Clarence Valley Council

FINAL DRAFT Glenreagh Floodplain Risk Management Study and Plan

March 2018

The Glenreagh Floodplain Risk Management Plan was adopted by Council at its meeting of 15 May 2018 (Resolution 14.050/18). The resolution amended this document by splitting Action 5.1 into two actions, with the installation of a new automatic flood gauge at the Glenreagh Bridge identified with a capital cost of $15,000 and an annual maintenance cost of $3,000, and schedule implementation of management actions as part of the Council's future Delivery Program and Operational Plans.

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1. Introduction

1.1 Background

The Orara River and Bucca Bucca Creek (Bucca Creek) catchments are located to the west of Coffs Harbour on the NSW Mid North Coast (Appendix A). Both watercourses drain to the Clarence River at Grafton. The watercourses rise in the south and flow generally in a north westerly direction. The Orara River flows through the villages of Karangi, Coramba, Nana Glen, Glenreagh and Coutts Crossing. The main road, Orara Way, is located along the western bank of the Orara River and the Grafton to Coffs Harbour railway line, along the eastern bank.

The catchment defining the creeks is bounded to the west by Bushmans Range some 2 – 3 km east of Ulong and Lowanna and to the east by Big Boambee, Red Hill and the Coastal Range, approximately 3km west of the Coffs Harbour coastline.

Upstream of Glenreagh the Orara River has a catchment of some 433 km^2 with a length of some 55 km km^2. The catchment area to downstream of the Glenreagh Gauge has some 111km^2 of additional catchment area entering the Orara River, predominantly from the Tallawudjah Creek catchment generally west of Glenreagh, to give a total catchment area of 544 km^2.

A number of major tributaries drain into the Orara River Basin, Including:

- Urumbillum River, Mirum Creek and Fridays Creek, discharging to the Orara River in Upper Orara;
- Wongiwomble Creek discharging to the Orara River near Karangi;
- Nana and Coldwater Creek discharging to the Orara River near Nana Glen;
- Kings and Finberg Creek discharging to Bucca Creek upstream of Nana Glen;
- Glenreagh Creek; and
- Tallawudjah creek discharging to the Orara River near Glenreagh.

The catchments in the upstream reaches of these creeks are generally steep and heavily forested. Lower reaches are mostly rural in nature. From downstream of Aurania the Orara River generally has a deep well defined channel with a wide floodplain. River slopes vary from 0.4% between Upper Orara to 0.1% downstream of Nana Glen. River slopes vary from 0.2% at Central Bucca to 0.05% at Glenreagh.

Over the years, a number of significant floods have occurred in the Orara Valley. Floodwaters in both catchments have been known to rise quickly and isolate communities and properties, and houses in Glenreagh can be inundated in flood events necessitating evacuations.

1.2 Previous Studies

The Flood Study for Orara River and Bucca Creek Valleys, June 1991 (CHCC,1991) made mention and included findings of earlier flood assessments, particularly by Coffs Harbour City Council in 1982 and Sinclair Knight in 1984. The June 1991 study primarily provided information on bridge upgrades. The earlier studies mentioned, could not be located for the current study, however were referenced throughout the 1991 study.

The June 1991 study was a preliminary investigation to provide a “reasonable” assessment of the land within the study area adjacent to the main river system, which might be liable to inundation in the 1% AEP flood event. Only limited survey and preliminary hydrologic and hydraulic analysis was undertaken. The theoretical analysis was to be supplemented with

readily available data held by various authorities, previous flood studies, interviews with local residents, field survey data and an examination of aerial photographs. The study brief of the 1991 study outlined the following tasks:

- Undertake a survey to determine if there is any local knowledge of significant flooding in the creek systems draining the Study Area which might be used in the flood study;
- Examination and collation of existing data available from Council's records in relation to historical and estimated flood levels at locations within the study area;
- An extension of the existing hydrological model developed for earlier studies, and determine peak flow rates for the creek system within the study area for the 1% AEP event;
- Hydraulic modelling of the Glenreagh study area, and determination of water surface levels in the creek system for the 1% AEP event. These were limited to linear hydraulic grade line estimations between bridges, thus without hydraulic modelling; and
- Assess the areas of land likely to be inundated during the 1% AEP event, with the areas of expected inundation shown on a 1:25 000 map of the study area.

The 1991 assessment was to be based on experience and professional judgement and was to be based on a collation of historical data and reports on flooding in the area. It was to be limited primarily to flooding from the Orara River and Tallawudjah creek tributaries. The brief specifically required the need for extensive survey detail as LiDAR survey was not available for this study.

The Orara River Flood Study (GHD 2012) was undertaken for Coffs Harbour City Council, and simulated flooding in the Orara River from the headwaters to the Coffs Harbour Local Government Area boundary. This boundary is located some approximately 7km upstream on the Orara River. The study produced a RORB model to simulate the Orara River hydrology, which was input to a TUFLOW model to simulate flood levels. The models were calibrated, and were used as a basis for the current study.

1.3 Objectives of the Project

Key objectives and outcomes of the current project are summarised in the table below.

Table 1-1 General Objectives and Outcomes

Key Objective	Specific Considerations
Undertake a Floodplain Risk Management Study and develop a Management Plan that addresses existing, future and continuing flooding.	Review the existing flood study and address flooding issues in Glenreagh
Undertake the study and develop the plan in accordance with the NSW Floodplain Development Manual, 2005.	Develop the Study and Plan in close consultation with Council and stakeholders, presenting and evaluating/floodplain mitigation measured.
Engage the community and stakeholders to solicit feedback, understanding and support of the Floodplain Risk Management Study and Plan.	Develop the Study and Plan in close consultation with Council and stakeholders, presenting and evaluating/floodplain mitigation measured.
Ensure consultation with the key stakeholders including Council, the	Consider issues and specific requirements raised by Council, as listed in the Brief.

Flood Risk Management Committee and the community are undertaken in a thorough manner throughout the project.	
	Provide Council with a plan to implement appropriate planning controls and provide a strategy to reduce the impact and damages caused by flooding

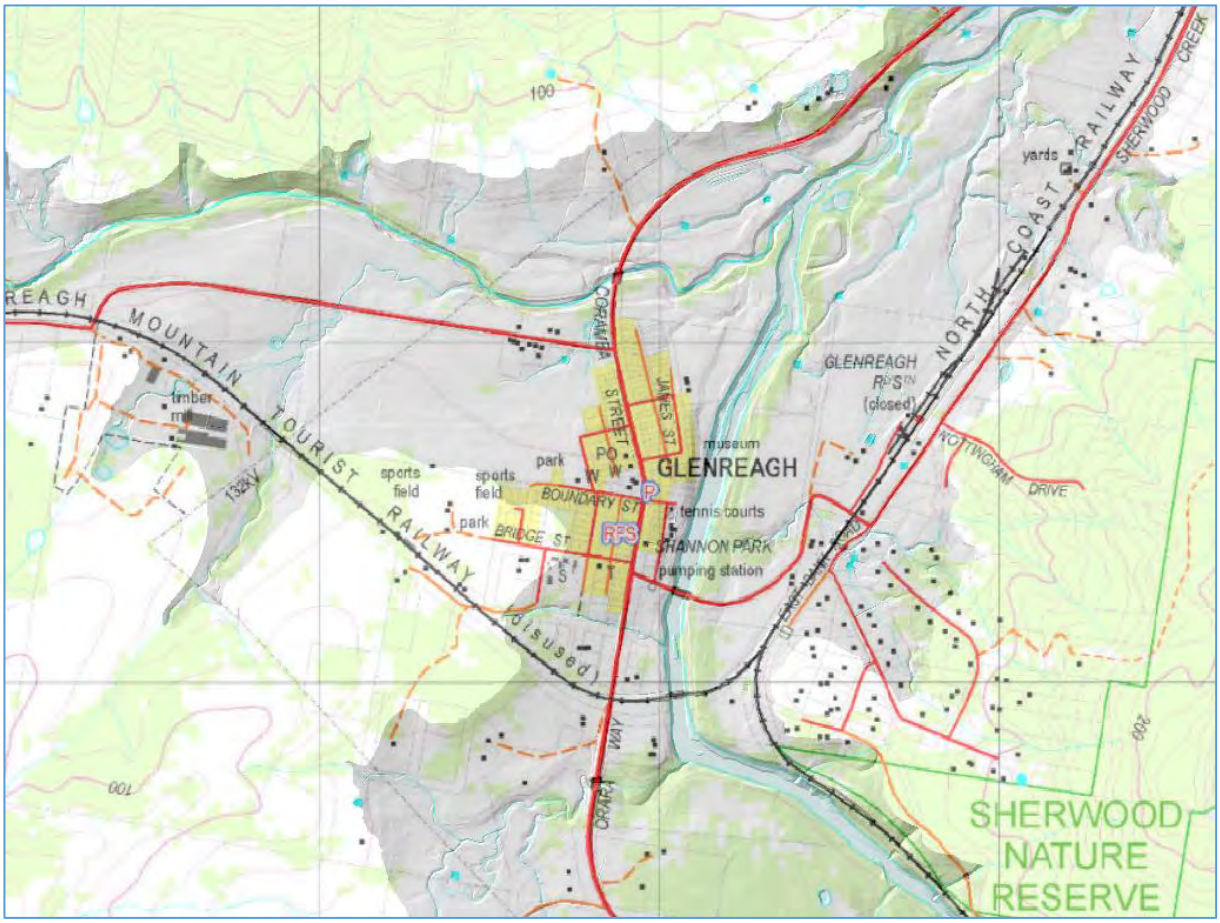

Figure 1-1 Location Plan

1.4 NSW Government's Floodplain Management Process

The prime responsibility for planning and management of flood prone lands in NSW rests with local government, and in the case of Glenreagh, Clarence Valley Council. The NSW Government provides assistance with state-wide policy issues and technical support. Financial assistance is also provided to undertake flood behaviour and floodplain management studies, for the implementation of works identified in these studies, through the NSW Governments Floodplain Management Program.

A Flood Prone Land Policy and a Floodplain Development Manual (NSW, 2005) forms the basis of floodplain management in NSW. The primary objectives of the Policy are to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive

methods where possible. The policy provides some legal protection for Councils and other public authorities and their staff against claims for damages resulting from their issuing advice or granting approvals on floodplains, provided they have acted substantially in accordance with the principles contained in the Floodplain Development Manual. The implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Management Plan.

To support this policy, the Floodplain Development Manual identifies four main stages in the floodplain risk management process which includes the following:

- Flood Study: Determines the nature and extent of flooding behaviour.
- Floodplain Risk Management Study: Identifies, develops and compares various floodplain management options utilising the results of the Flood Study as well as assessment of social, economic, ecological and cultural issues.
- Floodplain Risk Management Plan: Formalises outcomes of the previous studies and present the necessary information to enable relevant authorities to plan for the future.
- Plan Implementation: Includes construction of structural floodplain management measures as well as incorporation of non-structural measures into existing Local Authority Environmental and Development Control Plans.

A Flood Study for Glenreagh was completed (CVC, 2013). This subsequent report provides information for the Floodplain Risk Management Study and Plan.

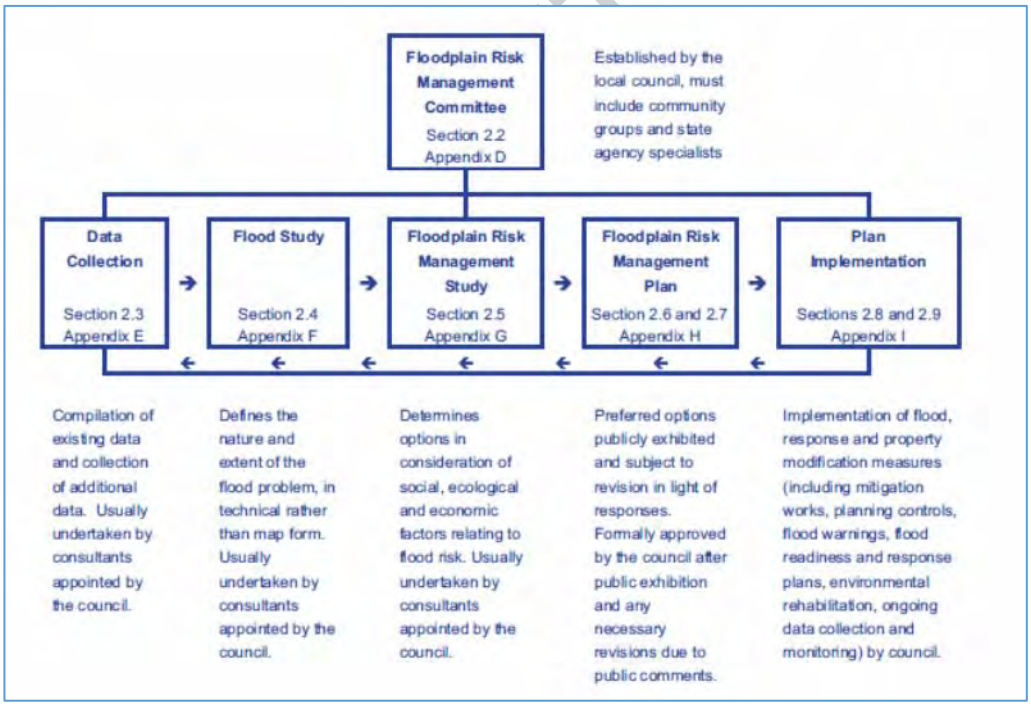

Figure 1-2 Flood Plain Risk Management Process (NSW, 2005)

1.5 Scope and Limitations

This report has been prepared by GHD for Clarence Valley Council and may only be used and relied on by Clarence Valley Council for the purpose agreed between GHD and the Clarence Valley Council as set out in this report. GHD otherwise disclaims responsibility to any person other than Clarence Valley Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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GHD has prepared the preliminary cost estimate set out in this report using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD. The Cost Estimate has been prepared for the purpose of comparative benefit/cost assessment and must not be used for any other purpose. The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

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2. Review of Glenreagh Flood Study (2013)

2.1 Précis of Flood Study

2.1.1 Background

The Glenreagh Flood Study (CVC, 2013) prepared the base data for the present study. This study produced flood mapping for a range of flood events including determination of preliminary flood hazard, calculation of preliminary flood damages and engaging the community. The flood study had three main components:

- Review of available data and previous investigations. Rainfall and flood level data were sourced from Council, the community and the Bureau of Meteorology (BOM). This information was used to compile and calibrate the hydrologic and hydraulic models. A Digital Terrain Model (DTM) was created from topographic survey data was used to define streams, floodplains and features influencing flooding patterns in the study area.
- Compilation of a hydrologic model (RORB model), which included calibration and validation. The model was used to simulate design storms for a range of storm events, for input to a hydraulic flood model.
- Compilation of a hydraulic model (TUFLOW model) for Glenreagh by extending existing models developed as part of the Orara River Flood Study (GHD, 2012). This model was used to simulate the flood conveyance, reporting flood levels, depths, flows, velocities and hazard for historic and design storm events. To achieve this objective, the study collected, compiled and reviewed all available relevant data (including survey, aerial photography and satellite imagery). The study simulated the following design events:
  - 20% AEP (5-year ARI)
  - 5% AEP (20-year ARI)
  - 1% AEP (100-year ARI)
  - 0.2% AEP (500-year ARI)
  - Probable Maximum Flood (PMF)

2.1.2 History of Flooding

Historically, a number of significant floods have occurred in the Orara Valley. It is understood, from community input that one of the largest floods in the valley occurred on 24 June 1950, when 502 mm was recorded at the Aurania rainfall gauge in a single day and 916 mm fell from 18 to 25 June.

Figure 2-1 shows the largest floods on record in the Orara River at Glenreagh from the early 1970's onwards (WaterNSW website). In March/April 2009, five significant events were recorded at the Glenreagh runoff gauge, all exceeding or close to the "Moderate Flood" classification. Of the floods since the early 1970's, the March/April 2009 event provided the highest peak, with a flood depth of some 13 m above the creek invert at the gauge. This depth was equalled in February 2013. This depth signifies a "Major Flood" classification at the gauge.

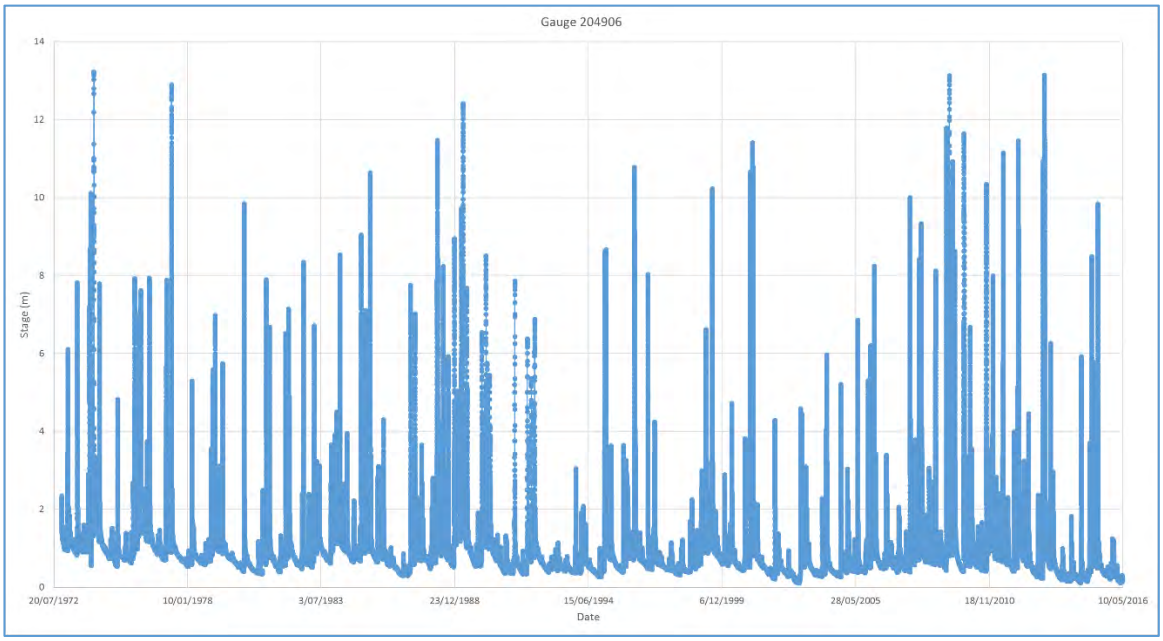


Figure 2-1 Largest Floods in the Orara at Glenreagh

Floodwaters in both the Orara and Tallawudjah Creek catchments have been known to rise quickly and isolate communities and properties. While flood peaks can recede equally quickly, properties at times can remain isolated for several days. Many houses in Glenreagh can be inundated in flood events necessitating evacuations. The nature of flooding varies considerably from in-stream flood ways to areas where the floodwaters bypass bends in the river and where floodwaters backup into the lower reaches of tributary creeks. Rainfall and river gauging data in the catchment is limited, however significant events have been recorded on gauges at Karangi and Glenreagh.

2.1.3 Flood Hydrographs

Calibration Data

A number of river gauges are located along the Orara River and were deemed suitable for calibration, as tabulated below.

Table 2-1 Runoff Gauge Data

Gauge Number	Gauge Name	River	Operational Dates	Comments
204906	Orara River At Glenreagh	Orara	15/11/1972 – Present	Orara River Approx. 2.5 km upstream Of Glenreagh
204068	Orara River At Orange Grove	Orara	14/08/1995 – Present	Orara River Approx. 33 km upstream Of Glenreagh and approx. 4 km upstream of Karangi Dam
204025	Orara River At Karangi	Orara	31/10/1925 – Present	Orara River Approx. 30 km upstream of Glenreagh, 6.8km upstream of Coramba and approx. 250m downstream of Karangi Dam

A number of rainfall gauges are located within the Orara River catchment, which include Bureau of Meteorology (BOM) gauges tabulated below and gauges operated by Manly Hydraulic Laboratory (MHL, 2009). While the daily rainfall data gauges are numerous, there are only a few pluviograph gauges in the catchment that provide temporal information on historic storms.

These include the Aurania Gauge within the Orara Valley, a number of MHL gauges around Coffs Harbour and the BOM gauge at the Coffs Harbour Airport. The MHL gauges are located in close proximity to, and east of the steeply rising topographic relief along the Coffs Coast. Here orographic effects (change in atmospheric conditions caused by a change in elevation) have been shown to have a significant effect on rainfall (CHCC, 2001). These effects were confirmed through preliminary assessment of the gauges during for the March/April 2009 event.

Table 2-2 A selection of available Rainfall Data from BOM

Gauge Number	Type	Operational Dates	Comments
059009 – Coramba (Glenfiddich)	Daily	1891 – Present	Confirmation of rainfall distribution with Aurania Gauge
059042 – Glenreagh PO	Daily	1953 – Present	Confirmation of rainfall distribution with Aurania Gauge
059006 – Lower Bucca	Daily	1901 – Present	Confirmation of rainfall distribution with Aurania Gauge
059095 – Upper Orara (Dairyville)	Daily	1899 – Present	Confirmation of rainfall distribution with Aurania Gauge
059026 – Upper Orara (Aurania)	Pluvio and Daily	1970 – Present	Calibration with Orara River
59040 – Coffs Harbour	Pluvio	1960 – Present	Calibration with Orara River (March/April 2009 Event)

Flood Frequency Analysis

Flood frequency analysis was undertaken using the data obtained from the PINEENA software for the Karangi Gauge (204025) and at the Glenreagh Gauge (204026). While reviewing this gauge data it was noted, that the Glenreagh Gauge rating curve is reliant upon gauging data to a gauge depth of approximately 8.5 m, which was a single point measured on 14/03/1974. Prior to this gauging, two measurements were taken on 14/03/1974 and 08/03/1995 with a gauge depth of 7.5 m. These gauged depths measured flows when the discharge is confined to the river channel, and flows have not emerged onto the floodplain (approximately 11.5m to 12m gauge depth). Beyond these gaugings, the rating curve relies on extrapolation up to a gauge depth of approximately 14 m.

Likewise, the Karangi Gauge was reliant upon gauging data to a gauge depth of approximately 3.5 m, which was a single point measured on 24/04/1988. Beyond these stages, the rating curve relies on extrapolation up to a gauge depth of approximately 6.8 m and the curve generally shows a “S” shape without confirmation through further gauging.

Thus beyond the gauge depth of 7.5 m at Glenreagh and 3.5 m for Karangi, the reported flood flows in PINEENA need to be treated with circumspection.

Observed Flood Heights (Flood Markers)

A field survey of March/April 2009 flood levels has been undertaken by Clarence Valley Council. This information was provided as a file of flood markers. Four measured flood levels were well placed around Glenreagh, to inform the flood study. The flood markers ranged from debris marks in trees, to flood marks observed on walls and structures.

RORB Simulation

The Orara River Flood Study (GHD, 2012) hydrology was developed using the RORB hydrological model. The model was setup as an end of catchment model, producing flood hydrographs for the Orara and Bucca Bucca Rivers upstream of the Glenreagh runoff gauge. For the Glenreagh Flood Study (CVC, 2013), this RORB model was extended for catchments downstream of the Glenreagh runoff gauge (including the Tallawudjah catchment), requiring a recalibration of the RORB model.

The recalibrations were based on the March and February 2009 events, Feb 2001 event and March 1974 event. It was found that using the RORB default "kc" calibration parameter of 51.32 for the extended RORB model, yielded similar degrees of accuracy when compared to the RORB model calibration used in the Orara Flood Study (GHD, 2012). On this basis, it was decided to accept the default RORB kc parameter for the extended RORB model.

The RORB model was simulated for a number of events, up to and including the PMF. For each event design flood hydrographs were input as an upstream boundary condition inflow to the TUFLOW model. The flood peaks determined for each event are summarised below.

Table 2-3 RORB Design Flood Peaks

Flood event AEP	Glenreagh Gauge Flood Peak m^3/s	Tallawudjah Creek Flood Peak m^3/s	Glenreagh at Confluencewith Tallawudjah Creek m^3/s
20% (48hr)	**1000**	**200**	**1115**
10% (48hr)	**1270**	**255**	**1435**
5% (48hr)	**1655**	**330**	**1850**
2% (48hr)	**2125**	**400**	**2405**
1% (48hr)	**2515**	**475**	**2890**
0.2%	**3735**	**693**	**4330**
PMF (12 critical duration)	**4974**	**1222**	**5790**

Probabilistic Rational Method

The Probabilistic Rational Method was used to provide an additional estimate of the flood peak for the 1% AEP event. This method is not suitable for catchment sizes of area greater than 250 km^2 and inherently does not necessarily account for catchment effects such as attenuation. However the method gives an indication of the flood peak "order of magnitude".

Using the Probabilistic Rational Method, the 1% AEP flood peak was estimated as 2650 m^3/s at the location of the Glenreagh flow gauging station, which compares favourably to the RORB estimate at the confluence in Table 2-3 (2890 m^3/s).

2.1.4 Flood Levels

TUFLOW Simulation

The flood conveyance through Glenreagh was calculated using the TUFLOW hydraulic model. The model extent for the purposes of flood mapping was defined in collaboration with Clarence Valley Council. The final model extent was adjusted slightly to provide model stability and negate the effects of boundary conditions. Since the area to be modelled is relatively small in comparison to the Orara River Flood Study (GHD, 2012) and in consideration of the extensive simulation time (2days per simulation) a stand-alone model was configured for Glenreagh, based on an 8m grid. Model roughness parameters adopted are summarised below.

Table 2-4 Roughness Modelling Parameters –2D domain

Feature	Value
Manning's "n" – Hardstand areas	0.02 to 0.05
Manning's "n" – Developed areas (residential, commercial, industrial, farm sheds), houses or blocked out with storage areas (zero conveyance)	0.5
Manning's "n" – creek/river channels depending on vegetation	0.04 – 0.18, with the majority being around 0.1 to 0.18
Manning's "n" – floodplain areas	0.06 – 0.25, with the majority being around 0.08 to 0.18

A number of significant structures are located in the Orara River and Tallawudjah Creek floodplains. A total of four structures were configured in the TUFLOW model. Details of each structure were provided by Council, with exception of the railway bridge. For this bridge, the deck level was determined from the survey data of the rail embankment.

2.1.5 Sensitivity Assessments

A number of sensitivity assessments were undertaken for the 1% AEP design flood events. These assessed sensitivities on:

Blockage

To assess the impacts of culvert and bridge blockages, the TUFLOW model was re-simulated using the amended waterway opening assumptions, representing an approximate 50% blockage on bridges throughout the study area. These generally represent the impacts should debris block bridges during flood events, potentially resulting in local increase in upstream flood levels and potential redistribution of flood flows. The impacts on the 1% AEP 48hr duration event flood level showed that increases in flood level of approximately 50mm, generally upstream of bridge, the increases in flood levels would be expected to be more significant for larger bridges on the main-stem of the Orara River and increases are more pronounced in situations where bridges are not overtopped. In cases where bridges are overtopped, the blockages of waterway openings have less of an impact.

Mannings roughness assumptions

To assess the impacts of roughness assumptions, the TUFLOW model was re-simulated using the amended roughness representing between a 10% and 40% increase in topography roughness. The impacts on the 1% AEP 48hr duration event flood level showed that increases in roughness could lead to increases of up to 0.5 to 0.7m, with more pronounced increases

likely in the faster flowing creek reaches and commensurate with the level increases, a number of areas in the flood plain would be expected to increase in flood extent.

Rainfall Losses

Increased antecedent moisture conditions and increased saturation of the soil after prolonged wet period could lead to reduced rainfall losses. To assess the impacts of rainfall loss parameter assumptions, both the RORB and the TUFLOW models were re-simulated using lower rainfall losses tabulated below. The impacts generally showed a 5 to 11% increase in the flood peak flow. The impacts on the 1% AEP 48hr duration event flood level showed flood level increases of in the order of 100mm can be expected in the lower reaches of the Orara River and flood level increases in the order of 250 mm downstream of the confluence of Tallawudjah Creek and Orara River.

2.1.6 Appropriateness of Flood Study

The Glenreagh Flood Study (CVC, 2013) comprising the RORB model for determining the hydrology and the TUFLOW model for determining the flooding conditions at Glenreagh provide the flood input to this Floodplain Risk Management Study and Draft Plan. These models and the work undertaken are deemed acceptable for the purposes of conducting the Floodplain Risk Management Study and compiling the Draft Floodplain Risk Management Plan.

2.2 Flood Behaviour

The Glenreagh Flood Study (CVC, 2013) prepared flood mapping together with hydraulic and flood hazard categorisation mapping. The selection of this flood mapping has been provided in Appendix B.

2.2.1 Flood Level and Depths

- In the 20% and 5% AEP events, flood flows are expected to surcharge the Orara River and Tallawudjah Creek channels, and spill onto the floodplain. While some properties to the north of Glenreagh, in the vicinity of the confluence of Tallawudjah Creek and the Orara River would be expected to be at risk, the majority of Glenreagh would largely be unaffected by flood waters. A number of bridges and roads are expected to be inundated in the study area, including the Sherwood Creek Road Bridge over the Orara River.
- In a 1% AEP event, widespread flooding is noted. Flood waters are expected to inundate large areas of the floodplain on the Orara River, Tallawudjah Creek and associated tributaries. Flood waters are expected to inundate properties north of Connell Street, Glenreagh and in the vicinity of the Tallawudjah Creek Road intersection. Flooding is also expected along Kookaburra Drive and Lorikeet Place in the vicinity of the railway line to the east of Glenreagh. A large number of rural properties are expected to be isolated by flood waters across all catchments.
- In a PMF event, flood levels are expected to be approximately 3 to 4 m deeper than the 1% AEP. This would result in significant and widespread flooding.

2.2.2 Flood Velocity

- Flood velocities are generally below 2m/s, in the 20% and 5% AEP flood events in the flood plains. However, in main creek channels of the Orara River and Tallawudjah Creek, which are steep and confined, flood velocities greater than 2m/s could be expected. For example, the areas upstream of the Glenreagh Gauge and downstream of the Glenreagh Bridge have narrow creek channels and elevated flood velocities would be expected in these locations.

- In the 1% AEP event, large areas of the floodplain would be expected to have flood velocities below 2 m/s. However, flood velocities within many of the creek channels would be expected to be in excess of 2m/s.

2.2.3 Flood Category

- In the 20% and 5% AEP event the floodway is associated with the creek and river channel. The Sherwood Creek and Tallawudjah Creek bridges would also experience zones of floodway. On the inundated floodplain area the flood category is predominantly Flood Storage, with very few areas on the edges of the floodplain designated as Flood Fringe.
- In the 1% AEP event, floodway areas are noted to extend onto the floodplain however not in the existing residential areas which still comprise Flood Storage areas. The Orara Valley Way southern access into town also becomes a floodway, due to backwater flooding and breakouts upstream of the railway bridge.

2.2.4 Provisional Flood Hazard

Provisional hazard was assessed in accordance with the NSW Floodplain Development Manual, 2005. The Provisional Hazard categories are provisional because they do not reflect the effects of other factors, such as warnings and flood preparedness, that influence hazard. In general, High Hazard could pose possible danger to personal safety, make wading difficult, result in structural damage to buildings and make evacuation by trucks difficult. Low Hazard would permit evacuation by trucks and able-bodied adults would have little difficulty in wading to safety. The provisional hazard show:

- The majority of the Orara River and Tallawudjah Creek channels are designated as being high hazard, due to the excessive flow depths and faster flowing flood waters. In the 20% and 5% AEP events, only small areas on the floodplain are designated as low or medium hazard, with many of the inundated residential areas of Glenreagh being high hazard.
- High hazard conditions are also noted for many of the rural areas around Glenreagh. This would mean that a number of access tracks to rural properties and road crossings would be expected to be isolated by high hazard flood waters.
- In a 1% AEP event, almost the entire floodplain, with exception of a few areas along the edge of the floodplain, are designated high hazard. Thus most flood storage areas are designated as High Hazard.

On the basis of the above it is considered that the provisional hazard be adopted as the true hazard in case of Glenreagh, and that much of the floodplain be designated as High Hazard. It will also be shown (in later Sections of this report) that no flood modification options prove favourable, which would later the hazard from a flood conveyance point of view.

2.2.5 Over Floor Flooding

Overflow flooding of dwellings in Glenreagh has been summarised in the table below. The table shows that in the 20% and 5% AEP events most of the dwellings experiencing over floor flooding are located on rural properties outside of the Glenreagh town. However in a 1% AEP event the majority of dwellings experiencing over floor flooding are located in town.

Table 2-5 Dwellings with over floor flooding

Flood Event (AEP)	Number of dwellings with over floor flooding	Indicative location of dwellings

20%	0	
5%	8	6 dwellings are rural properties located south of the railway 1 dwelling located along Tallawudjah Road 1 dwellings located along eastern bank
1%	54	32 dwellings are located in town 10 dwellings are rural properties located south of the railway 5 dwellings located along Tallawudjah Road 7 dwellings located along eastern bank

2.2.6 Flood Warning and Emergency Response Classification

A comparison of flood peaks during a 1% AEP event is shown in Figure 2-2. The figure shows:

- Tallawudjah Creek inflow peaks occur approximately 6 hours before the flood peak in the Orara River. The peak is approximately 20% of the Orara Flood Peak and would mostly impact the rising limb of the flood hydrograph in the Orara River. The effects of Tallawudjah Creek would expect to be significantly reduced at the time of the Orara flood peak.
- The flood peak at Glenreagh would be expected approximately 2 hours after the flood peak at Nana Glen, which would be expected approximately 2 hours after the flood peak at Coramba. The Glenreagh flood peak would be expected approximately 32 hours after the onset of the rainfall event.
- Flood Peaks tend to rise rapidly at Glenreagh at a rate of approximately 0.5m/hr for the major part of the hydrograph rising limb.

While flood peaks at Coramba and Nana Glen may provide an early indication of pending flooding at Glenreagh, possibly 4 hours before the peak at Glenreagh in the case of Coramba, warning times are still generally short. This demonstrates the importance of using the entire network of rainfall and runoff gauges in the Orara Valley, together with information provided by Bureau of Meteorology such as pre-event forecasting to extend the 'warning window', when planning evacuation strategies.

While the majority of town can evacuate to higher ground within the town, access to Glenreagh is severed due to inundation of Orara Way both northbound and southbound. In addition, properties along the east bank are isolated when the Sherwood Bridge is inundated during frequent flood events.

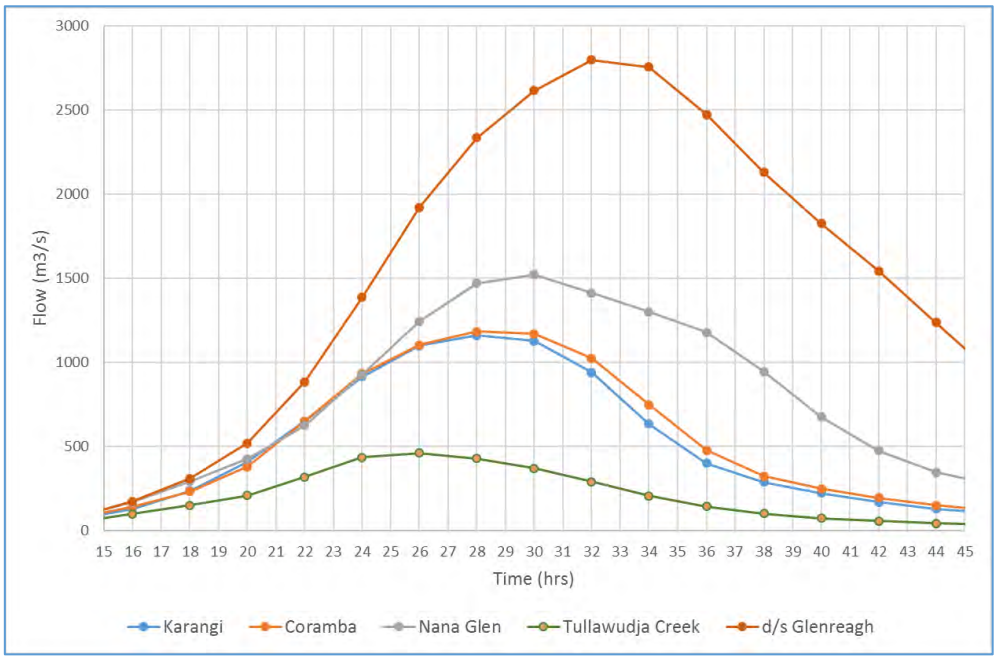


Figure 2-2 Simulated 1% AEP flood peaks

2.2.7 Inundation of Key Bridge and Culvert Structures

An assessment has been made of which key bridges and structures likely to be inundated in the 20%, 5% and 1% AEP events. The results are tabulated below, which shows inundation of many of the key trafficable structures, leading to isolation of the Glenreagh community from Grafton and Coffs Harbour. In addition the Glenreagh community on the east bank would be isolated when the Glenreagh Bridge is inundated in minor flood events, and some roads to the west of Orara Way would also be inundated leading to isolation of the community.

Apart from the roads, culverts and bridges inundated by backwater flooding of the Orara River, flooding of local tributaries discharging to the Orara River can potentially be isolated due to local rainfall events. Due to the timing of flood peaks, these structures could be cut early in the event, before the arrival of the Orara River flood peak. In some instances the local flood peaks may even recede, before structures are cut again due to the Orara flood peak.

It is noted that the Hayard's Crossing (Bluff Bridge), located some 15 km north of Glenreagh on route to Grafton, has bridge approaches located "at grade" on the floodplain, with the bridge spanning only the channel banks. The approaches are steep, dropping some 15m to a bridge level of approximately 31m AHD. This would make the structure highly susceptible to flooding, with the route being severed during minor flood events. This matter has been noted by the Glenreagh community as an important issue.

Table 2-6 Bridge Inundation Assessment

Location	20% Flood event AEP	5% Flood event AEP	1% Flood event AEP
Orara Way near Lurcocks Road	Inundated by approximately 3m	Inundated by approximately 5.8m	Inundated by approximately 8m
Orara Way near Shipmans Road	Not inundated	Inundated by approximate 0.5m at the bridge approaches	Inundated by approximate 2m at the bridge approaches

Sherwood Creek Road (Glenreagh Bridge)	Inundated by up to 2m on the eastern approach road to the bridge	Inundated by up to 3.8m on the eastern approach road to the bridge	Inundated by up to 5.6m on the eastern approach road to the bridge
Tallawudjah Creek Bridge	Inundated by approximate 0.3m at the bridge approaches	Inundated by approximate 2m at the bridge approaches	Inundated by approximate 3.9m at the bridge approaches
Orara Way north of Tallawudjah Creek Bridge	Inundated by approximately 0.3m	Inundated by approximately 1m to 1.5m	Inundated by approximately 3.5m
Hayard's Crossing (Bluff Bridge)	Expect to be inundated during minor events		

2.2.8 Summary

- In the 20% and 5% AEP events, flood flows are expected to surcharge the Orara River and Tallawudjah Creek channels, and spill onto the floodplain. In the 1% AEP event, widespread flooding is expected.
- Flood waters are expected to inundate large areas of the flood plains on the Orara River and associated tributaries. Flood waters are expected to inundate properties to the north of Glenreagh in the vicinity of the Tallawudjah Creek confluence and a number of key roads would be cut-off by flood waters. Many rural properties would be expected to be isolated by flood waters.
- In a PMF event, flood levels are expected to be approximately 3 to 4 m deeper than the 1% AEP event across the catchment. This would result in significant and widespread flooding.
- In the 20% and 5% AEP events most of the dwellings experiencing over floor flooding are located on rural properties outside of the Glenreagh town, however in a 1% AEP event the majority of dwellings experiencing over floor flooding are located in town.
- Flood ways are associated with the creek and river channel. The Sherwood Creek and Tallawudjah Creek bridges would also experience zones of floodway. On the inundated floodplain area the flood category is predominantly Flood Storage, with very few areas on the edges of the floodplain designated as Flood Fringe.
- In a 1% AEP event, almost the entire floodplain, with exception of a few areas, is considered high hazard. This would mean that a number of access tracks to rural properties and road crossings would be expected to be isolated by high hazard flood waters.
- Inundation of many of the key trafficable structures along Orara Way would be expected, leading to isolation of the Glenreagh community from both Coffs Harbour and Grafton. It is noted that the Hayard's Crossing (Bluff Bridge) approaches are located at grade on the floodplain, with the bridge spanning only the channel banks. This structure is expected to be highly susceptible to flooding with the route being severed during minor flood events.

2.3 Review of Flood Damage Assessment

2.3.1 Methodology

Flood damage calculations were undertaken to assess the direct financial costs of damage to property and the indirect financial costs associated with the disruption of social, community, industrial and commercial relationships during the post-flood period. The damage curves/parameters according to the NSW Office of Environment and Heritage (OEH, formerly DECCW) with limited amendments for single storey low (floor) set, single storey high (floor) set and double storey residential properties were adopted.

For residential properties, the direct damage estimates represented the sum of structural, contents and external damage, clean-up costs and costs for additional accommodation as a direct result of flooding. Indirect costs were for the disruption of social, community and business relationships and the costs of removal and storage, loss of business confidence, production, revenue and wages in the post-flood recuperative phase possible loss of schooling, loss of personal mementoes, and cancellation of social events.

The base date for revised damage estimation was set to 2016, by adjusting selected parameters within the OEH recommended curves/parameters. The factors adopted for the damage calculations are summarised in Table 2-7.

Table 2-7 Residential Damage Curves and Parameters

Parameter	Mainstream Flooding Parameters
Regional Cost Variation Factor	1.07
Post late 2001 adjustments	1.00
Post Flood Inflation Factor	1.00
Typical Duration of Immersion	12hrs
Building Damage Repair Limitation Factor	1
Typical House Size	Average 240 m2 representative of a 3 bedroom house
Average Contents Relevant to Site	$60,000 - adjusted based on typical house size within OEH spreadsheet
Contents Damage Repair Limitation Factor	0.90
Level of Flood Awareness	High
Effective Warning Time	12
Typical Table/Bench Height (TTBH)	0.9
External Damage	$6,700
Clean Up Costs	$4,000
Likely Time in Alternate Accommodation	3 weeks
Additional accommodation costs /Loss of Rent	$200

For commercial properties, the damages were calculated using an approach developed by OEH and WMAWater (ref WMA 2014) which has been used on a number of recent rural projects. This approach:

- Assumes external damages for commercial properties would be the same as for residential properties
- Damages associated with contents was increased from $60,000 to $150,000

- Increases the recommended $220 per week at 3 weeks to $1,500 per week for 3 weeks to allow for the additional costs which may be incurred by businesses, such as loss of business, loss of productivity, and wage
- All other values were assumed the same.

The numbers of residential and commercial properties that would experience flood damages are listed in Table 2-8.

Table 2-8 Property numbers experiencing flood damages

Flood Event (AEP)	Number of properties
20%	25
5%	61
1%	84
0.2%	116
PMF	136

2.3.2 Flood Damages

Based on the above, the direct damage of flooding in Glenreagh was calculated as a Net Present Value (NPV) 3.34 million over 20 years at 7%. The Annual Average Damage was calculated to be $314,765. Direct damages for each flood event are tabulated below.

Table 2-9 Direct Damages

AEP	Damage
20.0%	$179,152
5.0%	$1,262,543
1.0%	$4,614,821
0.2%	$9,400,748
PMF	$12,889,258

Table 2-10 Direct and Indirect Damages

Item	Description	Method	AAD ($ million)	% of Total
A	Residential Direct	OEH Curves	0.31	69%
B	Residential Indirect	20% of A	0.06	14%
C	Commercial/Industrial Direct	WMA method	0.00	0%
D	Commercial/Industrial Indirect	20% of C	0.00	0%
E	Social Damage	25% of (A + C)	0.08	17%
		TOTAL	0.45	

Table 2-11 Damage Summary

Item	Direct ($ million)	Direct + Indirect ($ million)
Annual Average Damage	0.31	0.45
Net Present Value (20yrs @ 7%)	3.34	4.84

3. Community Consultation

A community consultation plan for the project was developed identifying stakeholders to be consulted, the timing of that consultation, and activities to facilitate a process of open, effective and appropriate consultation.

The purpose of community and stakeholder involvement was to ensure information is presented and received clearly and unambiguously, that all key community and other stakeholder groups are reached through a selection of activities, and that their views are sought and become an integral part of the process.

Copies of relevant community information distributed as part of the study are provided in Appendix C.

3.1 Inception Meeting

At the inception meeting 12 July 2016, held with Council, a general outline of the proposed community consultation activities was provided, as well as a detailed discussion about the community in Glenreagh.

3.2 Identification of Key Stakeholders

The identification of stakeholders is treated as an ongoing process, with stakeholders being added to the stakeholder database and mailing lists throughout the project. This occurred when the project team made contact with stakeholders or when stakeholders made contact with Council/the project team with regards to the study.

Stakeholders identified during the community consultation process included all residents and landowners within the catchment, the SES and the Office of Environment and Heritage.

3.3 Consultation Activities

The first round of consultation activities undertaken, focused on introducing the project, advising residents and key stakeholders of investigations that were to take place over the initial stages of the study, and to gather as much historical information about flooding as possible. Community consultation is ongoing and tasks undertaken to date are described below.

3.3.1 Media Release

A Media Release was prepared for inclusion in the local media on 2 August 2016. It was also designed to reach stakeholders and the community and inform them of the project.

3.3.2 Community Newsletter & Feedback Survey

A community newsletter and feedback survey was prepared and posted to residents in Glenreagh. The newsletter provided stakeholders with an overview to the project and the reason why it was being undertaken. This newsletter invited the community to a Community Information Session and provided the project contact information as follows:

Glenreagh Floodplain Management Study and Draft Plan

Reply Paid 1340

COFFS HARBOUR NSW 2450

Facsimile – 02 6650 5601

Email – cfsmail@ghd.com

Project Information Line 6650 5600

A reply-paid feedback survey was also included in the newsletter. This survey was designed to examine the degree of flood awareness and preparedness by the local community, identify flood related issues of concern, and canvass options for flood protection.

3.3.3 Community Database

A community database has been developed for capturing all community input, in particular the feedback survey. To date 42 responses have been received from the community in the community database, which is considered good response.

3.3.4 Community Information Session 1 – 16 August 2016

The SES and 13 local residents attended the Community Information Session at the Glenreagh School of Arts Hall on the 16 August 2016, from approximately 6.30 pm to 8.30 pm. The community members that attended were found to be knowledgeable about flooding in the town. The aim of the information session was to provide the local community with information about the project, and to receive information from the community about flooding in the town and wider study area. The information presented to the community is provided in Appendix C.

3.3.5 Community Information Session 2 – 13 December 2017

Six local residents and Council officers attended the Community Information Session at the Glenreagh School of Arts Hall on the 13 December 2017, from approximately 6.30 pm to 8.30 pm. The aim of the information session was to present the findings of the study and provide the local community the opportunity for input on the findings. The information presented to the community is provided in Appendix C.

3.4 Summary of Community and Stakeholder comments

Below is a summary of the feedback received from the community survey and at the public meeting. This feedback was provided by the community and stakeholders.

3.4.1 Community Survey

- Of the residents who completed the survey, some recall the 2009 floods first hand. Many residents note flooding every year. The 1950 and 1954 floods were also experienced by a few residents, in one case the residents were rescued off the roof of their dwelling.
- Many residents note debris build up, damage to fences and paddocks, stormwater and local roads at times of flooding. In addition, septic system overflows to the Orara River were noted.
- Residents noted that they are isolated during flood events, in some cases up to 3 days. At times, this is without power, telephones and with limited mobile reception.
- Preparation at times of flooding varied. Some community noted that listening for flood alerts and stocking up on essential items of food, fuel and water and medication. Some residents raised furniture and other belongings in preparation of a flood. Some residents open farm gates and raise pumps and other infrastructure.
- There was a preference for educating the community, flood modification, improved development controls and improved drainage. The raising of bridges to provide access to Coffs Harbour and Grafton was noted. This included a suggestion to raise/rebuild Hayard's Crossing (Bluff Bridge). More careful consideration of flooding matters on new home sites and future development was suggested.
- A number of residents noted the requirement for co-ordinated flood warning, evacuation and meeting points. The residents felt it was useful to provide a real-time camera (accessible

from the internet) at Hayard's Crossing (Bluff Bridge). This would allow residents the ability to determine whether access to Grafton has been severed before leaving home. In addition, residents made a public submissions regarding raising road and bridge levels along Orara Way along the evacuation route to the north of Glenreagh.

- A recurring theme was associated with the build-up of vegetation silt and debris in the river channel and in stormwater drains impeding the conveyance of flood flows. This point was further linked to potential blockages at the causeway. Removing debris and silt from culverts for example East Bank Road and the adjacent railway culvert was requested.
- It was also suggested that providing a helicopter landing areas on both sides of the Orara River would assist in emergency rescue during a flood.

4. Socio-Economic Effects

4.1 Social Setting and Characteristics

The town of Glenreagh is located in the Clarence Valley Local Government Area (LGA), in the Northern Rivers region of north-eastern New South Wales. Glenreagh is a small township on the Orara Way, a road running between Coffs Harbour and Grafton. The town is surrounded by mainly rural land, which is largely used for farming and agriculture.

The town is overlooked by the sandstone ranges of the Orara Valley, and the Orara River runs alongside the town. The Orara River is one of the only coastal rivers in NSW to flow inland. Key features in the town include an art gallery, a memorial museum, and a country hotel. There is also a small Glenreagh Public School with around 60 students.

4.2 Social and Economic History

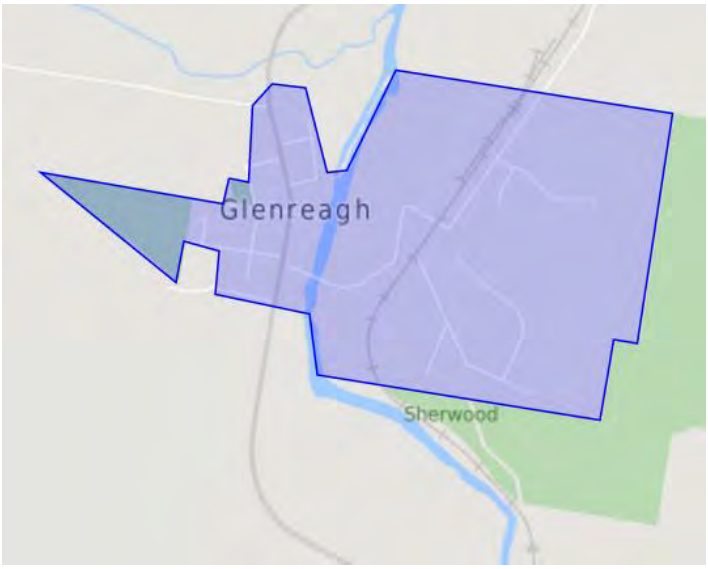
The town of Glenreagh is located in the traditional lands of the Gumbainggir people (AIATSIS map of Indigenous Australia). European settlement dates from about 1856 when early settlers arrived. The first timber mill was built in 1912, which was followed by a number of other mills. Many of the original timber dwellings still exist in Glenreagh and a number of buildings are heritage listed (Clarence Tourism, 2015).

Glenreagh is located on the North Coast railway line, which was completed in 1915 and closed in 1972. The Glenreagh Mountain Railway organization has been working to restore the Glenreagh to Ulong section of the rail line as a heritage tourist rail line (Clarence Tourism, 2015).

4.3 Population and Housing Profile

The profile for Glenreagh is based on 2011 Australian Bureau of Statistics (ABS) Census data for the town (ABS 'urban centre and locality'). The ABS catchment area is shown in Figure 4-1 below.

Figure 4-1 Map showing ABS Census 2011 Glenreagh town



In 2011, the population of Glenreagh was 477 people living in 168 dwellings. The population has increased by 13% since 2006 when the population was 422 people. Figure 4-2 and Table 4-1 below show the age profile for Glenreagh compared to the Clarence Valley LGA. The figure and table demonstrate that overall, Glenreagh had a younger age profile, with more children and fewer older people compared to the average for the LGA. This is consistent with the median age for Glenreagh, which was 39 years compared to 46 years for the Clarence Valley LGA.

Although Glenreagh has a small population of frail aged residents, there are a number of residents who could be vulnerable during flood events. In 2011, there were 29 people living in Glenreagh in need of assistance (6% compared to 8% for the LGA).

Figure 4-2 Age profile for Glenreagh and Clarence Valley LGA, 2011

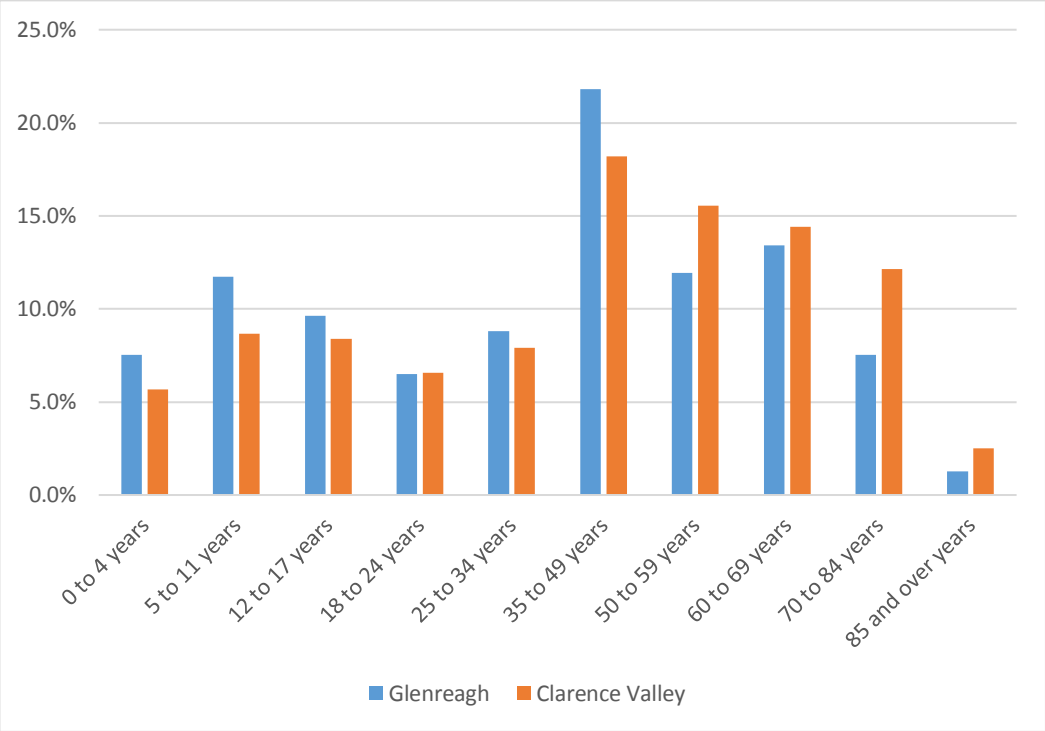


Table 4-1 Age profile for Glenreagh and Clarence Valley LGA, 2011

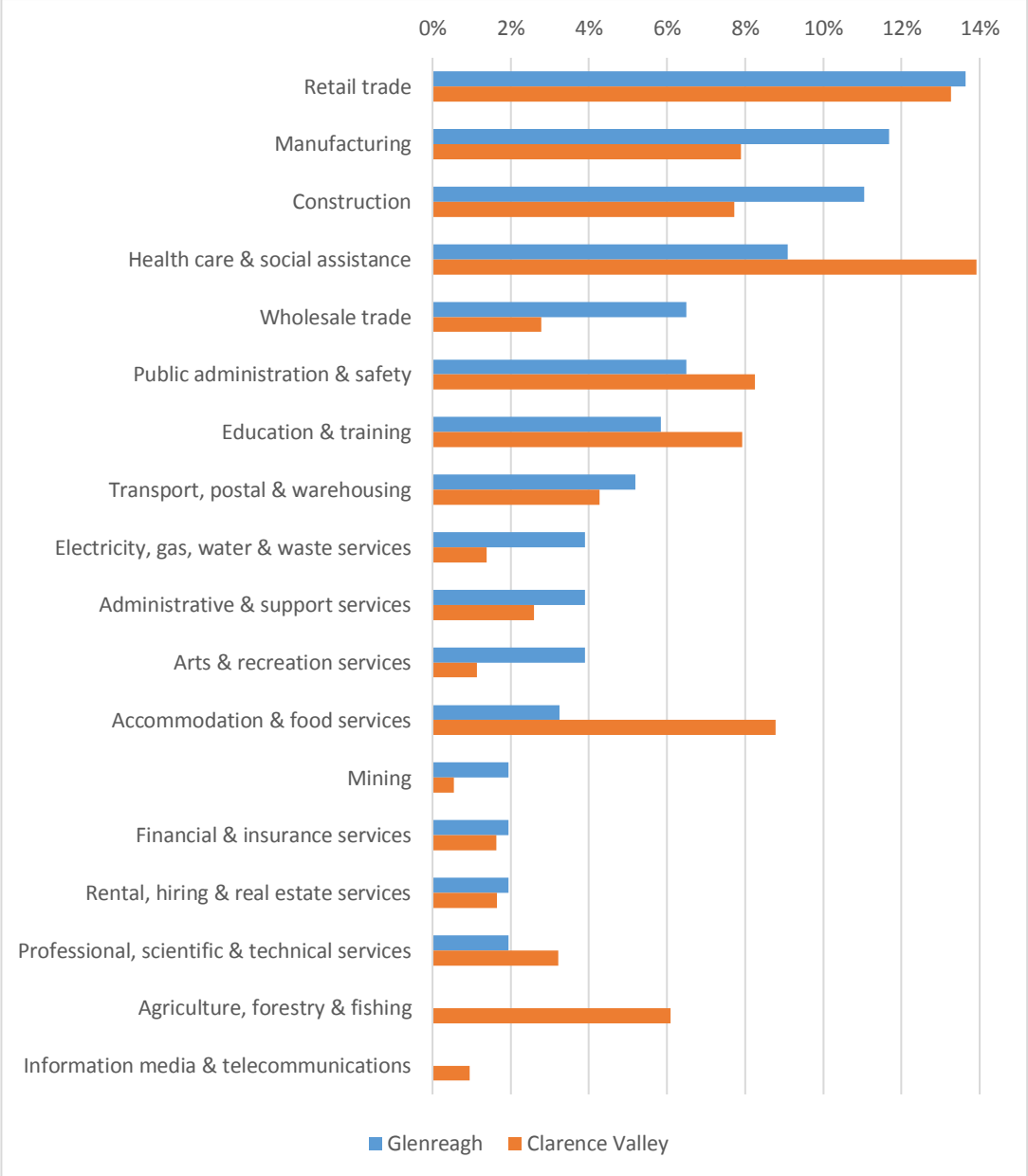
Age group	Glenreagh		Clarence Valley LGA	
	Number	Percent	Number	Percent
0 to 4 years	36	7.5%	2817	5.7%
5 to 11 years	56	11.7%	4306	8.7%
12 to 17 years	46	9.6%	4160	8.4%
18 to 24 years	31	6.5%	3260	6.6%
25 to 34 years	42	8.8%	3930	7.9%
35 to 49 years	104	21.8%	9030	18.2%
50 to 59 years	57	11.9%	7719	15.5%
60 to 69 years	64	13.4%	7157	14.4%
70 to 84 years	36	7.5%	6035	12.2%
85 and over years	6	1.3%	1252	2.5%
Total Persons	**477**	**100%**	**49665**	**100%**

Dwelling and household characteristics are typical of regional Australian towns. Of the total 168 occupied private dwellings, 91% were separate houses, followed by semi-detached/terrace/townhouse at 2.2%. 38% of dwellings were owned outright, which is lower than the LGA average at 45%. Almost half (45%) were owned with a mortgage.

Over three quarters of households were family households (77%) and a fifth (20%) were single person households. Household incomes were lower than the LGA average, with the median income in 2011 $688/week compared to $768/week for the LGA.

In 2011 the unemployment rate was 10.1%, which was higher than the LGA average at 8.9%. Figure 4-3 below demonstrates the industry of employment for residents of Glenreagh compared to the LGA. The highest industry was retail, which employed 14% of working residents and is consistent with the LGA average (13%). This was followed by manufacturing (12% compared to 8%), construction (11% compared to 8%) and health care and social assistance (9% compared to 14%).

Figure 4-3 Industry of employment for Glenreagh and Clarence Valley LGA, 2011



4.4 Socio-Economic Impacts of Flooding

The major impacts of flooding can be devastating causing a great deal of distress to people's lives. Impacts can range from death, injury and harm from sources such as contaminated water through to lasting psychological consequences caused by damaged homes, loss of personal possession and financial worries.

Social impacts are often intangible damages and relate to changes to social networks, lifestyles, community activities and individual state of well-being. The degree of disruption to people's lives depends on the severity of flooding and the ability of the community and individuals to recover from the flood event.

Flooding impacts within Glenreagh are concerned with residential, commercial and community areas, and the associated loss and damages caused by flooding. Social impacts may include stress for community members related to the loss of and damage to sentimental and personally valuable items including homes, stock and vehicles. These social impacts are particularly difficult to quantify as the personal and emotional value of the loss often exceeds that of material value. Anxiety, panic and insecurity may also increase amongst the community as a response to the possibility of future flood events. Community members who may be more vulnerable to these impacts include the frail aged and people in need of assistance. Although Glenreagh has a small population of frail aged residents, it is important to consider the needs of potentially more vulnerable residents during flood events. Floods in rural communities can also be particularly distressing due to the impacts on farm lands, which can lead to a loss of business and livelihood.

It is generally acknowledged that the degree of social impact caused by flooding is likely to reduce if the community is well-prepared for a flood event and has access to adequate and appropriate support services. In addition, small communities are known for their close relationships and ability to support each other through disasters and distressing events. This social capital is critical to building resilience in communities following disasters (Deloitte Access Economics, 2016).

Damages to local businesses pose economic risks for the local community. Flooding has the potential to cause disruption to business activities such as trading capacity and employment routines due to the isolation caused by floodwaters. Residential damages may have the potential to cause lifestyle changes as members of the community adjust personal activities to address flood damages. Damages to community facilities, can lead to community health and safety impacts, as well as disruption to community life.

Whilst consideration of direct economic impacts is important, it is not unusual to base flood mitigation schemes on largely socio-economic grounds such as intangible costs and social disruption. Economic costs would depend on the level of physical flood damage, the nature of the premises impacted, level of community flood 'readiness', and the level of readily available assistance.

In addition to damages to individual properties, there may also be disruptions to infrastructure such as roads, electricity, telecommunications and water supply.

A summary of the key potential impacts on the socio-economic character of the community is summarised in the table below.

Table 4-2 Potential Socio-Economic Impacts

Direct	Indirect	Intangible
Residential Areas		
Property damages including structural, contents and gardens Clean-up costs Replacement and repairs	Relocation costs Loss of ability to work Changes to work routines	Stress and Anxiety Loss of sentimental items Lifestyle changes Loss of amenity Restricted access Disruption to community cohesion
Commercial Businesses and Community Facilities		
Property damages including structural, internal and outdoor areas Clean-up costs Infrastructure damages Restricted access for community members	Loss of revenue/profit Loss of productivity Disruption to employment Loss of patronage	Stress and Anxiety Loss of sentimental items Lifestyle changes Loss of amenity Drop in property values Disruption to community services and social capital and community cohesion

5. Floodplain Management Measures

In accordance with the NSW Government Floodplain Development Manual (2005), this report considers floodplain risk management measures. Risk management measures can be broadly categorised into three categories as shown in Figure 5-1.

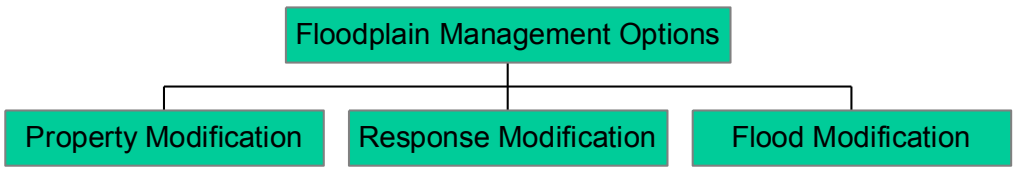


Figure 5-1 Floodplain Management Measures

In the project brief, Clarence Valley Council nominated, amongst others, the requirements to investigate:

- Structural Measures
- Flood Warning and Emergency Planning
- Raising Community Awareness
- Development control, Building control and Land Use Zoning
- Flood Planning Levels
- Section 149 certificates
- Enclosures below Flood Planning Level
- Voluntary House Purchase and Voluntary House Raising

In this context, the discussion follows the NSW Government Floodplain Development Manual (2005) risk management process and the NSW OEH Floodplain Management Programs Guidelines for Applicants.

5.1 Construction Cost Estimates

In assessing Floodplain Risk Management options, benefit costs assessment is undertaken for selected options. The benefit cost assessment considers the construction and maintenance cost of each management option (as appropriate) compared to the flood damage savings offered by the option. For this report, construction costing was undertaken subject to the limitations noted in Section 1.5 as follows:

- A base date of 2016 was used for all costing and damage calculations, using adjustment factors relevant to Glenreagh where applicable.
- The 2016 Version of Rawlinson's (Rawlinsons, 2016) was used to determine appropriate cost rates.
- Costing preliminary costs (14%), margin (6%), project/construct management (3%) and design and environmental (7%). A contingency of 30% was allowed for.
- All costing data excludes GST.

Costing assumed that material would need to be imported where relevant. Where options have been costed as part of benefit/cost assessments, the details and unit rates are provided in the Appendices.

5.2 Property Modification

Property modification measures are approaches to floodplain management that apply to existing properties and proposed developments. While these modifications will reduce damages and risk to life and property, they will not prevent flooding of premises. Thus, they will not necessarily address all the social impacts of flooding.

5.2.1 P1 - Land Use Planning

Land use planning is an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately. Planning not to develop land within high flood hazard or land that has the potential to impact flood behaviour in other areas, is a valuable long-term solution. This can be achieved through inclusion of provisions in the Local Environment Plans (LEP) and Development Control Plans (DCP). Planning instruments can be used as a floodplain management tool by controlling floor levels, freeboard, fill or excavation in the floodplain, site access during flood events, location of utilities and services, building materials and structural fitness of buildings when subject to flooding.

The Clarence Valley Local Environmental Plan 2011 (LEP) (see Figure 5-2 for flood provisions) is supported by the various zone-based Clarence Valley Development Control Plans 2011, which includes additional detail about development on flood-affected land (Part D – Floodplain Management Controls). The LEP is generally supported by flood mapping for the Grafton and Lower Clarence areas, however there is no Flood Planning Map for Glenreagh in the LEP.

Noteworthy is that the LEP and DCP do not define the Flood Planning Level nor the Flood Planning Area, which is often accepted as the 100 ARI (average recurrent interval) flood event plus 0.5m freeboard. However, reference is made to the *'land that is shown as "Flood planning area" on the Flood Planning Map'.* Since no mapping exists for Glenreagh, no flood planning area is designated.

Part D of the various Clarence Valley Development Control Plans 2011 (DCP):

- Explains the aims of the Floodplain Management Controls.
- Provides a 7-step process for applying the Floodplain Management Controls.
- Provides Performance Criteria and Prescriptive Controls with regards to floodplain management. The Prescriptive Controls listed in Schedules D3 and D4 outline the controls relevant to each of the floodplains to which the Plan applies. Compliance with the prescriptive controls is deemed to comply with the performance criteria unless, in Council's opinion, particular circumstances apply that require a variation. Proposals seeking a variation to the prescriptive controls specified in Schedules D3 or D4 will need to be justified in terms of the performance criteria.
- Defines special floodplain management requirements for fencing, filling and other matters.

Clarence Valley Local Environmental Plan 2011

Current version for 10 February 2017 to date (accessed 6 April 2017 at 12:32)
Part 7 > Clause 7.3

7.3 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land that is shown as "Flood planning area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the *Floodplain Development Manual* (ISBN 0 7347 5476 0), published in 2005 by the NSW Government, unless it is otherwise defined in this clause.

7.4 Floodplain risk management

(1) The objectives of this clause are as follows:

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to:

(a) land between the flood planning area and the line indicating the level of the probable maximum flood as shown on the Flood Planning Map, and

(b) land surrounded by the flood planning area,

but does not apply to land subject to the discharge of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) caravan parks,

(b) correctional facilities,

(c) emergency services facilities,

(d) group homes,

(e) hospitals,

(f) residential care facilities.

(g) tourist and visitor accommodation,

(4) In this clause:

probable maximum flood has the same meaning as it has in the *Floodplain Development Manual* (ISBN 0 7347 5476 0), published in 2005 by the NSW Government.

Note.

The ***probable maximum flood*** is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.

Figure 5-2 LEP 2011 Flood Planning Provisions

In reviewing the DCP, it is considered that the flood related controls would benefit from:

- Explicit definition of the Flood Planning Level and Flood Planning Area.
- Compilation of a Flood Planning area map for Glenreagh based on the findings of the Glenreagh Flood Study (CVC, 2013).
- Review of nomenclature to better align with the NSW Floodplain Development Manual, 2005. For example "General Floodplain" is noted as "means that part of the floodplain other than floodways or flood storage areas", however this does not reference flood fringe areas. It would be better to define the General Floodplain in the context of Flood Prone Land and acknowledge Flood Fringe Areas
- Consideration for Climate Change in the nomination of freeboard associated with the Flood Planning Level unless flood modelling has explicitly considered sea level rise and any other relevant effects of climate change such as rainfall frequency and intensity changes.

☑ *Land Use Planning and Flood Planning Levels are important measures to manage flood risk while assessing development. Much of this is contained in the Clarence Valley Development Control Plan 2011, however it is considered that the flood related controls could benefit from a review and the flood mapping be provided for Glenreagh.*

5.2.2 P2 - Voluntary House Raising

House raising is a voluntary structural solution to lift buildings above the flood planning level to avert damage to buildings, improve personal safety and reduce stress and post-flood trauma. House raising is a popular solution to flooding in rural areas, particularly for piered fibro or timber houses.

Consideration must be given to the type of house being raised, the level of hazard to be avoided, the duration of the flooding expected and social issues (physical access to the dwelling and ability to raise the balance of funding). An important consideration is that house raising will not mitigate flood risk entirely, since the effects of a flood of greater magnitude than the design flood (potentially up to the PMF) could still result in risk and damage. House raising at times attracts two-thirds funding from State Government, with the balance of funding provided by Council and/or property owner, however a number of funding models exist across NSW. The property value would be based on a determination by the State Valuer.

The OEH Floodplain Management Program provides guidelines for Voluntary House Raising schemes. The following criteria need to be met for a house within a Voluntary House Raising scheme to be eligible for funding (ref OEH, 2013).

1. Only Councils are eligible to apply for funding under the program. It is not open directly to individuals. Requests from home owners to raise houses for hardship reasons are not eligible for funding.

2. Subsidised funding is generally only available for residential properties and not commercial and industrial properties.

3. Funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government. Properties built after this date should have been constructed in accordance with the principles in the manual.

4. The individual properties in a scheme should be identified in a Floodplain Risk Management Plan developed in accordance with the Floodplain Development Manual (2005) and adopted by the Council.

5. Funding under the program is generally only available for properties identified in a Voluntary House Raising scheme that has been fully defined, scoped and prioritised. The report to scope and prioritise the Voluntary House Raising scheme is eligible for funding.

6. Under limited circumstances, Voluntary House Raising can be considered for funding prior to completion of a Floodplain Risk Management Plan. However scoping, prioritisation and assessments need to be completed and clear and compelling evidence provided as the basis for expediting consideration ahead of a completed Floodplain Risk Management Plan. This would generally include scoping the Voluntary House Raising scheme and addressing the issues outlined in Section 3 above.

7. Properties which are benefiting substantially from other floodplain mitigation measures – such as houses already protected by a levee or those that will be – will not be funded for Voluntary House Raising.

8. Voluntary House Raising should generally return a positive net benefit in damage reduction relative to its cost (benefit–cost ratio greater than 1). Consideration may be given to lower benefit–cost ratios where there are substantial social and community benefits or Voluntary House Raising is compensatory work for the adverse impacts of other mitigation works.

9. The scheme should involve raising residential properties above a minimum design level, generally the Council's flood planning level (FPL) and comply with the Council's relevant development control requirements.

With reference to Table 2-5, 52 dwellings would experience over floor flooding in a 1% AEP flood event. Many of these properties are slab on ground prohibiting house raising. Approximately 30 of the houses experience overfloor flooding at depths of less than 1m and thus raising would only be by a small amount. Under these circumstances, it is doubtful a benefit cost ratio of greater than 1 would be achieved (See Requirement 8), since many of the yards would still be at risk of flood damages.

From Section 4.3, it is noted that the population in Glenreagh tending towards older generations. It is likely that some of the residents may be retired or close to retirement, and that some funding from the residents will be required. Thus it is questionable whether there would be a large uptake in a house raising scheme.

Clarence Valley Council resolved at its ordinary meeting on 16 May 2017 to revoke its Voluntary House Raising Policy. The reason for the repeal, it is understood, is the Council funding availability for house raising. As such it is considered unlikely that Council would apply for funding for house raising at Glenreagh.

Given Council has revoked its Voluntary House Raising Policy this scheme is not further considered for Glenreagh.

5.2.3 P3 - Voluntary Purchase of High Hazard Properties

To avoid the economic and social expenses of flooding in high hazard areas, it may be viable for Council to purchase flood affected properties at an equitable price, where voluntarily offered. The property should then be rezoned to a flood compatible use, such as open space. It is important to note, that this option is 'voluntary' and the implementation strategy could be long-term (at times one dwelling per year).

Voluntary purchase at times attracts two-thirds funding from State Government, with the balance of funding provided by Council. The property value would be based on a determination by the State Valuer. Voluntary purchase will likely impact the Councils rates base albeit this is not significant.

The OEH Floodplain Management Program provides guidelines for Voluntary Purchase schemes. These provide the following general criteria for funding (ref OEH, 2013).

1. Only Councils are eligible to apply for funding under the program. It is not open directly to individuals. Requests from home owners for properties to be purchased for hardship reasons are not eligible for funding.

2. Voluntary purchase will be considered only where no other feasible flood risk management options are available to address the risk to life at the property.

3. Subsidised funding is generally only available for residential properties and not commercial and industrial properties.

4. Funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted by the State Government. Properties built after this date should have been constructed in accordance with the principles in the manual.

5. The individual properties within a scheme should be identified within a Floodplain Risk Management Plan developed in accordance with the Floodplain Development Manual (2005) and adopted by the council.

6. Funding under the program is only available for properties identified in a Voluntary Purchase scheme that has been fully defined, scoped and prioritised. The report to scope and prioritise the Voluntary Purchase scheme is eligible for funding.

7. Under limited circumstances, Voluntary Purchase can be considered for funding prior to completion of a Floodplain Risk Management Plan. However appropriate investigations and assessments need to be completed and clear and compelling evidence provided as the basis for expediting consideration ahead of a completed Floodplain Risk Management Plan. This would generally include scoping the Voluntary Purchase scheme.

8. Properties being considered for Voluntary Purchase should be located:

- *within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them – however, a house in a location that is classed as high hazard on the basis of depth or provisional hazard alone would not be automatically eligible for Voluntary Purchase. Hazard categorisation should be based on the true hazard assessment and consider a range of other factors that influence flood hazard as detailed in the Floodplain Development Manual (2005).*
- *within a floodway where the removal of the house may be part of a floodway clearance program aimed to reduce the significant impacts caused by the existing development on flood behaviour elsewhere in the floodplain and enable the floodway to more effectively perform its flow conveyance function.*
- *within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected – eligibility will be considered as part of the detailed investigation and design for the works project. Funding the purchase of the property would be considered as part of the total works package which could include pre-construction activities.*

9. Unless it is being purchased to facilitate a mitigation work, vacant land is not generally eligible for funding as it does not achieve the main aim of Voluntary Purchase. Development

controls should be used to limit the potential development of vacant land so that this is consistent with the flood function and flood hazard at the location.

10. Two or multi-storey properties may be eligible for funding despite the upper floors not being directly affected by over-floor flooding. Residents retreating to the upper floors and their potential rescuers may still face significant risk to life and the building may not be designed to be structurally sound for the potential range of flood conditions. An additional hazard assessment needs to be undertaken to confirm eligibility of multi-storey properties.

Most of Glenreagh town is located in a high flood hazard area, however only two dwellings are located within or on the edge of the floodway. It is considered that removal of these dwellings would not reduce the significant impacts caused by the existing development on flood behaviour, elsewhere in the floodplain, and enable the floodway, to more effectively, perform its flow conveyance function.

As noted before, Clarence Valley Council has repealed Councils House Raising Policy associated with the Clarence River. The reason for the repeal, it is understood, is the availability of Council funding. Hence, as the Voluntary Purchase Scheme would involve larger expenses, it is unlikely Council would fund its share of such a scheme in the foreseeable future.

In consideration, that only 2 dwellings in Glenreagh are located on the edge of a floodway with removal unlikely to improve conveyance and the funding availability, a Voluntary Purchase Scheme is not considered a potential floodplain mitigation option for Glenreagh

5.3 Response modification

Response modification measures are reactions to flooding that reduce potential social, economic and environmental damages from flooding. While response modifications will reduce the risk to life, they will not prevent flooding. Therefore, they will not address all the social impacts and reduce damages associated with flooding.

While insuring properties against flooding is a method of transferring the financial flood risk to the insurer. There is limited benefit in this flood risk management option because insurance does not mitigate flooding. Therefore, issues of community disruption, property values, flood hazards and safety remain. Flood insurance can also be difficult to purchase as many insurance companies are unwilling to insure against floods, particularly after the Brisbane flood in 2011. Insurance premiums have in recent times become expensive for many properties in flood prone areas. However, good quality mapping of flood risk may ensure that insurance premiums are more likely to be equitable between property owners.

5.3.1 P4 - Flood Information/Data

Comprehensive and up to date flood information is essential in managing and responding to flood events and to guide future development in flood prone areas. This information should include any changes to catchment conditions, advances in hydrological/hydraulic methods/approaches, and be undertaken as directed by the NSW Floodplain Development Manual 2005.

With completion of the Glenreagh Flood Study, 2013 and the current study, it would be desirable to update planning documents such as the LEP and DCP with the most up to date flooding information, showing:

- Flood prone land, as the land inundated by a PMF.
- Flood planning area and levels, as the land inundated by the 1% AEP flood plus 0.5 m.
- Flood category maps showing floodway, flood storage and flood fringe.
- Flood hazard in accordance with the NSW Floodplain Development Manual.

Since completing the Glenreagh Flood Study, an updated version of Australian Rainfall and Runoff (ARR2016) is increasingly gaining acceptance amongst flooding and hydrology practitioners. This version presents, amongst others, updated estimates of design rainfall and rainfall distributions. Flood modelling using the latest Australian Rainfall and Runoff (ARR2016) can be completed at any time and data on flood levels and velocities can be updated if revised modelling is undertaken.

☑ *With completion of the Glenreagh Flood Study, 2013, it would be desirable to update planning documents such as the LEP and DCP with the most up to date flooding information. Where resources allow updates using the latest Australian Rainfall and Runoff (ARR2016) should be completed.*

5.3.2 P5 - Flood Warning/Response

P5.1 Local Flood Plan and Flood Action Card Update

Two gauges exist at Glenreagh, namely:

- An automatic gauge (204906) located 2.5km upstream which is owned by WaterNSW
- A manual gauge (59123/204907) at the Glenreagh bridge which is owned by Bureau of Meteorology

The Bureau issues flood warnings referenced to the manual gauge, however they use flood levels recorded by the upstream automatic gauge to calculate their predictions for the downstream manual gauge. Online information is only available for the automatic gauge. This causes confusion with the public who compare the manual gauge to the online automatic gauge data and the two don't match. For example the prediction may be for the manual gauge height and which the automatic gauge has already exceeded.

Flood levels at the two gauges as extracted from the TUFLOW flood model are tabulated below:

Table 5-1 Flood Levels at Gauges (note that slight variations in flood levels can exist due to the local hydraulics and influences)

Event (AEP)	Manual Gauge Flood Level (m AHD) 204907 - BOM	Automatic Gauge Flood Level (m AHD) 204906- WaterNSW
20%	63.45	64.97
5%	65.38	67.05
1%	66.92	68.67
0.2%	69.20	70.87
PMF	70.70	72.43

The **NSW State Flood Plan (NSW 2015)** lists provision of, and requirements for, flood warning for Glenreagh. The target warning time for Glenreagh is 6 hours. Depending on warning time and resources available, flood warning systems and evacuation plans can be used to protect buildings, evacuate people, provide relief to evacuees and recover the flood-affected areas.

Figure 5-3 Manual Gauge (59123/204907)

The plan references the manual Bureau Gauge 59123/204907 at Glenreagh:

- Station Owner: Bureau of Meteorology (BOM), Gauge Type: Manual
- Flood Classifications:
  - Minor at 4m,
  - Moderate at 7m
  - Major at 10m
- Warnings provided: quantities, Target warning times: 6hrs, Trigger height: > 5.8m

The SES manages the **Clarence Valley Local Flood Plan (SES 2012, reviewed during the course of this study in August 2017)** which is a Sub-Plan of the Clarence Valley Local Emergency Management Plan (EMPLAN). The Clarence Valley Local Flood Plan covers preparation measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Clarence Valley Local Government Area. It covers operations for all levels of flooding within the Council area. It nominates that the NSW SES Clarence Valley Local Controller is responsible for dealing with floods. The Clarence Valley Local Flood Plan provides more detailed information than provided by the NSW State Flood Plan and includes a Glenreagh Sector Map (see Appendix D). It also references the manual BOM Gauge 59123/204907 at Glenreagh.

Figure 5-4 Automatic Gauge (204906)

The **SES Flood Action Card** for Glenreagh drives the on-ground response to flooding at Glenreagh. This Card references the automatic WaterNSW gauge (204906) some 2.5km upstream of Glenreagh, which has been monitoring river levels since November 1972. The following are key details nominated in the Flood Action Card:

- Gauge numbers/Location: 204906, Glenreagh
- Station Owner: Water NSW, Gauge Type: Automatic
- Flood Classifications:
  - Minor at 5m,

- Moderate at 9m
- Major at 13m

Interestingly the Flood Action Card states the gauge location as being *"upstream Glenreagh Bridge GR980751"* which is incorrect, because this is the location of the manual gauge.

There is thus clearly confusion as to which gauge information is referred to when flood warnings and predictions are issued in time of flooding. In a recent education campaign with the residents of Glenreagh, the SES has been working with the community to reference all flood bulletins and warnings away from the manual gauge, to the automatic gauge. As an alternative, it is recommended that a new automatic gauge at the location of the manual gauge be installed, and that consistency between the two gauges at this location be achieved. This new gauge could then be referenced by BOM and the SES to provide flood level information for Glenreagh, and the cost of installation potentially borne by the Bureau of Meteorology.

As part of the current study, the SES wished to confirm the trigger and flood classifications at the automatic gauge. To assist the SES, a workshop was held with the SES in Grafton, to discuss simulations which were undertaken for the purposes of relating key flood events in and around Glenreagh, to the Automatic Gauge recorder. In addition, mapping has been prepared (see Appendix D) in accordance with the SES Flood Emergency Response Planning Classification of Communities.

With reference to the discussion in Section 2.2.6, while flood peaks at upstream towns may provide an early indication of pending flooding at Glenreagh, possibly 4 hours before the peak arrival, the warning times are considered short. It is this important to monitor rainfall and river gauges throughout the Orara Valley when planning evacuation strategies.

From the above discussion, it is recommended that the NSW State Flood Plan and the Glenreagh Flood Action Card be reviewed and updated to provide overall consistency, in particular to ensure the correct gauge is referenced to drive flood responses.

P5.2 Raise flood awareness and Compile Floodsafe Brochure

The SES has suggested a community lead flood response for Glenreagh as it is unlikely the SES will be able to attend in time. Public Awareness and Response would assist in raising flood awareness and readiness, and increase the appreciation of the flood problem and prevention activities. Measures to increase flood awareness could include:

- The repeated distribution of the Glenreagh Flood Safe Brochure that could be sent to all owners, business operators and residents of potential flood impacted properties (see Brochure in Appendix D). The Flood Safe Brochure is to include a demarcated evacuation route. The NSW SES can provide a print-ready PDF of your localised FloodSafe guide and organise the printing and delivery of the localised FloodSafe guide (see SES website).
- The dissemination of flood certificates on a regular basis, which would inform each property owner of the flood situation at his or her particular property, flood data and advice (this information should be provided in a range of different languages).
- A review of signage in flood prone areas giving notification of flood depths and historic flood levels. Additional flood depth signage to be provided where appropriate.
- Provide flood mapping as determined through the study via Clarence Valley Council online maps, accessible on Clarence Valley Councils website.

P5.3 Remote Alert or webcam Information on Bluff Bridge (Hayard's Bridge)

A number of residents felt it was useful to provide a real-time camera (accessible from the internet) at Hayard's Crossing (Bluff Bridge), since this is the location access to Grafton is most

frequently severed through road closure. The information would allow residents to make informed decisions about evacuation from Glenreagh without having to undertake the 15 km drive (potentially at times in dangerous storm weather conditions), before learning of the road closure.

OEH recently provided approval to "digitally stream" images from the Webcam associated with the OEH Grafton water level recorder, on Clarence Valley Council's website. The initiative would value add to the flood data available to end users and the public, subject to disclaimers and acknowledgements. This was after, OEH commissioned Manly Lab in 2012/13 to install flood cameras on 5 high priority BoM flood warning sites at:

Figure 5-5 Grafton Flood Webcam

- Murwillumbah Bridge(Tweed River)
- Coraki (Richmond River)
- Grafton (Clarence River)
- Kempsey (Macleay River)
- Belmore Bridge (Hunter River).

It is understood that cameras have now been installed and are operating at Coraki, Grafton and Kempsey sites.

As an alternative to the Webcam, the DipStik - Flood Alert System (see Appendix D) has been used at selected locations in Coffs Harbour. This system could possibly be used as an alternative trigger to inform residents of likely inundation of the Hayard's Crossing (Bluff Bridge).

While these options may beneficial, it will be important to consider the following matters:

- The availability of mobile coverage and power at Bluff Bridge (Hayard's Bridge), albeit power may be possible through solar means
- The impact of loss of power at the site and to residents in Glenreagh during storm events, as has been the case in past flood events
- The availability and timing of the NBN, and the reliability of telephone communications for residents on the NBN, which requires power after the backup Uninterrupted Power Supply is drawn down.

At the present time telecommunications infrastructure doesn't appear to be adequate to support a warning system at this location. However should the capacity and coverage of the network improve this option be pursued.

P5.4 Evacuation Improvements

P5.4.1 Helicopter Landing Area for East Bank Residents and other areas

Sherwood Creek Bridge and eastern approaches are inundated during flood events as frequent as the 20% AEP flood. This leads to road closure of the access into Glenreagh. Residents would need to use Sherwood Creek Road for access. During rarer floods, the access along Sherwood Creek Road is also severed leading to isolation of residents on the east bank. Local isolation also occurs near East Bank Road, where residents have been forced to evacuate along the railway embankment. As such it is recommended that at least a second (and potentially a third) helicopter landing location should be sought for the east bank residents, in

case of emergency rescue or need for resupply. This is particularly relevant when it is not safe to use boats travelling from the west bank in Glenreagh Village and the bridge over the Orara River at Glenreagh is inundated.

Further, during the community consultation, the helicopter landing issue was raised in one of the submissions for sub-catchments/isolated properties other than East Bank. It is therefore recommended to identify helicopter-landing zones in other locations around Glenreagh, in case they are needed in the future.

P5.4.2 Investigate Flood Immunity along Evacuation Route to north of Glenreagh

Following the community meetings and submissions received from the public, it is recommended to investigate the capability and flood immunity of the evacuation route to the north of Glenreagh. While this route includes Bluff Bridge (Hayard's Bridge), which is subject of Option 5.3, there are a number of other locations where the route may be severed during flood events. Investigation of the flood immunity at these locations is beyond the scope of this study, however is recommended for future investigation, particularly if culvert, bridge and road upgrades are planned.

☑ *P5.1 - It is recommended that the NSW State Flood Plan, the Clarence Valley, Local Flood Plan (SES 2012) and the Glenreagh Flood Action Card be reviewed and updated to provide overall consistency, in particular to ensure the correct gauge is referenced to drive flood responses. As an alternative it is recommended that installation of a new automatic gauge at the location of the manual gauge be installed, and that consistency between the two gauges at this location be achieved. This new gauge could then be referenced by BOM and the SES to provide flood level information for Glenreagh.*

P5.2 - Public awareness through a Glenreagh Flood Safe Brochure and evacuation planning should be implemented for Glenreagh flood prone areas, supported by flood information and signage. Provide flood mapping as determined through the study via Clarence Valley Council online maps, accessible on Clarence Valley Councils website.

P5.3 - Provide Remote Alert or webcam information on Bluff Bridge (Hayard's Bridge) to inform residents of imminent road closure

P 5.4.1 - A second helicopter landing location should be sought for the east bank residents and identify helicopter-landing zones in other locations around Glenreagh, in case they are needed in the future

P 5.4.2 The evacuation route to north of Glenreagh should be investigated with respect to flood immunity, particularly if culvert, bridge and road upgrades are planned.

5.4 Flood modification

Flood modification measures are those that alter the flood conditions to reduce the flood hazard or change the flood behaviour. Flood modification is generally the only measures that will minimise both the social impacts and the risk to property and life. However, it is rarely viable to design for the PMF (the upper envelope of floods) and thus a residual risk will exist, associated with floods exceeding the design level of service provided by the flood modification scheme.

5.4.1 P6 - Flood Mitigating/Detention Basins

Flood mitigation and detention basins attenuate the peak discharge in a storm by temporarily storing the stormwater and discharging it a slower rate. In Glenreagh, to make a measurable difference, it would be necessary to throttle the 1% AEP flood flows to between the 20% AEP and 5% AEP levels, since that is when substantial inundation of dwellings commences.

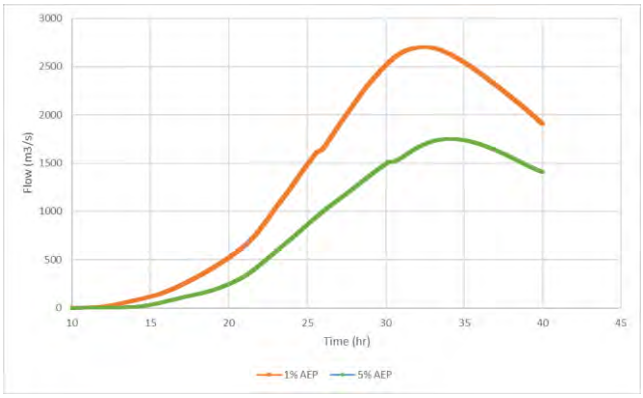


Figure 5-6 Flood Hydrographs

With reference to Figure 5-6, the 2700 m^3/s flood peak would need to be throttled to 1700 m^3/s. In considering the volume under these two hydrographs, this would require in excess of 25,000ML of storage which is clearly not practical and equates to approximately 1 km by 1.5 km storage 1.5 m deep.

In consideration of the magnitude of flooding affecting Glenreagh, the required throttling of flood peaks and volume under hydrographs, flood mitigation basins are not considered a practical flood mitigation measure

5.4.2 P7 – Levees and berms

General

The purpose of levees, berms and filling is to mitigate flooding and associated economic and social consequences of flooding, by preventing floodwaters from entering flooded areas. Of all the previously discussed management measures, a flood levee can provide the best protection against property damage, economic and social impacts associated with flooding. While there are opportunities to construct levees in local areas around parts of the town to reduce the impact of flooding, it will be important to ensure that no areas are adversely affected by the levee and flood is not increased outside of the levee area. In addition, consideration should be given to the following when deciding to build a levee:

- The level of flood protection sought.
- Extent of the levee (which dwellings are protected by a levee).
- Protection of future development areas.
- Impact of levee on local flood behaviour, in particular with regard to impacts on adjacent land.
- Aesthetic impact of the levee.
- Increased risk associated with levee overtopping and resulting rapid inundation.
- Maintenance of the levee.
- Environmental impact of levee.
- Emergency response when levee is overtopped and suitable evacuation routes.
- Local drainage from behind the levee.

Figure 5-7 Indicative Levee Location

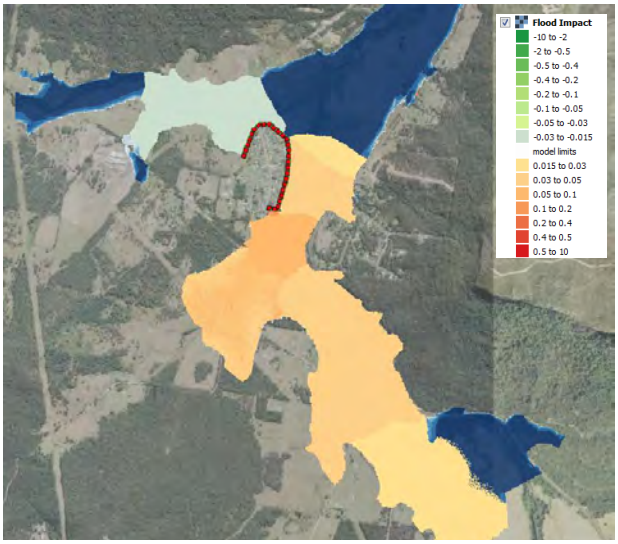


Figure 5-8 Potential Impact of levee

Levees at Glenreagh would benefit the town areas, if it were possible to divert flows away from residential areas. For rural properties, levees are generally not viable, since the benefit cost of constructing the levee versus savings in flood damages often proves unfavourable. In the case of Glenreagh, flows discharge into town from both Tallawudjah Creek and the Orara River. A levee would thus be of substantial length, and would need extend along both the Orara River and Tallawudjah Creek (Figure 5-7), and would thus be of considerable length. In some areas the levee would need to be 5 to 6m high, which would potentially require a 30 to 40m wide footprint. This would result in a construction cost substantially more than the flood damage savings that would be achieved.

Notwithstanding, a potential levee in the locations shown in Figure 5-7 was simulated in the flood model. The results in Figure 5-8 show that the levee would likely result in increased flood level of approximately 40 to 50mm in the East Bank residential areas and upstream of Glenreagh. This would include dwellings already under risk of overfloor flooding.

For rural properties, levees are generally not viable. For the town areas a levee would need to be of substantial length, and would need extend along both the Orara River and Tallawudjah Creek. In some areas the levee would need to be 5 to 6m high, which would potentially require a 30 to 40m wide footprint making this option economically unviable.

Levees for Glenreagh are thus are not considered a practical flood mitigation measure for Glenreagh

5.4.3 P8 – Fill Platforms

It is noted, that under the Clarence Valley Development Control Plan 2011, development involving filling of flood liable land must comply with the following criteria:

- (a) The filling of flood liable land must not increase the flood risk on other land within the floodplain.
- (b) Filling and associated works must not have any unacceptable associated environmental impacts such as detrimental effects on the ecology of riparian corridors.

The key relevant prescriptive controls are:

- D5.2.1 The flood impact of the development to be considered to ensure that the development will not increase flood affects elsewhere, having regard to:
  - (i) loss of flood storage;
  - (ii) changes in flood levels and velocities caused by alterations to the flood conveyance; and
  - (iii) the cumulative impact of multiple potential developments in the floodplain. An engineer's report may be required to address potential impacts.
- D5.2.2 If a Flood Storage Area has been defined in the floodplain, any filling of the floodplain inside this area is not permitted as it will reduce the volume of flood storage available on the floodplain and increase flood effects elsewhere, except:
  - i) where this occurs in conjunction with compensatory excavation, or
  - ii) where, in Council's opinion, such impacts are likely to be negligible

In some way, these filling controls can be extrapolated to enclosures under the flood planning levels. The enclosures would need to be assessed to determine if they would lead to loss of flood storage or result in unacceptable flood impact elsewhere. In Glenreagh, once flood waters enter the residential areas, flood depths rapidly increase, so that smaller enclosures on larger lots would not be expected to have a significant impact. However these matters would need to be assessed under the DCP.

It is noted, that an approved plan of subdivision exists for land off Tallawudjah Creek Road (see Appendix D). Referring to Figure 022 in Appendix B, the subject land comprises both flood storage and flood fringe areas.

To investigate the impact of subdivision proposal, flood simulations were undertaken by raising a development platform (as depicted in the subdivision approval). It must be noted, that the modelling simply blocked out the fill area and did not consider detailed design matters such as fill batters. The results showed flood level impacts to the town of Glenreagh, being less than 10 to 15mm, which is well within the accuracy of the modelling and are considered negligible.

Therefore, while the preliminary flood simulations show that the approved subdivision off Tallawudjah Creek Road may result in negligible impacts, more detailed simulations will be required to determine whether compensatory excavation may be required and convince Council that impacts are likely to be negligible (under DCP, D5.2.2). This however may require concept design of fill platforms that better consider fill batters and fill levels.

☑ *Preliminary flood simulations showed that the approved subdivision off Tallawudjah Creek Road may result in negligible impacts. However, more detailed simulations will be required to determine whether compensatory excavation may be required and convince Council's that impacts are likely to be negligible (under DCP, D5.2.2).*

5.4.4 P9 - Flood Conveyance Improvements

Flood conveyance would focus on matters, which maintain the conveyance of floodwaters in their current status or improve them. Typical conveyance improvements could relate to:

- Improving conveyance associated with structures in the floodplain, such as bridges and culverts. This could include the removal of bridges.
- Flood bypass channels.
- Maintaining waterways and managing vegetation.
- Minimising risk of obstructions to the flood conveyance such as by new structures in the flow path or woody debris reducing conveyance of flood waters in bridges and culverts
- Managing backwater effects.

Regular maintenance of creeks, culverts and flood bypasses

Regular maintenance of creek channels and culverts is imperative in order that these facilities operate as intended and optimally. A number of critical areas have been identified throughout the floodplain, where a build-up of sediment, erosion and/or vegetation will be important to maintain on an ongoing basis. It is noted that the community are concerned about the build-up of sediment at bridges and culverts.

In regards to the river channel, the beds of all watercourses change over time through natural processes. Council is constrained by environmental restrictions that are imposed by the Department of Primary Industries (Fisheries), so is not permitted to undertake works to clear the river bed (to the extent requested by some members of the community). Due to the same environmental constraints, Council is also not permitted to interfere with the natural process which has led to the changes in the river bed. It is appreciated that Council sometimes needs to undertake very minor, low risk but ongoing maintenance works that trigger Part 7 of the Fisheries Management Act 1994 (FM Act). To improve administrative efficiencies for both Council and Department of Primary Industries (Fisheries), the Department is preparing Maintenance Permits for Councils. The Maintenance Permit is for very minor, low impact dredging and reclamation works associated with maintenance works within the Local Government Area. Subject to conditions, these allow for removal of snags and in-stream debris occurring up to 10 meter upstream and downstream of Council infrastructure.

Table 5-2 Critical Locations for ongoing maintenance

Location	Issues	Risks
Culverts and channels conveying flows from the tributary drainage along Tallawudjah Creek Road	Maintain conveyance, remove vegetation/sediment	Elevated flood levels, Tallawudjah Creek Road overflow and inundation of surrounding properties
Culverts and channels conveying flows from the tributary drainage along Orara Valley Way	Maintain conveyance, remove vegetation/sediment, mow	Elevated flood levels, Orara Valley Way overflow and inundation/isolation of Glenreagh and rural properties

Glenreagh and Tallawudjah and Hayard's crossing bridges	Maintain conveyance, remove vegetation/sediment	Elevated flood levels and reduced conveyance leading to increased risk of isolation of Glenreagh and rural properties
Orara and Tallawudjah Creek channels	Maintain conveyance and remove non-native vegetation/sediment	Elevated flood levels and reduced conveyance leading to increased flood risk to Glenreagh

☑ *Regular maintenance of creek channels and culverts is imperative in order that these facilities operate as intended and optimally. A number of critical areas have been identified throughout the floodplain of Glenreagh, where a build-up of sediment, erosion and/or vegetation will be important as part of ongoing maintenance*

5.5 Summary and Recommendations

From the above discussion, Table 6 3 summarises the final options assessed and the options to be included in the Floodplain Management Plan.

	Option	Recommended Mitigation Option
P1	Land Use Planning Land Use Planning and Flood Planning Levels are important measures to manage flood risk while assessing development. Much of this is contained in the Clarence Valley Development Control Plan 2011, however it is considered that the flood related controls could benefit from a review and the flood mapping be provided for Glenreagh.	☑
P2	Voluntary House Raising Given Council has revoked its Voluntary House Raising Policy this scheme is not further considered for Glenreagh	☒
P3	Voluntary Purchase of High Hazard Properties In consideration, that only 2 dwellings in Glenreagh are located on the edge of a floodway with removal unlikely to improve conveyance and the Council funding availability, a Voluntary Purchase Scheme is not considered a potential floodplain mitigation option for Glenreagh	☒
P4	Flood Information/Data With completion of the Glenreagh Flood Study, 2013, it would be desirable to update planning documents such as the LEP and DCP with the most up to date flooding information. Where resources allow, updates using the latest Australian Rainfall and Runoff (ARR2016) should be completed.	☑
P5	Flood Warning/Response P5.1 - It is recommended that the NSW State Flood Plan, the Clarence Valley, Local Flood Plan (SES 2012) and the Glenreagh Flood Action Card be reviewed and updated to provide overall consistency, in particular to ensure the correct gauge is referenced to drive flood responses. As an alternative, it is recommended that a new automatic gauge at the location of the manual gauge be installed, and that consistency between the two gauges at this location be achieved. This new gauge could then be referenced by BOM and the SES to provide flood level information for Glenreagh. P5.2 - Public awareness through the Glenreagh Flood Safe Brochure and evacuation planning should be implemented for Glenreagh flood prone areas, supported by flood information and signage. Provide flood mapping as determined through the study via Clarence Valley Council online maps, accessible on Clarence Valley Councils website. P5.3 - Provide Remote Alert or webcam Information on Bluff Bridge (Hayard's Bridge) to inform residents of imminent road closure and road status. P 5.4.1 - A second helicopter landing location should be sought for the east bank residents and identify helicopter-landing zones in other locations around Glenreagh, in case they are needed in the future	☑

	Option	Recommended Mitigation Option
	P 5.4.2 The evacuation route to north of Glenreagh should be investigated with respect to flood immunity, particularly if culvert, bridge and road upgrades are planned.	
P6	Detention Basins In consideration of the magnitude of flooding affecting Glenreagh, the required throttling of flood peaks and volume under hydrographs, flood mitigation basins are not considered a practical flood mitigation measure	☒
P7	Levees and Berms For rural properties, levees are generally not viable. For the town areas a levee would need to be of substantial length, and would need extend along both the Orara River and Tallawudjah Creek. In some areas the levee would need to be 5 to 6m high, which would potentially require a 30 to 40m wide footprint making this option economically unviable. Levees for Glenreagh are thus are not considered a practical flood mitigation measure	☒
P8	Fill Platforms Preliminary flood simulations showed that the approved subdivision off Tallawudjah Creek Road may result in negligible impacts. However, more detailed simulations will be required to determine whether compensatory excavation may be required and convince Council's that impacts are likely to be negligible (under DCP, D5.2.2).	☑
P9	Flood Conveyance Improvements Regular maintenance of creek channels and culverts is imperative in order that these facilities operate as intended and optimally. A number of critical areas have been identified throughout the floodplain of Glenreagh, where a build-up of sediment, erosion and/or vegetation management will be important as ongoing maintenance	☑

5.6 Option Ranking

Options were discussed and assessed by the project team in the absence of a Floodplain Risk Management Committee. They considered social/environmental issues, economic and financial costs and overall benefit/cost of the option. Key issues considered are listed in Table 5-3, which were rated with a score of 1 to 5 (where 5 is the most preferred outcome). A weighting Table 5-4 was applied to the issue and multiplied against the rating. The assessment of options is provided in Table 5-5. From the table, the following is noted in general terms:

- Land Use Planning is the most favoured option for Glenreagh. Land Use Planning and Flood Planning Levels are important measures to manage flood risk while assessing development. Much of this is contained in the Clarence Valley Development Control Plan 2011, however it is considered that the flood related controls could benefit from a review and the flood mapping be provided for Glenreagh.
- Flood Warning/Response is the next favoured option, and in particularly the SES Flood Action Card and SES Clarence Valley, Local Flood Plan would benefit from an update to correct referencing and update information. In particular to ensure the correct gauge is

referenced to drive flood responses. As an alternative it is recommended that installation of a new automatic gauge at the location of the manual gauge be installed, and that consistency between the two gauges at this location be achieved. This new gauge could then be referenced by BOM and the SES to provide flood level information for Glenreagh.

- The third favoured option is flood conveyance improvements, with regular maintenance of creek channels and culverts to ensure these facilities operate as intended and optimally. A number of critical areas have been identified throughout the floodplain of Glenreagh, where a build-up of sediment, erosion and/or vegetation management will be important as ongoing maintenance

An implementation plan, showing option priority versus timing has been provided in Figure 5-9.

Table 5-3 Social, Economic and Environmental Issues for Assessing Options

Category	Issues
Social	
How the option will influence property values	*The capacity of the option to reduce flood hazards and personal safety risks to the community*
The capacity of the option to promote community growth	
The level of disruption to the community, either through implementing the option or through the resulting floodplain behaviour	
Economic	
The ongoing or maintenance costs of the option	*The capital costs associated with implementing the option*
The costs or savings of flood damage after the option is implemented	
Environmental	
Environmental pollution	*Change to ecology, habitats, riparian vegetation, and the "natural state" of the creek*
Energy and resources required to implement the option	
Energy and resources required for maintaining and decommissioning the option	

Table 5-4 Intangible Weightings

Intangible Issue	Weighting
Social	
Flood hazard reduction	10
Flood risk reduction	20
Long term community disruption	5
Community sustainability	15
Amenity	10
Short term community disruption	5
Stress, anxiety and health impacts	15
Increase in property values	10
Environmental	
Environmental impact to implement	5
Environmental impact to maintain	5
TOTAL	**100**

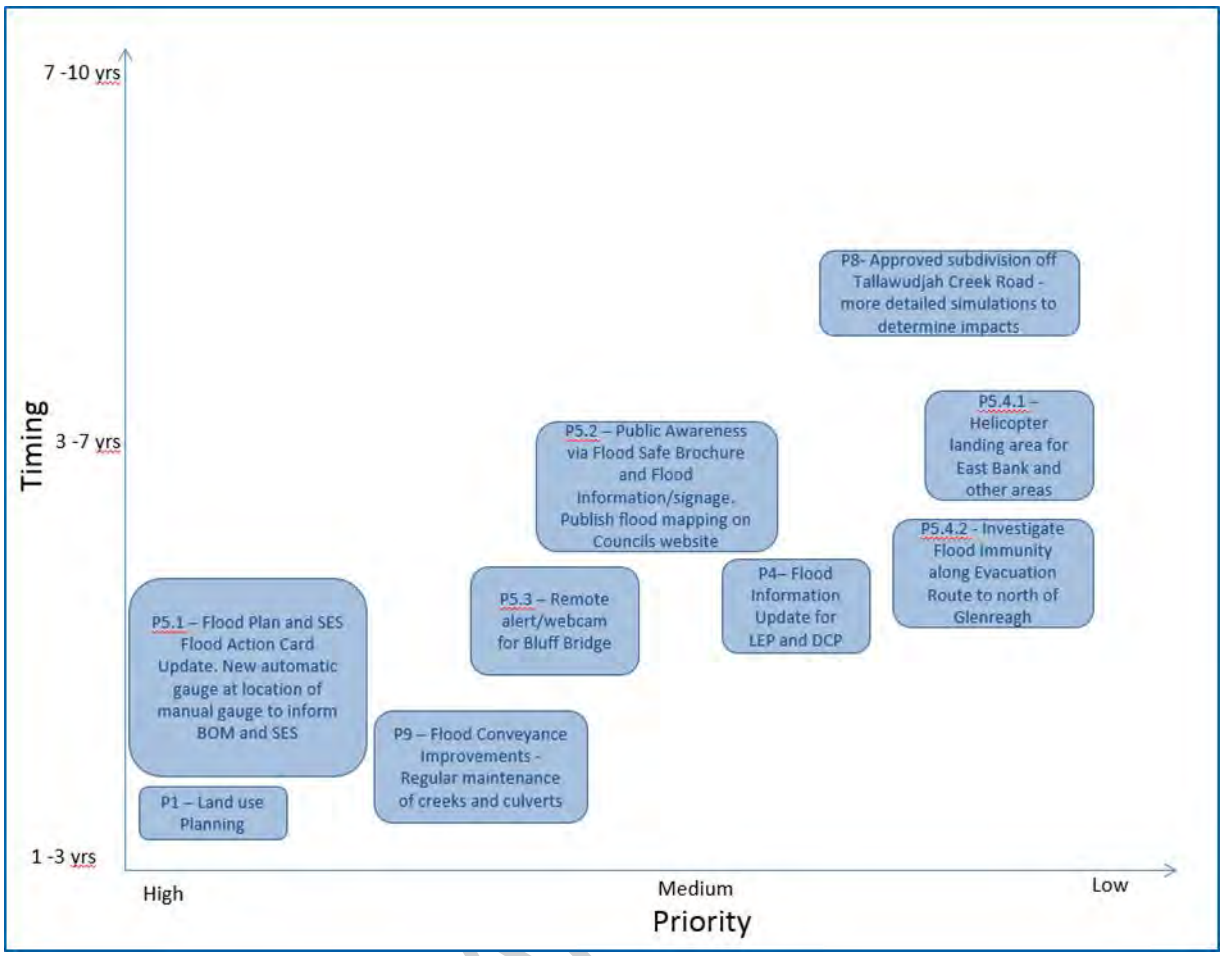


Figure 5-9 Implementation Plan

Table 5-5 Assessment of Options

	Issues	Intangible weightings	Options and Assessment (1 = option has negative impact, 3 =neutral, 5= option has positive impact)									
				P1	P4	P5					P8	P9
			Do nothing	Land Use and Flood Planning	Flood Information Update for LEP and DCP. Where resources allow updates using the latest Australian Rainfall and Runoff should be	P5.1 Flood Plan and SES Flood Action Card Update. New automatic gauge at location of manual gauge to inform BOM and SES	P 5.2 Public Awareness and Evacuation Planning, and flood information/signage. Publish flood mapping on Councils website	P5.3 Remote alert or webcam information on Bluff Bridge (Haywards Bridge)	P 5.4.1 Helicopter landing for east bank and other areas	P 5.4.2 Investigate Flood Immunity along Evacuation Route to north of Glenreagh	Approved subdivision off Tallawudjah Creek Road - more detailed simulations to determine impacts	Flood conveyance Improvements - Regular maintenance of creeks and culverts
Social	Flood hazard reduction	10	1	4	3	4	3	4	3	3	4	4
	Flood risk reduction	20	1	4	3	4	3	4	3	3	4	4
	Long term community disruption	5	3	3	3	3	3	3	3	3	3	3
	Community sustainability	15	2	4	3	3	3	3	3	3	3	3
	Amenity	10	2	4	3	3	3	3	3	3	3	4
	Short term community disruption	5	1	3	3	3	3	3	3	3	3	3
	Stress, anxiety and health impacts	15	2	3	4	3	4	3	3	3	3	3
	Property values	10	2	4	3	3	3	3	3	3	3	3
Environ-nmental	Environmental impact associated with implementation	5	2	3	3	3	3	3	3	3	2	2
	Environmental impact associated with maintenance	5	2	3	3	3	3	3	3	3	3	2
	Social and Environmental Rank		8	1	6	9	5	2	9	7	4	2
Economic	Present Value Damage Cost with Option Implimentation ($)											

	Present Value Capital Costs of Option ($)				10,000		5,000	20,000		40,000		
	Annual Maintenance Cost of Option ($)							2,000	2,000			10,000
	Present Value Damage Savings ($)											
	Benefit/ Cost Ratio											
Priority				High	Medium	High	Medium	Medium	Low	Low	Low	High

6. Floodplain Risk Management Plan

The Draft Floodplain Risk Management Plan has been provided in Appendix E. The Floodplain Risk Management Study and Draft Plan will be submitted to Council for adoption once completed.

7. Acknowledgements

- GHD has prepared this document with financial assistance from the NSW and Commonwealth Governments through the Natural Disaster Resilience Program. This document does not necessarily represent the opinions of the NSW or Commonwealth Governments.
- GHD acknowledge the assistance and support received from Clarence Valley Council, Council officers and the project team (including Clarence Valley Council, OEH and the SES) in the compilation of this study.

8. References

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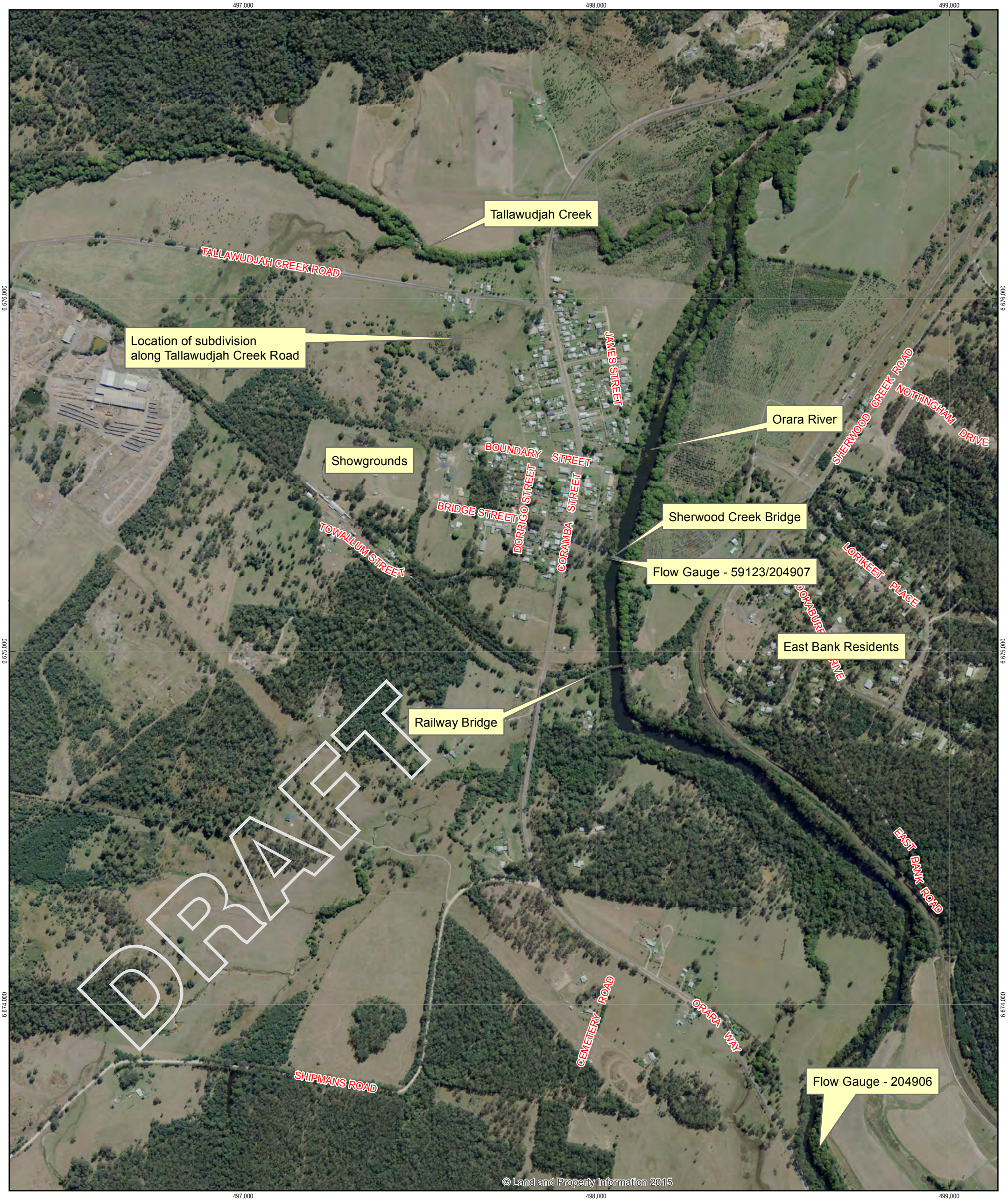
Appendices

Appendix A Location Map



LEGEND

Cadastre

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Location Map

Job Number	22-18407
Revision	A
Date	27 Apr 2017

Figure 1

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:rberg

Appendix B Flood Maps

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ORARA WAY

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

SHERWOOD CREEK ROAD

ORARA RIVER

ORARA RIVER

MIDDLE CREEK

SCRUBBY GULLY

© Land and Property Information 2015

LEGEND

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Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
5 year ARI - Flood Extent and Depth (m)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 001

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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59 60 61 62 62 63 63 64 64 64 65 65 65 66 66 67 67 67 68

ORARA WAY

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

SHERWOOD CREEK ROAD

MIDDLE CREEK

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

0.16 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 - 2.0 | 2.0 - 3.0 | 3.0 - 5.0 | 5.0 - 10.0 | 10.0 - 20.0 | Flood Level Contours (mAHD) | Cadastre

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
20 year ARI - Flood Extent and Depth (m)

Figure 003

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

SCRUBBY GULLY

LEGEND

- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- Flood Level Contours (mAHD)
- Cadastre

Paper Size A3

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
100 year ARI - Flood Extent and Depth (m)

Figure 005

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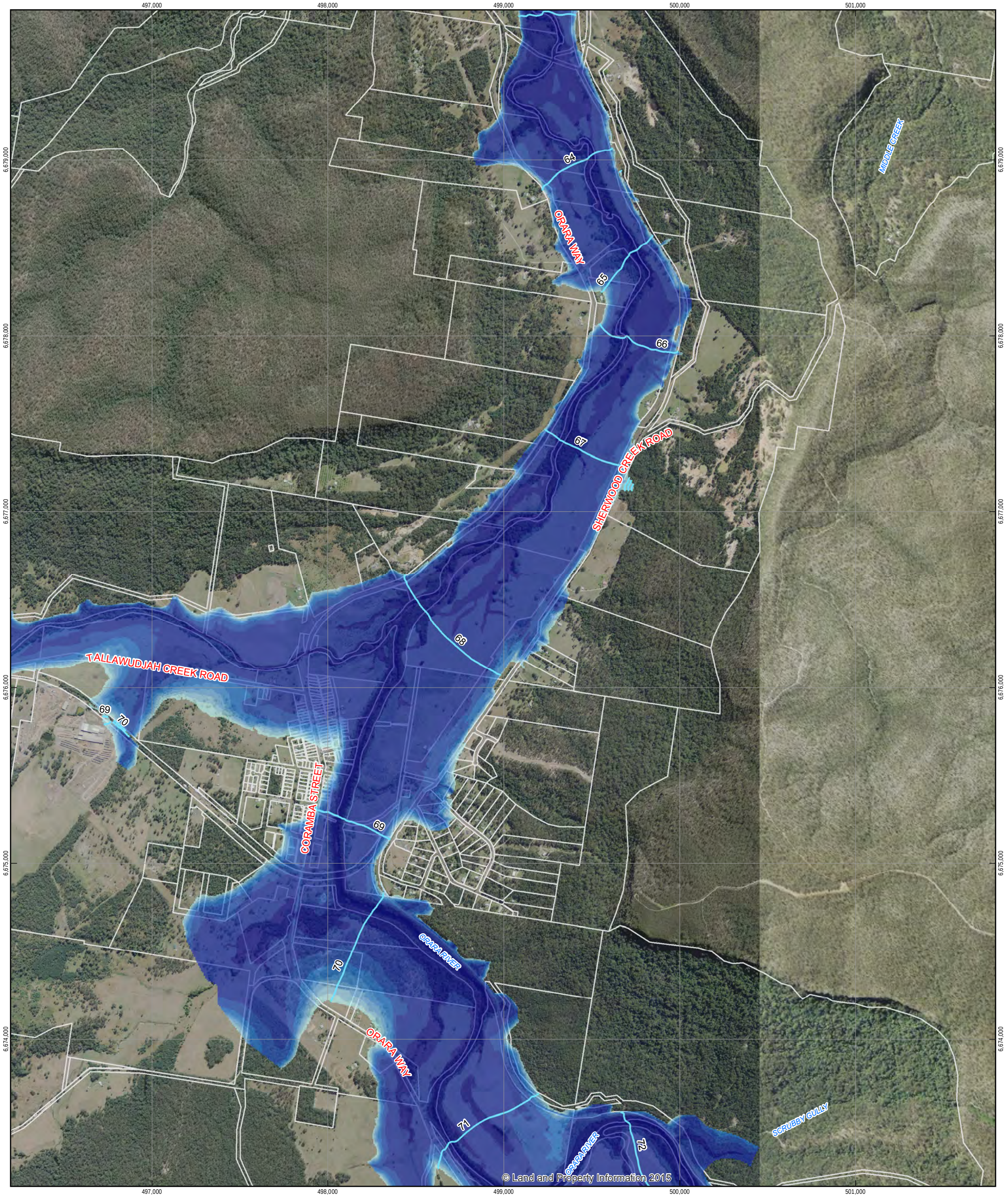
Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg



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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
500 year ARI - Flood Extent and Depth (m)

Figure 006

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

SCRUBBY GULLY

LEGEND

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1.0 - 1.5	3.0 - 5.0			

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Flood Extent and Depth (m)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 007

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
5 year ARI - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 008

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY
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TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
20 year ARI - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 010

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
100 year ARI - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 012

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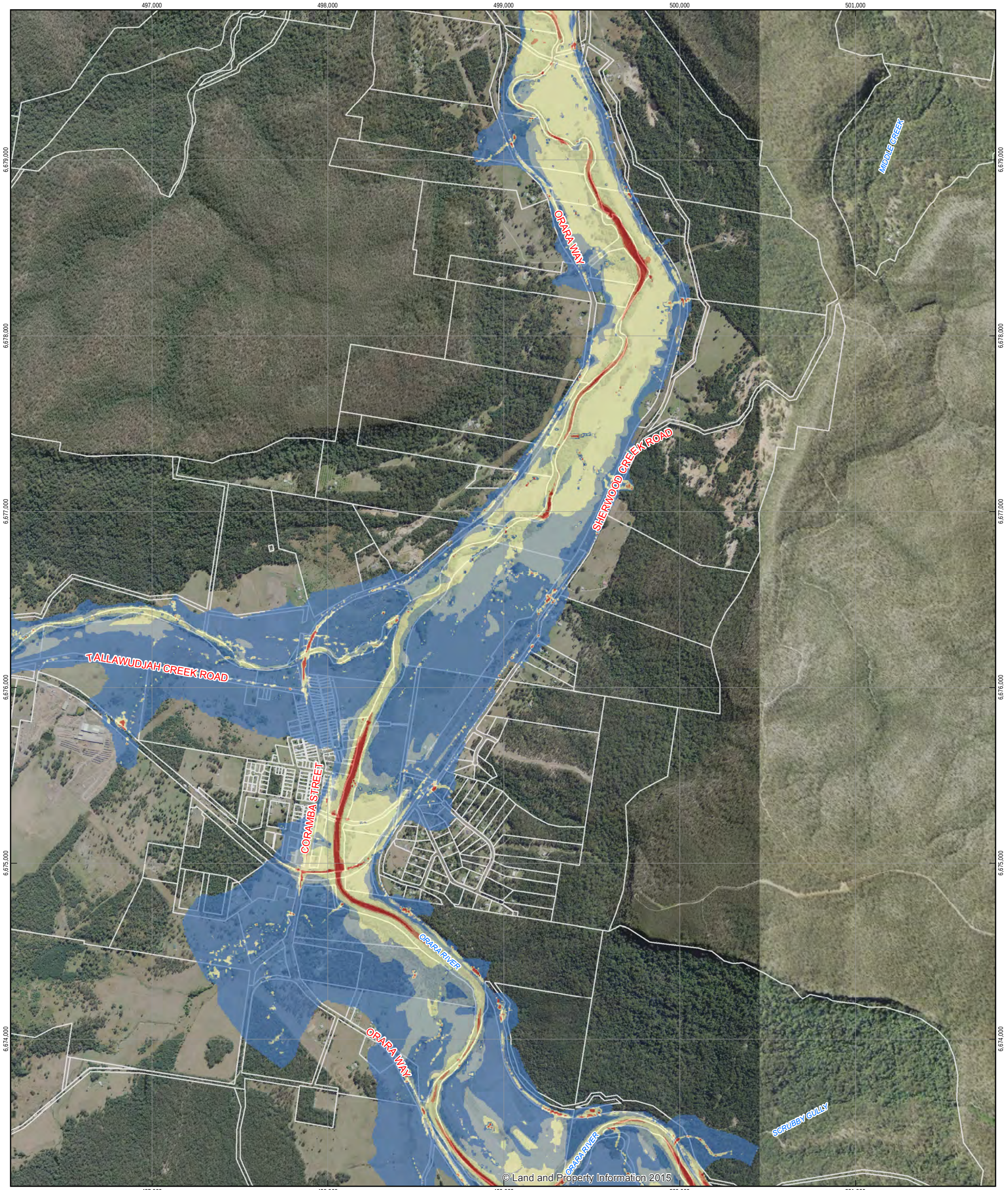
Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg



LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
500 year ARI - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 013

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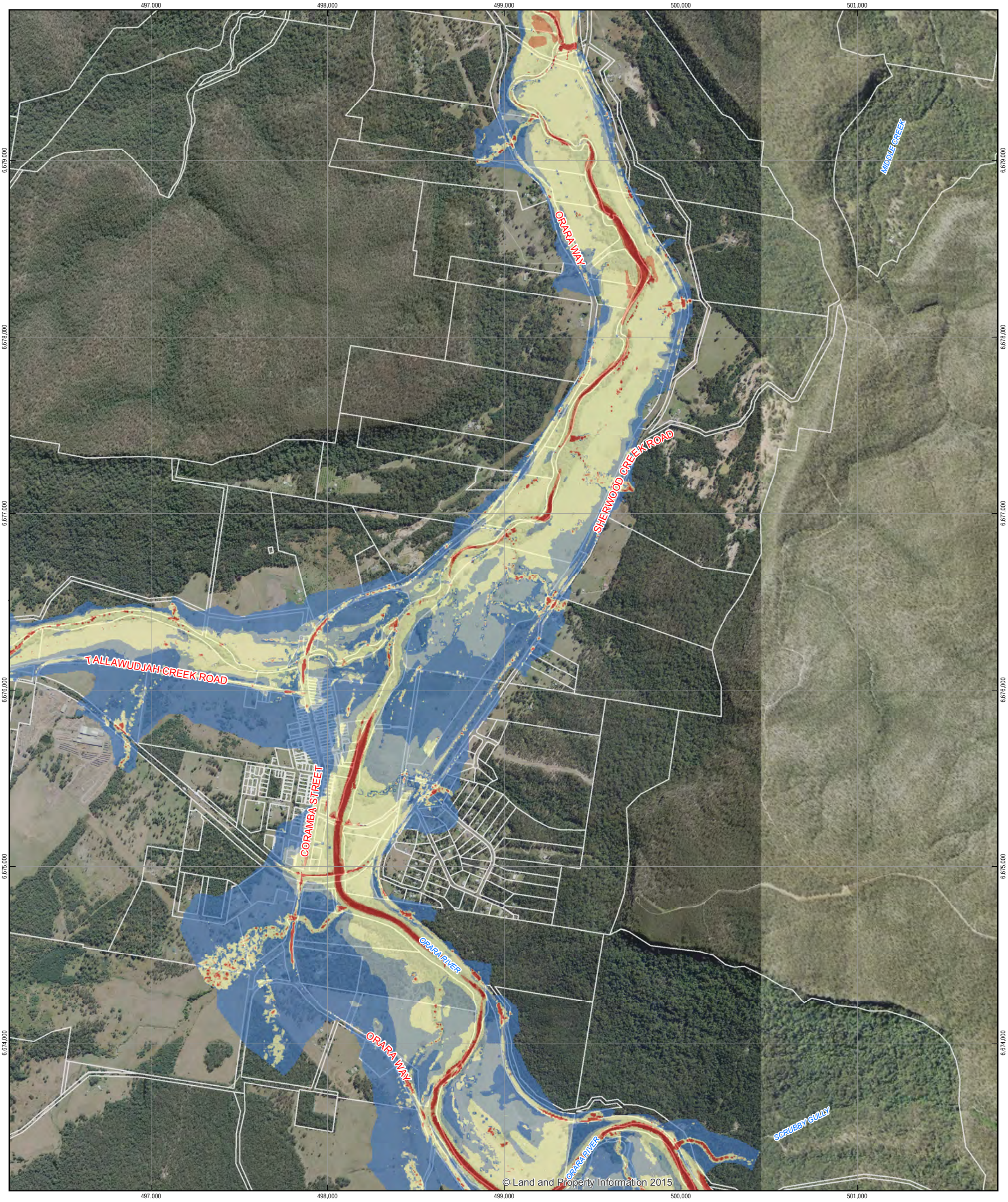
Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg



LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 014

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 10)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY
© Land and Property Information 2015

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
5 year ARI - Provisional Hydraulic Hazard

Figure 015

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 11)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY
© Land and Property Information 2015

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
20 year ARI - Provisional Hydraulic Hazard

Figure 016

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Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
100 year ARI - Provisional Hydraulic Hazard

Figure 017

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Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
500 year ARI - Provisional Hydraulic Hazard

Figure 018

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Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Provisional Hydraulic Hazard

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 019

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Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
5 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 020

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY
© Land and Property Information 2015

LEGEND

- Flood Fringe
- Flood Storage
- Flood Way
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
20 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 021

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- Flood Fringe
- Flood Storage
- Flood Way
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
100 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 022

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Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- Flood Fringe
- Cadastre
- Flood Storage
- Flood Way

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
500 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 023

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 19)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- Flood Fringe
- Cadastre
- Flood Storage
- Flood Way

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 024

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Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

Appendix C Community Consultation

Glenreagh Floodplain Risk Management Study & Draft Plan

COMMUNITY NEWSLETTER NO.1

June 2016

About the project

Historically, a number of significant floods have occurred in the Orara Valley. It is understood, from community input that one of the largest floods in the valley occurred on 24 June 1950, when 502 mm was recorded at the Aurania rainfall gauge in a single day and 916 mm fell from 18 to 25 June. Floodwaters have been known to rise quickly and isolate communities and properties. While flood peaks can recede equally quickly, properties at times can remain isolated for several days. Many houses in Glenreagh can be inundated in flood events necessitating evacuations.

To help mitigate the effects of such rainfall in the future, Clarence Valley Council has contracted GHD to investigate flooding in the catchment over the coming months and develop floodplain management options. The findings will then be compiled into a Draft Floodplain Risk Management Plan.

Council and GHD are committed to listening to the concerns and issues of the community and stakeholders. Throughout the study there will be opportunities for the local community and stakeholders to feedback their concerns and issues.

Floodplain Risk Management Committee

A floodplain management committee (FRMC) has been formed as part of the Floodplain Risk Management Study. The FMC will provide a link between the flood study team and the community throughout the various stages of the project. The FMC will meet throughout the course of the project.

Further information about the FRMC can be obtained by calling the community information telephone number below.

Community Information Session

The project team is keen to learn from local residents when and where past flooding has occurred in Glenreagh and the surrounding areas. We are interested in how you and your property were affected and how you prepare for a flood.

The community will be invited to attend a Community Information Session in mid 2016 to meet the study team and find out more about the project, as well as provide historical information to GHD about past flooding.

We are also interested in getting an understanding of your feelings towards particular flood management options. Attached is a survey questionnaire that all members of the community are being encouraged to fill out and return (postage paid) to ensure you have your say.

For more information contact:

Rainer Berg
Glenreagh Floodplain Management Study and Draft Plan
Reply Paid 1340
Coffs Harbour NSW 2450
Facsimile – 02 6650 5601
Email – cfsmail@ghd.com.au

Project Information Line
6650 5600 or 8898 8815

Clarence Valley Council

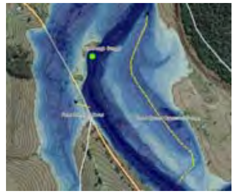
GLENREAGH FLOODPLAIN RISK MANAGEMENT STUDY and DRAFT PLAN

Community Meeting

16/08/2016

Flood History

- Floodwaters in Orara River and Bucca Creek catchments have been known to rise quickly and isolate communities and properties.
- Flood peaks can recede equally quickly, but properties can remain isolated for several days.
- Many houses can be inundated in flood events necessitating evacuations.
- In March/April 2009, five significant events were recorded at the Glenreagh runoff gauge, all exceeding or close to the "Moderate Flood"
- In March/April 2009, the second highest flood level recorded since the start of the Glenreagh Gauge (1972), was recorded in the Orara Valley.
- Anecdotal evidence, that the 1950 flood was significantly larger than the 2009 event.



Flood History

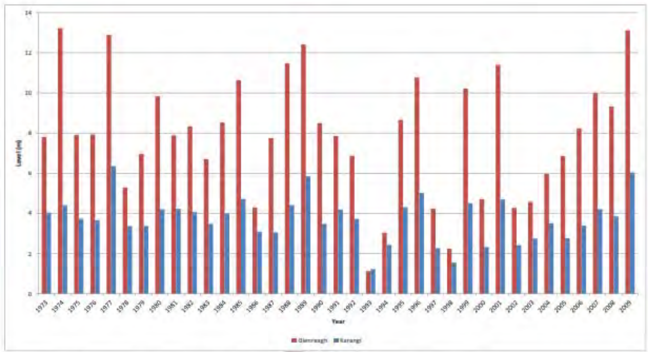


Figure 2-1 Largest Floods in the Orara at Karangi and Glenreagh

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Historic Flooding

The Sydney Morning Herald (NSW : 1842 - 1954), Thursday 13 July 1950, page 1

Families See Homes Washed Away By Flooded River

The flooded Orara River has washed away two homes and damaged several others at Glenreagh, about 20 miles from Grafton.

Eight families have been evacuated and are staying with friends.

(Other Flood News, p. 5)

National Library of Australia

The Sydney Morning Herald (NSW : 1842 - 1954), Thursday 11 February 1937, page 9

FLOODS IN ORARA.

RIVER HIGHEST FOR YEARS.

GRAFTON, Wednesday.

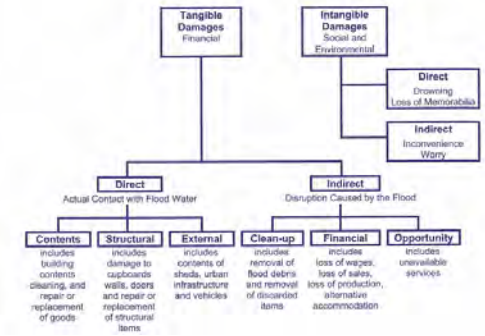
National Library of Australia

http://nla.gov.au/nla.news-article17311562

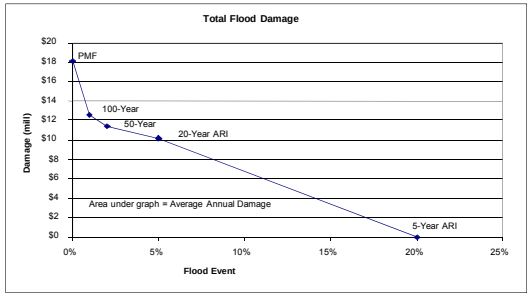
Flood History

@ Karangi 1990, 1997, 1973, 2002, 1986, 2000, 1989,1971, 1996, and 1982

Flood Damage



Flood Damage Calculation



Community Involvement

- Media Release
- Newsletter
- Survey

Community Involvement

- Survey, frequency of flooding, damage & access cut-off

3. If yes, in what years did the floods take place?
ANNUAL EVENT – SOME BIGGER THAN OTHERS
4. What effects did the river flood have on you and your property?
NO EFFECT ON OUR PROPERTY BUT INCONVENIENCE OF BEING CUT OF FROM COFFS HARBOUR AND/OR GRAFTON

3. If yes, in what years did the floods take place?
SEVERAL IN 1963, 1974, 1977, AND MANY SMALLER ONES SINCE
4. What effects did the river flood have on you and your property?
FENCE DAMAGE, ACCESS TRACK DAMAGE.

3. If yes, in what years did the floods take place?
6 times, but not the last 2 years
4. What effects did the river flood have on you and your property?
The roads to Grafton + Coffs are cut off.

..how does one manage Flood Liable Land?

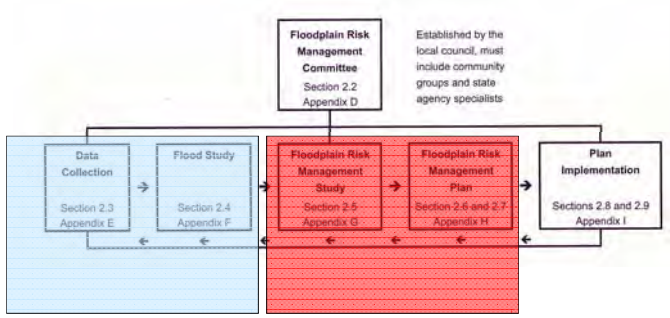
Floodplain Development Manual

the management of flood liable land

- Reduce the social and financial
- Increase the sustainable benefits of using the floodplain
- Improve or maintain floodplain

PROVIDES A PROCESS !!

Floodplain Risk Management Process



(What Happens?) → (What do WE do about it?)

Floodplain Risk Management Study & Plan - Key Tasks

1. Review Previous Work (Flood Study)
2. Update flood modelling (if necessary)
3. Obtain Community Input
4. Calculate Flood Damages
5. Look at Options to Manage Flooding & Assess
6. Provide a Plan

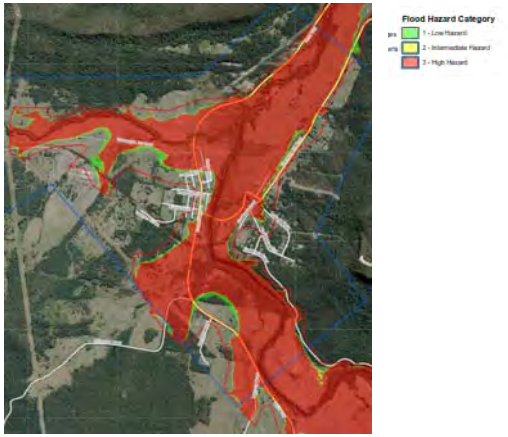
Flood Study Review - Depth

20yr

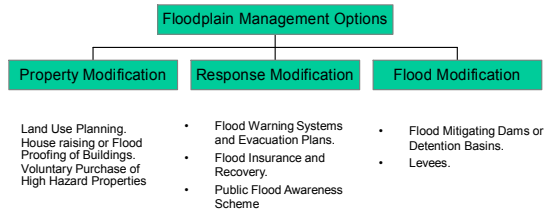
100yr

Flood Study Review - velocity

Flood Study Review - Hazard



Floodplain Management Options



Preliminary Assessments

- Berms/levee to reduce the frequency of flooding.
- Stormwater upgrades
- Regular maintenance to remove debris/silt
- Flood warning and locations of flood warning stations and other flood response measures, integration with other Local Plans
- Evacuation routes and warning strategies
- Planning controls for new and infill developments
- Flood runners/ flood ways in selected

Assessment of Options

Category	Issues
Social	◗ The capacity of the option to reduce flood hazards and personal safety risks to the community, ◗ How the option will influence property values; ◗ The capacity of the option to promote community growth; and ◗ The level of disruption to the community, either through implementing the option or through the resulting floodplain behaviour.
Economic and Financial	◗ The capital costs associated with implementing the option; ◗ The ongoing or maintenance costs of the option; and ◗ The costs or savings of flood damage after the option is implemented.
Environmental	◗ Change to ecology, habitats, riparian vegetation, and the "natural state" of the river; ◗ Pollution; ◗ Energy and resources required to implement the option; and ◗ Energy and resources required for maintaining and decommissioning the option.

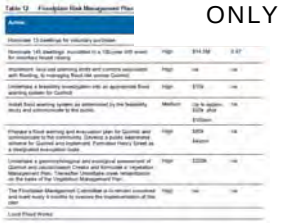
Detailed Assessments

- Simulate benefits in Flood Models
- Calculate the reduction in Flood Damages
- Preliminary costing of the option
- Cost/Benefit Assessment of the Option

Floodplain Risk Management Plan

- A synopsis of the flooding, social, economic and environmental issues;
- Description of the management measures
- Priorities and staging
- Funding requirements and sources
- Actions and responsibilities;
- Administrative requirements; and
- An implementation program.

EXAMPLE ONLY



www.ghd.com

Clarence Valley Council

GLENREAGH FLOODPLAIN RISK MANAGEMENT STUDY and DRAFT PLAN

Community Meeting

13/12/2017

Flooding History

The Sydney Morning Herald (NSW : 1842 - 1954), Thursday 13 July 1950, page 1

Families See Homes Washed Away By Flooded River

The flooded Orara River has washed away two houses and damaged several others at Glenreagh, about 20 miles from Grafton.

COFFS FLOOD DISTRICT

Nine families isolated by flood damage

COFFS FLOOD

Overflowing in Glenreagh

The Sydney Morning Herald (NSW : 1842 - 1954), Thursday 11 February 1937, page 9

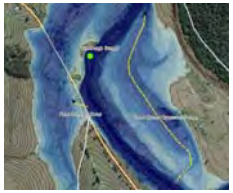
FLOODS IN ORARA.

RIVER HIGHEST FOR YEARS.

National Library of Australia

Flood History

- **Floodwaters in Orara River and Tallawudjah Creek rise quickly**
- **Can isolate communities and properties.**
- **Flood peaks can recede quickly, but isolated remains several days.**
- **Houses can be inundated in flood events necessitating evacuations.**
- **In March/April 2009, 5 significant events, all > than "Moderate Flood"**
- **In March/April 2009, 2nd highest flood level since 1972**
- **1950 flood was significantly larger than the 2009 event**
  - **502mm in 1 day, 916 mm over 7 days**



What you have told us.....

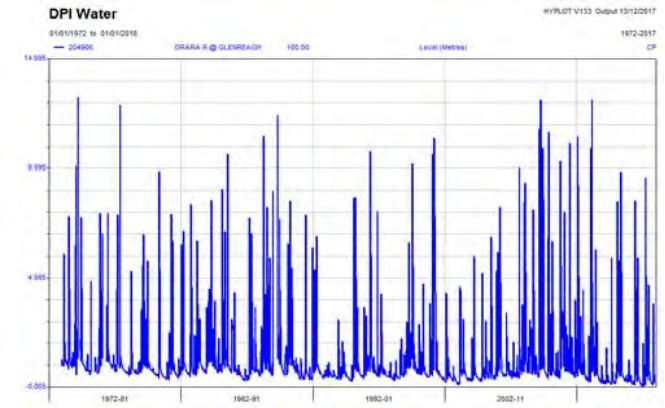
Community Survey

- Of the residents who completed the survey, some recall the 2009 floods first hand. Many residents note flooding every year. The 1950 and 1954 floods were also experienced by a few residents, in one case the residents were rescued off the roof of their dwelling.
- Many residents note debris build up, damage to fences and paddocks, stormwater and local roads at times of flooding. In addition, septic system overflows to the Orara River were noted.
- Residents noted that they are isolated during flood events, in some cases up to 3 days. At times, this is without power, telephones and with limited mobile reception.
- Preparation at times of flooding varied. Some community noted that listening for flood alerts and stocking up on essential items of food, fuel and water and medication. Some residents raised furniture and other belongings in preparation of a flood. Some residents open farm gates and raise pumps and other infrastructure.
- There was a preference for educating the community, flood modification, improved development controls and improved drainage. The raising of bridges to provide access to Coffs Harbour and Grafton was noted. This included a suggestion to raise/rebuild Hayard's Crossing (Bluff Bridge). More careful consideration of flooding matters on new home sites and future development was suggested.
- A number of residents noted the requirement for co-ordinated flood warning, evacuation and meeting points. The residents felt it was useful to provide a real-time camera (accessible from the internet) at Hayard's Crossing (Bluff Bridge). This would allow residents the ability to determine whether access to Grafton has been severed before leaving home.
- A recurring theme was associated with the build-up of vegetation silt and debris in the river channel and in stormwater drains impeding the conveyance of flood flows. This point was further linked to potential blockages at the causeway. Removing debris and silt from culverts for example East Bank Road and the adjacent railway culvert was requested.
- It was also suggested that providing a helicopter landing areas on both sides of the Orara River would assist in emergency response during a flood.

Key Messages

- Flooding just about every year
- Experience of 1950 flood
- Debris build up, river, stormwater drains, causeways
- Isolation – 3 days
- Community responds to warnings
- Want education, development controls
- Want coordinated flood warning, meeting points
- Hayards Crossing (Bluff Bridge)
- East bank residents

Flood History



Flood Study Review - Depth

Depth

- 5yr already surcharging river channel and inundating roads
- In 100yr widespread flooding. Inundation of properties north of Connell Street and Tallawudjah Creek road
- Flooding at Kookaburra Drive and Lorikeet Place
- Access cut north and south along Orara Valley Way

5yr

100yr

Flood Study Review - velocity

Velocity

- Higher velocities in river channel
- Floodplains generally less than 1 m/s
- Faster flowing flood water eastern bank at bridge

Flood Study Review - Hazard

Hazard

- Large areas designated as high hazard
- Rural areas also high hazard, including access tracks
- Most flood storage areas would be high hazard

Flood Warning

- Tallawudjah Creek arrives before Orara River Flood Peak
- Glenreagh flood peak, 2 hours after Nana Glen, 2hrs after Coramba
- Glenreagh flood peak about 32 hours after onset of rain
- Flood peaks rise rapidly about 0.5m/hr
- Most of town can evacuate to higher ground, however access severed and east bank dwellings isolated.
- Warning times are generally short

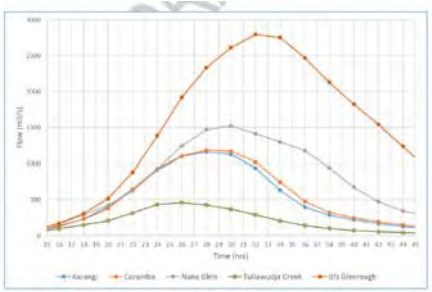


Figure 2-2 Simulated 1% AEP flood peaks

Bridge inundation

Table 2-6 Bridge Inundation Assessment

Location	20% Flood event AEP	5% Flood event AEP	1% Flood event AEP
Orara Way near Lurcocks Road	Inundated by approximately 3m	Inundated by approximately 5.8m	Inundated by approximately 6m
Orara Way near Shipmans Road	Not inundated	Inundated by approximate 0.5m at the bridge approaches	Inundated by approximate 2m at the bridge approaches
Sherwood Creek Road (Glenreagh Bridge)	Inundated by up to 2m on the eastern approach road to the bridge	Inundated by up to 3.6m on the eastern approach road to the bridge	Inundated by up to 5.6m on the eastern approach road to the bridge
Tallawudjah Creek Bridge	Inundated by approximate 0.3m at the bridge approaches	Inundated by approximate 2m at the bridge approaches	Inundated by approximate 3.9m at the bridge approaches
Orara Way north of Tallawudjah Creek Bridge	Inundated by approximately 0.3m	Inundated by approximately 1m to 1.5m	Inundated by approximately 3.5m
Hayard's Crossing (Bluff Bridge)	Expect to be inundated during minor events		

Flood Damage

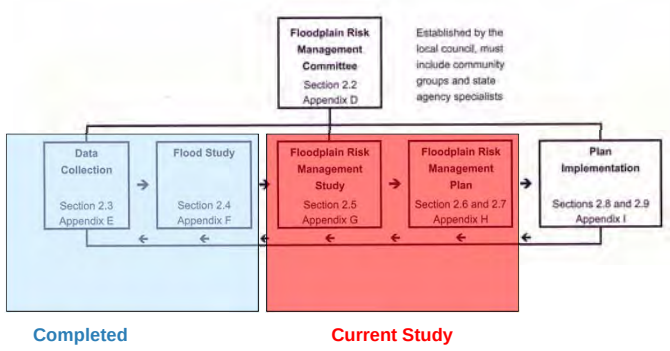
Table 2-8 Property numbers experiencing flood damages

Flood Event (AEP)	Number of properties
20%	25
5%	61
1%	84
0.2%	116
PMF	136

Table 2-11 Damage Summary

Item	Direct ($ million)	Direct + Indirect ($ million)
Annual Average Damage	0.31	0.45
Net Present Value (20yrs @ 7%)	3.34	4.84

Floodplain Risk Management Process



(What Happens?) → (What do WE do about it?)

Floodplain Management Options

Floodplain Management Options

Property Modification

- Land Use Planning.
- House raising or Flood Proofing of Buildings.
- Voluntary Purchase of High Hazard Properties

Response Modification

- Flood Warning Systems and Evacuation Plans.
- Flood Recovery.
- Public Flood Awareness Scheme

Flood Modification

- Flood Mitigating Dams or Detention Basins.
- Levees.

Property Modification

Land Use Planning

- Guideline for future development
- DCP would benefit from:
  - Explicit definition of the Flood Planning Level and Flood Planning Area.
  - Compilation of a Flood Planning area based on Glenreagh Flood Study (CVC, 2013).
  - Review of nomenclature to better align with the NSW Floodplain Development Manual, 2005.
  - Consideration for Climate Change in the nomination of freeboard associated with the Flood Planning.


Clarence Valley Local Environmental Plan 2011

Response Modification

Flood Information

- Used in planning and by SES
- Update planning documents with latest flood information:
- Flood prone land, as the land inundated by a PMF.
- Flood planning area and levels, as the land inundated by the 1% AEP flood plus 0.5 m.
- Flood category maps showing floodway, flood storage and flood fringe.
- Flood hazard in accordance with the NSW Floodplain Development Manual.
- Flood modelling using the latest Australian Rainfall and Runoff (ARR2016) at any time and data on flood levels and velocities can be updated

Clarence Valley Council
DRAFT Glenreagh Flood Study
(Extension of Orara Flood Study)

Response Modification

Flood Warning/Response

- SES to update the NSW State Flood Plan, Local Flood Plan and the Glenreagh Flood Action Card and updated to provide overall consistency, in particular to ensure the correct gauge is referenced to drive flood responses.
- Alternatively provide a new automatic gauge at the Glenreagh Bridge for use by BOM and SES
- Raise flood awareness:
  - The repeated distribution of the Glenreagh Flood Safe
  - The dissemination of flood certificates on a regular basis
  - A review of signage in flood prone areas giving notification of flood depths and historic flood levels.
  - Provide flood mapping on Clarence Valley Councils website.
- Provide Remote Alert or webcam information on Bluff Bridge (Hayard's Bridge) to inform residents of imminent road closure.
  (At the present time telecommunications infrastructure doesn't appear to be adequate to support a warning system at this location. However should the capacity and coverage of the network improve this option be pursued)
- A second helicopter landing location should be sought for the east bank residents

Flood Modification

Levee on Orara

☒ *For rural properties, levees are generally not viable. For the town areas a levee would need to be of substantial length, and would need extend along both the Orara River and Tallawudjah Creek. In some areas the levee would need to be 5 to 6m high, which would potentially require a 30 to 40m wide footprint making this option economically unviable.*

Levees for Glenreagh are thus are not considered a practical flood mitigation measure for Glenreagh

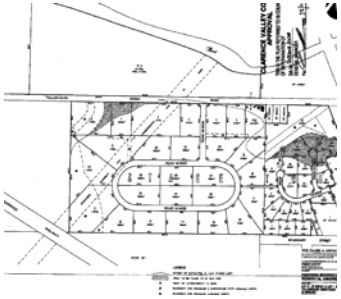
Figure 5-7 Indicative Levee Location

Figure 5-8 Potential Impact of levee

Flood Modification

Providing Fill Platforms

☑ *Preliminary flood simulations showed that the approved subdivision off Tallawudjah Creek Road may result in negligible impacts. However, more detailed simulations will be required to determine whether compensatory excavation may be required and convince Council's that impacts are likely to be negligible (under DCP, D5.2.2).*



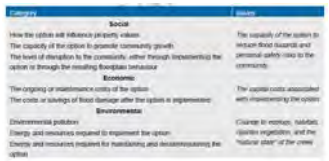
Flood Modification

Regular maintenance of creeks, culverts and flood bypasses

- Regular maintenance of creek channels and culverts is imperative in order that these facilities operate as intended and optimally.
- A number of critical areas have been identified throughout the floodplain of Glenreagh, where a build-up of sediment, erosion and/or vegetation will be important as part of ongoing maintenance

Location	Issues	Risks
Culverts and channels conveying flows from the tributary drainage along Tallawudjah Creek Road	Maintain conveyance, remove vegetation/sediment	Elevated flood levels, Tallawudjah Creek Road overflow and inundation of surrounding properties
Culverts and channels conveying flows from the tributary drainage along Orara Valley Way	Maintain conveyance, remove vegetation/sediment, mow	Elevated flood levels, Orara Valley Way overflow and inundation/isolation of Glenreagh and rural properties
Glenreagh and Tallawudjah and Hayard's crossing bridges	Maintain conveyance, remove vegetation/sediment	Elevated flood levels and reduced conveyance leading to increased risk of isolation of Glenreagh and rural properties
Orara and Tallawudjah Creek channels	Maintain conveyance and remove non-native vegetation/sediment	Elevated flood levels and reduced conveyance leading to increased flood risk to Glenreagh

Option Assessment and Ranking



Land Use Planning and Flood Planning Levels are important measures to manage flood risk while assessing development. Much of this is contained in the Clarence Valley Development Control Plan 2011, however it is considered that the flood related controls could benefit from a review and the flood mapping be provided for Glenreagh.

The SES Flood Action Card and SES Clarence Valley, Local Flood Plan need to be updated , in particular to ensure the correct gauge is referenced or to install a new automatic gauge at the location of the manual gauge. This new gauge could then be referenced by BOM and the SES to provide flood level information for Glenreagh.

Flood conveyance improvements, with regular maintenance of creek channels and culverts to ensure these facilities operate as intended and optimally. A number of critical areas have been identified for ongoing maintenance

Implementation Plan

Figure 5-9 Implementation Plan

www.ghd.com

GLENREAGH FLOODPLAIN RISK MANAGEMENT STUDY and DRAFT PLAN

Appendix D Flood Mitigation Options

P5 Flood Warning

During a flood

A Flood Warning is issued by the Bureau of Meteorology when flooding is about to happen and may be updated during floods. A Flood Warning provides a predicted flood level on a river gauge and a time at which the river is expected to reach that level.

During a flood, there are some simple things you can do to help protect your life, family, possessions and property:

- Never drive, ride or walk through floodwater
- Keep listening to your local radio station for information, updates and advice
- Keep in contact with your neighbours
- Be prepared to evacuate if necessary

After a flood

Do not return to a flood affected area until emergency services advise it is safe to do so. These areas can be dangerous for the health and safety of you and your family.

Follow safety advice when cleaning up after floods. Discard all food items that have come into contact with floodwater. Clean, sanitise and properly dry belongings.

Update your Home Emergency Plan or Business FloodSafe Plan with what you have learnt from the flood.

A local recovery centre, staffed by representatives from a range of agencies and services, may be established after a flood. This centre may be able to provide financial, insurance, housing, counselling and welfare assistance and advice.

Your Assembly Area

Glenreagh does not have a formal evacuation centre. Residents who do need to evacuate are encouraged to stay with friends or family out of the area. Residents without accommodation can contact NSW SES or NSW Family and Community Services for support.

If evacuation is necessary

NSW SES evacuates people whose lives are at risk from floods. It is important to follow all advice given to you by emergency services. Being prepared now will allow you to respond quickly.

How you may be advised of an evacuation:

Evacuation Warnings and Evacuation Orders are issued to residents and businesses that are likely to become inundated if floodwater reaches levels predicted by the Bureau of Meteorology. You may receive these warnings via the media, door knocking and/or telephone.

Prepare to evacuate:

- Locate important papers, valuables and mementos and put them in your emergency kit
- Turn off the electricity and gas at the mains and turn off and secure any gas bottles
- Stack possessions, records, stock or equipment on benches and tables, placing electrical items on top
- Secure objects that are likely to float and cause damage
- Relocate waste containers, chemicals and poisons well above floor level

When you evacuate:

- Register at the Assembly Area then stay with friends or relatives
- Take your emergency kit with you
- Take your pets with you
- Act early before roads and evacuation routes close

Local FloodSafe contacts

Emergency phone numbers

NSW SES	132 500
Life-threatening emergencies	000 (triple zero)

Phone numbers

NSW SES Information Line	1800 201 000
Police Assistance Line	131 444
Roads and Maritime Services (Live Traffic)	132 701
Clarence Valley Council	02 6643 0200
Disaster Welfare Assistance Line	1800 018 444
Department of Primary Industries	1800 814 647
Essential Energy	132 391
Telstra	132 203
Local Land Services	1300 795 299

Local broadcast radio stations

ABC North Coast	94.5 FM	738 AM
2GF Grafton	103.9 FM	1206 AM
Clarence Coast FM	104.7 FM	
TLC	100.3 FM	

Websites

NSW SES	www.ses.nsw.gov.au
Bureau of Meteorology	www.bom.gov.au
Clarence Valley Council	www.clarence.nsw.gov.au
Major roads - Live Traffic	www.livetraffic.com
Local Roads	www.myroadinfo.com.au

Facebook pages

NSW SES and NSW SES Clarence Nambucca Region

Free smartphone apps

NSW SES apps are available at your app store. Search for FloodSafe and StormSafe

NSW GOVERNMENT

NRMA INSURANCE

SES NSW STATE EMERGENCY SERVICE

FOR EMERGENCY HELP IN FLOOD, STORM AND TSUNAMI CALL

132 500

In life-threatening emergencies call 000 (triple zero)

For more information visit: www.floodsafe.com.au

#NSWSES /NSW SES /NSWSES

Community Floodsafe

SES NSW STATE EMERGENCY SERVICE

Glenreagh

FloodSafe

Are you at risk from floods?

The Orara River flows northward through a long, narrow valley and drains parts of the Dorrigo Plateau and the Coastal Range to join with the Clarence River. It has a long history of regular flooding.

In January 2013 the Orara River experienced major flooding. Significant flooding has also occurred in 1945, 1950, 1955, 1959, 1964, 1974, 1977, 1989 and more recently in 2009.

Glenreagh is located south of Grafton on the southern bank of the Orara River. The town is above major flood level, but may become isolated during moderate floods when local roads close, including the Orara Way. Surrounding areas may also become isolated including Kremnos, Kungala and Wells Crossing.

The period of isolation for these areas can vary depending on the size and duration of the flood. Any residents wanting to leave the area would need to do so before the onset of flooding causes local roads to close.

How NSW SES can help

NSW SES is responsible for the emergency management of floods in NSW. This includes planning for floods and engaging with communities to prepare themselves and their property.

During floods, NSW SES will provide flood information and safety advice and may arrange for the delivery of essential supplies to communities isolated by floodwater. NSW SES also warns communities of the need to evacuate and provides emergency help where required.

8 TIPS YOU CAN DO NOW TO PREPARE FOR FLOODS

1 KNOW YOUR RISK

2 KNOW WHERE TO GO

3 KNOW WHO TO CALL

4 KNOW YOUR PLAN

5 GET YOUR KIT TOGETHER

6 PREPARE NOW TO ACT EARLY

7 CHECK YOUR INSURANCE

8 LISTEN TO LOCAL RADIO

For more information visit www.floodsafe.com.au

What happens in Glenreagh floods?

13.24	**Highest flood on record** - 10 March 1974.
13.14	23 February 2013: Peak height.
13.00	**Major Flood Level** indicating extensive flooding and isolation.
11.61	7 November 2009: Peak height
11.44	27 January 2012: Peak height
9.00	**Moderate Flood Level** indicating extensive flooding and isolation. Homes and businesses should prepare for inundation.
7.00	Orara Way may close at Glenreagh Creek cutting access to Coffs Harbour and isolating Glenreagh.
5.20	Bluff Bridge on Orara Way may close cutting access between Grafton and Glenreagh. Kremnos and Kungala may start to become isolated due to local road closures.
5.00	**Minor Flood Level** causes inconvenience, closes minor roads and low-level bridges

Key heights in metres at the Glenreagh Gauge.

How you may be advised of floods

Flood information including flood forecasts, road closures and advice on evacuations and property protection will be broadcast on ABC and local radio stations.

Bureau of Meteorology weather forecasts and flood predictions including river height information are available at www.bom.gov.au

Emergency services personnel may door knock your area or you may receive a voice or text message to your phones.

If isolation is likely

If your property is likely to be isolated by floodwater, evacuating well before access roads are closed is your safest option. Deciding to remain at home when it is surrounded by floodwater can be dangerous.

During floods, isolated properties can lose access to emergency and medical assistance, lose power, water, phone lines and sewerage services as well as become a refuge for spiders, snakes and other animals.

If evacuation is not possible, keep a stock of at least seven days' supply of non-perishable foods, medications, drinking water, fuel and feed for your animals and pets. Some properties may be isolated for longer periods and therefore require additional supplies.

Talk with your local council who can provide you with information on floods specific to your property and plan now so that you can act early before flooding occurs.

When flooding is likely

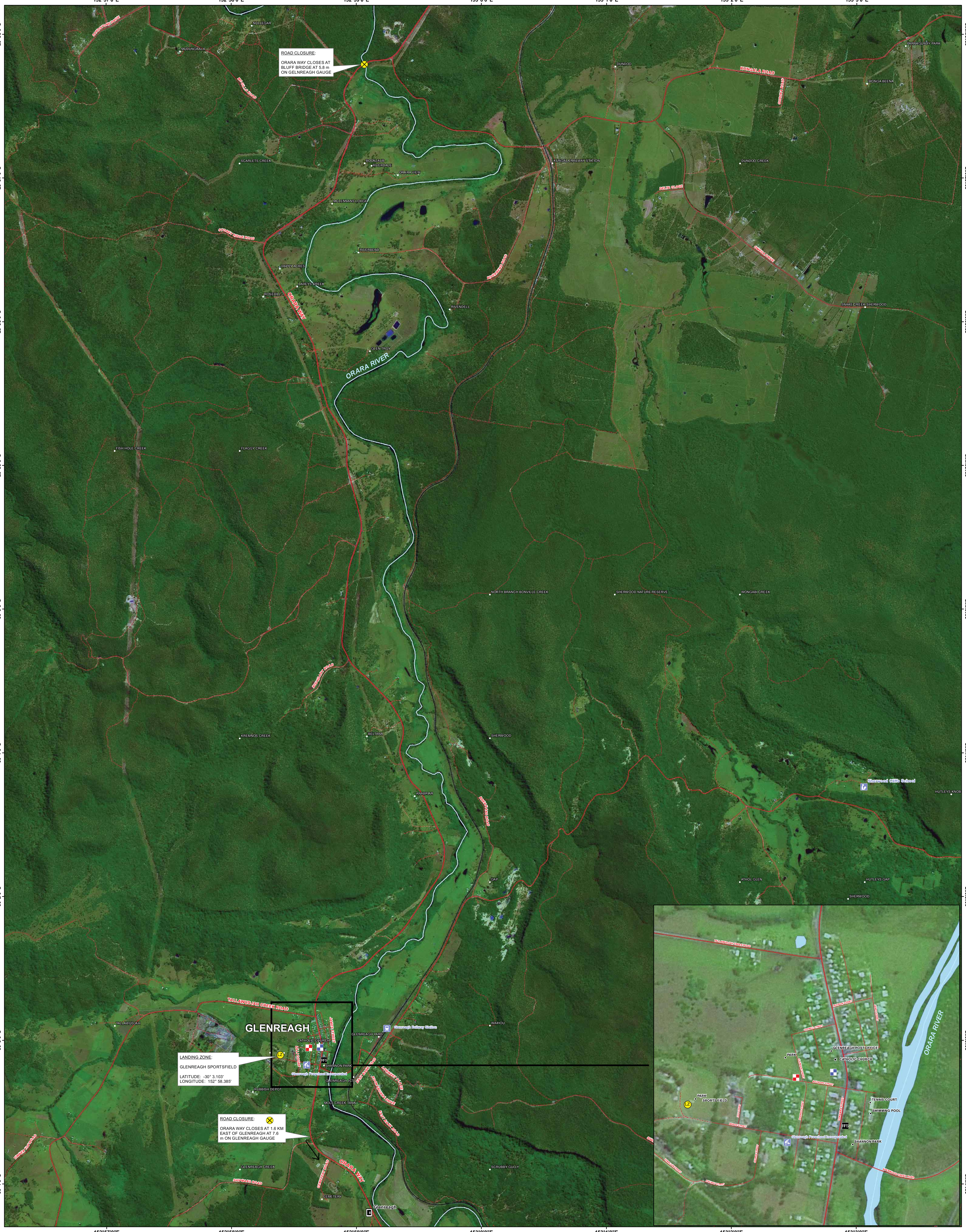
A Flood Watch is issued by the Bureau of Meteorology for possible flooding. A Flood Warning is issued when flooding is likely.

RESIDENTS AND BUSINESSES:

- Listen to your local radio station for information, updates and advice
- Locate and check your emergency kit and follow your Home Emergency Plan or Business FloodSafe Plan
- Check on your neighbours and make sure they are aware of possible flooding
- Prepare to move pets, including agisted animals to high ground
- Make preparations to raise or relocate possessions, stores, records, furniture and equipment
- Plan to leave well before evacuation routes may become closed

RURAL PROPRERTY OWNERS:

- Relocate livestock and farm equipment, including pumps, to high ground
- Check sheds and outbuildings. Raise equipment, feed and chemicals above predicted flood levels or to higher ground


ROAD CLOSURE:
ORARA WAY CLOSES AT BLUFF BRIDGE AT 5.8 m ON GELNREAGH GAUGE
NULLEGAR
MUDUNGKALA
SANDSTONE DRIVE
MC GILLS ROAD
SCARLETS CREEK
BOONJAUB
RIVERDALE
ORARA VIEW
MCLENNANS LODGE
STONEY RIDGE ROAD
RIVERBEND
HAPPY ACRES
LAHEYS CREEK
ROSEHILL
ORARA WAY
RIVENDELL
GLEN TROY
ORARA RIVER
RIVERBEND ROAD
DUNDOO
KUNGALA ROAD
COROKA ROAD
PARRAGUNDY PARK
WONGA BEENA
KUNGALA RAILWAY STATION
DUNDOO CREEK
DELTA CLOSE
OMEGA DRIVE
SNAKE CREEK SHERWOOD
FISH HOLE CREEK
FLAGGY CREEK
NORTH BRANCH BONVILLE CREEK
SHERWOOD NATURE RESERVE
WONGABI CREEK
BOUNDARY ROAD
KREMNOS CREEK
BELTANA
SHERWOOD
Sherwood Cliffs School
HUTLEYS KNOB
ANABRIAR
BRENNANS ROAD
GAP
ATHOL GLEN
HUTLEYS GAP
SHERWOOD
TALLAWUDJAH CREEK ROAD
TALLAWUDJAH
GLENREAGH
JAMES STREET
CATHOLIC CHURCH
LILLI COURT
Glenreagh Railway Station
GLENREAGH YARD
WAIHOU
LANDING ZONE:
GLENREAGH SPORTSFIELD
LATITUDE: -30° 3.103'
LONGITUDE: 152° 58.385'
LZ
RFS
SHANNON PARK
Glenreagh Preschool Incorporated
GLENREAGH JCT
EAST BANK ROAD
LORIKEET PLACE
KOOKABURRA DRIVE
RUBBISH DEPOT
MOLE CREEK TANK
ROAD CLOSURE:
ORARA WAY CLOSES AT 1.6 KM EAST OF GLENREAGH AT 7.6 m ON GLENREAGH GAUGE
TIMBER TOP ROAD
GLENREAGH CREEK
SHIPMANS ROAD
CEMETERY ROAD
CEMETERY
Glenreagh
SCRUBBY GULLY
PEARSON STREET
CONNELL STREET
GLENREAGH POST OFFICE
PARK
SPORTS FIELD
BOUNDARY STREET
TENNIS COURT
SWIMMING POOL
BRIDGE STREET
CORAMBA STREET
SHERWOOD CREEK ROAD
RAILWAY STREET
ORARA RIVER

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SES State Headquarters
gis@ses.nsw.gov.au
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Imagery sourc : Spot 2008
Production Date: 24 Feb 2012

CLARENCE VALLEY LOCAL FLOOD PLAN

ANNEX J - GLENREAGH SECTOR RESPONSE

CLARENCE NAMBUCAA REGION

Assembly Area
Evacuation Centre
Landing Zone
Road Closure
Evac Route
SES Headquarters
Police Stations
Ambulance Facilities
RFS Stations
FRNSW Stations
Aged Care Facilities
Caravan Park / Camping
Child Care Facilities
Educational Facilities
Hospitals
Airports
Railway Stations
Flood Gauge
Levee Alignments
Railway Lines
Major Rivers
Major Roads
Secondary Roads
Minor Roads
Track-Vehicular
Path

0 0.5 1 1.5 2
Kilometres(Approx.)

SES
STATE EMERGENCY SERVICE

NOTES

- Glenreagh does not have a formal evacuation or refuge centre
- Access to Grafton (North) and Coffs Harbour (south) is 'cut' early on in a flood event
- There are potentially additional Indirectly Affected Areas, not shown on this map

Map projection: Transverse Mecator
Horizontal datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

PMF

SES_Classification

High Trapped Perimeter Area

Indirecly Affected Area

Low Flood Island

Clarence Valley Council
Glenreagh Floodplain Risk

SES Flood Emergency Response Classification

Job Number 22/18407
Revision
Date 2018/03

Figure D.1

6/20 Smith St, Parramatta NSW 2150, (02) 8898 8800 www.ghd.com

DipStik - Flood Alert System
User's Guide

Introduction

DipStik is an autonomous flood monitoring/alert solution designed to measure water levels (and optionally rainfall intensity) in flood prone areas and alert local emergency management personnel when conditions become hazardous, so that appropriate action can be taken.

DipStik is self powered and requires no external cable connections to other infrastructure for effective operation. It utilises the national mobile phone network to communicate alert information to end users.

The DipStik unit is typically mounted in a low lying area (near a stream, within a retarding basin or floodway). It is secured to the ground by way of a unique ground pin arrangement which enables rapid installation in almost any location. The unit stands over 3m tall and houses all the sensitive electronic components at the top to keep them out of harms way and typically above expected flood water levels.

DipStik can send text/SMS messages directly to individuals mobile phones or it can be integrated into larger flood monitoring solutions (such as Melbourne Water's Flood Alert Network).

Once configured, DipStik will continually watch for hazardous conditions and will alert emergency management personnel when a potential problem is detected.

DipStik can save considerable time and cost that is often associated with direct manual observation/monitoring of flood conditions at specific locations as well as keeping both local and remote managers informed of prevailing conditions in near real time.

How the system works

DipStik incorporates embedded computing technology, a mobile network communications module, a solar power system and water level sensing technology to enable it to perform its monitoring and alert functions.

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Flood height measurement is performed within the mounting post of the unit, which is vented at the top and bottom to enable water to freely enter and exit the mounting/measuring tube. The electronics module at the top of the tube measures this depth using an integrated sensor. The sensor measures water pressure at the base of the unit via a flexible capillary within the mounting/measuring post. This pressure measurement is translated into an associated water height value.

The unit is self powered (battery/solar) and incorporates a number of techniques to minimise power consumption (such as turning off measuring and communications circuits between sample times) to ensure continued operation when needed most.

The unit takes water level samples at regular intervals (typically several minutes apart) and compares these measurements to alarm rules that have been previously configured in the unit. When these alarm rules are satisfied (ie water level too high or rate of water rise too great) then DipStik will send alert messages to a number of pre-programmed recipients (up to 10).

Normally DipStik would only send an alarm message once (when the alarm condition is first met) but it can be configured to send repeat messages at regular intervals for as long as the alarm condition persists. These repeat messages will be sent to all recipients simultaneously. The system managers will have to make a judgement call on the use of the repeat feature, as frequent messages could become annoying under some circumstances.

DipStik can be remotely interrogated by using the device's network address (phone number) and access password, over the mobile phone network using simple text messages. This enables those concerned about a flood situation to obtain immediate status information from the unit based on the last sampled data. This data will only be returned to the individual making the specific request (they need not be registered on the system).

Your DipStik unit may have been installed with one or more options as indicated in the following list:

- A flashing warning beacon mounted at the top of the electronics control module housing. This beacon can be configured to flash when a particular water level is exceeded. This level is independently set from the alarm level and can be used as a general warning to individuals in the local vicinity of the unit (particularly useful for road/pathway flood warnings at night).
- A tipping bucket rain gauge (TBRG) mounted above all other components at the top of the unit. The TRBG measures local precipitation rates and compares these to preset warning values. When the rainfall rate exceeds the preset value a warning message is sent via the mobile network to the registered message recipients.
- A digital camera fixed to the mounting post. This provides the ability to capture images and transfer these to a dedicated cloud server. Individuals with a standard web browser and knowledge of the cloud server address can look at these images to assist

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with the confirmation of prevailing local conditions. The capture rate of image snapshots can be adjusted and even increased when flood conditions are detected.

- Community SMS gateway access. DipStik units configured for access to the SMS gateway can send alert messages to sizable community groups in near real time. Messages can be potentially sent to several hundred recipients rather than the 10 recipients normally imposed by the base level DipStik units. Community members can even be provided with the ability to self register on the system thereby saving significant effort/cost in managing the system.

System accuracy considerations

DipStik has been designed as a cost effective solution for the monitoring of flood events and other environmental water level monitoring applications. It is not intended to provide scientifically accurate water level data.

DipStik can typically measure water levels over a range of 0 – 3000mm with resolution of approximately 10mm. System accuracy is limited to about +/-50mm under most circumstances which is adequate for the detection and monitoring of flood conditions.

System accuracy/reliability can depend on many factors, some of which include:

- Debris contamination of the measuring tube
- Ambient temperature
- Damage to the sensor components/electronics (physical damage, insect infestation, water ingress, etc)
- Leaks in the pressure (level) sensing system
- Incorrect calibration/installation
- Tampering/hacking of the system from outside sources (password protection used)

The TBRG (rain gauge) option also has overall accuracy limitations. It is not intended to provide metrologically accurate information. It is only to assist with the flood warning functionality of the DipStik unit.
A number of factors could affect the results obtained with the TRBG option:

- Wear within the rain gauge unit
- Debris build up externally and internally within the unit
- Strong winds
- Infrequent equipment maintenance
- Mechanical/electrical damage

DipStik is intended for the monitoring of transient flood water levels. It is not designed for the long term measurement of static water levels (such as may be found in a lake, pond, tank or similar) [A special version of DipStik, incorporating additional technology, is available that is more appropriate for the measurement of long term static water levels and in situations requiring a higher degree of accuracy].

The messaging system

Messages to/from DipStik are communicated over the national mobile phone network using simple SMS/text messages. This enables DipStik to communicate with almost any mobile

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phone available today. There is no need to install any special/complicated server facilities, back end computer software or local phone apps.

The following section details the structure of messages that might normally be required for regular day to day monitoring of the DipStik unit.

[Full details of the DipStik message structure, including set up and maintenance commands, are provided in the DipStik – SMS Message Format Reference]

Automatically generated system messages can be sent to a number of pre-configured recipient phone numbers (up to 10).

NOTE: We would recommend that you program the DipStik phone number into your personal mobile phone contacts list/phone book as an easily recognisable label. This could be "DIPSTIK – SITE NAME", to assist with the rapid identification of flood alert messages on reception of SMS messages from the unit.

To send commands to DipStik you simply send text/SMS messages to the devices phone number. You will also need to know the pre-programmed password, otherwise any message you send will be discarded. (SEE YOUR DEVICE ADMINISTRATOR FOR PASSWORD ACCESS).

NOTE: The access password must be stored carefully and should not generally be circulated to others. Incorrect use of the password and the SMS commands could enable individuals to alter the settings in your DipStik unit and cause it to malfunction!

NOTE: A high level of text/SMS messages sent to DipStik in a short space of time can result in messages being missed. DipStik can only buffer up to 10 individual messages in succession. Only one SINGLE received message is processed every 5 minutes to minimise system battery power drain.

SPECIAL NOTE: The national mobile SMS communications network does not offer a specific level of service guarantee. This means that messages can get lost and their order of delivery is not guaranteed in relation to other messages sent. This does not normally result in operational difficulties with DipStik but could potentially result in issues at times of high network congestion. This may also have a bearing on your system administrators desire to configure the repeat message transmission options.

Automatic system generated messages

There are essential 6 different types of text/SMS message that DipStik will automatically send. These include:

- Periodic system heart beat test message
- Flood warning message
- Flood alarm message
- End of event message
- Battery low message
- System Re-boot message

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P8 Fill Platforms

CLARENCE VALLEY COUNCIL
APPROVAL

THIS IS THE PLAN REFERRED TO IN COUNCIL'S NOTICE OF DETERMINATION OF
D/A No. 328/2008/DA
GENERAL MANAGER
Per ..... DATE 25/11/08

Tallawudjah Creek

TALLAWUDJAH CREEK ROAD

ORARA WAY

CONNELL ST.

CLARENCE STREET

BOUNDARY STREET

GLENREAGH/DORRIGO RAILWAY

ROAD 18 WIDE

ROAD 14 WIDE

STAGE ONE

POR. 22

POR. 97

Pt. 2 (13.76ha) TOTAL 14.43ha

1 9.409ha

62 DP 805441

DP 310907

DP 6206

1 DP 530969

1 DP 327442

PROPOSED EASEMENT

TRANSMISSION LINE EASEMENT

FOR EASEMENT

STAGE ONE SUBDIVISION PLAN
N.A. 1 : 6000

LEGEND

- EXTENT OF ESTIMATED 1% A.E.P. FLOOD LIMIT
- AREA TO BE FILLED TO RL 66.3 AHD
- RIGHT OF CARRIAGEWAY 10 WIDE
- EASEMENT FOR DRAINAGE & SURCHARGE PATH VARIABLE WIDTH
- EASEMENT FOR DRAINAGE VARIABLE WIDTH
- RESTRICTION ON DWELLINGS

NOTES

01. MINIMUM AREA OF RURAL RESIDENTIAL ALLOTMENTS 6000m²
02. MIN AREA OF RESIDENTIAL ALLOTMENTS 1965m²

TOCK PALMER & ASSOCIATES Pty Limited
PLANNING & DEVELOPMENT CONSULTANTS
LANDSCAPE ARCHITECTS

PROJECT
PROPOSED RESIDENTIAL & RURAL RESIDENTIAL SUBDIVISION

LOCATION
LOT 81 DP 805441 & LOT 1 DP 34500
TALLAWUDJAH CREEK ROAD
GLENREAGH

CLIENT
WOODWARD & CAMERON

DRAWING TITLE
DEVELOPMENT APPLICATION

DATE	SCALE	PROJECT No.
FEB. 2008	1 : 2000	05/07

DRAWING No.	STAGE	AMENDMENTS
01		C

Appendix E Glenreagh Floodplain Risk Management Plan

Clarence Valley Council

FINAL DRAFT Glenreagh Floodplain Risk Plan

12 March 2018

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Appendices

1. Introduction

1.1 Background

The Orara River and Bucca Bucca Creek (Bucca Creek) catchments are located to the west of Coffs Harbour on the NSW Mid North Coast (Appendix A). Both watercourses drain to the Clarence River at Grafton. The watercourses rise in the south and flow generally in a north westerly direction. The Orara River flows through the villages of Karangi, Coramba, Nana Glen, Glenreagh and Coutts Crossing. The main road, Orara Way, is located along the western bank of the Orara River and the Grafton to Coffs Harbour railway line, along the eastern bank.

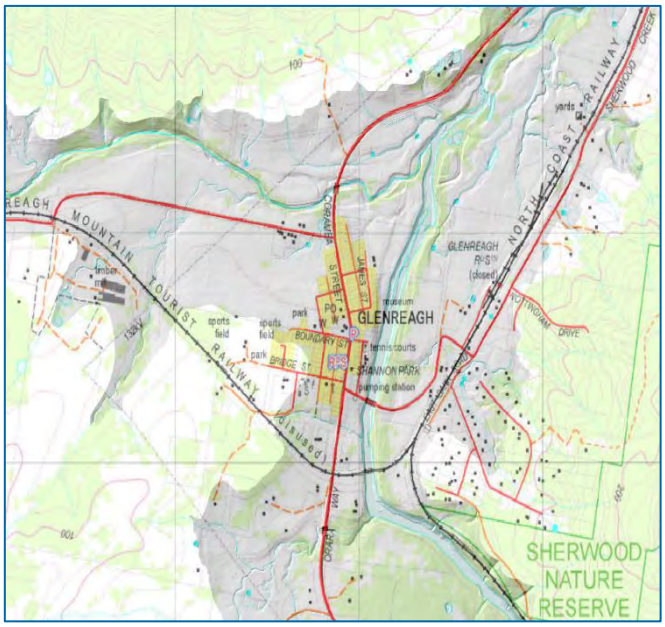


Figure 1-1 Glenreagh

The catchment defining the creeks is bounded to the west by Bushmans Range some 2 – 3 km east of Ulong and Lowanna and to the east by Big Boambee, Red Hill and the Coastal Range, approximately 3km west of the Coffs Harbour coastline. Upstream of Glenreagh the Orara River has a catchment of some 433 km^2 with a length of some 55 km km^2. A number of major tributaries drain into the Orara River Basin, including Urumbillum River, Mirum Creek, Fridays Creek, Wongiwomble Creek, Nana and Coldwater Creek, Kings and Finberg Creek, Glenreagh Creek and Tallawudjah creek. The catchments in the upstream reaches of these creeks are generally steep and heavily forested. Lower reaches are mostly rural in nature.

Over the years, a number of significant floods have occurred in the Orara Valley. Floodwaters in both catchments have been known to rise quickly and isolate communities and properties, and houses in Glenreagh can be inundated in flood events necessitating evacuations.

The Glenreagh Flood Study (CVC, 2013) showed that in the flood events rarer than approximately the 20% AEP event, flood flows are expected to surcharge the Orara River and Tallawudjah Creek channels, and spill onto the floodplain. In the 1% AEP event, widespread flooding is expected. A number of key roads would be cut-off by flood waters. Many rural properties would be expected to be isolated by flood waters.

1.2 Purpose of the Plan

The responsibility for planning and management of flood prone lands in NSW rests with local government, namely Clarence Valley Council in this instance. The NSW Government provides assistance with state-wide policy issues and technical support. A Flood Prone Land Policy and a Floodplain Development Manual (NSW, 2005) forms the basis of floodplain management in NSW. The objectives of the Policy include:

- Reducing the impact of flooding and flood liability on existing developed areas by flood mitigation works and measures including ongoing emergency management measures, voluntary purchase and house raising programs, flood mitigation works, and development controls.

- Reducing the potential for flood losses in new development areas by the application of ecologically sensitive planning and development controls.

The implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Management Plan. This formalises outcomes of a floodplain risk management study and present the necessary information to enable Clarence Valley Council to plan for the future. It presents floodplain management measures incorporating both structural and non-structural measures to manage flood risk at Glenreagh.

2. Flood Situation

2.1 Historic

Historically, a number of significant floods have occurred in the Orara Valley. It is understood, from community input that one of the largest floods in the valley occurred on 24 June 1950, when 502 mm was recorded at the Aurania rainfall gauge in a single day and 916 mm fell from 18 to 25 June. In March/April 2009, five significant events were recorded at the Glenreagh runoff gauge, all exceeding or close to the "Moderate Flood" classification. Of these the March/April 2009 event provided the highest peak, with a flood depth of some 13 m above the creek invert at the gauge. This depth was equalled in February 2013. This depth signifies a "Major Flood" classification at the gauge.

Floodwaters in both catchments have been known to rise quickly and isolate communities and properties. While flood peaks can recede equally quickly, properties at times can remain isolated for several days. Many houses in Glenreagh can be inundated in flood events necessitating evacuations. The nature of flooding varies considerably from in-stream flood ways to areas where the floodwaters bypass bends in the river and where floodwaters backup into the lower reaches of tributary creeks. Rainfall and river gauging data in the catchment is limited, however significant events have been recorded on gauges at Karangi and Glenreagh.

2.2 Flood Behaviour

The Glenreagh Flood Study (CVC, 2013) prepared flood mapping together with hydraulic and flood hazard categorisation mapping. The selection of this flood mapping has been provided in Appendix B. On the basis of the flooding information prepared the following is noted:

- In the 20% and 5% AEP events, flood flows are expected to surcharge the Orara River and Tallawudjah Creek channels, and spill onto the floodplain. In the 1% AEP event, widespread flooding is expected.
- Flood waters are expected to inundate large areas of the flood plains on the Orara River and associated tributaries. Flood waters are expected to inundate properties to the north of Glenreagh in the vicinity of the Tallawudjah Creek confluence and a number of key roads would be cut-off by flood waters. Many rural properties would be expected to be isolated by flood waters.
- In a PMF event, flood levels are expected to be approximately 3 to 4 m deeper than the 1% AEP event across the catchment. This would result in significant and widespread flooding.
- Flood ways are associated with the creek and river channel. The Sherwood Creek and Tallawudjah Creek bridges would also experience zones of floodway. On the inundated floodplain area the flood category is predominantly Flood Storage, with very few areas on the edges of the floodplain designated as Flood Fringe.
- In a 1% AEP event, almost the entire valley, with exception of a few areas, is considered high hazard. This would mean that a number of access tracks to rural properties and road crossings would be expected to be isolated by high hazard flood waters.
- Inundation of many of the key trafficable structures along Orara Way would be expected, leading to isolation of the Glenreagh community from both Coffs Harbour and Grafton. It is noted that the Hayard's Crossing (Bluff Bridge) approaches are located at grade on the floodplain, with the bridge spanning only the channel banks. This structure is expected to be highly susceptible to flooding with the route being severed during minor flood events.

3. Flood Damages

Flood damage calculations were undertaken to assess the direct financial costs of damage to property and the indirect financial costs associated with the disruption of social, community, industrial and commercial relationships during the post-flood period. The damage curves/parameters according to the NSW Office of Environment and Heritage (OEH, formerly DECCW) with limited amendments for single storey low (floor) set, single storey high (floor) set and double storey residential properties were adopted.

For residential properties, the direct damage estimates represented the sum of structural, contents and external damage, clean-up costs and costs for additional accommodation as a direct result of flooding. Indirect costs were for the disruption of social, community and business relationships and the costs of removal and storage, loss of business confidence, production, revenue and wages in the post-flood recuperative phase possible loss of schooling, loss of personal mementoes, and cancellation of social events.

The numbers of residential and commercial properties that would experience flood damages are listed in Table 3-1. A total 136 properties were noted as being within the PMF flood extent.

Table 3-1 Property numbers experiencing flood damages

Flood Event (AEP)	Number of properties
20%	25
5%	61
1%	84
0.2%	116
PMF	136

Based on the above, the direct damage of flooding in Glenreagh was calculated as a Net Present Value (NPV) 3.34 million over 20 years at 7%. The Annual Average Damage was calculated to be $314,765. Direct damages for each flood event are tabulated below.

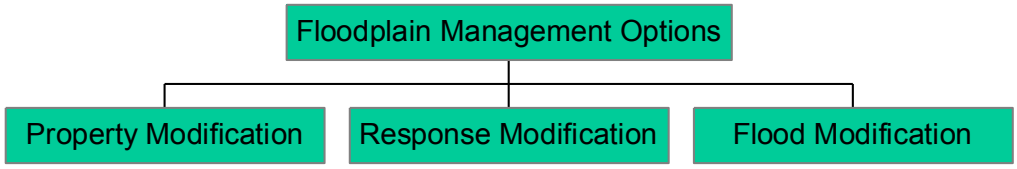
Table 3-2 Damage Summary

tem	Direct ($ million)	Direct + Indirect ($ million)
Annual Average Damage	0.31	0.45
Net Present Value (20yrs @ 7%)	3.34	4.84

4. Recommended Floodplain Management Measures

Floodplain risk management measures can be broadly categorised into three categories as shown in Figure 4-1.

Figure 4-1 Floodplain Management Measures



4.1 Property modification

Property modification measures are approaches to floodplain management that apply to existing properties and proposed developments.

4.1.1 P1 - Land Use Planning

Estimated Capital Cost	*Nil (undertaken by Council staff)*
Annual Maintenance Cost	*Nil*
Priority	*High*

Land use planning is an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately. Planning not to develop land within high flood hazard or land that has the potential to impact flood behaviour in other areas, is a valuable long-term solution. This can be achieved through inclusion of provisions in the Local Environment Plans (LEP) and Development Control Plans (DCP). Planning instruments can be used as a floodplain management tool by controlling floor levels, freeboard, fill or excavation in the floodplain, site access during flood events, location of utilities and services, building materials and structural fitness of buildings when subject to flooding.

The Clarence Valley Local Environmental Plan 2011 (LEP) is supported by the various zone-based Clarence Valley Development Control Plans 2011, which includes additional detail about development on flood-affected land (Part D – Floodplain Management Controls). The LEP is generally supported by flood mapping for the Grafton and Lower Clarence areas, however there is no Flood Planning Map for Glenreagh in the LEP.

Noteworthy is that the LEP and DCP do not define the Flood Planning Level nor the Flood Planning Area, which is often accepted as the 100 ARI (average recurrent interval) flood event plus 0.5m freeboard. However, reference is made to the 'land that is shown as "Flood planning area" on the Flood Planning Map'. Since no mapping exists for Glenreagh, no flood planning area is designated.

In reviewing the DCP, it is considered that the flood related controls would benefit from:

- Explicit definition of the Flood Planning Level and Flood Planning Area.
- Compilation of a Flood Planning area map for Glenreagh based on the findings of the Glenreagh Flood Study (CVC, 2013).

- Review of nomenclature to better align with the NSW Floodplain Development Manual, 2005. For example “General Floodplain” is noted as “means that part of the floodplain other than floodways or flood storage areas”, however this does not reference flood fringe areas. It would be better to define the General Floodplain in the context of Flood Prone Land and acknowledge Flood Fringe Areas
- Consideration for Climate Change in the nomination of freeboard associated with the Flood Planning Level unless flood modelling has explicitly considered sea level rise and any other relevant effects of climate change such as rainfall frequency and intensity changes.

4.2 Response modification

Response modification measures are reactions to flooding that reduce potential social, economic and environmental damages from flooding. While response modifications will reduce the risk to life, they will not prevent flooding. Therefore, they will not address all the social impacts and reduce damages associated with flooding.

4.2.1 P4 - Flood Information/Data

Estimated Capital Cost	*$10,000 for ARR2016 update*
Annual Maintenance Cost	*Nil*
Priority	*Medium*

Comprehensive and up to date flood information is essential in managing and responding to flood events and to guide future development in flood prone areas. This information should include any changes to catchment conditions, advances in hydrological/hydraulic methods/approaches, and be undertaken as directed by the NSW Floodplain Development Manual 2005.

With completion of the Glenreagh Flood Study, 2013 and the current study, it would be desirable to update planning documents such as the LEP and DCP with the most up to date flooding information, showing:

- Flood prone land, as the land inundated by a PMF.
- Flood planning area and levels, as the land inundated by the 1% AEP flood plus 0.5 m.
- Flood category maps showing floodway, flood storage and flood fringe.
- Flood hazard in accordance with the NSW Floodplain Development Manual.

Since completing the Glenreagh Flood Study, an updated version of Australian Rainfall and Runoff (ARR2016) is increasingly gaining acceptance amongst flooding and hydrology practitioners. This version presents, amongst others, updated estimates of design rainfall and rainfall distributions. Flood modelling using the latest Australian Rainfall and Runoff (ARR2016) can be completed at any time and data on flood levels and velocities can be updated if revised modelling is undertaken.

4.2.2 P5 - Flood Warning/Response

Flood Information

	P5.1	P5.2	P5.3	P5.4.1	P5.4.2
Estimated Capital Cost	*Nil*	*$5000*	*$20,000*	*Nil - by others*	*$40,000*
Annual Maintenance Cost	*Nil*		*$2000*	*$2000*	
Priority	*High*	*Medium*	*Medium*	*Low*	*Low*

P5.1 SES Local Flood Plan and Flood Action Card Update

The SES Flood Action Card for Glenreagh drives the on-ground response to flooding at Glenreagh. This Card references the automatic gauge (204906) some 2.5km upstream of Glenreagh, which has been monitoring river levels since November 1972. Interestingly the Flood Action Card states the gauge location as being *"upstream Glenreagh Bridge GR980751"* which is incorrect, because this is the location of the Manual Gauge.

There is thus clearly confusion as to which gauge information is referred to when flood warnings and predictions are issued in time of flooding. In a recent education campaign with the residents of Glenreagh, the SES has been working with the community to reference all flood bulletins and warnings away from the manual gauge, to the automatic gauge. As an alternative, it is recommended that a new automatic gauge at the location of the manual gauge be installed, and that consistency between the two gauges at this location be achieved. This new gauge could then be referenced by BOM and the SES to provide flood level information for Glenreagh.

While flood peaks at upstream towns may provide an early indication of pending flooding at Glenreagh, possibly 4 hours before the peak arrival, the warning times are considered short. It is this important to monitor rainfall and river gauges throughout the Orara Valley when planning evacuation strategies.

From the above discussion, it is recommended that the Glenreagh Flood Action Card be reviewed and updated to provide overall consistency, in particular to ensure the correct gauge is referenced to drive flood responses.

P5.2 Raise flood awareness and Compile Floodsafe Brochure

The SES has suggested a community lead flood response for Glenreagh as it is unlikely the SES will be able to attend in time. Public Awareness and Response would assist in raising flood awareness and readiness, and increase the appreciation of the flood problem and prevention activities. Measures to increase flood awareness could include:

- The repeated distribution of the Glenreagh Flood Safe Brochure that could be sent to all owners, business operators and residents of potential flood impacted properties. The Flood Safe Brochure is to include a demarcated evacuation route. The NSW SES can provide a print-ready PDF of your localised FloodSafe guide and organise the printing and delivery of the localised FloodSafe guide (see SES website).
- The dissemination of flood certificates on a regular basis, which would inform each property owner of the flood situation at his or her particular property, flood data and advice (this information should be provided in a range of different languages).
- A review of signage in flood prone areas giving notification of flood depths and historic flood levels. Additional flood depth signage to be provided where appropriate.

- Provide flood mapping as determined through the study via Clarence Valley Council online maps, accessible on Clarence Valley Councils website..
-

P5.3 Remote Alert or webcam Information on Bluff Bridge (Hayard's Bridge)

A number of residents felt it was useful to provide a real-time camera (accessible from the internet) at Hayard's Crossing (Bluff Bridge), since this is the location access to Grafton is most frequently severed through road closure. The information would allow residents to make informed decisions about evacuation from Glenreagh without having to undertake the 15 km drive (potentially at times in dangerous storm weather conditions), before learning of the road closure.

Figure 4-2 Example: Grafton Webcam

OEH recently provided approval to "digitally stream" images from the Webcam associated with the OEH Grafton water level recorder, on Clarence Valley Council's website. The initiative would value add to the flood data available to end users and the public, subject to disclaimers and acknowledgements. As an alternative to the Webcam, the DipStik - Flood Alert System has been used at selected locations in Coffs Harbour. This system could possibly be used as an alternative trigger to inform residents of likely inundation of the Hayard's Crossing (Bluff Bridge).

While these options may beneficial, it will be important to consider the following matters:

- The availability of mobile coverage and power at Bluff Bridge (Hayard's Bridge), albeit power may be possible through solar means
- The impact of loss of power at the site and to residents in Glenreagh during storm events, as has been the case in past flood events
- The availability and timing of the NBN, and the reliability of telephone communications for residents on the NBN, which requires power after the backup Uninterrupted Power Supply is drawn down.

At the present time telecommunications infrastructure doesn't appear to be adequate to support a warning system at this location. However should the capacity and coverage of the network improve this option be pursued.

P5.4 Evacuation Improvements

P5.4.1 Helicopter Landing Areas for East Bank Residents and other areas

Sherwood Creek Bridge and eastern approaches are inundated during flood events as frequent as the 20% AEP flood. This leads to road closure of the access into Glenreagh. Residents would need to use Sherwood Creek Road for access. During rarer floods, the access along Sherwood Creek Road is also severed leading to isolation of residents on the east bank. Local isolation also occurs near East Bank Road, where residents have been forced to evacuate along the railway embankment. As such it is recommended that at least a second (and potentially a third) helicopter landing location should be sought for the east bank residents, in case of emergency evacuation or need for resupply. This is particularly relevant when it is not safe to use boats travelling from the west bank in Glenreagh Village and the bridge over the Orara River at Glenreagh is inundated.

Further, during the community consultation, the helicopter landing issue was raised in one of the submissions for sub-catchments/isolated properties other than East Bank. It is therefore recommended to identify helicopter-landing zones in other locations around Glenreagh, in case they are needed in the future.

P5.4.2 Investigate Flood Immunity along Evacuation Route to north of Glenreagh

Following the community meetings and submissions received from the public, it is recommended to investigate the capability and flood immunity of the evacuation route to the north of Glenreagh. While this route includes Bluff Bridge (Hayard's Bridge), which is subject of Option 5.3, there are a number of other locations where the route may be severed during flood events. Investigation of the flood immunity at these locations is beyond the scope of this study, however is recommended for future investigation, particularly if culvert, bridge and road upgrades are planned.

4.3 Flood modification

Flood modification measures are those that alter the flood conditions to reduce the flood hazard or change the flood behaviour. Flood modification is generally the only measures that will minimise both the social impacts and the risk to property and life.

4.3.1 P8 – Fill platforms

Estimated Capital Cost	*Nil – developers cost*
Annual Maintenance Cost	*Nil – developers cost*
Priority	*Low*

It is noted, that an approved plan of subdivision exists for land off Tallawudjah Creek Road, on land that comprises both flood storage and flood fringe areas. Under the Clarence Valley Development Control Plan 2011, development involving filling of flood liable land must comply with the following criteria:

(a) The filling of flood liable land must not increase the flood risk on other land within the floodplain.

(b) Filling and associated works must not have any unacceptable associated environmental impacts such as detrimental affects on the ecology of riparian corridors.

Preliminary flood simulations were undertaken by raising a development platform (as depicted in the subdivision approval). It must be noted, that the modelling simply blocked out the fill area and did not consider details design matters such as fill batters. The results showed flood level impacts to the town of Glenreagh, being less than 10 to 15mm, which is well within the accuracy of the modelling and are considered negligible.

Therefore, while the preliminary flood simulations show that the approved subdivision off Tallawudjah Creek Road may result in negligible impacts, more detailed simulations will be required to determine whether compensatory excavation may be required and convince Council's that impacts are likely to be negligible (under DCP, D5.2.2). This however may require concept design of fill platforms that better consider fill batters and fill levels.

4.3.2 P9 - Flood Conveyance Improvements

Estimated Capital Cost	*Nil*
Annual Maintenance Cost	*$10,000*
Priority	*High*

Regular maintenance of creeks, culverts and flood bypasses

Regular maintenance of creek channels and culverts is imperative in order that these facilities operate as intended and optimally. A number of critical areas have been identified throughout the floodplain, where a build-up of sediment, erosion and/or vegetation will be important to maintain on an ongoing basis. It is noted that the community are concerned about the build-up of sediment at bridges and culverts.

In regards to the river channel, the beds of all watercourses change over time through natural processes. Council is constrained by environmental restrictions that are imposed by the Department of Primary Industries (Fisheries), so is not permitted to undertake works to clear the river bed (to the extent requested by some members of the community). Due to the same environmental constraints, Council is also not permitted to interfere with the natural process which has led to the changes in the river bed. It is appreciated that Council sometimes needs to undertake very minor, low risk but ongoing maintenance works that trigger Part 7 of the Fisheries Management Act 1994 (FM Act). To improve administrative efficiencies for both Council and Department of Primary Industries (Fisheries), the Department is preparing Maintenance Permits for Councils. The Maintenance Permit is for very minor, low impact dredging and reclamation works associated with maintenance works within the Local Government Area. Subject to conditions, these allow for removal of snags and in-stream debris occurring up to 10 meter upstream and downstream of Council infrastructure.

Table 4-1 Critical Locations for ongoing maintenance

Location	Issues	Risks
Culverts and channels conveying flows from the tributary drainage along Tallawudjah Creek Road	Maintain conveyance, remove vegetation/sediment	Elevated flood levels, Tallawudjah Creek Road overflow and inundation of surrounding properties
Culverts and channels conveying flows from the tributary drainage along Orara Valley Way	Maintain conveyance, remove vegetation/sediment, mow	Elevated flood levels, Orara Valley Way overflow and inundation/isolation of Glenreagh and rural properties
Glenreagh and Tallawudjah and Hayard's crossing bridges	Maintain conveyance, remove vegetation/sediment and debris build-up	Elevated flood levels and reduced conveyance leading to increased risk of isolation of Glenreagh and rural properties
Orara and Tallawudjah Creek channels	Maintain conveyance and remove non-native vegetation/sediment	Elevated flood levels and reduced conveyance leading to increased flood risk to Glenreagh

5. Funding and Implementation

5.1 Funding

Funding for the implementation of the Plan could be considered from a number of sources:

- State and Commonwealth funding for flood risk management measures through the NSW Office of Environment and Heritage.
- Direct Council funds, for example maintenance funds.
- Section 94 Contributions from future development.
- Volunteer Groups that may be able to assist in maintenance of the creek corridors or other flood awareness initiatives, such as Landcare Groups and Schools.

For the structural mitigation works (noting that none were proposed for Glenreagh), Council can apply for assistance to the NSW Office of Environment and Heritage. These funds are available to implement measures that contribute to reducing existing flood problems and are typically applied on an equal shared basis of Commonwealth/State/Council. Special grant money may also be available in some cases.

Government funds are allocated on an annual basis to competing projects throughout the State and application documents are provided on the NSW Office of Environment and Heritage website. Measures that receive Government funding must be of significant benefit to the community. Funding of investigation and design activities as well as any works is normally available, however maintenance is normally the responsibility of the Council.

5.2 Implementation

In progressing the floodplain management process and implementing the Plan:

- Council determines a program of works, based on overall priority, available Council funds and any other constraints.
- Council submits an application for funding assistance to the NSW Office of Environment and Heritage and negotiates other sources of funding.
- Implementation of the Plan proceeds, as funds become available and in accordance with established priorities.

An implementation plan, showing option priority versus timing has been provided in Figure 5-1 with benefit -cost, cost and rankings provided in Table 5-1.

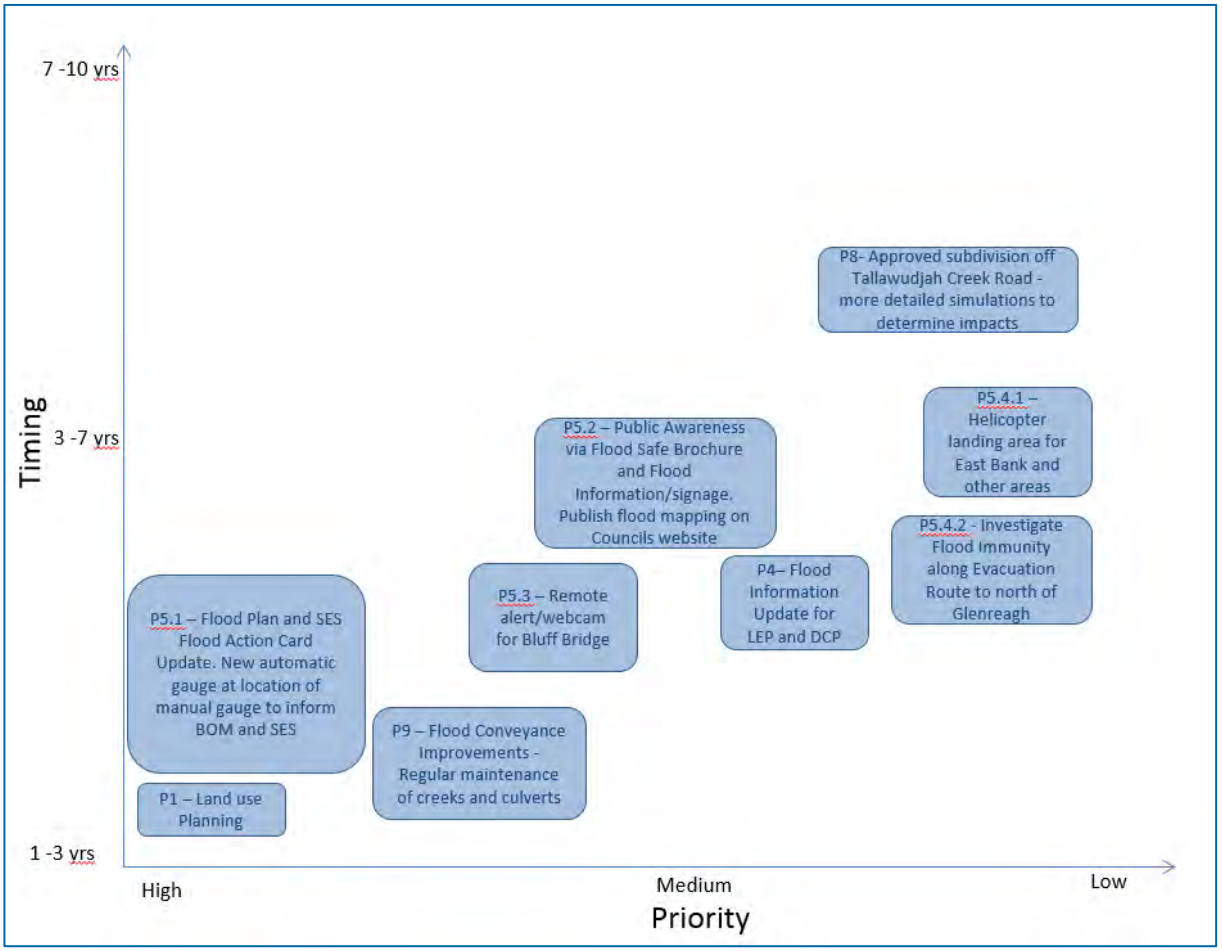


Figure 5-1 Implementation Plan

5.3 Plan Review

It is recommended that this plan be reviewed every 5 years in order for it to remain relevant. Modification of the Plan may be warranted after flood events, legislative change, alterations in the availability of funding, or changes to Council planning strategies.

Table 5-1 Option Benefit Cost Ratio, Cost and Ranking

	Issues	Intangible weightings	Options and Assessment (1 = option has negative impact, 3 =neutral, 5= option has positive impact)										
				P1	P4	P5						P8	P9
			Do nothing	Land Use and Flood Planning	Flood Information Update for LEP and DCP. Where resources allow updates using the latest Australian Rainfall and Runoff should be	P5.1 Flood Plan and SES Flood Action Card Update. New automatic gauge at location of manual gauge to inform BOM and SES	P 5.2 Public Awareness and Evacuation Planning, and flood information/signage. Publish flood mapping on Councils website	P5.3 Remote alert or webcam information on Bluff Bridge (Haywards Bridge)	P 5.4.1 Helicopter Landing Areas for East Bank Residents and other areas	P 5.4.2 Investigate flood immunity along Evacuation Route to north of Glenreagh	Approved subdivision off Tallawudjah Creek Road - more detailed simulations to determine impacts	Flood conveyance Improvements - Regular maintenance of creeks and culverts
	Social and Environmental Rank		8	1	6	9	5	2	9	7	4	2
	Present Value Capital Costs of Option ($)				10,000		5,000	20,000		40,000		
	Annual Maintenance Cost of Option ($)							2,000	2,000			10,000
Priority				High	Medium	High	Medium	Medium	Low	Low	Low	High

6. Scope and Limitations

This report has been prepared by GHD for Clarence Valley Council and may only be used and relied on by Clarence Valley Council for the purpose agreed between GHD and the Clarence Valley Council as set out in this report. GHD otherwise disclaims responsibility to any person other than Clarence Valley Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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GHD has prepared the preliminary cost estimate set out in this report using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD. The Cost estimate has been prepared for the purpose of comparative benefit/cost assessment and must not be used for any other purpose. The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

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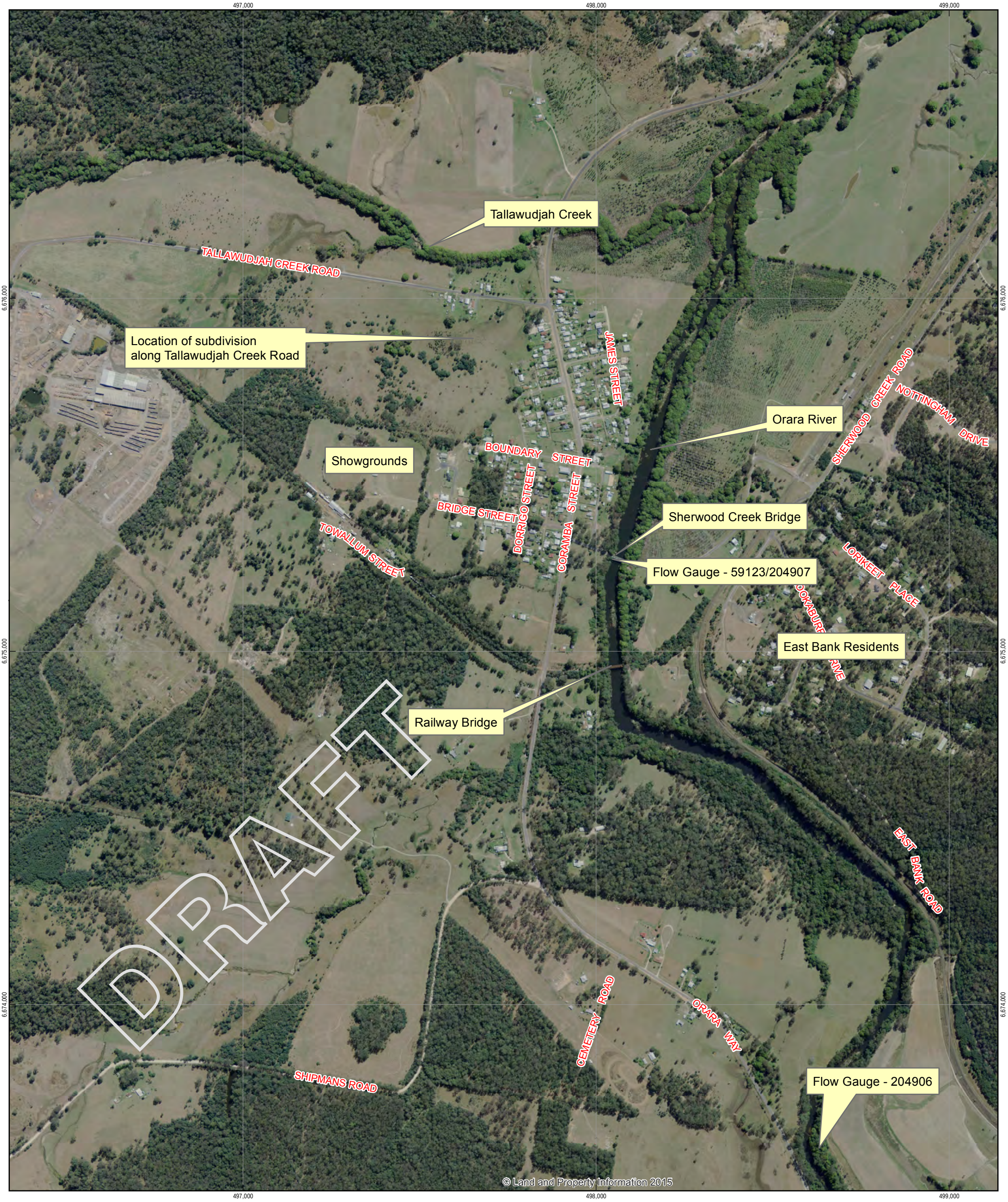
Appendices

Appendix A Study Area Map and Key Locations



LEGEND

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0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Location Map

Job Number	22-18407
Revision	A
Date	27 Apr 2017

Figure 1

N:\AU\Sydney\Projects\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\RRB_LocationMap.mxd

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:rberg

Appendix B Flood Mapping

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

57 57 58 59 60 61 62 62 63 63 63 64 64 64 64 65 65 65 65 66 67 69

ORARA WAY

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

SHERWOOD CREEK ROAD

ORARA RIVER

ORARA RIVER

MIDDLE CREEK

SCRUBBY GULLY

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LEGEND

0.16 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 - 2.0 | 2.0 - 3.0 | 3.0 - 5.0 | 5.0 - 10.0 | 10.0 - 20.0 | Flood Level Contours (mAHD) | Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
5 year ARI - Flood Extent and Depth (m)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 001

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 1)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

59 60 61 62 62 63 63 64 64 64 65 65 65 66 66 67 67 67 68

ORARA WAY

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

SHERWOOD CREEK ROAD

MIDDLE CREEK

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

0.16 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 - 2.0 | 2.0 - 3.0 | 3.0 - 5.0 | 5.0 - 10.0 | 10.0 - 20.0 | Flood Level Contours (mAHD) | Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
20 year ARI - Flood Extent and Depth (m)

Figure 003

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 2)

Level 15, 133 Castlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

61 62 63 64 65 66 67 68 69 70

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

SCRUBBY GULLY

LEGEND

- 0.16 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- Flood Level Contours (mAHD)
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

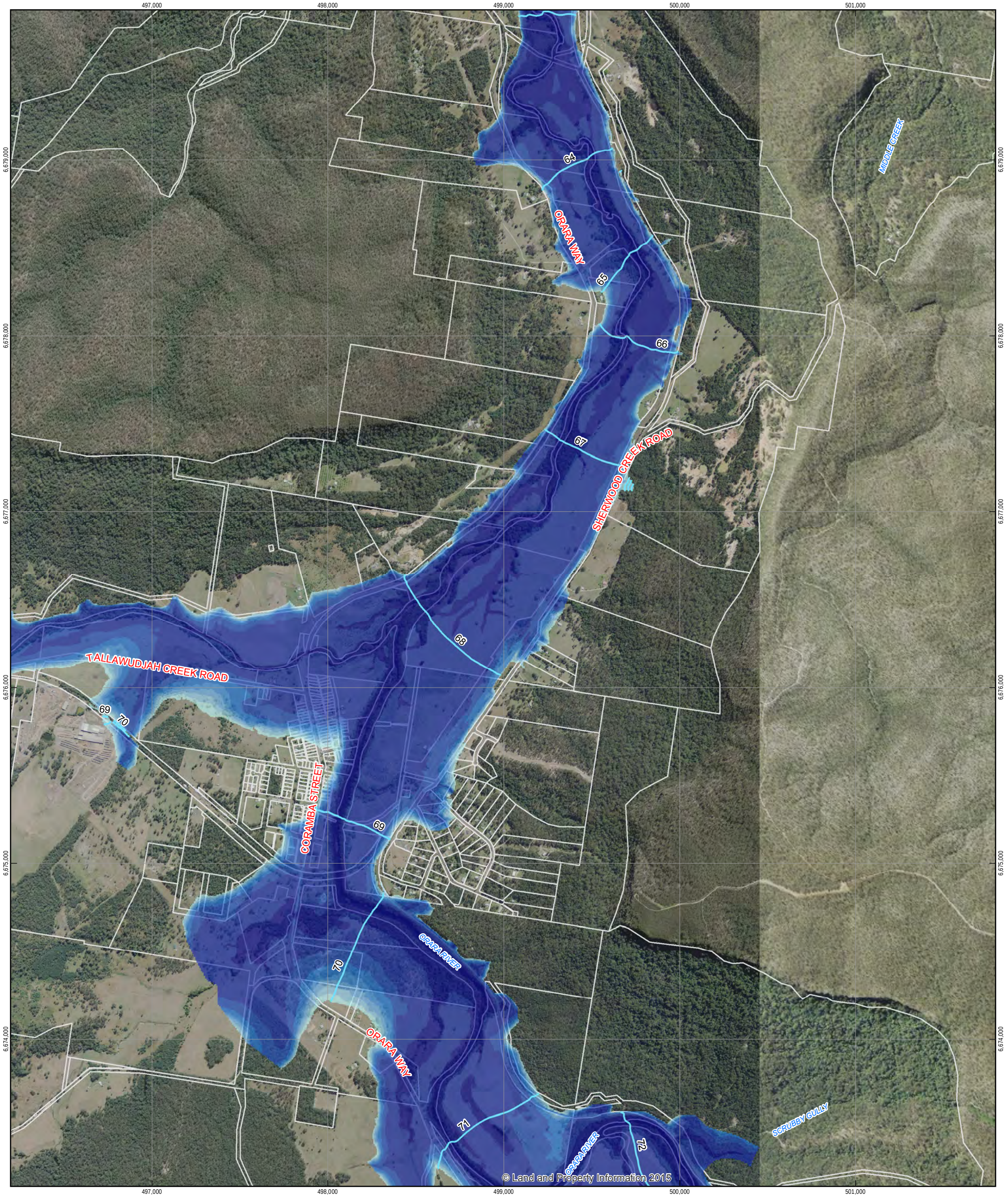
Existing Conditions
100 year ARI - Flood Extent and Depth (m)

Figure 005

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 3)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg



LEGEND

0.16 - 0.5 | 0.5 - 1.0 | 1.0 - 1.5 | 1.5 - 2.0 | 2.0 - 3.0 | 3.0 - 5.0 | 5.0 - 10.0 | 10.0 - 20.0 | Flood Level Contours (mAHD) | Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
500 year ARI - Flood Extent and Depth (m)

Figure 006

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 4)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

65 66 67 68 69 70 71 72 73

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

SCRUBBY GULLY

LEGEND

0.16 - 0.5	1.5 - 2.0	5.0 - 10.0	Flood Level Contours (mAHD)	Cadastre
0.5 - 1.0	2.0 - 3.0	10.0 - 20.0		
1.0 - 1.5	3.0 - 5.0			

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Flood Extent and Depth (m)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 007

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 5)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
5 year ARI - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 008

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 6)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
20 year ARI - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 010

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 7)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
100 year ARI - Peak Velocity (ms)

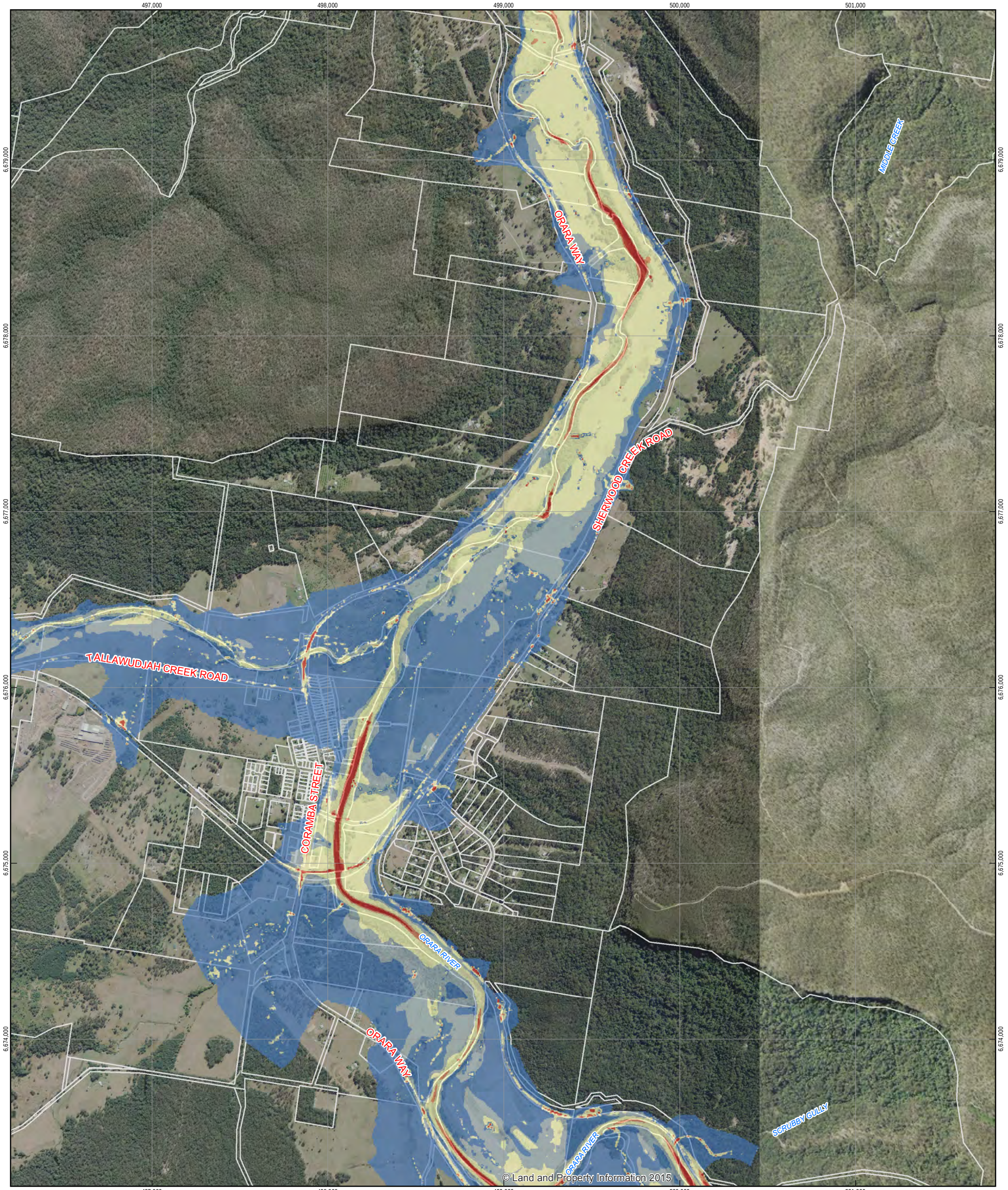
Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 012

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 8)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg



LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
500 year ARI - Peak Velocity (ms)

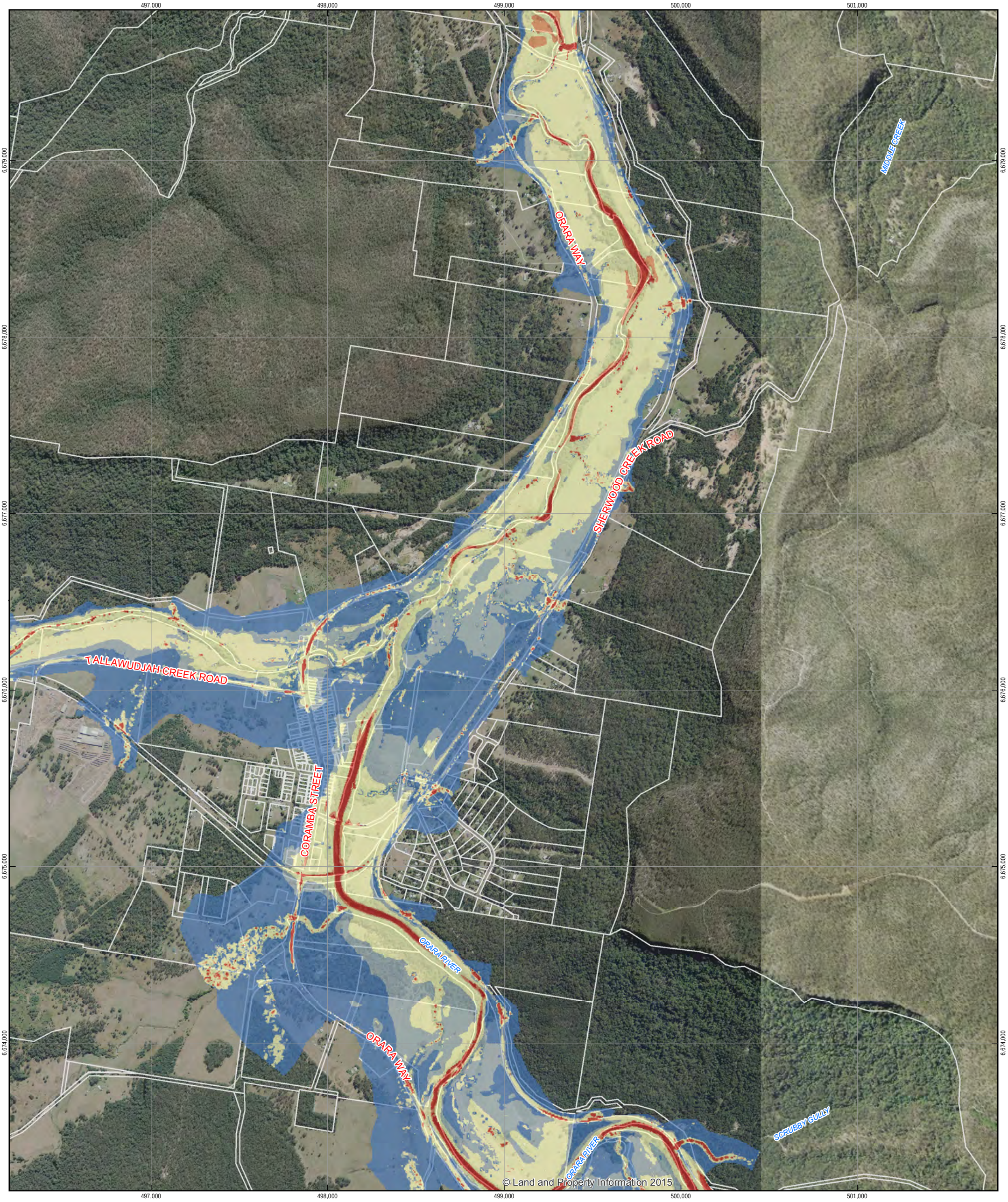
Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 013

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 9)

Level 15, 133 Castlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg



LEGEND

- 0.00 - 0.60
- 0.60 - 0.76
- 0.76 - 1.50
- 1.50 - 1.8
- > 1.8
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Peak Velocity (ms)

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 014

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 10)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY
© Land and Property Information 2015

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
5 year ARI - Provisional Hydraulic Hazard

Figure 015

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 11)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY
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LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
20 year ARI - Provisional Hydraulic Hazard

Figure 016

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 12)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
100 year ARI - Provisional Hydraulic Hazard

Figure 017

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 13)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Job Number 22-18407
Revision 0
Date 07 Mar 2018

Existing Conditions
500 year ARI - Provisional Hydraulic Hazard

Figure 018

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 14)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

- 1 - Low Hazard
- 2 - Intermediate Hazard
- 3 - High Hazard
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Provisional Hydraulic Hazard

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 019

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 15)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY

LEGEND

Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
5 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 020

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY
MIDDLE CREEK
SHERWOOD CREEK ROAD
TALLAWUDJAH CREEK ROAD
CORAMBA STREET
ORARA RIVER
ORARA WAY
ORARA RIVER
SCRUBBY GULLY
© Land and Property Information 2015

LEGEND

- Flood Fringe
- Flood Storage
- Flood Way
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
20 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 021

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- Flood Fringe
- Flood Storage
- Flood Way
- Cadastre

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
100 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 022

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 18)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- Flood Fringe
- Cadastre
- Flood Storage
- Flood Way

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
500 year ARI - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 023

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 19)

Level 15, 133 Cactlereagh Street Sydney NSW 2000 NSW Australia **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com.au

Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

497,000 498,000 499,000 500,000 501,000

6,679,000 6,678,000 6,677,000 6,676,000 6,675,000 6,674,000

ORARA WAY

MIDDLE CREEK

SHERWOOD CREEK ROAD

TALLAWUDJAH CREEK ROAD

CORAMBA STREET

ORARA RIVER

ORARA WAY

ORARA RIVER

SCRUBBY GULLY

LEGEND

- Flood Fringe
- Cadastre
- Flood Storage
- Flood Way

Paper Size A3

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Clarence Valley Council
Glenreagh Floodplain Risk Management Study

Existing Conditions
PMF - Hydraulic Category

Job Number	22-18407
Revision	0
Date	07 Mar 2018

Figure 024

G:\22\18407\GIS\Resources\Models_Scripts\BULKMAPPER\SMA.mxd (SMA record: 20)

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Data source: NSW LPI: DTDB & DCDB, 2012, GHD Flood Mapping (2016). Created by:rberg

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https://projects.ghd.com/OC/Newcastle/glenreaghfloodplainr/Delivery/Documents/2218407-REP-Glenreagh Flood Risk Management Plan.docx

Document Status

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		Name	Signature	Name	Signature	Date
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FINAL DRAFT	Minor changes			RBerg		28/02/17

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DRAFT	R Berg	S Douglas				25/5/2017
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