Roads and Maritime Services

Replacement of the Kings Highway bridge over the Clyde River at Nelligen

Flooding and Operational Water Quality Specialist Study

September 2016

Glossary and abbreviations

Term	Definition
Annual exceedance probability (AEP)	The annual exceedance probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. A one per cent event is a rainfall event with a one per cent chance of being exceeded in magnitude in any year. The current Australian Rainfall and Runoff recommendations (Institute of Engineers, Australia, 1987) are for use of AEP terminology rather than Average Recurrence Interval (ARI) terminology (refer below).
Afflux	With reference to flooding, afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario.
Australian Height Datum (AHD)	A common reference level used in Australia which is approximately equivalent to the height above sea level.
Average recurrence interval (ARI)	The average recurrence interval, like the annual exceedance probability, is a measure of the frequency of a rainfall event. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For example, a 100-year average recurrence interval event occurs or is exceeded on average once every 100 years. It is important to note that the ARI is an average period and it is implicit in the definition of the ARI that the periods between exceedances are generally random. Average recurrence intervals of greater than ten years are closely approximate to the reciprocal of the annual exceedance probability. A 100-year average recurrence interval is therefore approximately equivalent to a 1 per cent annual exceedance probability event. See also annual exceedance probability.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Consent	Approval to undertake a development received from the consent authority.
Critical duration	Duration of rainfall that produces the worst case scenario in any one particular area. I.e. the duration that produces peak water depth, velocity and time of inundation.
Datum	A level surface used as a reference in measuring elevations.
DEM	Digital elevation model
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic metres per second or megalitres per day.
Ephemeral	A stream that is usually dry, but may contain water for rare or irregular periods, usually after significant rainfall.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
F2, F50 and Skewness	Skewness is a statistical parameters and F2, F50 are geographical factors used in the calculation of rainfall intensity following the methods of Australian Rainfall and Runoff (Engineers Australia, 1987)

Term	Definition
Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land by water which escapes from, is released from, is unable to enter, or overflows from the normal confines of a natural body of water or watercourse such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Flood Frequency Analysis	Method used to estimate peak design flows for sites along a river. The technique involves using annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness and recurrence intervals.
Flood liable land	Land which is within the extent of the probable maximum flood and therefore prone to flooding.
Floodplain	The area of land subject to inundation by floods up to and including the probable maximum flood.
Floodway	The area of the floodplain where a significant portion of flow is conveyed during floods. Usually aligned with naturally defined channels.
Formation	A fundamental unit used in the classification of rock or soil sequences, generally comprising a body with distinctive physical and chemical features.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report, geomorphology relates to the form and structure of watercourses.
Groundwater	Subsurface water stored in pores of soil or rocks.
Hazard	The potential or capacity of a known or potential risk to cause adverse effects.
Headward erosion	The upstream lengthening and/or cutting of a valley or gully at its head, as the stream erodes away the rock and soil at its headwaters in the opposite direction to the stream flow.
Hydraulics	The physics of channel and floodplain flow relating to depth, velocity and turbulence.
Hydrograph	A graph which shows how a water level at any particular location changes with time.
Hydrology	The study of rainfall and surface water runoff processes.
Impervious	In the context of this report, impervious surfaces are surfaces non-permeable to water. These include hardstanding areas such as paved surfaces.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Landform	A specific feature of the landscape or the general shape of the land.
Light Detection and Ranging (LIDAR)	LiDAR is a remote sensing method used to examine the surface of the Earth. LiDAR has been used in this study to define the topography of the site and surroundings.
Meteorology	The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather.
Monitoring well/bore	A hole sunk into the ground and completed for the abstraction or injection of water or for water observation purposes. Generally synonymous with bore.
Overbank	The portion of the flow that extends over the top of watercourse banks.

Term	Definition
Overland flow path	The path that water can follow if it leaves the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Water travelling along overland flow paths, often referred to as ‘overland flows’, may either re-enter the main channel or may be diverted to another watercourse.
Permeability	The capacity of a porous medium to transmit water.
Pluviograph	A rain gauge with the capability to record data in real time to observe rainfall over a short period of time.
Probable maximum flood (PMF)	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that are reasonably possible at a given location.
Probable maximum precipitation (PMP)	The probable maximum precipitation is the greatest amount of rainfall which can theoretically occur over a given duration (period of time) for a particular geographical location.
RAFTS modelling	XP-RAFTS is a hydrology modelling software program used to simulate urban and rural runoff and routing through a watershed based on catchment characteristics and rainfall events.
Reach	Defined section of a stream with uniform character and behaviour.
Recharge	Addition of water to the zone of saturation; also the amount of water added. An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.
Risk	The chance of something happening that will have an impact measured in terms of likelihood and consequence.
Risk assessment	Systematic process of evaluating potential risks of harmful effects on the environment from exposure to hazards associated with a particular product or activity.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Salinity	The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million).
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Sinuosity	Extent of curvature or meandering of a stream. Highly sinuous streams meander over a low gradient and short distance. Low sinuosity streams are straighter and have a steeper gradient.
Stream order	Stream classification system, where order 1 is for headwater (new) streams at the top of a catchment. Order number increases downstream using a defined methodology relating to the branching of streams.
Study area	The subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly. The study area extends as far as is necessary to take all potential impacts into account.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Topography	Representation of the features and configuration of land surfaces.

Term	Definition
TUFLOW modelling	TUFLOW is a two dimensional hydraulic modelling software program used to simulate surface flow and estimate flood levels and flow velocities.
Watercourse	Generic term used to refer to rivers, streams and creeks.
Water quality	Chemical, physical and biological characteristics of water. Also the degree (or lack) of contamination.
Water sharing plan	A legal document prepared under the Water Management Act 2000 (NSW) that establishes rules for sharing water between the environmental needs of the river or aquifer and water users and also different types of water use.
Water table	The surface of saturation in an unconfined aquifer, or the level at which pressure of the water is equal to atmospheric pressure.

Executive summary

A hydrology and water quality study was carried out to determine the impact of the proposed new Kings Highway bridge over the Clyde River at Nelligen on flooding and water quality during operation.

Hydrology and flooding

Hydraulic modelling was undertaken to estimate flooding conditions with the existing bridge in place for a 1% Annual Exceedance Probability (AEP) event, a 0.05% AEP event and in the Probable Maximum Flood (PMF).

The assessment found that lower-lying areas of the town of Nelligen would be subject to substantial flooding during the flood events assessed. The bridge over the Clyde River, as well as the approach roads west would be inundated in a 1% AEP event.

Further flood modelling was undertaken to assess the impacts of flooding once the new bridge is in place and the existing bridge has been removed. The modelling found that in the flood events assessed, the change in flood level at the town of Nelligen would be small compared to the overall flood depths predicted.

The new bridge would be expected to be partially inundated in a 1% AEP event. Because the approach roads would be inundated to similar levels as previously, limited change to the use of the Kings Highway as an evacuation route would occur.

The study recommended that the location and orientation of the retaining wall abutment be reviewed so as to limit changes in velocity at this location. It also recommended that assessment of smaller flood events more typical or stream-forming flows be assessed to confirm that no geomorphological impacts would occur. Changes in flood level should also be reviewed for smaller events to confirm that the impact to the residents, roads and properties in the town of Nelligen is low.

The detailed design would need to incorporate consideration of and design for scour and bridge piers and abutments and structural design to withstand predicted flooding.

Water quality

There are ecologically sensitive wetland areas on the Clyde River immediately upstream of the bridge and the river itself is an important fish habitat. Further downstream, parts of the estuary are used for oyster cultivation. The New South Wales government has nominated water quality objective for the Clyde River that recognise its importance as a water resource for aquatic fauna and flora, as well as for primary industry and recreation.

The proposed bridge directs surface water along the road to the western approach whereas the existing bridge directs runoff into the Clyde River. Traffic volumes are not expected to increase in the proposed scenario. Therefore, operational water quality would not be expected to worsen with the provision of the new bridge. However, there is an opportunity to target improvement to water quality. An operational water quality management strategy was proposed and incorporated a series of vegetated swales, water quality basins (with bio retention) and spill containment measures as well as proprietary devices for the capture and treatment of gross pollutants, sediments, nitrogen and phosphorous.

The operational water quality management strategy would need to be developed further during future design stages.

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1. Introduction

1.1 Introduction and background

NSW Roads and Maritime Services (Roads and Maritime) is proposing a replacement of the Kings Highway bridge over the Clyde River at Nelligen. The proposal would involve constructing a new bridge on a new alignment to the north of the existing bridge, and removing the existing Bridge.

Roads and Maritime has engaged GHD Pty Ltd to assess the impacts of the proposal in accordance with the requirements of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and to prepare:

- A review of environmental factors (REF), in accordance with the requirements of Part 5 of the EP&A Act, is required to enable Roads and Maritime to meet the requirements of section 111 of the Act
- A development application with a supporting environmental impact statement (EIS) is to be submitted to Eurobodalla Shire Council (Council) under Part 4 of the EP&A Act, to seek approval for the section of the project that crosses the mapped extent (about 0.2 hectares) of wetlands that are subject to the requirements
- A hydrology impact assessment and assessment of operational water quality (accidental spill management).

1.1 The proposal

The proposal involves the construction of a new bridge to carry the Kings Highway over the Clyde River at Nelligen and works on the approach to the new bridge. The key features of the proposal include:

- Construction of a new 325 metre long bridge to the north of the existing Kings Highway bridge over the Clyde River. The height of the new bridge (at road level) would range between about 6.5 and 7.7 metres above the Clyde River. The new bridge would include the following:
  - One 3.5 metre wide traffic lane in each direction
  - 2.5 metre wide shoulders in each direction
  - A two metre wide pedestrian path on the southern side of the bridge
- Upgrading the Kings Highway approaches to the new bridge on both sides of the river including:
  - Improving the curve and building a new embankment on the eastern side of the river
  - Widening the existing cutting on the eastern side of the river
  - Providing a new Kings Highway intersection at Maisies Lane to maintain access to Nelligen village and relocation of the existing bus stop including a new shelter
  - Upgrading the Kings Highway intersections at Bridge View Road and Old Nelligen Road
  - Building new retaining walls at the western abutment of the new bridge
- Providing ancillary facilities such as temporary sedimentation basins and/or sumps, compound and stockpile areas and access tracks
- Providing operational water quality basins or other measures (as required)

- Adjusting existing utilities
- Demolishing the existing bridge following opening of the new bridge
- Removing sections of the existing Kings Highway road surface which are no longer required.

For the purposes of this report (and the REF) it has been assumed that construction of the new bridge would start in 2018/2019 and be completed in 2020. However, the timing of construction is yet to be confirmed and is dependent on a range of factors including condition assessments of the existing bridge and availability of funding.

1.2 Terms and definitions

The following terms are used in this report:

The proposal: the proposed construction of a new Kings Highway bridge spanning the Clyde River at Nelligen, including construction, upgrades and modification of adjoining lengths of the Kings Highway to the east and west, and associated roadside cut and fill.

Proposal site: the area to be directly impacted by the proposal. This comprises the future construction footprint of the proposed Nelligen bridge and associated Kings Highway upgrade, including all roadside cut and fill.

Study area: The subject site and additional areas that are likely to be affected by the proposal, either directly or indirectly. The extent of the flood impact assessment is from around two kilometres (km) upstream of the existing Nelligen Bridge and downstream to Batemans Bay. This includes a 2D hydraulic model component, which extends about 1 km proposed upstream of the existing Nelligen Bridge and 1.6 km downstream. Figure 13 in Appendix A shows a location map of the flood model area.

Locality: the area within a 10 km radius of the subject site.

A number of technical flooding terms are used in this report and definitions are provided in the glossary.

1.3 Limitations and assumptions

The TUFLOW/ESTRY model developed for this study is limited to the accuracy of the data that has been used to form its basis (outlined in Section 3.2). Clyde River bathymetry is based on the cross-section data (extracted from OEH website at approx. 300 – 400 m intervals). The bathymetry of the Clyde River represented in the two-dimensional model is limited to accuracy of the data extracted from this source.

The events modelled in this assessment are limited to the following:

- One percent AEP flood event
- 0.05 percent AEP flood event
- PMF flood event.

Impacts of more frequent flood events are not within the scope of this report.

The assumption of tide levels occurring with each flood event (section 3.4) are based on a common flood study approach in New South Wales and are not based on an analysis of joint probability analysis of tidal and rainfall events.

1.4 Objectives

The objectives of this assessment are:

- To assess the impact of operation of the new bridge on flood levels, velocities and water quality
- To provide hydraulic information for input into the structural design of the bridge.

1.5 Scope

The scope of the assessment is outlined as follows. Further detail is provided in Chapter 0

- Development of a hydrology model for the entire Clyde River catchment including sub-catchments downstream of Nelligen, which form inflow boundaries for the hydraulic modelling. Use the XP –RAFTS rainfall and-runoff model to calculate design hydrographs.
- Validation of the XP-RAFTS model to the stream gauge at Brooman (gauge 216002).
- Estimation of flood storm events from “Australian Rainfall and Runoff” and the Bureau of Meteorology Publications for derivation of the Probable Maximum Precipitation (PMP).
- Modelling of design flood events for the one percent and 0.05 percent [1] Annual Exceedance Probability and the Probable Maximum Flood (PMF).
- Development of a two-dimensional TUFLOW model at the project site, and linked to a one-dimensional ESTRY model, containing river cross sections extending downstream of the Princes Highway at Batemans Bay, 13 kilometres downstream of the Nelligen Bridge site.
- Determining the existing conditions with the existing bridge and proposed conditions with the proposed replacement bridge.
- Assessment of inundation times and impacts by means of comparison level hydrographs at various locations upstream and downstream of the projects site.
- Development of flood mapping to demonstrate the impact of the bridge on regional flood levels for the one percent AEP and PMF flood events. These maps include:
  - Existing flood levels
  - Proposed flood levels
  - Flood level impacts
  - Existing velocities
  - Proposed velocities
  - Velocity impacts
- Consideration of water quality treatment measures including operational and maintenance aspects associated with the solution.

[1] The 1% AEP is equivalent to a 1 in 100 year Average Recurrence Interval (ARI) event. The 0.05% AEP is equivalent to a 1 in 2000 year ARI event. Refer to the terms Average Recurrence Interval and Annual Exceedance Probability in the glossary for further explanation.

2. Legislation and guidelines

2.1 NSW State legislation

2.1.1 NSW Water Management Act

The *Water Management Act 2000* (NSW) *(WM Act)* is administered by the NSW Department of Primary Industries (DPI) Water (formerly NSW Office of Water) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. The intent and objectives of the WM Act have been considered as part of this assessment. Provisions of the WM Act require the development of management plans to deal with flooding regimes and the way they are managed in relation to risks to property and life and to ecological impacts. The WM Act also defines approvals required for carrying out works situated in the vicinity of a river or floodplain via flood work approvals or drainage work approvals.

2.2 Other policies and guidelines

2.2.1 New South Wales Floodplain Development Manual

The New South Wales Floodplain Development Manual (former Department of Infrastructure, Planning and Natural Resources, 2005) concerns the management of flood-prone land within NSW. It provides guidelines in relation to the management of flood liable lands, including any development that has the potential to influence flooding, particularly in relation to increasing the flood risk to people and infrastructure.

2.2.2 Managing Urban Stormwater: Soils and Construction (Blue Book)

The NSW Government publishes the following documents about the management of erosion and sediment control during construction and other land disturbance activities.

Managing Urban Stormwater: Soils and Construction – Volume 1 (Blue Book)

The document provides guidance for local councils and practitioners on the design, construction and implementation of measures to improve stormwater management, primarily erosion and sediment control, during the construction phase of urban development.

Managing Urban Stormwater: Main road construction – Volume 2D

This document provides guidelines, principles and recommended minimum design standards for managing erosion and sediment control during the construction of main roads. The construction of main roads and highways commonly involves extensive earthworks, with significant potential for erosion and subsequent sedimentation of watercourses and the landscape.

The erosion and sediment control impacts and mitigation measures are dealt with in a separate report but have some relevance to this study to hydrological processes and are referenced in this study.

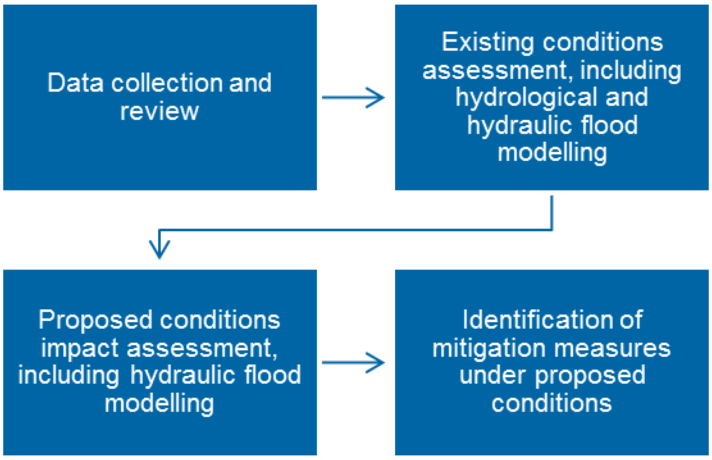
2.2.3 Nelligen village Development Control Plan

Council's Development Control Plan (DCP) for Nelligen village does not specify criteria in relation to flood impact, except with respect to stormwater management. The DCP notes that stormwater must be managed in order to minimise flooding and so as not to adversely impact on flooding of upstream or downstream properties. This will be a requirement for the development of drainage associated with the bridge.

3. Methodology

3.1 Overview

The steps followed in this assessment are outlined in the schematic below.



Schematic 1 – Study process overview

3.2 Data collection

A desktop study was undertaken to review the available data for the project. The following information was used for the purpose of this assessment.

3.2.1 Land and Property Information map data

Map data was sourced from New South Wales Land and Property Information 2015 dataset including:

- Topographic contours
- Regional transport (road) layouts
- Waterways layers

New South Wales Land and Property Information LIDAR (light and radar remote sensing) contour information (2013) was also used for catchment delineation and modelling.

3.2.2 Concept design information

The following references were made available:

- Detailed survey (Roads and Maritime, 2016/05/03)
- Concept bridge design (Roads and Maritime, 2016/05/03)
- Existing bridge design (Roads and Maritime, 2016/05/23).

3.3 Existing environment modelling and analysis

3.3.1 Background

There was no existing flooding data or modelling available for the site and it was therefore necessary to develop flood models to simulate flooding. These were used to estimate flooding conditions for the existing case and then later used to estimate impacts of the proposal (section 3.5).

The hydrology models were used to estimate flow quantities for various flood events and the hydraulic models were used to estimate flood levels, velocities and inundation times (i.e. length of time that areas are predicted to be flooded).

This section describes the technical details of the flood model development. The results of the flood modelling are discussed in Chapter 0.

3.3.2 Hydrological investigation

Hydrological modelling conducted for this study was undertaken using XP-RAFTS (RAFTS) hydrological modelling software package by XP Solutions.

The RAFTS models were established for the Clyde River catchment to simulate rainfall runoff. These models were used to derive flood hydrographs based on the Australian Rainfall and Runoff (ARR 1987) design storms and on the Generalised Southeast Australia Method. Parameters (ARR 2006) such as rainfall losses, sub catchment area, percentage impervious for each sub catchment, slope and catchment roughness (Mannings 'n') were used to describe the catchment's response to specific rainfall events in order to generate the hydrographs. The RAFTS version used for this study is XP-RAFTS 2013 – 12 Mar 2013.

RAFTS model configuration

Three RAFTS models were developed for the study to simulate the relevant design storm events.

The models produced for this study consisted of the following:

- Nelligen RAFTS model consisting of the one percent AEP rainfall event
- Nelligen RAFTS Probable Maximum Precipitation (PMP) model consisting of the Southeast Australia rainfall method with aerial reduction factors applied
- Nelligen RAFTS 0.05 percent AEP model with subcatchment rainfall depths for a 0.05 percent AEP storm event estimated using the one percent AEP rainfall event and PMP rainfall depths.

The outputs from the hydrological models were in the form of local subcatchment hydrographs that were applied as inputs to the hydraulic models.

Subcatchment delineation

The Nelligen River Catchment drains an area of about 1700 square kilometres. Delineation of the subcatchments was based on the use of topographic information, and aerial photography. The catchment was divided into 30 individual subcatchments as shown in Figure 3-1.

The delineation of the subcatchments allowed for the production of flow hydrographs in RAFTS, for input into the hydraulic TUFLOW model. Table 3-1 summarises the key catchment parameters applied to the RAFTS model, including the catchment area, slope and impervious fractions.

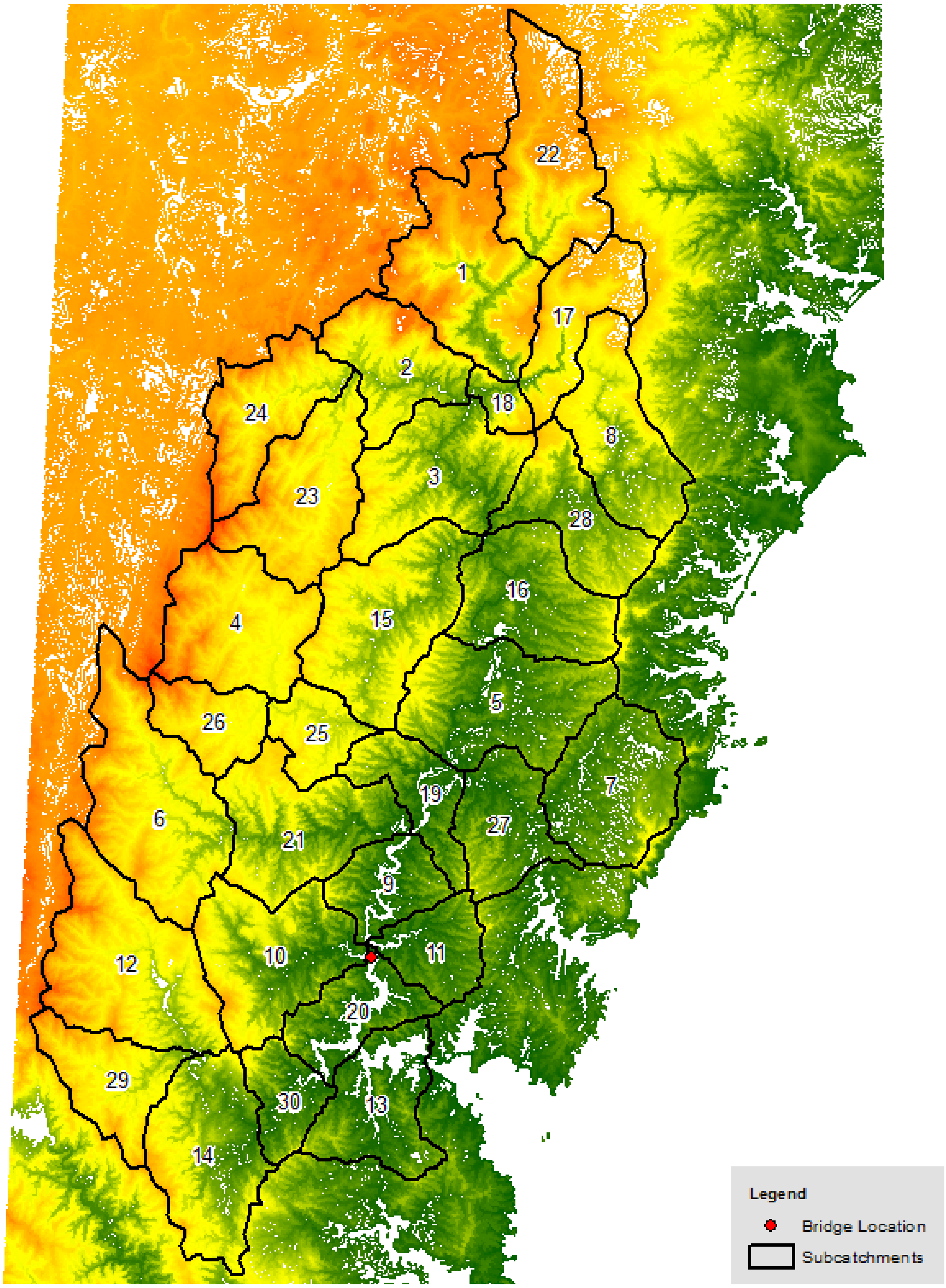


Figure 3-1 Subcatchment plan

Table 3-1 RAFTS subcatchment properties

Catchment ID	Area (Ha)	Slope (%)	Impervious Area (%)
1	8619	3.2	0
2	5152	3.5	0
2	7263	1.4	0
4	7331	2.5	0
5	8055	0.7	1
6	9783	3.5	0
7	6762	0.8	1
8	6386	1.7	0
9	3340	0.1	3
10	7377	0.7	3
11	3190	0.7	1
12	9720	2.3	0
13	5377	0.4	3
14	7523	2.1	3
15	8434	0.3	0
16	6435	1.1	1
17	4657	2.8	0
18	1123	5.6	1
19	3525	1.5	1
20	3851	0.5	3
21	7184	0.4	1
22	7484	3.2	0
23	6832	2.2	0
24	5436	3.1	0
25	5436	0.6	0
26	2686	5.4	0
27	3212	0.4	1
28	4501	1.1	0
29	4439	2.6	0
30	2708	0.5	0

Rainfall data

The one percent AEP design rainfall event was configured in RAFTS to model this design storm event in accordance with the guidelines and parameters as outlined in ARR (2001). The Intensity Frequency Duration (IFD) parameters adopted for the Nelligen catchments are listed in Table 3-2

Table 3-2 Rainfall IFD parameters

Parameter description	Value
1 Hour Rainfall Intensity (mm/hour)	104
12 Hour Rainfall Intensity (mm/hour)	25.5
72 Hour Rainfall Intensity (mm/hour)	8.22
Skewness	0.08
F2 Value	4.25
F50 Value	15.73

The Probable Maximum Precipitation (PMP) was estimated using the Bureau of Meteorology Generalised South-east Australia Method. The parameters used for this method are given in Table 3-3

Table 3-3 PMP rainfall parameters

Storm Duration (hours)	PMP Rainfall Depth (mm)	PMP Rainfall Intensity (mm/hr)
36	1040	28.89

The 0.05 percent AEP design rainfall event was estimated through interpolation between the PMP event and the one percent AEP design rainfall event. Details of the values used as part of the interpolation are outlined in Appendix B.

Initial and continuing losses

The initial loss and continuing loss approach was used in the model. ARR generally recommends initial loss values of 10 millimetres to 35 millimetres for catchments in Eastern New South Wales *(Volume 1, Book 2, Table 3.2)*.

The adopted loss values for the pervious and impervious values are presented in Table 3-4

Table 3-4 RAFTS initial and continuing losses

Losses	Events	Pervious	Impervious
Initial loss (mm)	Frequent to Large (1% AEP)	10	2.5
Continuing loss (mm/hr)	Frequent to Large (1% AEP)	1.5	0

Percentage impervious and pervious area

Impervious and pervious fractions were determined based on a combination of information including the use of aerial images, topographic data and confirmation from site visits.

Model validation

In order to check the validity of the model findings, a number of comparative estimation methods were used and were compared to the findings of the modelling.

The following methods were used to estimate peak flows as a means to check against the peak flows generated by the RAFTS model. These methods include:

- Probabilistic rational method for estimation of design peak flows (ARR 1987)
- Flood frequency analysis of annual peak flows of the Brooman Gauge (gauge number 216002) for estimation of the one percent AEP flow
- Use of FLIKE software (Newcastle University) for estimation of one percent AEP design flows using peak annual flow data from Brooman Gauge
- The draft regional flood frequency estimation model (ARR 2016) was used as an additional check against the other methods.

The results of the analysis are presented in Table 3-5:

Table 3-5 Summary of peak flow checks at Brooman Gauge

Method to estimate peak 1% AEP flow	1% AEP peak flow estimate (m3/s)
Rational Method	5990
Flood Frequency Analysis (FLIKE)	5940
Draft Regional Flood Frequency Analysis (ARR 2016)	6668
XP-RAFTS Model	5970

Table 3-5 shows a high level of consistency in peak flow estimation for the one percent AEP storm event for the Brooman gauge. Results show that a difference of 50 cubic metres per second (m^3/s) is present between the rational method, flood frequency analysis (FLIKE) and XP-RAFTS. The estimate provided by the streamflow data was slightly greater (approx. 9.5 percent).

Based on these checks, it was concluded the XP-RAFTS model flows provide a reasonable estimate of flows for use in the assessment.

Note that flow gauges were checked at Nelligen area to determine levels of significant flood events to calibrate against. After contacting the Manly Hydraulics Institute, it was determined that flood events captured in the data set were not significant enough to calibrate against a 100 yr ARI design flood event.

3.4 Hydraulic model

Overview

A two dimensional hydraulic TUFLOW model was established at the proposal site and linked to a one-dimensional ESTRY model. The combined model extends to the Princes Highway at Batemans Bay (13 kilometres downstream of Nelligen) and about two kilometres upstream of the bridge. The methodology for developing this model is outlined in this section.

TUFLOW

Flooding conditions were modelled using TUFLOW, a grid based two-dimensional hydrodynamic model. The model was developed with a 5 metre square grid.

Hydrographs were generated using XP-RAFTS (Section 3.3), and exported to a format that was read directly into TUFLOW.

The terrain for the hydraulic model was created using LIDAR data.

The model incorporated additional upstream and downstream extents of the Clyde River using TUFLOW's one-dimensional component, ESTRY. Cross sections of the LIDAR data were taken at regular intervals along the Clyde River, continuing to the Princes Highway at Batemans Bay.

Bathymetry for the Clyde River was created in the 2D model extents using cross section data provided by OEH.

The downstream boundary for the hydraulic model was defined as a peak design tide level, taken from a sea level study completed at Fort Denison (*Sydney Harbour Sea Level Rise Vulnerability Studies*).

The tidal boundary assumptions for each event modelled in TUFLOW are as follows:

- 5 percent AEP peak tidal elevation for the one percent AEP rainfall event
- One percent AEP peak tidal elevation for the 0.05 percent AEP rainfall event

- One percent AEP peak tidal elevation for the PMF event.

The model was simulated for the critical duration storm, which was found to be the 36-hour storm. The critical duration refers to the duration of rainfall that produces the peak flood depths, velocities and inundation times.

Model validation

There was no flood data available against which to compare the results of the flood model.

To check the performance of the TUFLOW model in modelling flood levels and, in particular, the bridge structure, a comparison was carried out against the findings of an alternative modelling package.

The TUFLOW model was verified against a HEC-RAS one dimensional model. The model was developed using the same cross sections as those used in the one-dimensional ESTRY model. Equivalent peak flow rates were used for both models. The results of the comparison located upstream of the existing bridge are summarised in Table 3-6.

Table 3-6 Comparison of peak levels for the existing scenario between 1D HEC-RAS model and combined 1D-2D TUFLOW model.

	HEC RAS	TUFLOW
1% AEP Event	6.9 m AHD	7.4 m AHD
PMF Event	10.6 m AHD	11.2 m AHD

Table 3-6 shows that results from the HEC-RAS and TUFLOW/ESTRY models are in reasonable agreement for both the one percent AEP flood event and PMF.

3.5 Impact assessment

The TUFLOW model was updated with the proposed bridge configuration and the resulting flood levels and velocities were reviewed as well as times of inundation.

The change in flood level or velocity (referred to as “afflux”) was reviewed to determine the impact on surrounding development and people.

3.6 Climate change assessment

A climate change assessment was carried out to determine the potential impact of rising sea levels and increased rainfall intensities on flooding at the bridge.

3.7 Mitigation measures

Where required, mitigation measures were identified based on the findings of the impact assessment (refer section 7).

4. Existing environment

4.1 Key features relevant to surface water

The township of Nelligen is located on the western banks of the Clyde River and consists mostly of residential dwellings with a small number of commercial/business properties. Further residential and rural dwellings are located on the eastern side of the river. The existing Nelligen bridge over the Kings Highway provides the only crossing point of the Clyde River in this location.

The bridge is located on the Kings highway between the Thule Road intersection on the eastern side of the Clyde river and the Braidwood Road intersection on the western side. The bridge deck extends about 260 m in length and includes 7 piers. Drawings of the existing bridge are included in Appendix C. The existing bridge extends on a straight alignment across the river. The deck is at an elevation of around 6.3 m AHD and Nelligen town is located at around 20 m AHD in the higher reaches with the lower reaches closer to the river level.

4.2 Catchment overview

The Clyde River is one of New South Wales' larger rivers. It has its headwaters between Sassafras and Tianjara (south west of Nowra) and is around 113 kilometres in length from its upper reaches to the estuary at Batemans Bay, where it discharges to the ocean. The river is tidally influenced for nearly 45 kilometres and Nelligen bridge is within these tidal limits.

The catchment of the Clyde River is largely undeveloped upstream of Nelligen, with the predominant land use being native and planted forests. Development is more concentrated downstream in Batemans Bay.

Although there are tidal influences at Nelligen, the dominant form of flooding is from runoff generated by rainfall falling on the large catchment area upstream of the site.

4.3 Flood extents

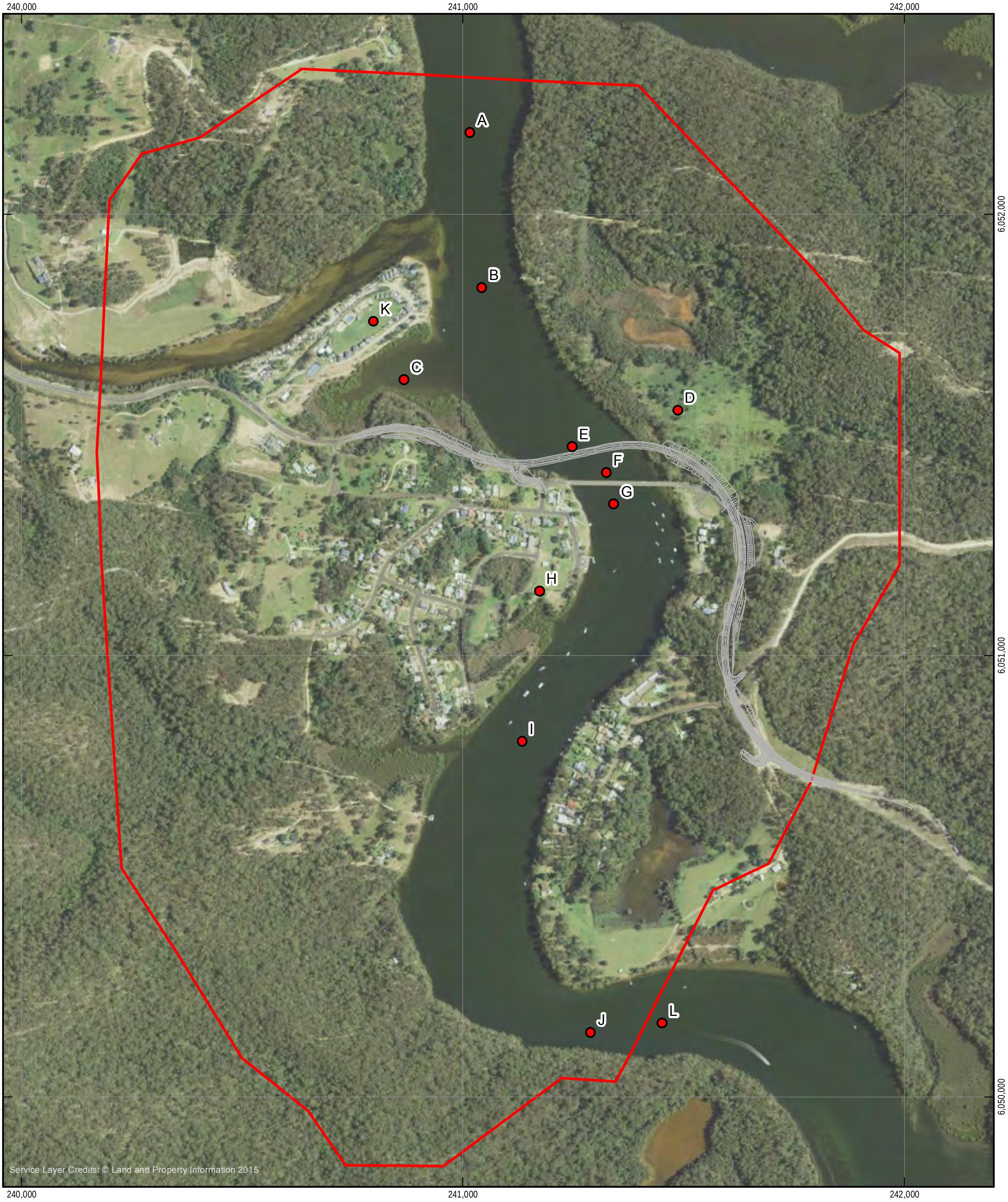
Flood extents and peak velocities are shown for the existing environment in Figures 1 – 4 of Appendix A of this report. These figures show that during the one percent AEP flood event, the bridge is inundated. The Kings Highway is cut at several locations on the western side of the bridge, including the intersection between Reid Street and Kings Street. Low lying properties and streets are also inundated, which include, Wharf St, Maisies Lane and Clyde Boulevard, as well as associated properties.

A number of properties located on the eastern side of Nelligen Bridge are also inundated, these include properties situated on Thule Road and Sproxton Lane.

One percent AEP flood depth results also show that the Big 4 Nelligen Holiday Park is inundated, as well as the wetland area located north-east of the existing bridge.

4.4 Peak flows and velocities

Table 4-1 below summarises results at several locations in the existing scenario. Figure 14 in Appendix A shows a map of the locations where results were taken. This map has been reproduced in this section



LEGEND

- Sample Locations
- Hydraulic Model Extent
- New bridge and road alignment

Paper Size A4

0 40 80 160 240 320

Metres

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

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GHD

Roads and Maritime Services
Nelligen Bridge REF

Locations of Flood Results

Job Number | 2125173
Revision | C
Date | 28 Jul 2016

Figure 4.1

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

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Sample Results Locations.mxd

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

Table 4-1 Summary of existing environment results

Location	1% AEP Flood Event		PMF Event	
	Flood level (m AHD)	Velocity (m/s)	Flood level (m AHD)	Velocity (m/s)
A	8.02	2.26	12.22	2.84
B	7.92	2.37	12.07	3.04
C	7.96	0.79	11.65	0.81
D	7.80	0.55	11.49	0.71
E	7.79	2.87	11.47	3.55
F	7.70	3.28	11.26	4.18
G	7.59	2.88	11.03	3.79
H	7.32	0.81	10.60	1.03
I	7.25	3.63	10.51	4.73
J	7.12	3.24	10.46	3.53
K	7.96	0.48	11.79	0.65

Table 4-1 and Figure 1 in Appendix A show that some areas of the Nelligen township are inundated by between three and six metres of flood depth and are at significant risk in such flood events. It can also be seen that the existing bridge is overtopped by depths between 1 to 1.5 metres in a one percent AEP event. In this situation the existing bridge acts as a flow constriction, with differences in flood levels up to 400 millimetres across the bridge as water builds up upstream. This indicates that the existing bridge is holding flood water back in upstream areas further increasing flood water depths upstream.

4.5 Existing emergency evacuation routes

The only egress route from Nelligen is via the Kings Highway to the west or the east. The Kings Highway is flooded during the PMF and hence there is no flood free evacuation route. The Kings Highway is predicted to be inundated for around two days (50 hours) under the critical duration PMF event. It would therefore be necessary to evacuate the town in advance of flooding. Inspection of results shows that water levels begin to rise about ten hours after the start of the storm event, and the Kings Highway is inundated about 15 hours after the start of the storm event. Visitors of the holiday park would need to be evacuated from the area well in advance with no route to higher ground being available except via the flood prone Kings Highway.

Other residences and businesses flooded under existing conditions include:

- On the west bank of the Clyde River in Nelligen town centre: properties in the low lying parts of Clyde Boulevard, Nelligen Place, Maisies Lane, Braidwood Street and Wharf Street
- On the east bank: properties in the low lying parts of Thule Road and Sproxton Lane.

Most of the roads in the Nelligen town are continuously rising away from the flood extents, meaning that they provide a route to higher ground for residences and businesses of these streets. The exception is Braidwood Street, which is flooded in two locations in the PMF and the Kings Highway itself which is extensively flooded west of the town by Nelligen Creek. Due to the depths and velocities of flooding predicted, evacuation to higher ground in advance of a flood event would be essential for affected residents.

4.6 Ultimate limit state design input

The 0.05 percent AEP storm was modelled to provide design input information for the ultimate limit state assessment for the bridge. The peak water elevation and velocity are provided in Table 4-2. Locations of the results for this table are shown in Figure 14 of Appendix A.

Table 4-2 0.05% AEP results for existing scenario

Approximate Location	Water Elevation (m AHD)	Peak Velocity (m/s)
Upstream of the existing bridge (Location F)	8.14	3.28
Downstream of the existing bridge (Location G)	8.01	2.88

4.7 Water quality

4.7.1 Sensitive receivers

The proposal is located within the Batemans Bay Marine Park, a marine protected area.

The Clyde River is considered to be a key fish habitat (refer to the *Biodiversity Impact Assessment* for this REF). It is classified as highly sensitive fish habitat because of the presence of SEPP 14 wetlands and extensive seagrass beds. It also has importance for fish passage and as habitat for the threatened Australian Grayling (*Prototroctes maraena*).

Other vegetation with importance for fish within the proposal footprint includes saltmarsh and mangroves.

The Clyde River is also important for aquaculture, with over 180 hectares designated as priority oyster aquaculture area and a number of oyster farms are located downstream of the site.

4.7.2 Existing water quality and objectives

The NSW Government publishes water quality and river flow objectives for a number of catchments in NSW, including the Clyde River.

Being a largely forested catchment discharging to an estuary, protection of water quality for aquatic ecosystems is considered important.

The Clyde River Estuary Report Card 2014-2015 (*Eurobodalla Shire Council)* indicated that water quality along much of the Clyde River was of fair to very good quality for the parameters measured.

Data regarding the quality of runoff from the existing road was not available. Typical contaminants from road runoff include suspended solids and containments including heavy metals and nutrients. Accidental spills of liquids including petroleum hydrocarbons may also impact water quality.

There are no known water quality treatment measures or spill containment measures within the study area.

5. Proposed environment

5.1 Key features relevant to surface water

The proposed bridge is located north (upstream) of the existing bridge location, with an embankment to extend north of the existing Kings Highway, and built to an elevation of about 8.3 m AHD.

The bridge deck is proposed to extend about 325 m in length with ten spans and nine piers. The bridge follows a curved alignment and is proposed to tie into the existing Kings Highway alignment north west of the Braidwood Road intersection with the Kings Highway. The proposed deck elevation ranges from between 8.3 m AHD on the eastern side of the Clyde River and 6.5 m AHD where it ties in with the existing alignment on the western side. A retaining wall is proposed at the western abutment to facilitate a relocated intersection with Maisies Lane. The retaining wall abutment is located on the river bank with minimal set-back. The existing bridge would be removed.

5.2 Peak levels and velocities

Flood extents and peak velocities are shown for the post developed case in Figures 7 – 10 of Appendix A of this report. Table 5-1 below summarises flood results once the new bridge is in place.

Table 5-1 Summary of proposed environment results

Location	1% AEP Flood Event		PMF Event	
	Elevation (m AHD)	Velocity (m/s)	Elevation (m AHD)	Velocity (m/s)
A	7.97	2.32	12.26	2.86
B	7.84	2.42	12.09	3.02
C	7.88	0.79	11.69	0.79
D	7.76	0.75	11.59	1.06
E	7.64	2.99	11.49	3.69
F	7.64	3.31	11.30	4.49
G	7.64	3.10	11.28	4.27
H	7.36	0.76	10.75	1.45
I	7.30	3.72	10.75	5.09
J	7.22	3.45	10.81	3.79
K	7.87	0.48	11.88	0.72

Note that flood maps in the Appendix show the flow occurring beneath or over the bridge.

The bridge is flooded in the PMF but is only partially flooded in the one percent AEP event.

5.3 Ultimate limit state

The 0.05 percent AEP storm was modelled to provide concept design information for the ultimate limit state assessment for the bridge. The peak water elevation and velocity in this event are provided in Table 5-2. Locations of the results for this table are shown in Figure 14 of Appendix A.

Table 5-2 0.05% AEP Results for Proposed Scenario

Approximate Location	Water Elevation (m AHD)	Peak Velocity (m/s)
Upstream of the proposed bridge (Location E)	8.04	3.02
Downstream of the proposed bridge (Location F)	8.03	3.41

6. Impact assessment

Potential flooding and water quality impacts from the bridge during operation include:

- Changes in flood flows or levels through the bridge due to increases or decreases in waterway area under the bridge
- Changes in flood levels due to fill in the floodplain through the construction of embankments and retaining walls
- Changes to period of inundation of properties and roads, impacting residents and evacuation routes
- Water quality impacts due to pollutant runoff from the bridge or accidental spills
- Changes to waterway erosion and sedimentation processes as a result of changes in velocity.

Table 6-1 Summary of existing and proposed bridge design information

	Existing	Proposed
Bridge deck level (m AHD)	6.7 m (approx.)	8.3 m eastern abutment to 6.5 m western abutment
Depth of superstructure	1.8 m (approx.)	1.6 m (approx.)
Bridge length	260 m (approx.)	325 m (approx.)
Number of piers	6	9
Pier width	10 m (approx.)	15 m (approx.)
Number of Spans	7	10
1% AEP flood level	7.79 m AHD	7.64 m AHD
PMF level	11.49 m AHD	11.47 m AHD

The section documents the findings of the hydraulic assessment in relation to effects on key hydraulic parameters and the impact arising from these changes.

6.1 Flood impacts

6.1.1 Flood levels and velocities

The results below draw on the information provided in Section 0 and Section 5 of this report. Figures 5, 6, 11 and 12 in Appendix A are impact maps showing change in velocity and flood level (afflux) resulting from the implementation of the concept bridge design outlined in this study.

Inspection of the design bridge drawing and existing drawings show that the length and height of the proposed bridge will be greater than that of the existing and therefore the waterway area will be larger. This will increase the amount of flow able to pass through the bridge with possible impact on flood levels and velocities downstream.

Table 6-2 summarises results in several locations in the flood model. Note that a positive value in the table indicates an increase in flood level or velocity from the existing case to the post developed case. A negative value in the table indicates a decrease in flood level or velocity from the existing case to the post developed case.

Table 6-2 Summary of flood impacts in 2D Model

Location	1% AEP Flood Event		PMF Event	
	Afflux (m)	Velocity Impacts (m/s)	Afflux (m)	Velocity Impacts (m/s)
A	-0.05	0.05	0.04	0.01
B	-0.08	0.05	0.02	0.00
C	-0.08	-0.02	0.05	-0.02
D	-0.04	0.18	0.1	0.32
E	-0.15	0.13	0.02	0.14
F	-0.06	0.05	0.04	0.28
G	0.05	0.23	0.24	0.46
H	0.04	-0.05	0.15	0.42
I	0.05	0.12	0.24	0.36
J	0.1	0.17	0.35	0.22
K	-0.08	-0.01	0.04	0.06

Table 6-2 shows a general trend of a decrease in flood levels upstream of the bridge location, and an increase in flood levels downstream of the bridge in the one percent AEP scenario. The new bridge has a larger opening, allowing more flow through and resulting in higher flood levels downstream. Upstream, with the greater constriction posed by the existing bridge removed, flood levels are reduced. Peak velocities increase through the main flow channel.

A negative afflux is present upstream of the proposed bridge deck (Location E). Table 5-1 shows a water elevation of about 7.64 m in the one percent AEP scenario. This level is lower than the highest proposed bridge deck elevation, but higher than the lowest proposed bridge deck location (refer Section 5.1 and Table 6-1 for additional details on the proposed bridge deck), indicating that the bridge would be partially overtopped in a one percent AEP event.

Table 6-2 also shows an increase in velocity and afflux in the PMF event. Results show that the bridge deck, at 8.3 m AHD, is overtopped substantially. This means the bridge will form an obstruction that is larger than the existing bridge during the PMF event.

Location J shows that some properties on the downstream extent may be negatively affected by afflux. Additional afflux results are shown based on the ESTRY results file (shown as location L in Figure 14 Appendix A). Results are shown in Table 6-3 below.

Table 6-3 1D Peak Water Elevations

	Existing Conditions metres AHD	Design Scenario m AHD	Afflux
1% AEP	5.43	5.48	0.05
PMF	8.01	8.05	0.04

Table 6-3 shows that about 50 millimetres of afflux is present in the one percent AEP flood event, and about 40 millimetres of afflux is present in the PMF event.

Discussion

The results in this section show that a negative afflux is present upstream of the proposed bridge location in the one percent AEP event (about 40 – 150 millimetre decrease in flood levels). This includes the wetland area northeast of the proposed bridge location. Table 6-2 also shows that a positive afflux is present downstream of the proposed bridge location (about 40 – 100 millimetre increase in flood levels). Peak velocities generally increase along the main channel in the one percent AEP flood event and the PMF. This may be caused by an increase in peak flow conveyance resulting from a larger waterway area under the proposed bridge design.

Flood extent figures in Appendix A show that properties in the areas which are flooded are already inundated to substantial depths under existing conditions (up to 10 m in the PMF and around 3-6 metres in the one percent AEP event). It is likely that a slight increase in flood depth (50 to 100 millimetre) will have little relative impact on an individual property because the properties would already be expected to be flooded to second-storey height or roof height.

6.1.2 Inundation times

Inundation time refers to the duration a location (not under water prior to a flood event) is affected by flood waters. Locations D and K in Figure 14, Appendix A are of particular interest to this study. Location D is south of an existing wetland area and location K is a low lying campground area.

Table 6-4 Inundation times in low lying areas near Nelligen

Location	1% AEP Event		PMF Event	
	Existing (hours)	Design (hours)	Existing (hours)	Design (hours)
D	58	70	70	70
K	139	134	153	146

Table 6-4 shows inundation times are minimally affected when comparing most scenarios tested in the flood plain. Location D shows that the wetland may be inundated for an additional 12 hours in the one percent AEP event. This is most likely due to the proposed construction of the bridge embankment on the eastern side on the concept bridge design which tends to prevent draining of flow from the wetland.

Location K shows that inundation times are reduced with implementation of the design bridge for the one percent AEP event and PMF.

6.1.3 Emergency evacuation routes

Inspection of Figures 2 and 8 in Appendix A show that flood extents remain largely similar during the onset of a PMF event. Flooding of the Kings Highway itself as well as Clyde Boulevard, Nelligen Place, Maisies Lane, Braidwood Street and Wharf Street on the west bank and Thule Road and Sproxton Lane on the east bank is predicted, to levels similar to that of the existing condition.

Table 6-5 shows the inundation times at the Reid Street and Kings Highway intersection for the existing and Design PMF events.

Table 6-5 Inundation times during the PMF

Location	PMF Existing (hrs)	PMF Design (hrs)	Variation
Intersection between Reid St and Kings Highway	50	50	0%

Table 6-5 shows minimal inundation time impacts are present at the Reid St and Kings Highway intersection.

Inspection of results shows that the times taken before major roads are cut remain largely unchanged for the existing case and the proposal case. This means that warning times will remain unchanged for both the one percent AEP event and the PMF.

6.2 Water quality

During operation, pollutants from vehicles would be washed from the pavement during rainfall events and discharge into the Clyde River. There is also potential for accidental spillage of hazardous materials which, without appropriate spill containment, could pollute the waterway or the nearby wetland.

Pollutants from vehicles and spills during operation would be similar to existing levels as vehicle numbers are not expected to change as a result of the proposal. However, the receiving environment is considered sensitive as described in section 4.7.1). Although the change in existing water quality would be limited, there is an opportunity to reduce the level of expected pollutants to appropriate levels in line with current practice (refer section 8.2).

7. Climate change

An assessment was carried out of the possible impacts of climate change on flooding at the bridge and its potential to exacerbate flood impacts.

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This can be identified by changes in the mean and/or the variability of measurable climatic properties that persist for an extended period, typically decades or longer.

Scientists and governments at an international level (for example, the Intergovernmental Panel on Climate Change) have accepted that climate change is occurring and that increasing amount of greenhouse gasses will continue to increase atmospheric, land and ocean temperatures. The potential effects of increased temperatures relevant to flooding include:

- Increases in sea level will exacerbate flooding problems in coastal areas, estuaries and along the tidal reaches of coastal draining rivers and creeks.
- Altered weather patterns may intensify storms and so increase the severity of the resulting floods. In effect, an increase in storm severities means that what is currently the one percent AEP rainfall event will become more frequent and the new one percent AEP may be worse than that under present day conditions.

7.1 Sea level rise

An analysis was conducted for the proposal to determine the effect of sea level rise on flood levels. The following increases in sea level were adopted from a sea level rise study completed at Fort Denison (*Sydney Harbour Sea Level Rise Vulnerability Studies*):

- A one percent AEP design event with sea level rise in the year 2050 of 0.38 metres, relative to 2008 levels.
- A one percent AEP design event with sea level rise in the year 2100 of 0.89 metres, relative to 2008 levels.

7.2 Rainfall intensity

An analysis was conducted to assess the potential impacts of a 20% increase in peak rainfall intensity. This was modelled in combination with a 0.38 m rise in sea level to represent the potential impacts climate change may have on flood extents at Nelligen.

7.2.1 Summary of climate change results

Table 7-1 below summarises information at locations within the model extents for the three climate change scenarios, with the new bridge in place.

Table 7-1 Summary of results of climate change on the 1% AEP event

Location	2050 Sea Level Rise		2100 Sea Level Rise		2050 Sea Level Rise with 20% increase in rainfall intensity	
	Elevation (m AHD)	Velocity (m/s)	Elevation (m AHD)	Velocity (m/s)	Elevation (m AHD)	Velocity (m/s)
A	8.10	2.31	8.16	2.31	9.46	2.62
B	7.99	2.43	8.04	2.40	9.28	2.73
C	8.04	0.84	8.09	0.91	9.34	0.85
D	7.89	0.85	7.94	0.82	9.16	0.99
E	7.83	2.92	7.90	2.90	9.07	3.34
F	7.82	3.24	7.88	3.2	8.99	3.74
G	7.83	3.18	7.90	3.06	8.98	3.51
H	7.55	0.82	7.61	0.89	8.7	0.83
I	7.47	3.7	7.53	3.67	8.62	4.21
J	7.29	3.26	7.35	3.2	8.52	3.59
K	8.03	0.49	8.10	0.52	9.36	0.49

Table 7-1 shows that water elevation in a one percent AEP event is predicted to be lower than the highest proposed bridge deck elevation, but higher than the lowest proposed bridge deck location for the 2050 sea level rise scenario. The water elevation upstream of the proposed bridge location shows that the deck is overtopped completely in the 2050 sea level rise scenario with an increase in rainfall intensity (refer Section 5.1 for additional details on the proposed bridge deck).

Comparing these results to those in section 5, flood levels are around 130 mm to 190 mm higher than the present day scenario for the 2050 year sea level rise scenario. Results for the 2100 sea level rise scenario are around 200 mm to 250 mm higher than without sea level rise.

The combination of sea level rise and an increase in rainfall intensity has the potential to produce flood levels 1.3 metres to 1.5 metres higher than without any climate change at all. It is noted that there is a large amount of uncertainty in climate change projections and the results should be seen as a test of the potential sensitivity of flooding to future climate change impacts, rather than an estimate of exact increases in flood levels.

Changes in velocities are small for the sea level rise only scenarios, but are greater for the combined sea level rise and rainfall intensity scenario.

The results mean that overtopping of the bridge could be worse in a 1% AEP event than it would be under present day climatic conditions. It is expected that the magnitude of the 0.05 scenario may also increase under climate change. Consideration should be given to the need to incorporate any allowance for additional factors such as climate change in the ultimate limit state and scour design of the bridge. This would be determined through a design risk assessment process in subsequent design stages.

8. Mitigation measures

8.1 Flood levels and velocities

The flood level impacts in the one percent AEP and PMF are considered unlikely to increase the risks to residents, due to the fact that those areas affected under existing conditions are already predicted to be flooded to significant depths. During design development, consideration should be given to flood levels during smaller flood events (e.g. five percent AEP) to confirm that the scale of impact is no worse than it is under the events assessed in this report.

The proposal alters the velocity flow distributions in the vicinity of the bridge with potential impacts on erosion and sedimentation processes (refer to Erosion and Sediment Management Report, SECC 2016). The high existing and proposed environment flow velocities and significant volumes of flow may result in scouring in and around bridge piers and abutments and in the channel upstream and downstream of the bridge unless appropriate design measures are taken. Although the waterway area is increased by the new bridge, there is a localised constriction formed by the proposed retaining wall which results in increased velocities in this location. The retaining wall is not set back from the waterway due to space constraints. In this location in particular, there is high potential for scour, especially given that existing velocities in the waterway are high.

Careful consideration should be given to developing the bridge configuration to limit increases in velocities during design development through orientation of the wall and transition from the channel to and from the retaining wall. The detailed design of the bridge should incorporate appropriate scour protection at piers and abutments. Structural design of the bridge footings and bridge structure needs to allow for the expected hydraulic forces and scour depths both at the bridge and locations where the river could be impacted by changes in velocity profile.

During design development, effects on geomorphological processes should be confirmed through simulation of smaller AEP events which are typically more representative of stream forming flows.

8.2 Water quality

8.2.1 Overview and criteria

As outlined in Section 1.4 and 6.2, there is a need to consider operational water quality and spill management for the proposal. Measures would be designed to capture and treat stormwater runoff and accidental spills.

The final design should aim to achieve the criteria set out in the Roads and Maritime document *Water sensitive urban design guideline – applying water sensitive urban design principals to NSW transport projects* (2016), which are indicated in Table 8-1 and which are also consistent with guidelines in Eurobodalla Shire Council's *Infrastructure Design Standard*.

Table 8-1 Design water quality criteria

Pollutant	Criteria
Total suspended solids (TSS)	80% retention of the annual average load
Total nitrogen (TN)	45% retention of the annual average load
Total phosphorous (TP)	45% retention of the annual average load
Litter	Retention of litter greater than 50 mm for flows up to 25% of the 1 year ARI peak flow
Course sediment	Retention of sediment courser than 0.125 mm for flows up to 25% of the 1 year ARI peak flow
Oil and grease	None visible for flows up to 1% of the 1 year ARI peak flow

8.2.2 Proposed measures

Indicative water quality and spill containment measures proposed are shown in Figure 8-1(Appendix A) and are based on high level drainage configuration information provided with the concept design. The final design measures would be developed together with the detailed design of the road and road drainage.

The Erosion and Sediment Management Report (SEEC, 2016) notes that there is minimal space in most areas for provision of construction stage basins, particularly to the west of the bridge, and for much of the road area on the Batemans Bay side (east of the bridge).

Water from the bridge is proposed to be collected and routed to the drainage network on either side of the bridge. Bridge design drawings show that the bridge is graded from east to west, and that water from the majority of the deck would drain to the western side of the bridge. Concept design drainage drawings show that some water would drain from the eastern side of the bridge, a bio retention and spill basin has therefore been proposed on the eastern side of the bridge (refer Figure 8-1 and Appendix A).

It may be possible to incorporate spill containment basins on the western side of the bridge in the location shown on Figure 8-1. The present design of the road cross fall is towards the north which would make drainage to a basin on the south of the road difficult without conveying flows back under the road via culverts. The location shown should be considered further during detailed design.

As an alternative, it is proposed to install proprietary tertiary treatment devices sufficient to treat sediment, nitrogen and phosphorous and to contain oils and hydrocarbons. Such devices offer the benefit of requiring limited space, though they do not provide large volumes for containment of accidental spills. The product selected may comprise a single device at each location or a combination of devices, for example, an oil and water separator and a biofiltration device.

An example device which may be suitable (subject to design development) would be a Jellyfish® filter by Humes though equivalent devices from other manufacturers exist.

Figure 5 of the Erosion and Sediment Management Report (SEEC, 2013) proposed four sediment basins at the eastern embankment of the proposed bridge location. It is recommended to convert one of these into a single operational basin immediately south of the new bridge alignment on the eastern side. Runoff from the road catchment immediately upstream would be directed to the basin for treatment (refer 8.2.3 for details).

Paper Size A3

0 25 50 100

Metres

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

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LEGEND

- New bridge
- Proposed drainage
- Proposed alignment
- Proprietry device, tertiary treatment
- Swale
- Bioretention & spill basin
- Bioretention/spill basin locations TBC

Roads and Maritime Services
Replacement of the Kings Highway
Bridge over the Clyde River at Nelligen

Job Number	21-25173
Revision	C
Date	19 Aug 2016

Operational Water Quality Treatment
Indicative layout

Figure 8-1

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\WQ Proposal.mxd

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

Data source: General topo - NSW LPI DTDB 2012, Aerial Imagery - sixmaps 2016. Created by:ncbailey

It is noted that ideally the basin should be located above the 20% AEP flood level and where flood velocities would not cause damage to the basin. The 20% AEP should be assessed during design development. Should the location selected not be suitable as a result, a possible alternative location for a basin on the eastern side of the bridge is also shown on the plan.

For the road areas on this side of the bridge that cannot be directed to the basin, provision of a combination of swales, where space permits, and proprietary treatment devices is proposed. Due to the steep road grade east of the bridge, swales would require the introduction of check dams to manage velocities and achieve suitable treatment.

A summary of the proposed treatment and considerations for each location is provided in Table 8-2.

Table 8-2 Water quality treatment considerations

Location	Water quality treatment	Spill containment	Comment	Vegetation and Access	Need for water quality treatment
Bridge View road	Y (swale)	N	Steep road alignment, swale check dams required	Constrained corridor, likely insufficient space for spill basin	To meet water quality targets
Thule Road South	Y (swale)	N	Steep road alignment, swale check dams required	Constrained corridor, likely insufficient space for spill basin	To meet water quality targets
Thule Road north	Y (swale and water quality basin)	Y	Large area available	Cleared land, access possible via Thule Road	Discharge in close proximity to SEPP 14 wetlands
Bridge and Kings Highway west	Y (proprietary device / water quality basin)	Y, space permitting	Constrained corridor but edge locations available	Minimal vegetation, access via Kings Highway / Murray Street	Discharge in close proximity to SEPP 14 wetlands

8.2.3 Water quality and spill basin

The basin would be designed as a water quality basin, combined with spill containment. Water quality basins provide treatment of runoff through filtration, detention and some uptake of pollutants by plants. Runoff is allowed to pond in the basin and filter through the planted basin to a drainage layer underneath. Such basins generally consist of a planted area and sandy loam filter media, underlain by a transition layer and drainage layer. Specification of the filter media, plants and final bioretention area size would be determined based on the final road and drainage design and requirements to meet the targets set out in Table 8-1.

The bioretention area would typically be sufficient to treat a three month flow, with additional volume to manage accidental spills and as well as incorporate spill containment with design of an appropriate overflow to manage higher flows.

A baffle plate or other exclusion device would be incorporated into the basin near the outlet to allow for separation of oils and prevention of discharge of these in the event of a spill. A minimum of 40 cubic metres of spill containment storage should be provided which is expected to be achievable at the nominated basin location.

9. Conclusion and recommendations

This report has been prepared to investigate flood impacts and operational water quality requirements related to construction of a new bridge at Nelligen in accordance with section 2.2 and 2.4 of Appendix C4 of the REF EIS Brief.

The assessment focused on impacts to properties that may become inundated during a flood event, and the change in depths and velocities in these affected areas. It was concluded that properties on Reid Street, Kings Street, Wharf St, Maisies Lane and Clyde Boulevard in the town are inundated by substantial depths greater than 1.5 metres during the events simulated (one percent, 0.05 percent AEP and PMF), and that increases in flood levels at these locations (typically less than 100 mm) were not of an order that would change the flood risk to people, although it was noted that this risk is already high to some areas within Nelligen town in the one percent AEP event.

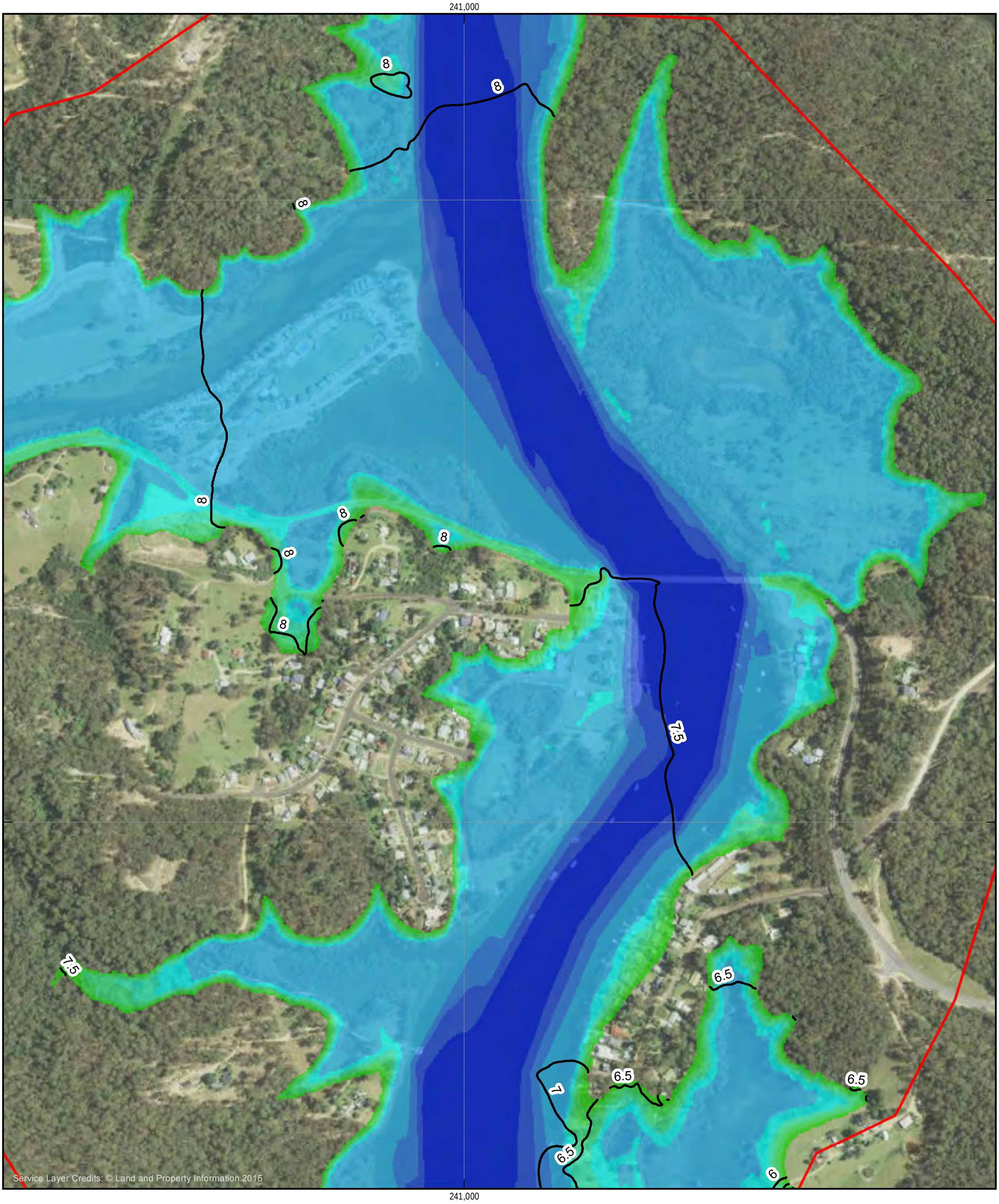
The study also concluded that the proposed bridge would be overtopped in some locations during the one percent AEP event (i.e. where the deck elevation drops to tie in with the existing alignment). Model results also show that the proposed bridge deck would be overtopped during the PMF event, and mostly overtopped during the 0.05 percent AEP event. However, the Kings Highway to the west is also flooded and therefore this does not present a new flood access constraint.

Model results show that velocities increase during the one percent AEP flood event with the implementation of the proposed bridge design. It is recommended to minimise velocities through orientation of the final retaining wall to transition smoothly between the waterway and the bank. The detail design of the bridge would need to incorporate pier and abutment protection measures to alleviate any scouring potential and to withstand the structural loads of the flood waters.

The proposed road design and bridge would require water quality control measures to treat water prior to being discharged into sensitive receiving environments. The proposed combination of measures includes a combined water quality and spill basin, together with other measures such as swales and proprietary treatment devices where limited space prevents provision of large basins.

Appendices

Appendix A – Flood Maps



Flood Depth (m)

0.15 - 1, 1 - 2, 2 - 3, 3 - 4, 4 - 5, 5 - 8, 8 - 10, 10 - 12, 12 - 15

LEGEND

Hydraulic Model Extent

0.5m Flood Elevation Contours

Paper Size A4

0 30 60 120 180 240

Metres

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

N

GHD

Roads and Maritime Services
Nelligen Bridge REF

Job Number 21-25173
Revision B
Date 08 Jul 2016

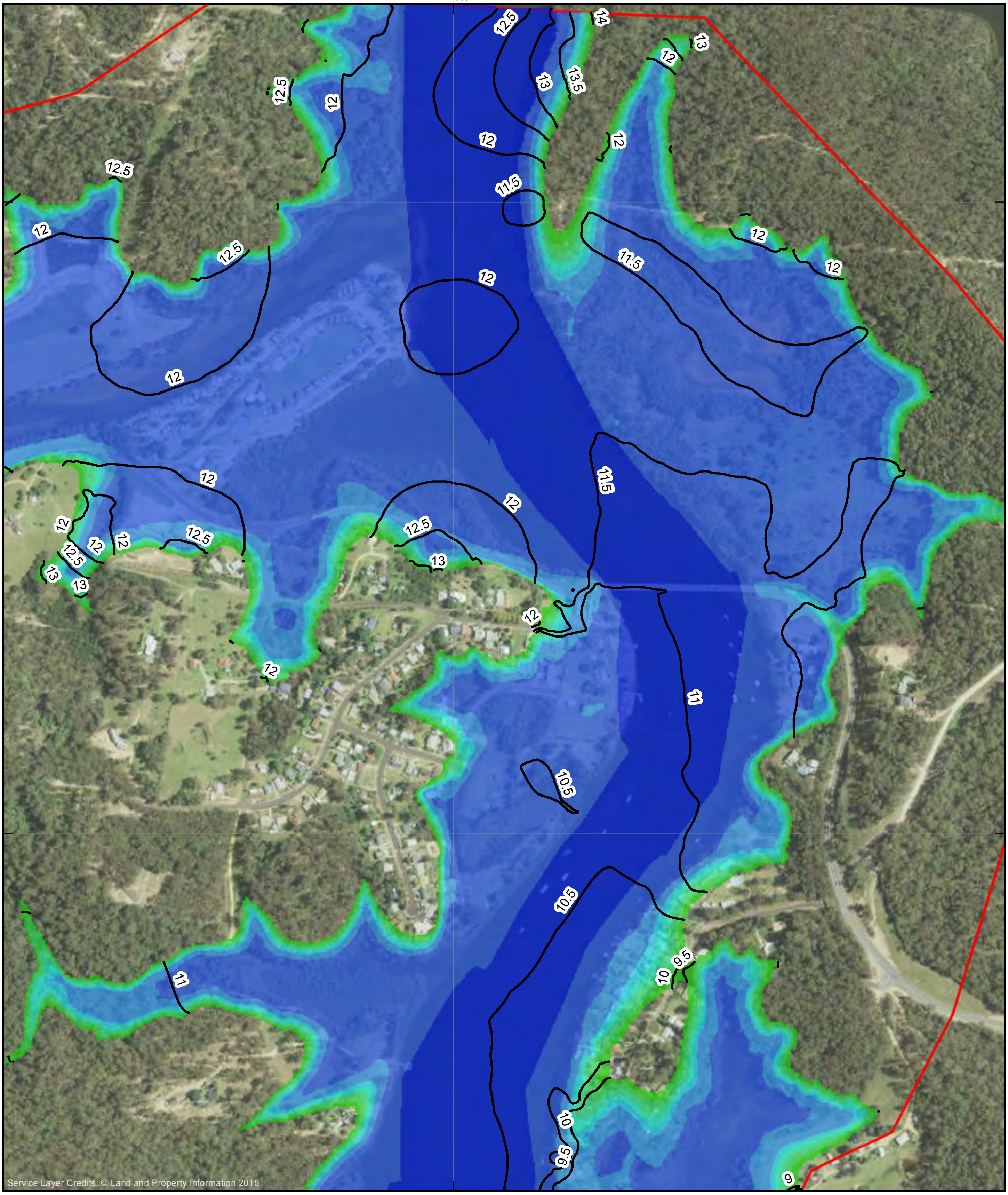
Flood Levels - Existing Scenario
1% AEP Flood Event

Figure 1

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Existing Flood Levels 1%.mxd

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



Flood Depth (m)

< 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 8 | 8 - 12 | > 12

LEGEND

Hydraulic Model Extent

0.5m Flood Elevation Contours

Paper Size A4

0 30 60 120 180 240

Metres

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

N

GHD

Roads and Maritime Services
Nelligen Bridge REF

Job Number 21-25173
Revision B
Date 08 Jul 2016

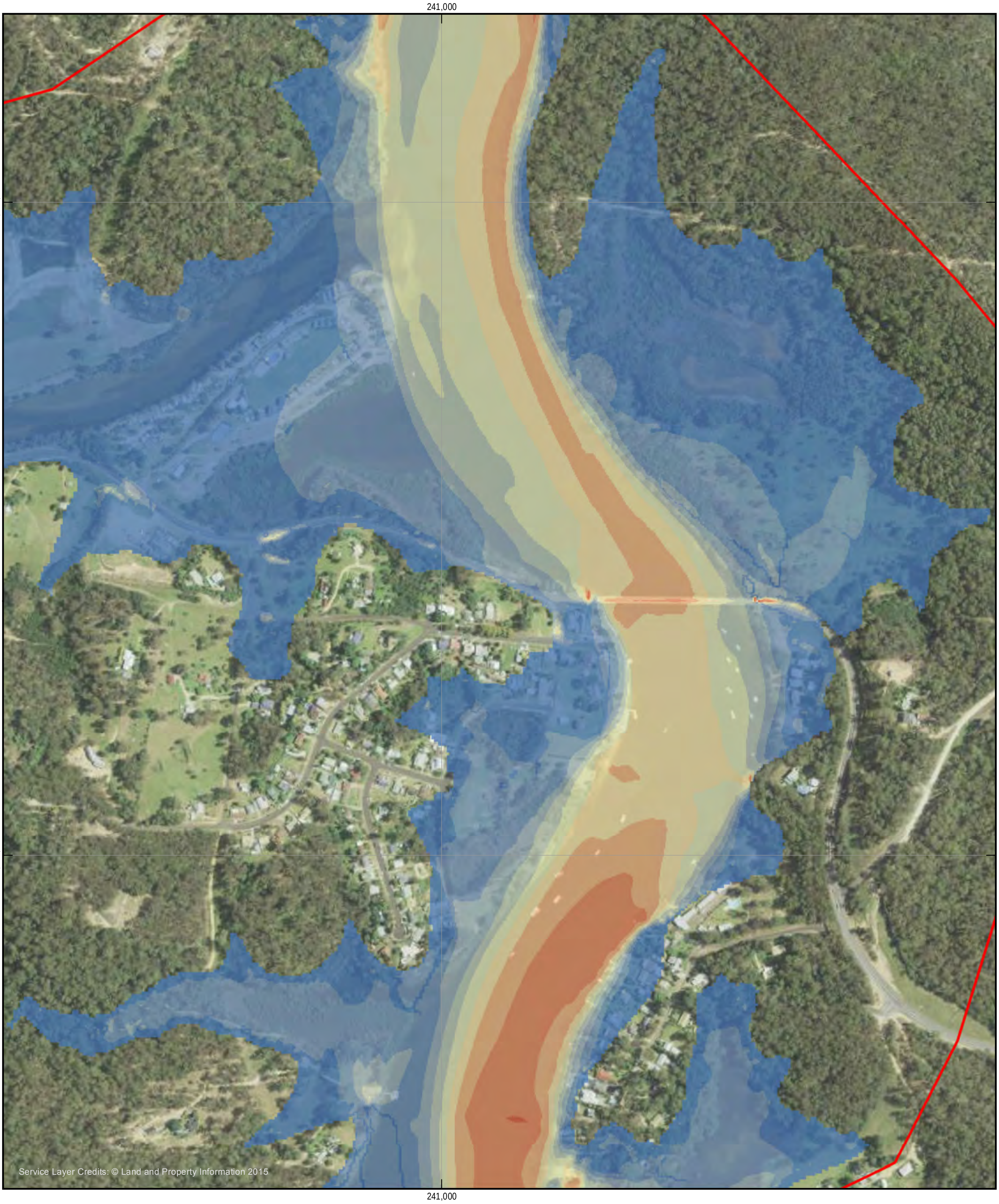
Flood Levels - Existing Scenario
PMF Flood Event

Figure 2

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Existing Flood Levels PMF.mxd

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



Velocity (m/s)

0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 5
> 5

LEGEND

Hydraulic Model Extent

Paper Size A4
0 25 50 100 150 200
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Roads and Maritime Services
Nelligen Bridge REF

Job Number 21-25173
Revision B
Date 08 Jul 2016

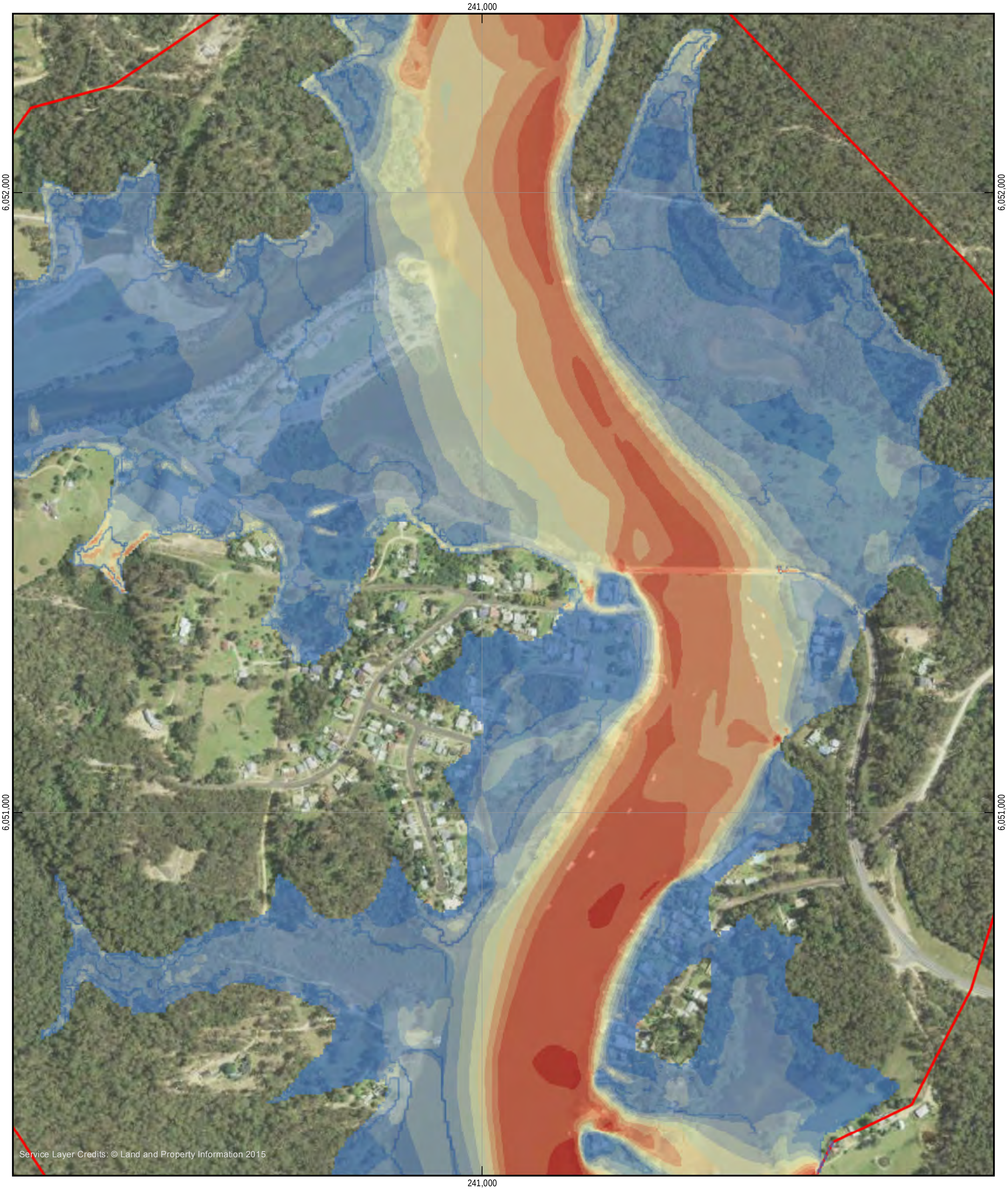
Peak Velocities - Existing Scenario
1% AEP Flood Event

Figure 3

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Existing Velocities 1%.mxd

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



Velocity (m/s)

0 - 0.5 | 0.5 - 1 | 1 - 1.5 | 1.5 - 2 | 2 - 2.5 | 2.5 - 3 | 3 - 3.5 | 3.5 - 4 | 4.5 - 5 | > 5

LEGEND

Hydraulic Model Extent

Paper Size A4

0 30 60 120 180 240

Metres

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

N

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Roads and Maritime Services
Nelligen Bridge REF

Job Number 21-25173
Revision B
Date 08 Jul 2016

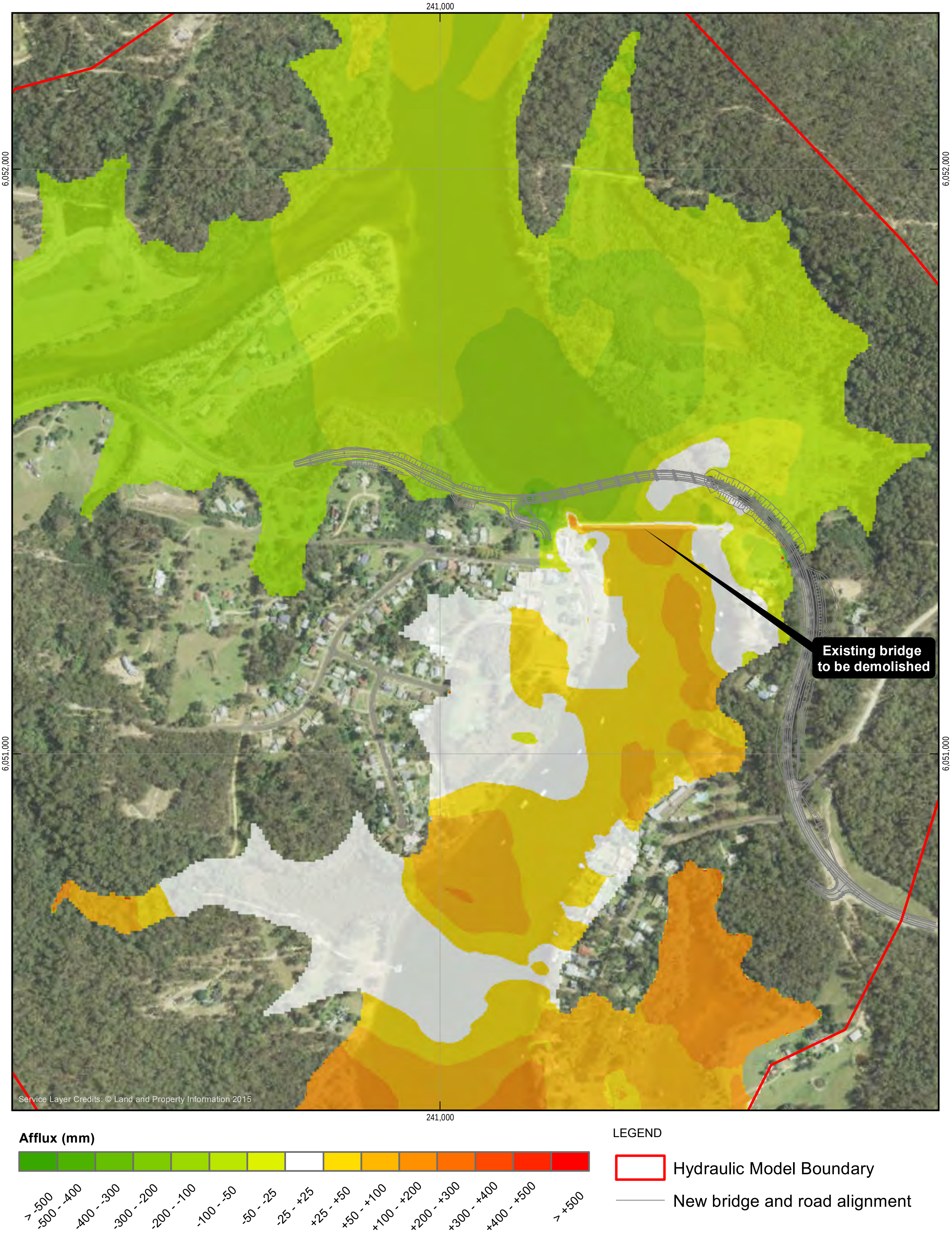
Peak Velocities - Existing Scenario
PMF Event

Figure 4

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Existing Velocities PMF.mxd

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



Paper Size A4

0 30 60 120 180 240

Metres

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

N

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Roads and Maritime Services
Nelligen Bridge REF

Flood Level Impacts
1% AEP Event

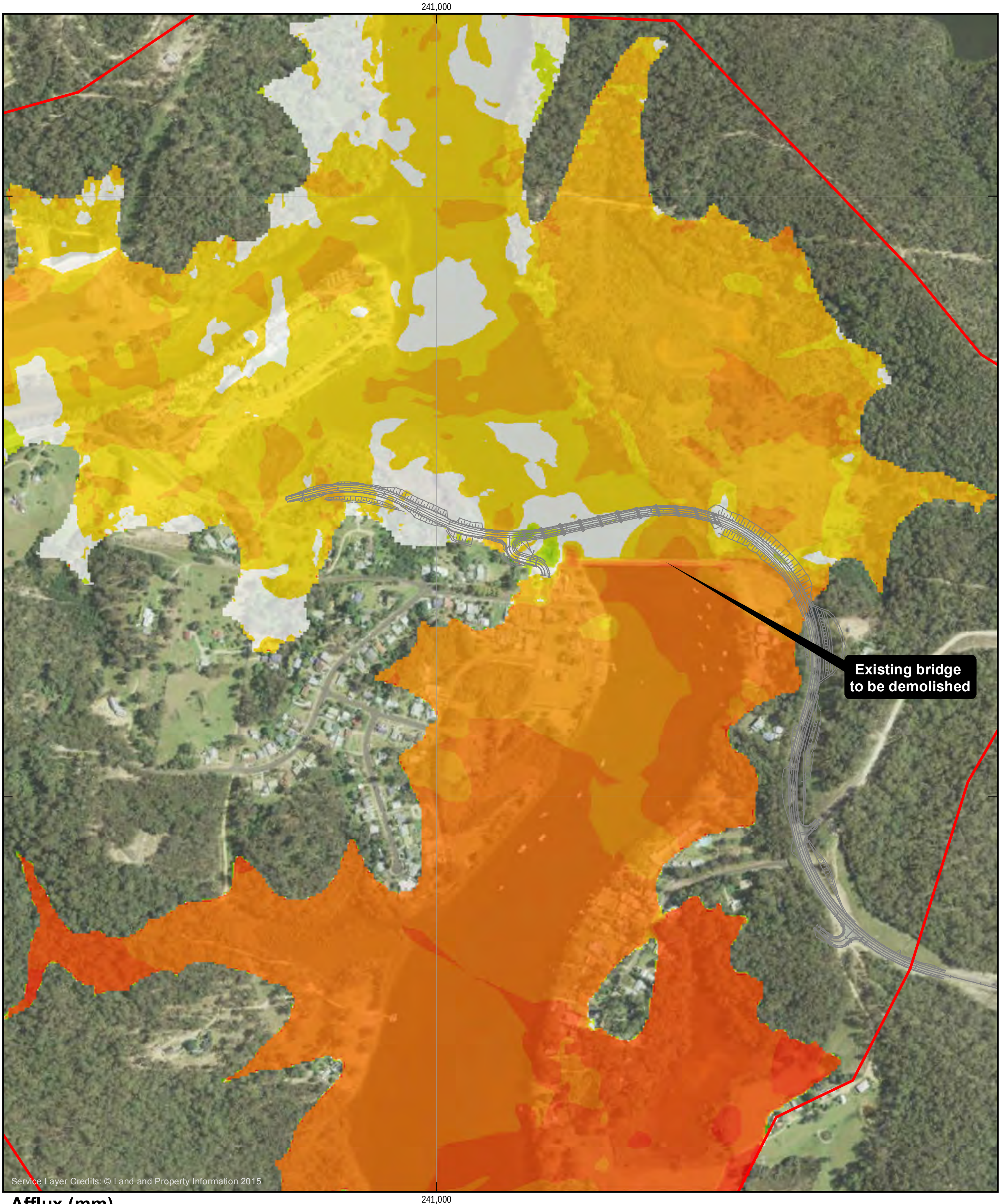
Job Number	21-25173
Revision	B
Date	08 Jul 2016

Figure 5

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Flood Level Impacts 1%.mxd

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



Afflux (mm)

> -500
-500 - -400
-400 - -300
-300 - -200
-200 - -100
-100 - -50
-50 - -25
-25 - +25
+25 - +50
+50 - +100
+100 - +200
+200 - +300
+300 - +400
+400 - +500
> +500

LEGEND

Hydraulic Model Extent

New bridge and road alignment

Paper Size A4

0 30 60 120 180 240

Metres

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

N

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Roads and Maritime Services
Nelligen Bridge REF

Job Number | 21-25173
Revision | B
Date | 08 Jul 2016

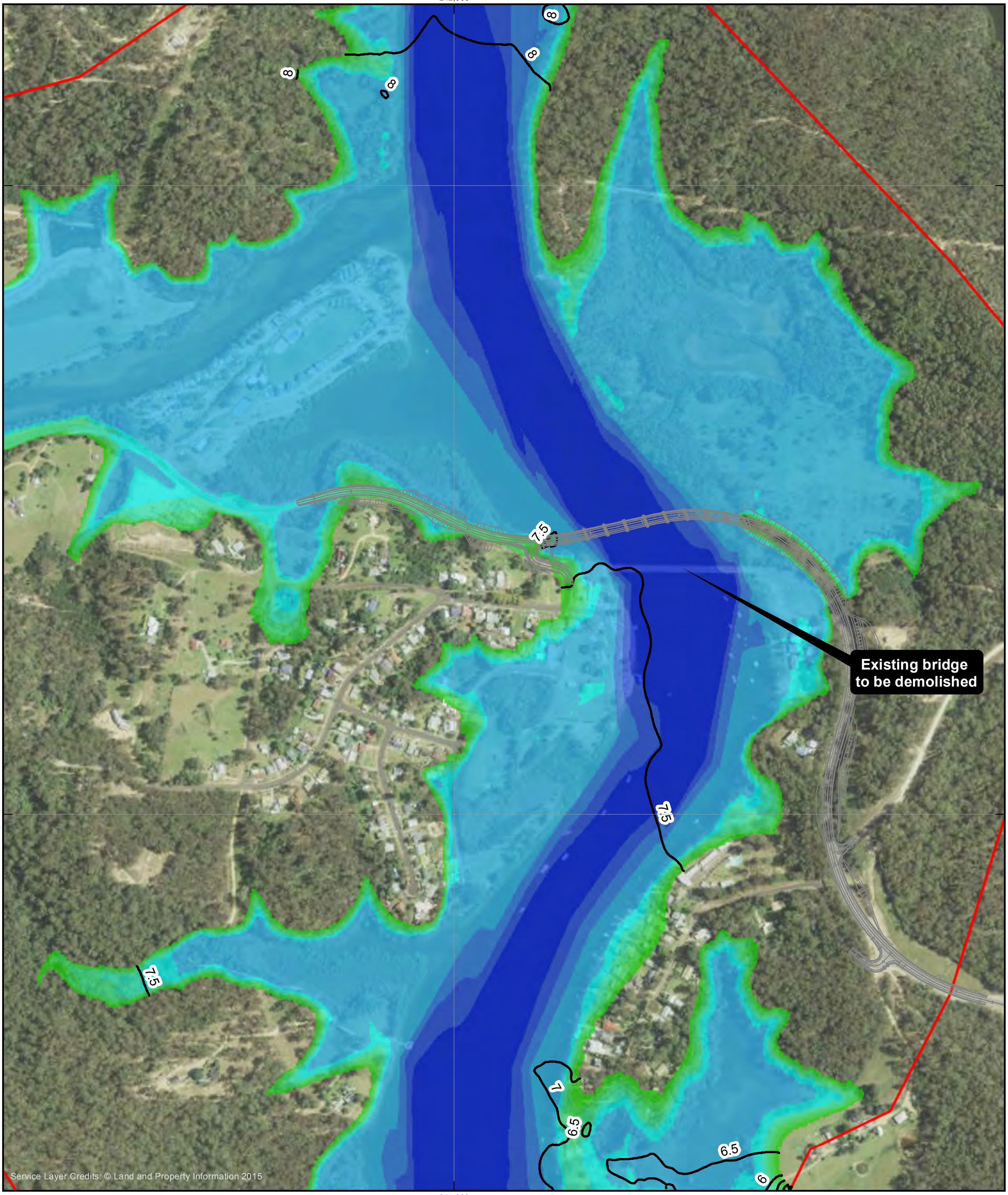
Flood Level Impacts
PMF Event

Figure 6

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Flood Level Impacts PMF.mxd

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



Flood Depth (m)

0.15 - 1, 1 - 2, 2 - 3, 3 - 4, 4 - 5, 5 - 8, 8 - 10, 11 - 12, > 12

LEGEND

Hydraulic Model Boundary

0.5m Flood Elevation Contours

New bridge and road alignment

Paper Size A4

0 30 60 120 180 240

Metres

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

N

Roads and Maritime Services
Nelligen Bridge REF

Job Number 21-25173
Revision B
Date 08 Jul 2016

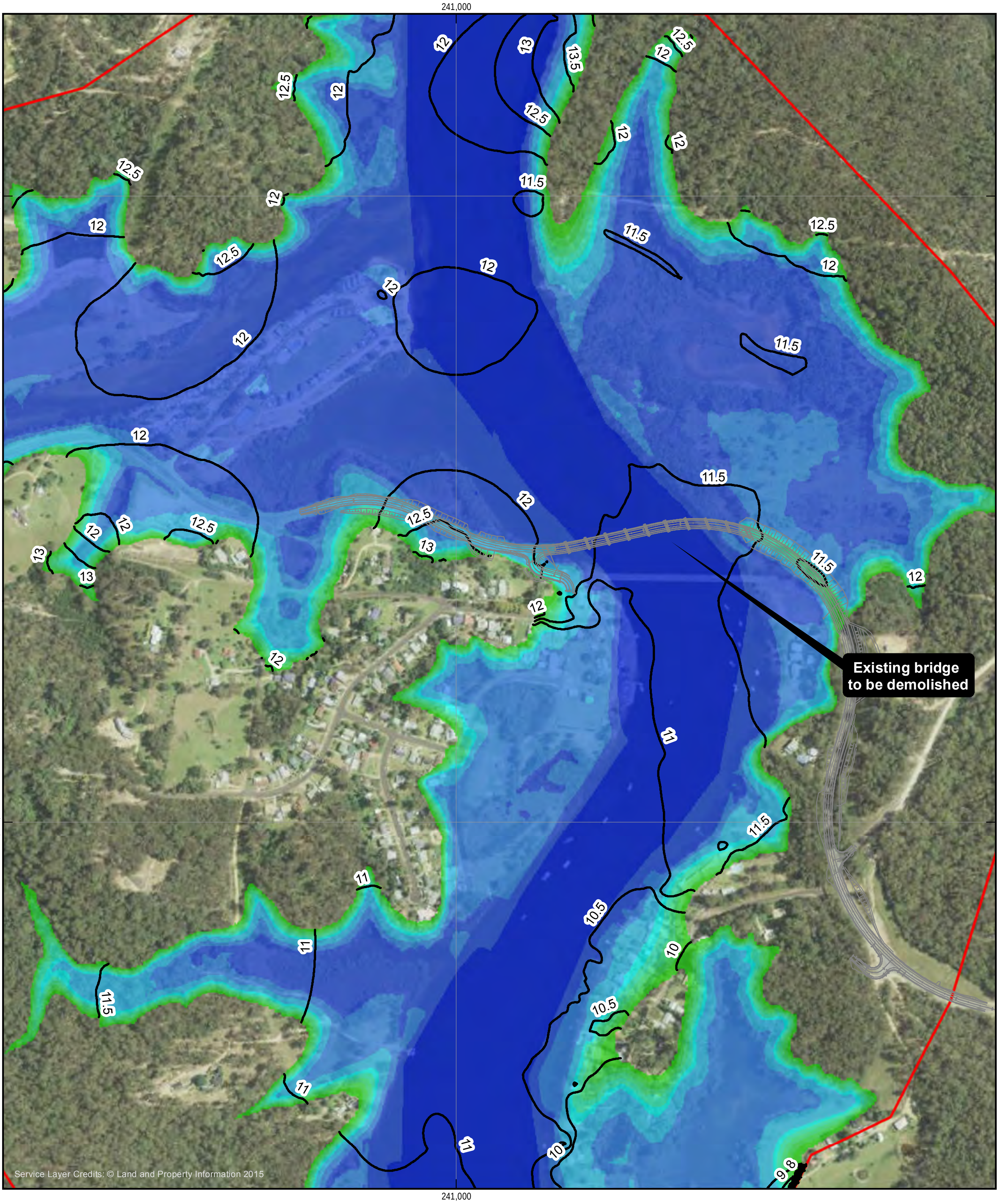
Flood Levels - Design Scenario
1% AEP Flood Event

Figure 7

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Proposed Flood Levels 1%.mxd

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



Flood Depth (m)

0.15 - 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 8 | 8 - 10 | 10 - 12 | >12

LEGEND

- Hydraulic Model Boundary
- 0.5m Flood Elevation Contours
- New bridge and road alignment

Paper Size A4

0 30 60 120 180 240

Metres

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

N

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Roads and Maritime Services
Nelligen Bridge REF

Job Number | 21-25173
Revision | B
Date | 11 Jul 2016

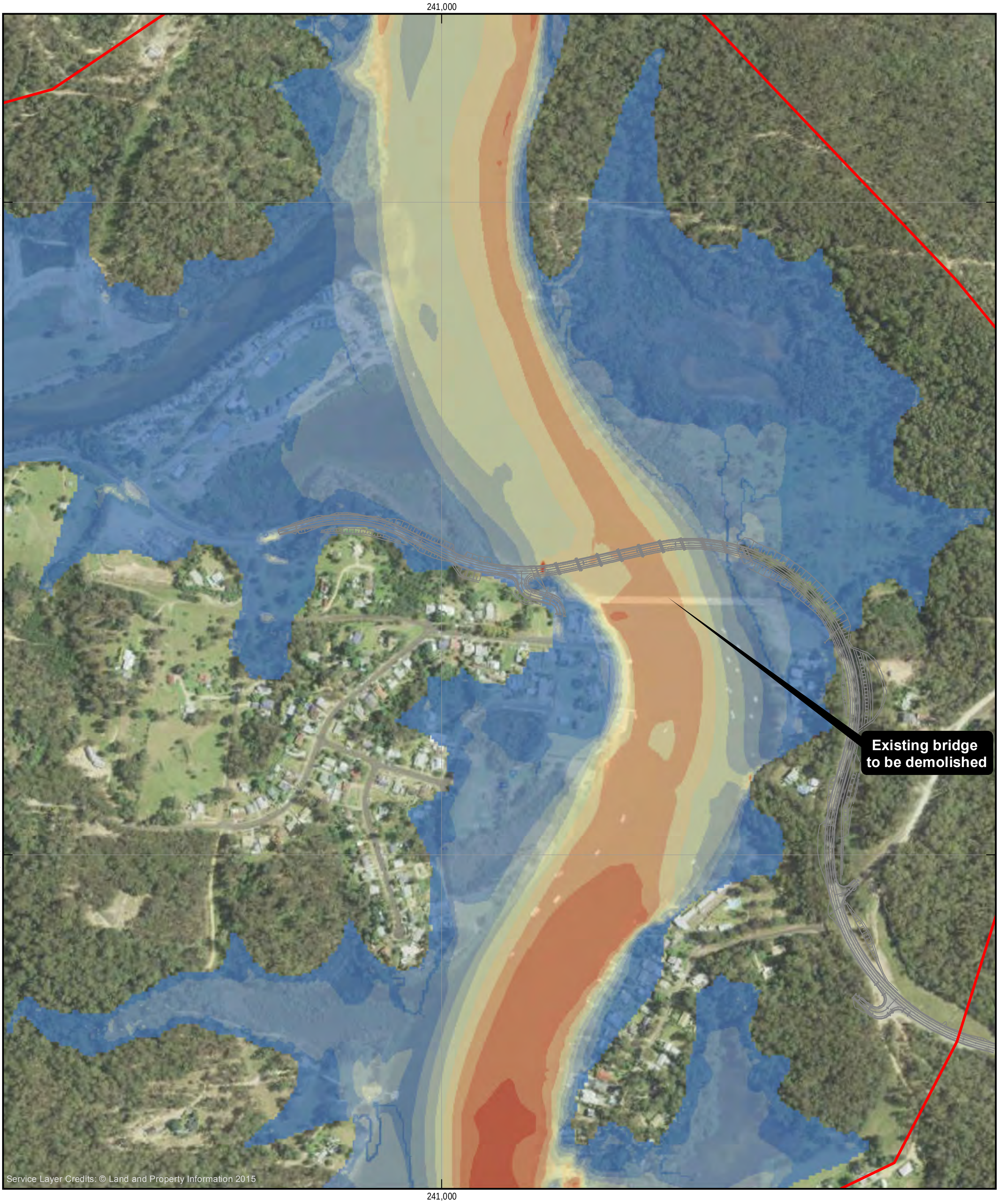
Flood Levels - Design Scenario
PMF Flood Event

Figure 8

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Proposed Flood Levels PMF.mxd

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



Velocity (m/s)

0 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 5
> 5

LEGEND
Hydraulic Model Extent
New bridge and road alignment

Paper Size A4
0 25 50 100 150 200
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Roads and Maritime Services
Nelligen Bridge REF

Job Number 21-25173
Revision B
Date 08 Jul 2016

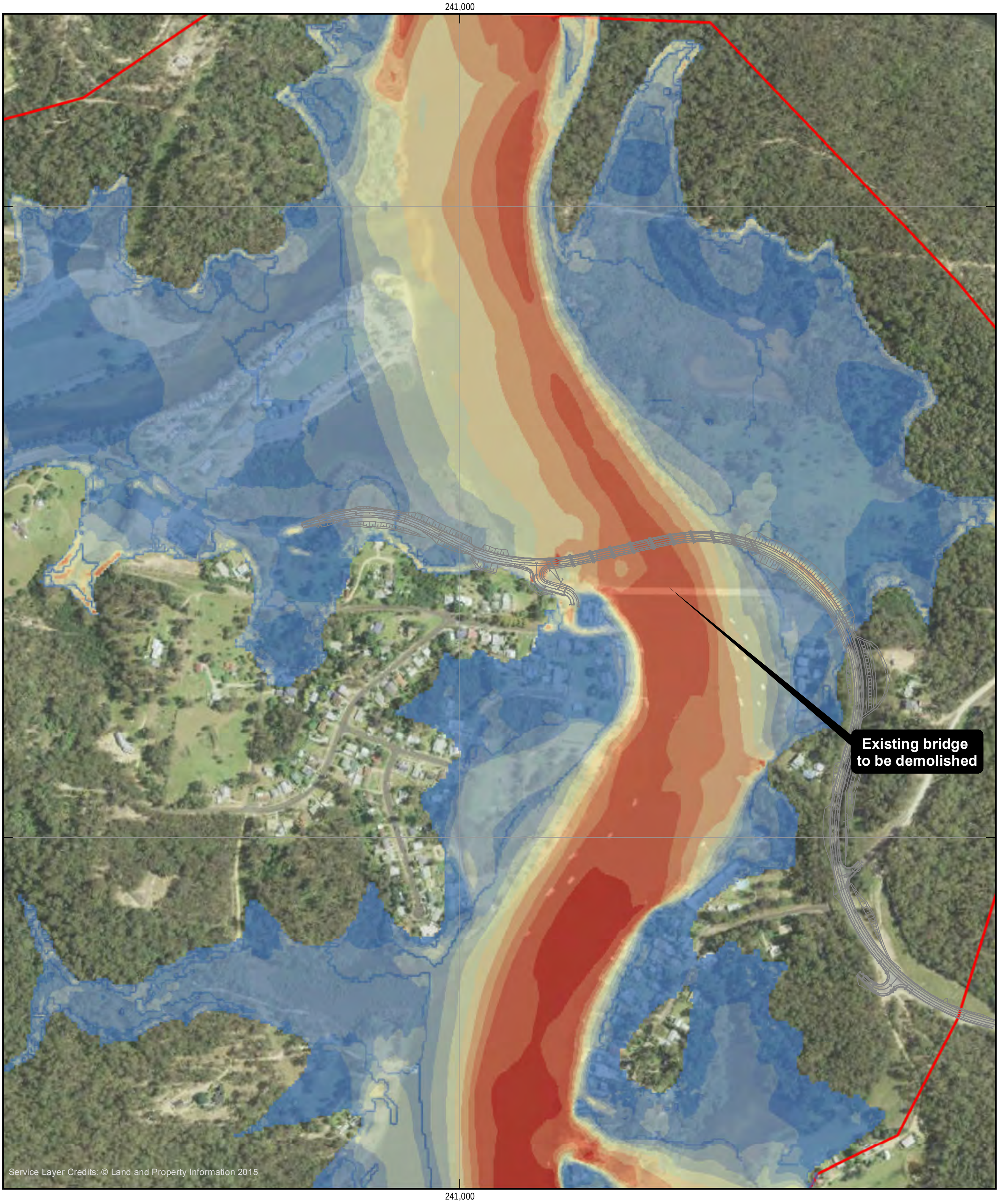
Peak Velocities - Design Scenario
1% AEP Flood Event

Figure 9

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Proposed Velocities 1%.mxd

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



Velocity (m/s)

0 - 0.5 | 0.5 - 1 | 1 - 1.5 | 1.5 - 2 | 2 - 2.5 | 2.5 - 3 | 3 - 3.5 | 3.5 - 4 | 4 - 5 | > 5

LEGEND

Hydraulic Model Extent

New bridge and road alignment

Paper Size A4

0 30 60 120 180 240

Metres

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

N

Roads and Maritime Services
Nelligen Bridge REF

Job Number	21-25173
Revision	B
Date	08 Jul 2016

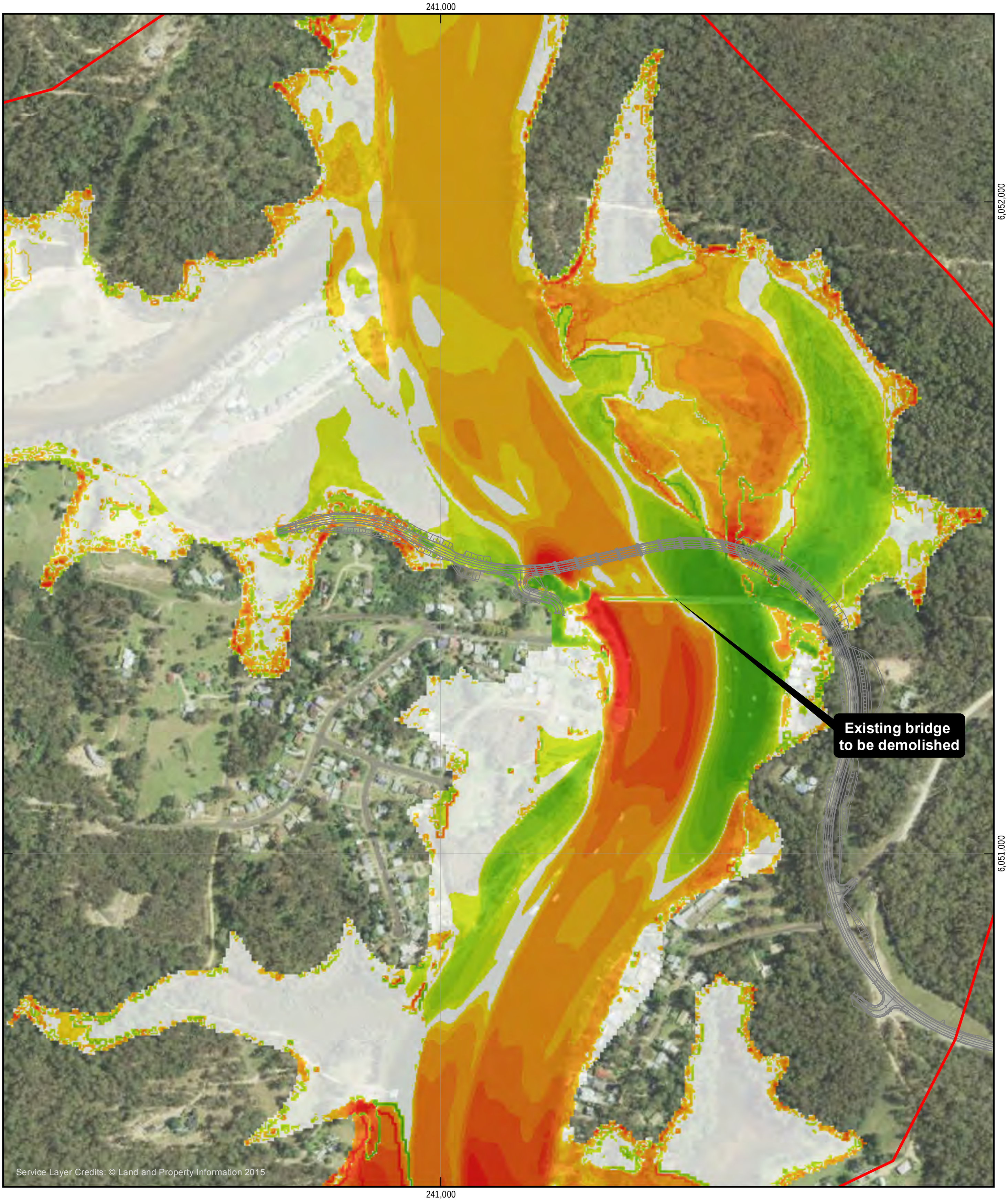
Peak Velocities - Design Scenario
PMF Event

Figure 10

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Proposed Velocities PMF.mxd

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



Velocity Impacts (mm)

> -0.5
-0.5 - -0.4
-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.025
-0.025 - +0.025
+0.025 - +0.05
+0.05 - +0.10
+0.10 - +0.20
+0.20 - +0.30
+0.30 - +0.40
+0.40 - +0.50
> +0.50

LEGEND

Hydraulic Model Extent

New bridge and road alignment

Paper Size A4

0 25 50 100 150 200

Metres

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

N

Roads and Maritime Services
Nelligen Bridge REF

Velocity Impacts
1% AEP Flood Event

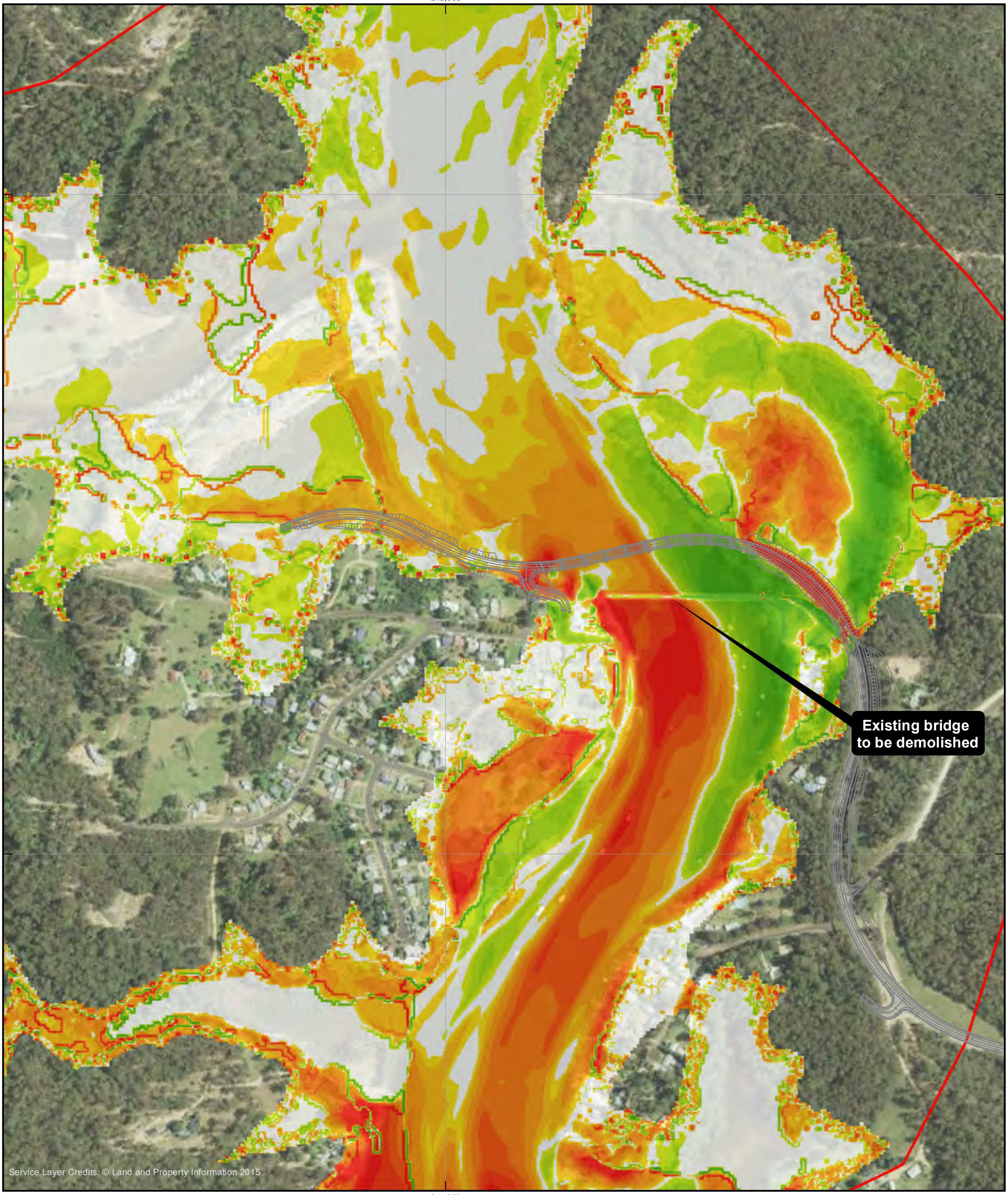
Job Number	21-25173
Revision	B
Date	08 Jul 2016

Figure 11

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Velocity Impacts 1%.mxd

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



Velocity Impacts (mm)

- > -0.5
- -0.5 - -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.025
- -0.025 - +0.025
- +0.025 - +0.05
- +0.05 - +0.10
- +0.10 - +0.20
- +0.20 - +0.30
- +0.30 - +0.40
- +0.40 - +0.50
- > +0.50

LEGEND

- Hydraulic Model Extent
- New bridge and road alignment

Paper Size A4
0 25 50 100 150 200
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Roads and Maritime Services
Nelligen Bridge REF

Velocity Impacts
PMF Event

Job Number	21-25173
Revision	B
Date	08 Jul 2016

Figure 12

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

LEGEND

Hydraulic Model Extent

Paper Size A4

0 62.5 125 250 375 500

Metres

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

N

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Roads and Maritime Services
Nelligen Bridge REF

2D Flood Model Extents

Job Number	21-25173
Revision	B
Date	08 Jul 2016

Figure 13

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\2D Model Extents.mxd

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

LEGEND

● Sample Locations

Hydraulic Model Extent

Paper Size A4

0 40 80 160 240 320

Metres

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

N

GHD

Roads and Maritime Services
Nelligen Bridge REF

Locations of Flood Results

Job Number | B
Revision | A
Date | 08 Jul 2016

Figure 14

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

N:\AU\Sydney\Projects\21\25173\GIS\Maps\MXD\Hydrology Impact Assessment\Sample Results Locations.mxd

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

Appendix B – 0.05 Percent AEP Rainfall Interpolation

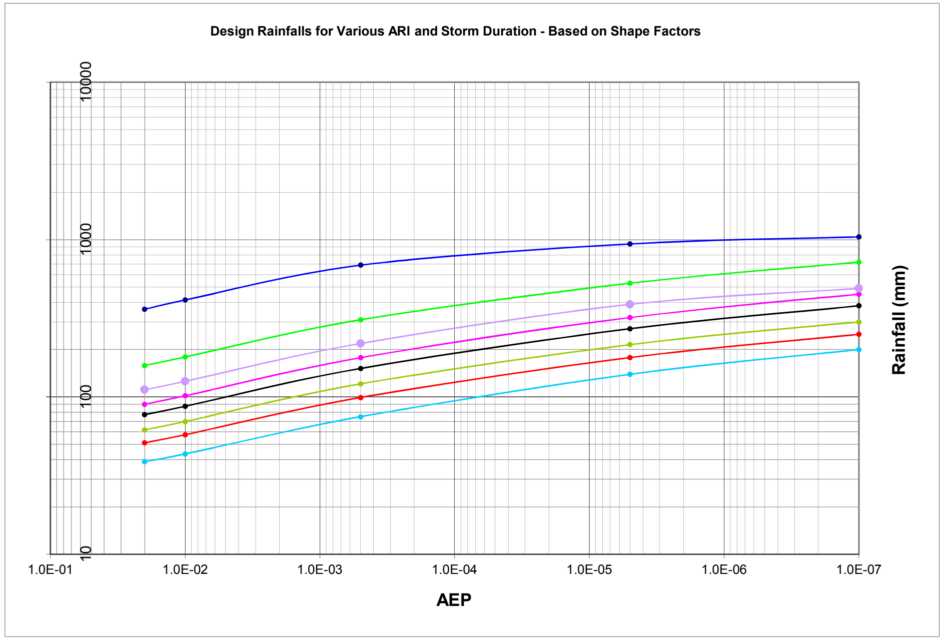
ARR Bk6, Sect 3.6.2: Interpolation Between 1 in 100 AEP and the PMP

Program : Rare Rainfall
Version : 1.0

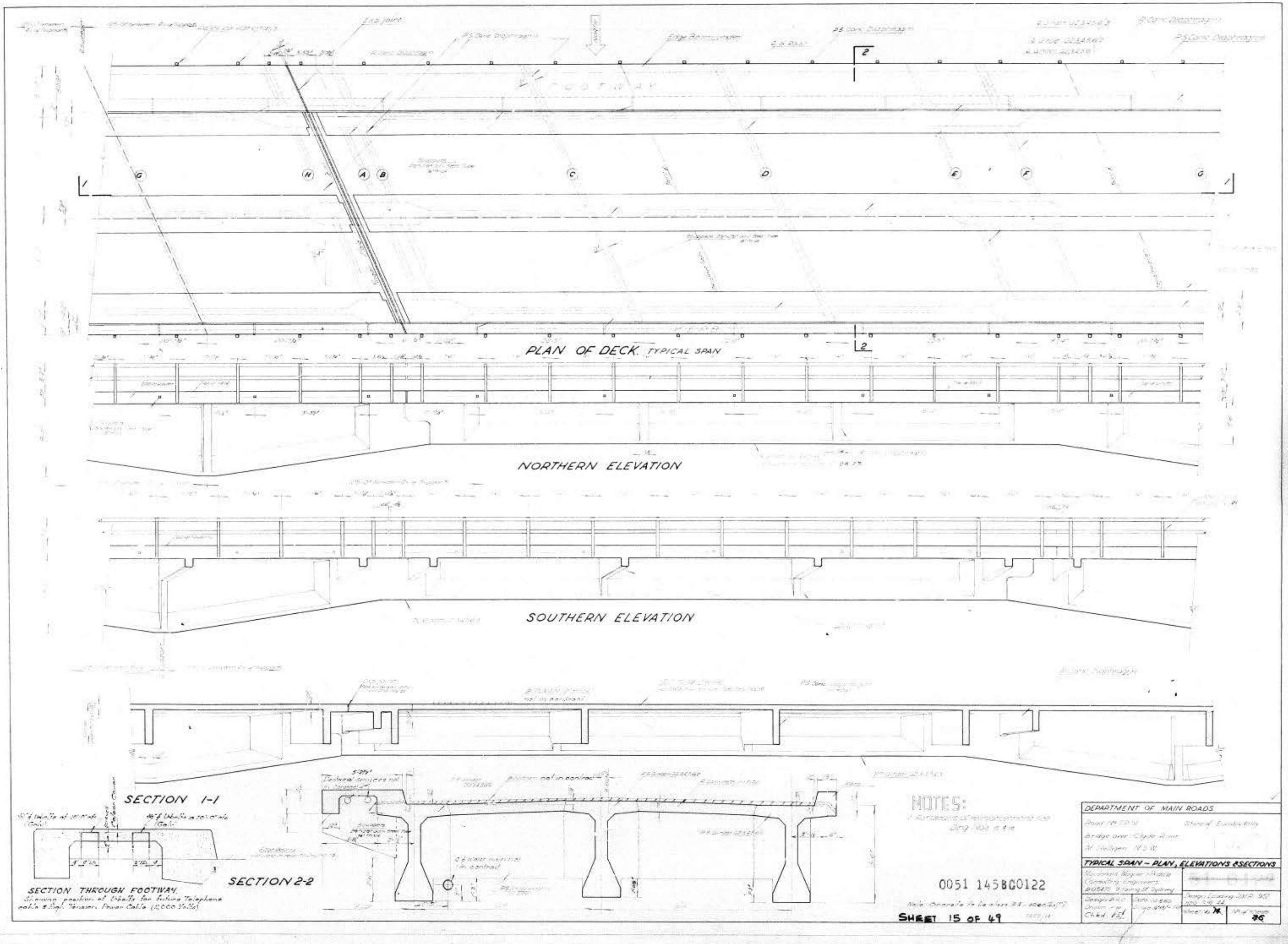
Step	Ref								
Storm Duration (hrs)		36	0.5	0.75	1	1.5	2	3	6
1 in 50 ARI Rainfall Intensity (mm/hr)	*Design IFD (if known)*	11.8	120.0	101.5	89.6	72.0	61.4	48.9	33.1
1 in 100 ARI Point Intensity (mm/hr)	*Design IFD (if known)*	13.6	134.7	114.3	101.3	81.4	69.5	55.4	37.6
1 in 50 ARI Point Rainfall (mm)	*Can enter or calculates*	424.8	70.9	88.8	103.7	123.4	139.3	164.6	218.8
1 in 100 ARI Point Rainfall (mm)	*Can enter or calculates*	489.6	79.5	100.1	117.2	139.6	157.6	186.4	247.9
Catchment Area	*Catchment Plan (km^2)*	1750.0							
1 in 50 ARI Areal Reduction Factor	*ARR, Bk 2, Section 8.2.1*	0.850	0.546	0.575	0.596	0.625	0.646	0.675	0.725
1 in 100 ARI Areal Reduction Factor	*ARR, Bk 2, Section 8.2.1*	0.845	0.546	0.575	0.596	0.625	0.646	0.675	0.725
1 in 50 ARI Areal Rainfall		361	39	51	62	77	90	111	159
1 in 100 ARI Areal Rainfall		414	43	58	70	87	102	126	180
PMP (mm)	*Bulletin 53 or Table 9*	1040	200	250	300	380	450	540	720
AEP of PMP	*ARR, Bk 6, Fig 6*	1.00E-07		*ie. =*			1.0E+07		
log(X_pmp/X_100) / log(X_100/X_50)		6.79	13.26	12.28	11.87	11.93	12.03	11.74	11.11
Intermediate AEPs									
Low value Intermediate AEP	*ARR, Bk 6,Table 6*	2,000	*Must correspond to PMF AEP ie cell D20*						
High Value Intermediate AEP	*ARR, Bk 6,Table 6*	200,000	*Must correspond to PMF AEP ie cell D20*						
X_Low Value Intermediate AEP Ratio	*ARR, Bk 6,Table 6*	0.551	0.357	0.371	0.377	0.376	0.375	0.380	0.392
X_High Value Intermediate AEP Ratio	*ARR, Bk 6,Table 6*	0.889	0.764	0.769	0.772	0.771	0.771	0.773	0.777
1 in Low Value ARI Rainfall (mm)		688	75	99	121	152	178	219	309
1 in High Value ARI Rainfall (mm)		939	139	178	215	272	320	388	528

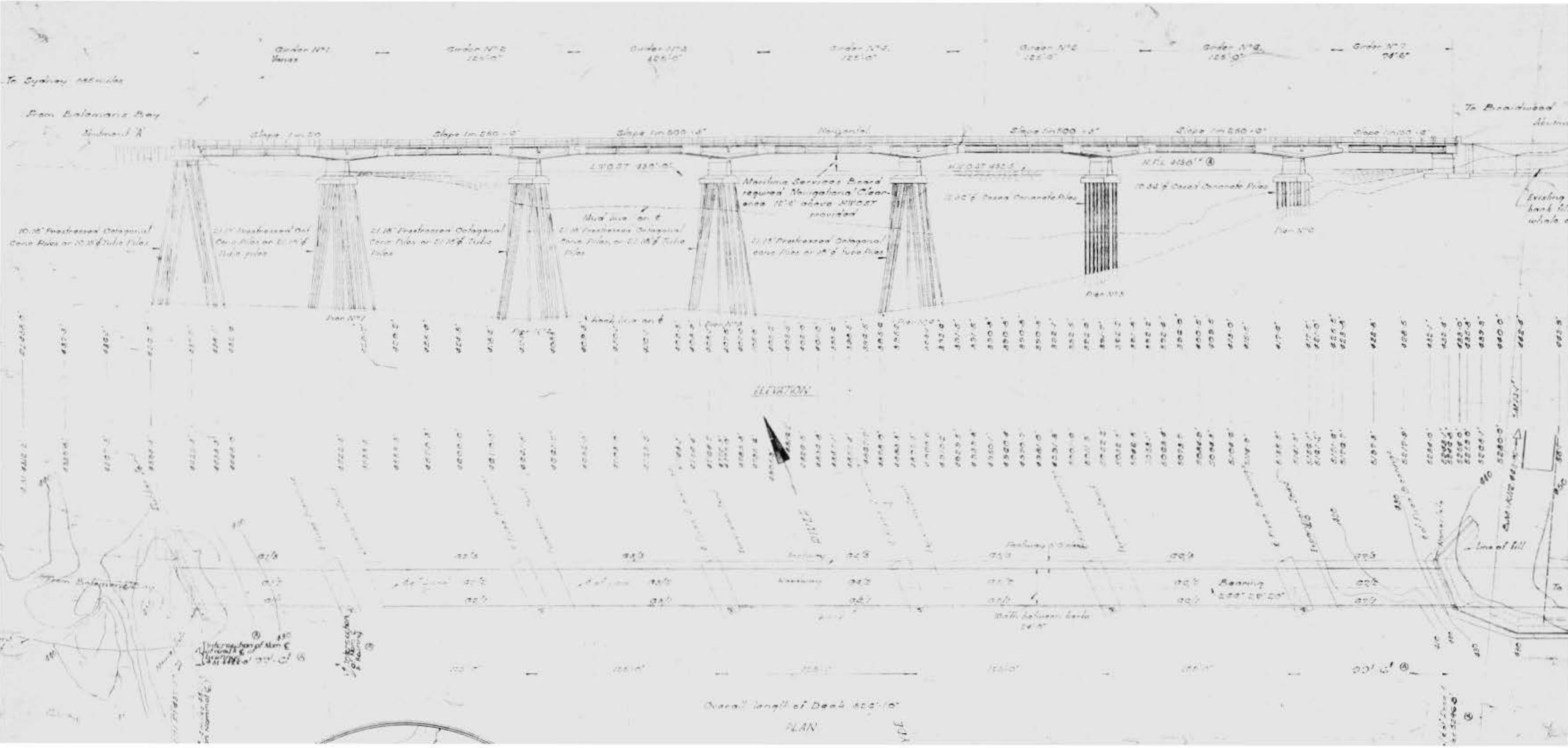
GRAPH DATA = Based on Shape Factors

Storm Duration (hrs)		36	0.5	0.75	1	1.5	2	3	6
0.02	*50*	361.2	38.7	51.1	61.8	77.2	89.9	111.1	158.5
0.01	*100*	413.7	43.4	57.6	69.9	87.3	101.8	125.8	179.6
0.00050	*2,000*	687.8	74.9	99.2	121.1	151.8	177.6	218.8	309.5
0.000005	*200,000*	939.1	139.5	178.2	215.2	271.5	320.1	387.8	528.4
0.0000001	*10,000,000*	1040.0	200.0	250.0	300.0	380.0	450.0	490.0	720.0
0.00500	*200*								
0.00200	*500*								
0.00100	*1,000*								
0.00020	*5,000*								
0.00010	*10,000*								
0.00005	*20,000*								
0.00002	*50,000*								
0.00001	*100,000*								
0.00000	*500,000*								



Appendix C – Existing bridge design drawings


PLAN OF DECK. TYPICAL SPAN
NORTHERN ELEVATION
SOUTHERN ELEVATION
SECTION 1-1
SECTION 2-2
SECTION THROUGH FOOTWAY.
Showing position of Uballs for future Telephone cable & Sml. Tension Power Cable (2,000 Volts)
NOTES:
0051 145BG0122
SHEET 15 OF 49
DEPARTMENT OF MAIN ROADS
Bridge over Clyde River
TYPICAL SPAN – PLAN, ELEVATIONS & SECTIONS
Consulting Engineers
Chkd.



ELEVATION
PLAN
Maritime Services Board required Navigational Clearance
Overall length of Deck
Line of fill
Bearing

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Document Status

Revision	Author	Reviewer		Approved for Issue		
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0	D Lloyd N. Bailey	N Bailey	On file*	K Smallwood		12/09/2016

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