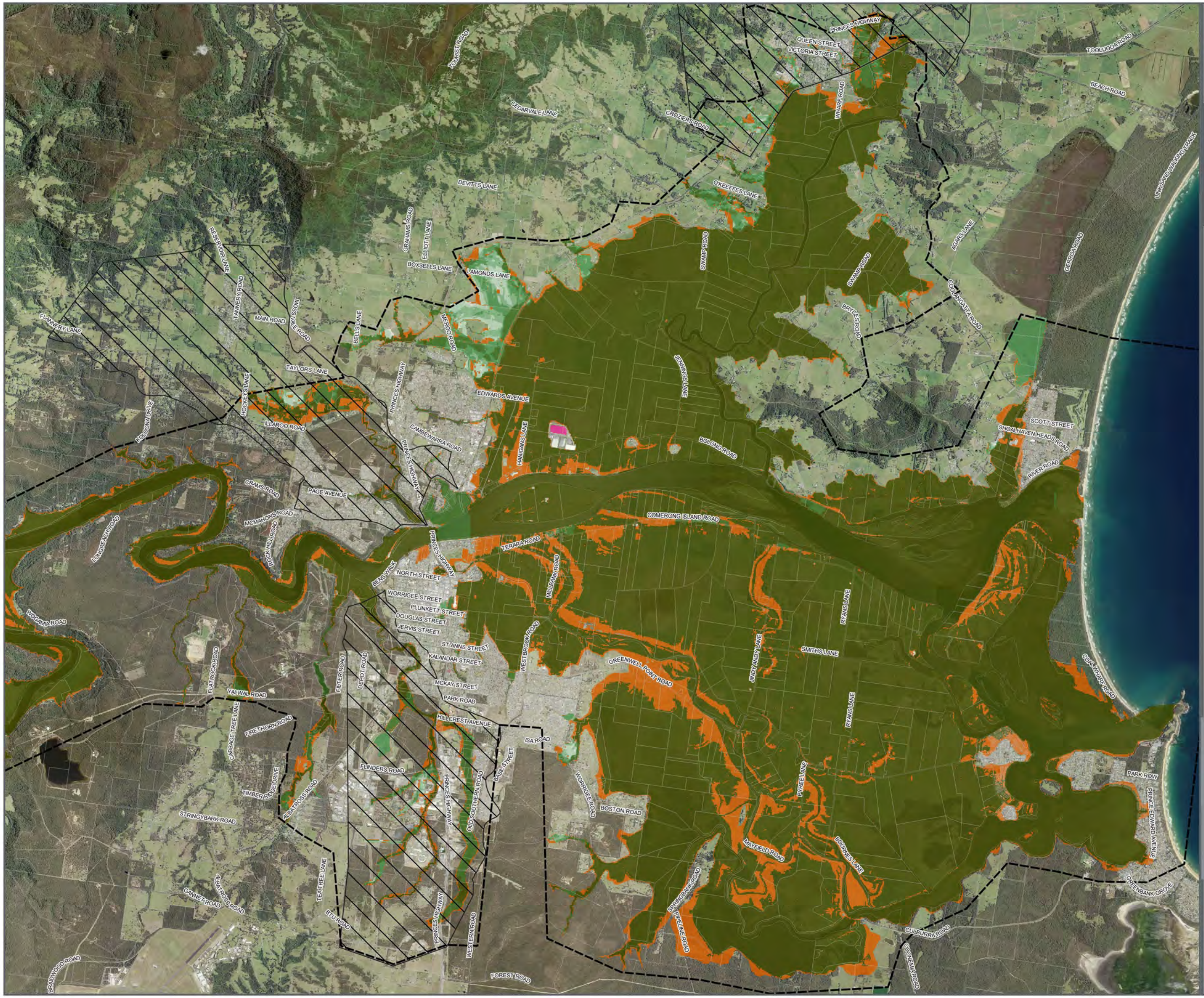
FIGURE H35

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987
5% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

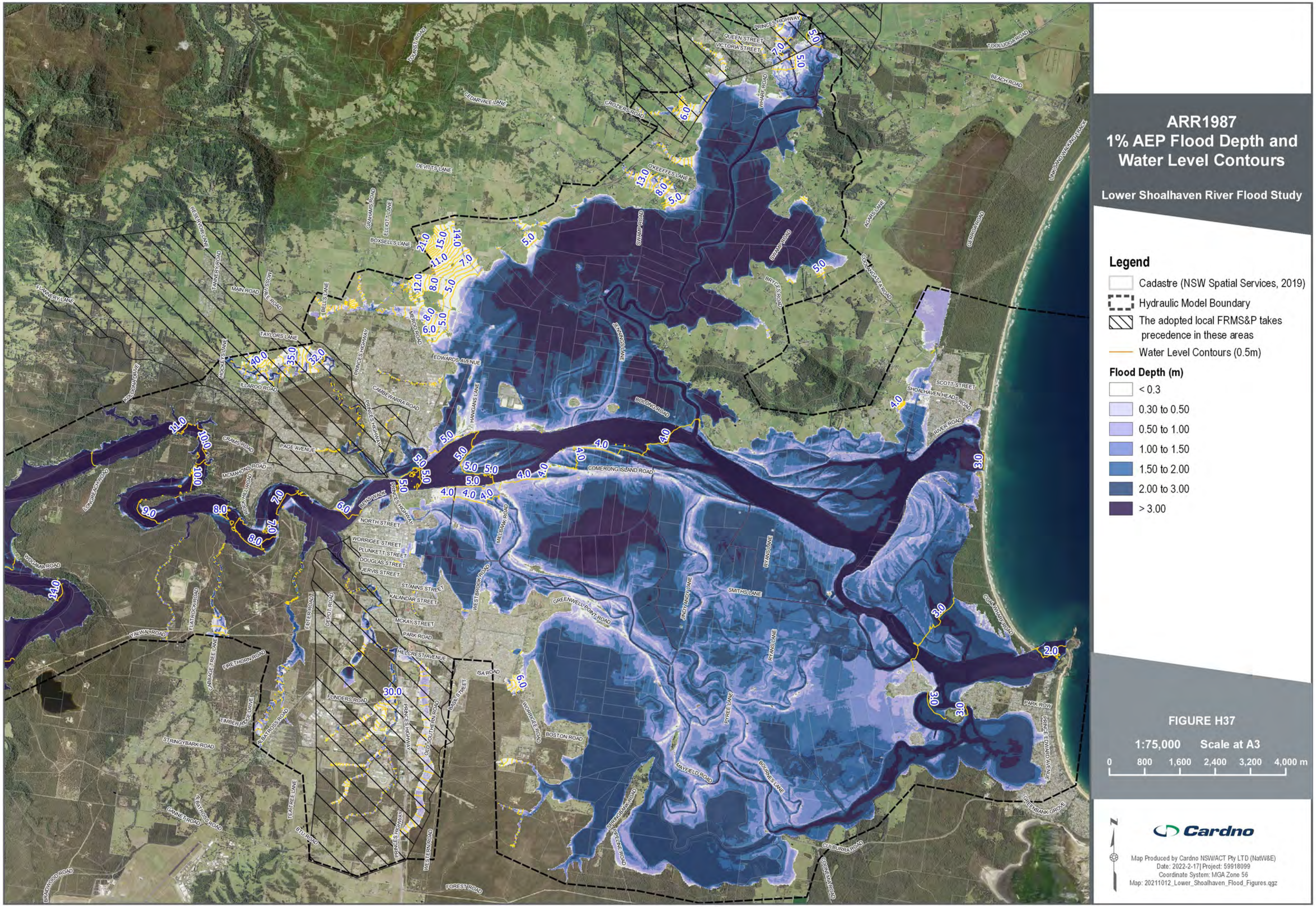
FIGURE H36

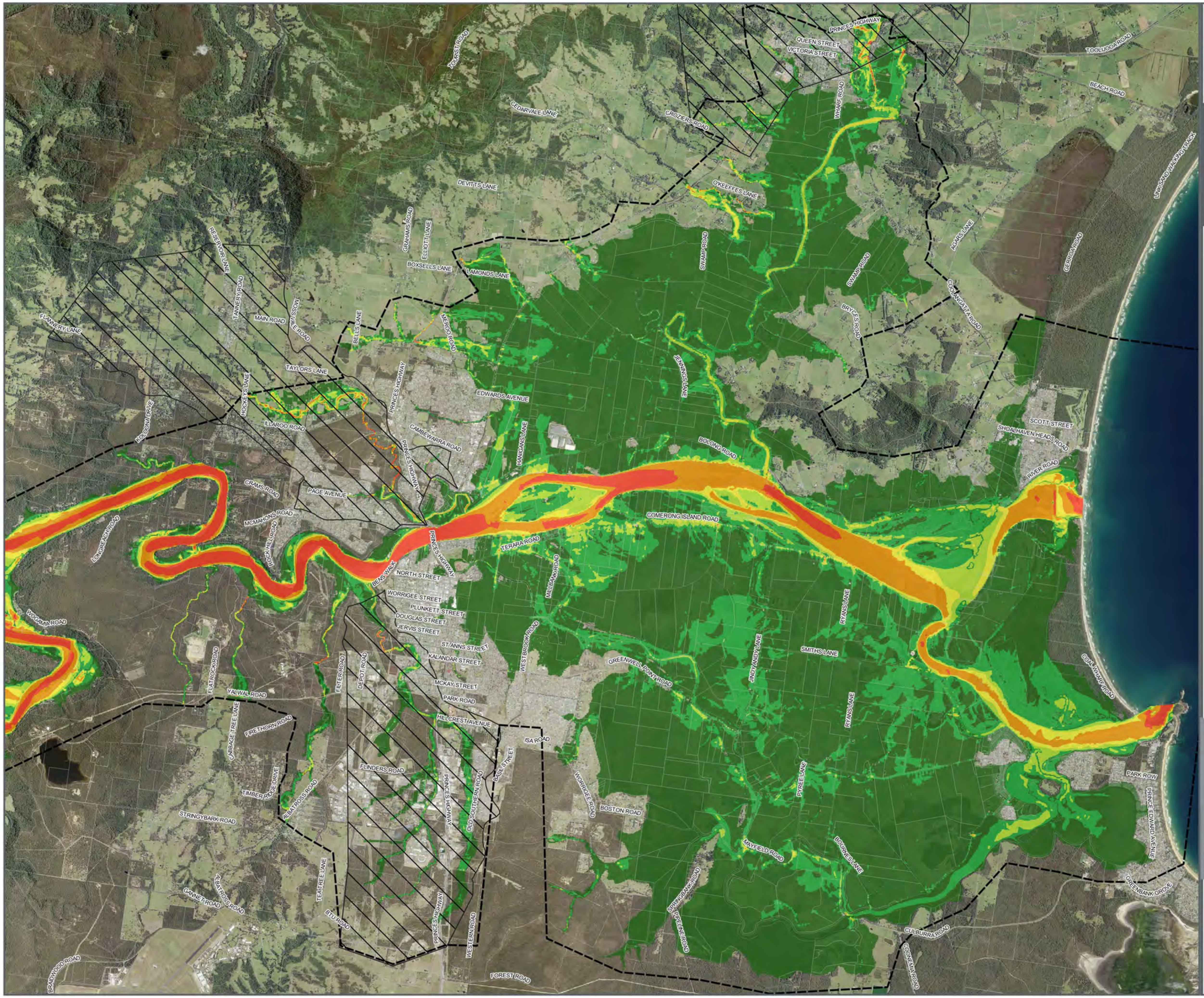
1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz


ARR1987
1% AEP Flood Depth and Water Level Contours
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Water Level Contours (0.5m)
Flood Depth (m)
< 0.3
0.30 to 0.50
0.50 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 3.00
> 3.00
FIGURE H37
1:75,000
Scale at A3
0
800
1,600
2,400
3,200
4,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987
1% AEP Velocity

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

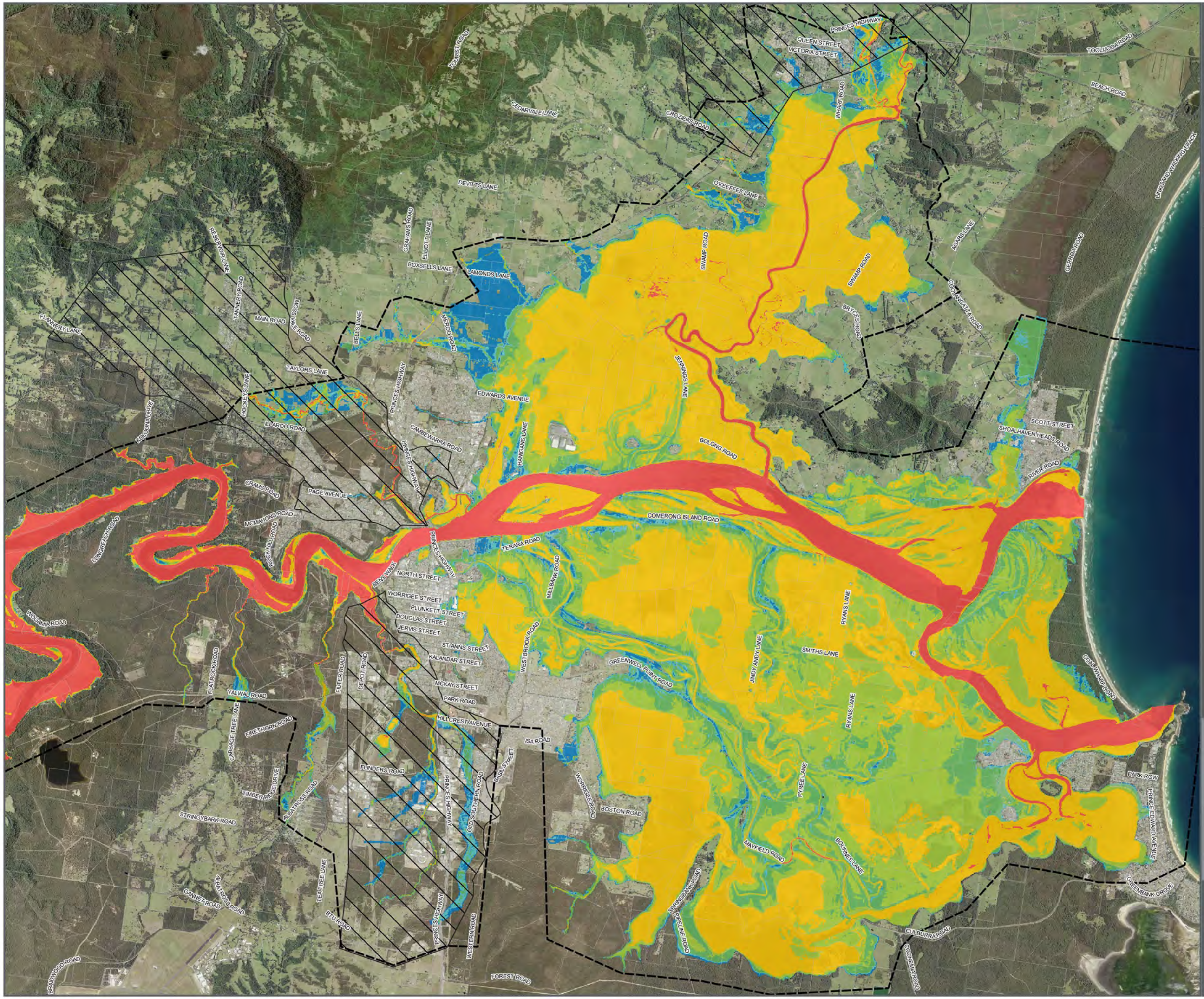
FIGURE H38

1:75,000 **Scale at A3**

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987
1% AEP Hazard

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Hazard (AEMI H1-H6)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles. children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

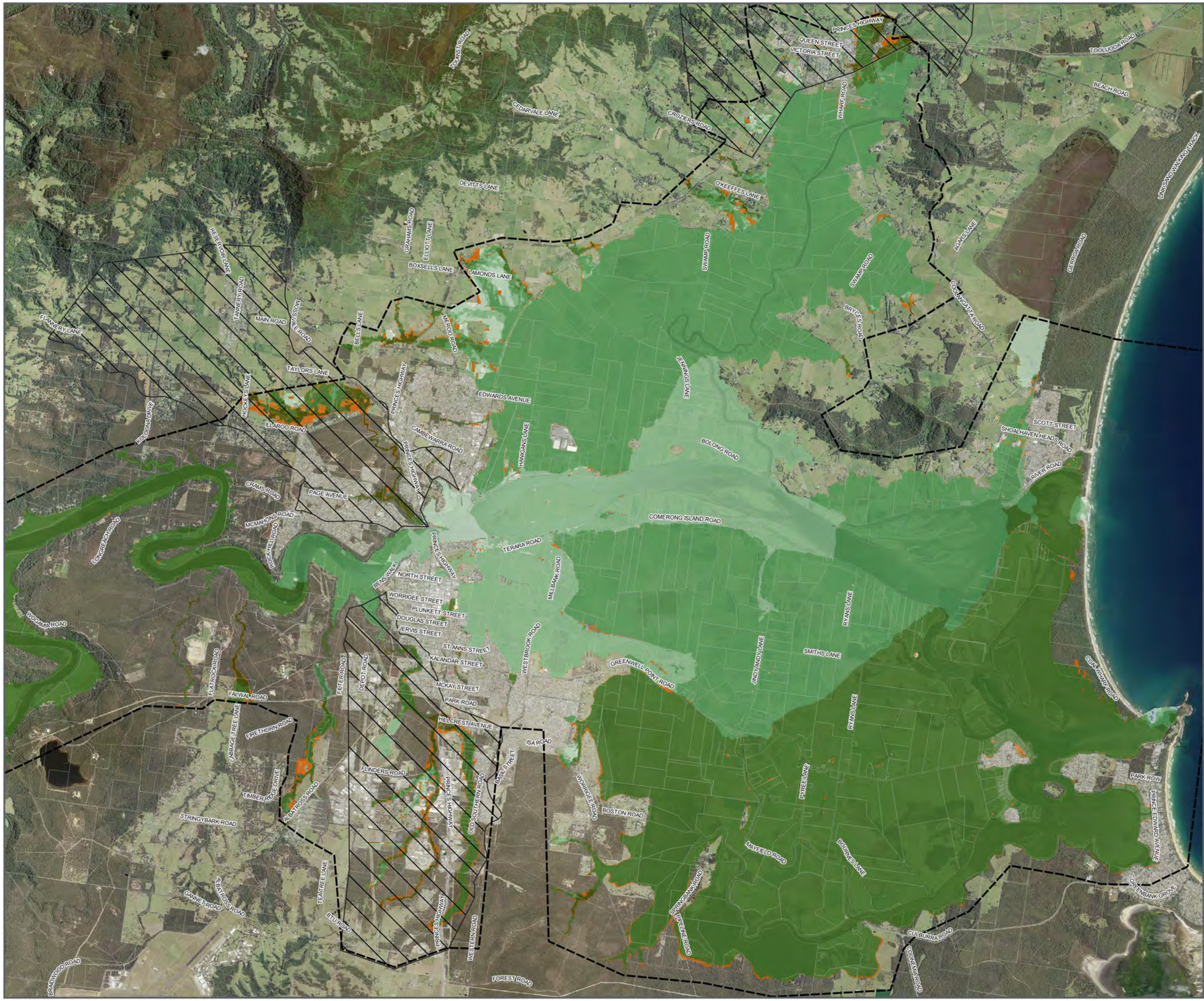
FIGURE H39

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



ARR1987
1% AEP Water Level Difference

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas

Change in Flood Levels (m)

- Was Wet, Now Dry
- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50
- Was Dry, Now Wet

FIGURE H40

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

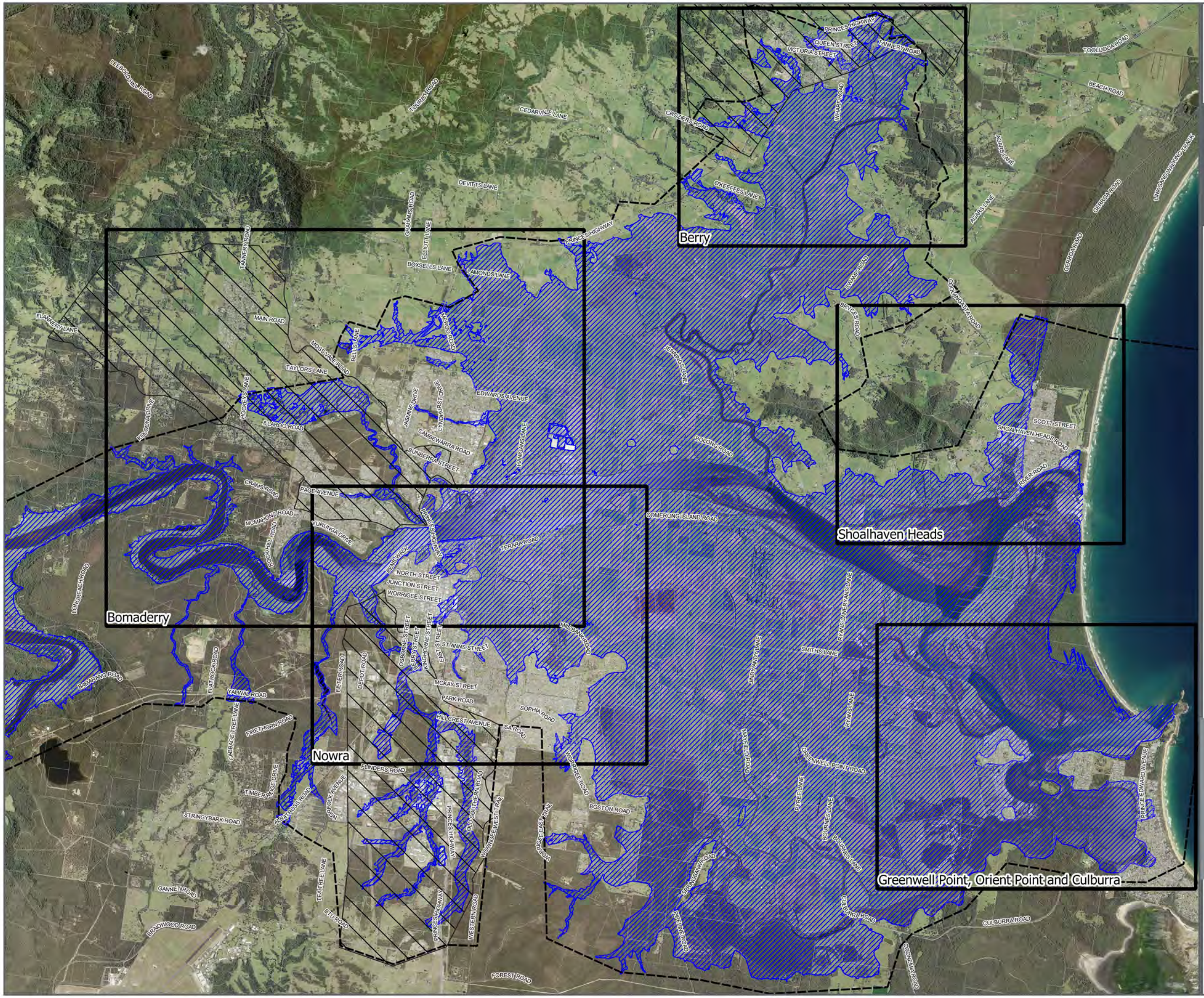
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-2-17| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

APPENDIX

I

FLOOD PLANNING AREA MAPS

Figure List:



Existing Flood Planning Area Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I01

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Existing Flood Planning Area Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

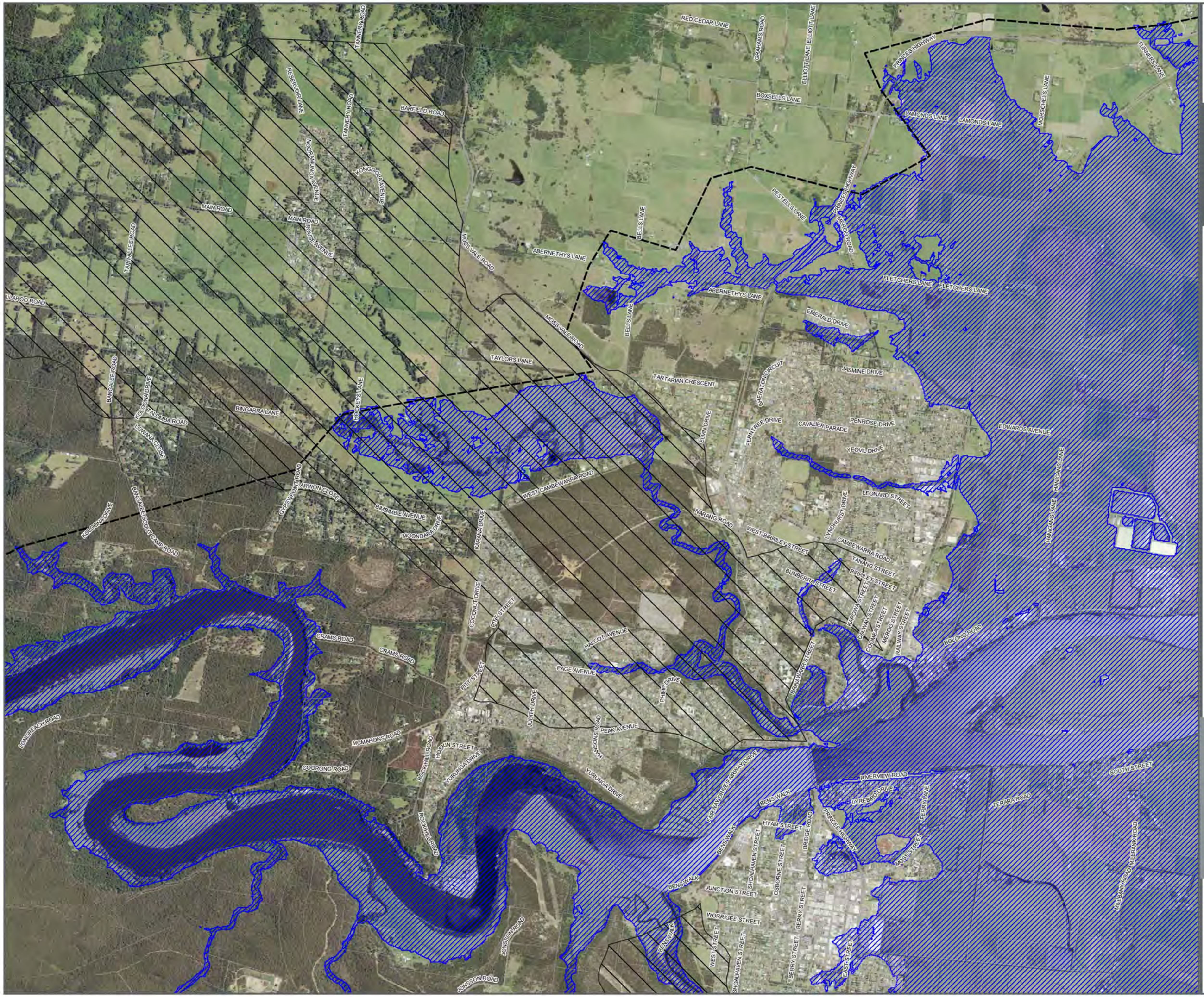
FIGURE I01.1

1:21,000 **Scale at A3**

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing Flood Planning Area Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I01.2

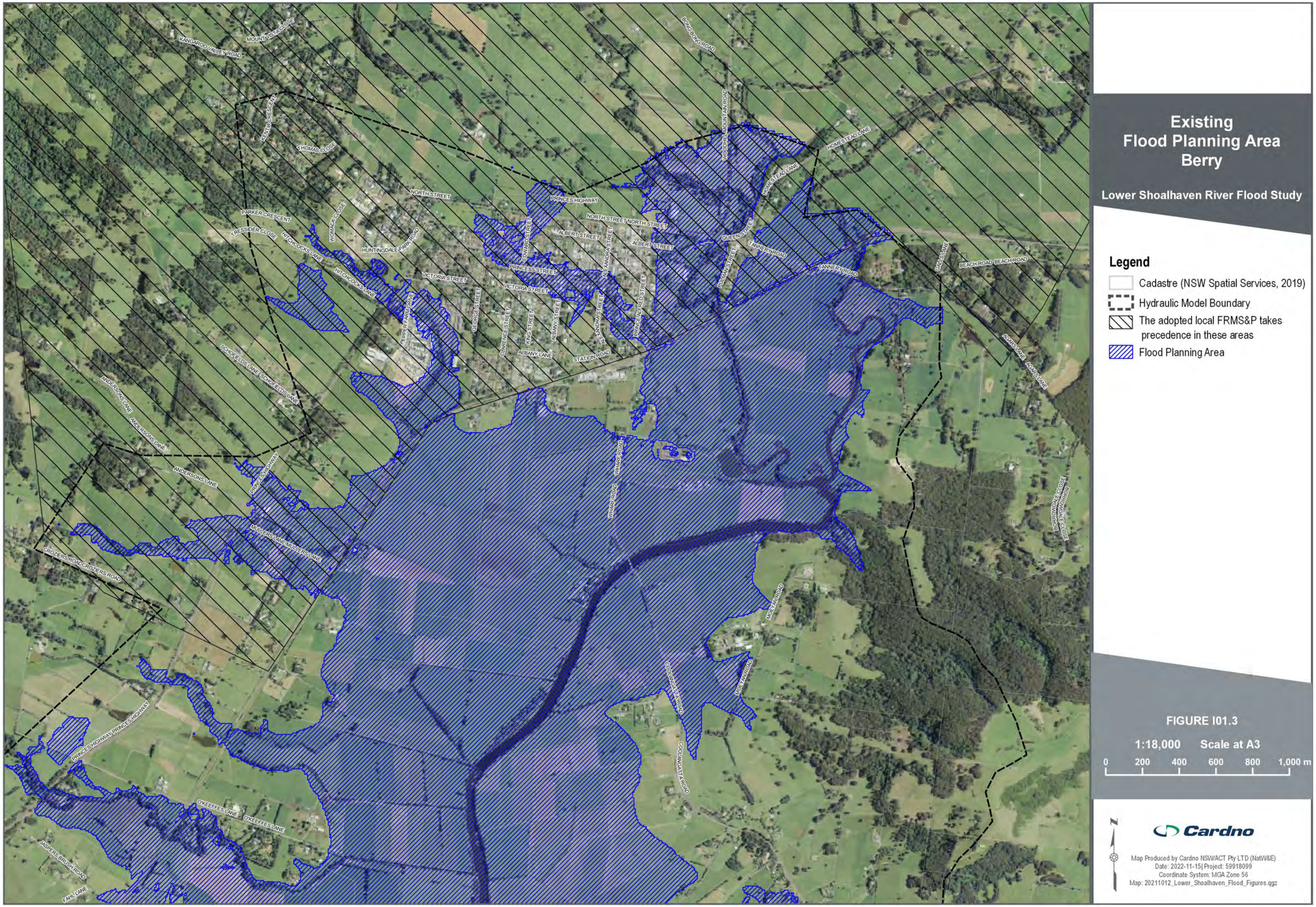
1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Existing
Flood Planning Area
Berry
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Flood Planning Area
FIGURE I01.3
1:18,000 Scale at A3
0 200 400 600 800 1,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz
PRINCES HIGHWAY
NORTH STREET
ALBERT STREET
VICTORIA STREET
PRINCESS STREET
QUEEN STREET
TANNERY ROAD
BEACH ROAD
STATION ROAD
ALBANY LANE
KANGAROO VALLEY ROAD
HOMESTEAD LANE
ANDERSONS LANE
OKEEFFES LANE

Existing Flood Planning Area Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I01.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Existing Flood Planning Area Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I01.5

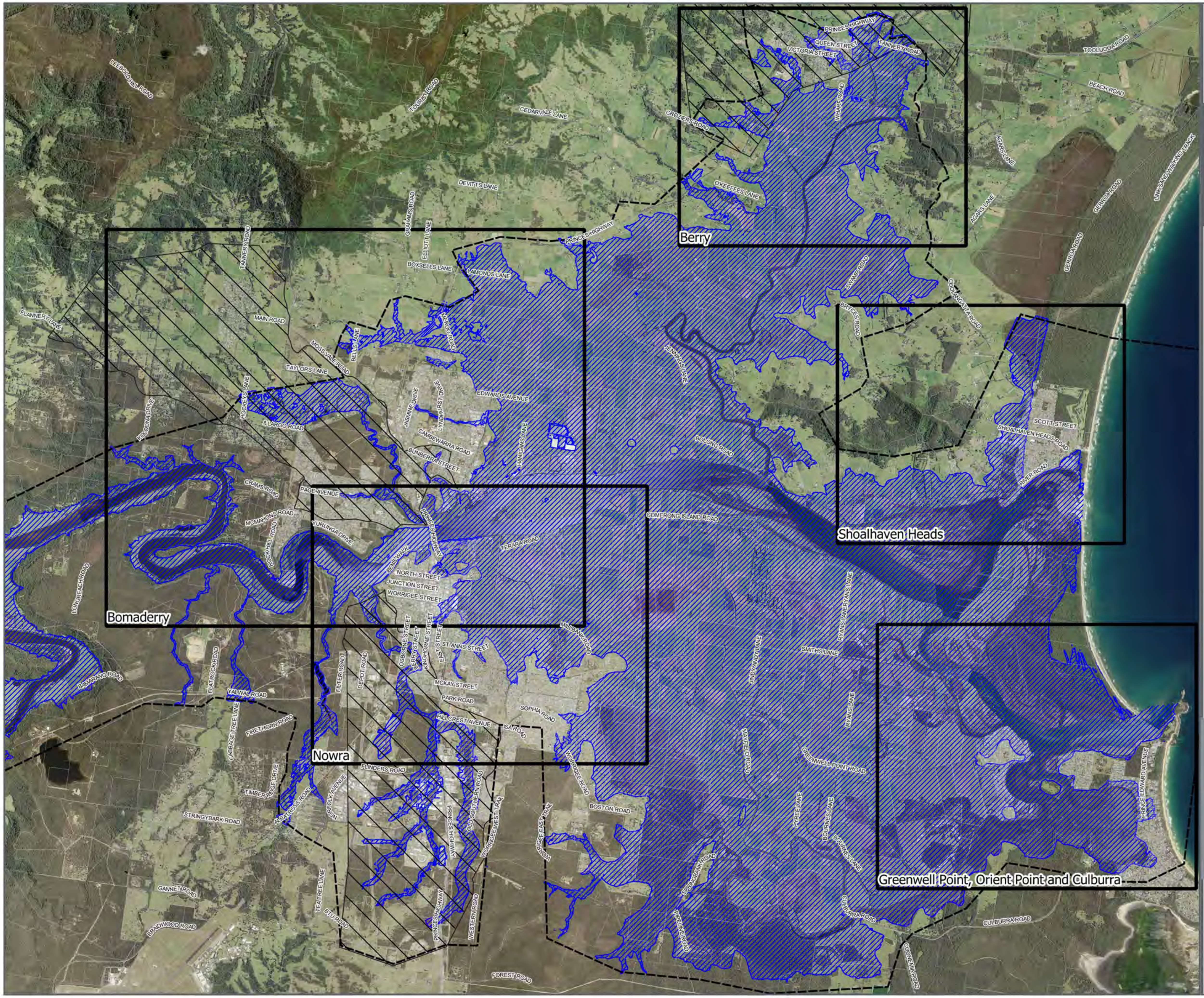
1:20,000 Scale at A3

0 200 400 600 800 1,000 m

N

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 Flood Planning Area Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I02

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15 | Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 Flood Planning Area Nowra

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

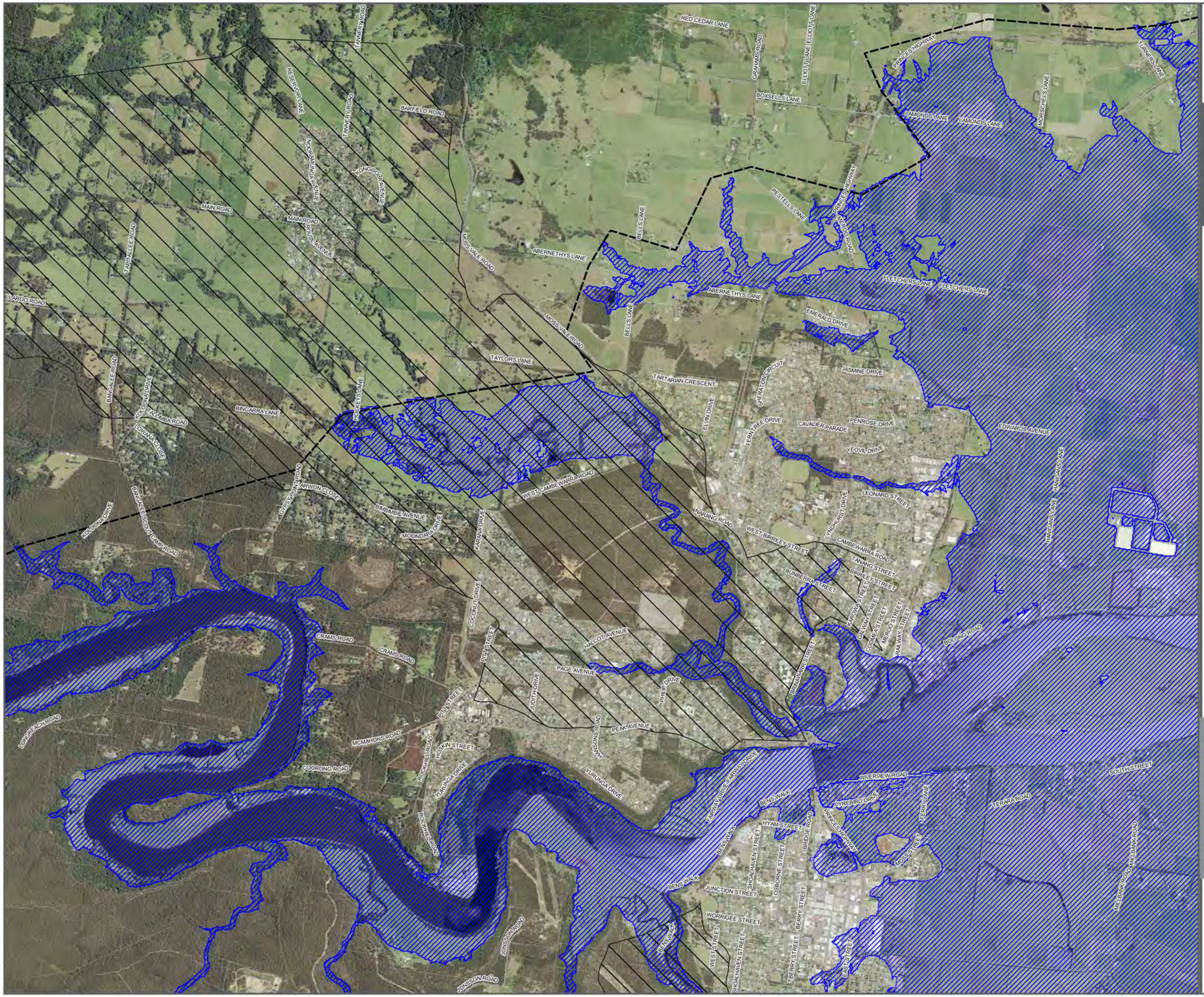
FIGURE I02.1

1:21,000 **Scale at A3**

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 Flood Planning Area Bomaderry

Lower Shoalhaven River Flood Study

Legend

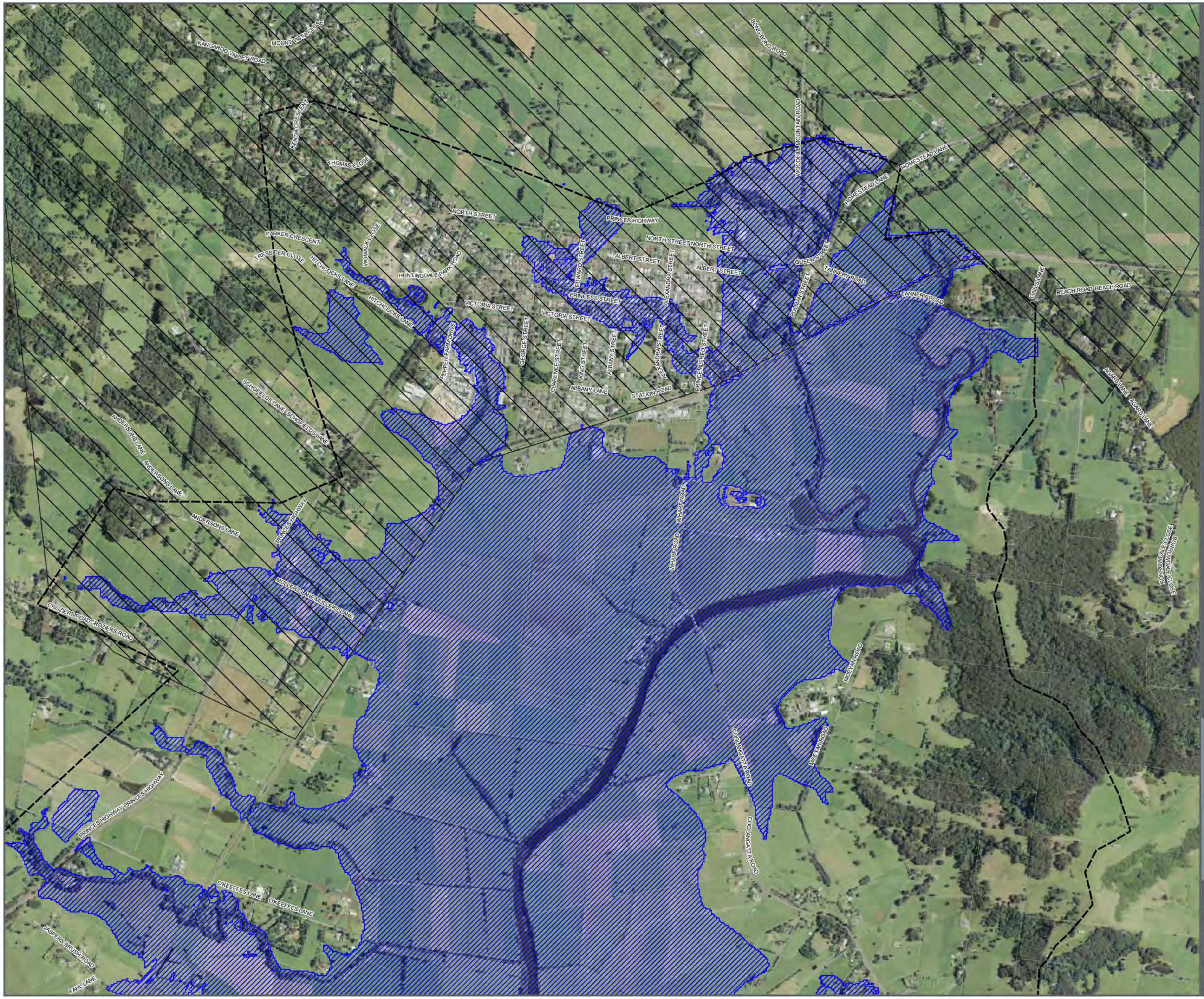
- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I02.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2050 Flood Planning Area Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I02.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

N

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 Flood Planning Area Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I02.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2050 Flood Planning Area Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

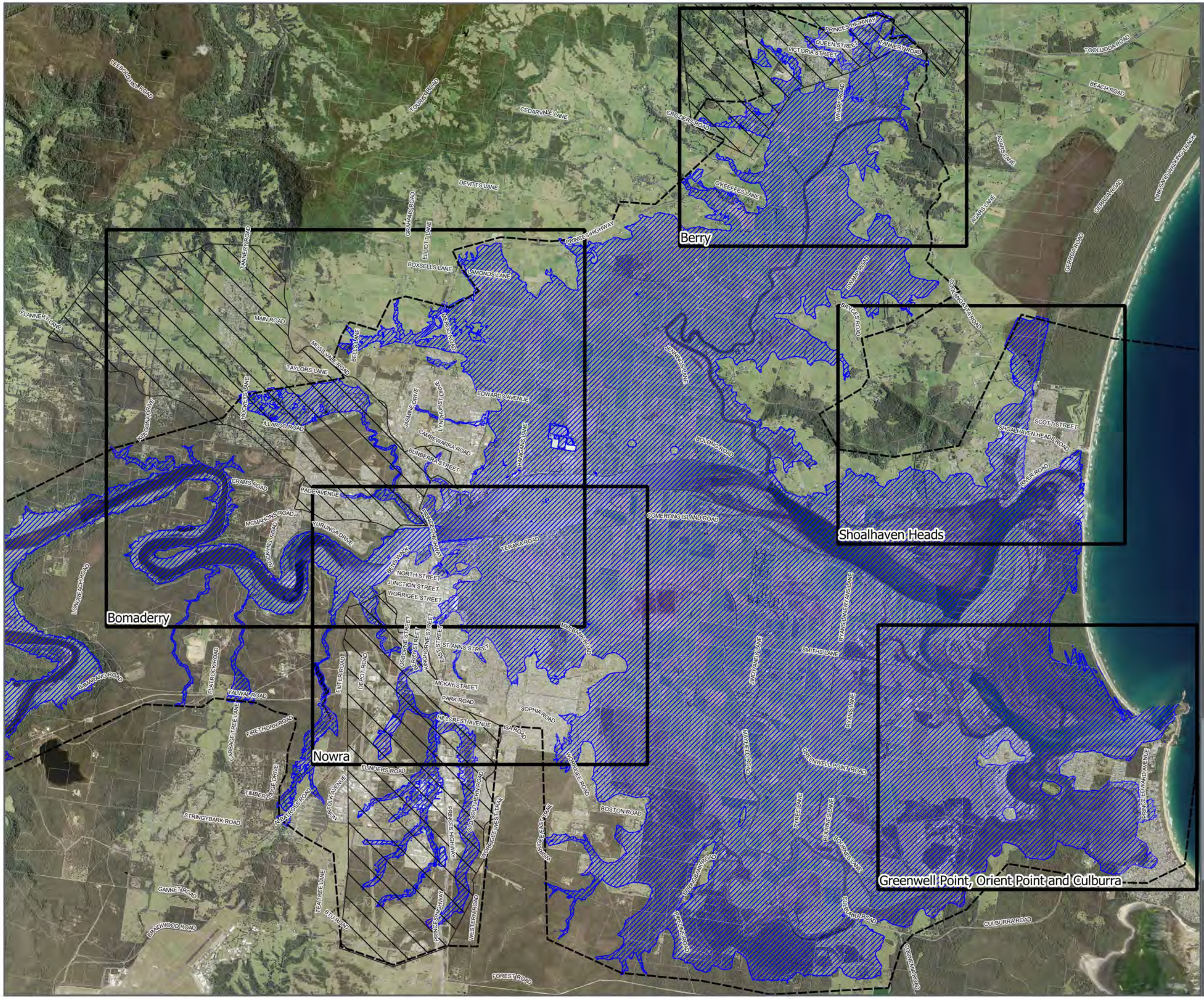
FIGURE I02.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 Flood Planning Area Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I03

1:75,000 Scale at A3

0 800 1,600 2,400 3,200 4,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 Flood Planning Area Nowra

Lower Shoalhaven River Flood Study

Legend

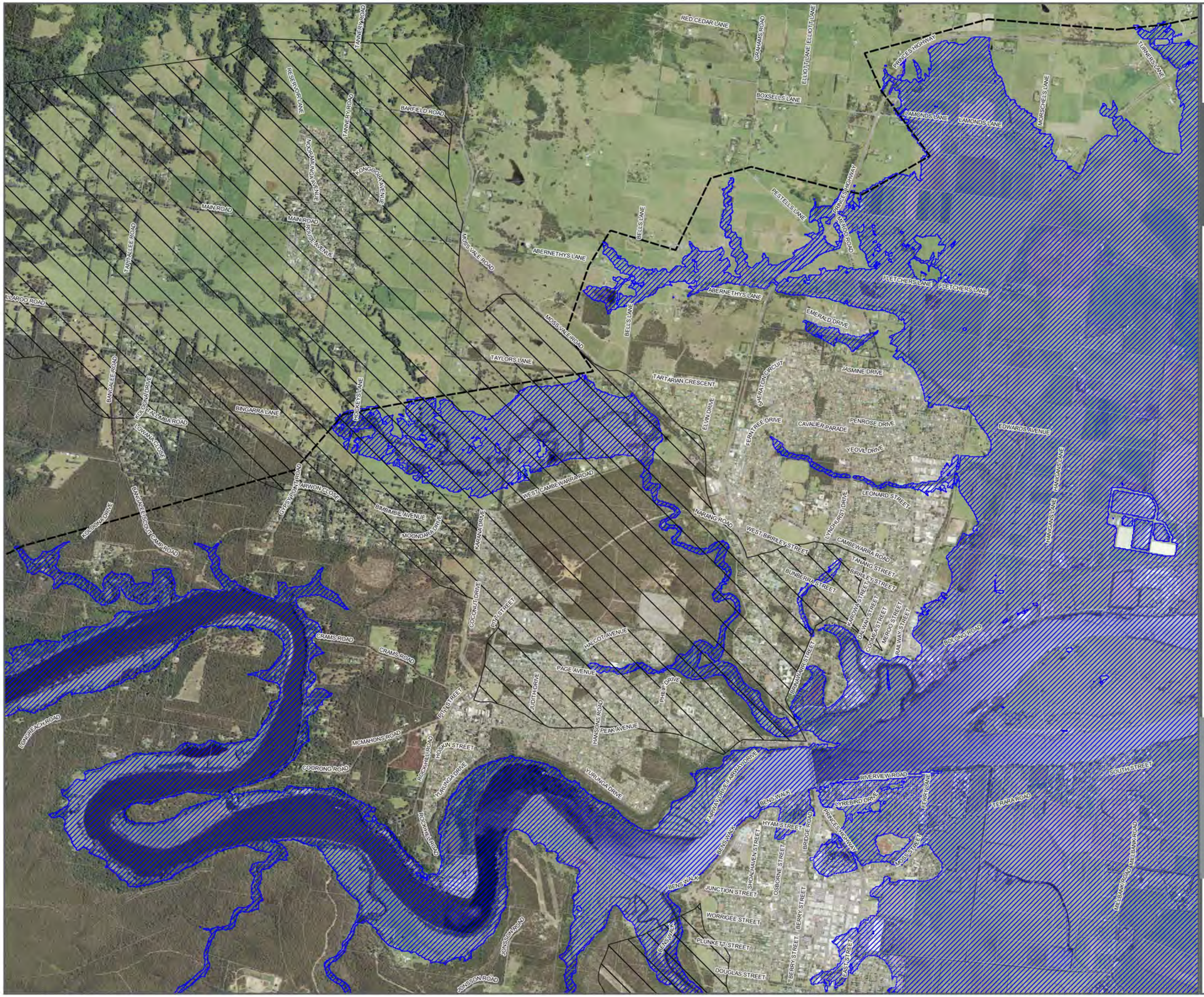
- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I03.1

1:21,000 Scale at A3

0 200 400 600 800 1,000 m

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 Flood Planning Area Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

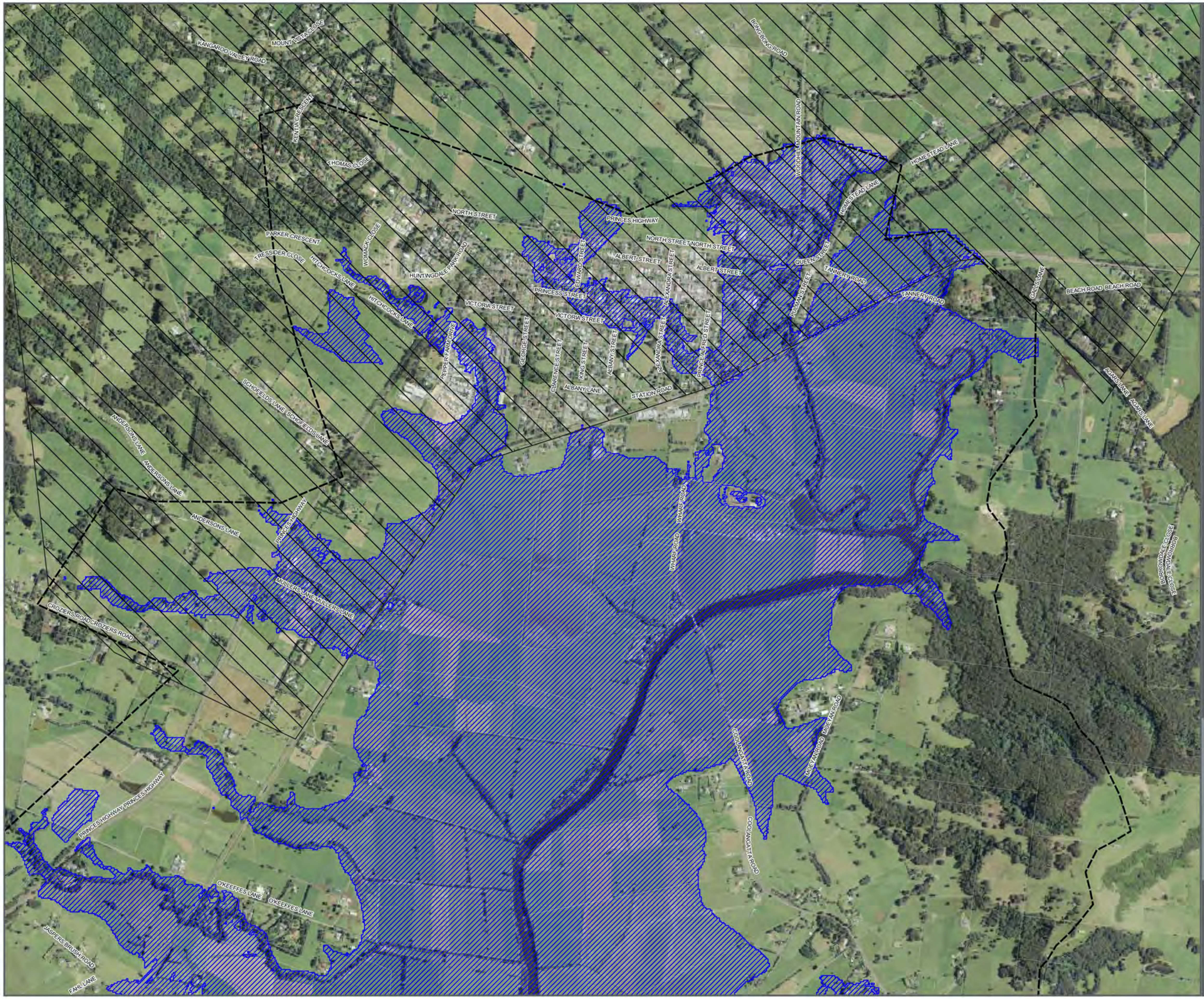
FIGURE I03.2

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz



Projected 2100 Flood Planning Area Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I03.3

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 Flood Planning Area Shoalhaven Heads

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I03.4

1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

Projected 2100 Flood Planning Area Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Flood Planning Area

FIGURE I03.5

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

N

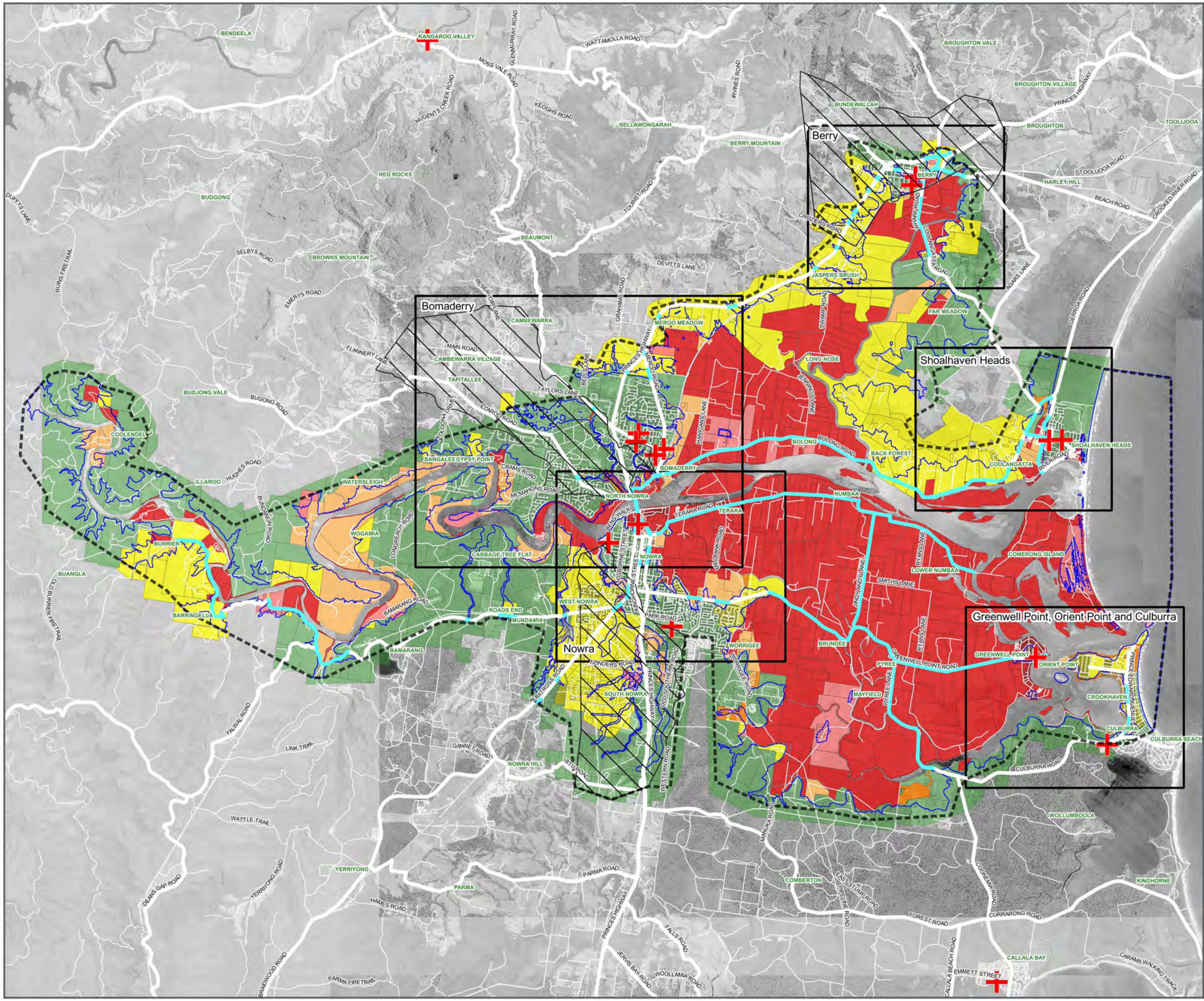
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: 20211012_Lower_Shoalhaven_Flood_Figures.qgz

APPENDIX

J

FLOOD EMERGENCY RESPONSE CLASSIFICATION MAPS

Figure List:



Flood Emergency Response Classification Overview

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Local Road
- Not Flooded Evacuation Route
- Flooded Evacuation Route
- Shoalhaven Evacuation Centres
- Existing PMF Extents

Flood Emergency Response Classification

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts

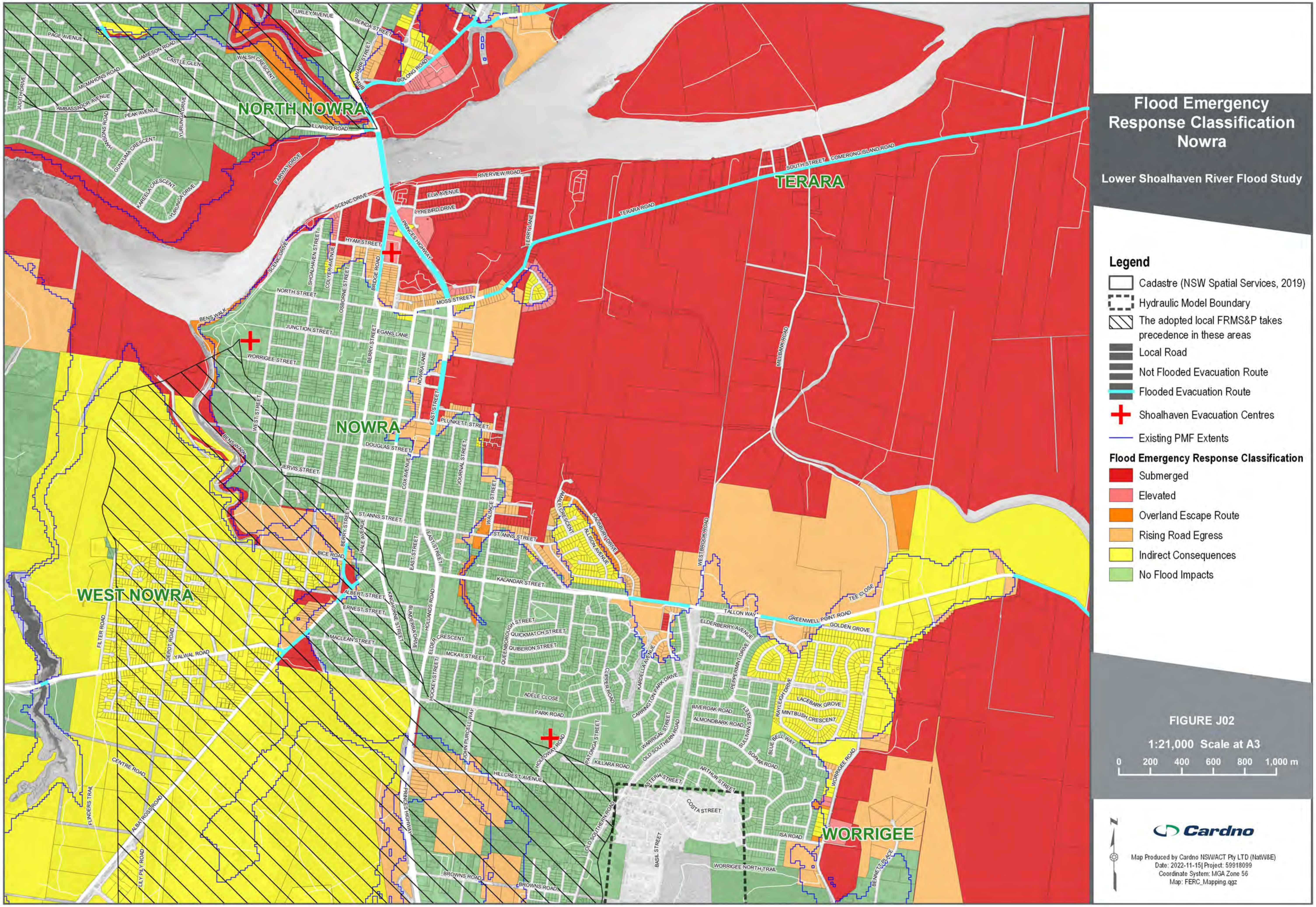
FIGURE J01

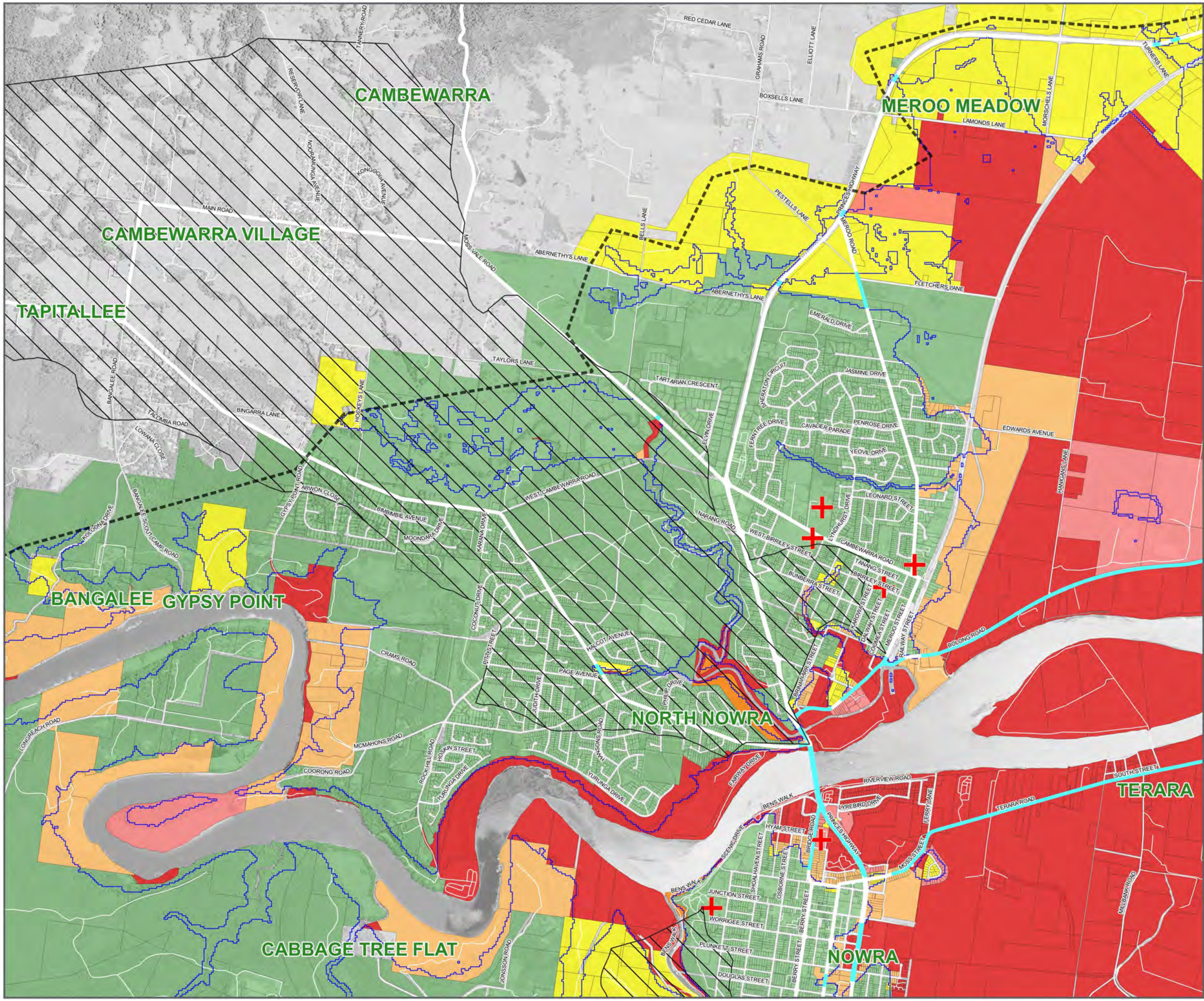
1:110,000 Scale at A3

0 1,000 2,000 3,000 4,000 5,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: FERC_Mapping.qgz


Flood Emergency Response Classification Nowra
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Local Road
Not Flooded Evacuation Route
Flooded Evacuation Route
Shoalhaven Evacuation Centres
Existing PMF Extents
Flood Emergency Response Classification
Submerged
Elevated
Overland Escape Route
Rising Road Egress
Indirect Consequences
No Flood Impacts
FIGURE J02
1:21,000 Scale at A3
0 200 400 600 800 1,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: FERC_Mapping.qgz
NORTH NOWRA
TERARA
NOWRA
WEST NOWRA
WORRIGEE
TERARA ROAD
COMERONG ISLAND ROAD
PRINCES HIGHWAY
GREENWELL POINT ROAD
YALWAL ROAD
OLD SOUTHERN ROAD
WORRIGEE ROAD
BTU ROAD
ALBATROSS ROAD



Flood Emergency Response Classification Bomaderry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Local Road
- Not Flooded Evacuation Route
- Flooded Evacuation Route
- Shoalhaven Evacuation Centres
- Existing PMF Extents

Flood Emergency Response Classification

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts

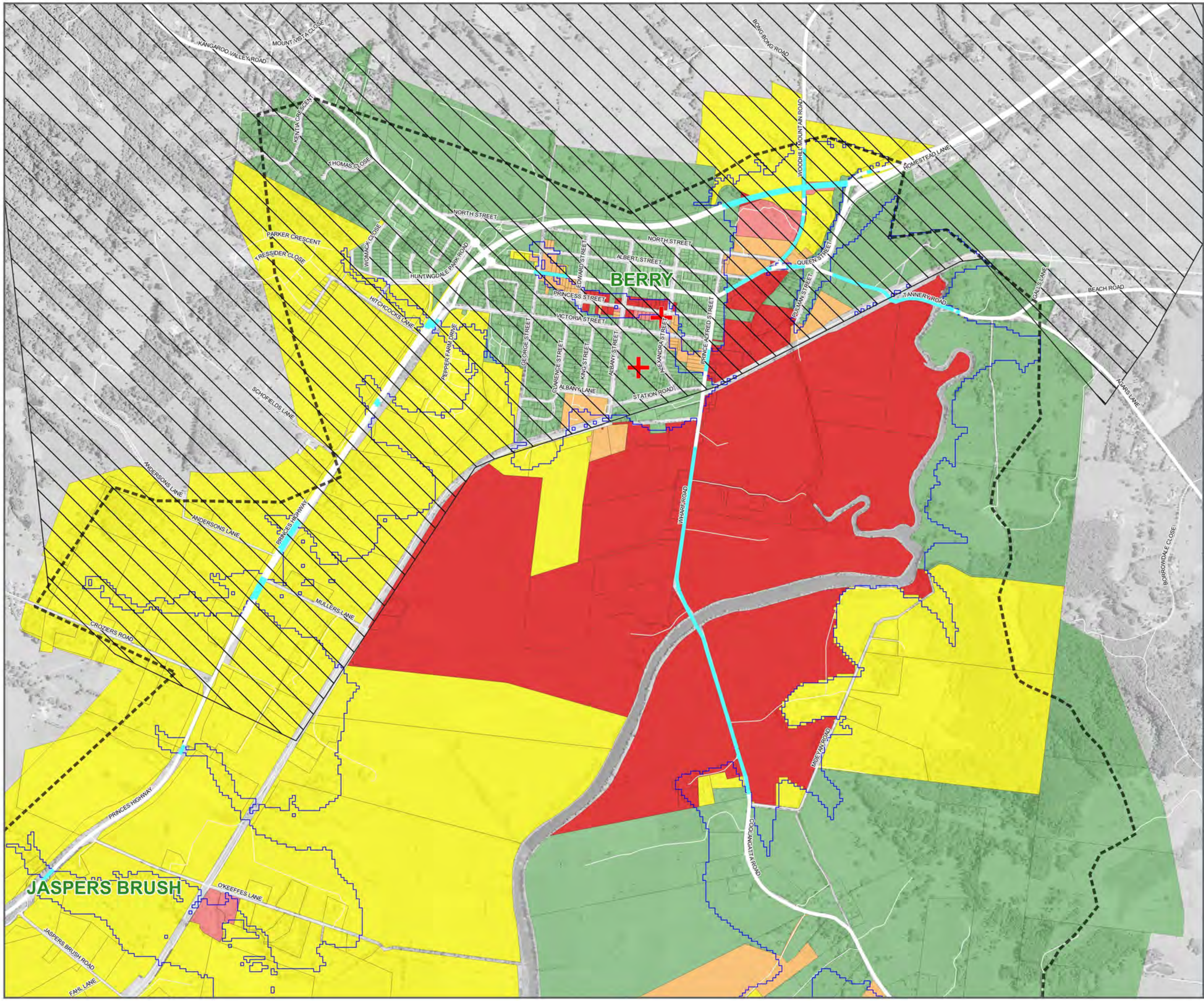
FIGURE J03

1:30,000 Scale at A3

0 300 600 900 1,200 1,500 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: FERC_Mapping.qgz



Flood Emergency Response Classification Berry

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Local Road
- Not Flooded Evacuation Route
- Flooded Evacuation Route
- Shoalhaven Evacuation Centres
- Existing PMF Extents

Flood Emergency Response Classification

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts

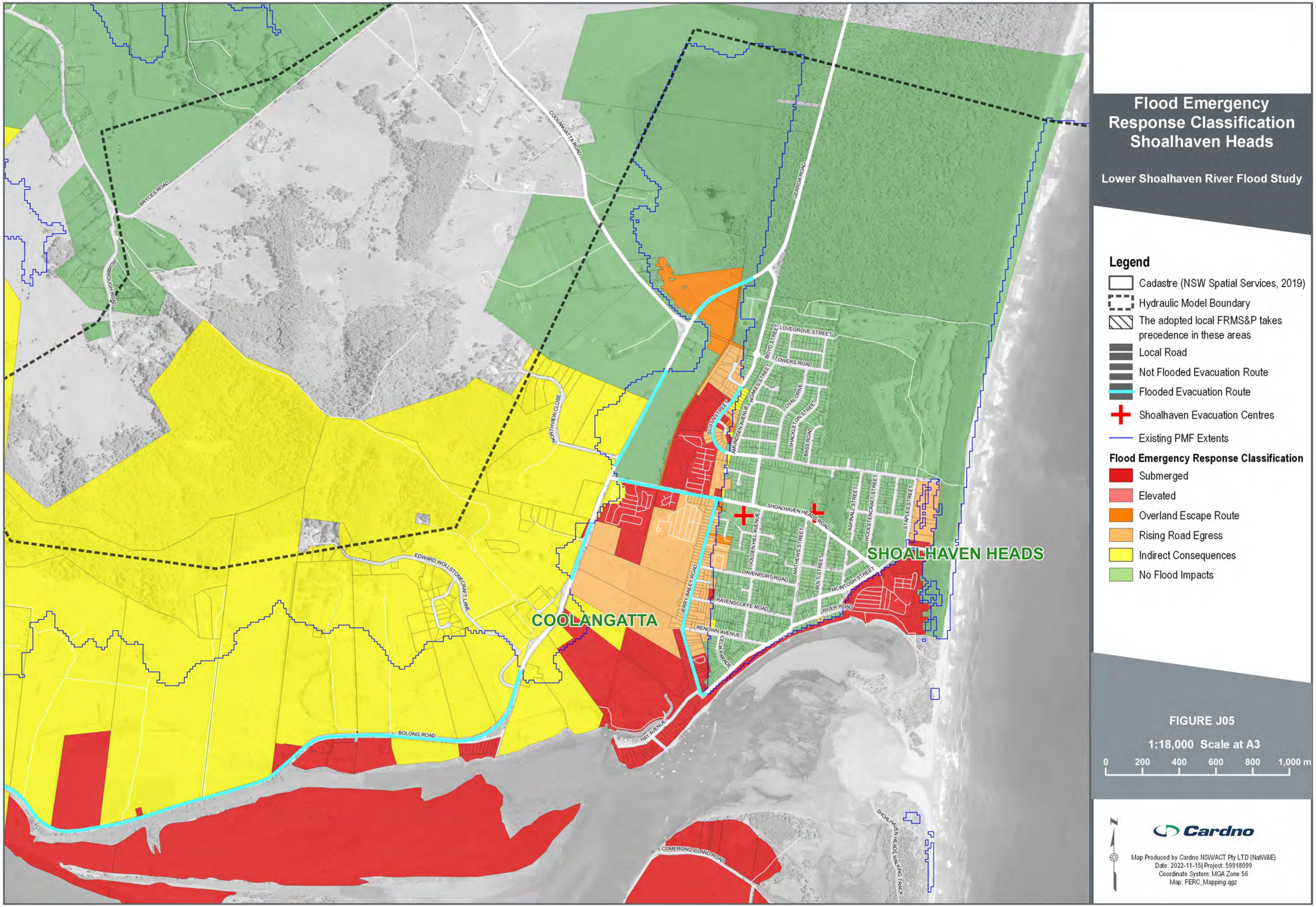
FIGURE J04

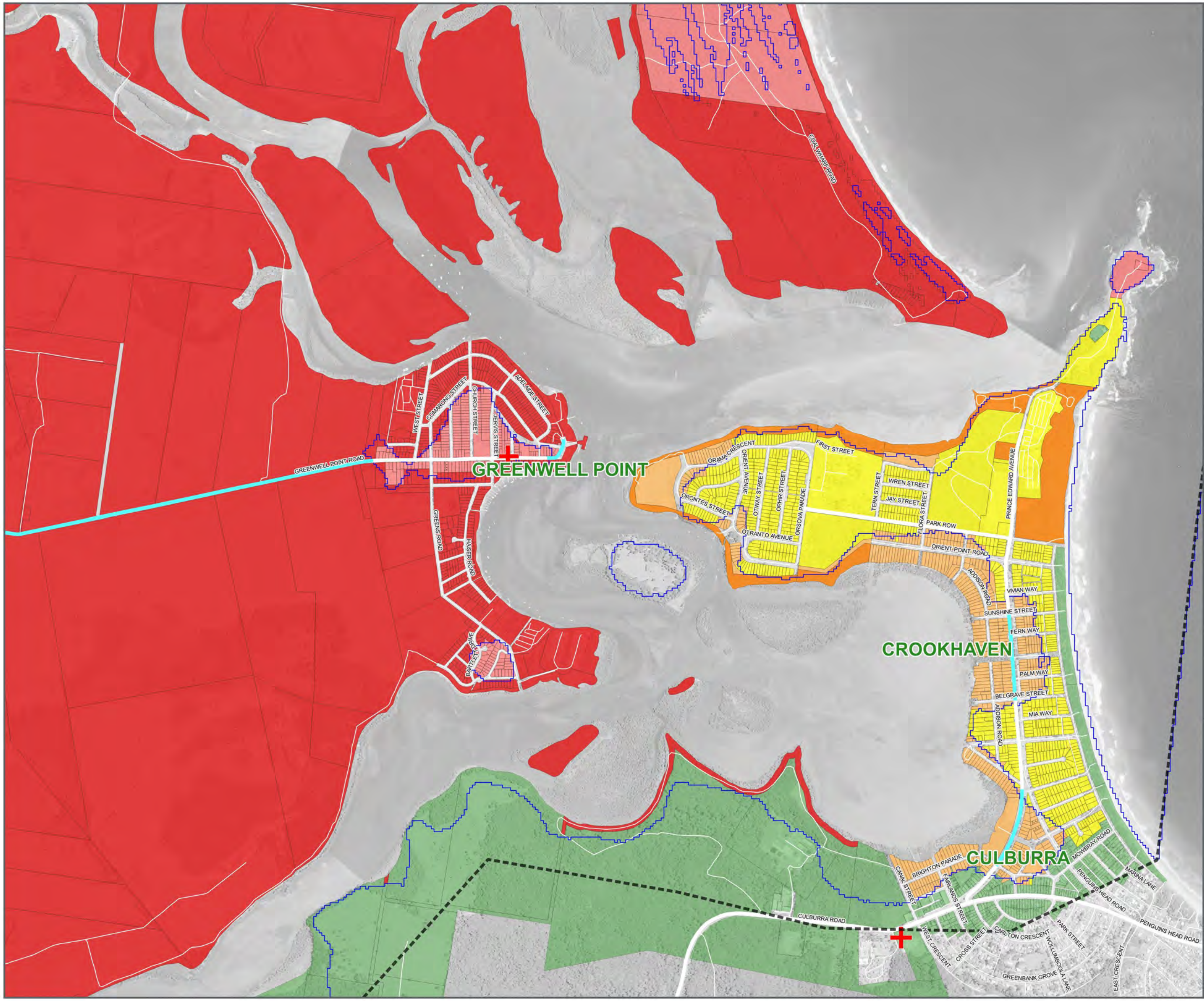
1:18,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: FERC_Mapping.qgz


Flood Emergency Response Classification Shoalhaven Heads
Lower Shoalhaven River Flood Study
Legend
Cadastre (NSW Spatial Services, 2019)
Hydraulic Model Boundary
The adopted local FRMS&P takes precedence in these areas
Local Road
Not Flooded Evacuation Route
Flooded Evacuation Route
Shoalhaven Evacuation Centres
Existing PMF Extents
Flood Emergency Response Classification
Submerged
Elevated
Overland Escape Route
Rising Road Egress
Indirect Consequences
No Flood Impacts
SHOALHAVEN HEADS
COOLANGATTA
COOLANGATTA ROAD
GERROA ROAD
BRYCES ROAD
BOLONG ROAD
HAY AVENUE
COMERONG ISLAND ROAD
SHOALHAVEN HEADS ROAD
EDWARD WOLLSTONECRAFT LANE
NORTHVIEW CLOSE
JERRY BAILEY ROAD
RENOWN AVENUE
CELIA PARADE
RAVENSCLIFFE ROAD
DAVENPORT ROAD
RIVER ROAD
MCINTOSH STREET
LOVEGROVE STREET
TOWERS ROAD
BOYD STREET
SCOTT STREET
AMUNDSEN AVENUE
OVAL DRIVE
SHACKLETON STREET
BASS ROAD
GOLDEN HILL AVENUE
MATHEWS STREET
BOLT STREET
ASPINALL STREET
WOOLSTENCRAFT STREET
STAPLES STREET
SHOALHAVEN HEADS WALKING TRACK
FIGURE J05
1:18,000 Scale at A3
0 200 400 600 800 1,000 m
Cardno
Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: FERC_Mapping.qgz



Flood Emergency Response Classification Greenwell Point, Orient Point and Culburra Beach

Lower Shoalhaven River Flood Study

Legend

- Cadastre (NSW Spatial Services, 2019)
- Hydraulic Model Boundary
- The adopted local FRMS&P takes precedence in these areas
- Local Road
- Not Flooded Evacuation Route
- Flooded Evacuation Route
- Shoalhaven Evacuation Centres
- Existing PMF Extents

Flood Emergency Response Classification

- Submerged
- Elevated
- Overland Escape Route
- Rising Road Egress
- Indirect Consequences
- No Flood Impacts

FIGURE J06

1:20,000 Scale at A3

0 200 400 600 800 1,000 m

Cardno

Map Produced by Cardno NSW/ACT Pty LTD (NatW&E)
Date: 2022-11-15| Project: 59918099
Coordinate System: MGA Zone 56
Map: FERC_Mapping.qgz

APPENDIX

K

ENTRANCE MODELLING TECHNICAL MEMO

1 Introduction

This Study aims to quantify the breach development at Shoalhaven Heads during flood events. This information is required as input into the Tuflow modelling being undertaken to assess the flood levels within the catchment.

2 Numerical Modelling Systems

Tide and storm surge/current investigations undertaken throughout the study area required application of high level model systems capable of simulating a range of processes – wind and pressure fields, tidal forcing and coupled hydrodynamic and wave processes. The models applied were Delft3D and SWAN.

2.1 Delft3D

The Delft3D hydrodynamic modelling system has been utilised in 2D for this investigation. It is a world leading hydrodynamic, sediment transport and water quality modelling system developed by Deltares in The Netherlands. It has been extensively utilised by Cardno at sites around Australia and internationally.

Investigations of water levels, currents, transport-dispersion and turbulent processes require the application of a high level model capable of simulating a range of processes including ocean wave and tidal forcing, with some confidence. Such simulations can be successfully undertaken using the Delft3D modelling system.

This modelling system can include, pressure, tide and wave forcing, three-dimensional currents, stratification, sediment transport and water quality descriptions and is capable of using irregular rectilinear or curvilinear coordinates. Delft3D also possesses the functionality of spatially and temporally variable wind forcing, which was utilised in this study to conduct modelling of cyclone wind fields.

Delft3D is comprised of several modules that provide the facility to undertake a range of studies. All studies generally begin with the Delft3D-FLOW module. From Delft3D-FLOW, details such as velocities, water levels, density, salinity, vertical eddy viscosity and vertical eddy diffusivity can be provided as inputs to the other modules. The wave and sediment transport modules can work interactively with the FLOW module through a common communications file. In the case of wave modelling this ensures physically realistic wave set-up in a 2D plan layout.

The following sections provide a brief introduction to the numerical scheme and application of the Delft3D model system.

2.1.1 Hydrodynamic Numerical Scheme

Delft3D can be set up using rectilinear or curvilinear grids, both with spatially varying grid sizes. This is especially important in complex waterways where the shoreline is not 'straight' and also where regional wave set-up is important.

The Delft3D FLOW module is based on the robust numerical finite-difference scheme developed by G. S. Stelling of the Delft Technical University in The Netherlands. Since its inception, the Stelling Scheme has undergone considerable development and review by Stelling and others.

This scheme arranges modelled variables on a horizontal, staggered Arakawa C-grid. The water level points (pressure points) are designated in the centre of a continuity cell and the velocity components are perpendicular to the grid cell faces. Finite difference staggered grids have several advantages including: -

> Boundary conditions can be implemented in the scheme in a rather simple way;
> It is possible to use a smaller number of discrete state variables in comparison with discretisations on non-staggered grids to obtain the same accuracy; and
> Staggered grids minimise spatial oscillations in the water levels.

Delft3D can be operated in 2D (vertically averaged) or 3D mode. In 3D mode, the model uses the σ-coordinate system first introduced by N Phillips in 1957 for atmospheric models. The σ-coordinate system is a variable layer-thickness modelling system, meaning that over the entire computational area, irrespective of the local water depth, the number of layers is constant. As a result, a smooth representation of the bathymetry is obtained. Also, as opposed to fixed vertical grid size 3D models, the full definition of the 3D layering system is maintained into the shallow waters and until the computational point is dried. 2D modelling was adopted for this investigation because it has been found in previous storm tide investigations that there is no significant difference in water levels computed by 2D and 3D models and the tidally and wind driven flows on the reef shelf relatively shallow.

Horizontal solution is undertaken using the Alternating Direction Implicit (ADI) method of Leendertse for shallow water equations. In the vertical direction (in 3D mode) a fully implicit time integration method is also applied.

2.1.2 Wetting and Drying of Intertidal Flats

Many near shore areas include shallow inter-tidal regions; consequently Delft3D includes a robust and efficient wetting and drying algorithm to handle this process. In combination with the flooding scheme for advection in the momentum equation, the algorithm is also effective and accurate for rapidly varying flows with large water level gradients because of the presence of hydraulic jumps or the occurrence of bores as a result of dam breaks.

2.1.3 Conservation of Mass

Problems with conservation of mass, such as a ‘leaking mesh’, do not occur within the Delft3D system. However, whilst the Delft3D scheme is unconditionally stable, inexperienced use of Delft3D, as with most modelling packages, can result in potential mass imbalances.

Potential causes of mass imbalance and other inaccuracies include: -

- Inappropriately large setting of the wet/dry algorithm parameters and coarse inter-tidal grid definition;
- Inappropriate bathymetric and boundary definition causing steep gradients; and
- Inappropriate time-step selection (that is, lack of observation of the scheme’s allowable Courant Number condition) for simulation.

2.1.4 Domain Decomposition

Delft3D provides the facility to adopt a modelling approach known as ‘domain decomposition’. Domain decomposition is a technique in which a model is divided into several smaller model domains that are dynamically coupled. The subdivision is based on the horizontal and vertical model resolution required for adequately simulating physical processes. Computations can be carried out separately, yet concurrently, on these domains. The communication between the domains takes place along internal boundaries. Computations are carried out concurrently, via parallel computing, thus reducing the turn-around time of multiple domain simulations. Domain decomposition allows for local grid refinement, both in the horizontal direction and in the vertical direction in 3D models. Grid refinement in the horizontal direction means that in one domain smaller mesh sizes (fine grid) are used than in other domains (coarser grids). In the case of vertical grid refinement one domain, for example, may use ten vertical layers whereas another domain uses five layers, or a single layer (depth-averaged).

Domain decomposition is widely recognised as an efficient and flexible tool for the simulation of complex physical processes. The structured multi-domain approach combines the advantages of the modelling flexibility of the single-domain unstructured approach with the efficiency and accuracy of the single-domain structured approach.

2.2 SWAN Wave Modelling System

The wave model Cardno applied in this study is based on the third generation wind/wave modelling system, SWAN, which is incorporated as a module into the Delft3D modelling system. This model was developed at the Delft Technical University and includes wind input (local sea and developing storm cases), combined sea and swell, offshore wave parameters (swell cases), refraction, shoaling, non-linear wave-wave interaction, a full directional spectral description of wave propagation, bed friction, white capping, currents and wave breaking. SWAN also includes phase-averaged diffraction based on the model of Holthuijsen et al.

SWAN includes a nested grid capability that allows coarser grids in deeper water and finer grids in shallow water where better definition of seabed form and depth are needed and may use the same or different grids from those used in the hydrodynamic modelling. Output from the model includes significant wave height, dominant wave direction, spectral peak and mean periods and (optionally) the full directional wave spectra. It can be coupled with Delft3D to include the inter-action between waves and tidal/wind driven flows.

3 Model Setup

Data sources and adopted values for the purpose of Morphological Modelling are discussed in subsequent sub-sections.

3.1 Bathymetric and Topographic Data

Bathymetric and topographic data used for this study were derived from the following data sources:

> 1m DEM from the Elvis Baseline Data, primarily derived from the 2018 OEH NSW Marine Lidar dataset;

> Survey data of Shoalhaven Heads (closed configuration), provided to Cardno

- Filename: Grid_Bathymetry_RiverMouth.asc

> Bathymetry of the river, heads, and ocean extracted from the Tuflow model;

- Filename: Grid_Bathymetry_RiverAndStreams.asc

> Shorelines digitised from Google Earth.

A composite topographic and bathymetric dataset was generated from the above data, and is shown below in **Figure 3-1**.

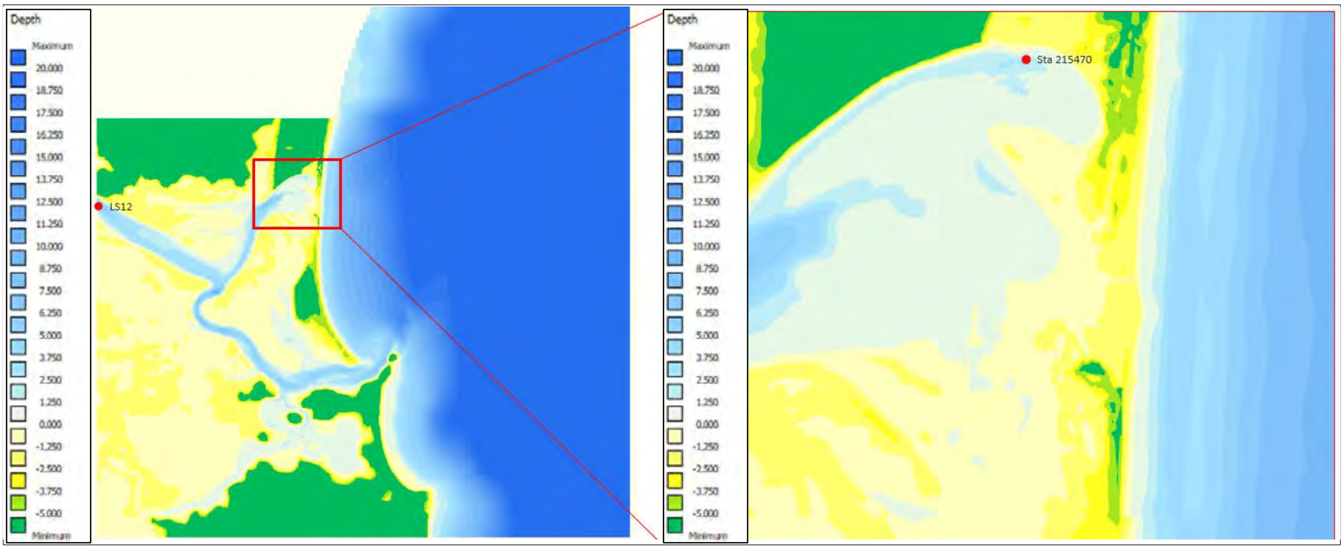


Figure 3-1 Composite Topography and Bathymetry of Shoalhaven Adopted for this Scenario Study

As per the Shoalhaven Heads Entrance Management Plan, a 4 metre wide and 1m deep pilot channel (notch) with a bed level of **1mAHD** has been incorporated in the topography at Shoalhaven Heads. This notch can be seen in **Figure 3-2** and has been put into the model to represent the mechanical entrance breakout undertaken by Shoalhaven Council during flood events.

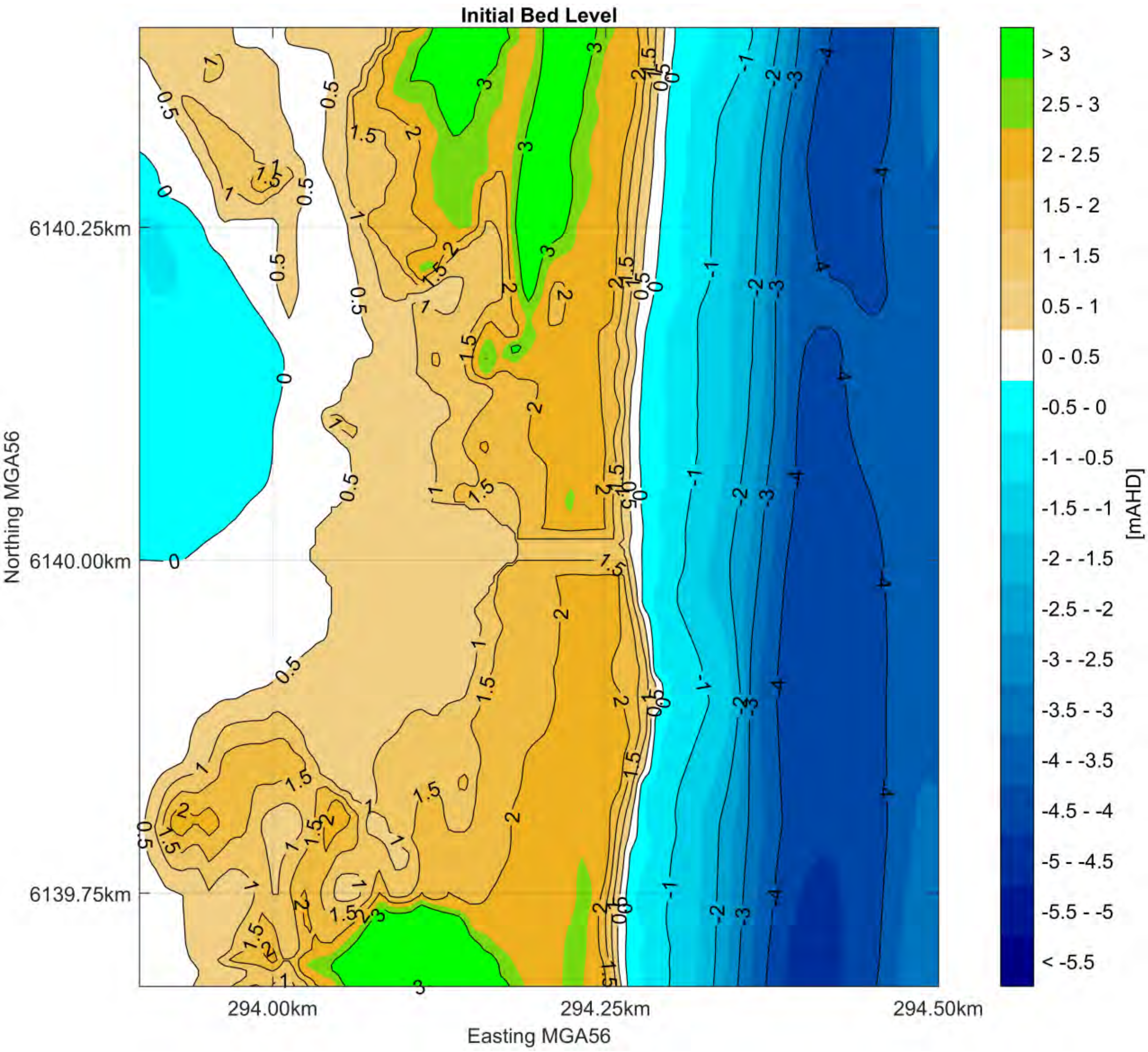


Figure 3-2 Shoalhaven Heads Pre-breach Topography/Bathymetry

3.2 Model Grid

This model utilises domain decomposition to provide high resolution around the entrance area and lower resolution elsewhere. The following grid configuration was applied:

> Coarse Grid (100m resolution) – covers some 8km inland and of 8km open sea;

> Medium Grid (20m resolution) – covers Shoalhaven River mouth area; and

> Fine Grid (5m resolution) – covers the Shoalhaven Heads.

Figure 3-3 describes the model grids and their extent.

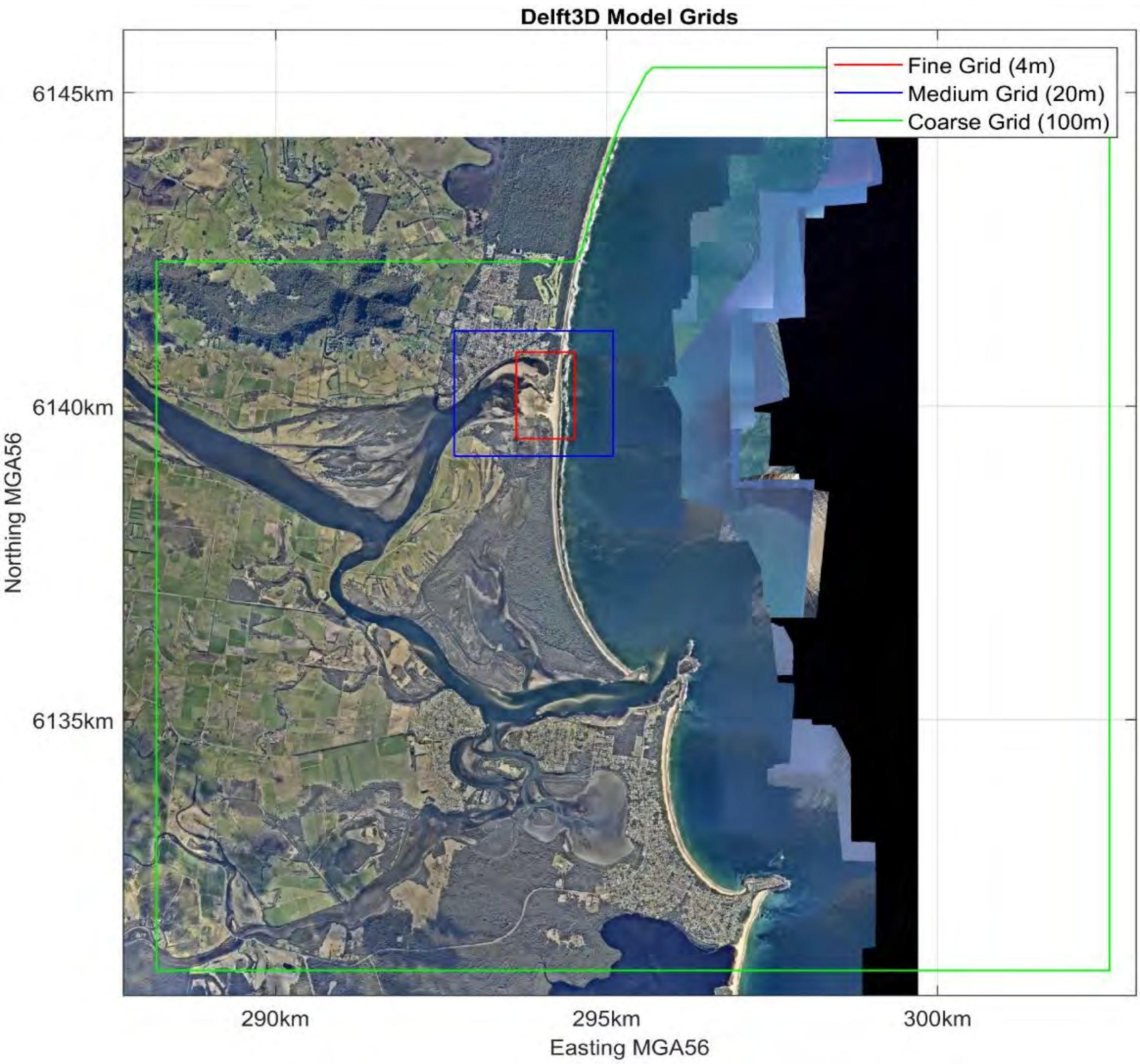


Figure 3-3 Delft3D Model Grid Extents

3.3 Model Boundary Conditions

Boundary conditions were specified as a flow time series upstream and tidal water levels along the eastern boundary. Note that these conditions varied for the different scenarios. Scenarios considered in this study are as follows:

> PMF 72hr GSAM Event;

> 1% AEP 18hr Flow;

> 5% AEP 18hr Flow; and

> 20% AEP 18hr Flow.

Time series of these flows and water levels are presented in **Figure 3-4**, **Figure 3-5**, **Figure 3-6**, and **Figure 3-7** respectively. The flows were derived from the hydrology modelling undertaken by the flooding team.

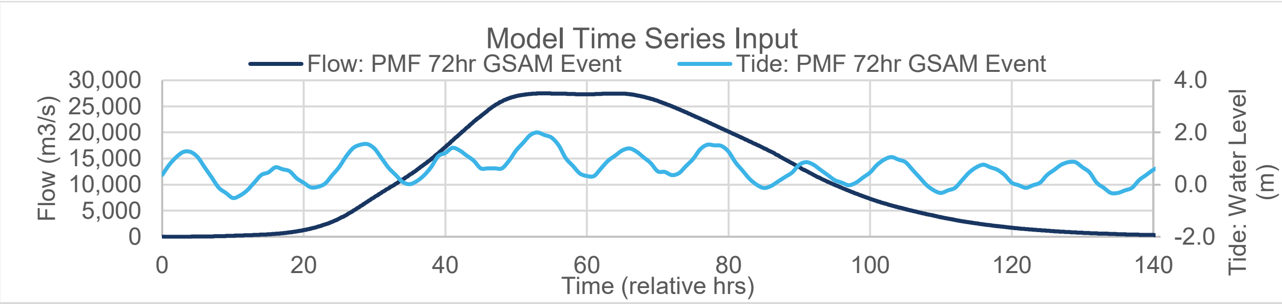


Figure 3-4 PMF Event Boundary Conditions

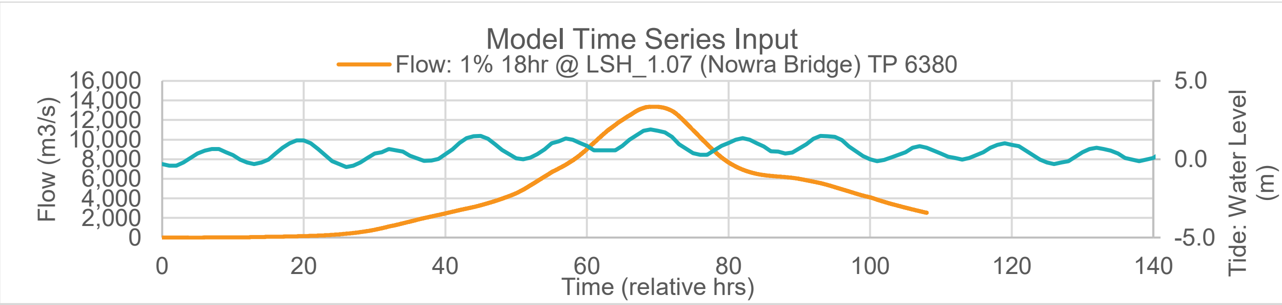


Figure 3-5 1% AEP event Flow Boundary Conditions

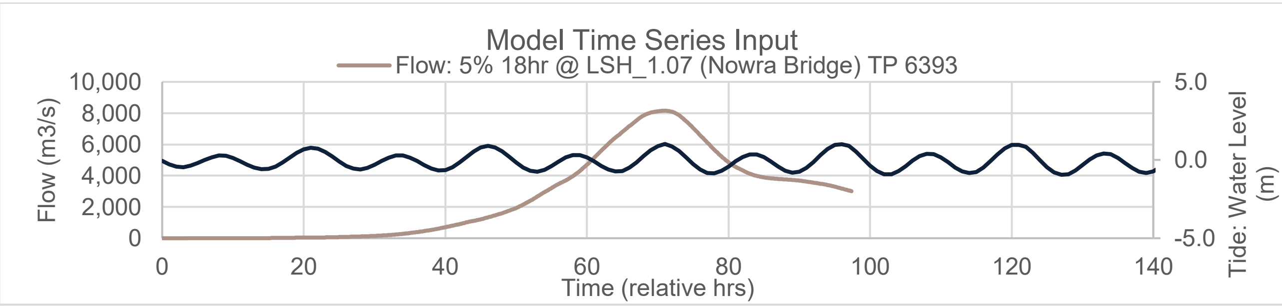


Figure 3-6 5% AEP event Flow Boundary Conditions

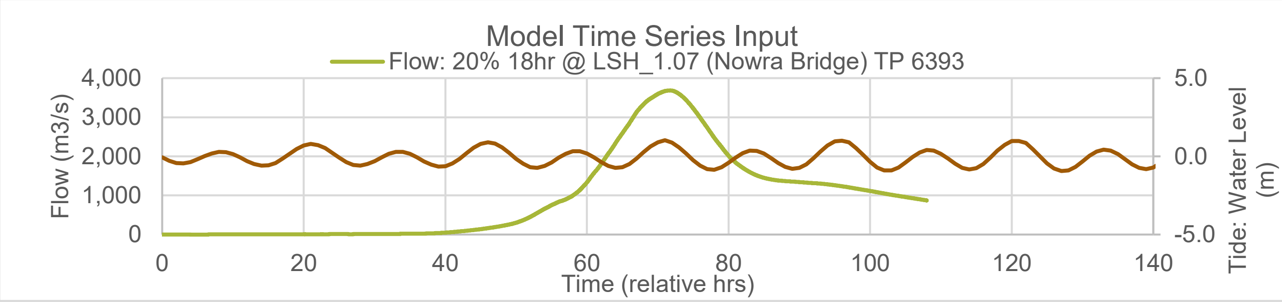


Figure 3-7 20% AEP event Flow Boundary Conditions

3.3.2 Sediment Property

Based on sediment samples from 7 Mile Beach provided by Shoalhaven City Council, a sediment size D_{50} of **0.25mm** was adopted for the erodible sediment in this study.

4 Model Calibration

Extensive sensitivity of the model to various parameters were tested. The model results were also compared with expected value range when applicable.

4.1 Sensitivity Testing

Initial sensitivity testing was undertaken to assess the processes that are important to the study. These include an assessment of:

1. Time series – vs – constant inflows;
2. Constant tailwater levels – vs – a tidal boundary; and
3. Simulations with and without waves.

The outcome of the sensitivity testing indicated that the model needed to include the actual hydrographs and ocean tides, as these had a marked difference in the entrance scouring behaviour.

Waves were not included in the final simulations, as the modelling indicated that wave processes do not affect the development of the entrance breach. The effect of waves on the simulation results are presented in **Section 4.3**.

4.2 Morphology Parameters

In Delft3D, two parameters are important in controlling the development of the inlet scouring: the transverse bed gradient factor (α_{bn}) and the dry cell erosion factor (θ_{sd}) (Deltares, 2014) (**Figure 4-1**).

The transverse bed gradient factor (α_{bn}) accounts for the effect of bed slope in the direction perpendicular to the flow direction. The smaller the value of α_{bn}, the deeper and narrower the inlet channels and vice versa (Walstra et al., 2004).

The standard sediment transport equations are unable to change the elevation of dry cells, i.e., those cells with water depth smaller than zero. In reality, dry cells adjacent to wet cells (i.e., bank cells) can erode both by undercutting and by mass failure. A phenomenological approach can be used to erode dry cells by setting their erosion proportional to the erosion of the adjacent wet cells, where θ_{sd} is the proportionality constant (van der Wegen et al., 2008), that is

$$Erosion\ at\ a\ dry\ cell\ =\ \theta_{sd}\ \times\ Erosion\ at\ adjacent\ wet\ cell$$

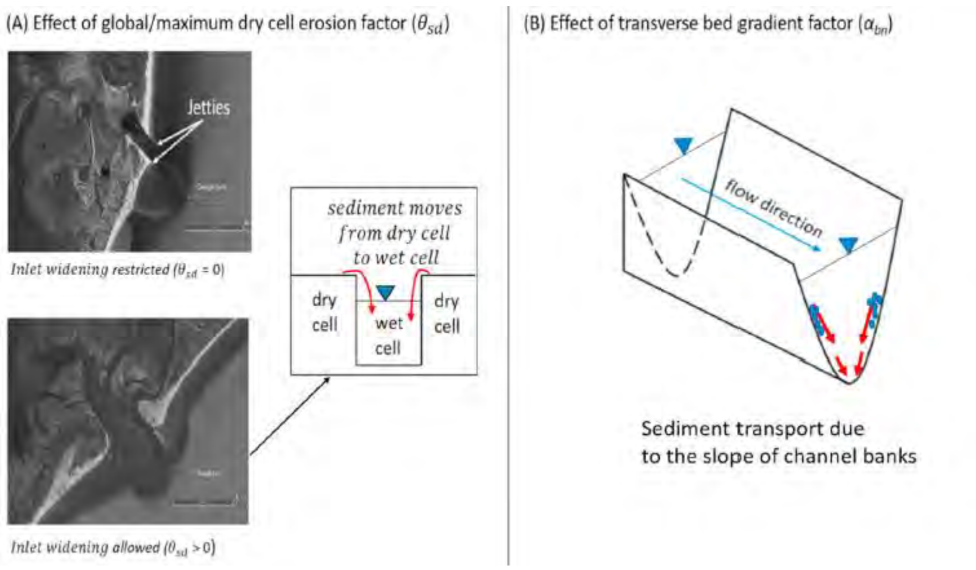


Figure 4-1 Qualitative illustration of the effects of dry cell erosion factor (A) and transverse bed gradient factor (B) on channel configurations in Delft3D (Murshid & Mariotti, 2021)

A range of α_{bn} and θ_{sd} values were tested in the model and the resulting channel width was investigated using the August 2015 flood event, for which post event survey information was available.

Due to lack of data for the determination of the maximum erodible depth limit, a range of maximum erodible depths were also investigated. Parameters and ranges tested during the calibration were:

> α_{bn} = [1.5 (default), 5, 10, 20]
> θ_{sd} = [0.65, 1]
> Max erodible depth = [5m, 3.5m]

The simulations with Increased α_{bn}, and θ_{sd} values yielded slightly wider channels, but only in the order of about ~10m for the tested range (at elevation 0mAHD). Limiting the erodible depth resulted in a generally wider channel profile (in the order of ~30m width difference @0mAHD).

The results were compared with the post-event survey (**Figure 4-2**). It should be noted that the post-survey was collected approximately two (2) weeks after the event, and as such some infilling and smoothing of the deeper parts of the entrance channel would be expected.

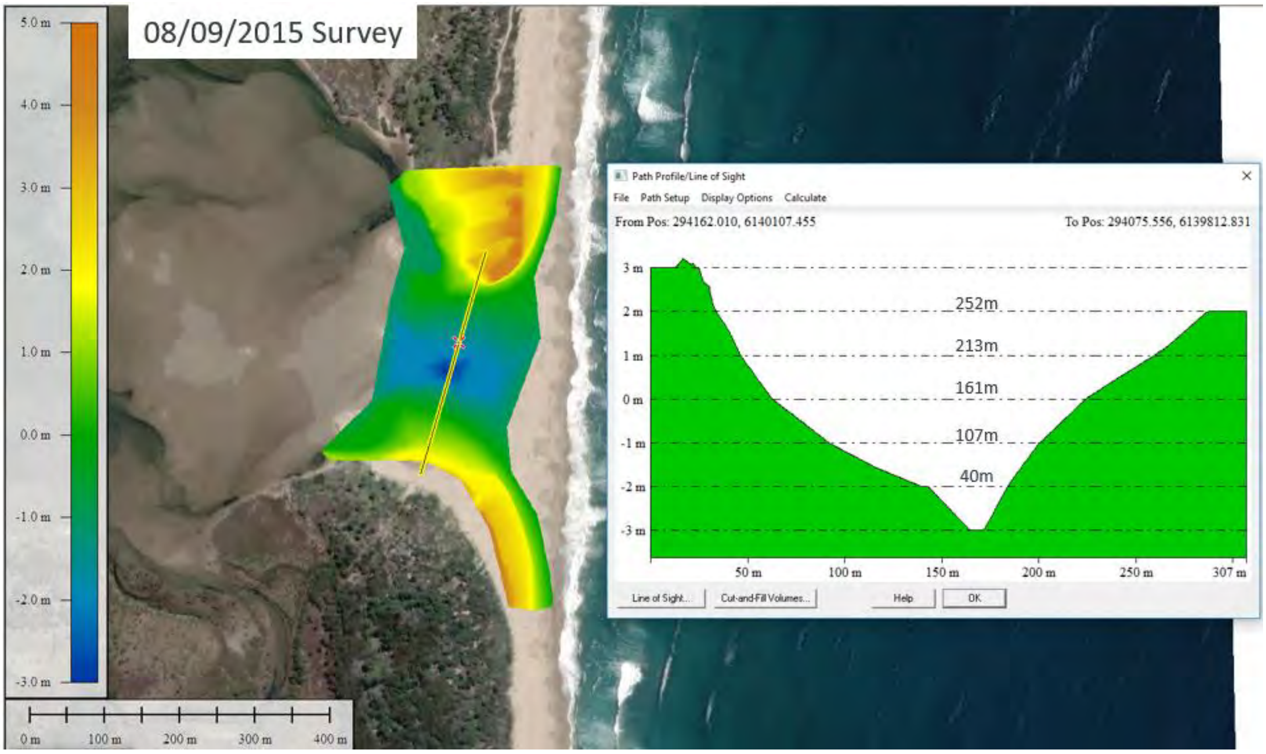


Figure 4-2 Post August 2015 Flood River Mouth Survey

Table 4-1 presents the results for the modelled breach width using the upper limit values for the dry cell erosion factor and the transverse bed gradient factor, compared to the post-event survey width data. Only allowing the seabed to erode to a depth of -3.5m AHD appears to give a more reasonable representation of the developed channel width considering the post-event survey values. Note that the historic survey information also indicates that the channel bed was above -3.5m AHD.

Table 4-1 Model Post-Event Channel Width VS Post-Event Survey ($\alpha_{bn} = 20,\ \theta_{sd} = 1$)

Bed scouring cap	Breach model result Channel Width at elevation level					08/09/2015 Survey Channel Width at elevation level				
	-2mAHD	-1mAHD	0mAHD	1mAHD	2mAHD	-2mAHD	-1mAHD	0mAHD	1mAHD	2mAHD
[m below 0mAHD]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
5	113	116	123	130	233	40	107	161	213	252
3.5	140	150	157	165	233					

Given these results, the following values were adopted for the design model scenario runs:

> α_{bn} = 20
> θ_{sd} = 1
> Max erodible depth = -3.5 mAHD

4.3 Channel Width Sensitivity to Waves

As indicated in **Section 4.1** the effect of waves on the entrance breach development was tested.

The same case was simulated with and without waves. Waves from the east-south-east with a significant wave height (Hs) of **3m**, and peak wave period (Tp) of **12 seconds** were specified on the models offshore boundary.

A comparison of the predicted entrance scouring is presented below in **Figure 4-3.** This figure shows that waves tend to affect the bathymetry offshore of the shoreline, resulting it a smoothed and less steep slope compared to the simulation without waves. However, the resulting post-breach channel width does not appear to be sensitive to wave processes, with a very similar width and depth predicted in both simulations.

Based on these results wave processes were not included in the flood event scenario runs. Note that including wave processes significantly increases the computational effort, resulting in run times of greater than 10 days per scenario.

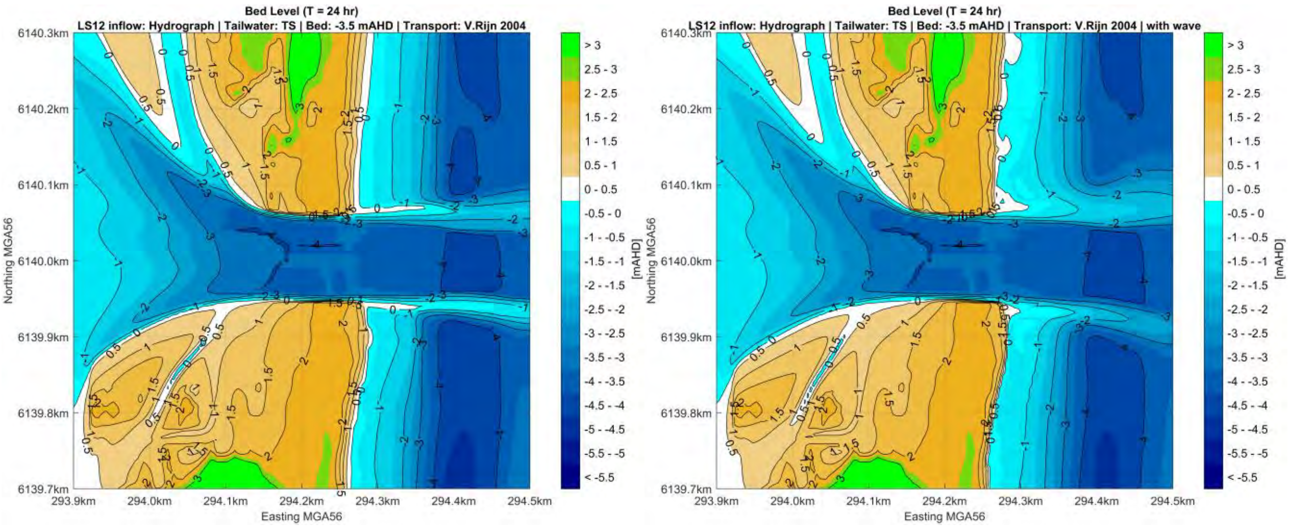


Figure 4-3 Channel width sensitivity to waves test: (left) without waves, (right) with waves

5 Breach Modelling

5.1 Breach Development Methodology

The following steps were applied for the breach modelling:

> The model is run with the initial inlet configuration fully closed (with a sub-grid structure). Sediment transport and morphology was not included in the 'warm-up' period;

> Once the water levels near the upstream boundary (LS12) reaches 2m AHD the model is stopped and used to generate an initial condition for the full process simulations; and

> From the above time point, which varied per simulation, the simulation is continued with the morphology module activated and the inlet notch opened.

5.2 Scenarios

The morphological model was used to simulate the entrance breach development for the below flood events:

> PMF 72hr Event;

> 1% AEP 18hr event Flow;

> 5% AEP 18hr event Flow; and

> 20% AEP 18hr event Flow.

5.3 Results

5.3.1 Water Level and Discharge Results

Figure 5-1, **Figure 5-2**, **Figure 5-3**, and **Figure 5-4** present the modelled water level and discharge through the breached entrance at Shoalhaven Heads during the four design scenarios.

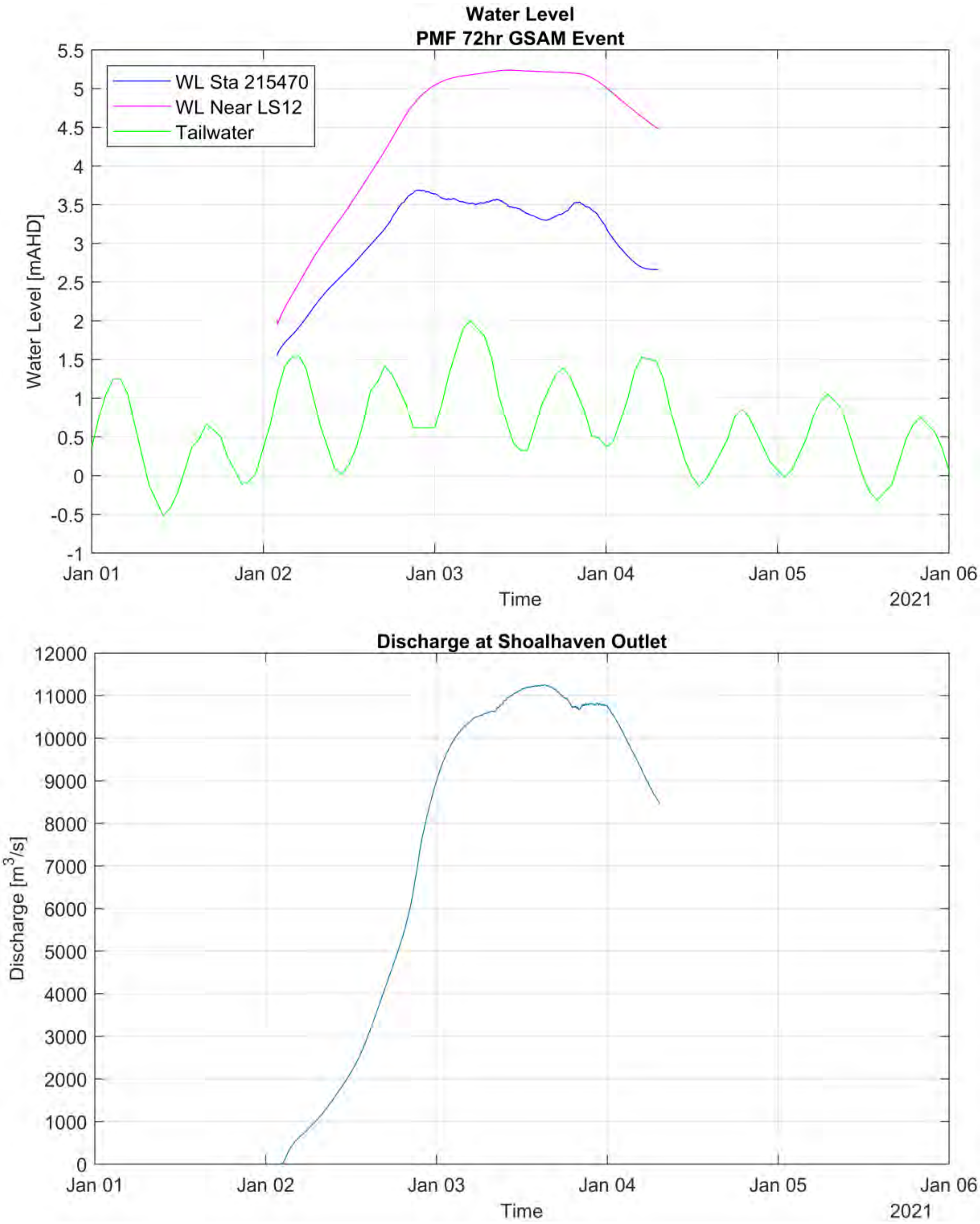


Figure 5-1 PMF 72hr GSAM Event: (Top) Water Levels and (Bottom) Shoalhaven Outlet Discharge

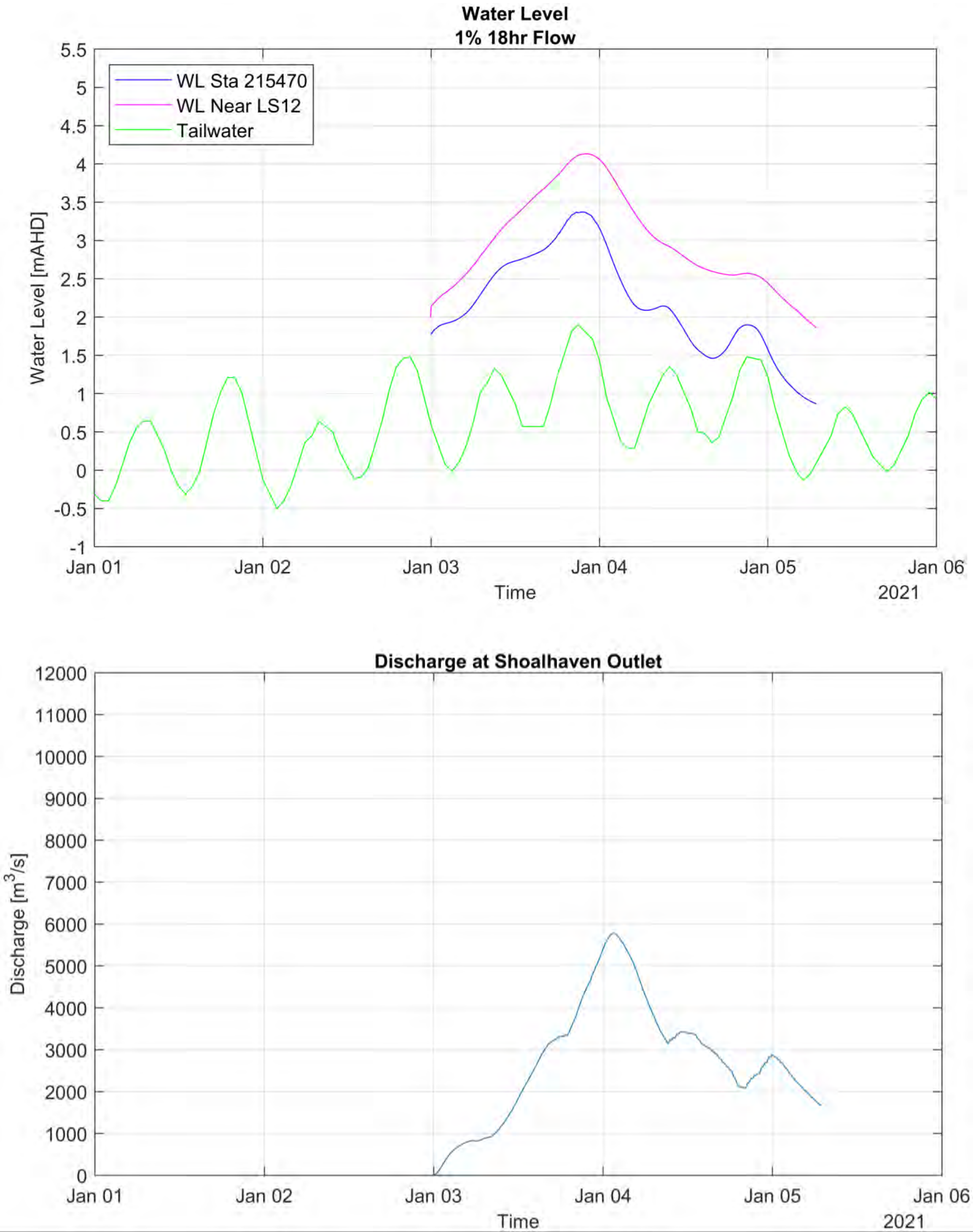


Figure 5-2 1% AEP Flow Event: (Top) Water Levels and (Bottom) Shoalhaven Outlet Discharge

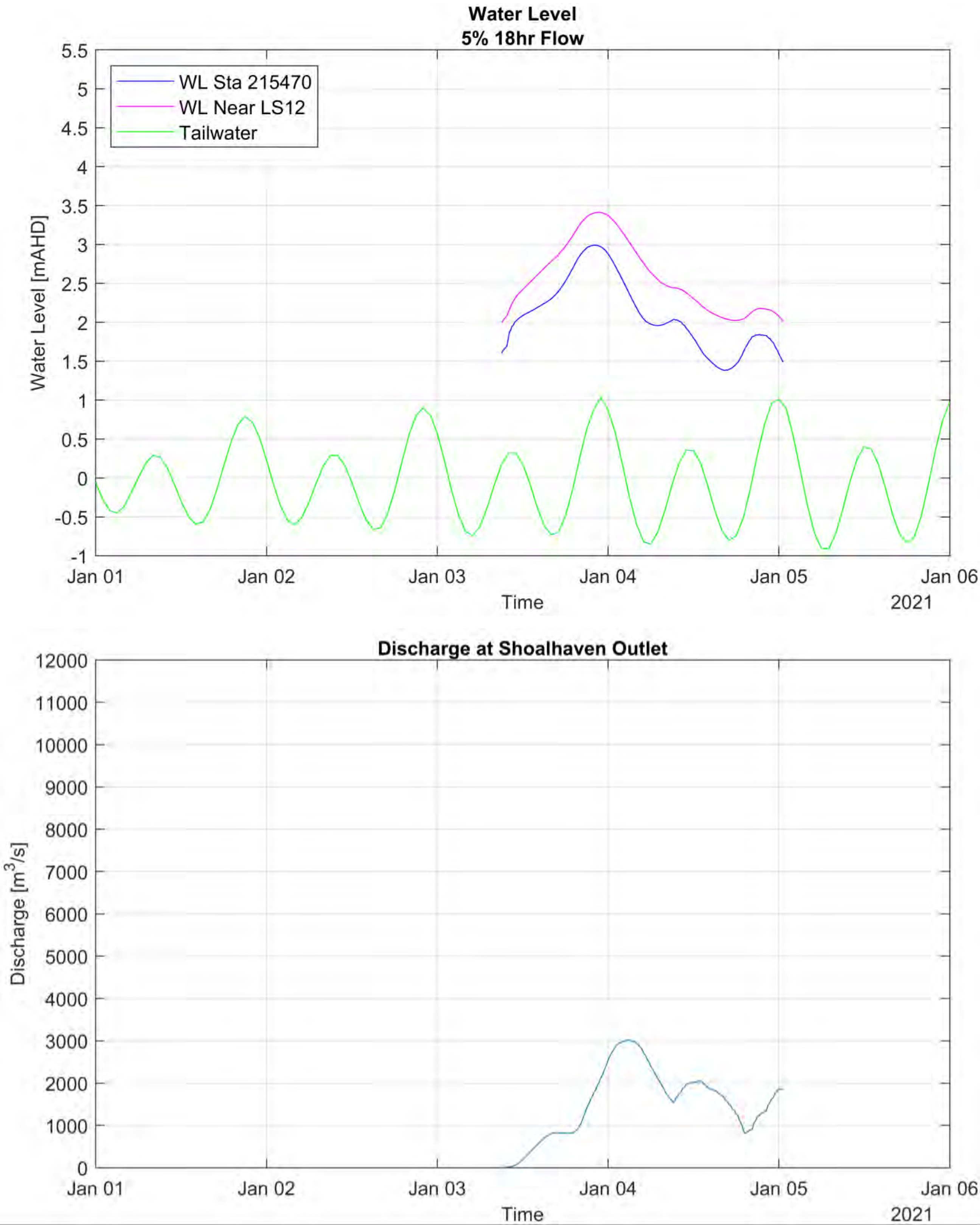


Figure 5-3 5% AEP Flow Event: (Top) Water Levels and (Bottom) Shoalhaven Outlet Discharge

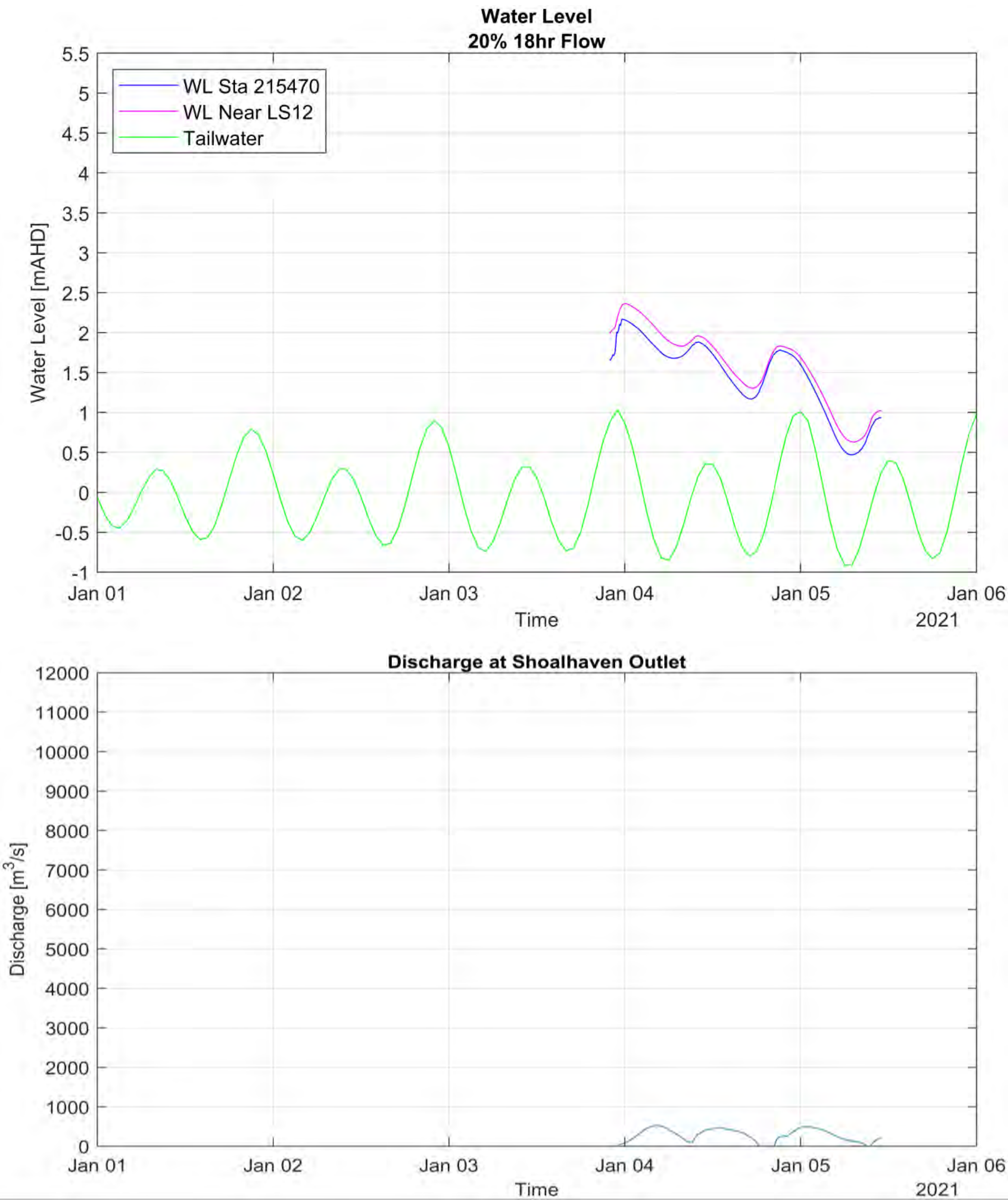


Figure 5-4 20% AEP Flow Event: (Top) Water Levels and (Bottom) Shoalhaven Outlet Discharge

5.4 Breach Width Propagation

Figure 5-5, **Figure 5-6**, **Figure 5-7**, and **Figure 5-8** present the development of the scoured entrance cross section during the different design scenarios. The denoted time=00hr is from the start of the morphological model, i.e. the time from when the entrance is mechanically opened.

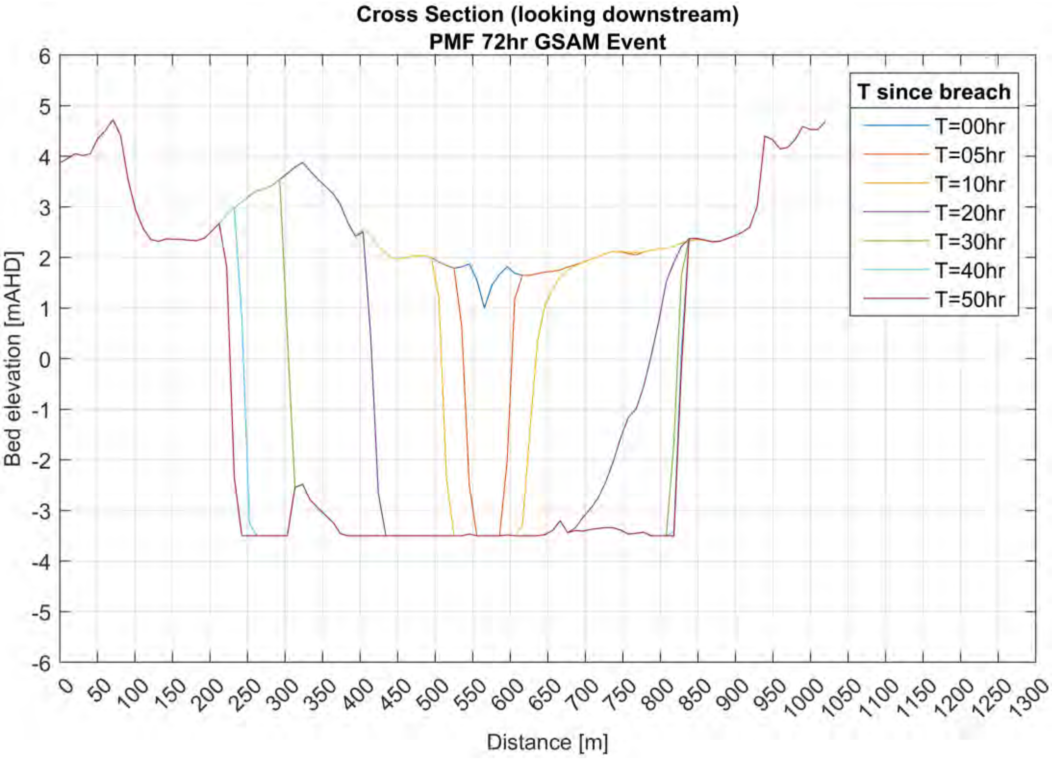


Figure 5-5 PMF 72hr GSAM Event Breach Width Profile Development

Figure 5-6 1% AEP 18hr Flow Event Breach Width Profile Development

Figure 5-7 5% AEP 18hr Flow Event Breach Width Profile Development

Figure 5-8 20% AEP 18hr Flow Event Breach Width Profile Development

5.5 Post-Breach Bed Level

Figure 5-9, **Figure 5-10**, **Figure 5-11**, and **Figure 5-12** present the post-breach bed levels at the end of the different Design Scenarios.

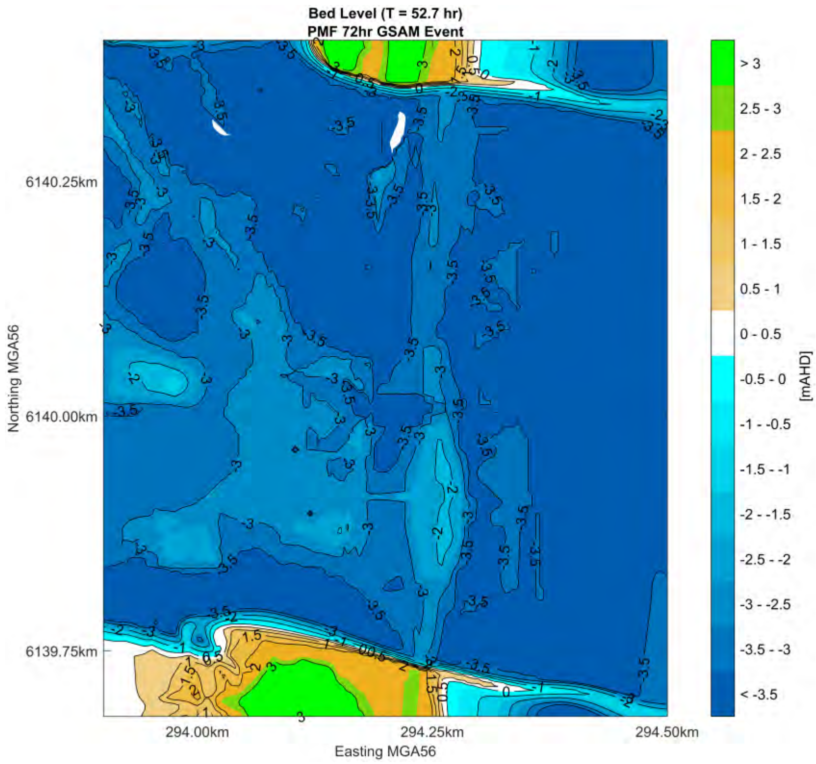


Figure 5-9 PMF 72hr GSAM Event Post-Breach Event Bed Level

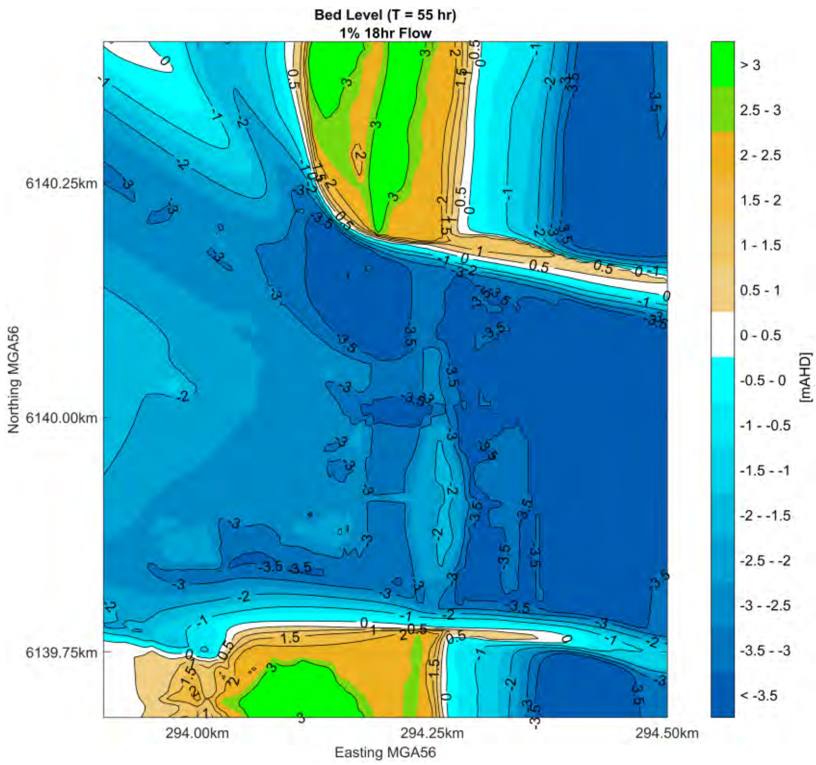


Figure 5-10 1% AEP 18hr Flow Event Post-Breach Event Bed Level

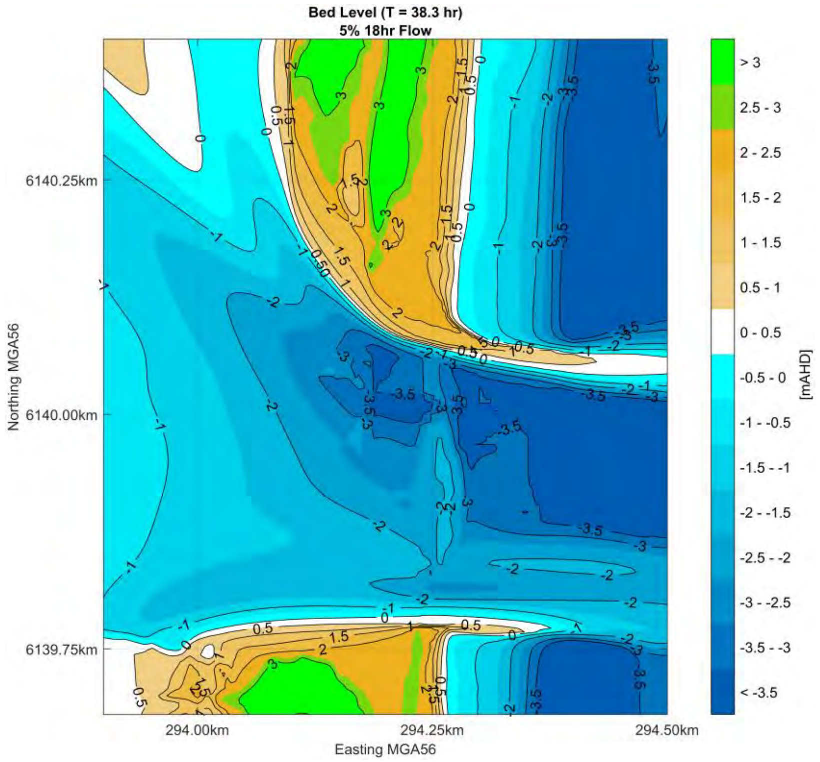


Figure 5-11 5% AEP 18hr Flow Event Post-Breach Event Bed Level

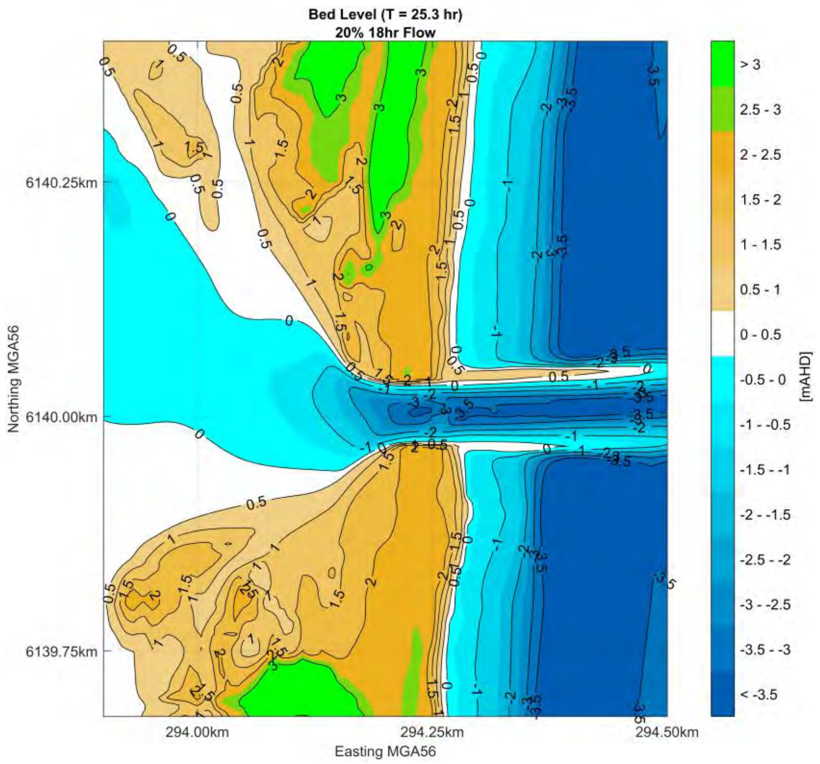


Figure 5-12 20% AEP 18hr Flow Event Post-Breach Event Bed Level

5.6 Summary

Table 5-1 provides a summary of the modelled peak discharges and post-breach channel width predicted by the model.

Table 5-1 Breach Model Summary: Peak Discharges and Post-breach Channel width at Shoalhaven Heads

Flow Event	Peak Discharge at SH Outlet [cms]	Post-breach channel width @0mAHD [m]
PMF 72hr GSAM	11,256	600
1% AEP 18hr	5,781	400
5% AEP 18hr	3,015	320
20% AEP 18hr	523	70