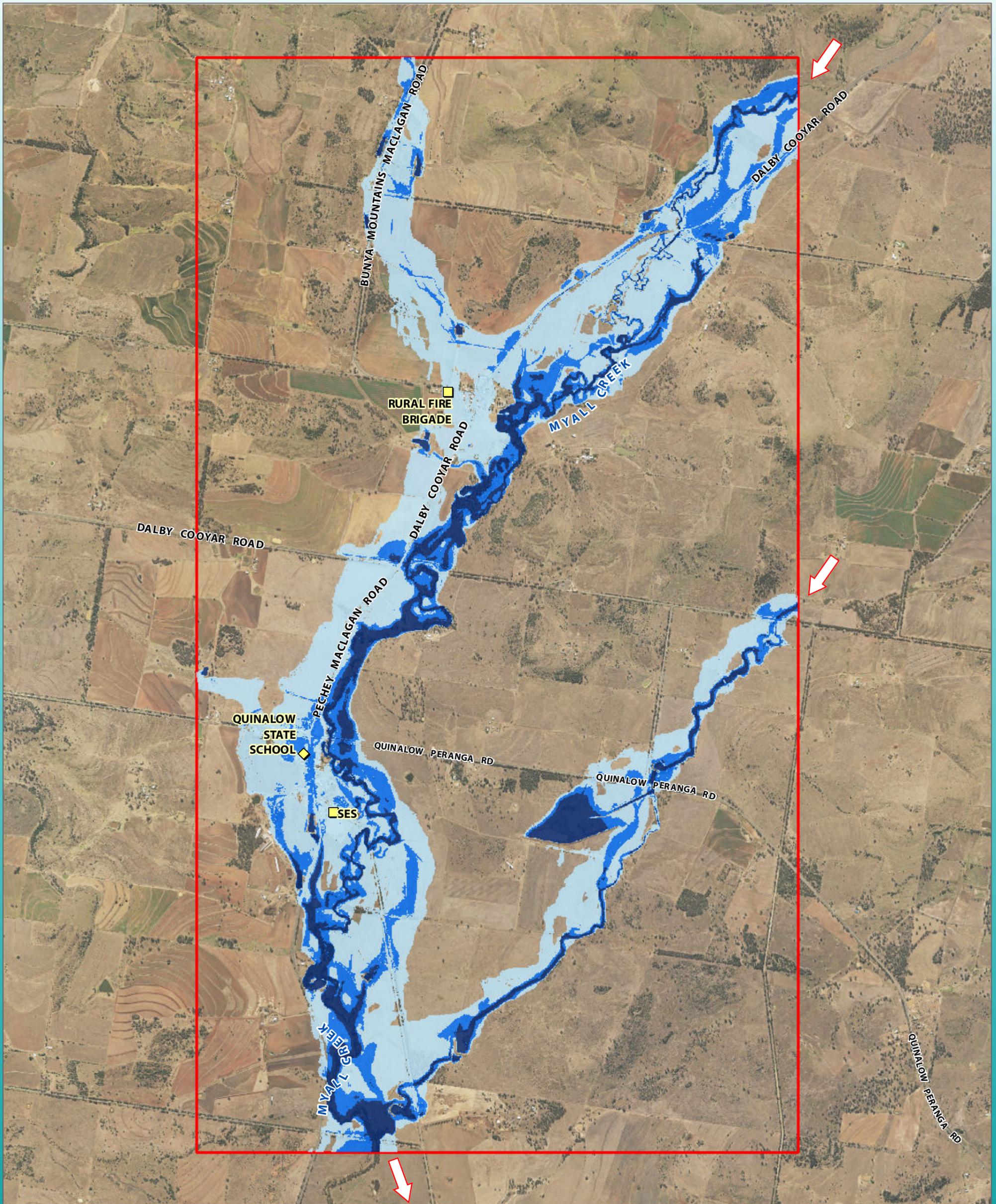


MACLAGAN-QUINALOW



1:25,500 (at A3)
 0 200 400 600 800
 Metres



1% AEP FLOOD DEPTH RIVERINE

Water Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1+



Model Extent



DirectionFlow



Emergency Services



School

Flood Studies



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2D Flood Study for Maclagan and Quinalow

August 2014 • *Endorsed on 25 February 2015*

GENERAL NOTE

These reports/documents are a base source of information that will be continually refined over time.

DISCLAIMER

While every care is taken by the Toowoomba Regional Council (TRC) to ensure the accuracy of the data used in the study and published in the report, Toowoomba Regional Council makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of data being inaccurate or incomplete.

REPORT TITLE: Work Package 9,2D Flood Study for Maclagan and Quinalow, Final Report
CLIENT: Toowoomba Regional Council
REPORT NUMBER: 0965-04-C5

Revision Number	Report Date	Description	Report Author	Reviewer
DRAFT	1 November 2013	First Pass Results Report	TK/MB	SM/TV
DRAFT 2	13 February 2014	Draft Report	TK/MB	SM/TV
FINAL 1	14 March 2014	Final Report	TK/MB	SM/TV
FINAL 2	9 April 2014	Final Report (rev 1)	TK/MB	SM/TV
FINAL 3	21 August 2014	Final Report (rev 2)	TK/MB	SM/TV

For and on behalf of
WRM Water & Environment Pty Ltd



Sharmil Markar
Director

NOTE: This report has been prepared on the assumption that all information, data and reports provided to us by our client, on behalf of our client, or by third parties (e.g. government agencies) is complete and accurate and on the basis that such other assumptions we have identified (whether or not those assumptions have been identified in this advice) are correct. You must inform us if any of the assumptions are not complete or accurate. This report may only be used by our client for the purpose for which it has been provided by us.

EXECUTIVE SUMMARY

Toowoomba Regional Council (TRC) has appointed WRM Water and Environment Pty Ltd (WRM) in association with DHI Water and Environment Pty Ltd (DHI) to carry out hydrologic and hydraulic investigations of flooding in the towns of Maclagan and Quinalow. The hydrological modelling was undertaken using XP-RAFTS. The hydraulic modelling was undertaken using a coupled MIKE FLOOD 1D/2D hydrodynamic model.

The majority of the data for the construction of the hydraulic model was derived from a 1 m LiDAR Digital Elevation Model (DEM) provided by TRC. A site visit was undertaken on September 3rd, 2013. The purpose of the site visit was to allow the project team to identify key drainage features within the catchment, survey structures with potential significant hydraulic impact, gain a general feel for the floodplain and collect information on previous flood events from identified stakeholders.

The validation data consisted of recorded rainfall, stream flow, spot water levels and five locations where flooding was observed during the January 2011 event. The XP-RAFTS and MIKE FLOOD models were validated to this event iteratively using a joint calibration approach. Flows from XP-RAFTS were adjusted and applied in the MIKE FLOOD model until a good match between modelled and recorded flood levels was achieved and areas of known flooding were reproduced by the model. All predicted levels were within the required accuracy of $\pm 0.25\text{m}$ except for one outlier, which appears to be an erroneous level observation.

The hydraulic model results show that Maclagan and Quinalow were flooded from the Myall Creek during the January 2011 event. The Dalby-Cooyar Road and Pechey-Maclagan Road connecting the two towns were cut off during the event. The January 2011 flood event at Maclagan and Quinalow is estimated to have an Average Recurrence Interval (ARI) of approximately 10 years.

A comparison of the XP-RAFTS model design discharges against discharges estimated using the Rational Method for design events up to the 100 year Average Recurrence Interval (ARI) shows that the design discharges estimated from the two methods are consistent.

Design flood discharges, flood levels, flood depths, flood velocities and flood hazards under existing catchment conditions for design rainfall events ranging from 2 year ARI to 500 year ARI and for the Probable Maximum Flood (PMF) were predicted using the validated XP-RAFTS and MIKE FLOOD models. In addition, sensitivity analysis on predicted 100 year ARI flood behaviour was undertaken and used to assess the impacts of changes to adopted design discharges ($\pm 30\%$), hydraulic roughness ($\pm 30\%$) and hydraulic structure blockage (50%). Potential impacts of climate change (2°C, 3°C and 4°C temperature increase by 2050, 2070 and 2100 respectively) on 100, 200 and 500 year ARI events were assessed.

The study results show that:

- The design flood levels in Quinalow are relatively insensitive to adopted design discharges. The 500 year ARI design discharge at Quinalow is 7 times larger than the 2 year ARI discharge; however the peak flood level is only 0.7 m higher;
- The design flood levels in Maclagan are more sensitive to adopted design discharges than at Quinalow. The 500 year ARI design discharge at Maclagan is also 7 times larger than the 2 year ARI discharge; however the peak flood level is 1.2 m higher; and
- The majority of road crossings in the study area have low flood immunity; with four of the five major road crossings in the model extent overtopped in a 2 year ARI design event. The Dalby Cooyar Road structure near the corner of Dalby-Cooyar Road and Woodleigh Maclagan Road has flood immunity up to a 500 year design event.

Sensitivity analysis results for the 100 year ARI design event indicate the following:

- At Quinalow and Maclagan, a 30% increase and decrease in design discharge results in an increase and decrease in peak flood level of up to about 0.18 m and 0.23 m respectively;
- The modelled hydraulic structures are relatively insensitive to 50% blockage, with the exception of the bridge at Quinalow which increases the upstream peak flood level by 0.12 m and the maximum velocity through the bridge by 0.9 m/s.

Climate change scenario results indicate the following:

- In all of the climate change scenarios investigated, the peak discharge has increased at the reporting locations; and
- Flood levels increased by a maximum of up to 0.20 m at the reporting locations.

The study limitations and recommendations on how model predictions could be improved are also presented.

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1

INTRODUCTION

1.1 BACKGROUND

Toowoomba Regional Council (TRC) is a large local government area located in the Darling Downs part of Queensland, Australia. TRC comprises an area of nearly 13,000 km² with a population of approximately 172,000 people in 33 towns. In 2009 TRC commenced the Toowoomba Regional Planning Project (RPP) to develop one integrated planning scheme policy covering the entire Council area. Later that year TRC commissioned Water Technology Pty Ltd to collate and review the existing flood data in the region and provide advice on the applicability of the data for use in the Planning Scheme (Water Technology Pty Ltd, 2013). One of the findings from the study was that only a small portion of the Council area is covered by high/medium quality flood mapping.

In 2012 the State Government approved Council adopting the Toowoomba Regional Planning Scheme with a set of conditions to be met to ensure the scheme was compliant with nominated State Planning Policies. To meet the conditions established by the State Government, a scoping study was completed by Council to identify the information required to meet the specified conditions. The study highlighted the need to investigate the flood behaviour and flood risk in several towns in the region.

WRM in association with DHI was commissioned by TRC to undertake the flood study for the towns of Maclagan and Quinalow. The flood study will provide Council with information needed for land development control, infrastructure development and management, emergency planning, and emergency response in the study area.

This report describes the methodology, available data, and development of hydrologic and hydraulic models for historical and design event simulations for Maclagan and Quinalow. The report ends with concluding remarks and recommendations to further improve the model accuracy.

1.2 SCOPE OF PROJECT

The primary objective of this project was to define the nature and extent of flood behaviour in the Maclagan and Quinalow study area to enable TRC to:

- *“Develop a Flood Risk Management Study and plan to address the flood hazards identified in the flood studies; and*
- *Amend the Toowoomba Regional Planning Scheme to appropriately reflect the flood requirements of State Planning Policy 1/03 and the recommendations of the Queensland Commission of Inquiry” (TRC, 2013).*

The project was divided into a number of phases. The scope of each phase is briefly outlined below.

Information Review and Project Start-Up

- Completion of project briefing;
- Development of stakeholder consultation strategy;
- Site visit; and
- Collection and review of available data.

Hydrologic Model Development

- Development of a XP-RAFTS hydrologic model.

MIKE FLOOD Model Development

- Development of a coupled 1D/2D MIKE FLOOD model; and
- Adjusting parameters to ensure model stability.

Model Validation

- Adjustment of flows and roughness values to achieve the following targets:
 - 90% of spot levels within $\pm 0.25\text{m}$
 - All spot levels within $\pm 0.5\text{m}$.

Sensitivity Analysis

- Assessment of model sensitivity to flow, roughness and blockage of hydraulic structures.

Design Event Modelling

- Simulation of design scenarios for the 2, 5, 10, 20, 50, 100, 200 and 500 year ARI and PMF design events; and
- Assessment of the potential impact on flood behaviour for three climate change scenarios for the 100, 200 and 500 year ARI design events.

Deliverables

- Report detailing methodology and modelling results including A3 flood maps for the validation event, design events and sensitivity analysis; and
- Handover of all model setup and result files.

1.3 STUDY AREA

Maclagan and Quinalow are small towns located approximately 60 km northwest of Toowoomba on the Myall Creek floodplain. The primary source of flood risk to the towns is Myall Creek flow from a catchment extending to the northeast for approximately 15 km upstream. Both towns are located on the western side of Myall Creek close to the creek channel, with some properties in Quinalow being within 50 m of the channel banks. Both Maclagan and Quinalow are accessible by road from several directions, and are unlikely to be cut off from all surrounding towns by creek flooding.

Land use within the Myall Creek catchment is primarily agricultural. Within the local areas of Maclagan and Quinalow townships the land use is predominantly residential. According to the regional planning scheme very little future residential development is proposed within these two towns. The study area is shown in Figure 1.1.

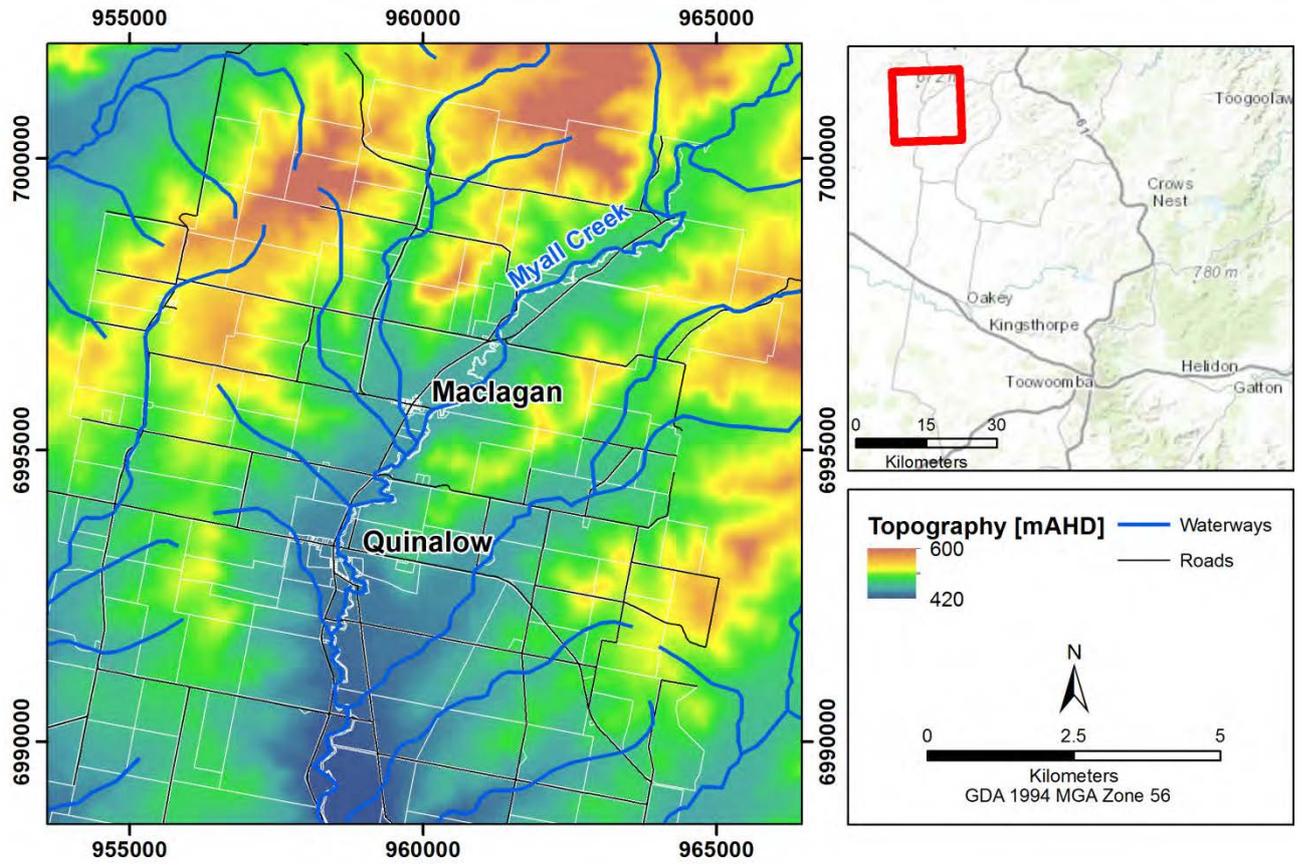


Figure 1.1 Study Area

2 AVAILABLE DATA

Information relevant to the flood study was obtained from a range of sources including TRC records and Quinalow residents.

2.1 TOPOGRAPHIC DATA

Tiles of 1m LiDAR-derived gridded topographic data were provided by TRC. The 1m tiles were merged to create a seamless 1m Digital Elevation Model (DEM) of the study area, see Figure 2.1.

2.2 GIS LAYERS

The available GIS layers provided by TRC included:

- Aerial photography;
- Cadastral data;
- Road and rail network;
- Structures with a likely hydraulic impact;
- Land use data; and
- Future planning scheme.

2.3 HISTORICAL FLOOD INFORMATION

Historical pluviograph and daily rainfall data were available from the Bureau of Meteorology (BoM) for a number of rainfall stations within and adjacent to the Myall Creek catchment. Rainfall data available for the January 2011 validation event is described in Section 3.2.2.

Historical water level hydrographs were available from BoM for two flood warning stations along Myall Creek. Water level data along Myall Creek available for the January 2011 validation event is described in Section 3.2.4.

Available recorded historical flood levels and locations where flooding was observed were supplied by TRC. The available historical flood information was limited to the January 2011 flood event, except one flood mark near Quinalow Hotel which was also available for the December 2010 and January 2013 flood events. Photographic evidence of flood depths and inundated areas during the January 2011 flood was also obtained from Quinalow residents. Please note that TRC has collected flood data for this study from a variety of sources including debris marks, flood marks visible and accessible at the time of survey after the January 2011 flood, eyewitness accounts, community consultation, etc. It is possible that some the flood data available to TRC may not be accurate or complete. The validation data for the January 2011 event is summarised in Table 2.1 and shown in Figure 2.1.

Information used is the best information available at this time for the purposes of this study. Marks observed and other anecdotal information obtained after flood events have been obtained from a range of sources and have varying degrees of uncertainty.

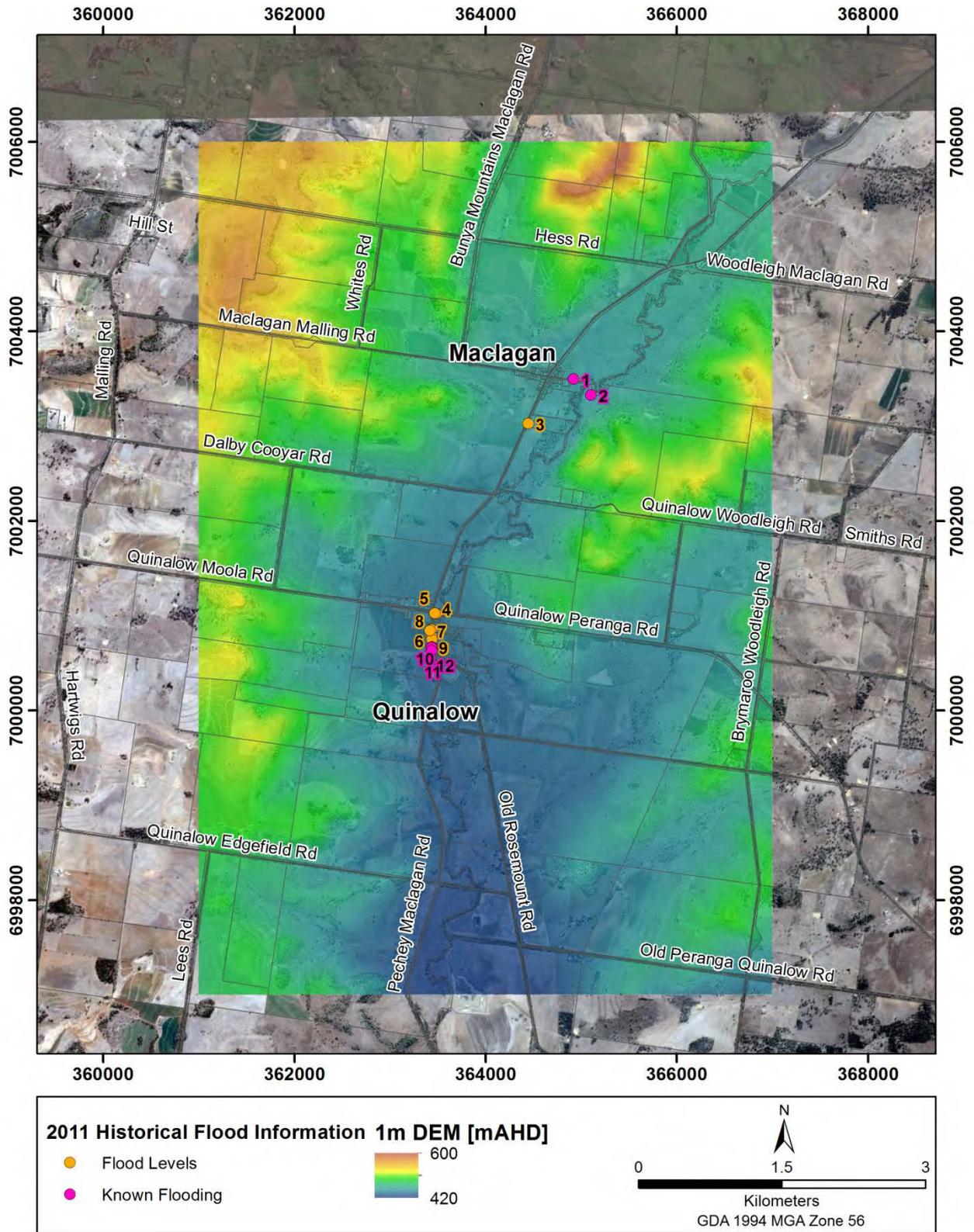


Figure 2.1 LiDAR-Derived DEM Extent and Available Historical Flood Information

Table 2.1 Historical Flood Event Data

ID	Town	Location	Flood Reference
1	Maclagan	Bismark Street (flood point right side of causeway looking downstream)	Known flooding
2	Maclagan	Flood point left side of causeway looking downstream	Known flooding
3	Maclagan	4282 Dalby-Cooyar Road (front of property near road)	Flood level
4	Quinalow	Quinalow Hotel (steps near front of hotel)	Flood level
5	Quinalow	Quinalow Hotel (steps near back of hotel)	Flood level
6	Quinalow	9 Progress Street (front of property)	Flood level
7	Quinalow	9 Progress Street (back of property)	Flood level
8	Quinalow	13 Progress Street	Flood level
9	Quinalow	15 Progress Street	Flood level
10	Quinalow	23 Progress Street (front of property)	Known flooding
11	Quinalow	23 Progress Street (side of property)	Known flooding
12	Quinalow	23 Progress Street (tree line next to property)	Known flooding

3

HYDROLOGICAL MODEL DEVELOPMENT AND VALIDATION

3.1 OVERVIEW

The following section presents the methodology and results of the hydrological model validation for the Myall Creek catchment.

3.2 MODEL VALIDATION DATA

3.2.1 Adopted Validation Event

The largest recent flood event (January 2011) at Maclagan and Quinalow was selected for hydrologic and hydraulic model validation due to availability of rainfall and flood data.

3.2.2 Rainfall Data

Table 3.1 shows the available pluviograph and daily rainfall data from rainfall stations within and adjacent to the Myall Creek catchment for the selected model validation event. Figure 3.1 shows the recorded cumulative rainfall at the Cooringa Alert pluviograph station for the January 2011 flood event. Figure 3.2 shows the locations of the pluviograph and daily rainfall stations.

Table 3.1 Pluviograph and Daily Rainfall Data Availability for Myall Creek Catchment

Station Name	Station No.	Total Rainfall (mm) ^a
<i><u>Pluviograph Stations</u></i>		
Cooringa Alert	746243	108.0
<i><u>Daily Rainfall Stations</u></i>		
Talgai	041202	144.4
The Bluestone	041528	116.8
Grahamville	041271	119.2
Little Ridge	041242	137.2
Vincent Vale	040307	147.8

Notes: ^a Total from 9am 8th January to 9am 12th January 2011

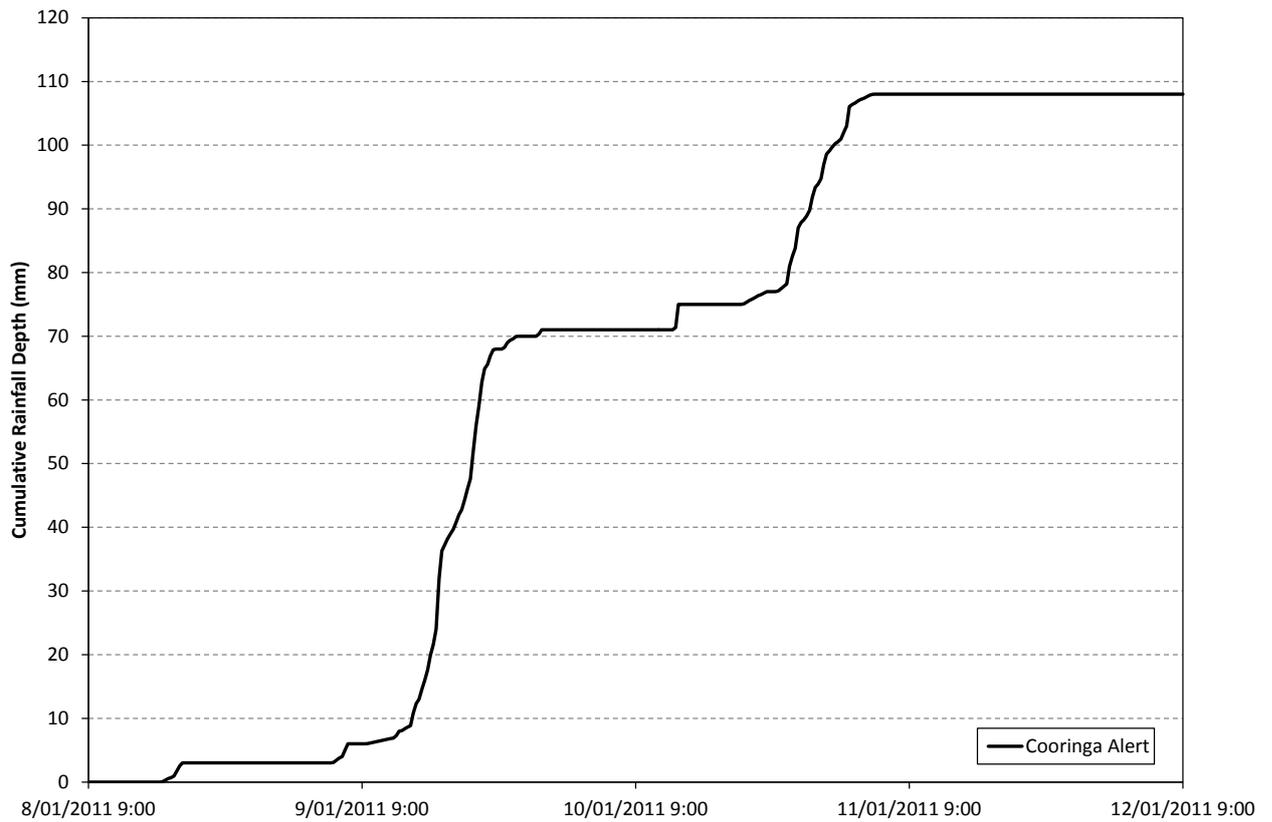


Figure 3.1 Cumulative Rainfall at Cooringa Alert Station, January 2011 Event

3.2.3 Rainfall Distribution

Figure 3.2 shows the rainfall distribution in the Myall Creek catchment during the January 2011 validation event, based on all available pluviograph and daily rainfall data. The following is of note:

- Higher total rainfalls (greater than 140 mm) were recorded in the upper catchment of Myall Creek than the downstream study area (110 mm); and
- The total rainfall recorded during the January 2011 flood event varied by approximately 30 mm across the catchment.

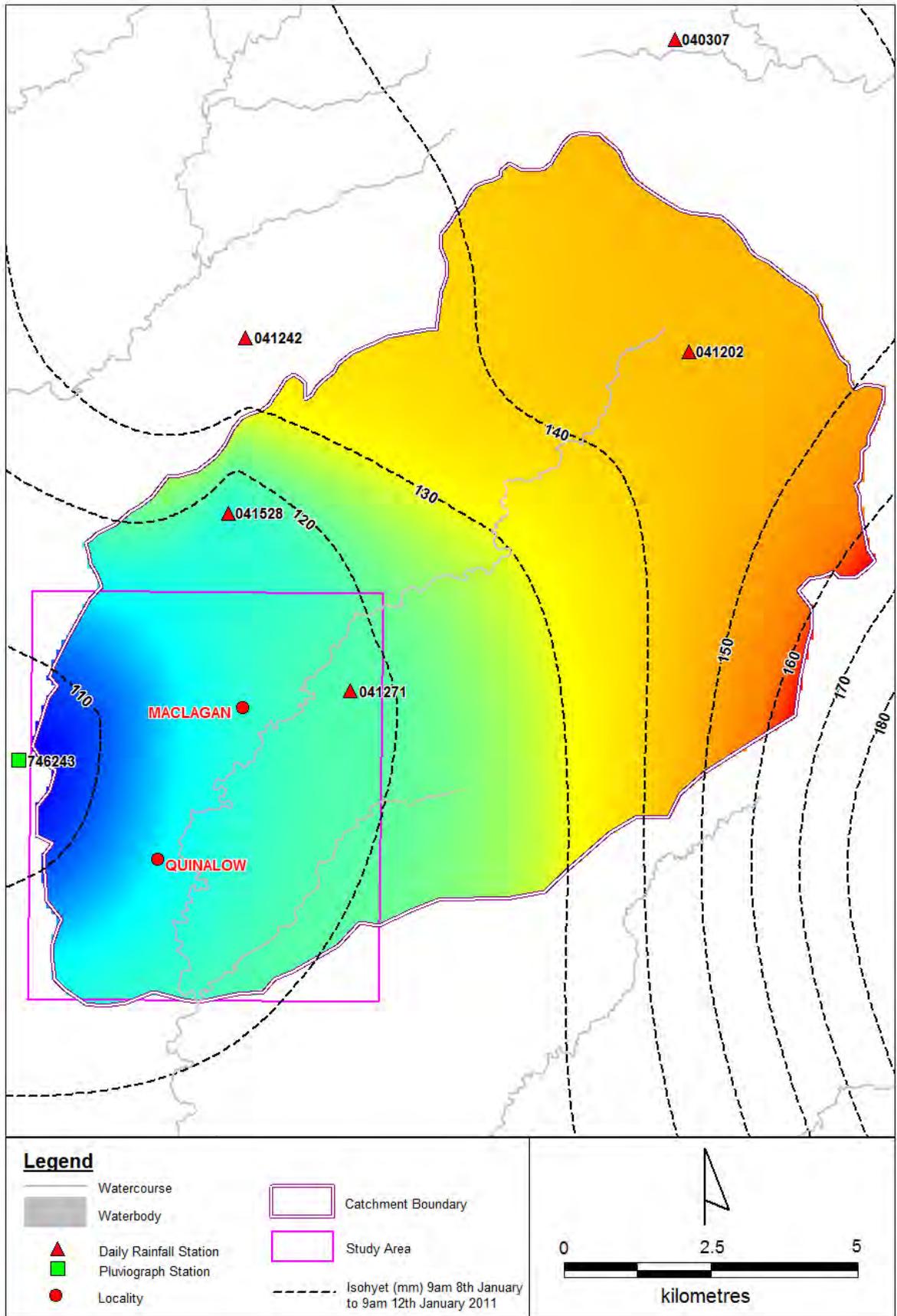


Figure 3.2 Rainfall Station Locality and Total Rainfall Distribution in the Myall Creek Catchment, January 2011 Flood Event

3.2.4 Streamflow Data

The only stream gauging data available for the January 2011 validation event along Myall Creek were from BoM's Myall Creek at Clydesdale Alert (541043) and Myall Creek at Dalby Alert (541041) flood warning stations. The Dalby Alert and Clydesdale Alert are located approximately 54 km and 26 km downstream of the study area respectively. These stations are outside the extent of the hydrological model developed for this study.

Figure 3.3 and Figure 3.4 show the recorded water levels at Clydesdale Alert and Dalby Alert for the January 2011 event, respectively. The following is of note:

- There are four peaks recorded at each station. The third peak had the highest recorded water levels for each gauge during the event.
- The peak water level was recorded at about 0300 hours on 10 January at Clydesdale Alert and at about 1644 hours on 10 January at Dalby Alert.

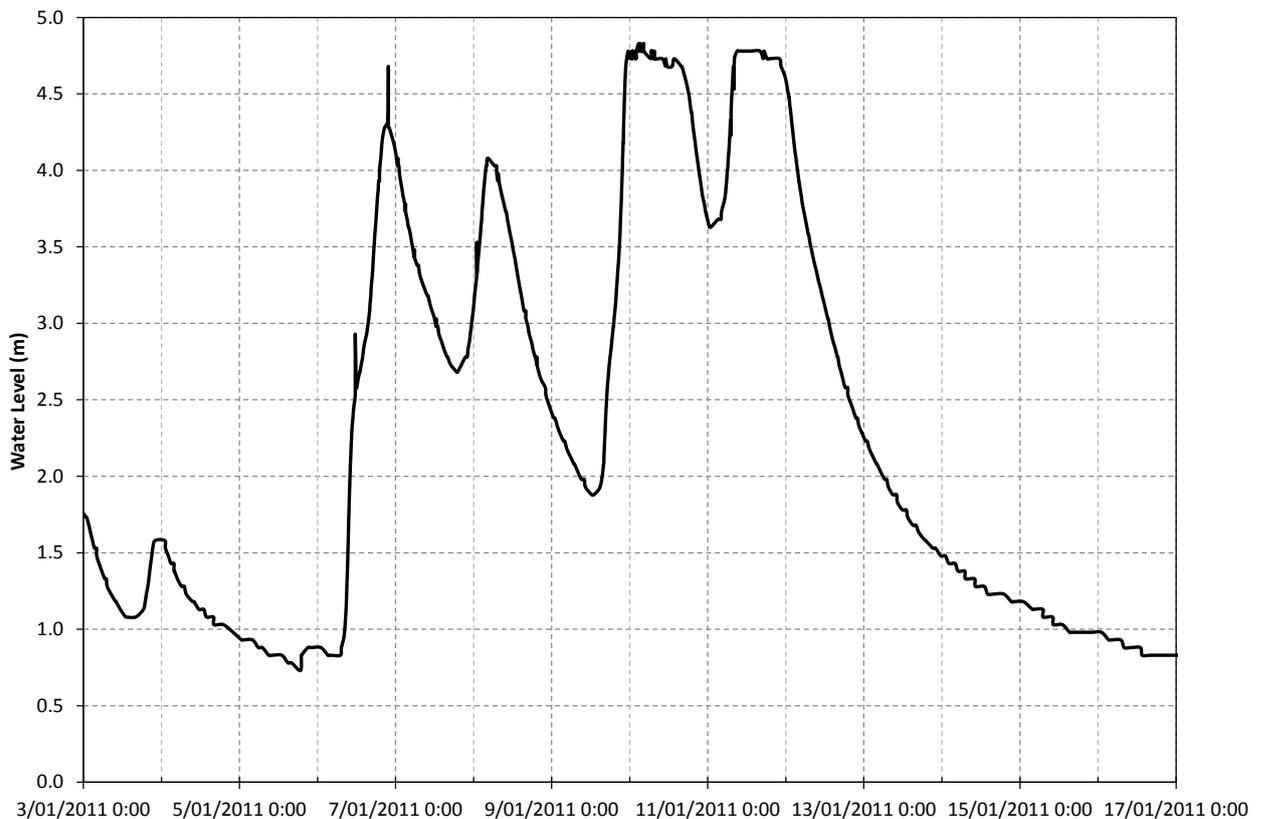


Figure 3.3 Recorded Water Level Hydrograph at Clydesdale Alert, January 2011 Flood Event

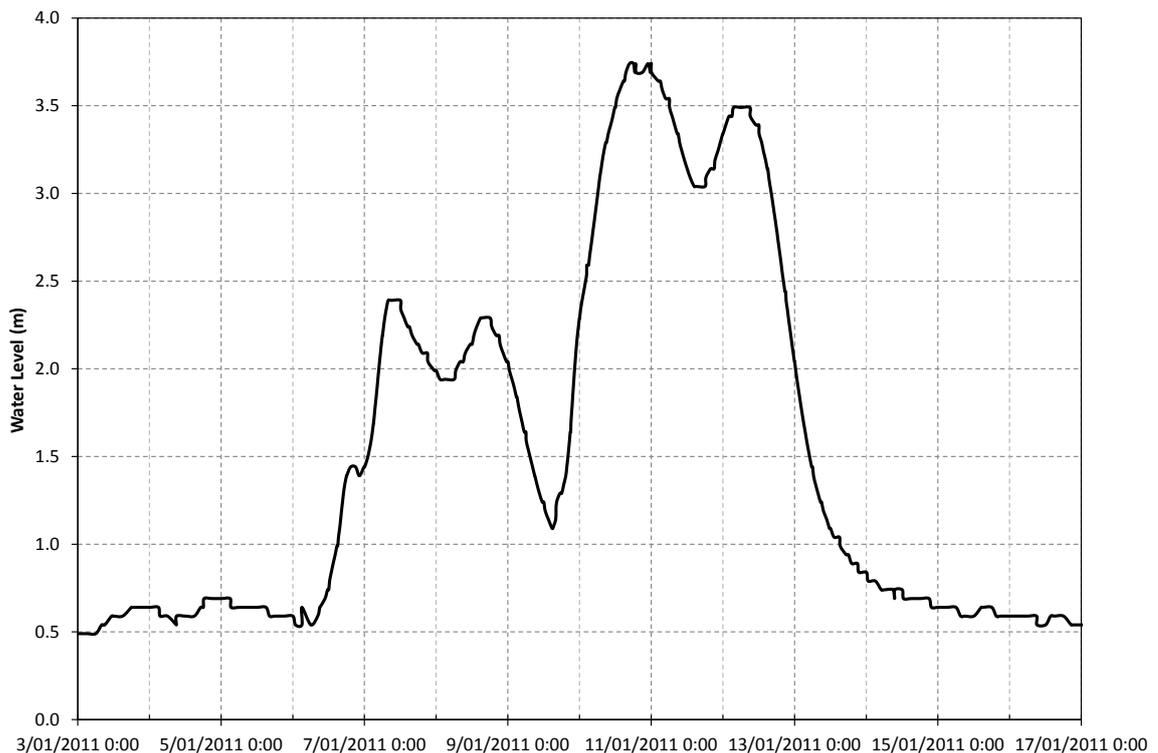


Figure 3.4 Recorded Water Level Hydrograph at Dalby Alert, January 2011 Flood Event

3.3 HYDROLOGIC MODEL

3.3.1 Methodology

Flood discharges within the Myall Creek catchment were estimated using the XP-RAFTS runoff-routing model (XP Software, 2013). The XP-RAFTS model extends from the Great Dividing Range in the north-east to approximately 4 km downstream of Quinalow Township.

The hydrologic and hydraulic models were iteratively calibrated to recorded water levels from the January 2011 flood event in the study area.

3.3.2 XP-RAFTS Model Configuration

Figure 3.5 shows the Myall Creek XP-RAFTS model configuration, consisting of 23 sub-catchments areas totalling 147 km². XP-RAFTS sub-catchment boundaries were delineated using 5m contours where possible, and 50m contours in the upper catchment area. Table 3.2 shows the adopted XP-RAFTS sub-catchment parameters for the Myall Creek catchment.

- The adopted fraction impervious for each sub-catchment was 0% based on the TRC regional planning scheme that shows the vast majority of the catchment is designated 'rural', with a very small portion of the catchment area designated 'township' at Maclagan and Quinalow;
- Average catchment slope was determined from the contours;
- The catchment Manning's 'n' value was used as a calibration parameter for the model, the final value adopted was a uniform catchment Manning's 'n' of 0.065.
- The global storage 'Bx' factor adopted was 1.0.

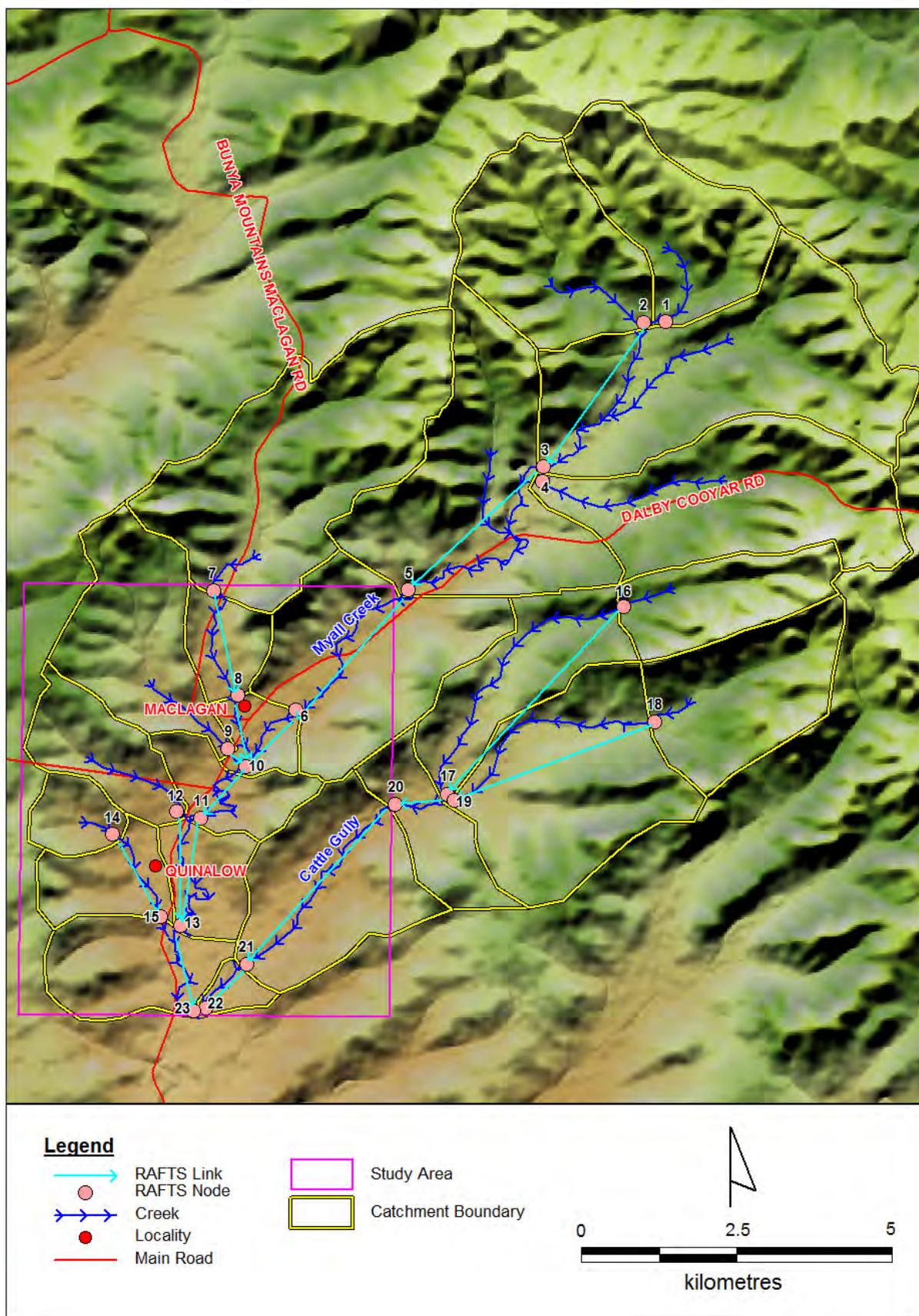


Figure 3.5 XP-RAFTS Model Configuration

Channel routing links have been included in the XP-RAFTS model. The channel routing parameters were developed based on the physical channel characteristics including channel length and slope. The timing of the peak hydrograph at the downstream boundary of the model extent was compared to the timing of the peak hydrographs at the Clydesdale Alert and Dalby Alert to ensure consistency with adopted flood velocities.

Table 3.2 Adopted XP-RAFTS Sub-Catchment Parameters

Sub-Catchment	Catchment Area (ha)	Catchment Slope (%)
1	717	7.9%
2	845	2.9%
3	1,485	2.0%
4	1,134	2.9%
5	1,250	4.9%
6	962	3.2%
7	1,438	3.6%
8	215	5.7%
9	697	3.4%
10	162	2.5%
11	280	3.0%
12	365	3.7%
13	261	5.2%
14	180	2.2%
15	287	4.9%
16	475	3.1%
17	577	1.4%
18	699	1.7%
19	1,047	1.1%
20	333	2.0%
21	785	7.9%
22	74	2.9%
23	449	2.0%

3.3.3 Assignment of Total Rainfalls and Temporal Patterns

Total rainfalls from pluviograph and daily stations were assigned to each sub-catchment based on Thiessen polygons. The nearest available pluviograph temporal pattern (at Cooringa Alert station) was applied to the daily rainfall stations. This approach ensures all the available data are used. Figure 3.2 shows the locations of the available daily and pluviograph rainfall stations within and adjacent to the catchment.

3.3.4 Initial and Continuing Losses

Table 3.3 shows the adopted initial loss and continuing loss for the validation event. These loss rates are based on the recommended design loss rates for Eastern Queensland (Pilgrim, 1998). Note that the flood peak is not overly sensitive to lower initial losses, which would have been expected given the very wet conditions experienced prior to this event. The adopted initial loss removes the pre-storm and pre-burst rainfall only.

Validation Event	Initial Loss (mm)	Continuing Loss (mm/hr)
January 2011	15	2.5

3.4 XP-RAFTS MODEL RESULTS

Figure 3.6 shows the estimated discharge hydrograph at the downstream boundary of the model. It is of note that the peak discharge of 299 m³/s at the downstream boundary occurs at about 2030 hours on 9th January. Based on the recorded times of peak discharge at Clydesdale Alert and Dalby Alert stations (refer Section 3.2.4), this translates to a Myall Creek flood wave velocity of between 0.7 and 1.2 m/s, which is consistent with the routing parameters adopted in the XP-RAFTS model.

Figure 3.7 shows the locations of the inflow hydrographs to the hydrodynamic model described in Section 4. Table 3.4 shows a summary of the peak discharges at each boundary inflow location and at the downstream boundary.

Table 3.4 Peak Discharges at Inflow Hydrograph Locations to Hydrodynamic Model and at the Downstream Boundary

Boundary Location	Type	Peak Discharge (m ³ /s)
5	Total Inflow (External)	129.0
7	Total Inflow (External)	27.1
20	Total Inflow (External)	60.8
Downstream Boundary	Total Outflow	300

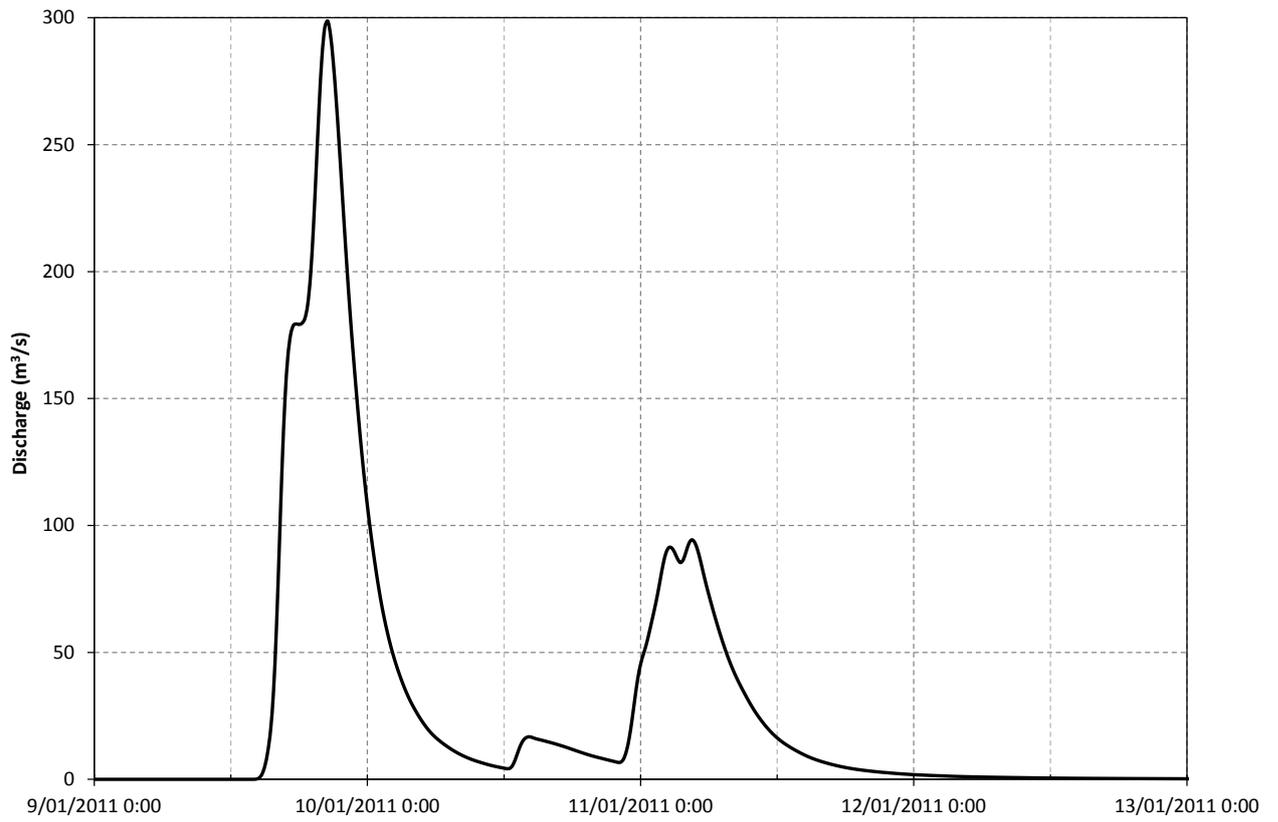


Figure 3.6 Myall Creek Discharge Hydrograph at Downstream Boundary of the XP-RAFTS Model

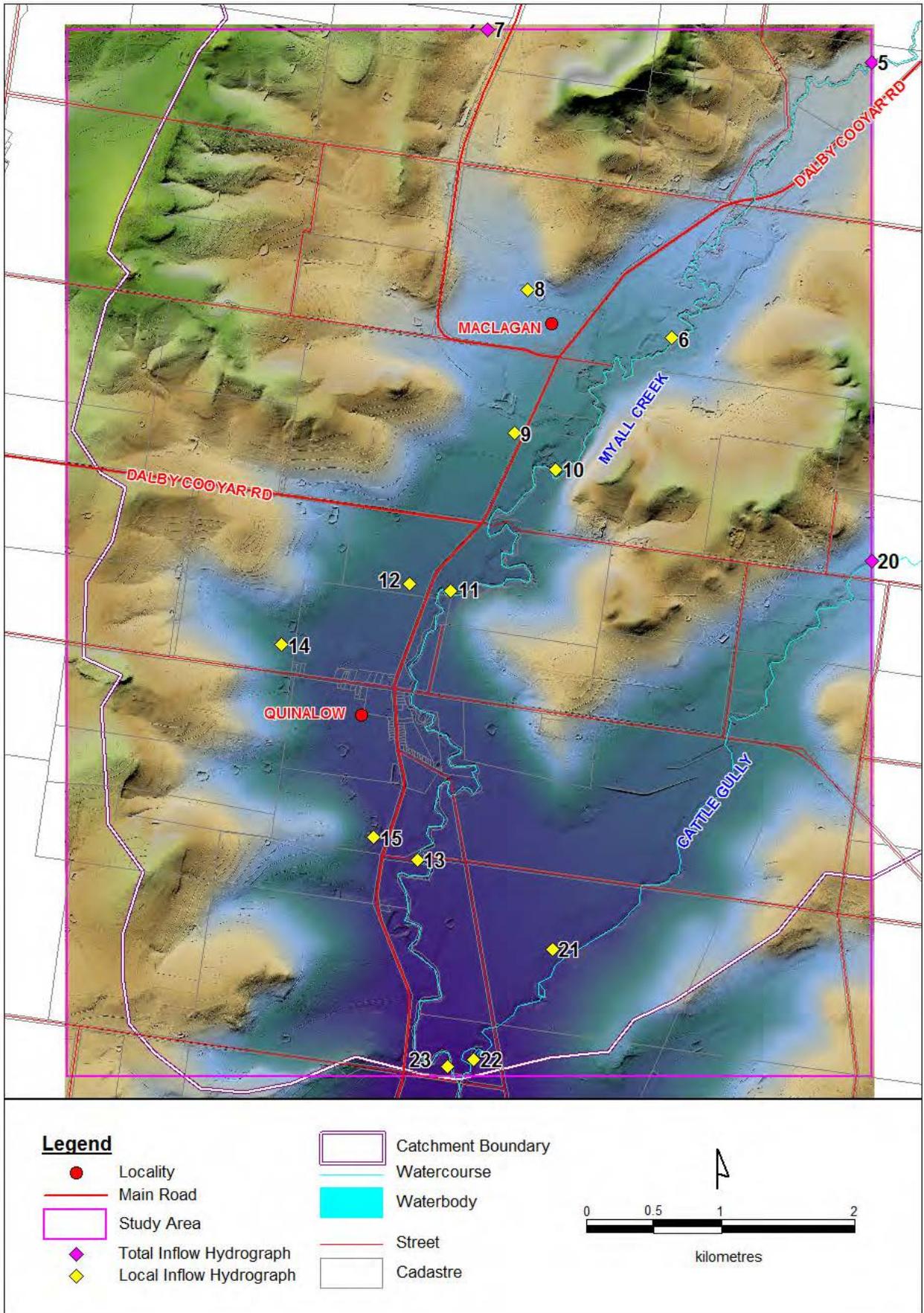


Figure 3.7 Hydrodynamic Model Hydrograph Inflow Locations

4 HYDRODYNAMIC MODEL DEVELOPMENT

4.1 OVERVIEW

The following section documents the development and validation of the hydrodynamic model, selection of key model parameters and assumptions made. The hydrodynamic model was developed in the MIKE FLOOD Release 2012 (Service Pack 2), which was the most recent version available at the time of the project. MIKE FLOOD is a software program that allows coupling of a MIKE 11 (1D) model and a MIKE 21 (2D) model to run together in parallel. The fundamental principle of MIKE FLOOD is that features smaller than the MIKE 21 grid resolution (e.g. small channels and structures) can be represented in MIKE 11, with linkages (couples) that transfer water levels and discharges between MIKE 11 and MIKE 21 at each time step. The MIKE FLOOD model schematisation (DHI, 2013) was agreed with TRC prior to the commencement of model development.

4.2 MIKE 21 MODEL

The 2D model domain for Maclagan and Quinalow extends approximately 3.2 km upstream of the Bismark Street crossing along Myall Creek to approximately 6.5 km downstream of the crossing as shown in Figure 4.1. The eastern, western and northern model extents match the extent of the DEM provided by TRC. The rectangular model domain is approximately 6 km by 8 km.

4.2.1 Bathymetry

The MIKE 21 model incorporates a detailed elevation model (bathymetry) of the ground surface. The DEM used in this model was created from the 1 m DEM supplied by TRC; the DEM was then resampled to a 5 m grid resolution.

Features of the floodplain likely to influence the flow of floodwaters were included in the 2D model. This included appropriate discretisation of elevated embankments, levees and roads in a form that ensures correct representation of the features both for smaller floods, where the influence on flow behaviour has been observed, and for more extreme events, where the feature may be overwhelmed. Correct and appropriate representation of these features is paramount for the model to correctly extrapolate flood behaviour for extreme events.

The crest levels of major roads as well as levees in Quinalow (Figure 4.2) were incorporated into the model using the following steps:

- Digitise polylines along the crown of roads and levees;
- Create a 10 m buffer around the digitised polylines;
- Extract the elevations within the buffer from the 1 m DEM;
- Convert the extracted raster to points with 1 m spacing;

- Interpolate the 1 m points to a 5m raster by selecting the maximum elevation within each 5m by 5m cell; and
- Update the 'base' bathymetry with this raster.

Small flow structures and crossings on secondary flow paths, including the culverts on Reimers Road, were implemented as they were represented in the source DEM data. This implies that most small culverts and structures were assumed to be 100% blocked during a flood, thus producing a conservative estimate of the known flood locations.

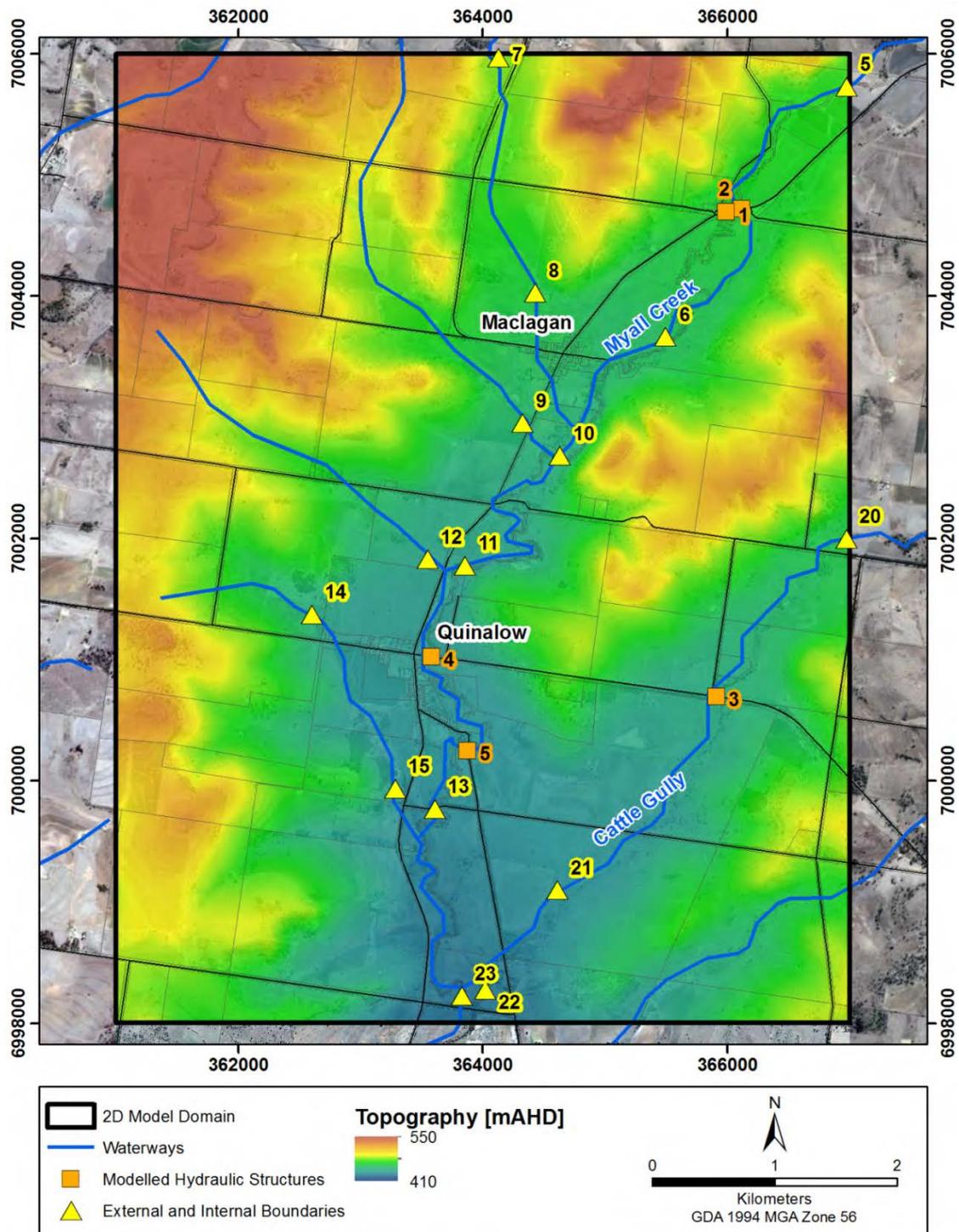


Figure 4.1 MIKE FLOOD Model Setup

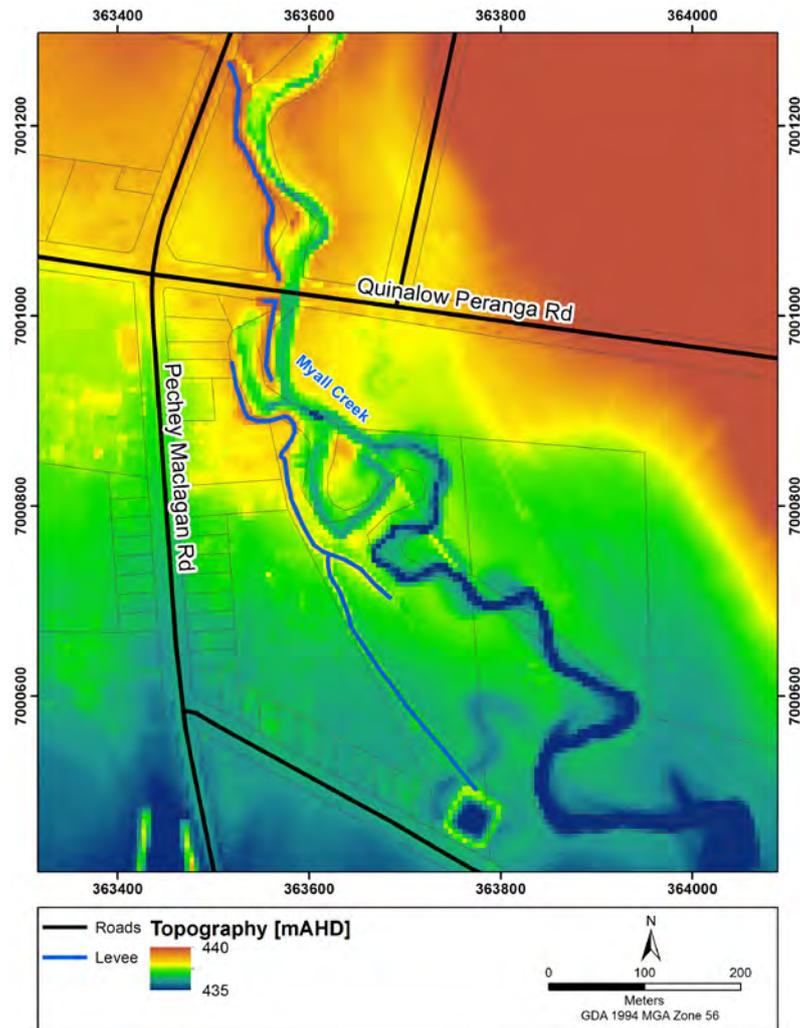


Figure 4.2 Levee Implementation

4.2.2 Hydraulic Roughness

MIKE21 models require the specification of hydraulic roughness to be applied in each cell, either as a constant value or in the form of a map (grid) of roughness values. Note that MIKE21 uses a 'Manning's 'M' number', which is the reciprocal value of Manning's 'n' coefficient (Manning's 'M' = 1/Manning's 'n'). A spatially distributed roughness map for the model domain was created based on the land uses classes provided by TRC as well as vegetation coverage identified from the aerial photography, also supplied by TRC. Four distinct land use classes were identified within the study area. The adopted hydraulic roughness values (Manning's 'n' and associated 'Manning's 'M' number') for each class are shown in Table 4.1. These values were based on DHI's previous experience in Queensland, whilst also taking into account Australian Rainfall and Runoff (ARR) Revision Project's valid Manning's 'n' ranges for different land use types (Smith and Wasko, 2012). It should be noted that the adopted Manning's 'n' value for 'Developed Areas' is slightly lower than the ARR recommended range of roughness values for this land use type. This is due to the coarse delineation of 'Developed Areas' based on land use classes, resulting in a Manning's 'n' value of 0.083 being applied to buildings as well as some open pervious areas. The spatial distribution of roughness is presented in Figure 4.3.

Table 4.1 Adopted Hydraulic Roughness Values in MIKE FLOOD

Land Use	Manning's 'n'	Range of Manning's 'n' Values ^a	Manning's 'M' number
Floodplain	0.04	0.03 - 0.05	25
Roads	0.025	0.02 - 0.03	40
Developed Areas	0.083	0.1 - 0.2	12
Waterways	0.033	0.02 - 0.04	30

Notes: ^a (Smith and Wasko, 2012)

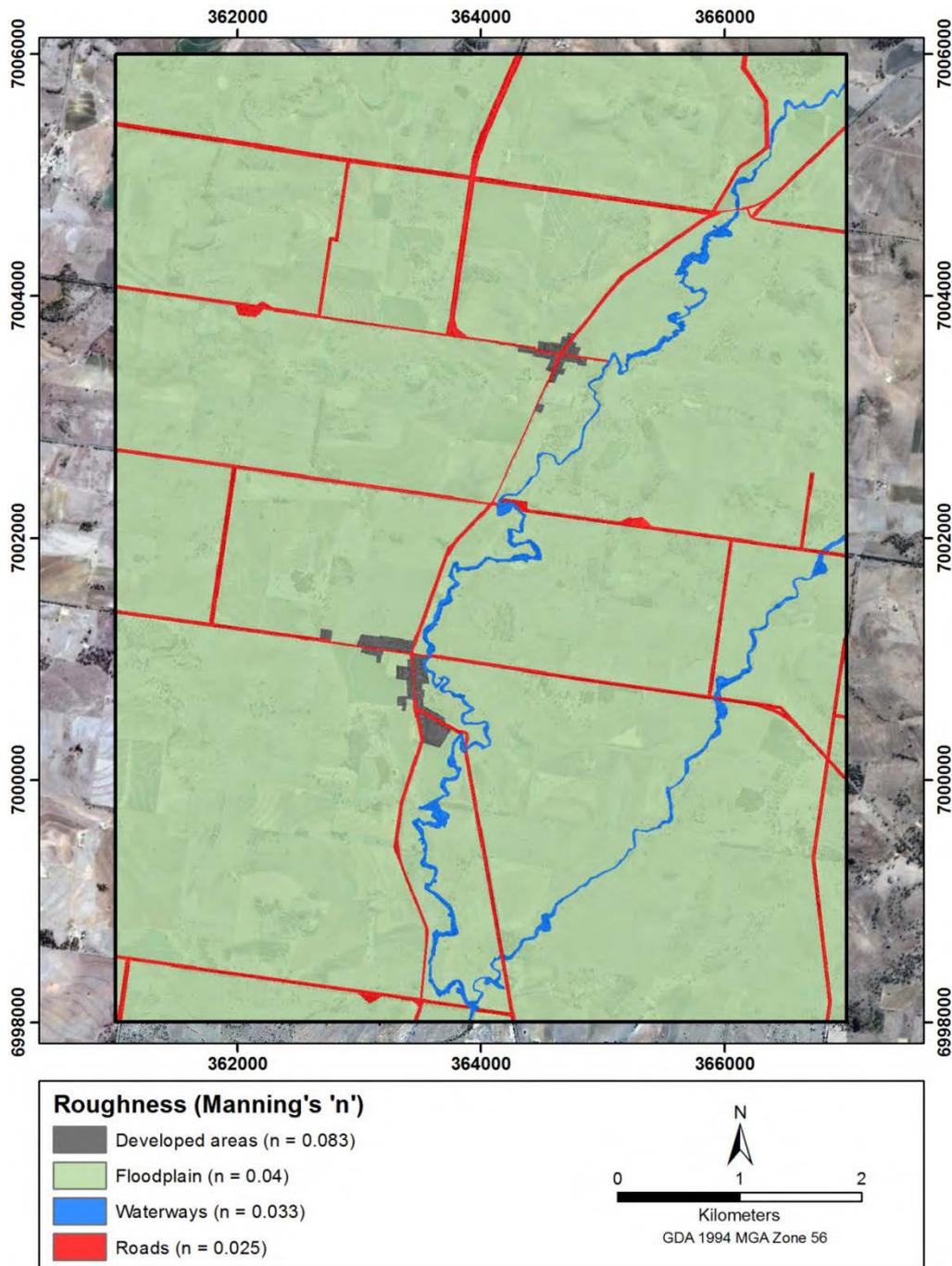


Figure 4.3 Spatial Distribution of Roughness

4.2.3 Flooding and Drying Depths

In the MIKE FLOOD Release 2012, there is a new 'Inland Flooding' option available which results in much improved mass balances in urban flooding and floodplain applications. Continuity is fully preserved during the flooding and drying process, as the water depths at the points which are dried out are saved and then reused when the point becomes flooded again. A flooding depth of 0.05 m and a drying depth of 0.02 m were adopted in this study.

4.2.4 Eddy Viscosity

Eddy viscosity is used to represent sub-grid scale turbulence to provide the modeller with the opportunity to enhance or retard the natural generation of flow eddies in the solution scheme for the purpose of matching observed flow phenomena. A velocity-based eddy viscosity formulation was applied and is recommended in floodplain applications.

Values for eddy viscosity can be calculated using a number of empirical formulas related to grid size and time step. Selecting an eddy viscosity value that is too high will result in the modelled flow having a more uniform velocity distribution tending to distribute more of the total flow to the floodplain. Selecting an eddy viscosity value that is too low can result in significant variability in the velocity field, formation of large modelled eddies in areas of no physical manifestation of this hydraulic phenomenon and contribute to model instability.

In this study, the eddy viscosity was set to 0.5 m²/s, which is consistent with the model resolution and based on DHI's previous experience with selection of secondary model parameters. At a small number of locations an eddy viscosity of 5 m²/s was used to improve model stability.

4.2.5 Model Boundaries

External model boundaries were specified at three inflow locations to the model (see Figure 4.1) and at the downstream exit point. Catchment flows from the XP-RAFTS model were applied to the MIKE 21 model at the three external boundaries as well as twelve internal boundaries (source points). Source points with large peak discharges were split equally and applied over a number of grid cells to enhance model stability.

A Q-h rating was used at the downstream model boundary. The rating curve was derived from a cross-section extracted from the 1 m DEM at the location of the MIKE 21 downstream boundary. The cross-section width was set to match the width of the MIKE 21 boundary. An average bed slope of 3.3 m/km and a Manning's 'n' of 0.04 were used to derive the rating curve.

4.2.6 Time Step and Save Step

A 0.5 second time step was used in the Maclagan/Quinalow model based on Courant number considerations. The save step in MIKE 21 was set to 15 minutes.

4.3 MIKE 11 MODEL

4.3.1 Network and Structures

The MIKE 11 network consists of five short branches (up to 30m) used to model structures with potential significant hydraulic impact. Structure dimensions were implemented based on the

measurements taken during the site visit. Invert levels of structures and their waterway length were estimated from the 1 m DEM and aerial photography, respectively. Bridge railings have not been considered in the structure definition, i.e. it was assumed no blockage of rails occurred during the validation flood event.

4.3.2 Cross-Sections

The cross-sections defined at the upstream and downstream ends of each MIKE 11 branch were extracted from the 1 m DEM. Cross-sections upstream and downstream of structures were enlarged if they were smaller than the structure dimensions. This is necessary to ensure a realistic head loss across the structure.

4.3.3 Time Step and Save Step

When MIKE 11 and MIKE 21 models are coupled, MIKE 11 is forced to use the same time step as MIKE 21. The MIKE 11 results were saved every 5 minutes.

4.4 MIKE FLOOD MODEL

A total of five coupling points were implemented in the MIKE FLOOD model. The structures and couple types are listed in Table 4.2. Photographs of the structures taken during the site visit are shown in Appendix A. Structures with a waterway length greater than two MIKE 21 grid cells (10m) were modelled using the 'Standard' link type, where structure submergence and overtopping is modelled in MIKE 11 and MIKE 21, respectively. In a 'Structure' link the upstream and downstream linked MIKE 21 cells must be adjacent. This link type was therefore applied to structures with a waterway length of 10m or less. Structure submergence and overtopping are both modelled in MIKE 11 for this link type.

Table 4.2 Structures Implemented in MIKE FLOOD

Structure	Link Type	Modelled Structure	Dimensions
1. Dalby Cooyar Rd (near Corner of Dalby-Cooyar Road and Woodleigh Maclagan Road)	Standard	Culvert	4 box culverts Width = 2.7m, Height = 1.5m
2. Dalby Cooyar Rd (near Corner of Dalby-Cooyar Road and Woodleigh Maclagan Road)	Standard	Culvert	8 box culverts Width = 2.4m, Height = 0.8m 7 box culverts Width = 2.46m, Height = 1m
3. Quinalow Peranga Rd (near corner of Quinalow-Peranga Road and Kanowskis Road)	Structure	Culvert/weir	4 circular culverts Diameter = 1.2m
4. Quinalow Peranga Rd (Near Quinalow Hotel on Quinalow-Peranga Road)	Structure	Bridge	2 bridge span of 8.67m Pier width = 0.6m
5. Old Rosemount Rd	Structure	Culvert/weir	2 circular culverts Diameter = 0.45m

4.4.1 Standard/Structure Link Options

The standard/structure link parameters adopted in the MIKE FLOOD model are summarised in Table 4.3. The momentum factor was set to 1 at all explicit links. In general, an exponential smoothing factor of 0.2 was adopted; however, 0.1 was adopted at one structure to promote stability.

Table 4.3 **Adopted Standard/Structure Link Parameters**

Parameter	Value/Option
Momentum factor	1
Extrapolation factor	0
Add/Replace Flow	Replace
Depth Adjustment	Yes
Exponential Smoothing Factor	0.1/0.2

5

ASSESSMENT OF MODEL PERFORMANCE

The XP-RAFTS and MIKE FLOOD models were validated for the January 2011 flood event using a joint calibration approach. The fit between modelled and observed spot levels and known flood locations is summarised in Table 5.1 and presented in Appendix C.

Table 5.1 Measured and Modelled Flood Levels

ID	Town	Location	Observed Flood Level (mAHD)	Modelled Flood Level (mAHD)	Difference (m)
1	Maclagan	Bismark Street (flood point right side of causeway looking downstream)	Flooded	Flooded	-
2	Maclagan	Flood point left side of causeway looking downstream	Flooded	Flooded	-
3	Maclagan	4282 Dalby-Cooyar Road (front of property near road)	452.68	451.51	-1.17
4	Quinalow	Quinalow Hotel (steps near front of hotel)	438.65	438.61	-0.04
5	Quinalow	Quinalow Hotel (steps near back of hotel)	438.62	438.68	0.06
6	Quinalow	9 Progress Street (front of property)	437.35	437.45	0.10
7	Quinalow	9 Progress Street (back of property)	437.53	437.41	-0.12
8	Quinalow	13 Progress Street	436.90	437.04	0.14
9	Quinalow	15 Progress Street	436.85	436.94	0.09
10	Quinalow	23 Progress Street (front of property)	Flooded	Flooded	-
11	Quinalow	23 Progress Street (side of property)	Flooded	Flooded	-
12	Quinalow	23 Progress Street (tree line next to property)	Flooded	Flooded	-

All locations known to have been inundated during the January 2011 flood have been reproduced by the model. All differences between measured and observed water levels are within the targeted ± 0.25 m except one outlier where the model underestimates the flood level by 1.17 m. This spot level has been observed at the front of the property at 4282 Dalby-Cooyar Rd which is located downstream of a dam, see Figure 5.1. It is unlikely that the observed flood level was caused by backwater effects from Myall Creek. Rather it is believed the discrepancy between modelled and observed flood levels may be the result an erroneous reading or due to a localised runoff process not being captured in the modelling. Given the magnitude of the discrepancy it is most likely to be an erroneous reading. This is also supported by the fact that the modelled flood extent matches the two known flood locations upstream of the outlier (see

black circles in Figure 5.1) very well and the differences between modelled and observed water levels downstream of the outlier are all within ± 0.15 m.



Figure 5.1 Location of Outlier

6 DESIGN FLOOD ESTIMATION

6.1 ESTIMATION OF DESIGN DISCHARGES

6.1.1 Overview

The validated XP-RAFTS model was used to estimate design flood discharges in Myall Creek at Maclagan and Quinalow. Minor changes to the downstream boundary were made to the validation model to ensure model stability for the large design events (i.e. greater than 200 year ARI). These changes are detailed in Section 6.1.2. The XP-RAFTS model design discharge estimates were compared against Rational Method estimates at 4 sub-catchments for consistency.

The following sections detail the design rainfall data (IFD data, temporal patterns, areal reduction factors, rainfall spatial distribution and design rainfall losses) that were adopted for the Myall Creek catchment upstream of the Maclagan-Quinalow area. Design flood discharge hydrographs were estimated for a range of storm durations up to 12 hours for the 2, 5, 20, 20, 50, 100, 200 and 500 year Average Recurrence Interval (ARI) and the Probable Maximum Precipitation (PMP) events.

6.1.2 Changes to Validation Model for Design Flood Estimation

The downstream model boundary condition was changed from a Q-h rating curve to a constant water level boundary for the two largest design events modelled (the 500 year ARI, 4°C increase by 2100 climate change scenario and the PMF event) to aid model stability. The constant water levels were set to 425.0 mAHD and 428.5 mAHD for the 500 year ARI 2100 climate change scenario and the PMF event, respectively. These levels were based on the Q-h rating curve and the total flows applied in the model. A sensitivity analysis of the Maclagan-Quinalow model to the assumed downstream boundary level revealed that the modelled flood levels in both towns are insensitive to the adopted downstream water level boundary.

6.1.3 Design Rainfalls for Events up to 100 Year ARI

Rainfall Depth Estimation

Design rainfall intensities for storms of varying durations (15 minutes to 12 hours) for all ARI events up to and including the 100 year ARI were determined at the centroid of the catchment using the methodology given in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim, 1998). The average rainfall intensities for each duration and ARI were then converted to total rainfall depths. Adopted design rainfall intensities are provided in Table 6.1.

Table 6.1 Intensity-Frequency-Duration Data (mm/hour)

Duration (Hours)	Average Recurrence Interval (years)					
	2	5	10	20	50	100
0.25	74	93	105	122	144	163
0.5	53	66	74	85.3	101	113
1	35.1	43.4	48.5	55.8	65.6	73.3
1.5	26.8	33.0	36.8	42.1	49.4	55.0
2	21.8	26.8	29.9	34.2	40.1	44.7
3	16.2	19.8	22.1	25.2	29.5	32.8
6	9.6	11.7	13	14.8	17.3	19.2
9	7.09	5.67	9.63	11.0	12.8	14.3
12	5.73	7.00	7.77	8.86	10.3	11.5

Areal Reduction Factors

Areal reduction factors (ARF) for the catchment were calculated from regional data using the CRC-Forge method (DNRM, 2005). An ARF of 0.926 was adopted for durations less than 24 hours.

Temporal Patterns

Temporal patterns for design storm events for durations from 15 minutes to 12 hours for design events up to and including the 100 year ARI were adopted from *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim, 1998). The modelled catchment is within the transition zone between Zone 2 and Zone 3. The temporal patterns for Zone 3 were adopted because the nature of the weather systems that result in large floods in the study area tend to be the rainfall from ex-tropical cyclone activity.

Spatial Distribution

The design rainfalls for durations from 15 minutes to 12 hours for all ARIs up to and including the 100 year ARI were estimated at the centroid of the catchment using standard procedures (Pilgrim, 1998), and assumed to be uniform across the catchment.

Rainfall Losses

The initial (IL) / continuing loss (CL) method of accounting for rainfall losses was adopted for this study. Book II, Section 3 of *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim, 1998) recommends design loss rates of 15-35mm initial loss, and 2.5mm/h continuing loss for eastern Queensland up to and including the 100 year ARI event. An initial loss of 15mm has been adopted for all ARI's up to the 100 year ARI. The recommended continuing loss of 2.5mm/h has been adopted for all events up to the 100 year ARI. This is consistent with the initial loss of 15mm adopted for the January 2011 model validation event (refer Section 3.3.4), and provides results consistent with the Rational Method.

6.1.4 Design Rainfalls for 200 and 500 Year ARI Events

Rainfall Depth Estimation

Design rainfall depths for the 200 and 500 year ARI events were estimated using the approach recommended in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim, 1998). CRC-Forge rainfall (DNRM, 2005) was also considered for design rainfalls for the 200 and 500 years ARI events. The CRC-Forge rainfall intensities were found to be between 5-11% less than the ARR rainfall intensities. The higher ARR rainfall intensities were adopted to produce conservative discharge estimates. The adopted design rainfalls are provided in Table 6.2.

Table 6.2 Intensity-Frequency-Duration Data (mm/hour)

Duration (hours)	Average Recurrence Interval (years)	
	200	500
0.25	182	208
0.5	125	143
1	82	94
1.5	61	69
2	49	56
3	36	41
6	21	30
9	16	18
12	13	14

Areal Reduction Factors

Similar to the methodology for design rainfall events up to the 100 year ARI, an areal reduction factor of 0.926 for durations less than 24 hours has been adopted, which was calculated from regional data using the CRC-Forge method (DNRM, 2005).

Temporal Patterns

The temporal patterns for the 200 and 500 year ARI design events for all durations up to and including 6 hours were obtained from The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BOM, 2003).

Spatial Distribution

The design rainfalls for durations from 15 minutes to 12 hours for the 200 and 500 year ARI events were estimated at the centroid of the catchment using standard procedures (Pilgrim, 1998), and assumed to be uniform across the catchment.

Rainfall Losses

The initial rainfall loss for the 200 and 500 year ARI design events was interpolated between the 100 year ARI and PMP design event ILs using the approach recommended in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim, 1998). The continuing loss rate has not been reduced. The initial loss and continuing loss rates adopted for the 200 and 500 year ARI design events are 5 mm and 2.5 mm/h respectively.

6.1.5 Probable Maximum Precipitation (PMP) Rainfall Estimates

Rainfall Depth Estimation

PMP rainfall depth estimates for durations up to 6 hours were obtained using the methodology given in The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BOM, 2003). The notional AEP of the estimated PMP design event is 1.5×10^{-7} (or 1 in 7,000,000) (BOM, 2003).

The PMP initial mean rainfall depths and intensities (unadjusted) for durations up to 6 hours are shown in Table 6.3. Design spatial distribution was then applied to the values shown in Table 6.3 using the ellipse methodology described in BOM (2003). The centroid of each sub-catchment was used to obtain the individual sub-catchment PMP estimates from the overall PMP estimate.

Table 6.3 PMP Estimates - Initial Mean Rainfall Depths and Intensities

Duration (hours)	PMP Estimate*	
	mm	mm/h
0.25	130	520
0.5	190	380
1	290	290
1.5	370	247
2	430	215
3	530	177
6	690	115

Notes: *Initial Mean Rainfall Depth

Areal Reduction Factors

Areal reduction factors are incorporated in the BOM (2003) PMP rainfall estimation methodology, and as such no ARFs were applied to the rainfalls estimated for the catchment using this method.

Temporal Patterns

Temporal patterns for the PMP design storm events for durations up to 6 hours were obtained from The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BOM, 2003).

Spatial Distribution

Spatial distribution of rainfall is accounted for in the BOM (2003) PMP rainfall estimation methodology.

Rainfall Losses

Minimum IL and CL values of 0 mm and 1 mm/h respectively were adopted for the PMP design event estimation as recommended in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Pilgrim, 1998).

Terrain Category

A roughness fraction of 1 (i.e. 100% roughness) was adopted, based on the topographical data available.

Catchment Elevation Adjustment

An elevation adjustment factor of 1.0 was adopted based on the mean elevation of the catchment.

Moisture Adjustment

A moisture adjustment factor of 0.81 was adopted based on guidelines given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BOM, 2003).

6.1.6 Design Discharges

Design Event Critical Duration

Table 6.4 shows the predicted Myall Creek critical storm durations for the various design events adopted for hydraulic modelling.

Table 6.4 Design Event Critical Durations

Event ARI (Years)	Critical Storm Duration
2	3 hours
5	3 hours
10	3 hours
20	3 hours
50	3 hours
100	3 hours
200	3 hours
500	2 hours
PMF	3 hours

100 Year ARI Design Event

Table 6.5 shows the XP-RAFTS model predicted design peak discharge for the 100 year ARI, critical duration (3 hours) event at key locations.

Table 6.5 XP-RAFTS Model Predicted Design Discharges at Key Locations, 100 year ARI, 3 hour Event

Boundary Location*	Inflow Type	Peak Discharge (m ³ /s)
5	Total (External)	250
7	Total (External)	67.5
20	Total (External)	122
Downstream Boundary	Total Catchment Outflow	654

Notes: * Refer Figure 3.7.

6.1.7 Design Flow Comparison Using Alternative Methods

Design discharges estimated using the XP-RAFTS model were compared against design discharges estimated using the Rational Method at 4 locations in the Myall Creek catchment (refer Figure 3.5 for the locations):

- Sub-catchment 8 (local flows);
- Sub-catchment 12;
- Sub-catchment 14; and
- Sub-catchment 16.

Table 6.6 shows the comparison of the XP-RAFTS model and Rational Method peak discharges. Results indicate differences of no more than 20% for design events up to the 100 year ARI event. Rational Method calculations are shown in Appendix D.

Table 6.6 XP-RAFTS Model and Rational Method Peak Discharges Comparison (m³/s)

Location	Design Storm Event (ARI)					
	2	5	10	20	50	100
<u>Sub-catchment 8</u>						
XP-RAFTS	4.9	7.4	9.0	11.4	14.1	16.8
Rational Method	4.8	7.0	8.5	10.6	14.2	16.9
% Difference	1%	5%	5%	7%	<1%	-1%
<u>Sub-catchment 12</u>						
XP-RAFTS	5.9	9.5	11.8	15.0	19.3	22.9
Rational Method	6.4	9.3	11.2	13.8	18.3	21.7
% Difference	-8%	2%	5%	9%	5%	5%
<u>Sub-catchment 14</u>						
XP-RAFTS	2.7	4.2	5.3	6.8	8.7	10.4
Rational Method	3.4	4.8	5.8	7.1	9.4	11.1
% Difference	-20%	-14%	-8%	-5%	-7%	-7%
<u>Sub-catchment 16</u>						
XP-RAFTS	6.7	10.6	13.3	17.0	22.1	26.3
Rational Method	8.4	12.3	14.8	18.4	24.9	29.7
% Difference	-20%	-14%	-10%	-8%	-11%	-12%

6.2 ESTIMATION OF DESIGN FLOOD LEVELS, DEPTHS AND VELOCITIES

6.2.1 Methodology

The validated MIKE FLOOD hydrodynamic model was used to estimate design peak flood surface elevation, peak water depths and velocities in the vicinity of Maclagan and Quinalow for the 2, 5, 10, 20, 50, 100, 200 and 500 year ARI and PMF design events. The validated model was modified to reflect the design event inflows at the external and internal boundaries.

All other model parameters remained unchanged, including bathymetry, hydraulic roughness, flooding and drying depths, eddy viscosity, downstream model boundary, time step and save step; and hydraulic structure setup.

6.2.2 Design Flood Levels and Extents

Maps of predicted peak flood levels, velocities and flood depths under existing catchment conditions for the 10, 50, 100, 500 year ARI and PMF design events are provided in Appendix E. Hazard category and flood hydraulic category maps for the 100 year and PMF events for existing catchment conditions are provided in Appendix F.

Table 6.7 shows predicted flood levels and discharges for the various design events at selected representative locations in the study area, shown in Figure 6.1. Simulated flood levels and discharges for the January 2011 validation event is also shown for comparison. The key locations are:

- A: Quinalow-Peranga Road at Myall Creek crossing, near Quinalow township;
- B: Bismarck Street at Myall creek crossing, near Maclagan township;
- C: Hess Road at Myall Creek Tributary crossing, near the intersection of Bunya Mountains-Maclagan Road;
- D: Intersection of Dalby-Cooyar Road and Woodleigh-Maclagan Road, near Myall Creek crossing;
- E: Quinalow-Woodleigh Road at Cattle Gully crossing; and
- F: Quinalow-Peranga Road at Cattle Gully crossing.

Table B2 in Appendix B shows the predicted affluxes at hydraulic structures.

The design event modelling results show that:

- The design flood levels in Quinalow are relatively insensitive to adopted design discharges. The 500 year ARI design discharge at Quinalow is 7 times larger than the 2 year ARI discharge; however the peak flood level is only 0.7 m higher;
- The design flood levels in Maclagan are more sensitive to adopted design discharges than at Quinalow. The 500 year ARI design discharge at Maclagan is also 7 times larger than the 2 year ARI discharge; however the peak flood level is 1.2 m higher; and
- The majority of road crossings in the study area have low flood immunity; four of the five major road crossings in the model extent are overtopped in a 2 year ARI design event. The 'Dalby Cooyar Road 2' crossing has flood immunity up to a 500 year design event.
- The levees in Quinalow (see Figure 6.2 for location) protect parts of the town from flooding for events up to a 2 year ARI event. However the area on the corner of Quinalow Peranga Road and Pechey Maclagan Road gets flooded even in a 2 year ARI event due to the Quinalow Peranga Road bridge being overtopped.

- The levee behind properties on Daly Street and Pechey Maclagan Road is overtopped in a 5 year ARI event, see Figure 6.2. This causes the majority of the properties on Daly Street as well as properties near the corner of Pechey Maclagan Road and Daly Street to become inundated.

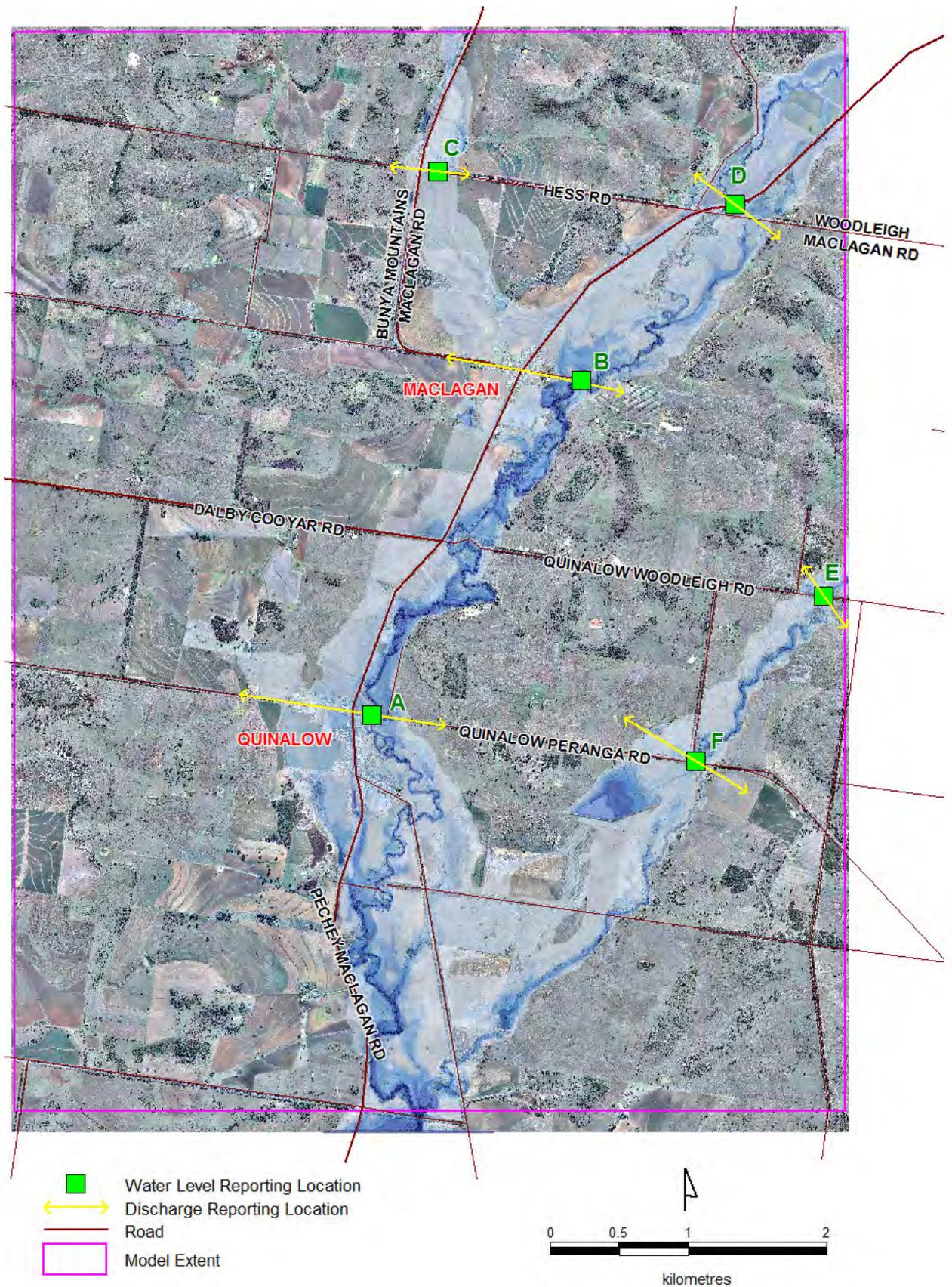


Figure 6.1 Design Flood Level and Discharge Reporting Locations

Table 6.7 Predicted Design Flood Levels and Discharges at Reporting Locations, including Validation Event Simulated Design Flood Levels and Discharges¹

Event	A: Quinalow-Peranga Rd at Myall Ck Crossing		B: Bismark St, Maclagan at Myall Ck Crossing		C: Hess Rd at Myall Ck Tributary Crossing		D: Intersection of Dalby-Cooyar Rd & Woodleigh-Maclagan Rd		E: Quinalow-Woodleigh Rd at Cattle Gully Crossing		F: Quinalow-Peranga Rd at Cattle Gully Crossing	
	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)
January 2011 (Validation Event)	439.28	198	452.65	174	471.54	27	463.72	129	458.02	61	447.15	60
2 year ARI	439.10	108	452.27	90	471.46	16	463.62	63	457.87	29	446.91	29
5 year ARI	439.22	171	452.54	144	471.53	26	463.68	101	457.97	47	447.07	47
10 year ARI	439.30	213	452.67	181	471.58	32	463.71	125	458.02	60	447.15	60
20 year ARI	439.38	271	452.80	231	471.63	42	463.75	159	458.08	77	447.23	77
50 year ARI	439.49	361	452.97	304	471.68	56	463.80	208	458.15	102	447.32	101
100 year ARI	439.55	438	453.09	366	471.71	67	463.84	250	458.19	123	447.39	122
200 year ARI	439.67	601	453.30	501	471.77	93	463.93	341	458.28	170	447.46	169
500 year ARI	439.72	721	453.45	602	471.80	109	464.00	416	458.33	198	447.52	197
PMF	441.19	5,037	455.88	4,183	472.40	827	465.13	2,571	459.34	1,496	448.42	1,497

Table 6.8 Sensitivity Analysis Results, Predicted Design Flood Levels and Discharges at Reporting Locations

Event	A: Quinalow-Peranga Rd at Myall Ck Crossing		B: Bismark St, Maclagan at Myall Ck Crossing		C: Hess Rd at Myall Ck Tributary Crossing		D: Intersection of Dalby-Cooyar Rd & Woodleigh-Maclagan Rd		E: Quinalow-Woodleigh Rd at Cattle Gully Crossing		F: Quinalow-Peranga Rd at Cattle Gully Crossing	
	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)
100 year ARI, Plus 30% Flow	439.64	573	453.27	477	471.76	87	463.91	324	458.26	159	447.44	159
100 year ARI, Minus 30% Flow	439.42	296	452.86	255	471.65	47	463.76	175	458.10	86	447.27	85
100 year ARI, Plus 30% Roughness	439.59	428	453.21	363	471.75	67	463.88	249	458.23	123	447.38	122
100 year ARI, Minus 30% Roughness	439.51	441	453.03	367	471.69	67	463.83	250	458.15	123	447.40	122
100 year ARI, 50% Blockage	439.67	438	453.09	366	471.71	67	463.85	250	458.19	123	447.46	122

Table 6.9 Climate Change Scenario Results, Predicted Design Flood Levels and Discharges at Reporting Locations

Event	A: Quinalow-Peranga Rd at Myall Ck Crossing		B: Bismark St, Maclagan at Myall Ck Crossing		C: Hess Rd at Myall Ck Tributary Crossing		D: Intersection of Dalby-Cooyar Rd & Woodleigh-Maclagan Rd		E: Quinalow-Woodleigh Rd at Cattle Gully Crossing		F: Quinalow-Peranga Rd at Cattle Gully Crossing	
	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)	Flood Level (mAHD)	Discharge (m ³ /s)
100 year ARI, 2050 horizon	439.61	509	453.19	424	471.74	78	463.88	289	458.23	143	447.43	142
100 year ARI, 2070 horizon	439.63	546	453.23	453	471.75	83	463.90	308	458.25	154	447.43	153
100 year ARI, 2100 horizon	439.64	584	453.28	485	471.76	89	463.92	328	458.27	165	447.45	165
200 year ARI, 2050 horizon	439.71	678	453.39	564	471.79	103	463.97	387	458.31	187	447.50	187
200 year ARI, 2070 horizon	439.73	724	453.45	602	471.80	109	464.00	412	458.33	199	447.52	198
200 year ARI, 2100 horizon	439.76	769	453.49	641	471.81	115	464.02	438	458.35	212	447.54	210
500 year ARI, 2050 horizon	439.78	815	453.54	680	471.82	122	464.04	465	458.37	224	447.56	222
500 year ARI, 2070 horizon	439.79	869	453.60	726	471.84	131	464.07	496	458.39	238	447.59	236
500 year ARI, 2100 horizon	439.83	922	453.65	771	471.85	139	464.09	527	458.41	253	447.61	252

¹ Approximate road centre line elevation at crossing locations: A: 438.8 mAHD; B: 450.8 mAHD; C: 471.0 mAHD; D: 463.3 mAHD; E: 457.1 mAHD; and F: 446.5 mAHD.

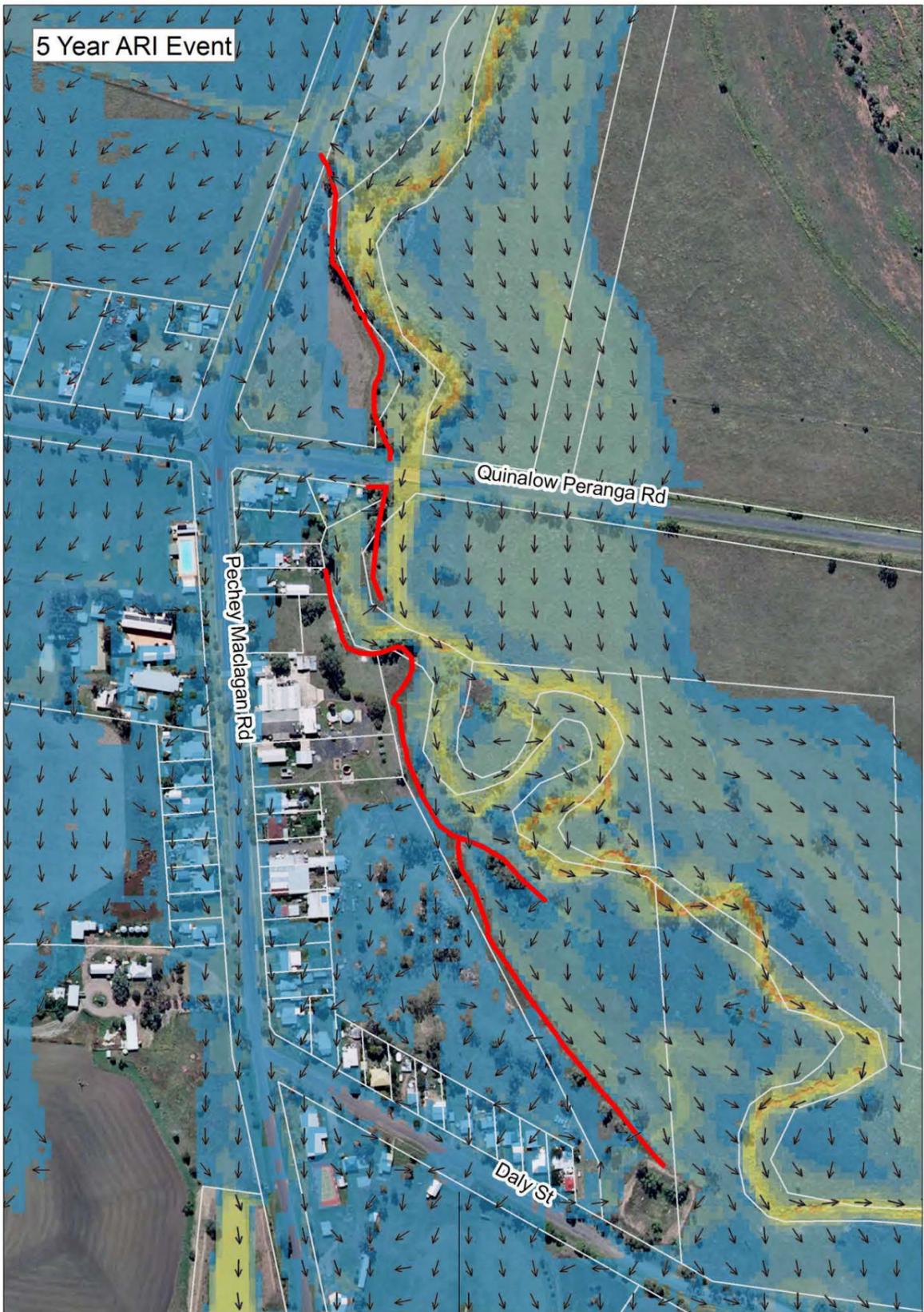
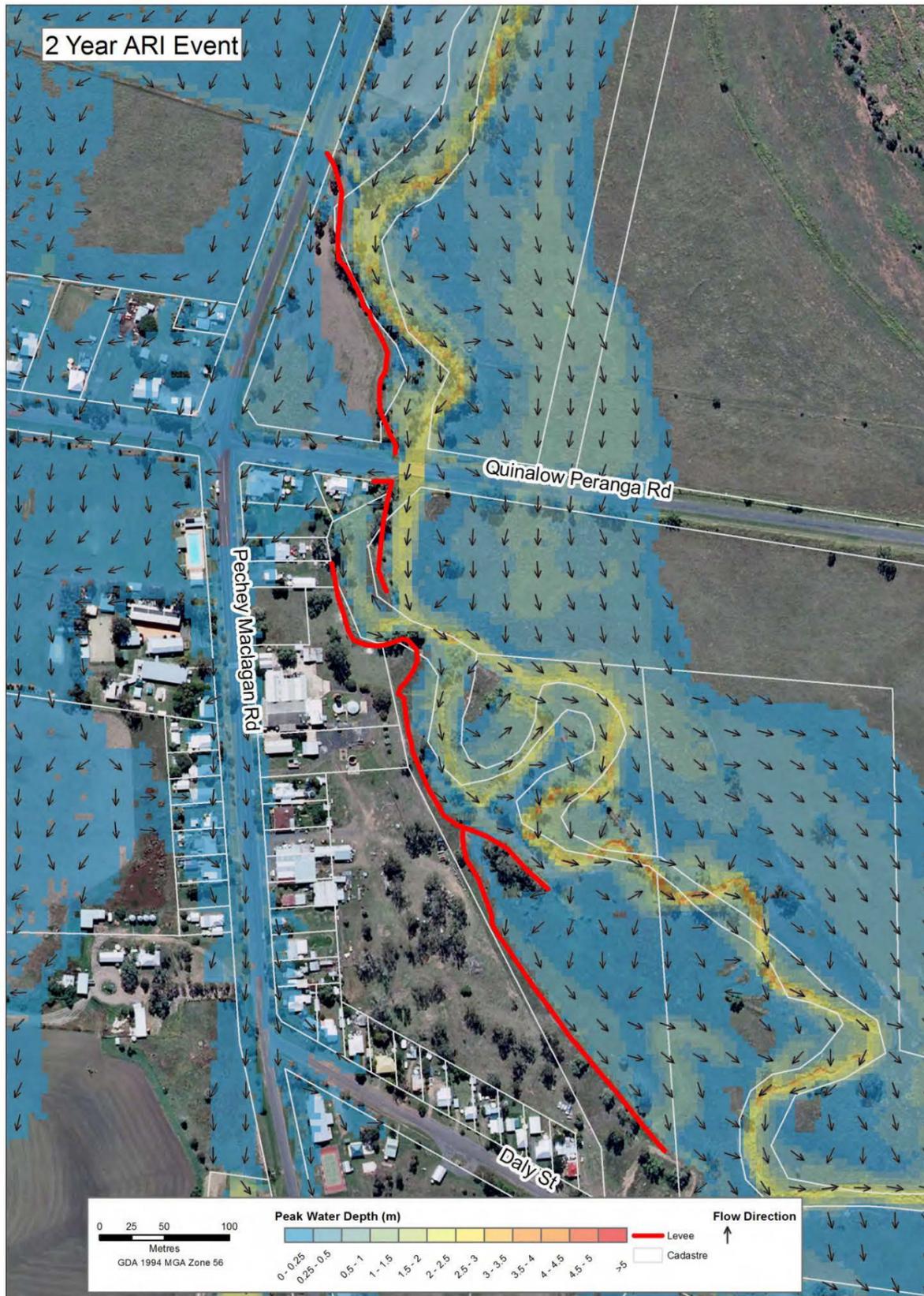


Figure 6.2 Effect of the Levees on Flooding in Quinalow in a 2 year and a 5 year ARI Event

6.3 DESIGN FLOOD LEVEL SENSITIVITY ANALYSIS

6.3.1 Case 1: Variation in Discharge

The model was tested for sensitivity to a variation in flow for the existing development case, 100 year ARI, critical duration design event, which was assessed as follows:

- A 30% increase in all inflow hydrographs to the hydrodynamic model; and
- A 30% decrease in all inflow hydrographs to the hydrodynamic model.

6.3.2 Case 2: Variation in Roughness

The model was tested for sensitivity to a variation in hydraulic roughness for the existing development case, 100 year ARI critical duration design event, which was assessed as follows:

- A 30% increase in the hydraulic roughness (Manning's 'M'); and
- A 30% decrease in the hydraulic roughness (Manning's 'M').

6.3.3 Case 3: Hydraulic Structure Blockage

The model was tested for sensitivity to 50% blockage of hydraulic structures for the existing development case, 100 year ARI critical duration design event, which was assessed as follows:

- The width of rectangular culverts was halved while maintaining the existing invert and obvert levels;
- The cross-sectional area of circular culverts was halved by reducing the diameter;
- The pier blockage factor was set to 0.5 for bridge openings; and
- Handrails were treated as fully blocked. The blockage of handrails was modelled by raising the road level in the MIKE 21 bathymetry file.

Table 6.8 shows peak flood levels and discharges estimated in the sensitivity analyses at the 6 reporting locations in the study area, shown in Figure 6.1. Maps of water surface levels for the climate change scenarios are presented in Appendix G.

Sensitivity analysis results for the 100 year ARI design event indicate the following:

- A 30% increase in design discharge translates to about a 0.09 m and 0.18 m increase in peak flood levels at Quinalow and Maclagan respectively;
- A 30% decrease in discharge translates to about a 0.13 m and 0.23 m decrease in peak flood levels at Quinalow and Maclagan respectively;
- A 30% increase in roughness translates to a 0.04 m and 0.12 m increase in peak flood levels at Quinalow and Maclagan respectively;
- A 30% decrease in roughness translates to a 0.04 m increase and 0.06 m decrease in peak flood levels at Quinalow and Maclagan respectively;
- A 50% blockage of structures increases peak flood levels at the bridge at Quinalow (Myall Creek crossing) by 0.12 m. The peak flood levels at the other reporting locations are basically unchanged. The upstream flood levels at the modelled hydraulic structures are also basically unchanged, with the exception of the bridge at Quinalow. Velocities through the culvert or bridge increased at the bridge at Quinalow (+0.9 m/s) and the Old Rosemount Road crossing (+0.18 m/s), and were unchanged at the remaining hydraulic structures.

6.4 CLIMATE CHANGE ANALYSIS

The model was assessed for three scenarios investigating climate change effects for the existing development case for each of the 100, 200 and 500 year critical duration design events, assessed as follows:

- A 2°C temperature increase by 2050;
- A 3°C temperature increase by 2070; and
- A 4°C temperature increase by 2100.

The effects of climate change were simulated assuming a 5% increase in rainfall intensity per degree of global warming. Table 6.10 shows the critical storm durations for the climate change scenarios assessed, determined from the peak discharges at the townships of Quinalow and Maclagan. Note that the 200 year climate change scenarios have a different critical duration (2 hours) when compared to the 200 year design event (3 hours).

Table 6.10 Climate Change Scenario Critical Storm Durations

Event ARI (Years)	Critical Storm Duration
100 year 2050 horizon	3 hours
100 year 2070 horizon	3 hours
100 year 2100 horizon	3 hours
200 year 2050 horizon	2 hours
200 year 2070 horizon	2 hours
200 year 2100 horizon	2 hours
500 year 2050 horizon	2 hours
500 year 2070 horizon	2 hours
500 year 2100 horizon	2 hours

Table 6.9 shows peak flood levels and discharges estimated in the climate change scenarios at selected representative locations in the study area, shown in Figure 6.1. Maps of water surface level for the climate change scenarios are provided in Appendix H.

Climate change scenario results indicate the following:

- For the 100 year ARI climate change scenarios, peak discharges increase by between 13% and 35% (at the reporting locations). Peak flood levels increase by between 0.03 m and 0.19 m.
- The 200 year ARI climate change scenarios have a different critical storm duration (2 hours) when compared to the 200 year ARI design event (3 hours). The peak discharges are up to 28% larger for the climate change scenarios. The peak water levels increase by up to 0.19 m (at the reporting locations).
- For the 500 year ARI climate change scenarios, peak flood levels increase by up to 0.20 m at the reporting locations. The peak discharges are up to 28% larger for the climate change scenarios.

6.5 DEVELOPED CATCHMENT FLOOD BEHAVIOUR

Figure 6.3 shows the proposed future changes in land use in the Myall Creek catchment in the vicinity of Maclagan and Quinalow, based on the TRC regional planning scheme. Figure 6.3 shows that a small area (10ha) directly to the south-west of the existing Quinalow township, currently used for farming, is allocated as 'urban residential no timeframe'.

The proposed future development area represents 3.4% of sub-catchment 15, and 0.07% of the total catchment to the downstream model boundary. The potential change in land use of the designated area from farming to urban residential may have minor impacts on local drainage, however considering the size of the area and its location (close to the downstream end of the model boundary), the change in land use will have negligible impact on the design flood discharges and flood levels. Hence, model runs of the fully developed catchment conditions case were not undertaken in this study.

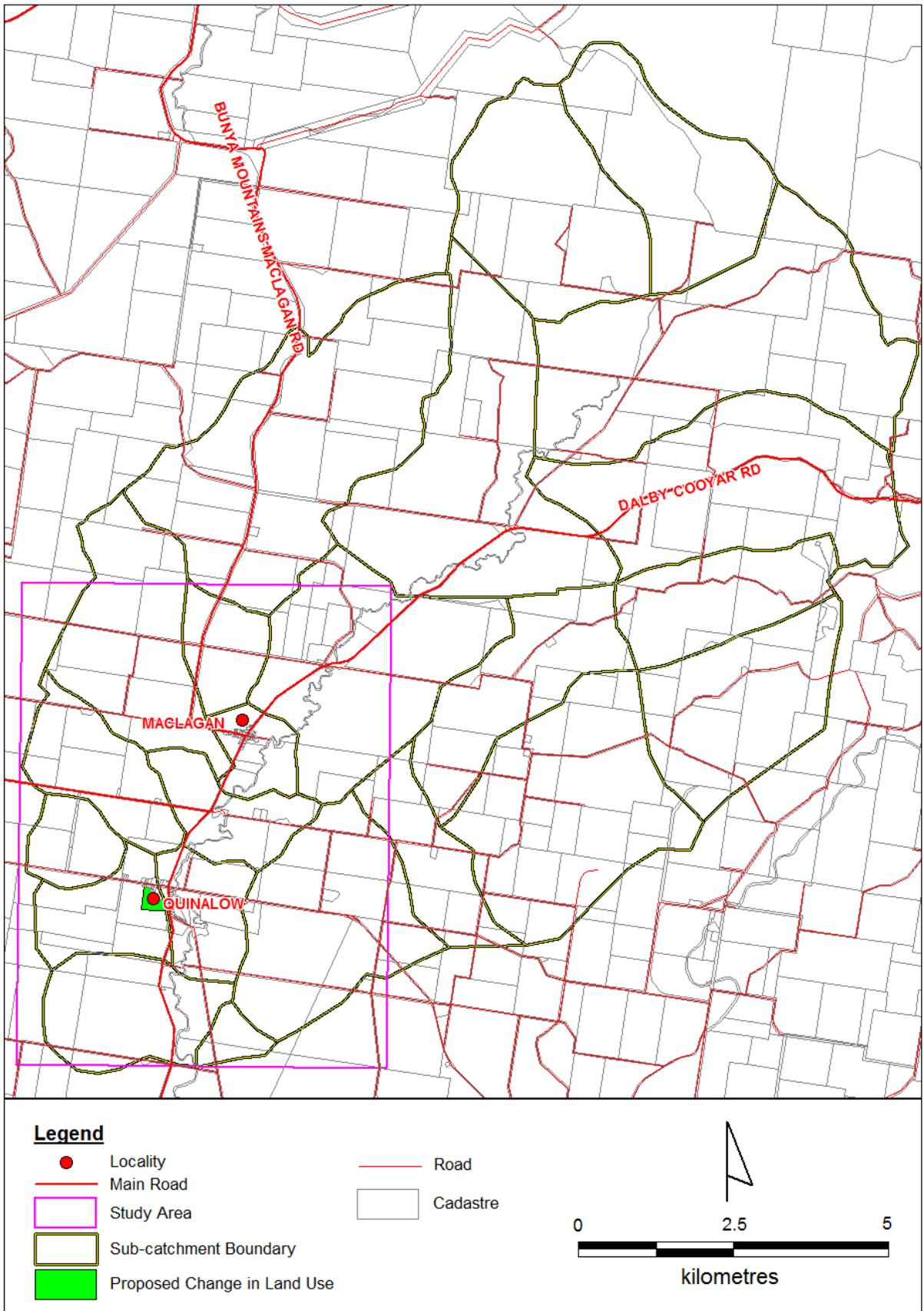


Figure 6.3 Proposed Future Development within the Catchment

7 SUMMARY AND CONCLUSIONS

The primary objective of this flood study was to define the nature and extent of flood behaviour in the Maclagan and Quinalow study area to enable Toowoomba Regional Council to develop a Flood Risk Management Study and amend the regional planning scheme to reflect flood requirements of the State Planning Policy and the recommendations of the Queensland Commission of Inquiry.

Significant flooding occurred in the Myall Creek catchment in January 2011, resulting in partial inundation of Maclagan and Quinalow. A hydrologic (XP-RAFTS) model and a coupled 1D/2D (MIKE FLOOD) hydraulic model have been successfully developed and validated for the January 2011 flood event for the Maclagan and Quinalow study area using a joint calibration approach. The validation results are presented graphically and the predicted levels are within the required accuracy of ± 0.25 m except for one outlier, which appears to be an erroneous level observation.

The validated MIKE FLOOD hydrodynamic model was used to estimate design peak flood surface elevations, peak water depths and velocities in the vicinity of Maclagan and Quinalow for the 2, 5, 10, 20, 50, 100, 200 and 500 year ARI and PMF design events. The sensitivity of predicted 100 year ARI model results was tested to assess the impacts of changes to adopted design discharges, hydraulic roughness and blockage of hydraulic structures. Additionally, the potential impact on flood behaviour was assessed for three climate change scenarios for the 100, 200 and 500 year ARI design events.

The study results show that:

- The design flood levels in Quinalow are relatively insensitive to adopted design discharges. The 500 year ARI design discharge at Quinalow is 7 times larger than the 2 year ARI discharge; however the peak flood level is only 0.7 m higher;
- The design flood levels in Maclagan are more sensitive to adopted design discharges than at Quinalow. The 500 year ARI design discharge at Maclagan is also 7 times larger than the 2 year ARI discharge; however the peak flood level is 1.2 m higher; and
- The majority of road crossings in the study area have low flood immunity; four of the five major road crossings in the model extent are overtopped in a 2 year ARI design event. The 'Dalby Cooyar Road 2' structure near the corner of Dalby-Cooyar Road and Woodleigh Maclagan Road has flood immunity up to a 500 year design event.
- The levees in Quinalow protect parts of the town from a 2 year ARI flood. However, some properties are still affected by flooding in a 2 year ARI event due to Myall Creek overtopping Quinalow Peranga Road.

Sensitivity analysis results for the 100 year ARI design event indicate the following:

- At Quinalow and Maclagan, a 30% increase and decrease in design discharge results in an increase and decrease in peak flood level of up to about 0.18 m to 0.23 m respectively;
- The modelled hydraulic structures are relatively insensitive to 50% blockage, with the exception of the bridge at Quinalow which increases the upstream peak flood level by 0.12 m and the maximum velocity through the bridge by 0.9 m/s.

Climate change scenario results indicate the following:

- In all of the climate change scenarios investigated, the peak discharge has increased at the reporting locations; and
- Flood levels increased by a maximum of up to 0.20 m at the reporting locations.

8

RECOMMENDATIONS

The following recommendations should be considered to improve the accuracy of the model performance.

- Model validation is based on limited data from only one historical event, the accuracy of which is not known. Detailed calibration for at least two historical flood events should be performed to improve the model accuracy if more data becomes available. Because the model has only been validated for the January 2011 event, the model results should be used with caution.
- One flood mark close to the Quinalow Hotel is available for both the December 2010 and January 2013 flood events. However, calibration of the model for these events is unlikely to improve the model credibility given the limited historical flood information available.
- In case channel cross-section data as well as additional calibration data becomes available; implementing the major channels in 1D and coupling them laterally to the 2D grid could improve model performance.
- Configurations of hydraulic structures were measured by hand in the field. Survey of the hydraulic structures would improve model accuracy at these locations.

9 REFERENCES

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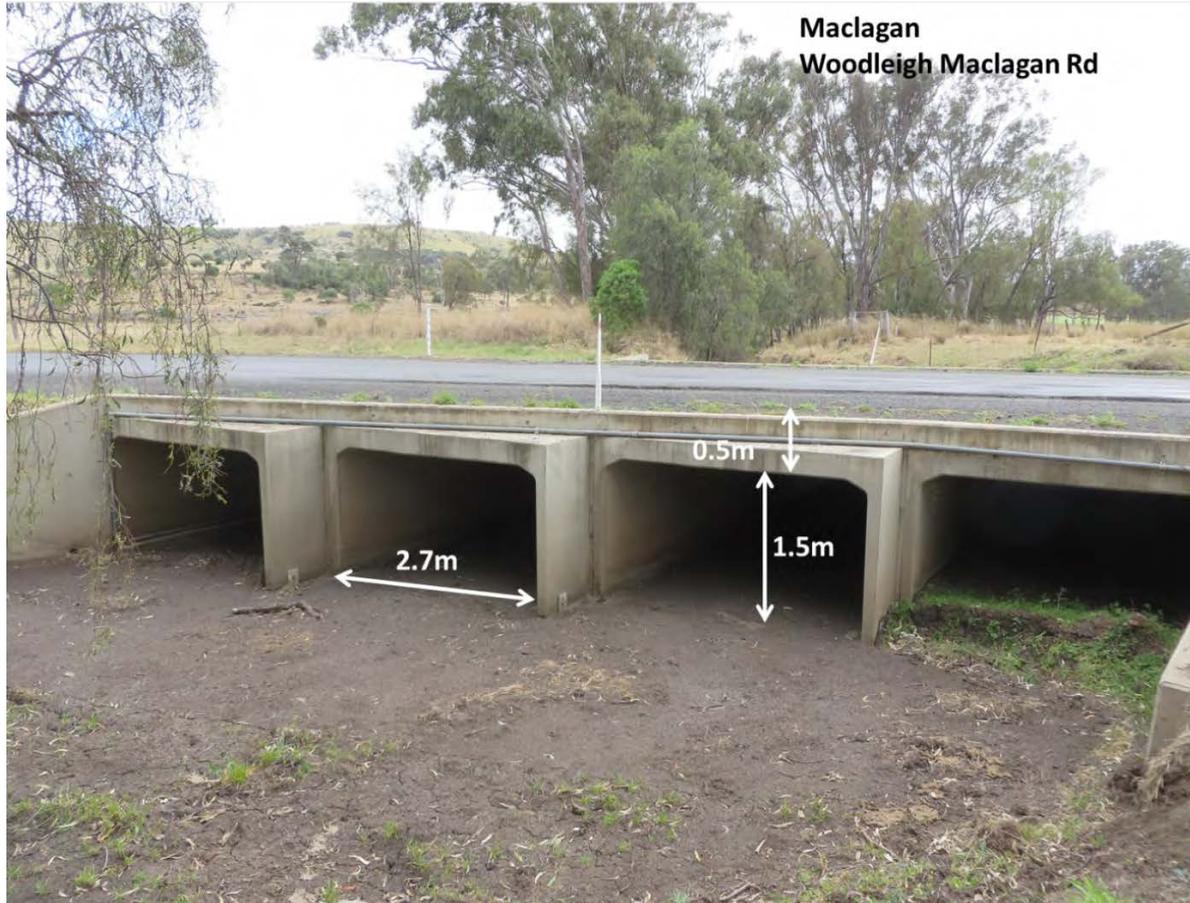
10 DISCLAIMER

Information used is the best information available at this time for the purposes of this study. Marks observed and other anecdotal information obtained after flood events have been obtained from a range of sources and have varying degrees of uncertainty.

While every care is taken by the Toowoomba Regional Council (TRC) to ensure the accuracy of the data used in the study and published in the report, Toowoomba Regional Council makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of data being inaccurate or incomplete.

APPENDIX A

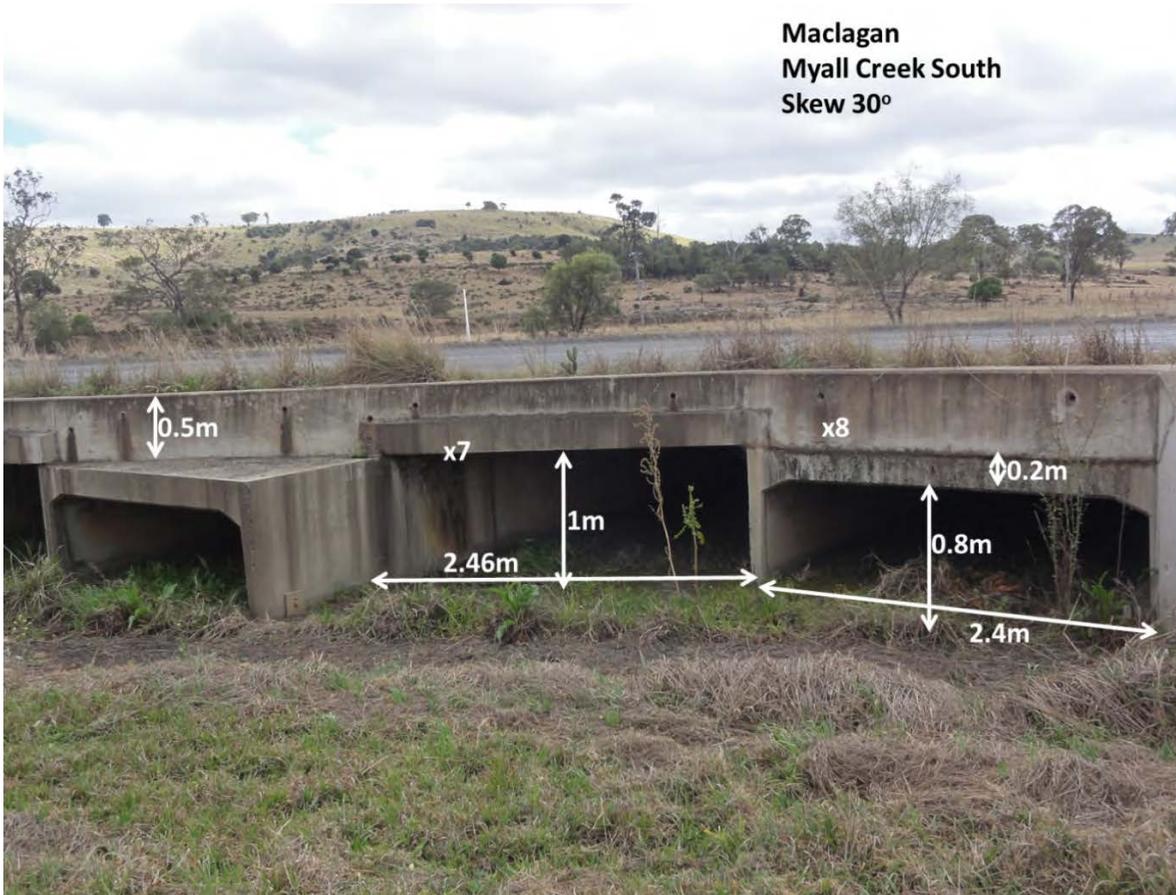
STRUCTURE ATTRIBUTES



Dalby Cooyar Rd 1 (Near Corner of
Dalby-Cooyar Road and Woodleigh
Maclagan Road)

Location:
-27.0733730
151.6497928

**Maclagan
Myall Creek South
Skew 30°**



Dalby Cooyar Rd 2 (Near Corner of
Dalby-Cooyar Road and Woodleigh
Maclagan Road)

Location:
-27.0735817
151.6485002



**Quinalow Peranga Rd
4 culverts, d=1.2m
App. 1m drop downstream**

Quinalow Peranga Rd 1 (near
corner of Quinalow-Peranga Road
and Kanowskis Road)

Location:
-27.1096840
151.6472784



Quinalow Peranga Rd 2 (Near
Quinalow Hotel on Quinalow-
Peranga Road)

Location:
-27.0735817
151.6485002



Old Rosemount Road

Location:
-27.1135131
151.6266781

APPENDIX B

STRUCTURE HEAD LOSSES, DISCHARGES AND VELOCITIES FOR THE VALIDATION & DESIGN EVENTS

VALIDATION EVENT: TABLE B.1

DESIGN EVENTS: TABLES B.2 – B.10

SENSITIVITY ANALYSES: TABLES B.11 – B.15

CLIMATE CHANGE SCENARIOS: TABLES B.16 – B.24

Table B.1 Head Losses, Discharges and Velocities at Structures for the January 2011 Validation Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.45	463.3	463.42	0.03	19	1.2	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.77	463.3	462.76	0.01	9	0.3	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.13	446.8	446.06	0.59	15	3.4	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.26	438.8	438.85	0.41	47	2.2	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	434.97	432.9	434.84	0.13	1	1.7	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.2 Head Losses, Discharges and Velocities at Structures for the 2 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.32	463.3	463.30	0.02	18	1.08	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.67	463.3	462.66	0.01	6	0.21	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	446.87	446.8	446.36	0.51	13	3.10	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.10	438.8	438.69	0.42	42	2.16	The downstream water level is below the road level. The water backs up upstream of the bridge.
Old Rosemount Rd	434.83	432.9	434.71	0.12	11	2.48	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.3 Head Losses, Discharges and Velocities at Structures for the 5 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.40	463.3	463.38	0.03	19	1.15	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.73	463.3	462.72	0.01	8	0.26	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.04	446.8	446.47	0.57	16	3.44	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.22	438.8	438.82	0.43	46	2.18	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	434.95	432.9	434.82	0.13	11	2.05	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.4 Head Losses, Discharges and Velocities at Structures for the 10 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.44	463.3	463.41	0.03	19	1.18	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.76	463.3	462.75	0.01	9	0.30	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.12	446.8	446.52	0.59	17	3.33	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.30	438.8	438.89	0.43	48	2.19	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.00	432.9	434.87	0.13	11	2.43	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.5 Head Losses, Discharges and Velocities at Structures for the 20 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.48	463.3	463.44	0.04	20	1.25	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.79	463.3	462.78	0.01	11	0.34	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.20	446.8	446.59	0.61	18	3.34	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.38	438.8	438.97	0.43	51	2.19	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.05	432.9	434.92	0.13	11	2.65	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.6 Head Losses, Discharges and Velocities at Structures for the 50 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.53	463.3	463.49	0.04	21	1.30	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.84	463.3	462.83	0.01	13	0.39	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.29	446.8	446.66	0.63	20	3.38	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.49	438.8	439.06	0.44	55	2.25	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.10	432.9	434.97	0.13	11	2.04	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.7 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.58	463.3	463.53	0.05	22	1.35	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.88	463.3	462.86	0.01	15	0.45	Culverts fully submerged, the road does not get overtopped.
Quinalow Peranga Rd 1	447.37	446.8	446.72	0.65	21	3.43	Culverts fully submerged, the road gets overtopped.
Quinalow Peranga Rd 2	439.55	438.8	439.13	0.42	57	2.28	Bridge fully submerged. The downstream water level is 33cm higher than the road level.
Old Rosemount Rd	435.14	432.9	435.01	0.13	11	1.78	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.8 Head Losses, Discharges and Velocities at Structures for the 200 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.67	463.3	463.60	0.06	24	1.46	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.97	463.3	462.94	0.02	19	0.58	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.47	446.8	446.74	0.94	24	3.89	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.67	438.8	439.25	0.43	61	2.32	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.20	432.9	435.07	0.85	11	2.28	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.9 Head Losses, Discharges and Velocities at Structures for the 500 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.74	463.3	463.66	0.08	25	1.52	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	463.05	463.3	463.02	0.04	23	0.70	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.53	446.8	446.72	0.95	25	3.93	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.72	438.8	439.34	0.41	62	2.29	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.23	432.9	435.10	0.19	11	1.74	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.10 Head Losses, Discharges and Velocities at Structures for the PMF Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	464.95	463.3	464.69	0.26	35	2.16	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	464.26	463.3	464.07	0.19	56	1.68	Culverts fully submerged, the road gets overtopped.
Quinalow Peranga Rd 1	448.48	446.8	447.24	1.24	54	4.88	Culverts fully submerged, the road gets overtopped.
Quinalow Peranga Rd 2	441.19	438.8	440.62	0.57	154	3.21	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	436.25	432.9	436.15	0.60	13	2.73	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.11 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, Plus 30% Flow

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.65	463.3	463.59	0.06	23	1.44	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.95	463.3	462.93	0.02	18	0.56	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.44	446.8	446.75	0.94	23	3.87	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.64	438.8	439.26	0.41	58	2.24	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.19	432.9	435.06	0.19	11	1.72	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.12 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, Minus 30% Flow

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.50	463.3	463.46	0.07	21	1.27	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.81	463.3	462.80	0.01	11	0.36	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.24	446.8	446.61	0.62	19	3.34	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.42	438.8	439.00	0.43	52	2.21	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.07	432.9	434.94	0.63	11	2.69	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.13 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, Minus 30% Roughness

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.58	463.3	463.52	0.23	23	2.04	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.86	463.3	462.84	0.01	14	0.44	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.37	446.8	446.70	0.99	21	3.78	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.51	438.8	439.07	0.46	57	2.31	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.15	432.9	435.00	0.24	12	1.85	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.14 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, Plus 30% Roughness

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.60	463.3	463.55	0.05	21	1.27	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.92	463.3	462.90	0.02	15	0.46	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.36	446.8	446.75	0.61	21	3.32	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.59	438.8	439.26	0.36	54	2.13	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.13	432.9	435.03	0.61	10	2.66	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.15 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, 50% Blockage

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.69	463.3	463.44	0.25	16	1.95	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.91	463.3	462.85	0.06	14	0.82	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.41	446.8	446.31	1.10	15	3.74	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.67	438.8****	438.99	0.81	30	3.17	Bridge fully submerged, the road gets overtopped. Downstream water level is lower than blocked handrail level.
Old Rosemount Rd	435.14	432.9	435.01	0.31	11	1.77	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

**** Bridge handrail is blocked, top of handrail at 439.31 mAHD

Table B.16 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, 2°C by 2050 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.62	463.3	463.56	0.06	22	1.39	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.92	463.3	462.90	0.02	16	0.51	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.41	446.8	446.75	0.93	22	3.82	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.61	438.8	439.27	0.40	55	2.17	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.17	432.9	435.04	0.20	11	1.73	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.17 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, 3°C by 2070 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.64	463.3	463.58	0.06	23	1.42	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.93	463.3	462.91	0.02	17	0.54	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.43	446.8	446.75	0.93	23	3.85	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.63	438.8	439.21	0.43	60	2.30	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.18	432.9	435.05	0.56	11	2.60	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.18 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event, 4°C by 2100 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.66	463.3	463.59	0.06	23	1.44	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.95	463.3	462.93	0.02	18	0.57	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.46	446.8	446.75	0.94	24	3.88	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.64	438.8	439.26	0.41	59	2.24	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.19	432.9	435.06	0.22	11	1.78	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.19 Head Losses, Discharges and Velocities at Structures for the 200 Year ARI Design Event, 2°C by 2050 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.71	463.3	463.64	0.07	24	1.50	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	463.02	463.3	462.99	0.03	22	0.66	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.50	446.8	446.74	0.94	25	3.91	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.71	438.8	439.38	0.40	59	2.20	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.22	432.9	435.09	0.58	11	2.65	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.20 Head Losses, Discharges and Velocities at Structures for the 200 Year ARI Design Event, 3°C by 2070 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.73	463.3	463.66	0.08	25	1.52	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	463.05	463.3	463.01	0.04	23	0.70	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.53	446.8	446.73	0.95	25	3.93	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.73	438.8	439.40	0.41	60	2.21	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.23	432.9	435.10	0.28	11	1.98	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.21 Head Losses, Discharges and Velocities at Structures for the 200 Year ARI Design Event, 4°C by 2100 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.76	463.3	463.68	0.08	25	1.55	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	462.08	463.3	463.04	0.04	25	0.74	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.55	446.8	446.75	0.95	26	3.95	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.76	438.8	439.34	0.44	65	2.37	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.24	432.9	435.11	0.22	13	1.81	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.22 Head Losses, Discharges and Velocities at Structures for the 500 Year ARI Design Event, 2°C by 2050 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.79	463.3	463.70	0.09	26	1.58	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	463.11	463.3	463.06	0.05	27	0.79	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.57	446.8	446.74	0.96	26	3.96	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.78	438.8	439.45	0.41	62	2.24	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.25	432.9	435.13	0.19	11	1.76	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.23 Head Losses, Discharges and Velocities at Structures for the 500 Year ARI Design Event, 3°C by 2070 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.82	463.3	463.73	0.21	26	1.61	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	463.14	463.3	463.09	0.05	29	0.84	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.59	446.8	446.72	0.96	27	3.97	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.79	438.8	439.38	0.45	66	2.37	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.27	432.9	435.14	0.84	11	2.48	Culverts fully submerged, the road gets overtopped.

* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

Table B.24 Head Losses, Discharges and Velocities at Structures for the 500 Year ARI Design Event, 4°C by 2100 Climate Change

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Head Loss* (m)	Peak Discharge** (m ³ /s)	Peak Velocity*** (m/s)	Comments
Dalby Cooyar Rd 1	463.84	463.3	463.75	0.27	26	2.00	Culverts fully submerged, the road gets overtopped.
Dalby Cooyar Rd 2	463.18	463.3	463.12	0.06	31	0.90	Culverts partially full, the road does not get overtopped.
Quinalow Peranga Rd 1	447.61	446.8	446.74	0.96	27	3.99	The road gets overtopped; significant increase in channel conveyance downstream of Quinalow Peranga Road.
Quinalow Peranga Rd 2	439.83	438.8	439.41	0.44	69	2.42	Bridge fully submerged, the road gets overtopped.
Old Rosemount Rd	435.28	432.9	435.15	0.38	12	2.24	Culverts fully submerged, the road gets overtopped.

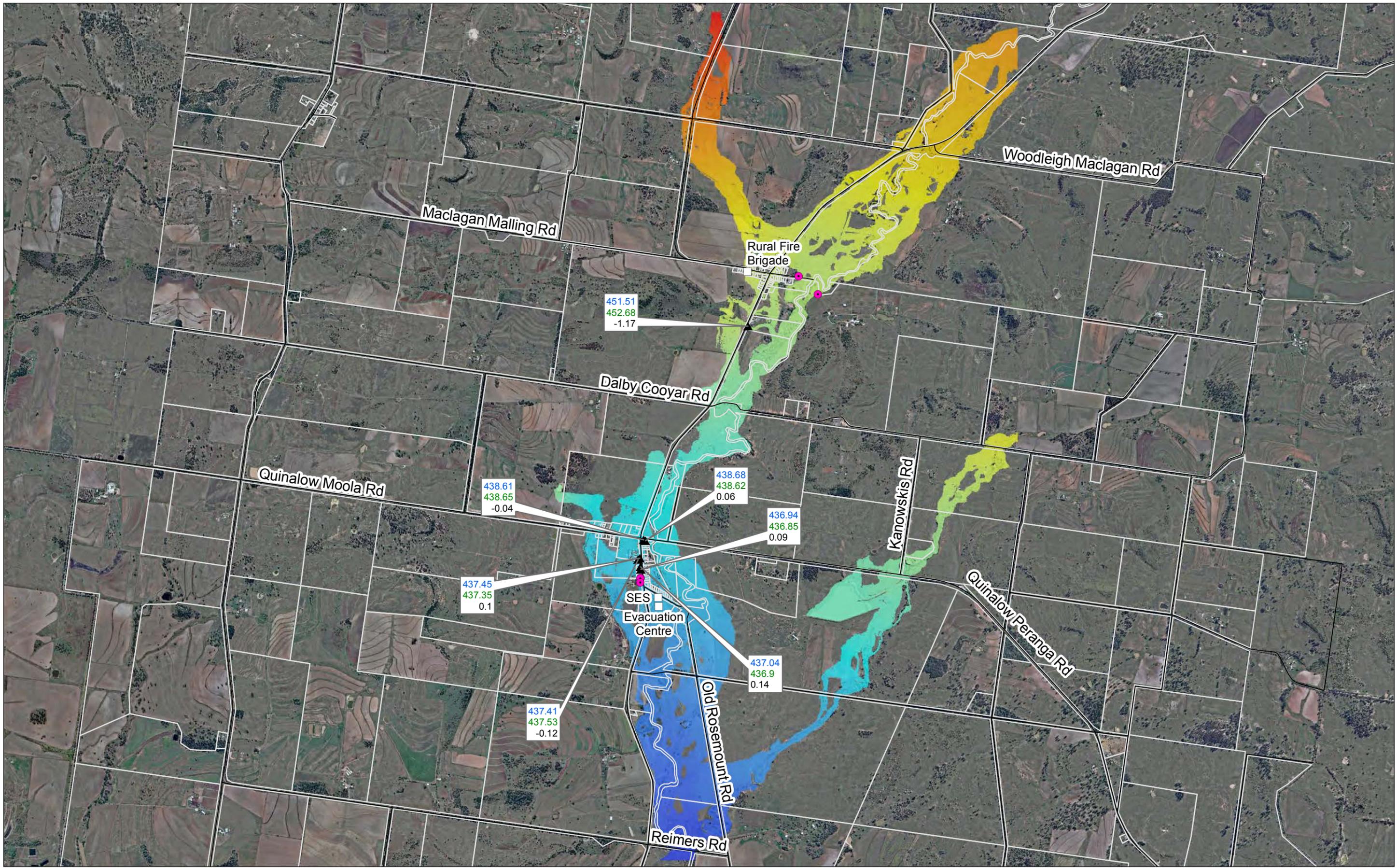
* The head loss is calculated as the maximum difference between water levels at the upstream and downstream MIKE 11 cross-sections

**Peak discharge is reported through the culvert or bridge

***Peak velocity is reported through the culvert or bridge

APPENDIX C

VALIDATION MAPPING



1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHd]

480

420

— Road Centrelines

□ Cadastre

□ Emergency Services

2011 Validation Data

▲ Flood Levels

● Known Flooding

Modelled

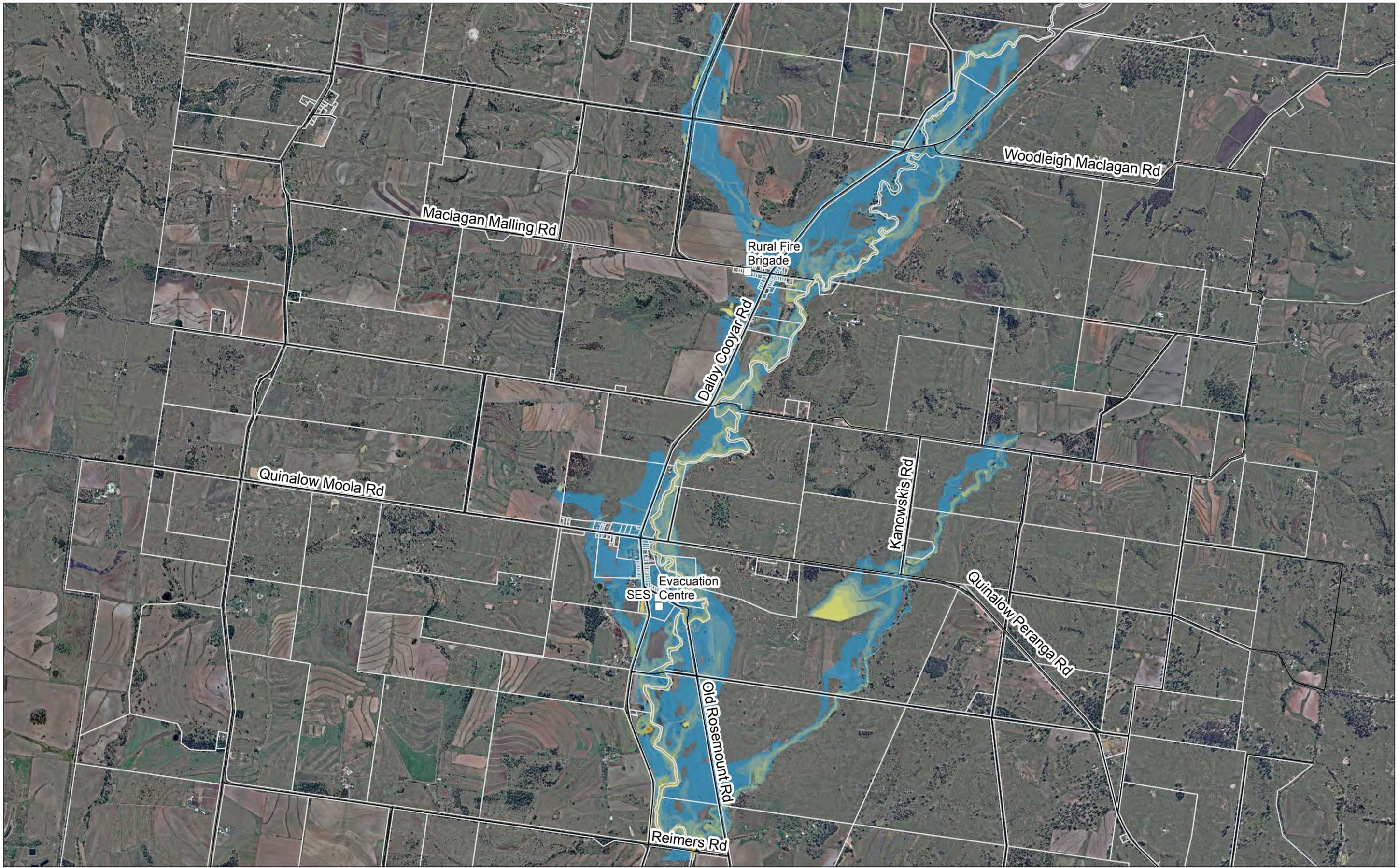
Observed

Modelled-Observed

Disclaimer: The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood extent and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
January 2011
Water Surface Elevation

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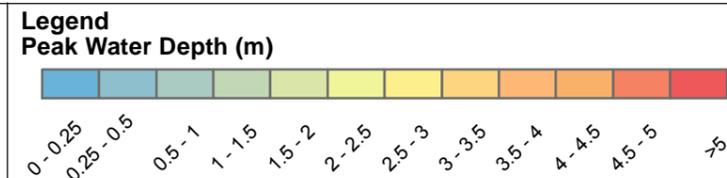


1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N



- Road Centrelines
- Cadastre
- Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
January 2011
Peak Flood Depth

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APPENDIX D

RATIONAL METHOD CALCULATIONS

Table D 1 Rational Method Calculations at Location Sub-Catchment 8

Rational Method Parameters	Units	Design Storm Event					
		2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Catchment Area	ha	214.8	214.8	214.8	214.8	214.8	214.8
C10	-	0.2	0.2	0.2	0.2	0.2	0.2
Time of Concentration							
Overland Flow Time (Friend's Eqn.)	min	11	11	11	11	11	11
Manning's 'n'		0.04	0.04	0.04	0.04	0.04	0.04
Length	m	50	50	50	50	50	50
Slope of Channel	m/m	0.05	0.05	0.05	0.05	0.05	0.05
Channel Flow Time	min	25	22	20	19	17	16
Length	m	2500	2500	2500	2500	2500	2500
Manning's 'n'		0.045	0.045	0.045	0.045	0.045	0.045
Slope of Channel	m/m	0.020	0.020	0.020	0.020	0.020	0.020
Total Time of Concentration	min	36.1	33.0	31.6	30.1	28.4	27.4
Runoff Coefficient (Cy)		0.17	0.19	0.20	0.21	0.23	0.24
Frequency Factor (Fy)		0.85	0.95	1	1.05	1.15	1.2
Rainfall Intensity (ly)	mm/h	47.6	62.0	71.6	84.8	103.2	118.1
Discharge (Local)	m³/s	4.8	7.0	8.5	10.6	14.2	16.9

Table D 2 Rational Method Calculations at Location Sub-Catchment 12

Rational Method Parameters	Units	Design Storm Event					
		2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Catchment Area	ha	365	365	365	365	365	365
C10	-	0.2	0.2	0.2	0.2	0.2	0.2
Time of Concentration							
<i>Overland Flow Time (Friend's Eqn.)</i>	min	23	23	23	23	23	23
<i>Manning's 'n'</i>		0.04	0.04	0.04	0.04	0.04	0.04
<i>Length</i>	m	200	200	200	200	200	200
<i>Slope of Channel</i>	m/m	0.015	0.015	0.015	0.015	0.015	0.015
<i>Channel Flow Time</i>	min	33	29	27	25	22	21
<i>Length</i>	m	3587	3587	3587	3587	3587	3587
<i>Manning's 'n'</i>		0.045	0.045	0.045	0.045	0.045	0.045
<i>Slope of Channel</i>	m/m	0.030	0.030	0.030	0.030	0.030	0.030
Total Time of Concentration	min	56.0	51.7	49.8	47.8	45.4	44.0
Runoff Coefficient (Cy)		0.17	0.19	0.20	0.21	0.23	0.24
Frequency Factor (Fy)		0.85	0.95	1	1.05	1.15	1.2
Rainfall Intensity (ly)	mm/h	37.2	48.3	55.1	64.7	78.6	89.3
Discharge	m³/s	6.4	9.3	11.2	13.8	18.3	21.7

Table D 3 Rational Method Calculations at Location Sub-Catchment 14

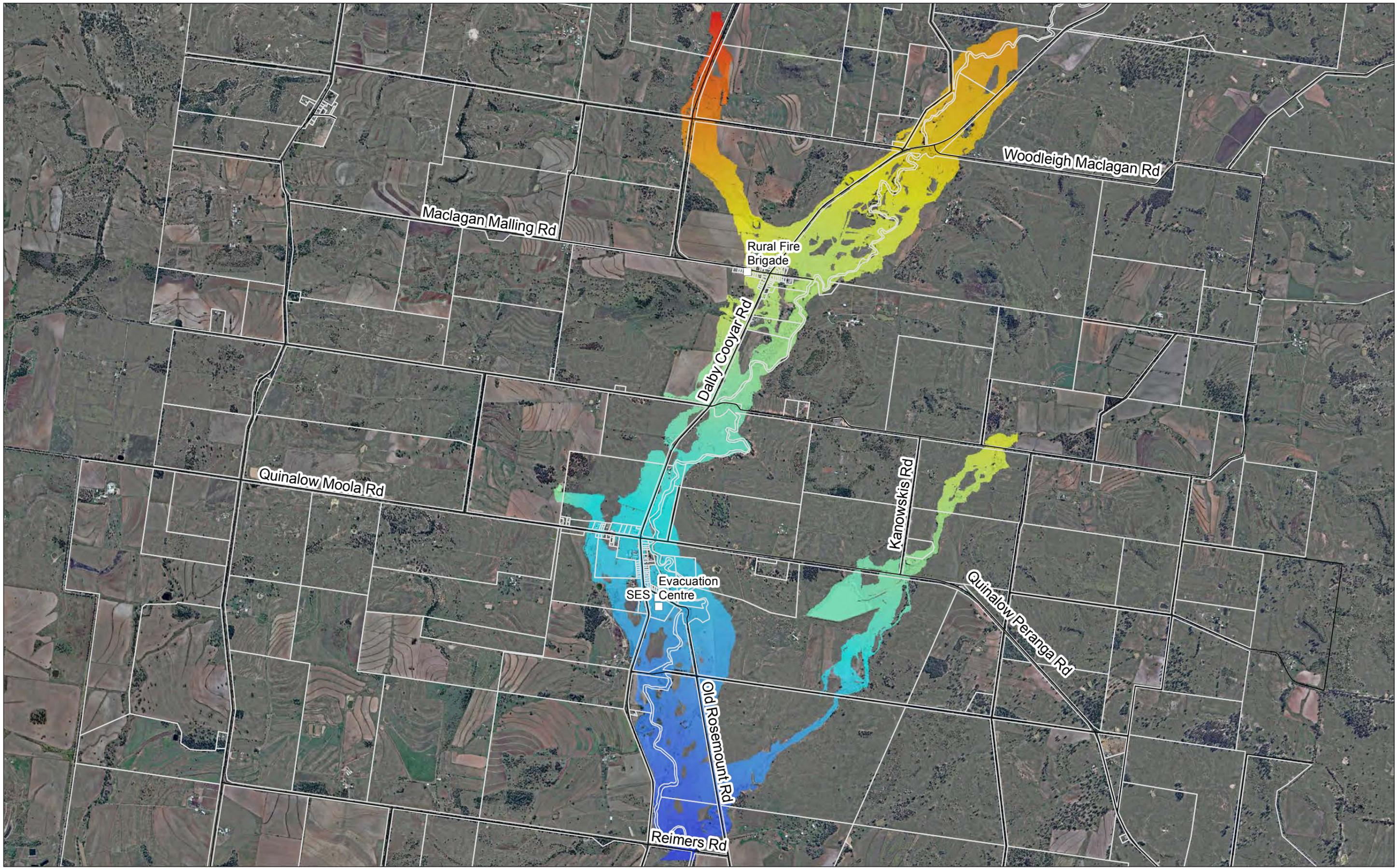
Rational Method Parameters	Units	Design Storm Event					
		2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Catchment Area	ha	180.2	180.2	180.2	180.2	180.2	180.2
C10	-	0.2	0.2	0.2	0.2	0.2	0.2
Time of Concentration							
Overland Flow Time (<i>Friend's Eqn.</i>)	min	25	25	25	25	25	25
<i>Manning's 'n'</i>		0.04	0.04	0.04	0.04	0.04	0.04
<i>Length</i>	m	200	200	200	200	200	200
<i>Slope</i>	m/m	0.01	0.01	0.01	0.01	0.01	0.01
Channel Flow Time	min	25	22	21	19	18	17
<i>Length</i>	m	2260	2260	2260	2260	2260	2260
<i>Manning's 'n'</i>		0.045	0.045	0.045	0.045	0.045	0.045
<i>Slope of Channel</i>	m/m	0.020	0.020	0.020	0.020	0.020	0.020
Total Time of Concentration	min	50.4	47.3	45.9	44.4	42.6	41.6
Runoff Coefficient (Cy)		0.17	0.19	0.20	0.21	0.23	0.24
Frequency Factor (Fy)		0.85	0.95	1	1.05	1.15	1.2
Rainfall Intensity (ly)	mm/h	39.5	50.7	57.4	67.6	81.9	92.7
Discharge	m³/s	3.4	4.8	5.8	7.1	9.4	11.1

Table D 4 Rational Method Calculations at Location Sub-Catchment 16

Rational Method Parameters	Units	Design Storm Event					
		2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
Catchment Area	ha	474.6	474.6	474.6	474.6	474.6	474.6
C10	-	0.2	0.2	0.2	0.2	0.2	0.2
Time of Concentration							
Overland Flow Time (<i>Friend's Eqn.</i>)	min	16	16	16	16	16	16
<i>Manning's 'n'</i>		0.065	0.065	0.065	0.065	0.065	0.065
<i>Length</i>	m	50	50	50	50	50	50
<i>Slope</i>	m/m	0.1	0.1	0.1	0.1	0.1	0.1
Channel Flow Time	min	56	51	48	46	42	41
<i>Length</i>	m	3582	3582	3582	3582	3582	3582
<i>Manning's 'n'</i>		0.055	0.055	0.055	0.055	0.055	0.055
<i>Slope of Channel</i>	m/m	0.028	0.028	0.028	0.028	0.028	0.028
Total Time of Concentration	min	55.9	50.5	48.1	45.5	42.4	40.7
Runoff Coefficient (Cy)		0.17	0.19	0.20	0.21	0.23	0.24
Frequency Factor (Fy)		0.85	0.95	1	1.05	1.15	1.2
Rainfall Intensity (ly)	mm/h	37.3	49.0	56.2	66.6	82.1	94.0
Discharge	m³/s	8.4	12.3	14.8	18.4	24.9	29.7

APPENDIX E

DESIGN EVENT MAPPING




1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation

480

420

— Road Centrelines

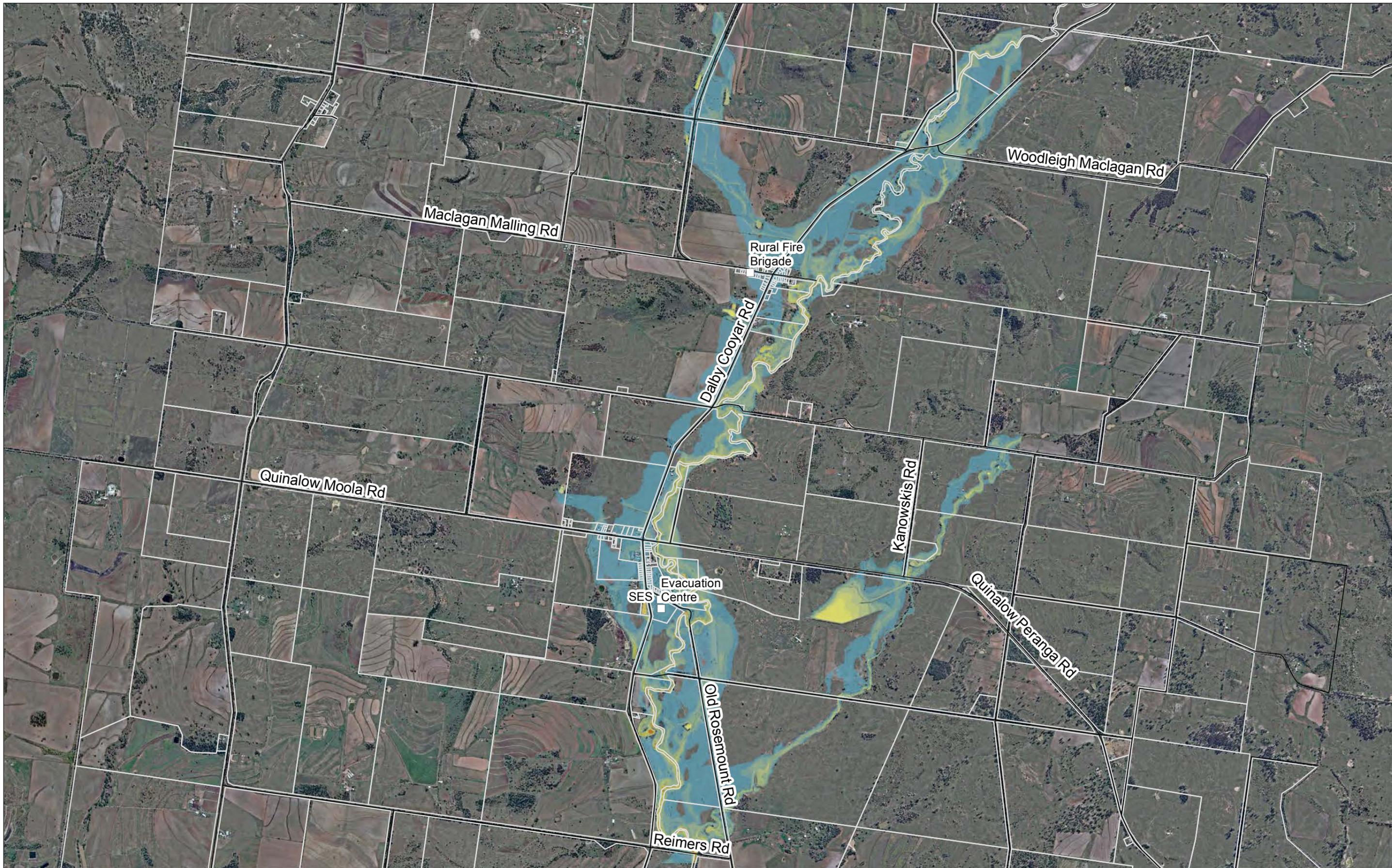
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
10 Year ARI Event
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Peak Depth (m)

0-0.25	0.25-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	>5
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- Emergency Services
- Road Centrelines
- Cadastre

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
10 Year ARI Event
Peak Flood Depths

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation

480

420

— Road Centrelines

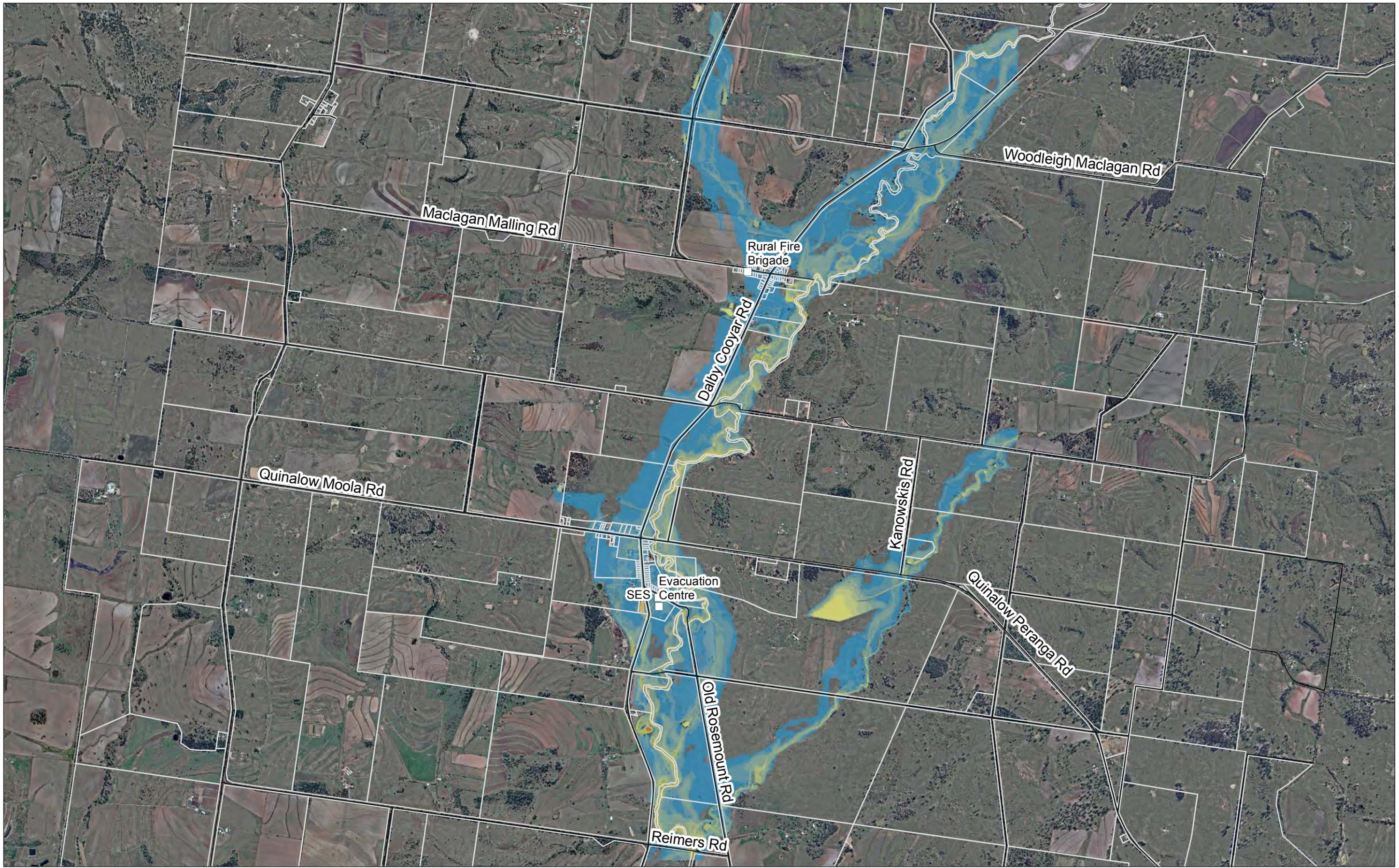
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
50 Year ARI Event
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Peak Water Depth (m)

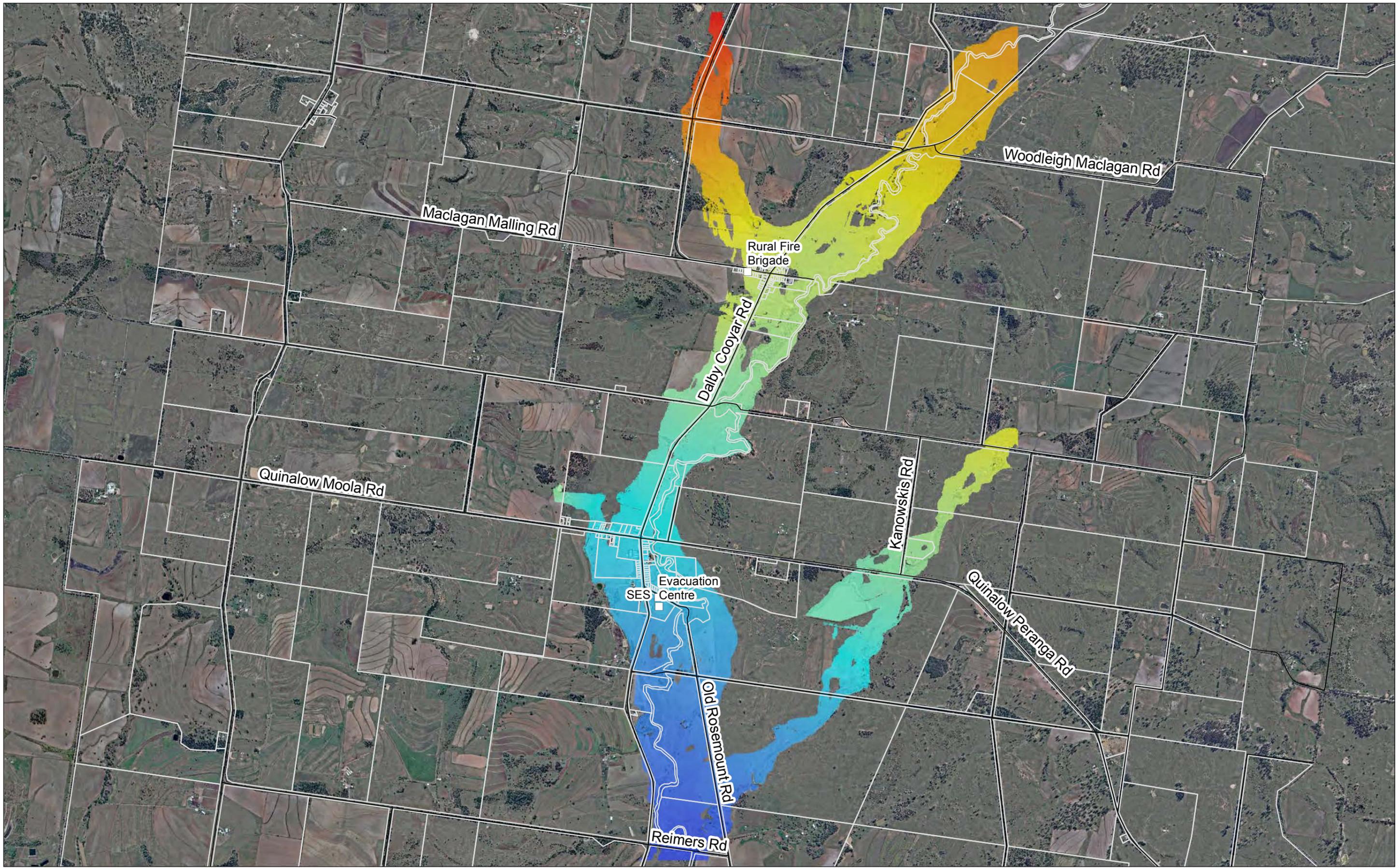
0-0.25	0.25-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	>5
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- Emergency Services
- Road Centrelines
- Cadastre

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
50 Year ARI Event
Peak Flood Depths

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD] — Road Centrelines

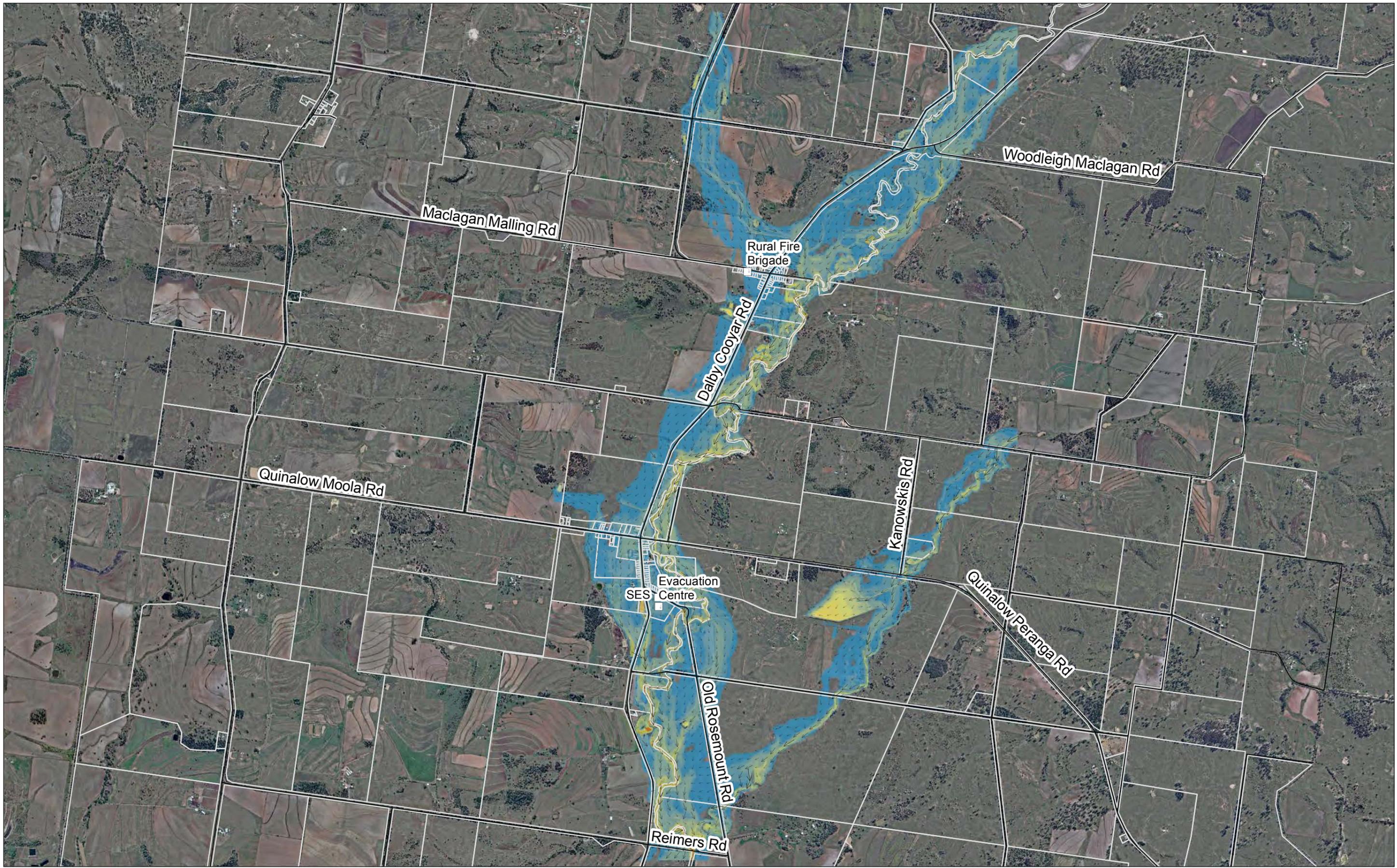
480 — Cadastre

420 — Emergency Services

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**SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event
Water Surface Elevation**

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56



Legend

Peak Water Depth (m)

0-0.25	0.25-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	>5
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- Road Centrelines
- Cadastre
- Emergency Services

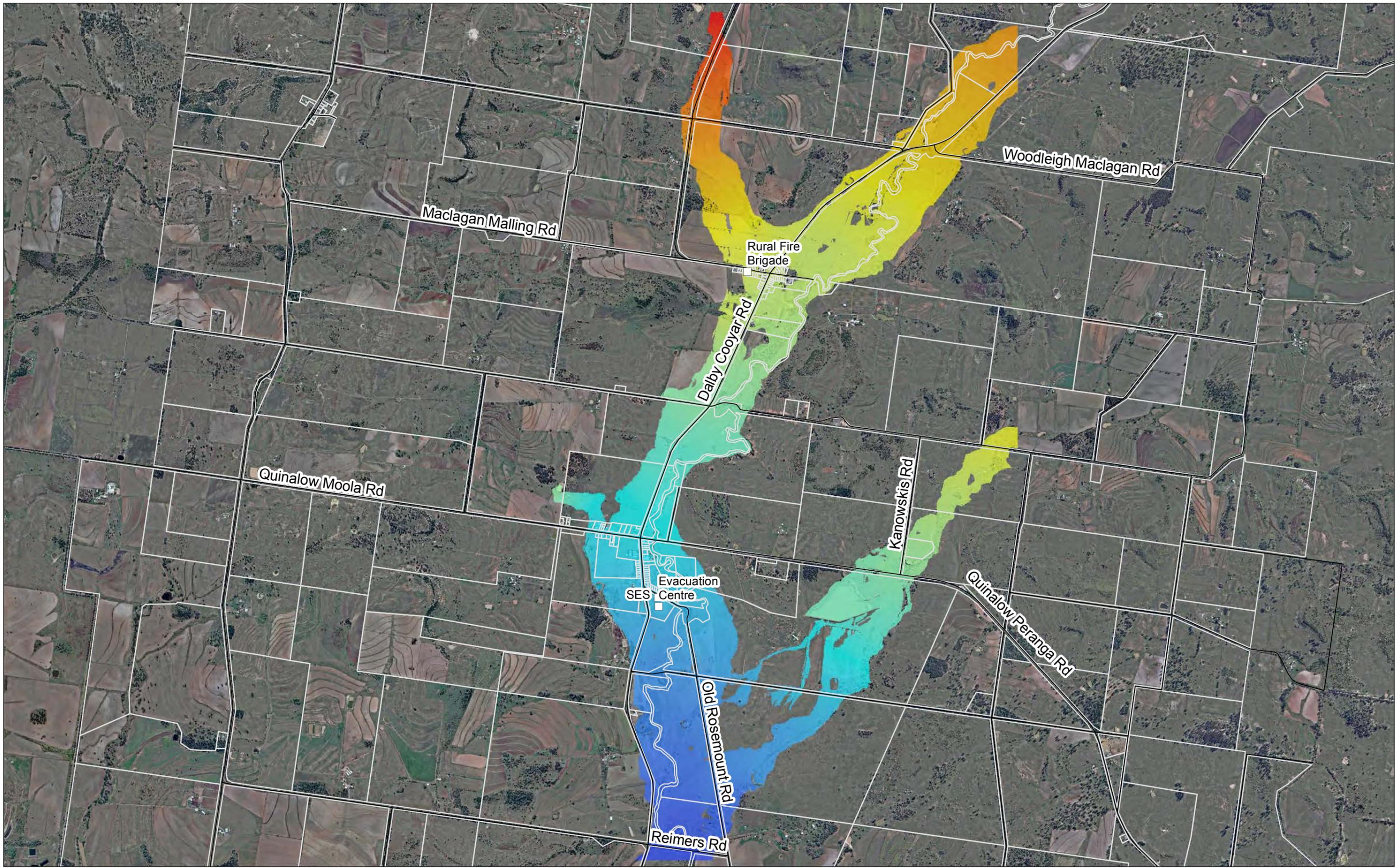
Velocity (m/s)

0-1	1-2	>2
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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event
Peak Flood Depths and Velocities

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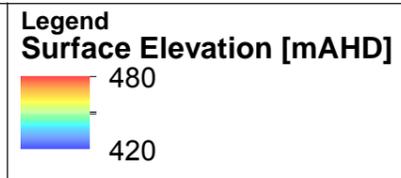


1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

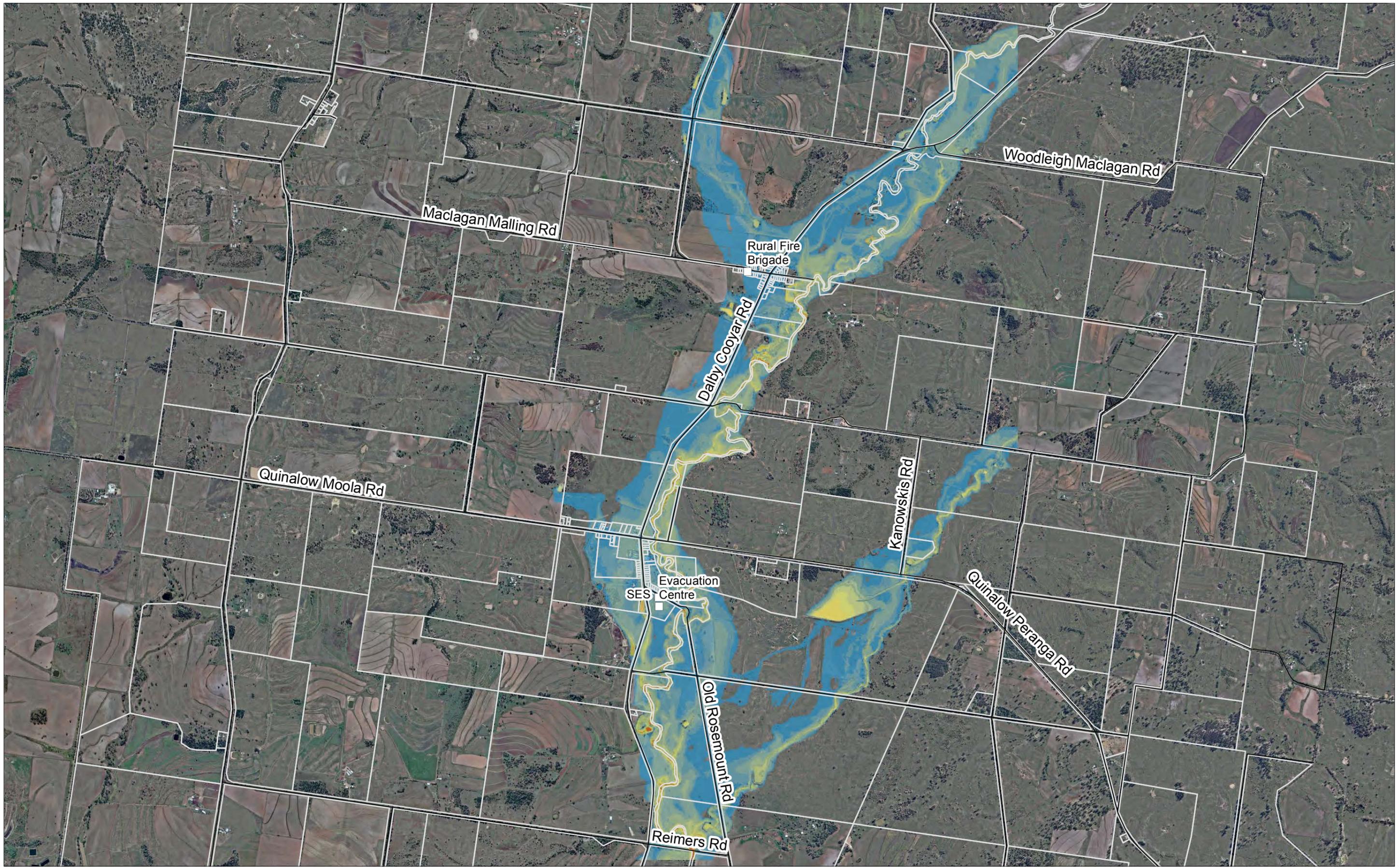


- Road Centrelines
- Cadastre
- Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
200 Year ARI Event
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56



Legend

Peak Water Depth (m)

0-0.25	0.25-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	>5
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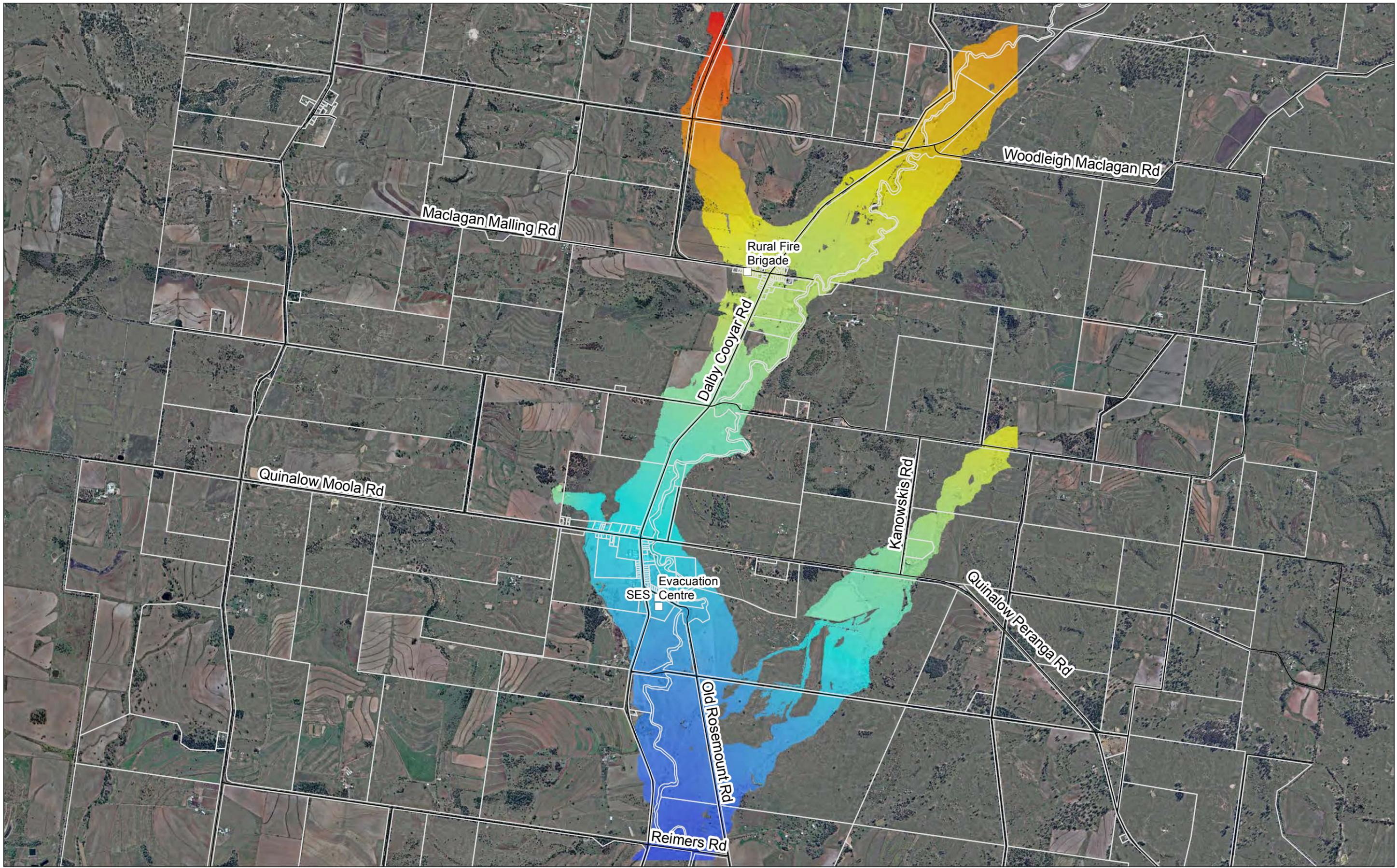
- Road Centrelines
- Cadastre
- Emergency Services

Legend

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
200 Year ARI Event
Peak Flood Depths

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

480

420

— Road Centrelines

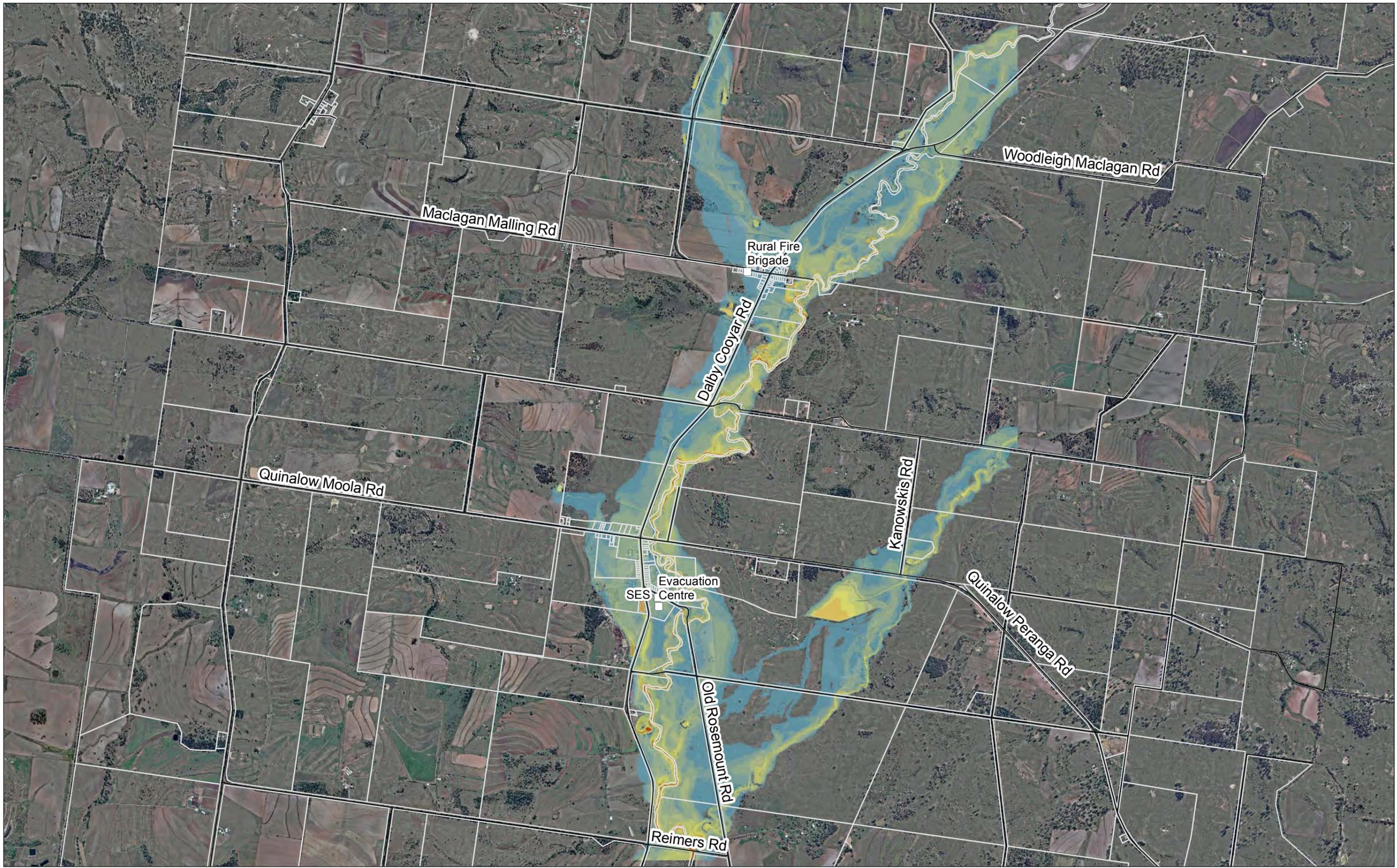
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
500 Year ARI Event
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Peak Water Depth (m)

0-0.25	0.25-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2-3	3-3.5	3.5-4	4-4.5	4.5-5	>5
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— Road Centrelines

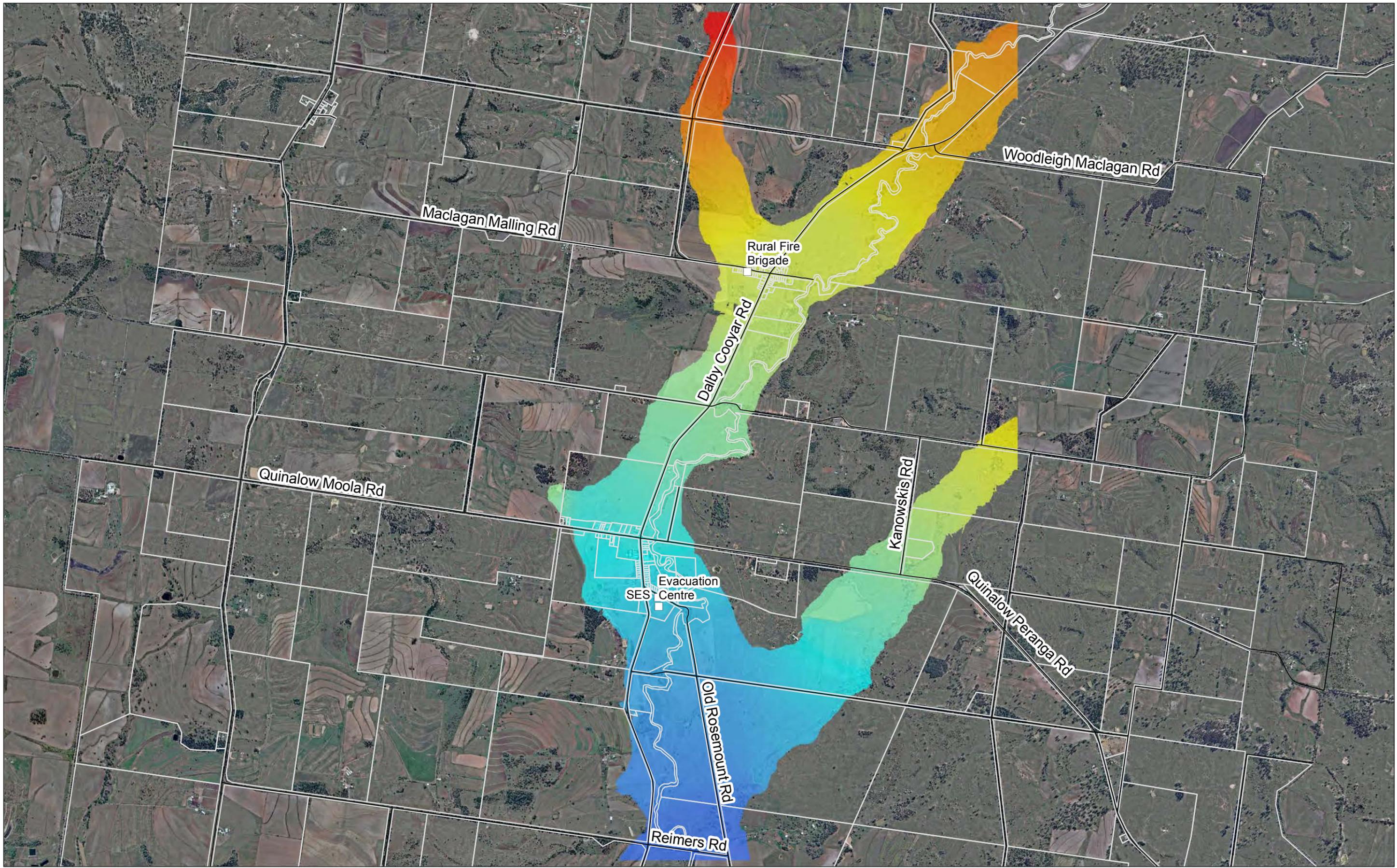
▭ Cadastre

▭ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
500 Year ARI Event
Peak Flood Depths

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1:32,000 (at A3)

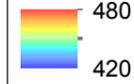
0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]



480

420

— Road Centrelines

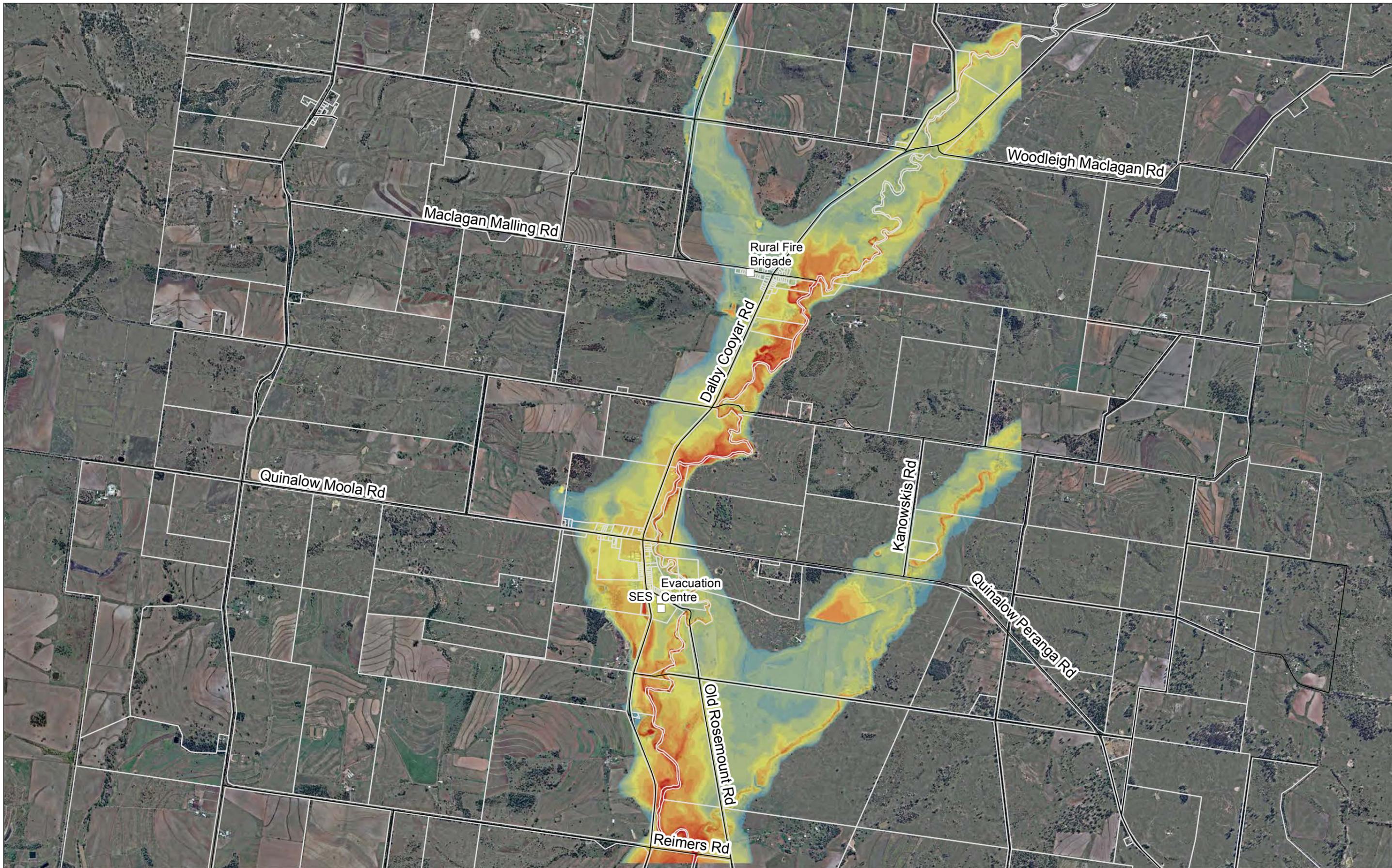
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
Probable Maximum Flood
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56



Legend

Peak Depth (m)

0-0.25	0.25-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	4.5-5	>5
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— Road Centrelines
 □ Cadastre
 □ Emergency Services

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**SP051 Flood Studies
 Work Package 9 Maclagan and Quinalow
 Probable Maximum Flood
 Peak Flood Depths**

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APPENDIX F

HAZARD AND HYDRAULIC CATEGORY MAPPING

Hazard Category Mapping

Flood hazard categories are as defined in Schedule 4 of the Queensland Reconstruction Authority's *Planning for stronger, more resilient floodplains* (2012), see Figure F.1.

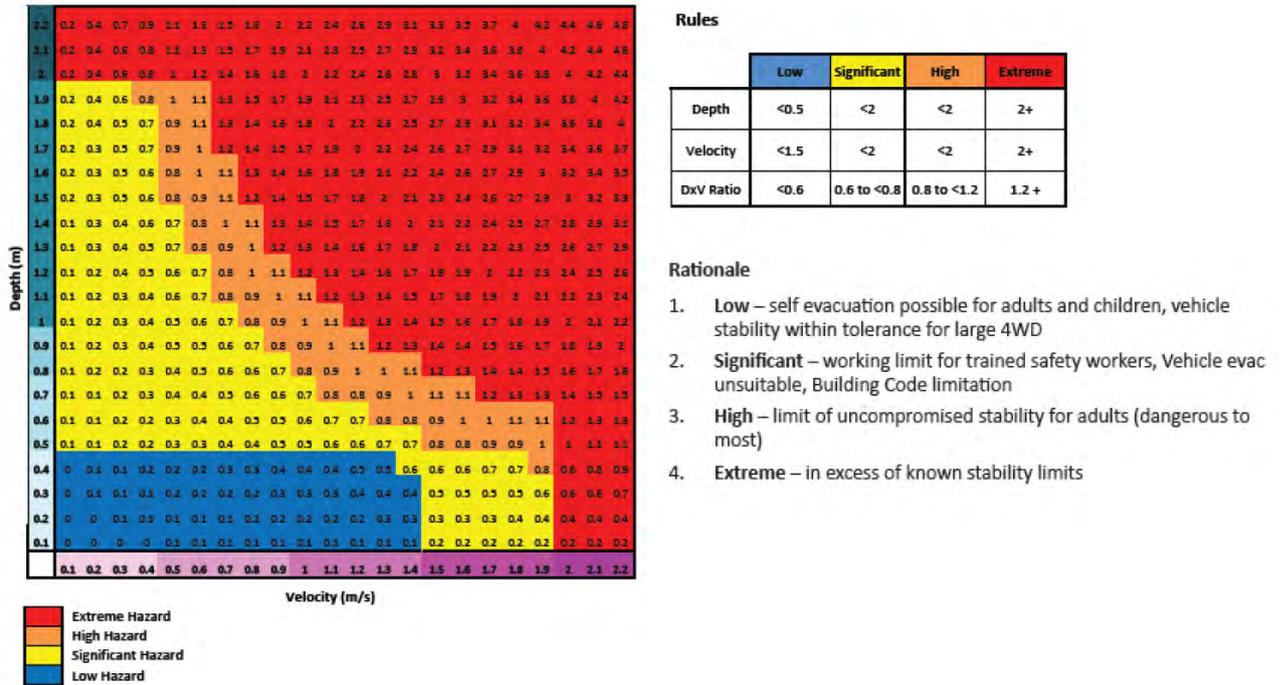
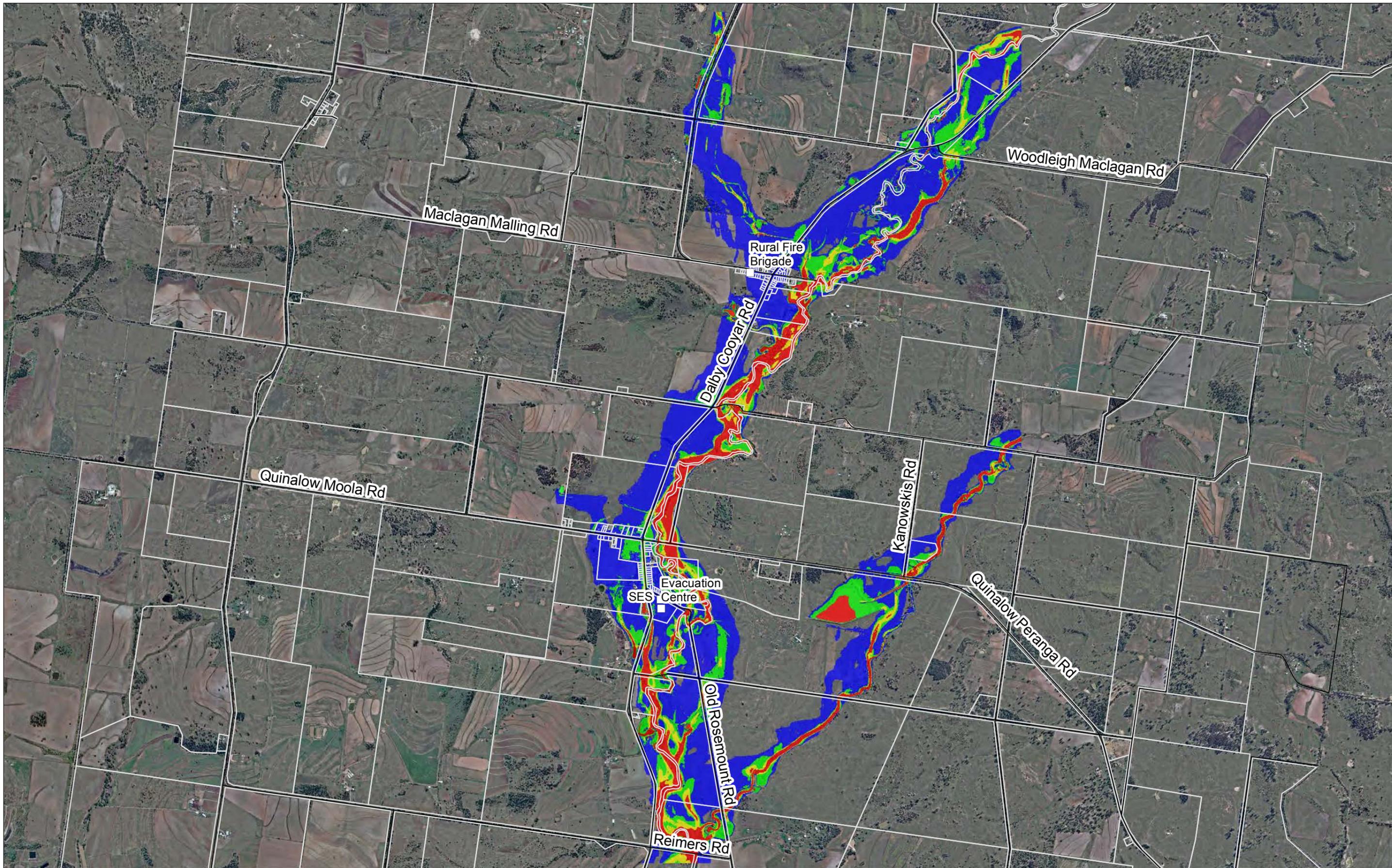


Figure F.1 Adopted Flood Hazard Classification

Hydraulic Category Mapping

The following hydraulic categories were adopted.

- Floodway
 - Velocity-depth product $\geq 0.5 \text{ m}^2/\text{s}$ or
 - Velocity $\geq 1 \text{ m/s}$
- Flood storage
 - Velocity-depth product $< 0.5 \text{ m}^2/\text{s}$ and
 - Depth $\geq 0.5 \text{ m}$
- Flood fringe
 - Velocity-depth product $< 0.5 \text{ m}^2/\text{s}$ and
 - Depth $< 0.5 \text{ m}$



1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Hazard Category

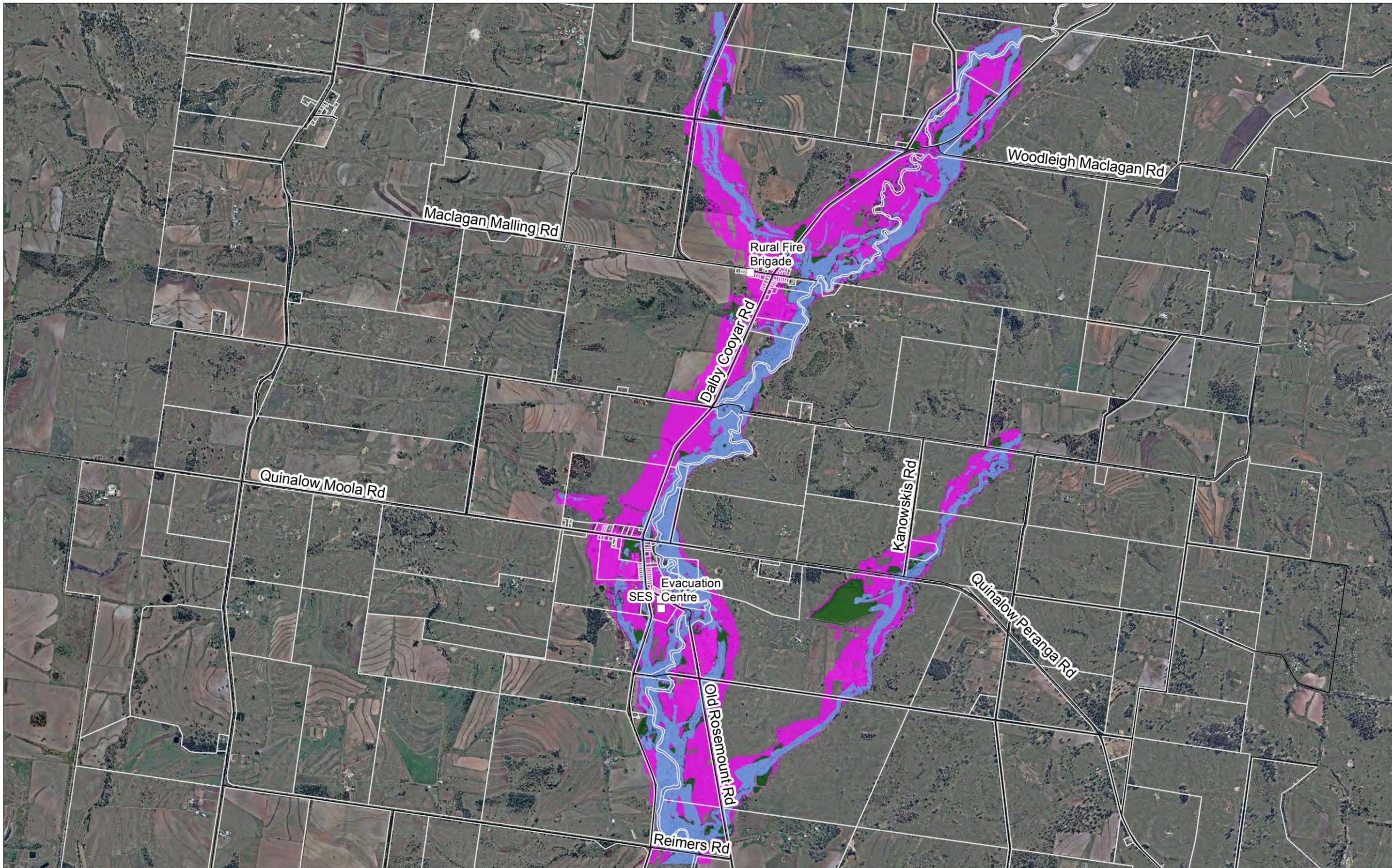
- Low
- Significant
- High
- Extreme

- Road Centrelines
- Cadastre
- Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event
Hazard Category

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

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Legend

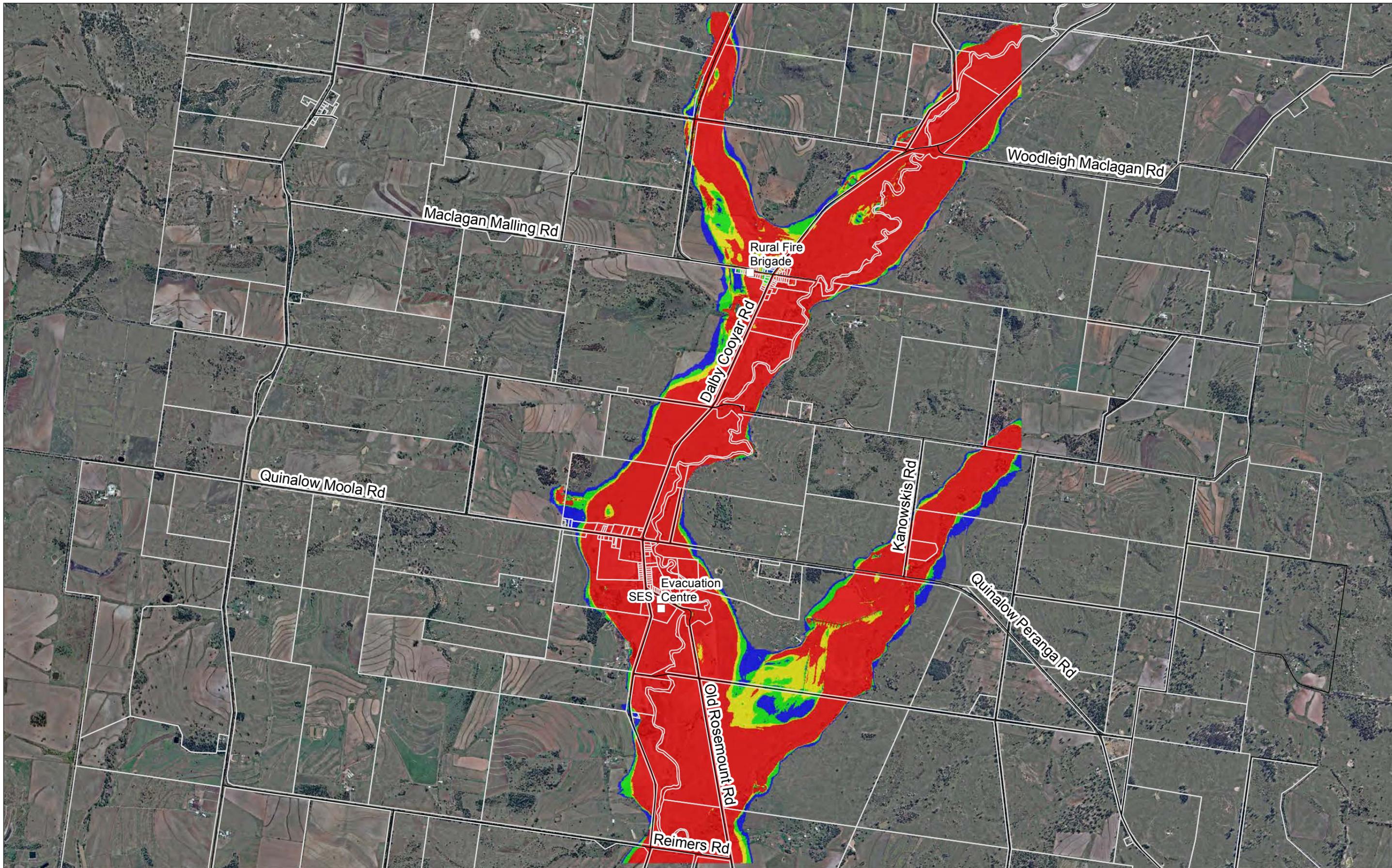
Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Road Centrelines
- Cadastre
- Emergency Services

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**SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event
Hydraulic Category**

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Hazard Category

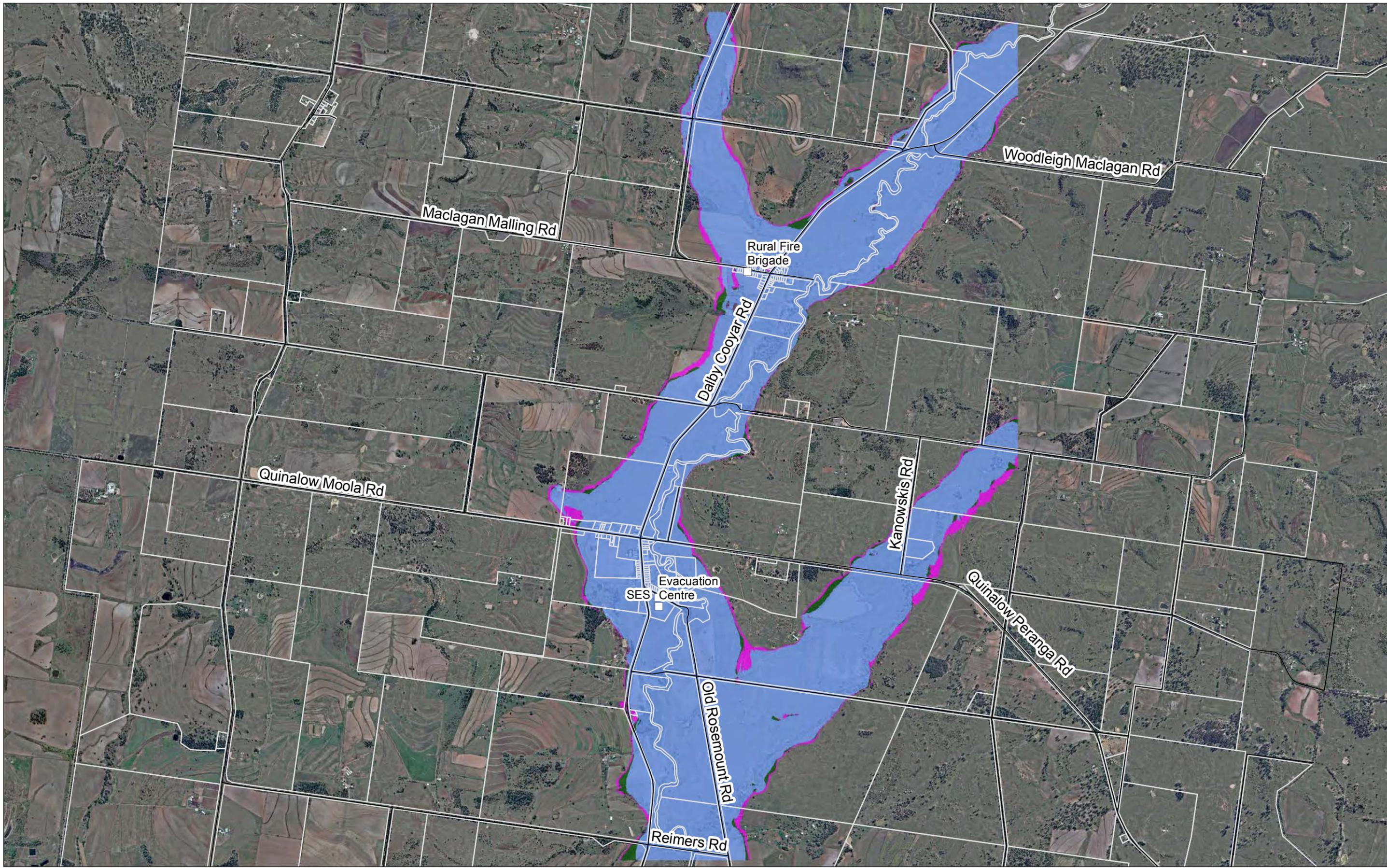
- Low
- Significant
- High
- Extreme

- Emergency Services
- Road Centrelines
- Cadastre

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**SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
Probable Maximum Flood
Hazard Category**

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Road Centrelines
- Cadastre
- Emergency Services

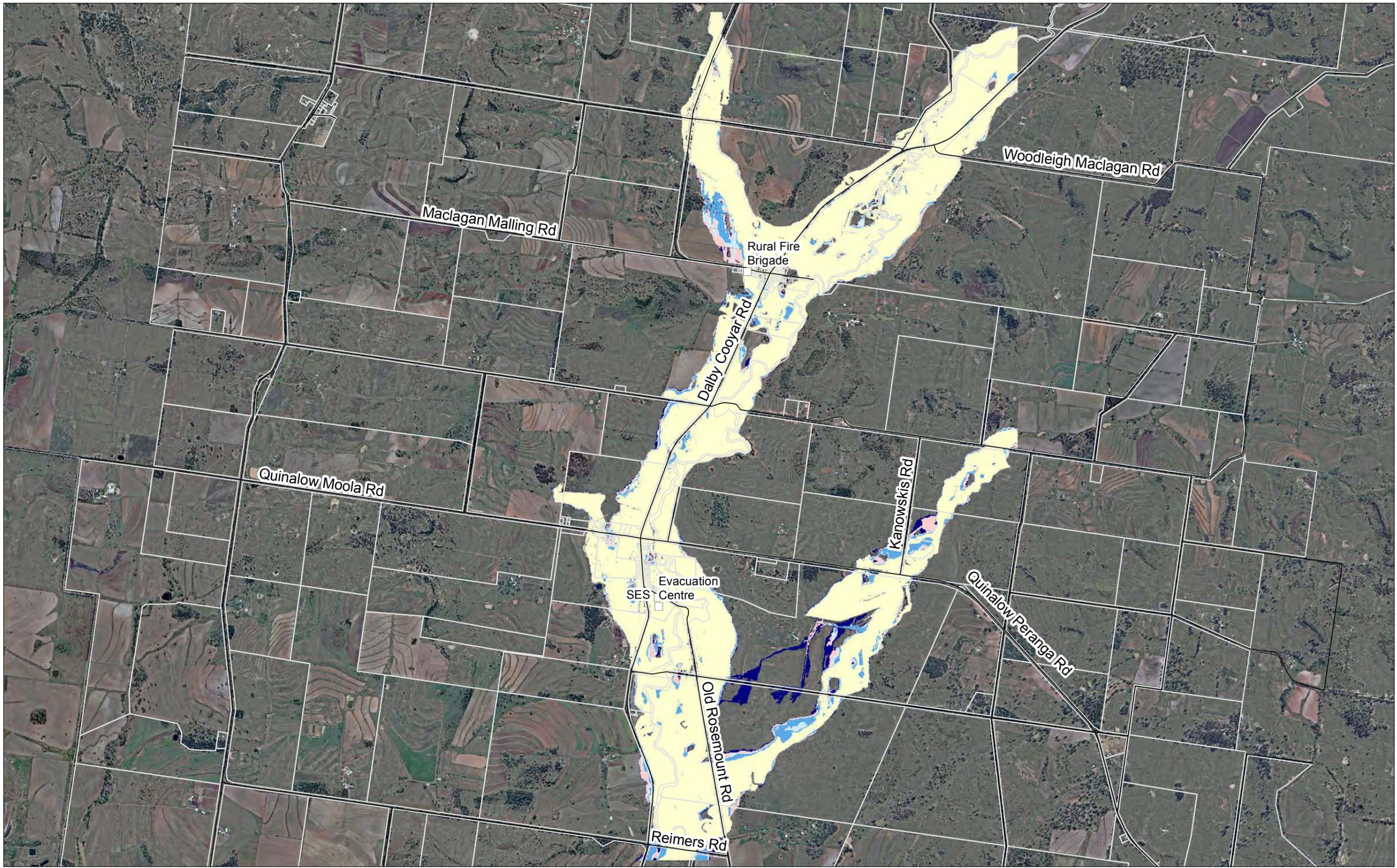
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**SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
Probable Maximum Flood
Hydraulic Category**

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APPENDIX G

SENSITIVITY ANALYSIS MAPPING



1:32,000 (at A3)

0 250 500 1,000
Meters
GDA 1994 MGA Zone 56

Legend

Inundation Extent

- 30% Reduction in Flow
- 30% Reduction in Roughness
- Baseline
- 30% Increase in Roughness
- 30% Increase in Flow

- Emergency Services
- Road Centrelines
- Cadastre

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**SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
Sensitivity to Flow and Roughness**

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Inundation Extent

- Baseline
- 50% Blockage of Structures
- Emergency Services
- Road Centrelines
- Cadastre

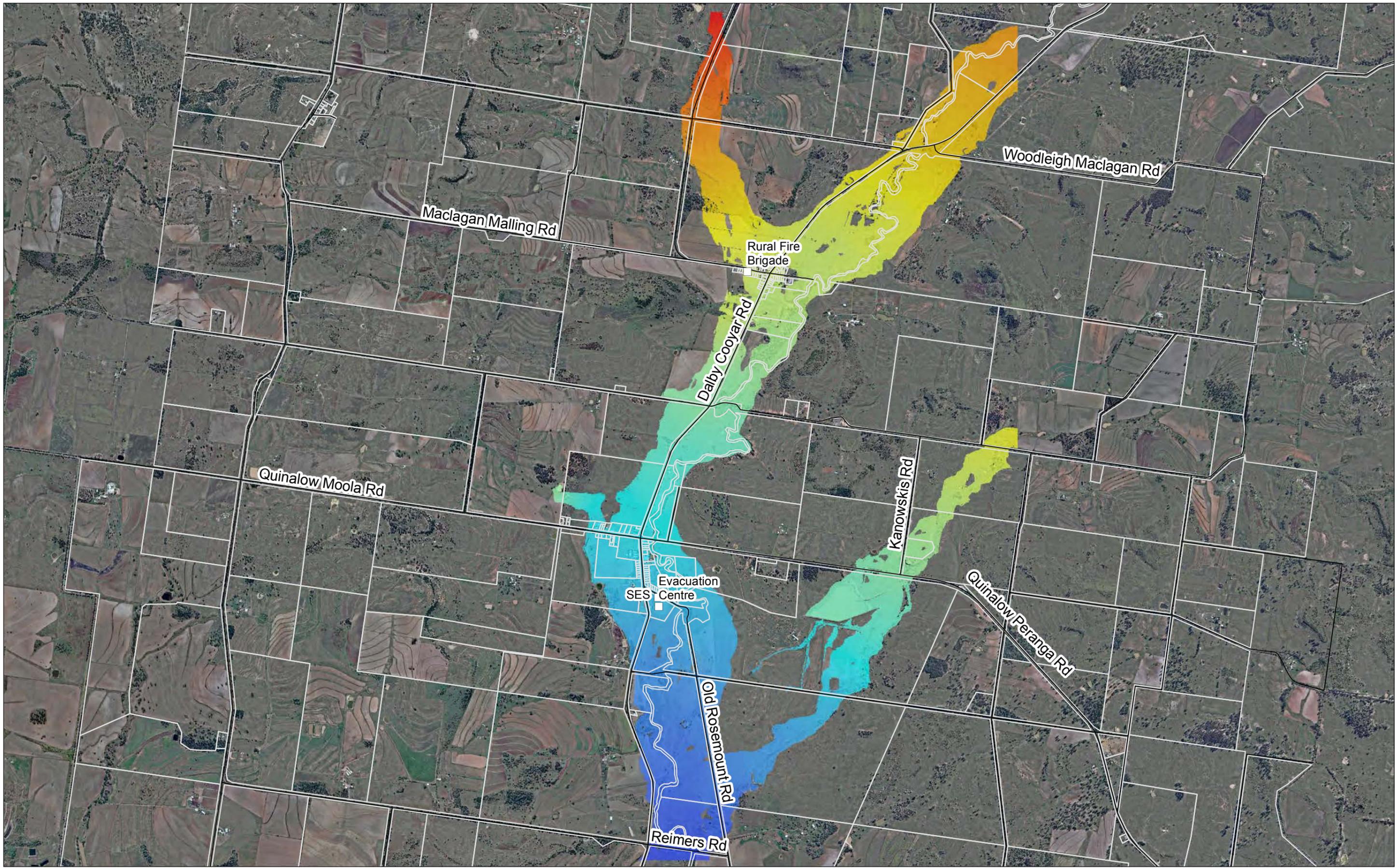
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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
Sensitivity to Blockage of Structures

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APPENDIX H

CLIMATE CHANGE SCENARIO MAPPING



1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

480

420

— Road Centrelines

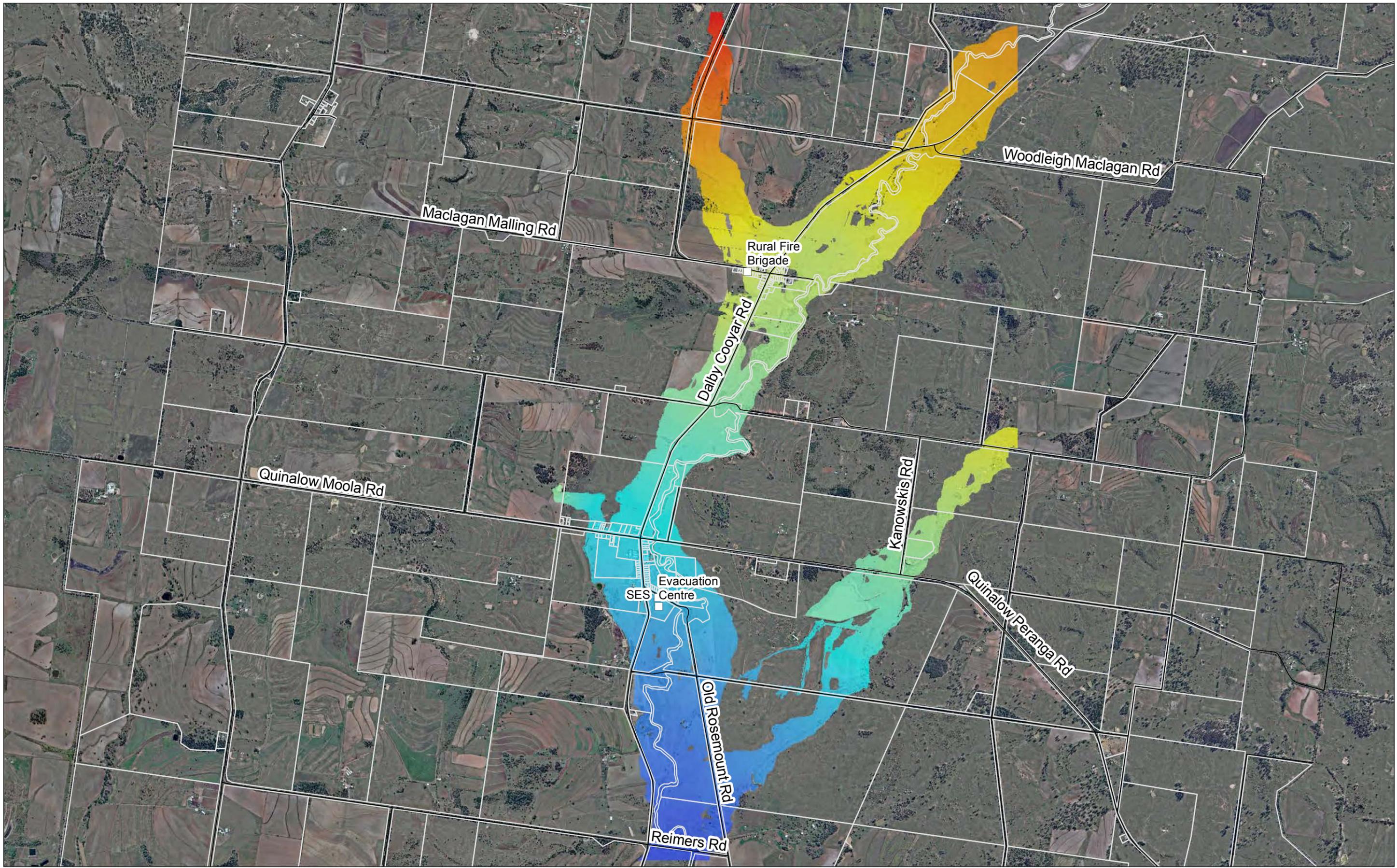
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event Climate Change 2050
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation

480

420

— Road Centrelines

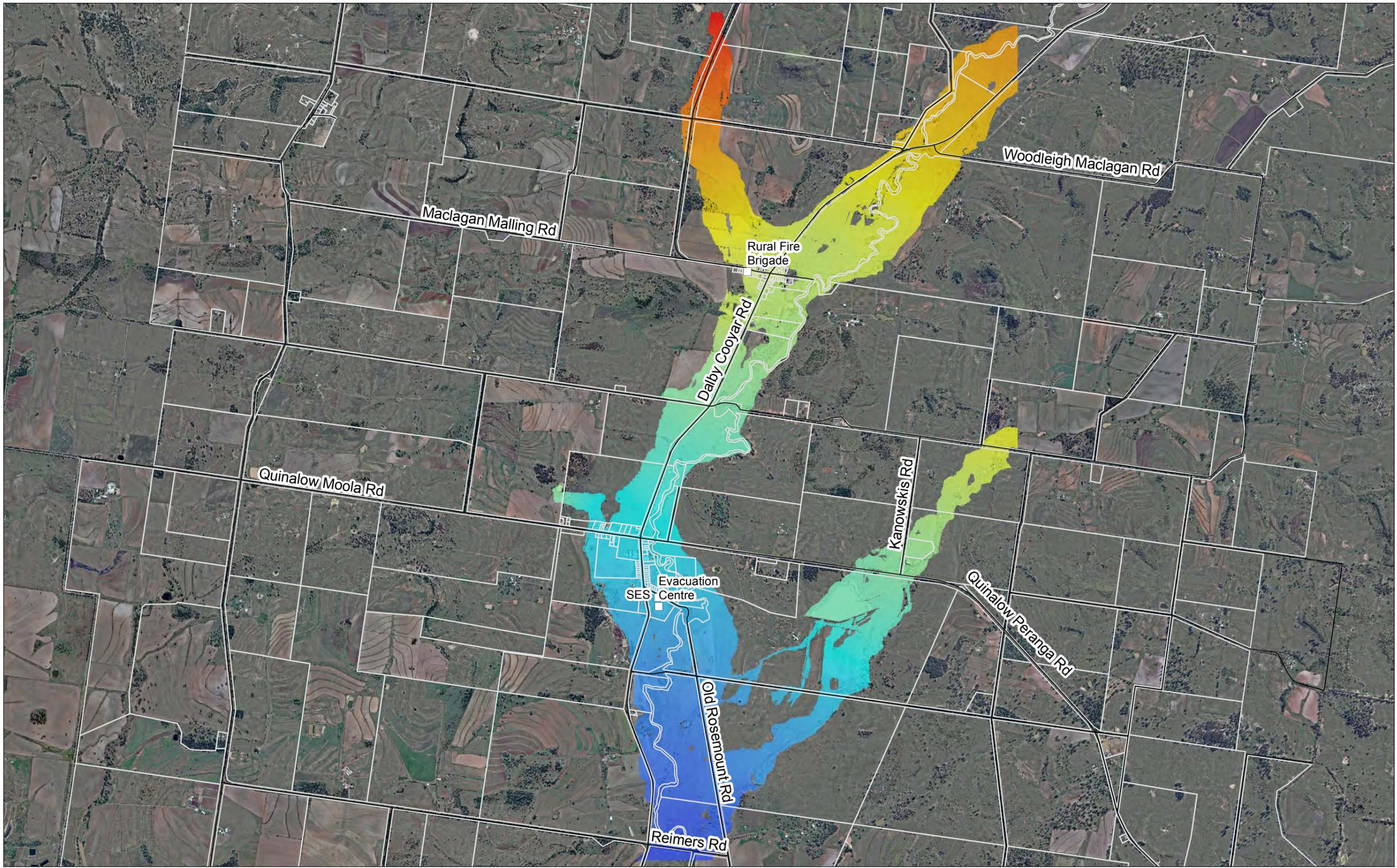
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event Climate Change 2070
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

480

420

— Road Centrelines

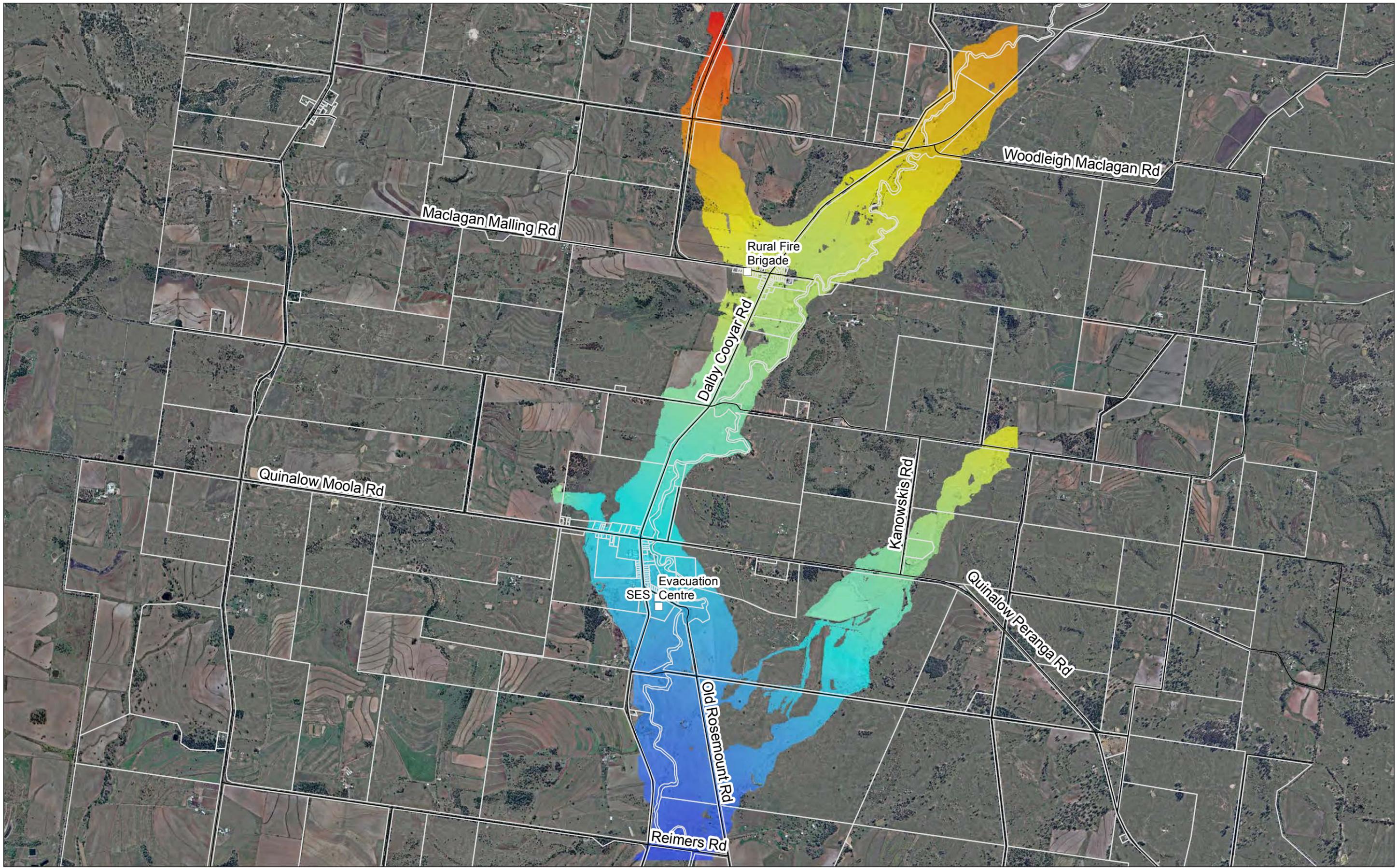
□ Cadastre

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
100 Year ARI Event Climate Change 2100
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

— Road Centrelines

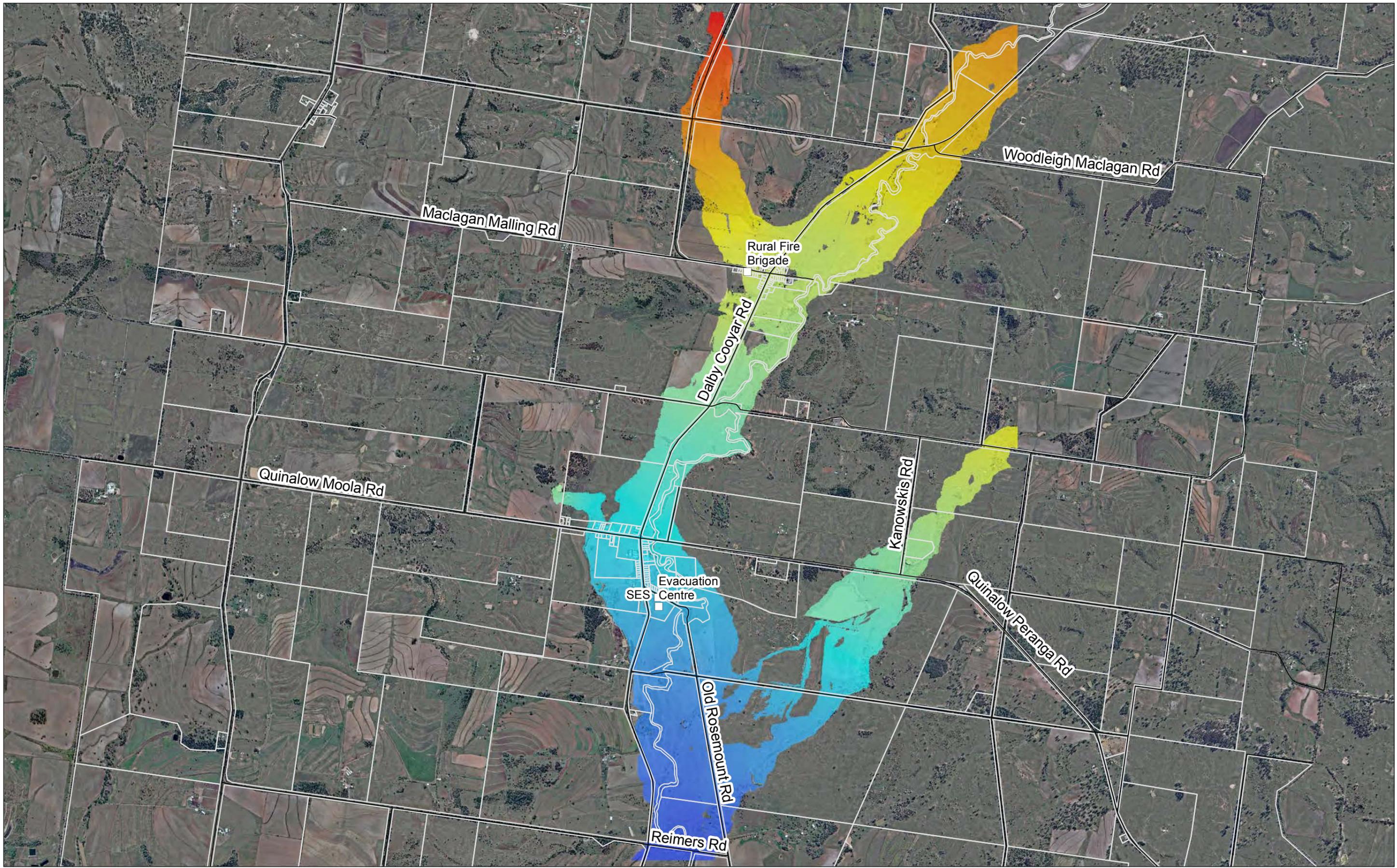
▭ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
200 Year ARI Event Climate Change 2050
Water Surface Elevation

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1:32,000 (at A3)

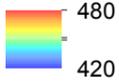
0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]



480

420

— Road Centrelines

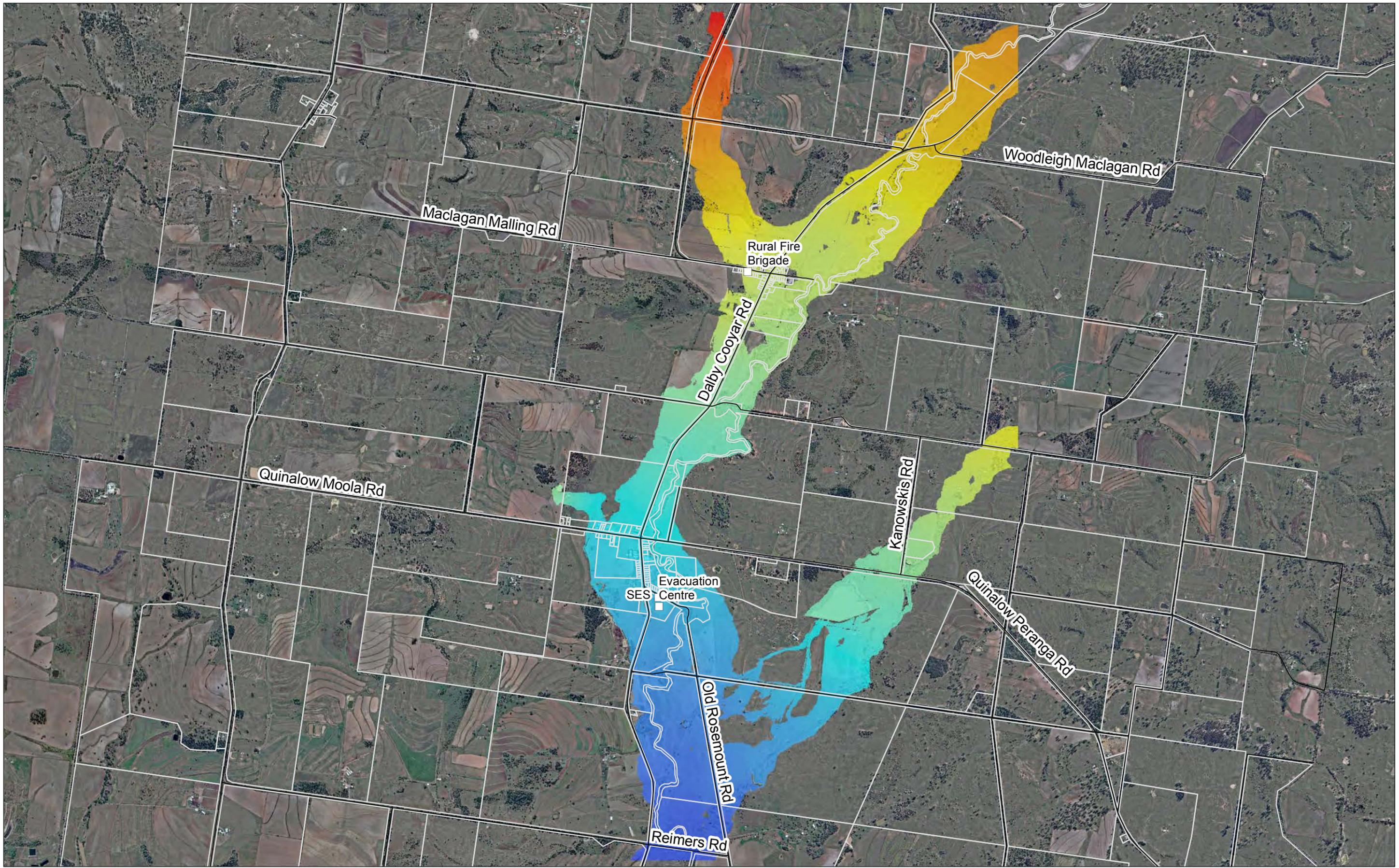
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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
200 Year ARI Event Climate Change 2070
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

480

420

— Road Centrelines

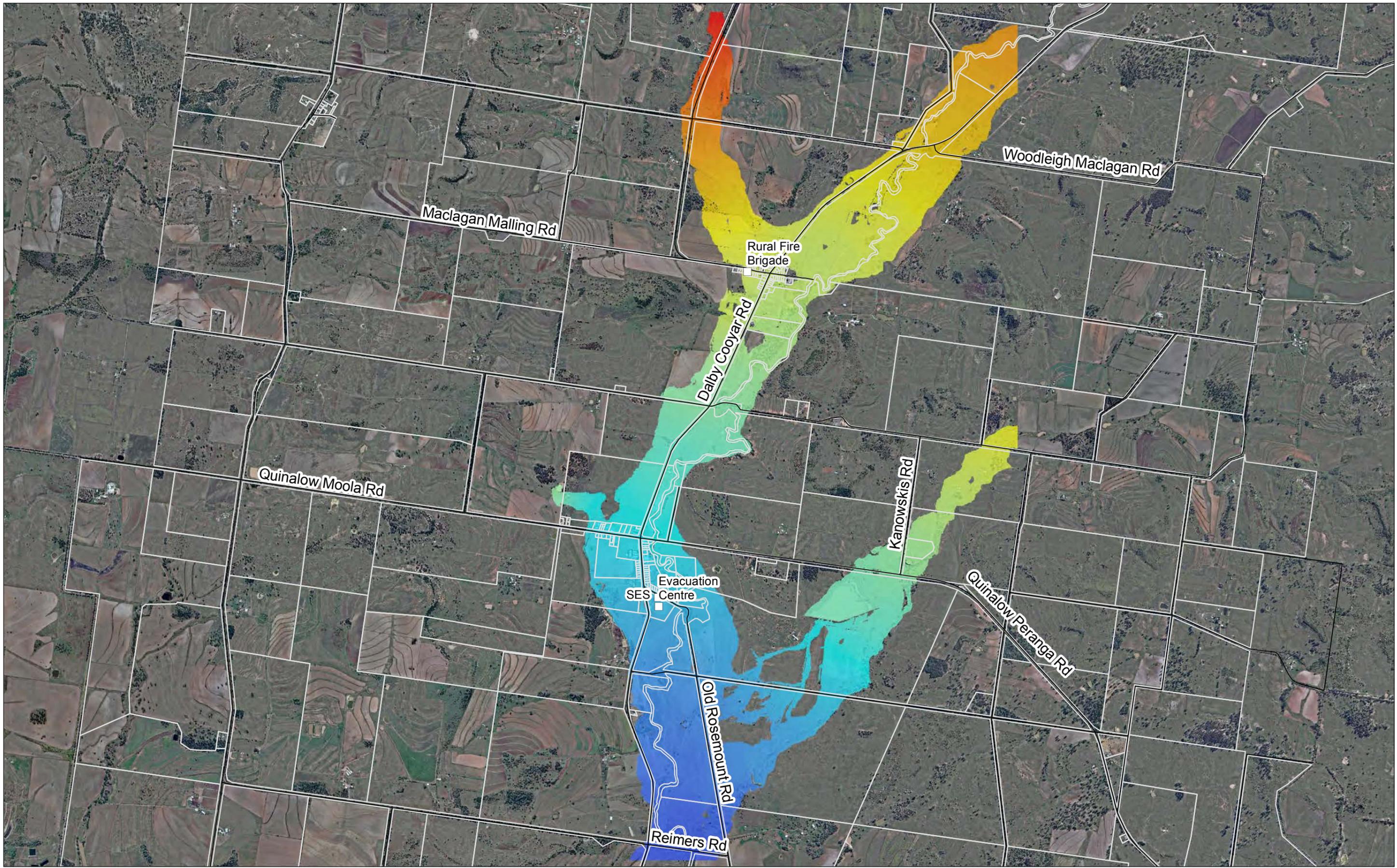
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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
200 Year ARI Event Climate Change 2100
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

480

420

— Road Centrelines

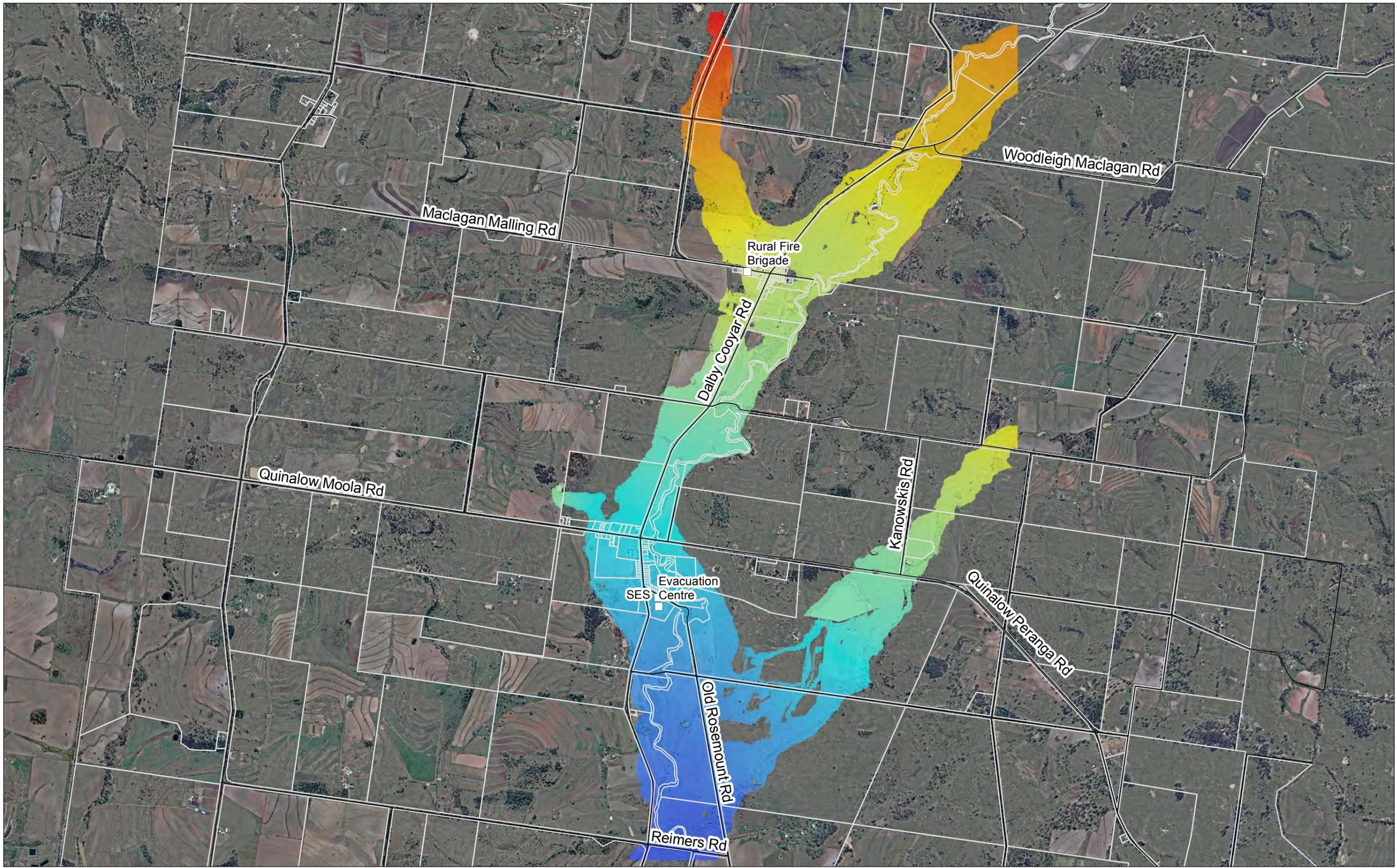
▭ Cadastre

□ Emergency Services

Disclaimer: The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood extent and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
500 Year ARI Event Climate Change 2050
Water Surface Elevation

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1:32,000 (at A3)

0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

480

420

— Road Centrelines

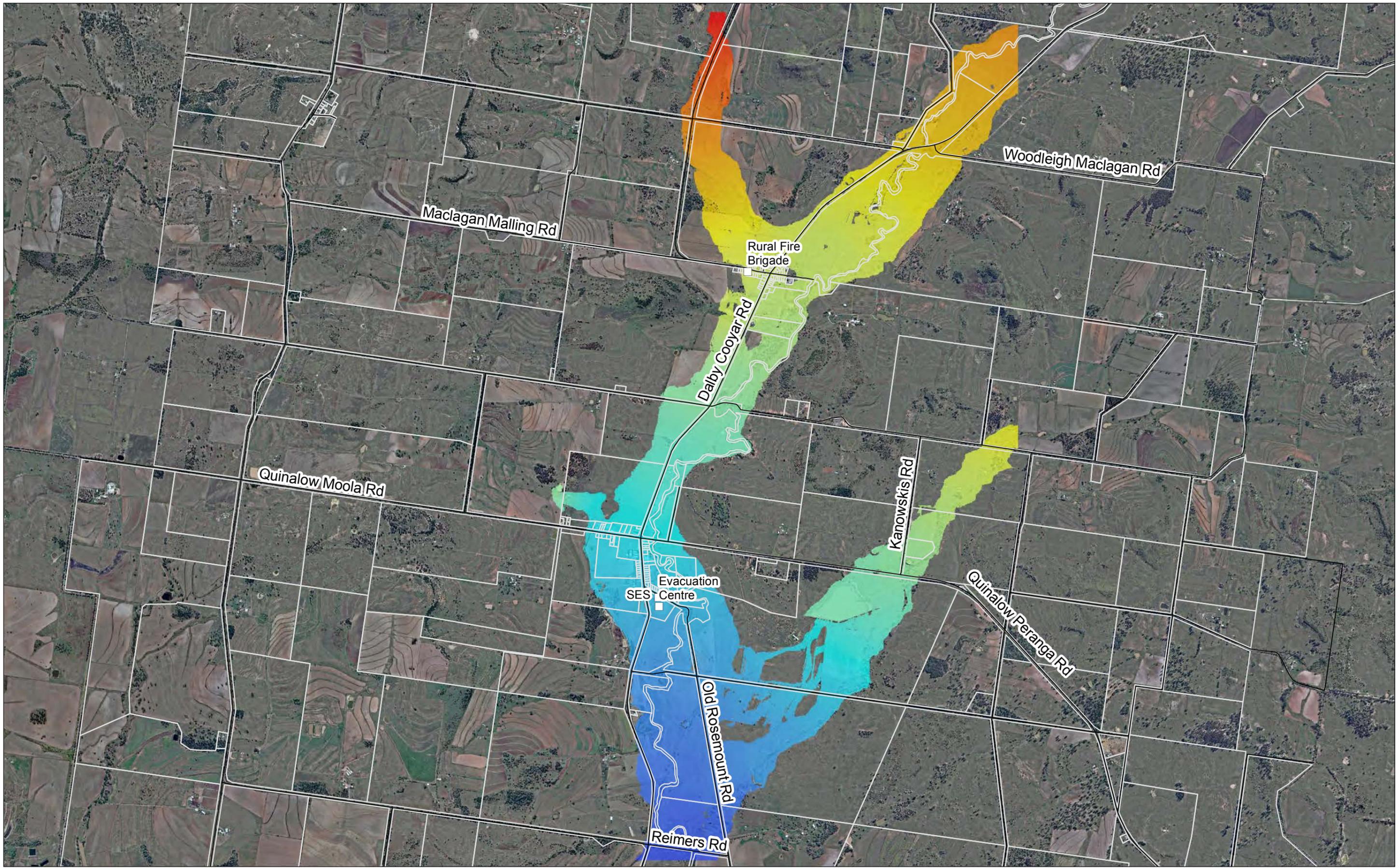
□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
500 Year ARI Event Climate Change 2070
Water Surface Elevation

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1:32,000 (at A3)

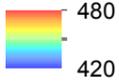
0 250 500 1,000
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]



480

420

— Road Centrelines

□ Cadastre

□ Emergency Services

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SP051 Flood Studies
Work Package 9 Maclagan and Quinalow
500 Year ARI Event Climate Change 2100
Water Surface Elevation

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yoursay.toowoombaRC.qld.gov.au/flood-resilience

A safer, stronger, more resilient region

Financially, socially and
environmentally sustainable



Maclagan & Quinalow Flood Studies Information Sheet

WHY UNDERTAKE FLOOD STUDIES?

Following extensive flooding across the Toowoomba region, we commissioned a number of flood studies to better understand how flooding can impact our communities. These studies are now complete and available on our website.

The flood studies found that flood behaviour can be complex and vary between locations, depending on landscape, infrastructure and rainfall pattern.

SOME BASIC FLOOD TERMS

- 1 Overland flow** – short duration flooding of backyards, drainage paths, streets and rural properties caused by stormwater as it makes its way into the creek/river system;
- 2 Creek flooding** – short to medium duration flooding caused by creeks rising and breaking their banks, which can then flood nearby homes, businesses and rural properties;
- 3 River flooding** – longer duration flooding caused by significant rises in a river which can break its banks in the same way as smaller creeks.

Most of the studies undertaken or commissioned by Council relate to the first two types of flooding – overland flow and creek flooding. It's important to note that these types of flooding can occur separately or together.

KEY MESSAGES

1. Council has a legislative requirement to undertake flood management and the whole community needs to be involved.
2. Flood studies are a foundation and an essential step towards our goal of a safer, stronger, more resilient region.
3. Flood studies have been undertaken by specialist engineers and incorporate the latest data, modelling techniques and community input.
4. Community consultation enables two-way information sharing about the project to increase community awareness, enhance decision making and help achieve our goal of a safer, stronger, more resilient region.



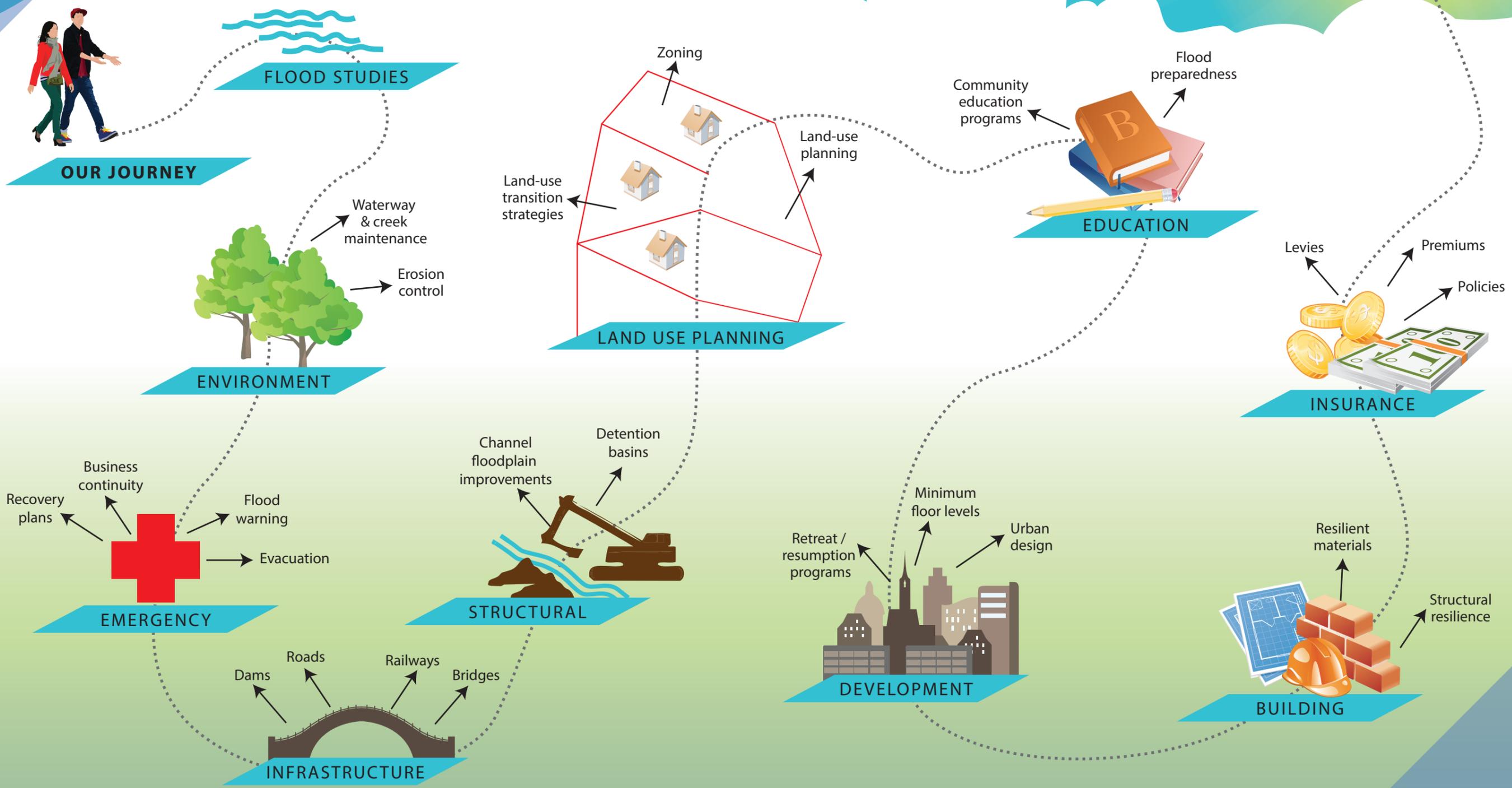
Flood + us - our journey

Steps on the path to achieving our goal

**A safer,
stronger,
more resilient
region**

Financially, socially and environmentally sustainable

OUR GOAL





Maclagan & Quinalow Flood Studies Information Sheet

WHAT ARE MACLAGAN & QUINALOW'S FLOOD STORIES?

A flood study and flood maps are now available for Maclagan and Quinalow residents. The primary source of flood risk to the towns is creek flooding.

Both towns are located on the western side of Myall Creek close to the creek channel, with some properties in Quinalow being within 50 metres of the channel banks. Maclagan and Quinalow were affected by flooding from Myall Creek during the January 2011 flood event. A number of roads were cut off during the event, including the Dalby-Cooyar Road and Pechey-Maclagan Road. The flood study has modelled a range of possible flood scenarios, from moderate through to rare and extreme events, and provides maps on depth, velocity and hazard. The deeper and faster flowing waters are generally confined to the main creek system. Low hazard areas are prominent on the western side of the creek through Maclagan prior to opening up on both sides of the creek through Quinalow and to the south of town as the floodplain widens. The levees in Quinalow offer some protection for parts of the town from more frequent flood events.

Even in these frequent events, the area on the corner of Quinalow-Peranga and Pechey-Maclagan roads are exposed to flooding, as the road bridge flows over. Properties behind the levee on Daly Street and Pechey-Maclagan Road are also subject to inundation when the levee flows over in events of 20% Annual Exceedance Probability

– meaning there is a 20% chance in any year of such an event or a larger one occurring.

The study modelled the January 2011 flooding and estimated that the event was a 10% Annual Exceedance Probability event – meaning that a flood of the size of that which occurred in January 2011, or a larger flood, has a 1% chance of occurring in any year. According to the Bureau of Meteorology, the record flood for the towns is the February 1981 flood.

Annual Exceedance Probability (AEP) means the chance of a flood of a given size or larger size occurring in any one year, usually expressed as a percentage.

COMMUNITY INVOLVEMENT

Improving the way we prepare for and respond to flooding as a community is very important to us. Many residents in our region contributed information to build and validate our flood knowledge during the region-wide consultation sessions and other flood studies engagement opportunities.

Community involvement with this project continues to help our region become safer, stronger and more resilient. We encourage you to access the flood study information online and stay up to date with the project by visiting the web address below.

GET INFORMED

You can access our region's current flood studies and maps by heading to

<http://yoursay.toowoombarc.qld.gov.au/flood-resilience>

For more information, please contact the project team by phone, email or post.

Phone: 131 872

Email: info@tr.qld.gov.au

Post: Strategic Planning & Economic Development,
Toowoomba Regional Council, PO Box 3021, Toowoomba Q 4350.



**TOOWOOMBA
REGION**