Appendix G

Hydrology and flooding impact assessment

Transport for NSW

Townson Road Upgrade between Richmond Road and Jersey Road – Stage 1

Hydrology and flooding impact assessment

December 2020

Executive Summary

Transport for NSW (TfNSW) is proposing to construct a four-lane divided road along Townson Road/Burdekin Road corridor linking Richmond Road, Marsden Park in the west and Burdekin Road, Schofields in the east. The length of the overall program of work is about 3.6 kilometres.

Stage 1 (the proposal) involves an upgrade of about 1.6 kilometres of road extending from Richmond Road to south of Jersey Road. Staged delivery of the proposal would involve:

- Interim phase – two lanes plus earthworks
- Ultimate phase – completion of remainder of the works for a four-lane dual carriageway.

The proposal crosses Bells Creek and a tributary of Eastern Creek. The existing Townson Road formation that crosses Bells Creek is frequently overtopped by flood waters in the existing condition. The proposal will upgrade the flood immunity to 0.2 per cent AEP to provide a flood evacuation route for the developable land which lies to the east of the creek crossing. The proposal will include new bridges across Bells Creek and new culverts and swales to manage stormwater flows east of Victory Road.

Existing and proposed flooding behaviour in Bells Creek has been modelled using TUFLOW for the five per cent, two per cent and one per cent AEP and PMF flood events. Additionally, the 0.2 per cent AEP event was modelled for proposed conditions to confirm that the proposal can operate as a flood evacuation route for this event.

Flood maps were prepared from the flood model outputs showing existing and proposed flood levels, flood velocities and flood hazard. Flood level impacts and velocity impacts were also mapped.

For the one per cent AEP event, on the western floodplain, a maximum flood level impact of 0.02 metres occurs on existing commercial land which adjoins and forms part of the Bells Creek floodplain, south of Townson Road. This increase in flood levels will not impact existing buildings on this land. On the eastern floodplain, the maximum impact is 0.19 metres at the edge of the floodplain, south of Townson Road. This impact occurs in land that is zoned as ‘drainage land’ and is not currently developable land.

Downstream (north) of Townson Road, there are localised minor increases in flood levels adjacent to Townson Road, which occur at the proposed bridge opening locations, but which reduce to zero within one hundred metres downstream of the proposal. The land affected by these altered flood levels is zoned under Blacktown Council’s Local Environment Plan as “Parks” and is not developable.

The raising of Townson Road will result in increased flood levels in the PMF event, with flood level increases of up to 1.0 metres predicted to occur upstream (south) of Townson Road. adjacent properties will have rising access to higher ground for refuge during a PMF.

The proposal will incorporate measures to mitigate potential changes to flooding conditions and manage the conveyance of stormwater throughout the proposal. These measures will include:

- The inclusion of two floodplain bridges across the Bells Creek floodplain to mitigate upstream flood impacts and provide passage for 0.2 per cent AEP flood event to enable Townson Road to act as a flood evacuation route during rare flood events.
- Culverts to allow passage for stormwater across the proposal and to minimise flooding impacts on adjacent land.

- Vegetated swales on both sides of the proposal east of Victory Road to direct off-site stormwater flows safely to the east towards the tributary of Eastern Creek.
- Scour protection to the Bells Creek bridge abutments to minimise the possibility of scour of the road embankment. Scour protection comprising of rock or scour resistant vegetation will also be provided on culvert outlets and within channels.
- Inclusion of a bund adjacent to the existing nursery designed to minimise flooding impacts on the nursery in the interim phase of the project to replicate existing conditions. Flood modelling demonstrates that this bund will provide effective flood mitigation to the nursery.

Climate change modelling considering rainfall intensity increasing by 15 per cent showed that one per cent AEP flood levels could rise by up to 0.15 metres in Bells Creek. This would not impact the flood immunity of the proposal. Consideration of climate change impacts on rarer events to assess the evacuation route flood immunity was not undertaken due to current uncertainty around climate change impacts on rarer rainfall events.

Glossary of terms

Definitions	
Annual Exceedance Probability	The likelihood of a flood of a given magnitude occurring in any one year, expressed as a percentage.
Australian Height Datum	A common reference level used in Australia which is approximately equivalent to the height above sea level.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Cumulative impact	The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.
Direct impact	Where an event or circumstance is a direct consequence of the action.
Indirect impact	Where a primary action is a substantial cause of a secondary event or circumstance.
Locality	The area within a 5-kilometre radius of the study area.
Mitigation	Action to reduce the severity of an impact (OEH 2014).
Mitigation measure	Any measure that facilitates the safe movement of wildlife and/or prevents wildlife mortality.
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.
Probable Maximum Flood	The largest flood that could conceivably occur at a given location.
Proposal site	The area of land that is directly impacted on by a proposed Major Proposal that is under the EP&A Act, including access roads, and areas used to store construction materials (OEH 2014). Includes areas impacted by construction and operational footprints.
Study area	The area directly affected by the development and any additional areas likely to be affected by the development, either directly or indirectly (OEH 2014).

Abbreviations	
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
BOM	Bureau of Meteorology
CEMP	Construction Environmental Management Plan
CGM	Global Climate Model
FMP	Flood Management Plan
LiDAR	Light Detection and Ranging
PMF	Probable Maximum Flood
RCP	Representative Concentration Pathway
REF	Review of Environmental Factors

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1. Introduction

1.1 Overview

Transport for NSW (TfNSW) is proposing to construct a four-lane divided road along Townson Road/Burdekin Road corridor linking Richmond Road, Marsden Park in the west and Burdekin Road, Schofields in the east. The length of the overall program of work is about 3.6 kilometres.

The overall program of work consists of two stages:

- Stage 1 (the proposal) involves an upgrade of about 1.6 kilometres of road extending from Richmond Road to south of Jersey Road (see Figure 1-1).
- Stage 2 is about two kilometres in length involving the construction of a new road between the Stage 1 tie-in and Burdekin Road.

Stage 2 is subject to a separate planning approval.

Staged delivery of the proposal would involve:

- Interim phase – two lanes plus earthworks (Figure 1-2).
- Ultimate phase – completion of remainder of the works for a four-lane dual carriageway.

The proposal is located within the Marsden Park Industrial and West Schofields precincts of the North West Growth Area, about 37 kilometres north-west of the Sydney central business district and three kilometres west of Schofields

TfNSW is the proponent of the proposal, and an environmental assessment in the form of a review of environmental factors (REF) is being prepared in accordance with the requirements of Division 5.1 of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act).

This report assesses and documents the potential flooding and hydrology impacts of the proposal.

1.2 Proposal outline

The key features of the proposal are shown in Figure 1-1 and include:

- Widening and upgrading about 1.6 kilometres of Townson Road, between Richmond Road and Durham Road/Jersey Road, to provide:
  - Two traffic lanes, about 3.5 metres wide in each direction
  - A new section of Townson Road about 250 metres long, to the east of the existing alignment, between Meadow Road and Durham Road/Jersey Road
  - A temporary connection road extending from the stub to Durham Road/Jersey Road to maintain access and connectivity until Stage 2 is operational
  - A new southbound slip lane at Richmond Road intersection from Townson Road
- Constructing two bridges, each about 36 metres long, to reduce flooding afflux with one bridge over Bells Creek and another bridge about 50 metres east of Bells Creek
- Providing two new signalised intersections allowing all turning movements to and from Townson Road/Victory Road/A New Road, and formalised pedestrian crossings at each leg of the signalised intersections
- Constructing stubs for Victory Road north and the new road to the north and south of the Townson Road intersection, with a traffic lane in each direction about 3.5 metres wide and a footway on either side, about 1.2 metres wide

- Providing a shared path about three metres wide for pedestrians and cyclists on the southern side of Townson Road along the length of the proposal, and a pedestrian crossing across the new southbound slip lane from Townson Road to Richmond Road
- Providing a footpath about 1.2 metres wide on the northern side of Townson Road along the length of the proposal and at the intersections.

This interim phase allows the surrounding developments to progress and allows utilities to be relocated to their ultimate location. It is anticipated that construction of the interim phase would commence in early 2022 and would be open to traffic in 2023. Completion of the ultimate phase of the proposal would take place around five years after completion of the interim phase.

1.3 Scope of this assessment

The purpose of this report is to document the outcomes of the assessment of the impacts of the proposal on regional flooding. This report supports the REF for the proposal. The scope of assessment included:

- Identification of the existing flooding conditions in the proposal area
- Assess the potential operational flooding impacts of the proposal
- Determine suitable mitigation measures in order to minimise or eliminate any flooding impacts resulting from the proposal
- Prepare a report summarising the findings of the study.

1.4 Legislative context

An REF is prepared to satisfy Transport for NSW duties under Section 5.5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" and Section 5.7 in making decisions on the likely significance of any environmental impacts. This hydrology assessment forms part of the REF being prepared for the proposal and assesses the hydrology impacts to meet the requirements of the EP&A Act.

Environmental Planning and Assessment Act 1979

The proposed development is a Division 5.1 activity under the EP&A Act. The EP&A Act forms the legal and policy platform for proposal assessment and approval in NSW and aims to, amongst other things, 'encourage the proper management, development and conservation of natural and artificial resources. All development in NSW is assessed in accordance with the provisions of the EP&A Act and the *Environmental Planning and Assessment Regulation 2000*. The determining authority for the project is Transport for NSW.

New South Wales Flood Prone Land Policy

The primary objective of the flood prone land policy is to reduce the impact of flooding and flood liability of owners and occupiers of flood prone land. The policy adopts a merit-based approach for development decisions in the floodplain taking into account social, economic and ecological factors, as well as flooding considerations.

The NSW Floodplain Development Manual (2005) supports the NSW Government's Flood Prone Land Policy. The manual provides strategies for managing occupation and use of the floodplain, conserving risk management principles. These are based on a hierarchy of avoidance, minimisation (using planning controls) and mitigation works. The manual applies to floodplains across NSW in both rural and urban areas and is used to manage major drainage issues in overland flooding areas.

Water Management Act 2000

The Water Management Act 2000 (WM Act) provides a framework for the sustainable and integrated management of water sources across NSW. The Act primarily deals with the establishment of management plans for committees who manage water management areas, issue of access licenses for users to retrieve water from a designated area and approvals for the use of water from a particular location.

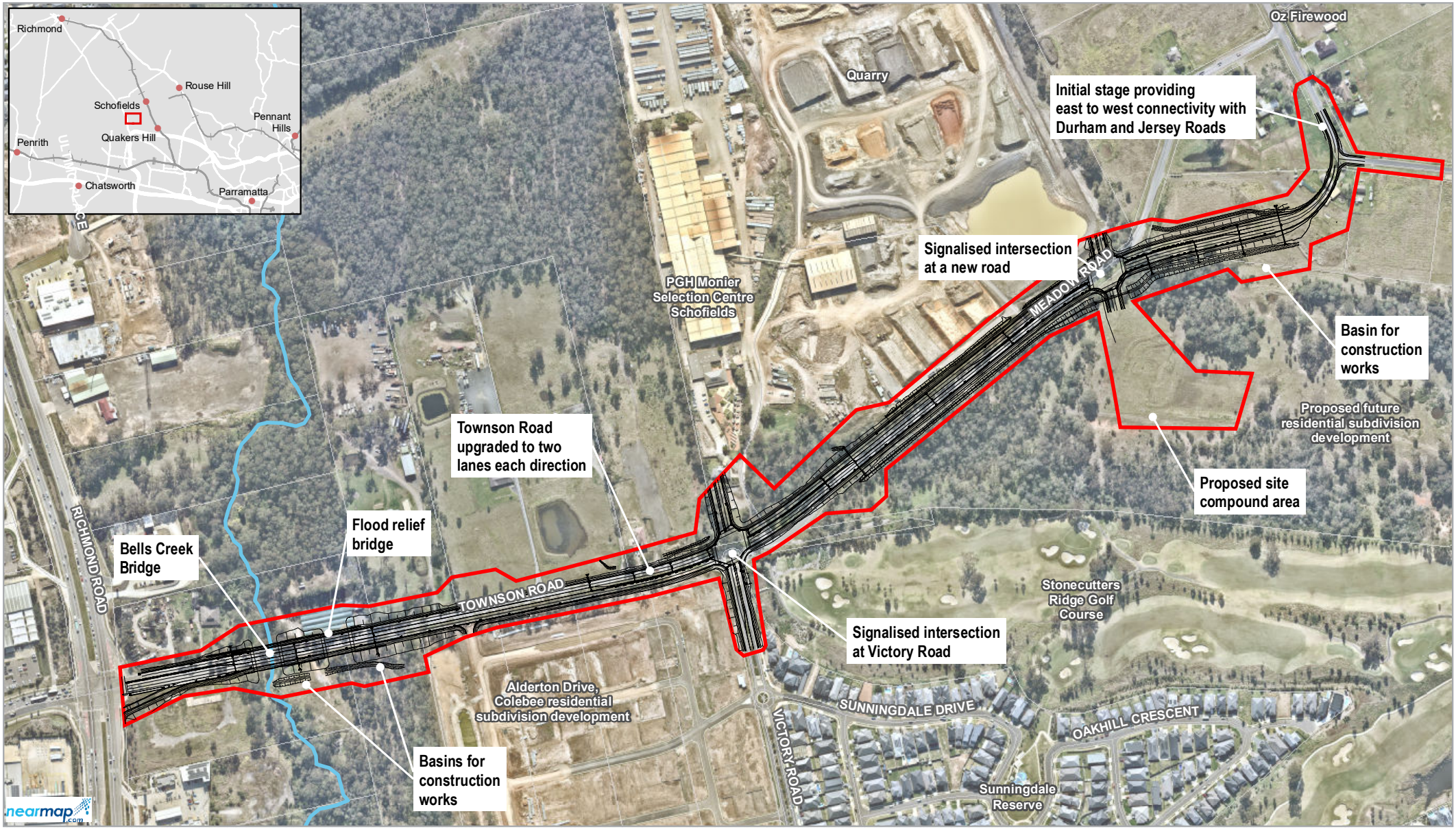
Under Section 91 of the WM Act, approval is required for a 'controlled activity that is undertaken on 'waterfront land'. The proposed activity is not considered to be a controlled activity under the WM Act.

It is important to note that public authorities are exempt from carrying out a controlled activity on waterfront land (Section 91E of the WM Act) in accordance with clause 38 of the Water Management (General) Regulation 2011.

1.5 Report structure

The report is comprised of the following sections:

- **Section 2 – Methodology:** a brief summary of the methods and guidance used for the assessment of the proposal
- **Section 3 – Existing environment:** summarises the existing hydrology environment
- **Section 4 – Criteria:** outlines the relevant criteria for the proposal during construction and operation
- **Section 5 – Construction impact assessment:** discusses the construction impacts of the proposal and results of the hydrology assessment
- **Section 6 – Operational impact assessment:** discusses the operational impacts of the proposal and results of the hydrology assessment
- **Section 7 – Cumulative impacts:** discusses the impacts of nearby projects which may be under construction or operational during a similar timeframe
- **Section 8 – Mitigation and management measures:** provides recommendations of proposed mitigation options for the construction and operational impacts of the proposal
- **Section 9 – Conclusion:** presents a summary of flooding and hydrology assessment findings and sets out the principal conclusions for the study
- **Section 10 – References:** presents the documents that have been referenced within this report.



LEGEND

The proposal *Subject to detailed design

Construction

Cadastre

Paper Size ISO A4

0 25 50 75 100

Metres

N

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

GHD

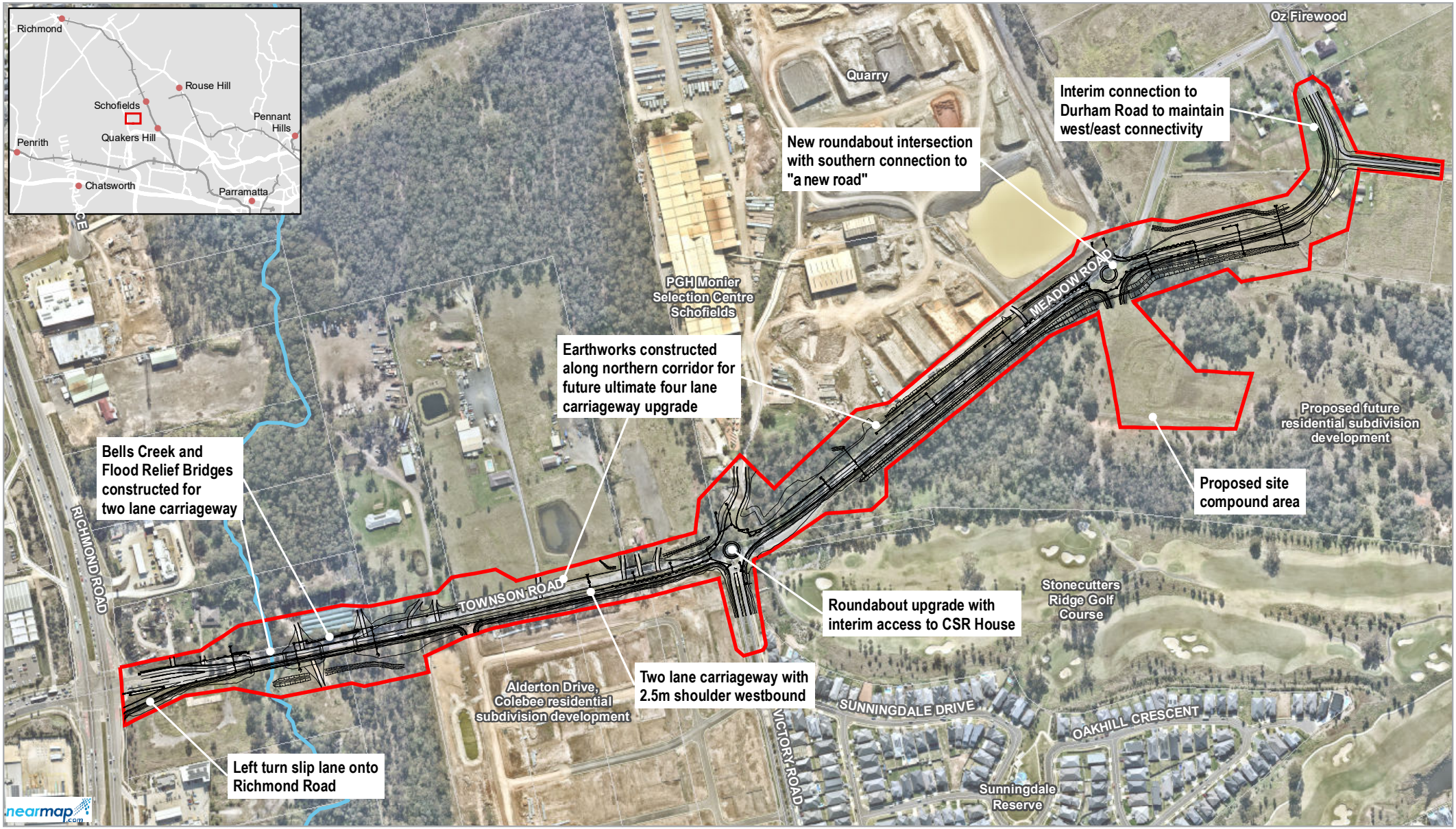
Transport for NSW
Townson Road Upgrade Stage 1
Between Richmond Road and Jersey Road

The Ultimate Phase of the Proposal

Project No. **21-12511195**
Revision No. **-**
Date **6/11/2020**

FIGURE 1-1

Data source: Aerial Imagery - Nearmap 2019 (image date 12/09/2019, image extracted 21/09/2019) and NSW Six Maps, 2019 . Created by: eibbertson



LEGEND

- The proposal **Subject to detailed design*
- Construction footprint
- Cadastre

Paper Size ISO A4

0 25 50 75 100

Metres

N

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

GHD

Transport for NSW
Townson Road Upgrade Stage 1
Between Richmond Road and Jersey Road

Interim phase of the proposal

Project No. **21-12511195**
Revision No. **-**
Date **4/12/2020**

FIGURE 1-2

Data source: Aerial Imagery - Nearmap 2020 (image date 03/08/2020, image extracted 28/09/2020) and NSW Six Maps, 2020 . Created by: eibbertson

2. Methodology

2.1 General

The methodology adopted for this assessment is summarised as follows:

- Review of previous studies relating to the flooding and hydrology of the study area
- Review of project design criteria, applicable design standards and relevant legislation and policies
- Collation of input data to enable development of a flood model
- Flood modelling to assess the existing conditions, proposed conditions and effectiveness of mitigation options
- Recommendations for monitoring and management of identified impacts and risk, including mitigation measures as appropriate.

The specific methodologies used for these components are described in the following sections.

2.2 Review of previous studies

The Townson/Burdekin Road corridor traverses the floodplains of Bells Creek and Eastern Creek analysed as part of a number of studies carried out prior to the current assessment. These are described below.

Eastern Creek Catchment – Hydrological Assessment, WMAwater 2013

This study was prepared for Blacktown City Council (BCC) as the first stage of the Floodplain Planning Study for Eastern Creek catchment. The purpose of the study was to update earlier outdated studies by determining design flowrates across the Eastern Creek catchment based on existing and future land use conditions. The Runoff Analysis and Flow Training System (XP-RAFTS) software was used to develop a rainfall runoff model of the catchment.

The study also assessed the performance of detention basins in controlling increases in runoff as a result of future development. The design flow hydrographs developed in this study formed inputs to a second stage hydraulic assessment (described below).

Eastern Creek Hydraulic Assessment, Catchment Simulation Solutions (CSS) November 2014

This study represented the second stage of the Floodplain Planning Study for Eastern Creek catchment (prepared for Blacktown City Council). The purpose of the study was to develop updated hydraulic models to represent existing land use characteristic's using flowrates derived in the Stage 1 study (WMAwater, 2013).

A hydraulic model of the Eastern Creek catchment was developed using TUFLOW software and applied to determine hydraulic behaviour throughout the study area. TUFLOW is used to analyse the hydraulic behaviour of water flowing through watercourses and floodplains. Modelled one per cent Annual Exceedance Probability (AEP) flood levels are shown in Table 2-1. This compares the Blacktown City Council (BCC) flood level (prior to the CSS study) and CSS reported flood level of Bells Creek at Townson Road.

Table 2-1 Modelled 1% AEP flood levels (CSS 2014)

Location	BCC (pre 2014)	CSS (2014)
Bells Creek at Townson Road	26.89 mAHD	27.34 mAHD

Eastern Creek Catchment – Development Scenario Hydraulic Assessment, CSS June 2016

The development scenario hydraulic assessment was carried out by CSS for Blacktown City Council (BCC) to assess the effect of future development on flooding characteristics throughout the Eastern Creek Catchment. The TUFLOW model described in the Stage 2 assessment (CSS, 2014) was updated to include various development scenarios. The cases considered included existing catchment conditions and various future development, flood management and climate change scenarios.

Burdekin Road and Townson Road Hydrology Assessment, UMWELT 2020

Umwelt was engaged by TfNSW to prepare a hydrologic and hydraulic model of the Eastern Creek and Bells Creek tributaries for the purposes of the project design development. The hydrology was calculated using XP-Storm software. XP-Storm is a hydrologic modelling software package that is used to calculate flood discharges in a network of streams, using catchment characteristics and rainfall as model inputs.

The TUFLOW model extent included Eastern Creek and its tributaries extending to a location 3.3 kilometres upstream of the confluence with South Creek, an area subject to backwater flooding from Hawkesbury River. The study adopted *Australian Rainfall and Runoff 1987* (ARR87) rainfall intensities and temporal patterns. A range of storm durations were modelled and the critical storm duration at the project site was determined to be nine hours.

Modelled existing flood levels at Townson Road are shown in Table 2-2. The modelled flood conditions included an assumption in relation to the water level of the Hawkesbury River that may occur in combination with local rainfall induced flooding in Bells Creek. For example, the 1 per cent AEP local flood in Bells Creek was combined with a 5 per cent AEP flood condition in the Hawkesbury River, which is considered to be a reasonable combination of possible local and regional flood conditions. Similarly, the 0.2 per cent AEP local flood in Bells Creek was combined with a 1 per cent AEP flood in the Hawkesbury River. Flood levels are shown as metres above Australian Height Datum (mAHD).

Table 2-2 Modelled flood levels - UMWELT (2020)

Event	Flood level at Bells Creek at Townson Road (mAHD)	Peak Discharge (m^3/s)
1% AEP (with 5% AEP Hawkesbury River tailwater)	27.21	125
0.2% AEP (with 1% AEP Hawkesbury River tailwater)	27.38	170

A comparison of the UMWELT (2020) and the CSS (2014) flood modelling results for Bells Creek is provided in Table 2-3. The UMWELT calculated flowrates at the outlet of Bells Creek near Eastern Creek are four per cent lower than the CSS flows. While the exact CSS reporting location is not documented and flood levels are variable across the floodplain (and lower in proximity to the existing Townson Road culvert upstream inlet), the UMWELT reported flood level at Townson Road is 0.13 metres lower than the level reported by CSS.

Table 2-3 Flood Model Results for Bells Creek - UMWELT (2020) versus CSS (2014)

Event	Umwelt (2020)	CSS (2014)
1% AEP flood level – Bells Creek at Townson Road	27.21 mAHD	27.34 mAHD
1% AEP flowrate – Bells Creek at Townson Road	125 m^3/s	(flowrate not documented)
1% AEP flowrate – Bells Creek near Eastern Creek confluence	130 m^3/s	135 m^3/s

2.3 Review of project design criteria, applicable design standards and relevant legislation and policies

The project design criteria determined by TfNSW is discussed further in Section 4. In addition, various design standards, legislation and policies were reviewed and considered in this assessment. The applicable documents include:

- TfNSW Project Design Criteria
- NSW Government Floodplain Development Manual (2005)
- Australian Rainfall and Runoff (1987, 2019)
- Blacktown City Council Local Environment Plan.

2.4 Input data

2.4.1 Survey

Airborne Light Detection and Ranging (LiDAR) survey is available covering the Bells Creek catchment. This survey is available as a one metre grid Digital Elevation Model (DEM). LiDAR survey is obtained from an aircraft and is used to determine the ground levels across the floodplain. This information is used in the flood modelling, in combination with more detailed ground survey, to represent the topography of the floodplain and watercourses. The LiDAR used in this study is dated 2019.

In addition, TfNSW have obtained detailed ground survey within the project corridor which includes existing road levels, drainage and limited utilities infrastructure and other ground surface features.

2.4.2 Aerial photography

Aerial photography is available covering the study area and surrounding region. Aerial photography is used in the flood modelling to identify features such as vegetation, buildings and roads which have different effects on the movement of flood water due to varying material type.

2.5 Flood modelling assessment

2.5.1 Bells Creek

The hydraulic behaviour of the Bells Creek bridges was assessed using a TUFLOW hydraulic model. TUFLOW is hydraulic modelling software which is used to model the hydraulic behaviour of flood water moving through flood plains and streams and waterway structures including bridges and pipe culverts. This model was initially developed by UMWELT and modified by GHD to include the project features such as the proposed road embankment and bridge structures.

The XP-STORM model was used to calculate stream tributary inflows entering the TUFLOW model from upstream of the area covered by the TUFLOW model. The overall UMWELT XP-STORM model layout covering the wider Eastern Creek catchment is shown on Figure 2-1.

Direct rainfall storm depths were applied over the surface of the TUFLOW model to account for storm rainfall falling over the area covered by the model (downstream of the tributary inflows). For the modelling of Bells Creek, GHD extracted a portion of the overall TUFLOW model covering the Bells Creek tributary downstream to near the confluence with Eastern Creek.

UMWELT adopted the ARR87 design storms (ie rainfall intensities and temporal patterns) for this project to maintain consistency with BCC approach (WMAwater, 2013 and CSS, 2016). The ARR87 design storm approach has therefore been adopted by GHD for the design phase modelling of the proposal.

From the UMWELT model, a truncated TUFLOW model was prepared by GHD for the Bells Creek tributary. The larger model extent was adopted but only for the area upstream of Schofields Road which formed the downstream truncated model extent. The TUFLOW model extent is shown on Figure 2-2.

Inflow boundaries were applied at the upstream limit of the model and at incoming tributaries from catchments external to the TUFLOW model extent. Direct rainfall was applied over the TUFLOW model extent.

The TUFLOW model topography is based on LiDAR survey sampled on a five-metre grid spacing. For the proposed conditions model, the road design surface was read into the TUFLOW model as a terrain adjustment.

The design proposes to adopt two bridges across Bells Creek, each about 36 metres in length. These were input to the TUFLOW model as openings through the road embankment as well as layered flow constrictions to represent the bridge deck and piers.

Both bridges will require excavation of the floodplain locally to transition floodwaters smoothly through the structures and back to the floodplain. Bells Creek will also include a low flow channel to allow for connectivity between the upstream and downstream creek channel. This would provide for safe fish passage. Floodplain excavation including a low flow channel in Bells Creek was modelled in 12d and incorporated into the TUFLOW model topography.

The TUFLOW model uses a Manning “n” roughness map to calculate hydrology and surface water levels and flows. Manning ‘n’ is a friction parameter used in the TUFLOW model to account for the effect of different land use or channel surfaces on the flow of water. Low values on Manning ‘n’ are used to represent smooth surfaces which provide low resistance to flow while high values represent rough surfaces which impede flows. The TUFLOW material ID’s, adopted roughness values (Manning ‘n’) and land use type adopted for existing and post developed model is shown in Table 2-4.

Table 2-4 TUFLOW Manning 'n' values

Material ID	Land Use	Manning n
1	Grass	0.045
2	Road reserve	0.016
3	Rail corridor	0.022
4	Creek channel	0.035
5	Open water	0.035
6	Buildings- industrial	2
7	Hardstand	0.025
8	Quarry	0.03
9	Forested Area	0.08
10	Residential Area	2

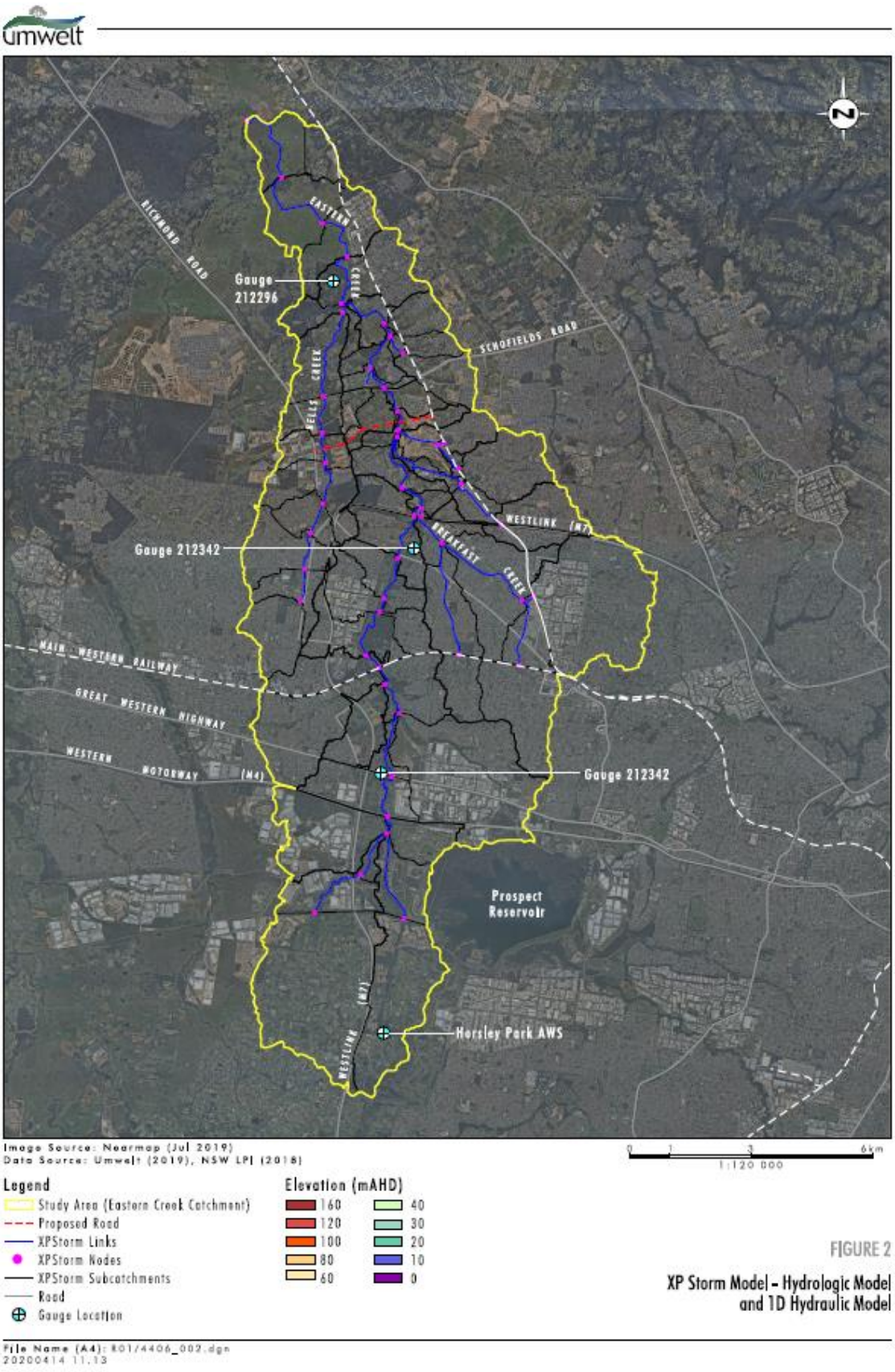


Figure 2-1 XP-STORM model layout (Source: UMWELT, 2020)

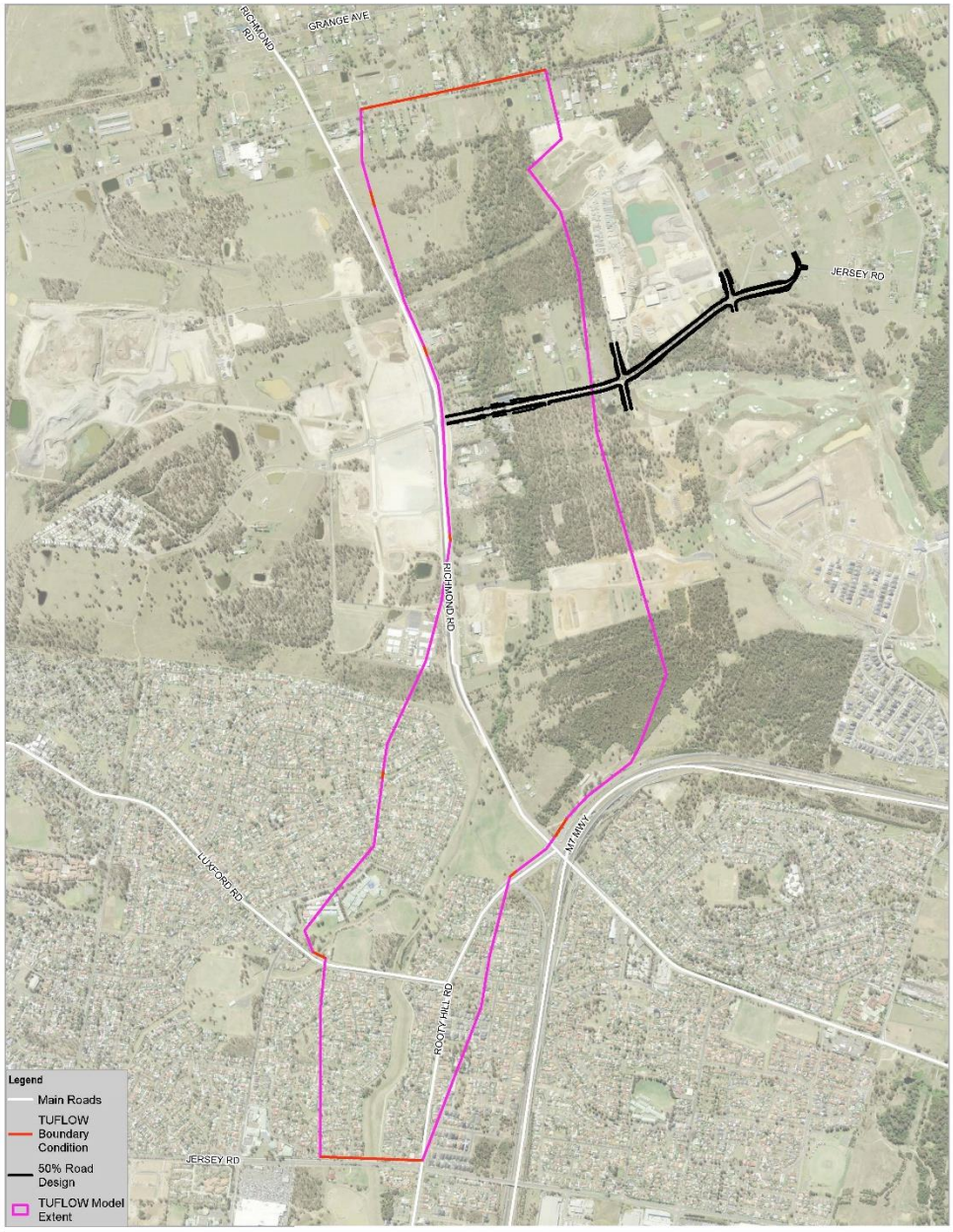


Figure 2-2 Bells Creek TUFLOW model extent

The TUFLOW calculated flood levels, depths and velocities were mapped for existing and proposed conditions. Using the calculated velocities and depths, the flood hazard was also determined in accordance with the Australian Institute for Disaster Resilience publication "Technical Flood Risk Management Guideline: Flood Hazard" (Reference 1). Flood hazards are categorised as shown in Table 2-5.

Table 2-5 Flood hazard categories

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure

2.5.2 Minor tributaries

There is a minor tributary branching of Eastern Creek which flows west to east, parallel to the existing Meadows Road and crosses the proposal at two locations. Culverts have been designed for the determined waterway area to convey the one per cent AEP flowrate across the proposal without flooding the proposed road carriageways.

2.6 Monitoring and management of identified impacts

The operational impact of the proposal was assessed by comparing the existing and proposed case TUFLOW model results to determine the flood impacts of the proposal for the twenty per cent, five per cent and one per cent AEP and PMF flood events. The flood modelling enabled comparison of flood levels and velocities in the vicinity of the project to determine whether the project would result in impacts to the flooding characteristics of the drainage systems adjoining the proposal and if so how these impacts could be managed through appropriate mitigation strategies.

3. Existing environment

3.1 Catchment description

The proposal lies within the catchment of Eastern Creek. The proposal crosses Bells Creek and tributaries of Eastern Creek. Eastern Creek is a tributary of South Creek and lies within the Hawkesbury River catchment. The location of Bells Creek and Eastern Creek in relation to Townson Road are shown on Figure 3-1.

Bells Creek flows in a generally northerly direction. The catchment extends six kilometres south of Townson Road. Bells Creek joins Eastern Creek approximately three kilometres downstream of Townson Road. The southern portion (upstream) of the catchment is heavily urbanised with residential development being the primary land use. Closer to Townson Road and to the north (downstream) there are areas of semi-rural and light industrial land use. Further development is planned within the Bells Creek catchment as part of the North West Growth Area which is one of a number of priority growth areas that are being planned by the Department of Planning, Industry and Environment across the Blacktown and other Local Government Areas.

The Bells Creek watercourse is currently conveyed under Townson Road through a three-cell box culvert with each cell opening approximately three metres wide and two metres high. Townson Road is formed as a causeway to allow major flows that exceed the culvert capacity to overtop the road surface. A flood level marker is currently installed to indicate flood depths during heavy storms.

East of Victory Road, the proposal drains to a tributary of Eastern Creek which flows from west to east. Stormwater flows enter this tributary from catchments to the north and south of Meadow Road.

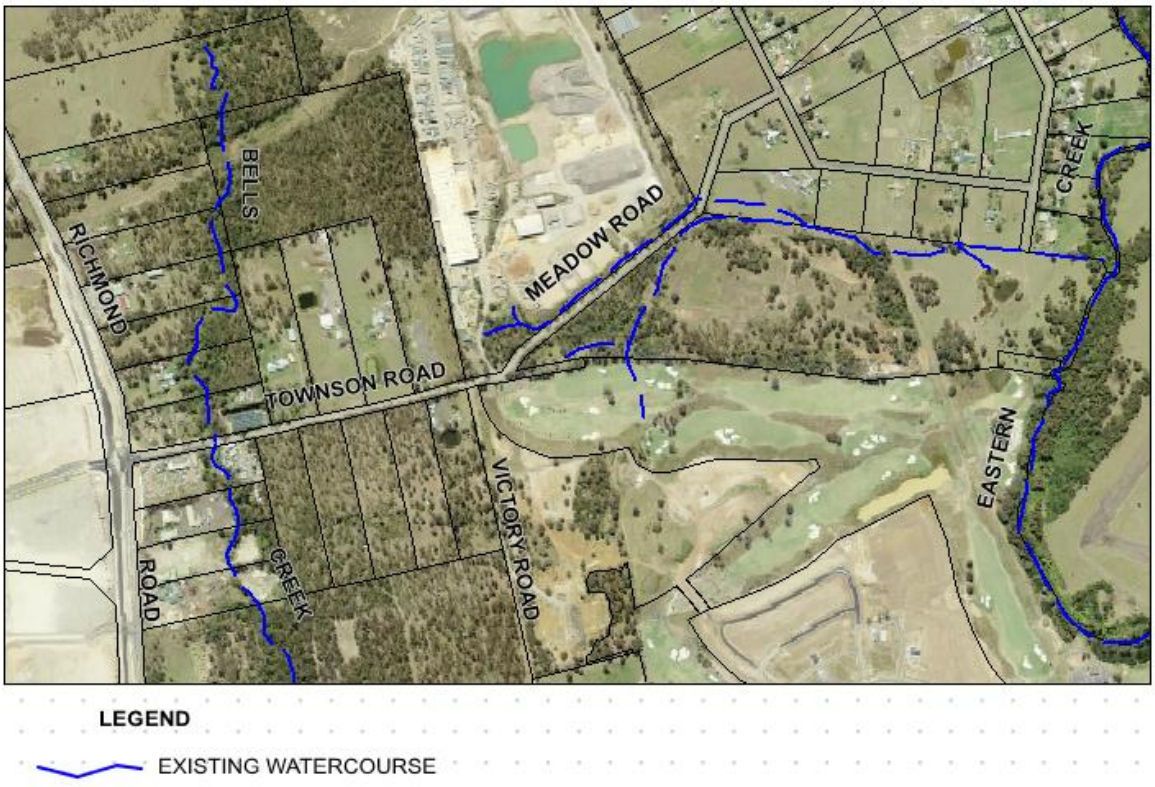


Figure 3-1 Local Waterways

3.2 Existing flooding behaviour

Existing flooding behaviour in the Bells Creek watercourse and floodplain has been modelled using TUFLOW for the five per cent, two per cent and one per cent AEP and PMF flood events.

Maps showing existing flood levels, flood velocities and flood hazard are shown on Figures A-01 to A-12 in Appendix A.

The modelled existing one per cent AEP flood levels are shown on Figure 3-2. The one per cent AEP flood level immediately upstream of Townson Road varies from 27.43 metres AHD on the western edge of the floodplain to 27.52 metres AHD on the eastern side. During a one per cent AEP flood, the model indicates that Townson Road is overtopped across a width of approximately 200 metres to a depth of up to 0.5 metres above the road crest.

The modelled existing one per cent AEP velocities are shown on Figure 3-3. Near Townson Road, the one per cent AEP velocities within the Bells Creek channel vary from around 1.5 metres per second (m/s) to 3 m/s. The floodplain velocities vary but are typically in the order of 0.2 m/s at the outer edges of the floodplain, increasing to around 0.5 m/s across the floodplain with higher values near the main channel as noted above.

The modelled existing one per cent AEP flood hazards are shown on Figure 3-4. The existing Townson Road is categorised as unsafe for vehicles where the Bells Creek floodplain is crossed due to unsafe overtopping depths over the road carriageway. Other than where Townson Road is currently overtopped, high hazard flooding is confirmed to the upstream and downstream floodplains of Bells Creek.

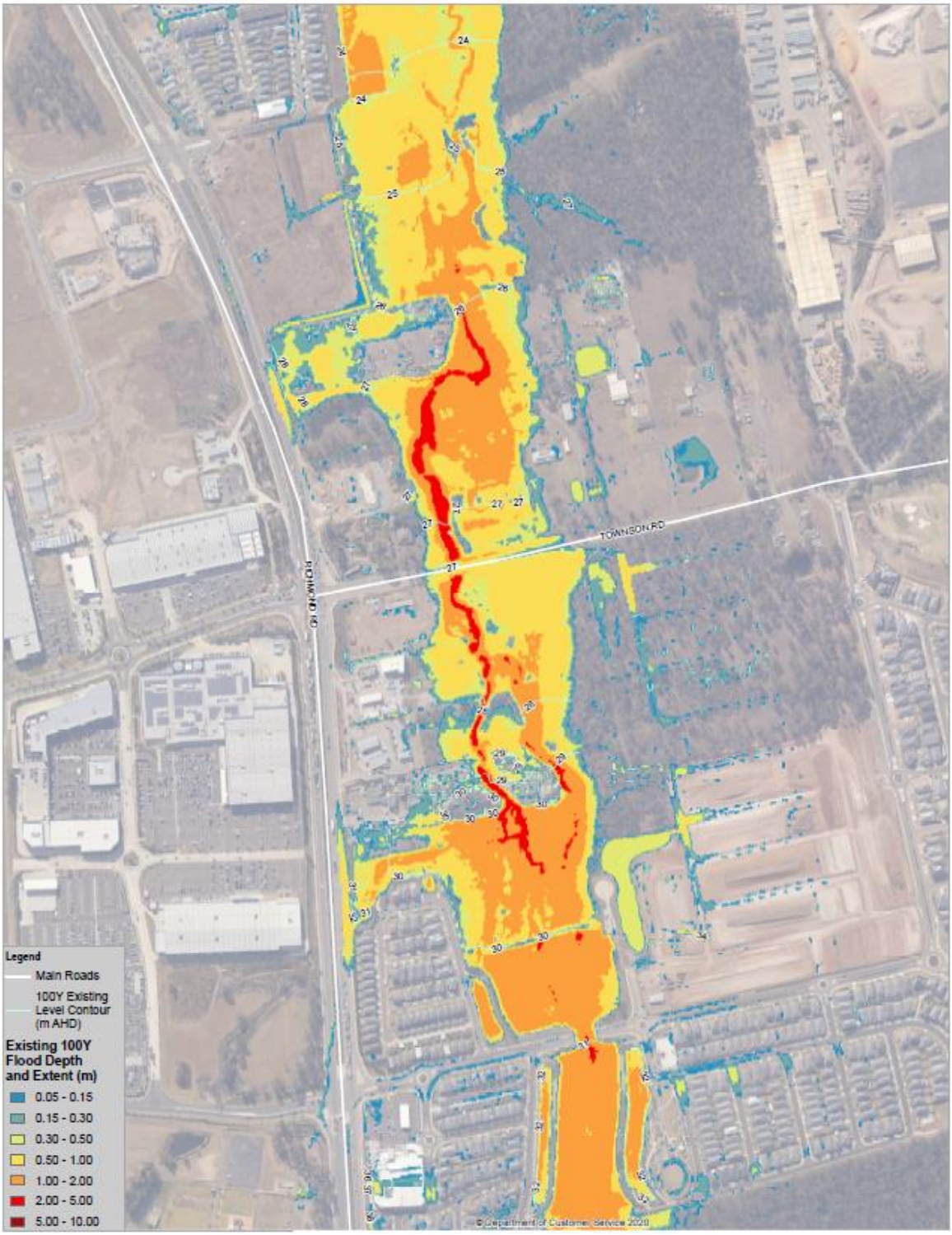


Figure 3-2 Existing 1% AEP flood levels

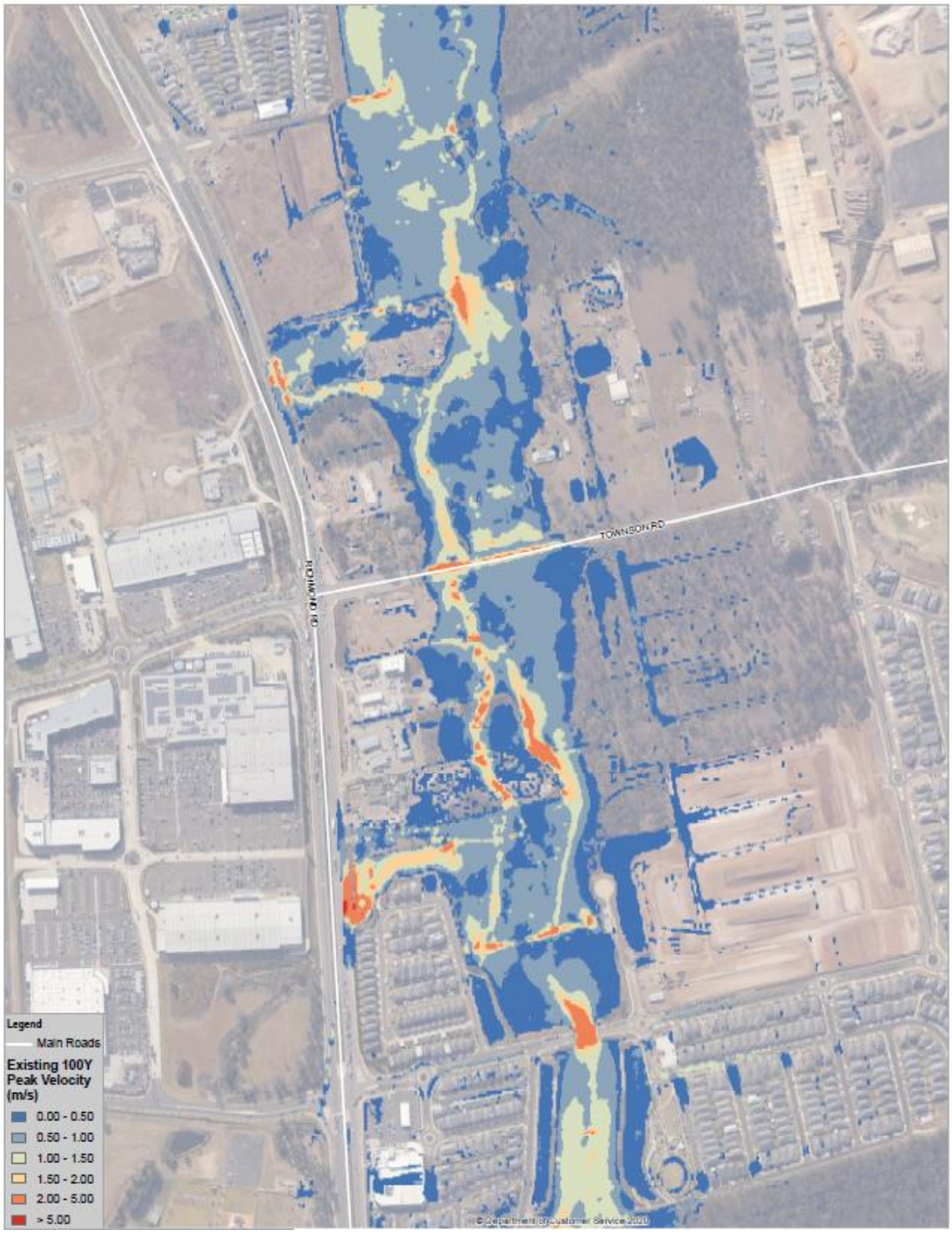


Figure 3-3 Existing 1% AEP velocities

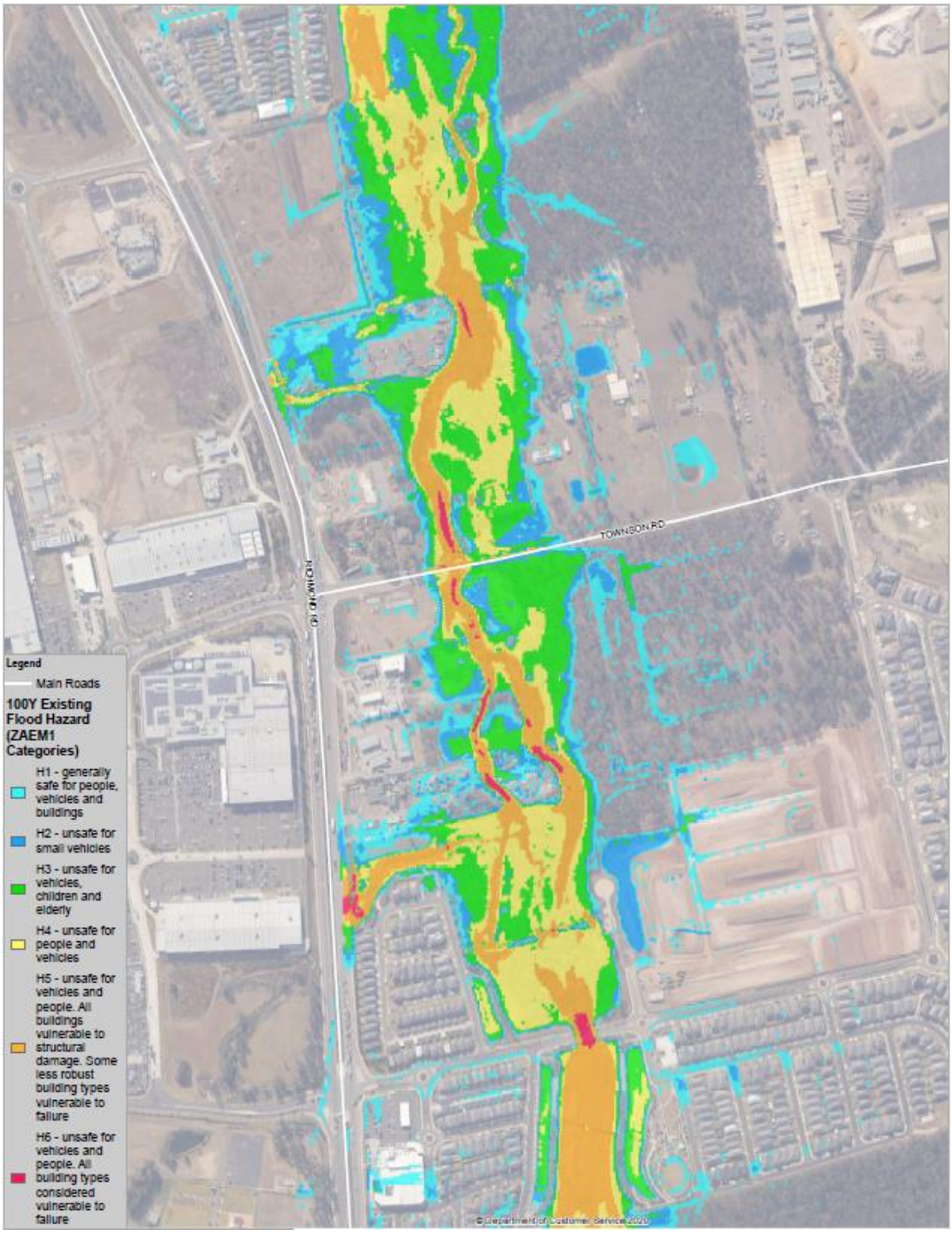


Figure 3-4 Existing 1% AEP flood hazard

4. Criteria

TfNSW has developed a series of hydrologic design criteria with the aim of meeting the project objectives with respect to flooding impacts and flooding performance of the project elements. The project objectives relating to flooding are:

- Construct Townson Road as a local evacuation route across the Bells Creek floodplain with a flood immunity of 0.2 per cent AEP
- The project will not have adverse flooding impacts on adjoining properties and infrastructure
- Adverse impacts to the environment are minimised
- Project be safe to construct and operate and meets WHS requirements.

The flood compliance criteria for the proposal are summarised in Table 4-1.

Table 4-1 Hydrology criteria

Element	Criteria
No surcharging of channels and open drains	20% AEP
Capacity of culverts where surcharge is allowable	2% AEP
Capacity of waterway structures where surcharge is undesirable	1% AEP
Major storm event for which the project should cause no property damage	1% AEP
Major storm event for which the project should cause no structural damage	0.05% AEP
Flood immunity across the Bells Creek floodplain	0.2% AEP

5. Construction impact assessment

The construction of the road formation and floodplain bridges across Bells Creek could potentially result in flood impacts as a result of construction works undertaken on the floodplain. These works may include:

- Staged placement of the proposed new road formation across the floodplain, while maintaining trafficability for local on Townson Road using the road existing formation and existing culverts as a temporary floodplain crossing
- Placement of temporary stockpiles within the floodplain
- Construction of temporary piling platforms for the bridge construction.

Flood impacts would include the potential for increased flood levels resulting from floodplain obstructions during the construction stages and localised scour and erosion. This may result from concentration and redistribution of flood flows.

The nominated site compounds are located outside the extent of overland flooding. However, it will be necessary for the construction contractor to provide for minor localised catchment diversions around the compounds and stockpiles in accordance with standard construction stormwater management practices.

A Construction Environmental Management Plan (CEMP) will be developed prior to construction of the proposal. As part of the CEMP, a Flood Management Plan (FMP) will need to be developed to provide a strategy to minimise flood impacts on the floodplain and adjoining land during construction. In particular it will be necessary for the construction contractor to undertake flood modelling in support of the construction staging to ensure that the construction sequence for the road and bridges across the Bells Creek floodplain does not endanger life through increased flood hazard or result in adverse flood impacts to surrounding land.

6. Operational impact assessment

The proposal has the potential to affect the flood behaviour of Bells Creek and therefore operational impacts have been considered as part of this flooding assessment. Existing flood behaviour could potentially be altered as a result of the following aspects of the proposal:

- Removal of existing causeway road embankment and redistribution of flood flows through the proposed floodplain bridges
- Loss of floodplain storage due to widened embankment within the floodplain of Bells Creek
- Increased runoff from the additional impervious area created by the widened road pavement.

Flooding behaviour has been modelled and compared at numbered locations on the Bells Creek floodplain north and south of the proposal, shown in Table 6-1 and on Figure 6-1 for the five per cent, two per cent and one per cent AEP and PMF flood events.

Maps of post developed flood levels, flood velocities and flood hazard are provided in Appendix A, Figures A-13 to A-24. Maps showing the impact of the proposal on flood levels and velocities, compared to existing conditions are provided in Appendix, Figures A-25 to A-32.

Table 6-1 Flood impact assessment location descriptions

Point Number	Description
1	90 m north of Townson Road, western edge of floodplain
2	90 m north of Townson Road, Bells Creek watercourse
3	90 m north of Townson Road, eastern edge of floodplain
4	30 m north of Townson Road, western edge of floodplain
5	30 m north of Townson Road, Bells Creek watercourse
6	30 m north of Townson Road, existing nursery structure
7	50 m north of Townson Road, eastern edge of floodplain
8	25 m south of Townson Road, western edge of floodplain
9	25 m south of Townson Road, Bridge 1
10	25 m south of Townson Road, Bridge 2
11	25 m south of Townson Road of Townson Road, eastern edge of floodplain
12	100 m south of Townson Road, western edge of floodplain
13	100 m south of Townson Road, Bells Creek watercourse
14	100 m south of Townson Road, eastern edge of floodplain
15	110 m south of Townson Road, western edge of floodplain
16	175 m south of Townson Road, western edge of floodplain
17	175 m south of Townson Road, Bells Creek watercourse
18	175 m south of Townson Road, eastern edge of floodplain

Figure 6-1 Flood impact assessment locations

6.1 Post developed flooding behaviour

6.1.1 Flood levels

Modelled operational flood levels immediately upstream and downstream of Townson Road at the proposed bridge sites and floodplain are shown in Table 6-2. Through the proposed raising of Townson Road and increased capacity to convey flood waters beneath the road, the proposal will provide for improved safety and trafficability of Townson Road during flood events and will improve the existing flooding immunity of Townson Road.

As noted in Section 4, Townson Road is to be constructed as a local evacuation route across the Bells Creek floodplain. The lowest level on the proposed Townson Road in proximity to the Bells Creek floodplain will be 28.5 m AHD while the modelled operational 0.2 per cent AEP flood level is 27.6 m AHD (Point 8 in Table 6-2). The design therefore provides approximately 0.9 metres of freeboard to the 0.2 per cent AEP flood level. This will enable Townson Road to remain trafficable as a flood evacuation route during rare flood events up to a 0.2 per cent AEP magnitude. The 0.2 per cent AEP operational flood levels in Bells Creek are mapped on Figure A-35 in Appendix A.

The development scenario hydraulic assessment CSS (2016) found that discharges and flood levels in the Bells Creek catchment may increase in future due to planned urban development. It was reported that the 0.2 per cent AEP flood levels in Bells Creek near Townson Road could, in future, rise by between 0.1 and 0.25 metres under a fully developed scenario. While these modelled flood level increases did not account for the raising of Townson Road, the flood freeboard of 0.9 metres provided by the design is considered to be sufficient for Townson Road to provide flood immunity across Bells Creek in a 0.2 per cent AEP event under future development scenarios.

Table 6-2 Modelled operational flood levels

Point ID	5% AEP Flood Level (m AHD)	2% AEP Flood Level (m AHD)	1% AEP Flood Level (m AHD)	0.2% AEP Flood Level (m AHD)	PMF Flood Level (m AHD)
1	26.77	26.89	26.98	27.20	28.22
2	26.79	26.92	27.00	27.23	28.27
3	26.65	26.78	26.89	27.13	28.14
4	26.87	27.01	27.11	27.34	28.32
5	26.87	27.01	27.11	27.34	28.34
6	26.80	26.87	26.94	27.14	28.23
7	26.77	26.86	26.95	27.15	28.11
8	27.03	27.21	27.33	27.61	29.46
9	26.86	27.02	27.14	27.42	29.31
10	27.39	27.48	27.56	27.77	29.48
11	27.51	27.61	27.70	27.91	29.56
12	27.33	27.49	27.60	27.84	29.53
13	27.36	27.50	27.60	27.83	29.53
14	27.55	27.65	27.74	27.94	29.56
15	27.50	27.61	27.70	27.92	29.53
16	27.52	27.64	27.73	27.94	29.55
17	27.68	27.78	27.86	28.06	29.59

6.1.2 Flood level impacts

The one per cent AEP flood level impacts are shown on Figure 6-2. Upstream of Townson Road, on the western floodplain, a maximum flood level impact of 0.02 metres occurs on existing commercial land which adjoins and forms part of the Bells Creek floodplain, south of Townson Road. This increase in flood levels will not impact existing buildings on this land. On the eastern floodplain, the maximum impact is 0.19 metres at the edge of the floodplain, south of Townson Road. This impact occurs primarily in land that is zoned as ‘drainage land’ and which is not currently developable land.

The adjacent residential development located to the east of the floodplain on the south side of Townson Road includes a stormwater retarding basin which is currently being constructed on the fringe of the floodplain. The basin high level outlet is set at RL 28.9 metres AHD which is 1.2 metres above the one per cent AEP flood level at this location. A hydraulic assessment of the basin performance was undertaken and this showed that the hydraulic performance of the basin will not be impacted by the proposal in the one per cent AEP flood. The residential lots that form the development are set above RL 29.5m AHD and minimum building floor levels will be set above the PMF flood levels.

Downstream of Townson Road, there are localised minor increases of up to 0.05 metres in flood levels adjacent to Townson Road which occur at the proposed bridge opening locations but which reduce to zero within one hundred metres downstream of the proposal. However, there is also a small reduction in flood levels of up to 0.10 metres on the eastern floodplain. The land affected by these altered flood levels is zoned under Blacktown Council's Local Environment Plan as "Parks" and is not developable.

The raising of Townson Road will result in increased flood levels in the PMF event, with flood level increases of up to 1.0 metre predicted to occur upstream of Townson Road. Townson Road would be overtopped in a PMF and would not be trafficable. Developments on the eastern bank of the floodplain will have rising access to the east and refuge can be taken in higher ground east of the floodplain as an initial response measure. On the western floodplain, rising access to higher ground is available to Richmond Road.

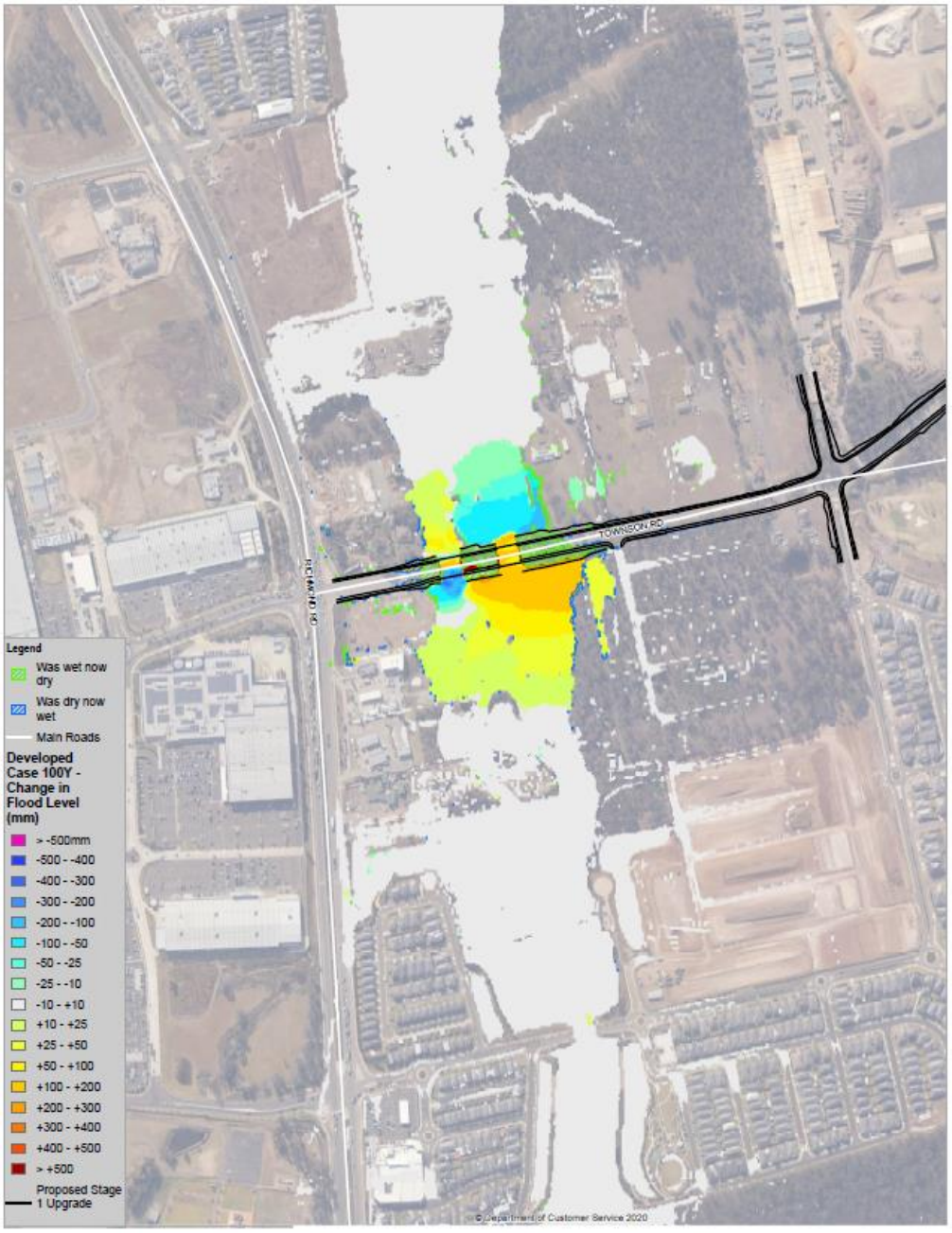


Figure 6-2 1% AEP post developed flood level impacts

Table 6-3 Modelled operational flood level impacts

Point ID	5% AEP flood level impact (m)	2% AEP flood level impact (m)	1% AEP flood level impact (m)	PMF flood level impact (m)
1	0.02	0.02	0.02	-0.04
2	0.02	0.03	0.02	-0.01
3	-0.03	-0.04	-0.04	-0.10
4	0.04	0.05	0.04	-0.07
5	0.05	0.06	0.05	-0.04
6	-0.04	-0.07	-0.10	-0.12
7	-0.08	-0.08	-0.08	-0.20
8	-0.23	-0.15	-0.08	0.90
9	-0.32	-0.25	-0.20	0.76
10	0.09	0.12	0.16	0.99
11	0.11	0.15	0.19	1.03
12	-0.06	-0.02	0.02	0.76
13	-0.05	-0.01	0.03	0.79
14	0.04	0.06	0.09	0.82
15	-0.02	0.00	0.02	0.73
16	-0.02	0.00	0.02	0.75
17	0.00	0.01	0.02	0.63

6.1.3 Velocity impacts

Velocity impacts for the one per cent AEP flood are shown in Figure 6-3. Velocity increases of up to 1.1 m/s are observed on the floodplain leading into and out of the proposed bridges. Such impacts, if not mitigated, have the potential to result in the potential for increased scour in proximity to the bridges. Recommended mitigation measures are described in Section 8.

Velocities are predicted to be reduced upstream of Townson Road on the eastern floodplain as a result of the proposal. A reduction in velocities can, in some circumstances result in increased deposition of silt following flood events. This reduction occurs in an area where existing velocities are currently low and where some deposition may already occur due to water pooling and slowing before overtopping the existing Townson Road. The proposal is not expected to measurably alter this behaviour.

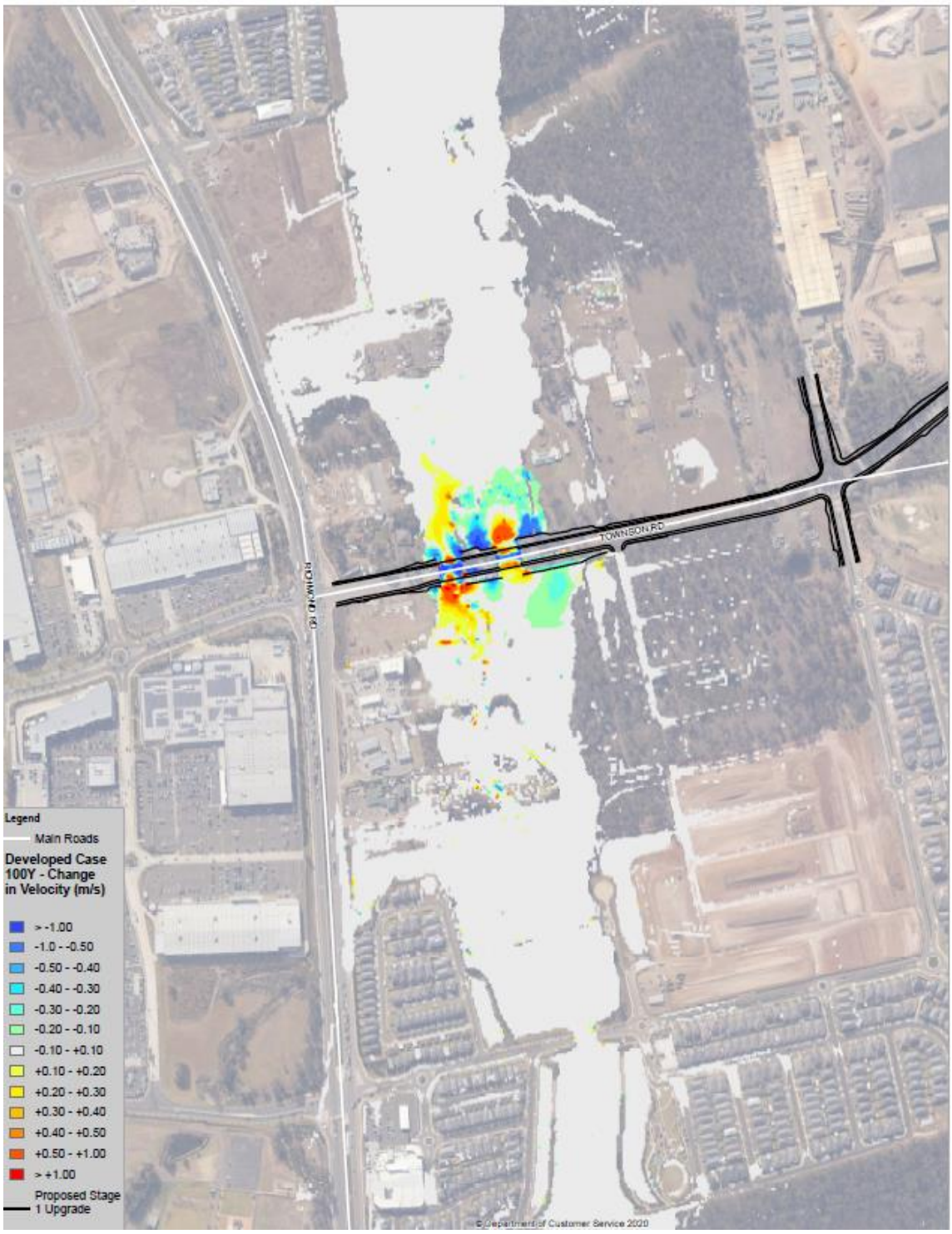


Figure 6-3 1% AEP post developed velocity impacts

6.1.4 Flood hazard impacts

Flood hazard mapping for the five per cent, two per cent and one per cent AEP flood events for proposed conditions is provided in Appendix A. For events up to the one per cent AEP, under post developed conditions floodwaters will be conveyed under the proposed raised Townson Road and the high hazard flooding conditions occurring on the current road are removed. A new area of high hazard flooding is introduced on the floodplain beneath the proposed eastern bridge, but this new hazard is generally confined on the floodway within the proposed road boundary.

6.2 Interim phase flood impacts

The interim phase of the proposal would incorporate a 36 metre span bridge over Bells Creek and a 36 meter span flood relief bridge to the east of Bells Creek. The interim phase bridges would be constructed to provide a single carriageway in each direction and these will ultimately be widened to form a dual carriageway arrangement as part of the ultimate phase of works.

The interim phase flood relief bridge would be located directly opposite an existing nursery on the north side of Townson Road. The presence of this bridge adjacent to the nursery would potentially increase the frequency of inundation of the nursery building and flood water would potentially flow into the nursey building more frequently than under current conditions.

The interim phase works would incorporate mitigation measures to alleviate potential flood impacts of the proposal on the existing nursery. These works would include a flood diversion bund, constructed in front of the nursery building which would, during times of flooding, intercept floodwaters flowing through the flood relief bridge and divert these floodwaters north-west (downstream) toward Bells Creek. This bund would be set at RL 27.0 metres AHD (similar to the level of the existing Townson Road) to mimic the flooding overtopping behaviour of the existing road at this location. Consequently, the bund would overtop in large flood events in a manner similar to which Townson Road is currently overtopped.

Flood level mapping for the interim phase proposal for the 50 per cent AEP, 20 per cent AEP and one per cent AEP is shown in Appendix A, Figures A36 to A56. Flood level impacts for these events are shown in Table 6-4.

Within the nursery, peak flood levels would be no more than 0.02 metres higher than for existing conditions for the 50 per cent AEP flood and 0.03 metres lower for the 20 per cent AEP flood. In a one per cent AEP flood, levels would be 0.11 metres lower than under existing conditions.

By comparing Figures A-54 and A-09 in Appendix A, it may be seen that the flood hazard within the nursery building would be slightly reduced in the one per cent AEP for the interim condition compared to existing conditions.

It is therefore concluded that the bund provided as part of the interim phase of the proposal would be effective in mitigating both flood level increases and changes in flood hazard associated with the proposed floodplain relief bridge.

Table 6-4 Modelled interim phase flood level impacts

Point ID	50% AEP existing flood level (mAHD)	50% AEP interim flood level (mAHD)	50% AEP flood level impact (m)	20% AEP existing flood level (mAHD)	20% AEP interim flood level (mAHD)	20% AEP flood level impact (m)	1% AEP existing flood level (mAHD)	1% AEP interim flood level (mAHD)	1% AEP flood level impact (m)
1	26.44	26.44	0.00	26.55	26.56	0.01	26.97	26.99	0.02
2	26.40	26.41	0.00	26.55	26.57	0.02	26.98	27.02	0.04
3	26.51	26.51	0.00	26.51	26.51	0.00	26.93	26.88	-0.06
4	26.63	26.63	0.00	26.67	26.68	0.01	27.07	27.14	0.07
5	26.43	26.45	0.03	26.59	26.64	0.05	27.06	27.14	0.08
6	26.55	26.56	0.02	26.65	26.62	-0.03	27.03	26.92	-0.11
7	26.62	26.63	0.01	26.68	26.65	-0.03	27.03	26.93	-0.11
8	26.95	26.66	-0.29	27.08	26.80	-0.28	27.41	27.34	-0.07
9	26.87	26.44	-0.42	27.00	26.63	-0.37	27.33	27.18	-0.15
10	27.13	27.20	0.07	27.19	27.29	0.10	27.40	27.60	0.20
11	27.21	27.26	0.05	27.29	27.36	0.07	27.50	27.70	0.20
12	27.12	27.11	-0.02	27.20	27.15	-0.05	27.58	27.61	0.02
13	27.07	26.95	-0.12	27.21	27.10	-0.11	27.57	27.61	0.03
14	27.26	27.29	0.02	27.36	27.40	0.03	27.65	27.74	0.09
15	27.44	27.44	0.00	27.44	27.44	0.00	27.68	27.71	0.03
16	27.26	27.26	0.00	27.33	27.30	-0.03	27.70	27.73	0.03
17	27.42	27.41	-0.01	27.52	27.52	-0.01	27.83	27.86	0.03
18	27.36	27.36	0.00	27.47	27.48	0.00	27.82	27.85	0.03

6.3 Climate change impacts

Climate change impacts have been assessed using Australian Rainfall and Runoff 2019 (ARR 2019) guidelines (Reference 2). The ARR 2019 guidelines recommend that climate change should be considered for the design of significant infrastructure.

The ARR 2019 climate change assessment processes adopt findings from the IPCC Fifth Assessment Report (IPCC, 2013), (Reference 7). The process adopts projected changes from Global Climate Models (GCMs) and can be explored for four Representative Concentration Pathways (RCP's) for greenhouse gas and aerosol concentrations that were used to derive the GCMs. The use of RCPs 4.5 (low emissions) and 8.5 (high emissions) are recommended by the guidelines for the assessment.

The ARR 2019 guidelines provide a framework for the assessment of critical elements based on the following considerations:

- The Assets effective service life or planning horizon; and
- The purpose and/or Nature of the Asset and consequences of its failure.

Where the design service life or planning horizon is considered to be "long", a more detailed screening analysis of climate change impacts with respect to the consequence of failure is warranted.

Given the effective service life of the proposal, a screening analysis with respect to elements with a relatively long design life (such as the drainage network) is warranted during detailed design.

Using the processes defined by ARR 2019, Table 6-5 below presents outcomes of the climate change assessment and the expected increases in rainfall intensity based on the asset design life or planning horizon.

Table 6-5 ARR 2019 climate change assessment

Parameter	Value
Catchment Location	East Coast Cluster
End of Planning Horizon[1]	2090
Maximum Consensus Case for RCP 4.5	1.5 to 3.0 degrees hotter
Maximum Consensus Case for RCP 8.5	Greater than 3.0 degrees hotter
Adopted temperature Midpoint (°C)	2.25 – 4.1
Projected Increase in Rainfall Intensity (RCP 4.5)	12%
Projected Increase in Rainfall Intensity (RCP 8.5)	22%

Note: 1. Year 2090 adopted for climate change assessment (maximum ARR2019 projected timeframe)

Consideration of the low emissions and high emissions pathways results in projected rainfall intensity increases of 12 per cent and 22 per cent respectively by 2090. ARR 2019 recommends that the RCP 4.5 scenario increase (in this case 12 per cent) should be considered as a minimum basis for climate change consideration in the design.

For this assessment, a 15 per cent increase in rainfall intensities due to climate change has been considered to assess how flooding conditions may alter in future along Bells Creek. Modelled one per cent AEP flood levels for a 15 per cent increase in rainfall intensities are compared to those for present day intensities in Table 6-6. The assessment shows that one per cent AEP flood levels could increase by up to 0.15 metres over the area assessed. Townson Road would remain trafficable in a one per cent AEP flood event. The potential effect of climate change on more rare rainfall events is not currently well understood and extrapolation of climate change scenarios to events rarer that the one per cent AEP has not been undertaken. Climate change mapping is provided in Appendix A, Figures A-33 and A-34.

Table 6-6 1% AEP Climate Change impacts

Point ID	Proposed case 1% AEP flood level (present day climate) (mAHD)	Proposed case 1% AEP flood level (future climate) (mAHD)	Climate change impact (m)
1	26.98	27.11	0.12
2	27.00	27.13	0.13
3	26.89	27.03	0.13
4	27.11	27.24	0.12
5	27.11	27.23	0.12
6	26.94	27.05	0.11
7	26.95	27.06	0.11
8	27.33	27.48	0.15
9	27.14	27.29	0.15
10	27.56	27.67	0.11
11	27.70	27.81	0.11
12	27.60	27.74	0.14
13	27.60	27.73	0.13

Point ID	Proposed case 1% AEP flood level (present day climate) (mAHD)	Proposed case 1% AEP flood level (future climate) (mAHD)	Climate change impact (m)
14	27.74	27.85	0.11
15	27.70	27.82	0.12
16	27.73	27.84	0.11
17	27.86	27.97	0.11

7. Cumulative impacts

The proposal is located within a region comprising of a mixture of residential, semi-rural, commercial and light industrial land use. Further regional development is planned in this area as part of the North West Priority Growth Area. This regional development would include residential and commercial development which may impact on the hydrology of Bells Creek and the broader Eastern Creek catchment.

Below is a description of current and future projects that are most relevant to the proposal's cumulative impacts.

- **Luxeland** – The Luxeland project (DIHE Holdings Pty Ltd) is a current residential development immediately to the south of Townson Road.
- **Alltove Development** – The Alltove Development project (Stockland and DHA) is a current residential development immediately to the north and south of Townson Road.
- **Compound site** – The compound site project (CSR) is a residential development of unknown status immediately south of Townson Road.
- **Marsden Park Industrial Precinct** – The Marsden Park Industrial Precinct development is located upstream of the proposal area with approximately 200 hectares of its footprint within the Bells Creek catchment.

No future development that would directly encroach into the Bells Creek floodplain is planned on the eastern side of the floodplain. Development of commercial land on the western side of the floodplain would be limited to the flood fringes and development impacts would be managed through development controls. Regionally, other developments that drain to the Bells Creek and Eastern Creek waterways will make use of planned regional flood mitigation measures and development controls to manage flood impacts resulting from increased impervious surfaces and loss of flood plain storage. In preparing this assessment it has assumed that these planned projects will incorporate controls to mitigate their potential to increase flows within the broader catchment.

The proposal will contribute to increased runoff to Bells Creek and Eastern Creek as a result of pavement widening and the conversion of pervious surfaces to impervious surfaces. While the proposed road formation will encroach into the existing floodplain, the flood modelling shows that in the one per cent AEP flood there will be a net increase in flood storage during the passage of flood water across the proposal due to increased flood levels upstream of the proposed road embankment.

In a one per cent AEP flood event, the changes in flood level that would occur as a result of the proposal (described in Section 6) do not extend beyond three hundred metres upstream of and one hundred metres downstream of the proposal. Within this affected area of floodplain, it is calculated that there is a cumulative increase of around 1700 m^3 of flood storage at the peak of a one percent AEP flood. This represents around two per cent of the total volume of floodwater stored in this area.

The elevation of Bells Creek is at Townson Road is sufficiently high that there will be no impact on backwater flood storage for floods in the Hawkesbury River. The one per cent AEP flood level in the Hawkesbury River is 17.3 m AHD, while the creek invert of Bells Creek at Townson Road sits around six metres above this level.

8. Mitigation and management measures

To minimise the potential flooding impacts that could result from the construction of the proposal, a series of mitigation measures have been proposed. These are described in the following sections.

8.1 Construction phase

Construction phase mitigation measures would generally include:

- Temporary drainage or drainage diversions to be installed as necessary so that stormwater drainage function is not impeded during construction of new stormwater drainage lines and connections to existing stormwater network.
- Limiting the placement of stockpiles to non-critical areas of the floodplain.
- Minimising the footprint of piling platforms on the floodplain.
- Ensuring that a sufficient unobstructed waterway area is provided to enable the safe passage of flood waters across the proposal corridor at all times during the construction phase. The required waterway area would be determined by the construction contractor and may require the use of flood modelling to determine the flooding impacts of the works at various construction stages
- Developing a Flood Management Plan (FMP) as part of the Construction Environmental Management Plan (CEMP) detailing construction flooding mitigation measures. This will require detailed flood modelling to assess flooding vulnerability at various stages of construction.

A list of potential mitigation measures is provided in Table 8-1.

Table 8-1 Potential construction risks and mitigation measures

Risk	Potential impacts	Measures to avoid, mitigate and minimise impacts
Hydrologic		
Impact on surface water flow in watercourses	• Changed surface flow paths across the project site due to the presence of site compounds/stockpiles etc	• Install drainage works prior to or concurrent with site compound set-up and/or stockpiling • Works within or near the creek will be undertaken with consideration given to the NSW Department of Primary Industries (Water) *Guidelines for controlled activities on waterfront land – Riparian corridors* (2018)
Hydraulic issues		
Impact of widening the road corridor	• Additional impacts upstream and downstream of structures	• Carry out detailed flood modelling to assess construction flood risk and inform the construction staging • Install drainage works prior to or concurrent with road formation construction to minimise potential adverse impacts • Avoid or minimise obstruction of overland flow paths and limit the extent of flow diversion required

Risk	Potential impacts	Measures to avoid, mitigate and minimise impacts
		• Consider how the works will affect the existing stormwater network such that alternatives are in place prior to any disconnection or diversion of stormwater infrastructure
Working in the floodplain or flood prone areas	• Impact to construction workers working on flood prone land	• Locate stockpiles where they do not impact flow paths and patterns • Prepare wet weather working and construction flood management plans

8.2 Operational phase

The one per cent AEP flood event has been assessed to understand the likelihood of flooding impacts from the proposed project to the surrounding floodplain area including downstream. The structural elements as they are currently designed are predicted to cause minimal impacts on surrounding areas for events up to and including the one per cent AEP climate change event.

The residual risks remaining would be addressed through either further design development and/or specific mitigation measures outlined below.

The following operational mitigation measures will be implemented:

- The inclusion of two floodplain bridges across the Bells Creek floodplain to minimise flood impacts and mimic existing flooding behaviour as far as practicable. The floodplain bridges will allow flows to distribute across the floodplain during major flood events to minimise the scour impacts that may result from a single concentrated bridge opening. The location of proposed bridges is shown on Figure 8-1.
- A landscaped low flow waterway will be constructed through the Bells Creek waterway bridge which will provide for aquatic habitat including fish passage.
- Culverts have been incorporated into the design to allow for the passage of stormwater across the proposal and to minimise flooding impacts on adjacent land. These are located about 150 metres east of Victory Road (a pipe culvert), at the new road intersection (a box culvert) and 130 metres east of Meadow Road (a pipe culvert). Each structure has been sized to convey the one per cent AEP flood across the proposal.
- Vegetated swales will be included on both sides of the proposal east of Victory Road to direct off-site stormwater flows safely to the east towards the tributary of Eastern Creek. The location of proposed swales is shown on Figure 8-1.
- Scour protection. The predicted increase in velocity is expected to occur adjacent to and as a direct influence of the proposal. This will be assessed during the detailed design phase and mitigated using measures such as scour protection where required. Scour protection will be provided on the Bells Creek bridge abutments to minimise the possibility of scour of the road embankment. Scour protection comprising rock or scour resistant vegetation will also be provided on culvert outlets and within channels.

A comprehensive list of mitigations measures is provided in Table 8-2

Table 8-2 Potential impacts and mitigation measures

Risk	Potential impacts	Measures to avoid, mitigate or minimise impacts
Hydrologic		
Impact on surface flow in watercourse and flows in channels/drainage structures	• Modified surface flow volume or rate downstream of the road corridor	• Avoid installation of stormwater drainage elements that create localised surface water ponding
	• Changed surface flow paths across the project site	• Minimise regrading of terrain along the road corridor • Install appropriately sized stormwater drainage pipes along the road corridor
Hydraulic issues		
Impact of widening the road corridor	• Increased upstream flooding depths, extents and hazard • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (eg road closures) • Additional impacts downstream of structures	• The design has included consideration of this by designing the bridges so that impacts on flood hydraulics are minimised
Impact of providing increased stormwater drainage capacity	• Increased downstream flooding depths, extents and hazard • Increased downstream flood durations and reduced emergency access • Increased downstream impacts on buildings • Increased impacts on adjacent infrastructure (eg road closures) • Increased downstream velocities and scour potential	• Do not reduce watercourse flow areas • Reinstatement of local scour protection works in unlined channels, where present. • Where practical, detailed design will result in no net increase in stormwater runoff rates in all storm events, unless it can be demonstrated that increased runoff rates as a result of the project would not increase downstream flood risk and scour potential
Impact of raising Townson Road	• Increased upstream levels in floods that would no longer overtop the road	• Floodplain bridges to increase hydraulic capacity under road
Impact of filling/works in flood storage areas	• Increases in flood levels, or hazard • Changes in flow paths	• Avoid filling in flood storage areas where there is potential for adverse impacts on surrounds • Provide additional capacity/mitigation if required

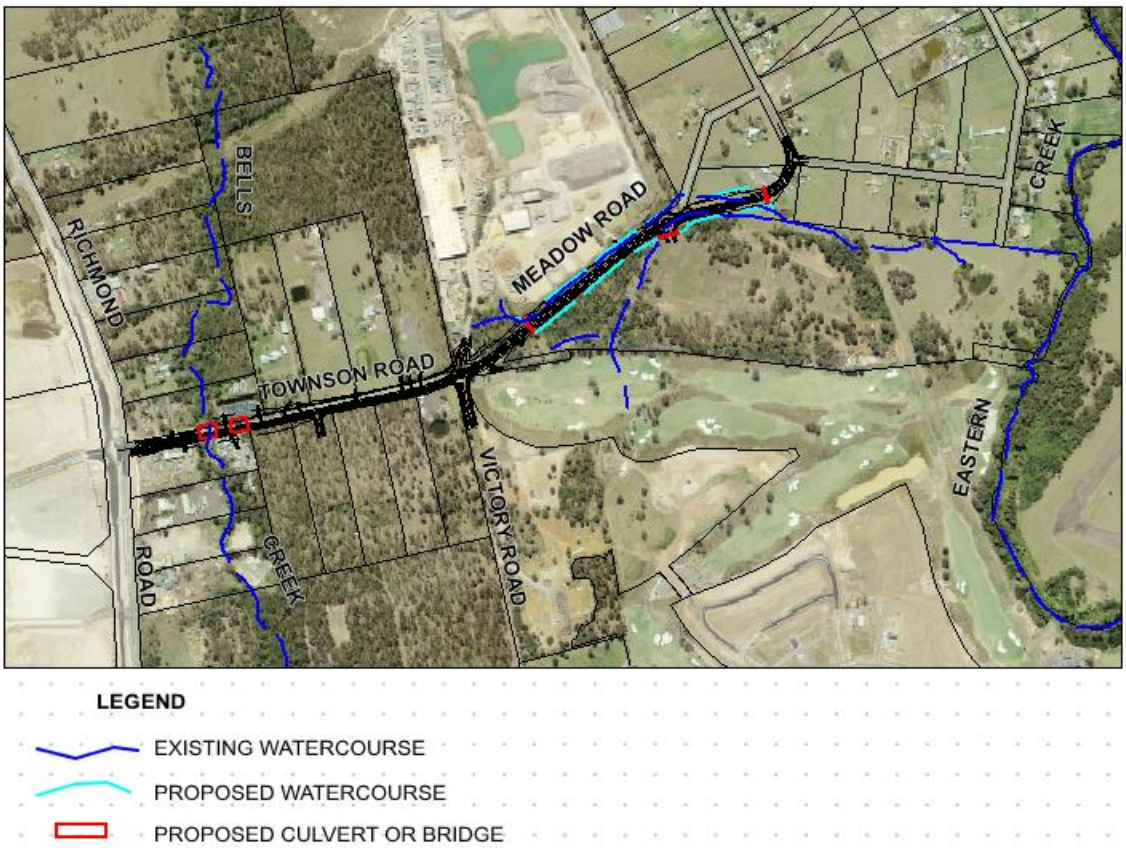


Figure 8-1 Existing and proposed waterways

9. Conclusion

The proposal crosses Bells Creek and a tributary of Eastern Creek. The existing Townson Road formation that crosses Bells Creek is frequently overtopped by flood waters. The proposal will upgrade the flood immunity to 0.2 per cent AEP to provide a flood evacuation route for the developable land which lies to the east of the creek crossing. The proposal will include two new bridges across Bells Creek and new culverts and swales to manage stormwater flows east of Victory Road.

Existing and proposed flooding behaviour in Bells Creek has been modelled using TUFLOW for the five per cent, two per cent and one per cent AEP and PMF flood events. Additionally, the 0.2 per cent AEP event was modelled for proposed conditions to confirm that the proposal can operate as a flood evacuation route. A future climate change scenario has also been modelled for the one per cent AEP event to assess the potential for future flood level increases in Bells Creek.

Flood maps were prepared from the model results showing existing and proposed flood levels, flood velocities and flood hazard. Flood level impacts and velocity impacts were also mapped.

For the one per cent AEP event, on the western floodplain, a maximum flood level impact of 0.02 metres occurs on existing commercial land which adjoins and forms part of the Bells Creek floodplain, south of Townson Road. This increase in flood levels will not impact existing buildings on this land. On the eastern floodplain, the maximum impact is 0.19 metres at the edge of the floodplain, south of Townson Road. This impact occurs in land that is zoned as ‘drainage land’ and which is not currently developable land.

Downstream of Townson Road, there are localised minor increases in flood levels adjacent to Townson Road, which occur at the proposed bridge opening locations, but which reduce to zero within one hundred metres downstream of the proposal. The land affected by these altered flood levels is zoned under Blacktown Council’s Local Environment Plan as “Parks” and is not developable.

The raising of Townson Road will result in increased flood levels in the PMF event, with flood level increases of up to 1.0 metre predicted to occur upstream of Townson Road. Adjacent properties will have rising access to higher ground for refuge during a PMF.

The proposal will incorporate measures to mitigate potential changes to flooding conditions and manage the conveyance of stormwater through the proposal. These measures will include:

- The inclusion of two floodplain bridges across the Bells Creek floodplain to mitigate upstream flood impacts and provide for passage of the 0.2 per cent AEP flood event to enable Townson Road to act as a flood evacuation route during rare flood events.
- Culverts to allow for the passage of stormwater across the proposal and to minimise flooding impacts on adjacent land.
- Vegetated swales on both sides of the proposal east of Victory Road to direct off-site stormwater flows safely to the east towards the tributary of Eastern Creek.
- Scour protection to the Bells Creek bridge abutments to minimise the possibility of scour of the road embankment. Scour protection comprising rock or scour resistant vegetation will also be provided on culvert outlets and within channels.
- Inclusion of a bund adjacent to the existing nursery designed to mitigate flooding impacts on the nursery in the interim phase of the project. Flood modelling demonstrates that this bund will provide effective flood mitigation to the nursery.

Climate change modelling considering rainfall intensity increases of 15 per cent showed that one per cent AEP flood levels could increase by up to 0.15 metres in Bells Creek. This would not impact the flood immunity of the proposal. Consideration of climate change impacts on rarer events to assess the evacuation route flood immunity was not undertaken due to current uncertainty around climate change impacts on rarer rainfall events.

10. References

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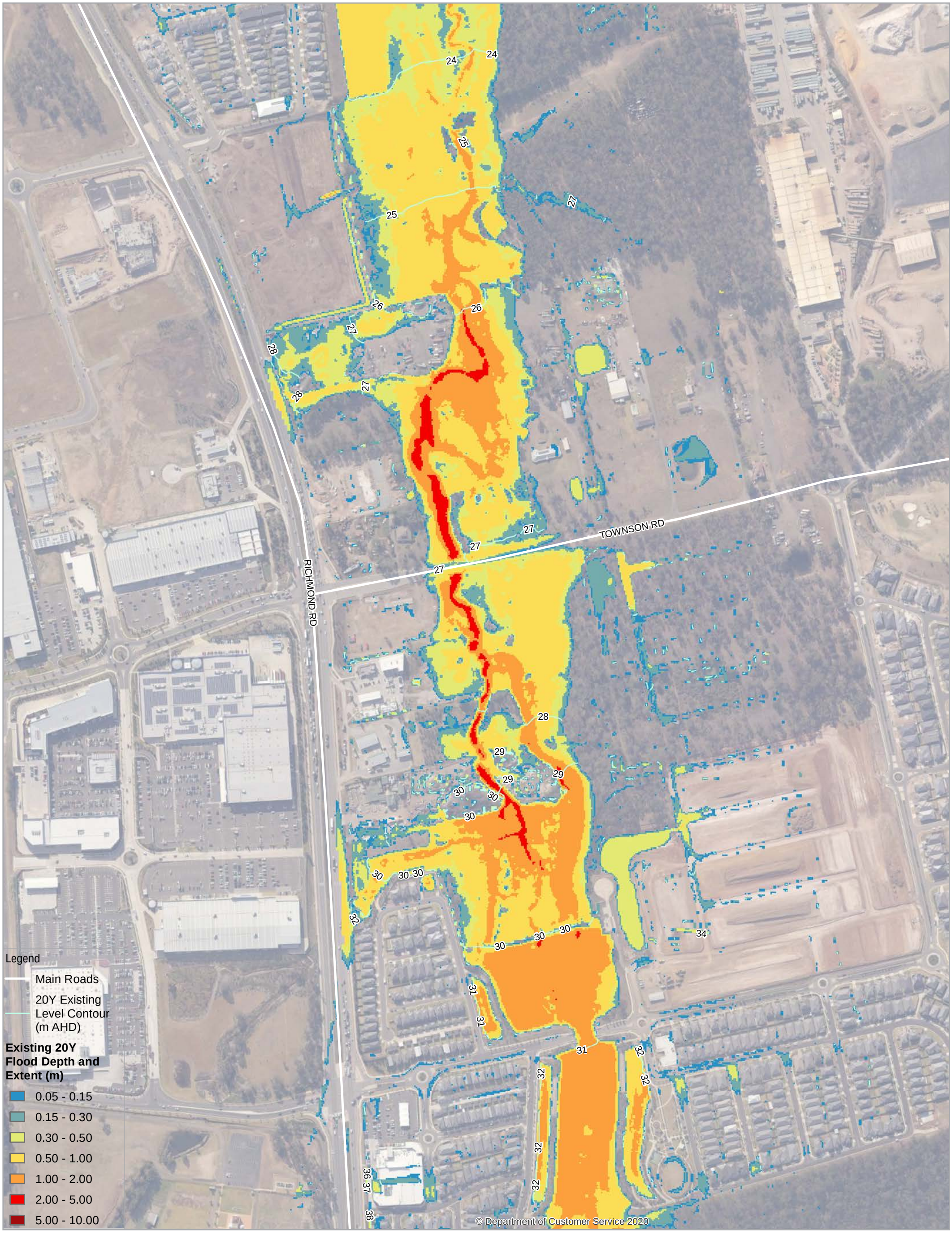
Appendices

Appendix A – Flood Mapping



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Kilometers

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Depth and Level Contours
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-01

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Kilometers

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flooding Velocity
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-02

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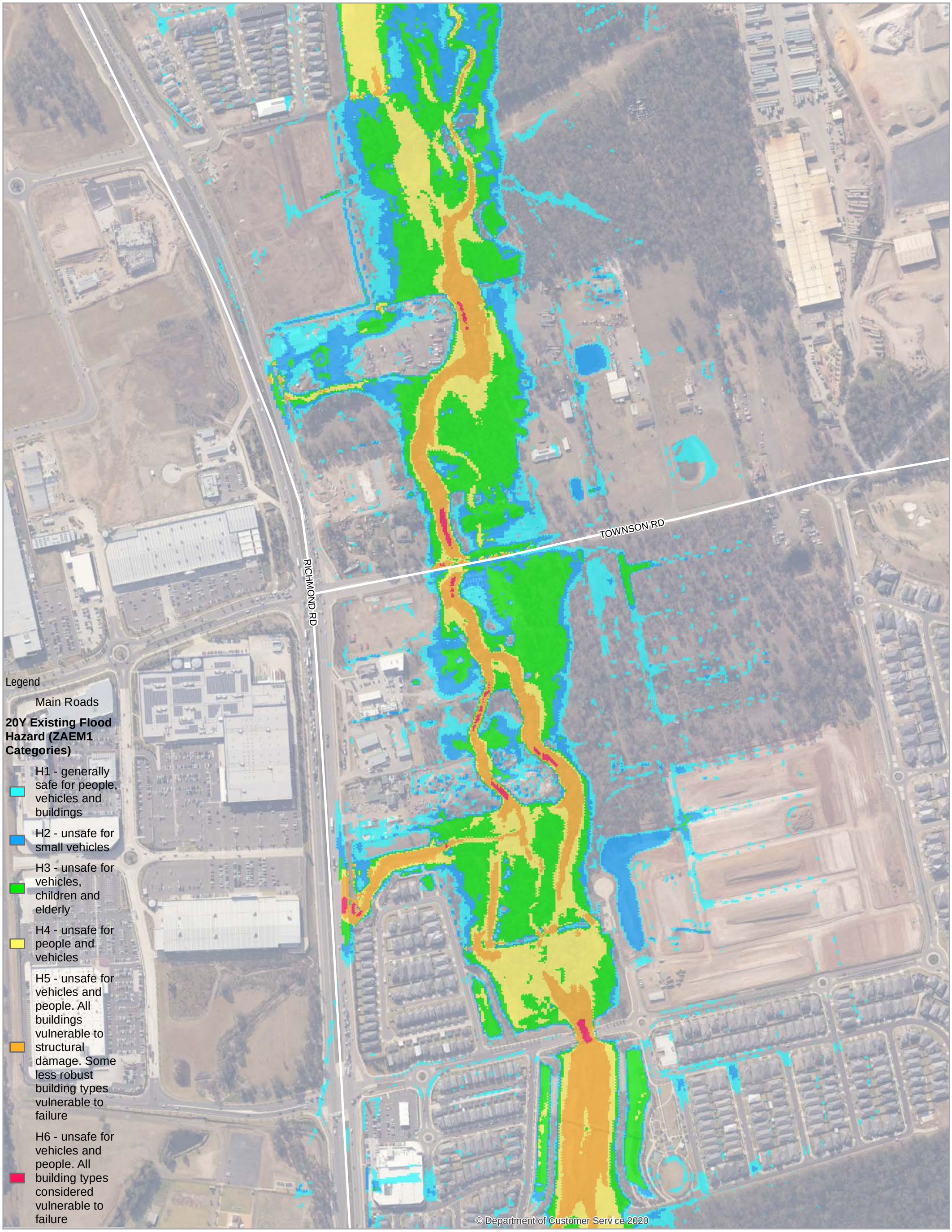

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GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Hazard Category ZAEM1
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-03

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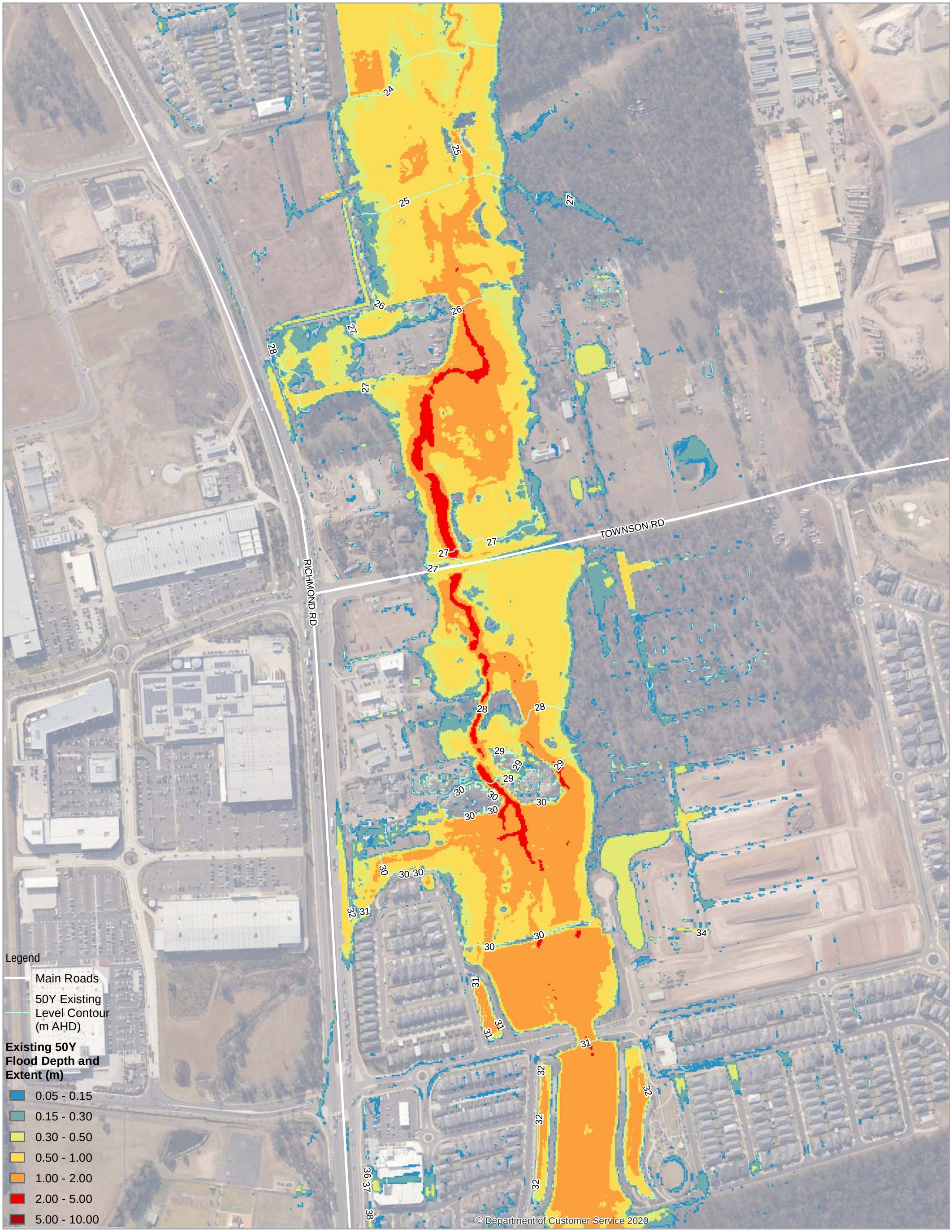

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Kilometers

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Depth and Level Contours
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-04

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Kilometers

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flooding Velocity
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-05

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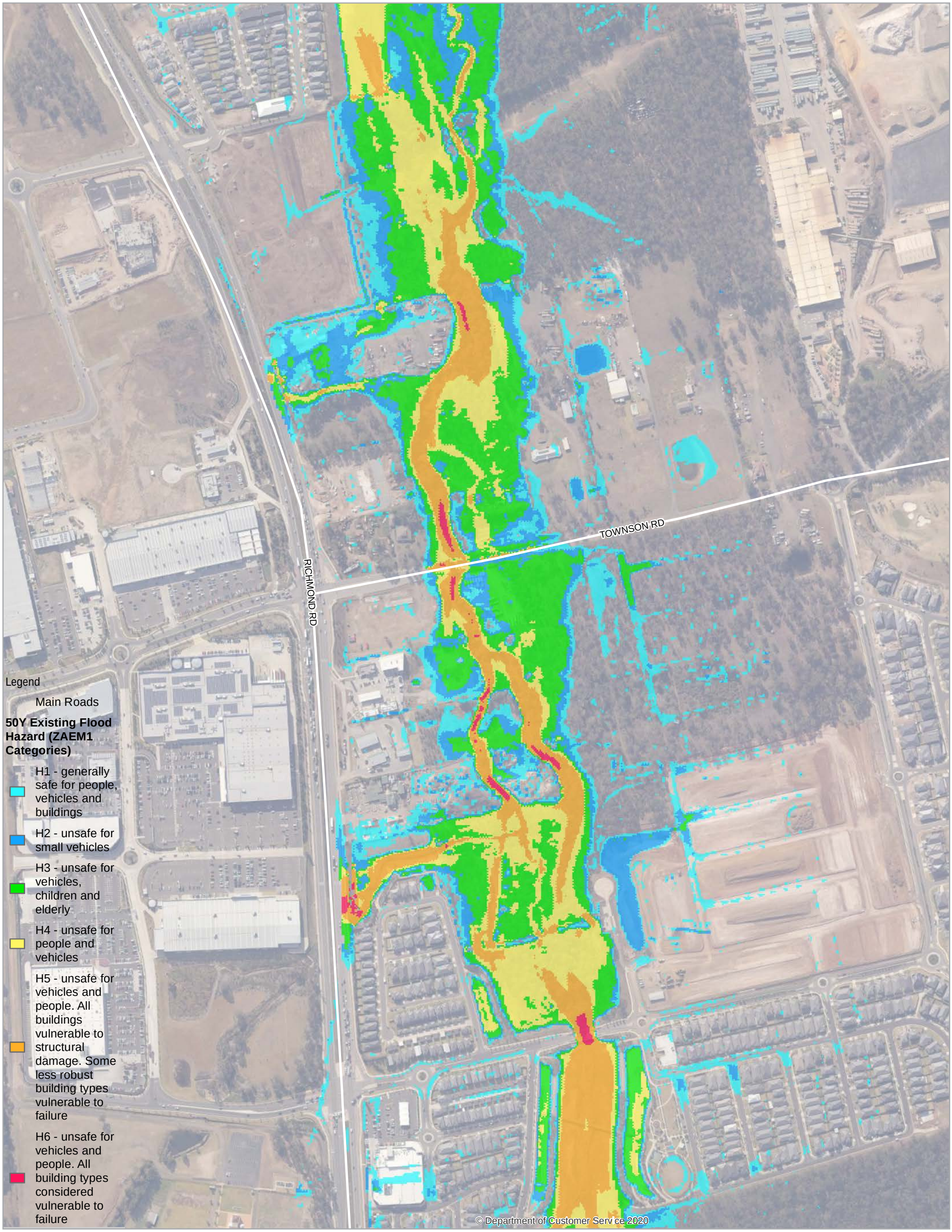

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Kilometers

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Grid: GDA 1994 MGA Zone 56

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Hazard Category ZAEM1
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-06

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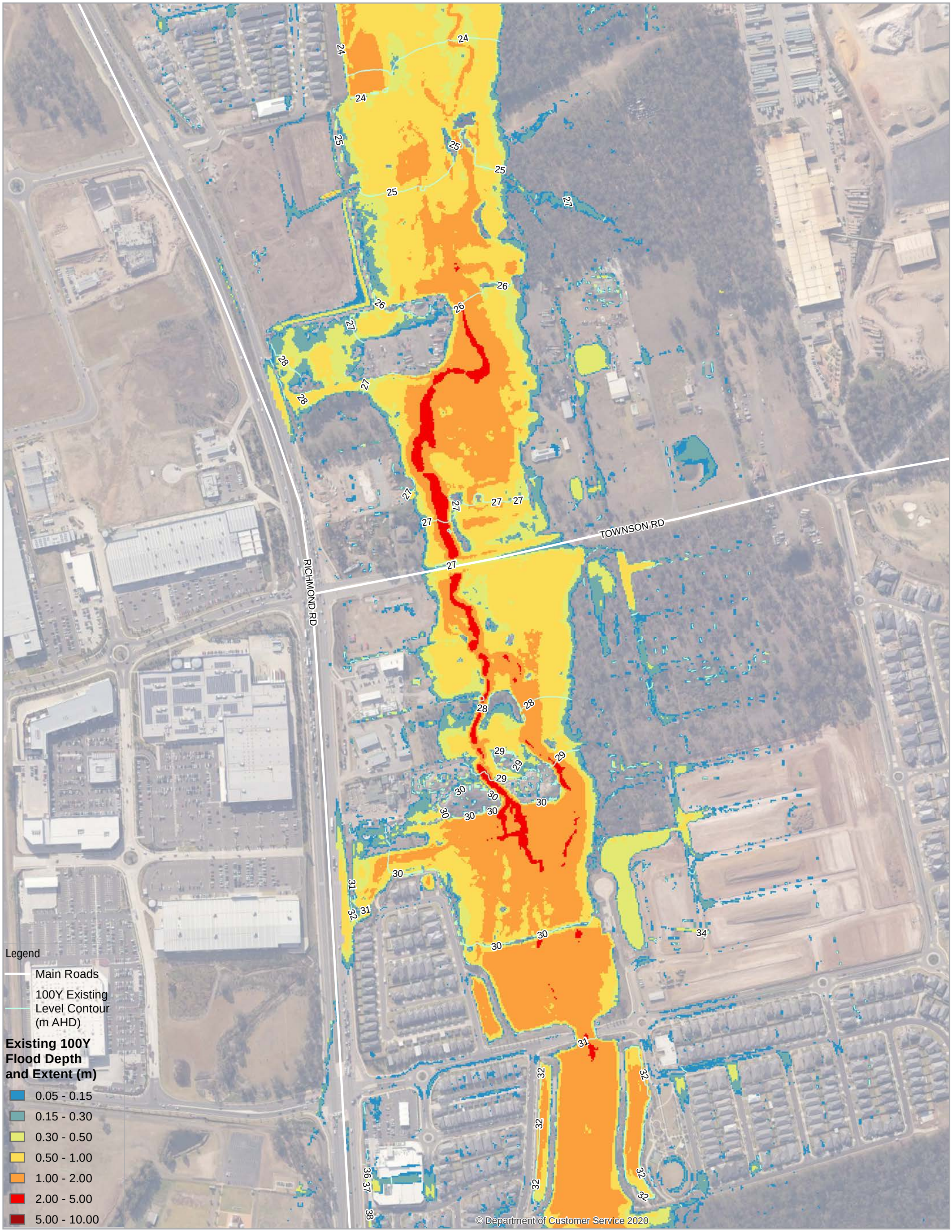

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Kilometers

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Depth and Level Contours
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-07

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flooding Velocity
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-08

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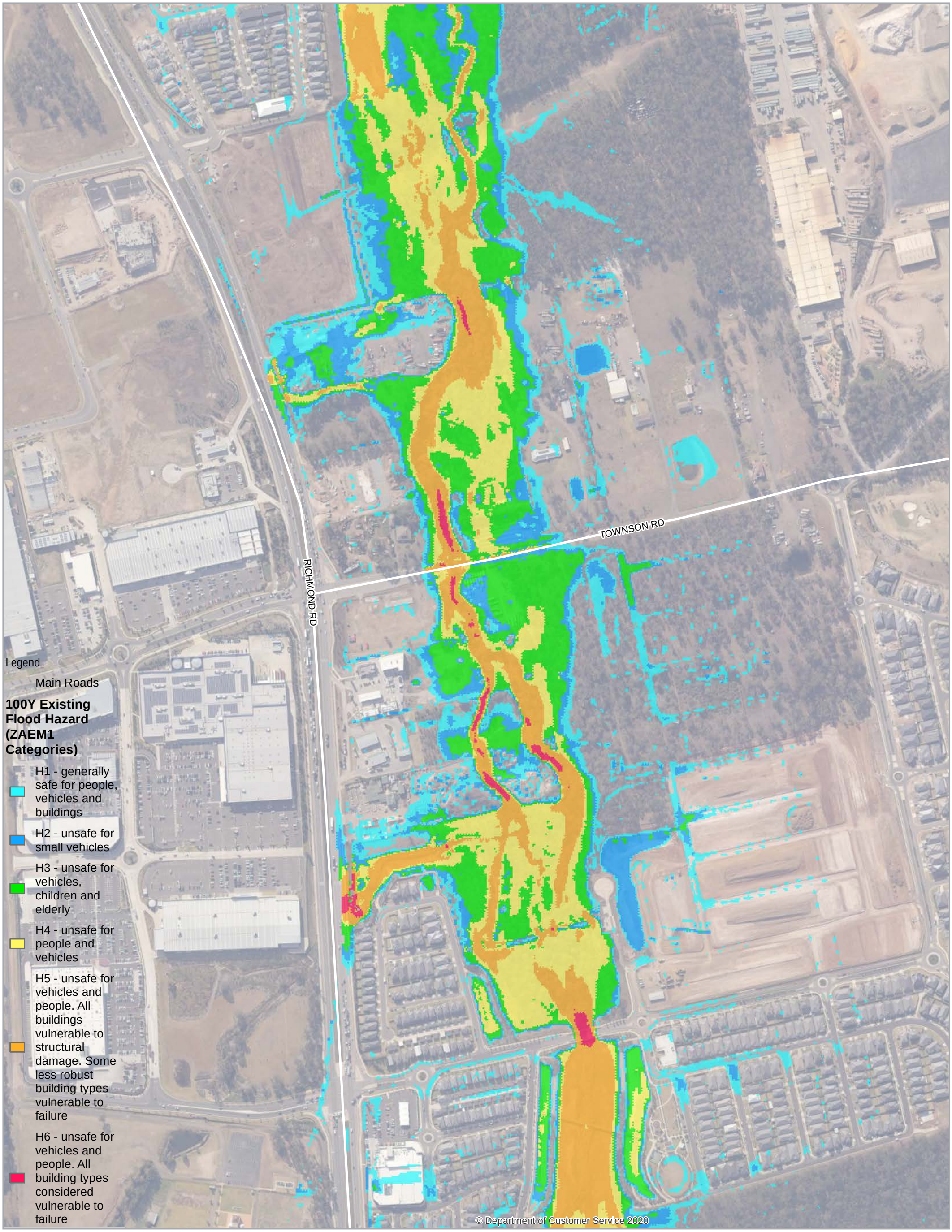

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Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Hazard Category ZAEM1
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-09

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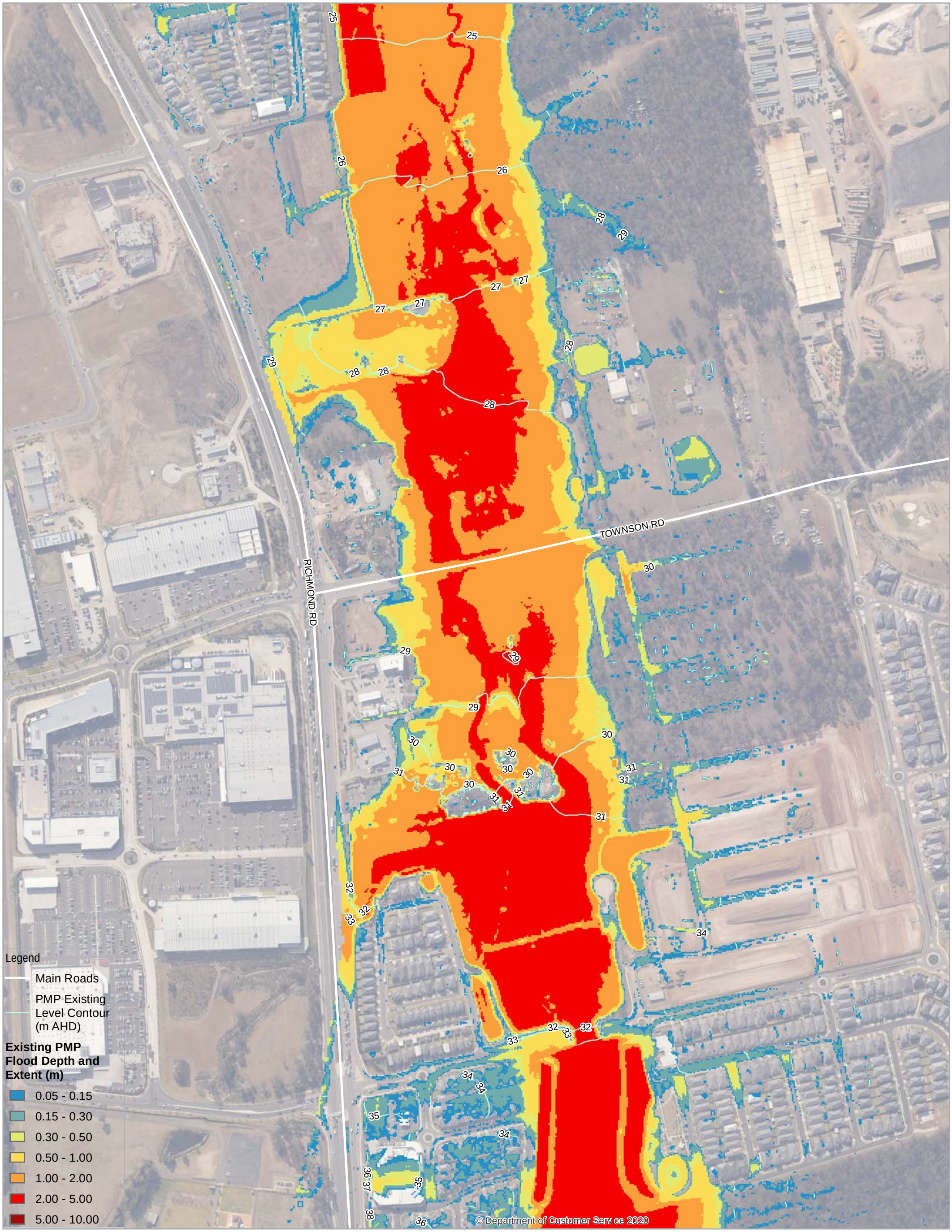

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Grid: GDA 1994 MGA Zone 56

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Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Depth and Level Contours
PMP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-10

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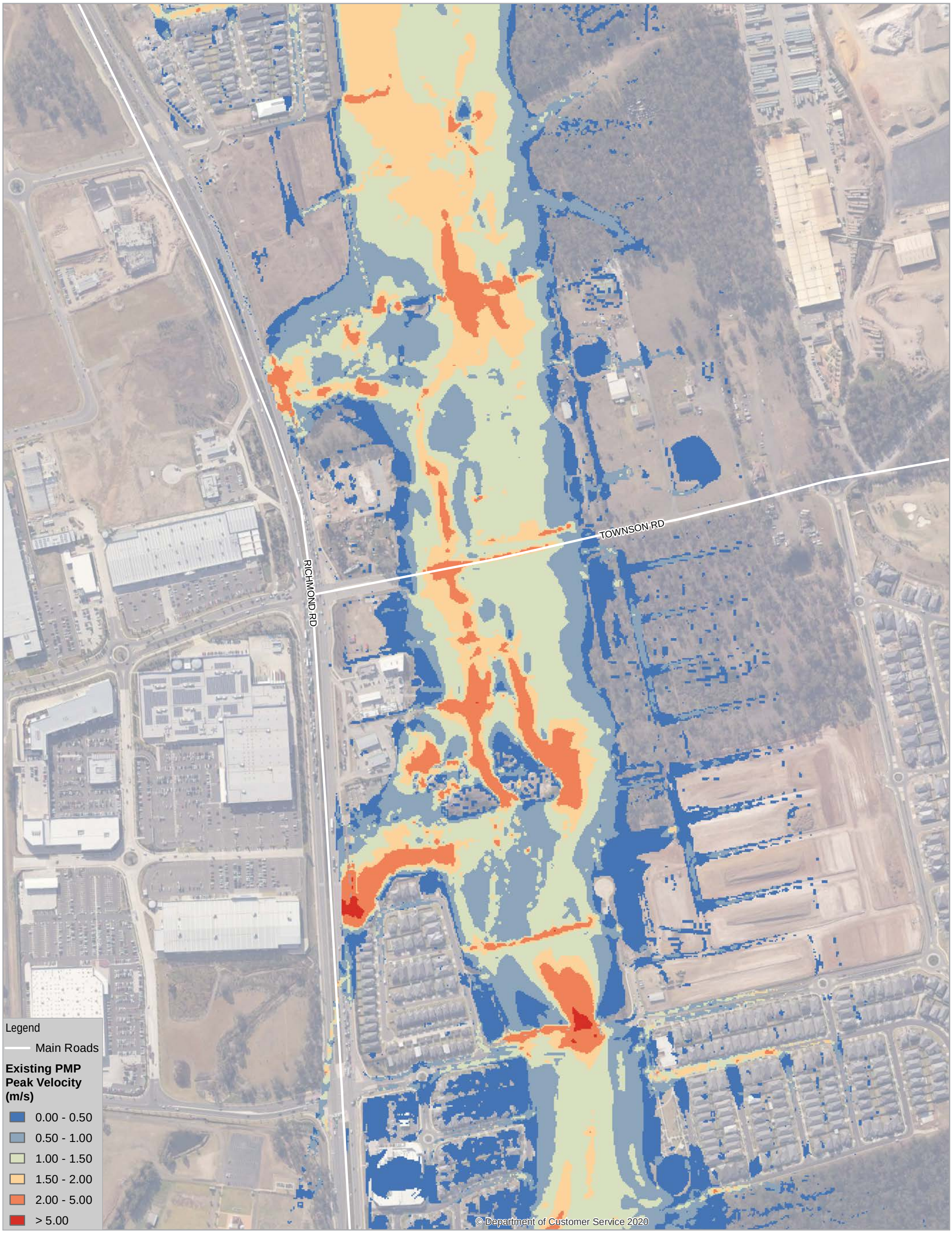

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Kilometers

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Grid: GDA 1994 MGA Zone 56

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flooding Velocity
PMP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-11

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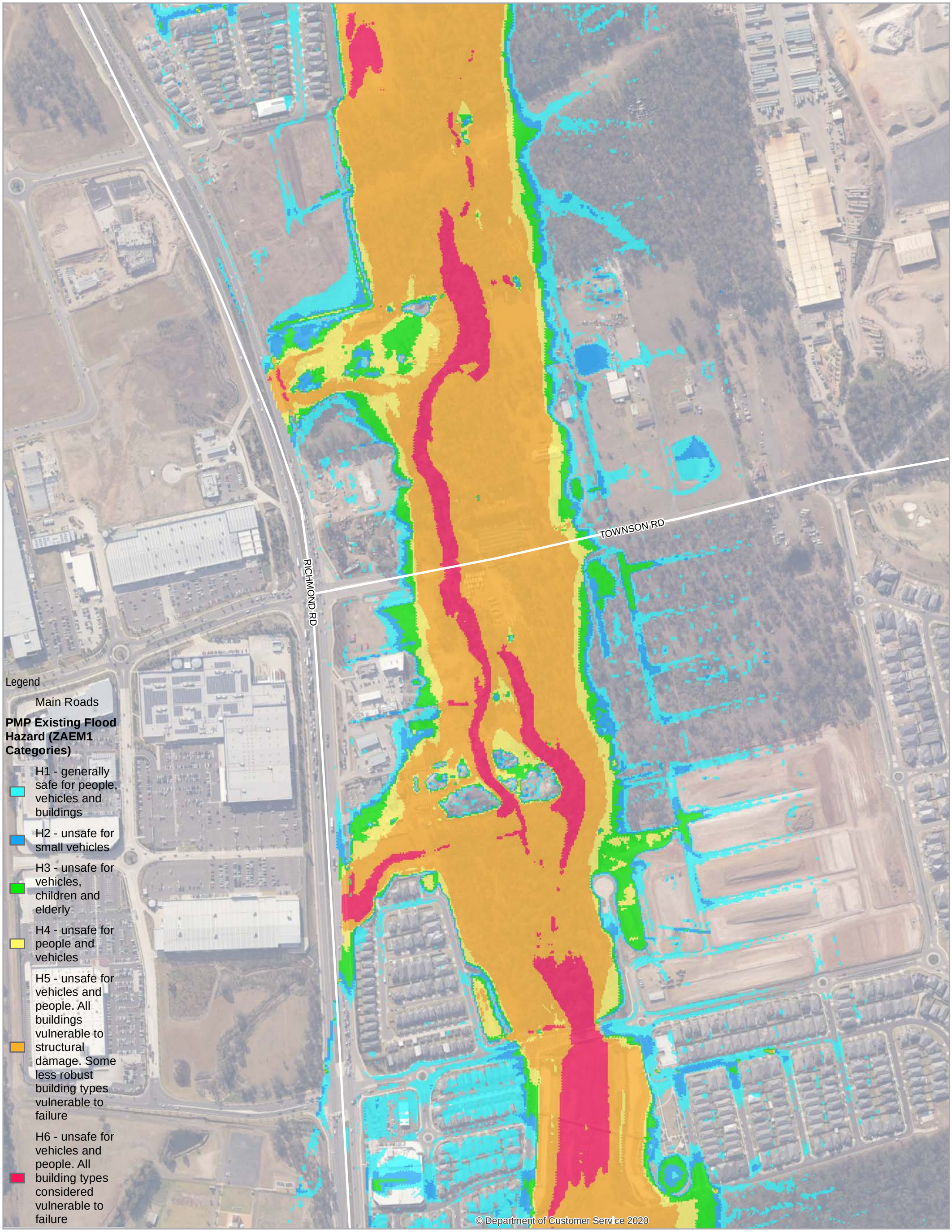

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Kilometers

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Grid: GDA 1994 MGA Zone 56

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Hazard Category ZAEM1
PMP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-12

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RICHMOND RD

TOWNSON RD

Legend

Main Roads

20Y Option Level Contour (m AHD)

Option 20Y Flood Depth and Extent (m)

- 0.05 - 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00

Proposed Stage 1 Upgrade

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

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

N

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option Flood Depth and Level Contours 5% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-13

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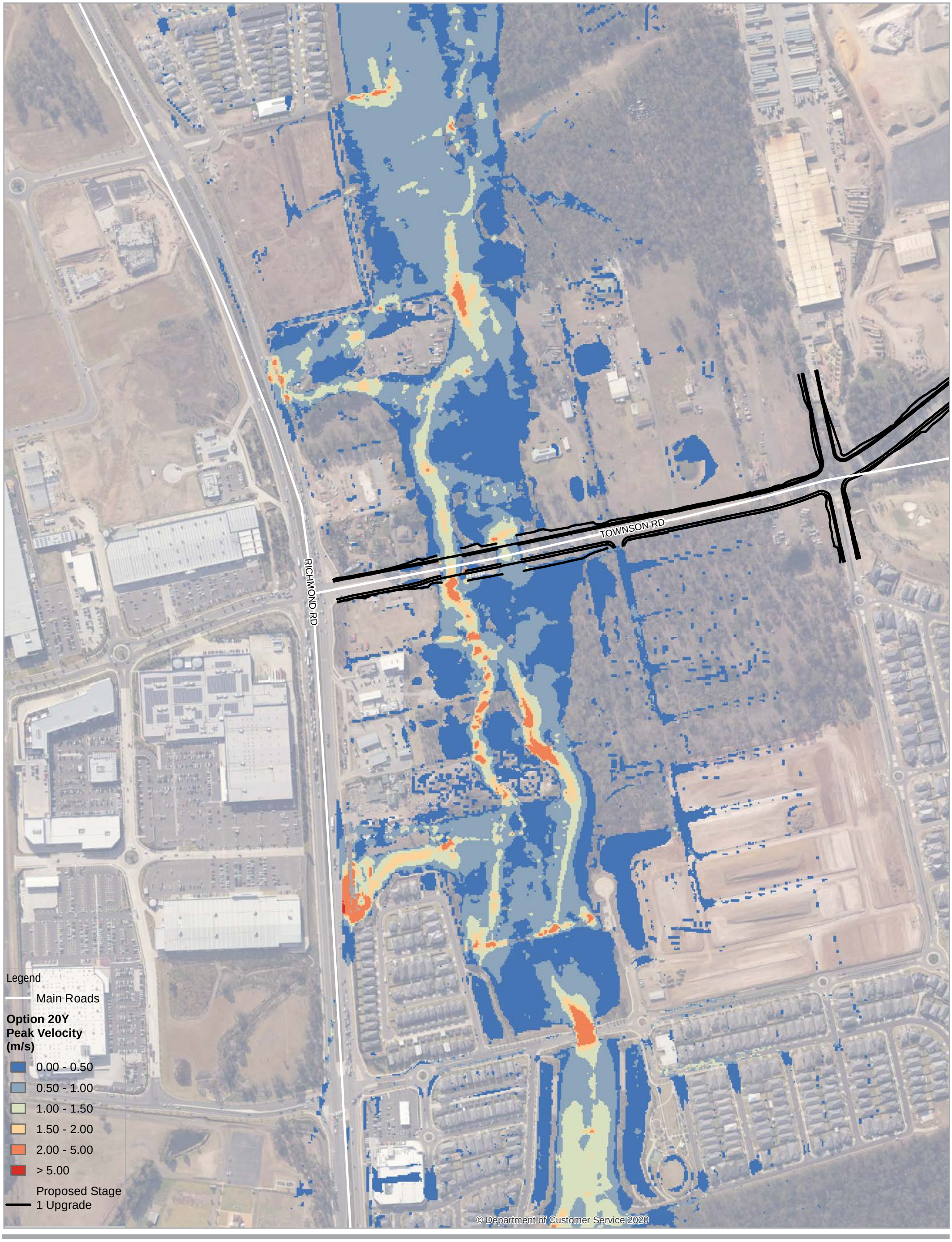

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Kilometers

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

N

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flooding Velocity
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-14

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TOWNSON RD

RICHMOND RD

Legend

Main Roads

Option 20Y Flood Hazard (ZAEM1 Categories)

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

Proposed Stage 1 Upgrade

Paper Size ISO A3

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Kilometers

N

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

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Hazard Category ZAEM1
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-15

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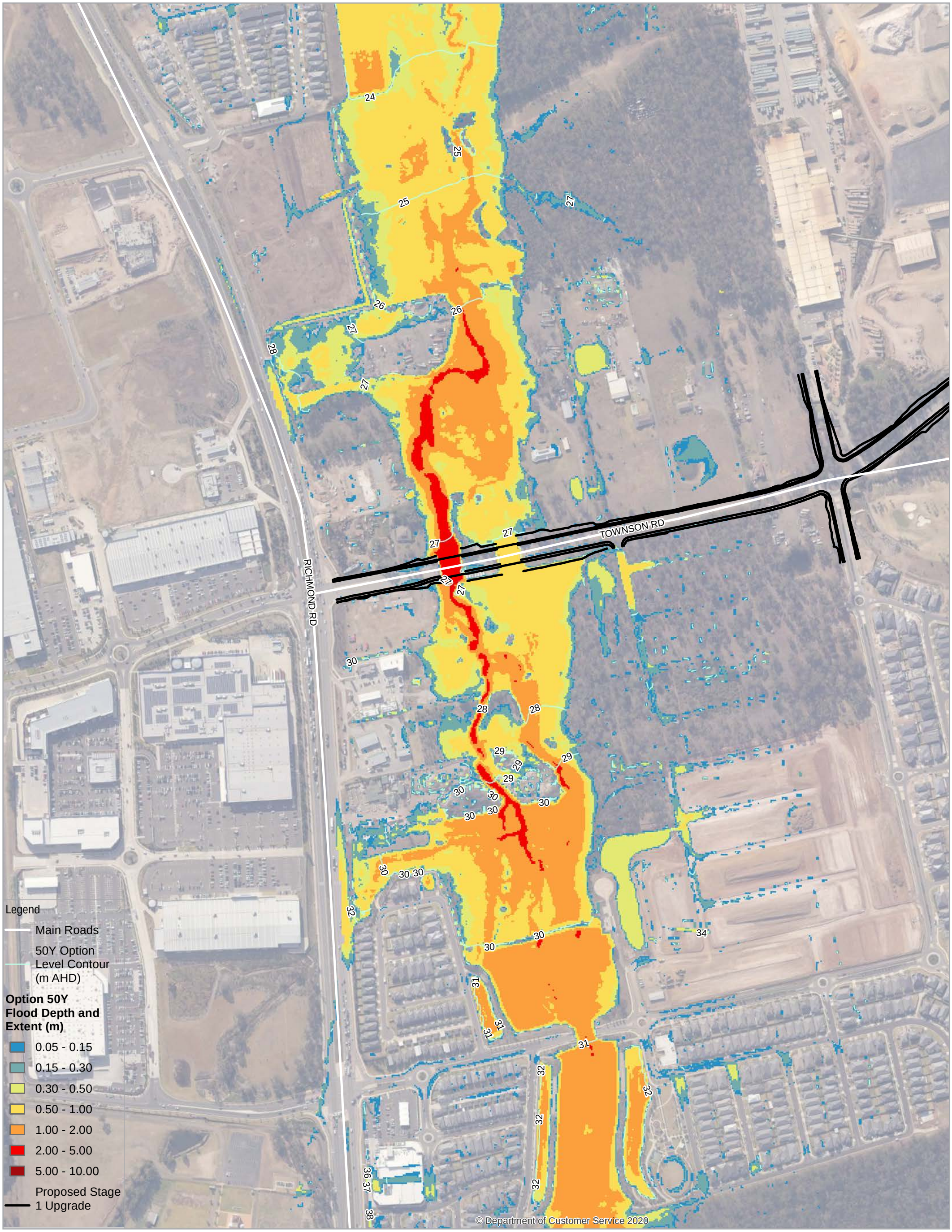

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Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option Flood Depth and Level Contours 2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-16

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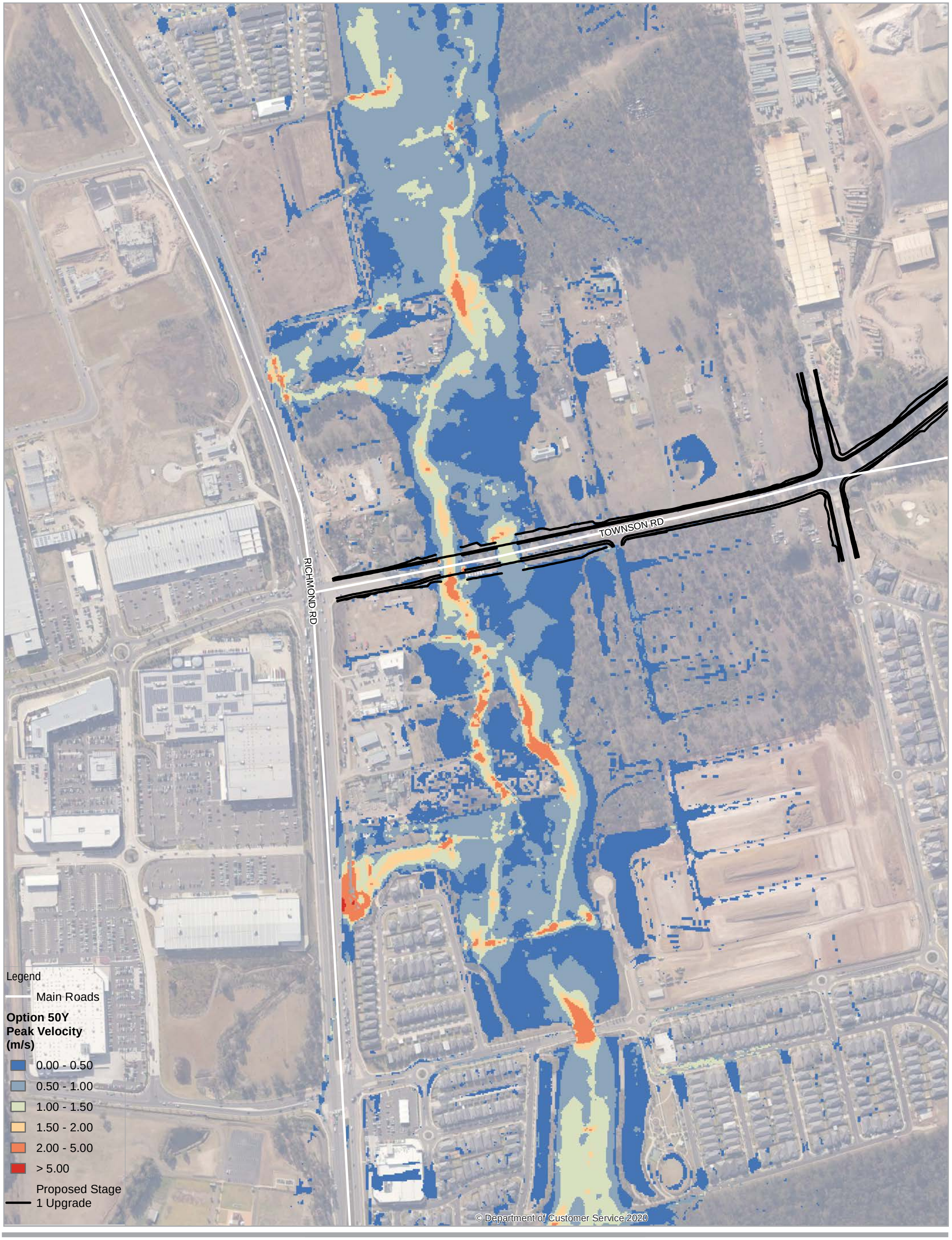

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Kilometers

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Grid: GDA 1994 MGA Zone 56

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flooding Velocity
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-17

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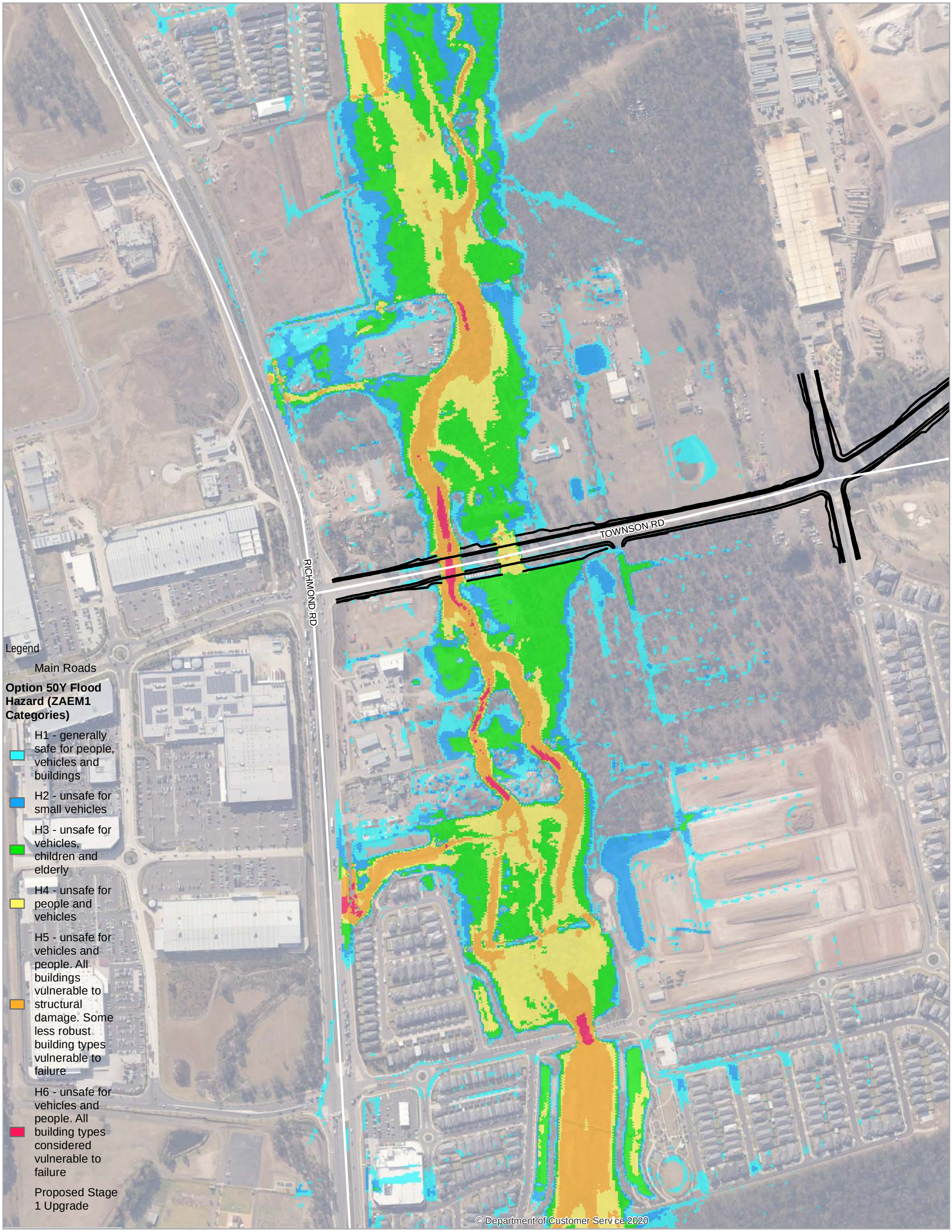

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Kilometers

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Grid: GDA 1994 MGA Zone 56

N

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Hazard Category ZAEM1
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-18

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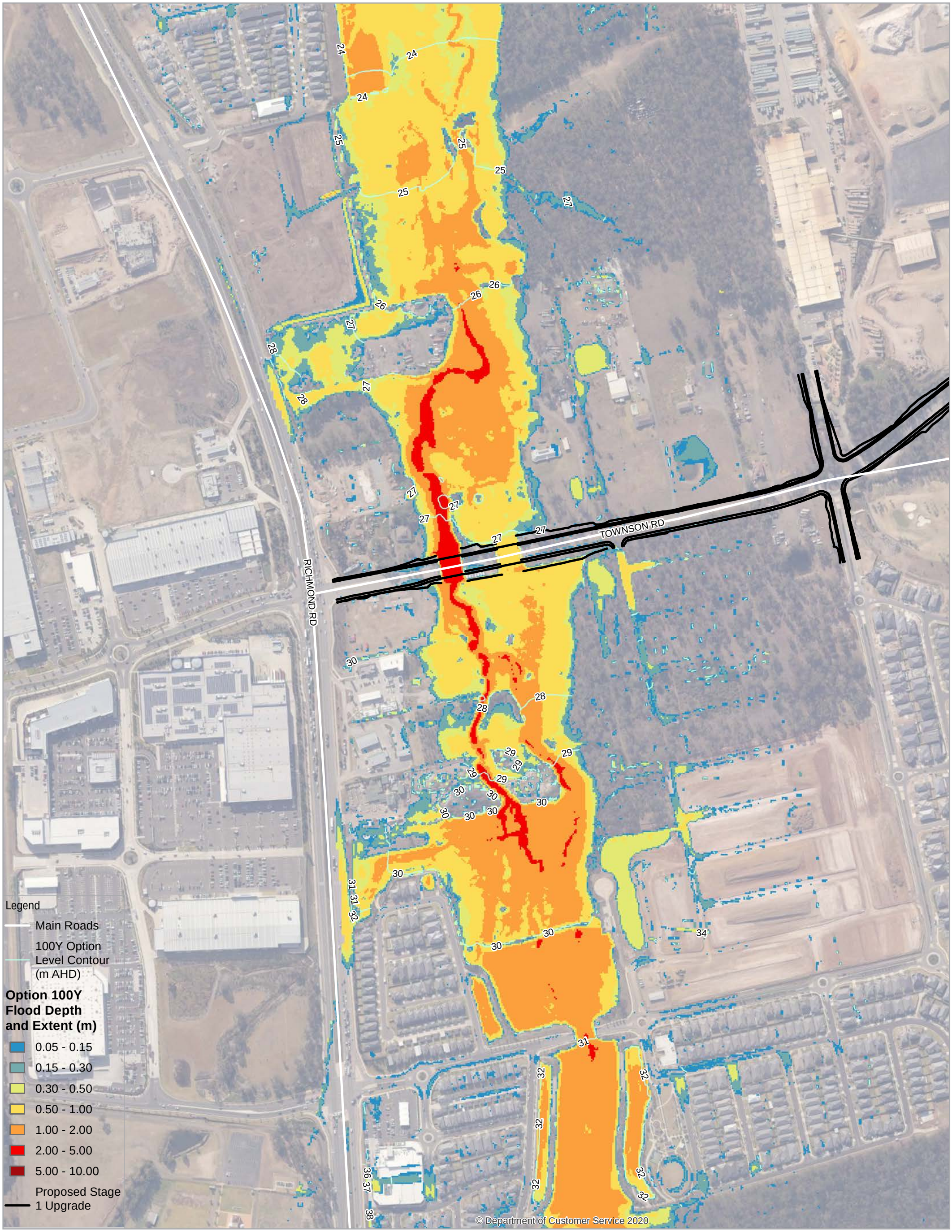

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Kilometers

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Grid: GDA 1994 MGA Zone 56

N

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Depth and Level Contours
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-19

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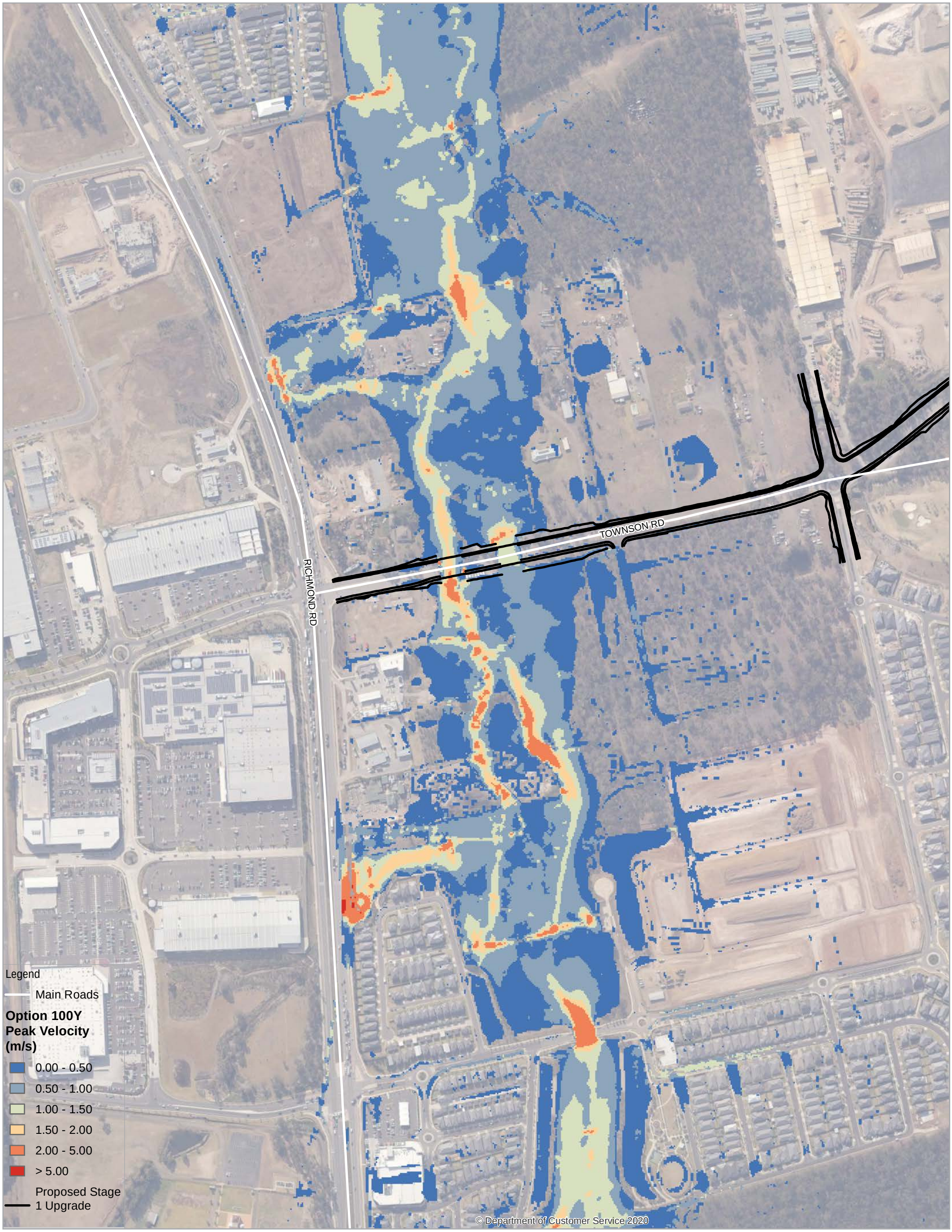

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Kilometers

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flooding Velocity
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-20

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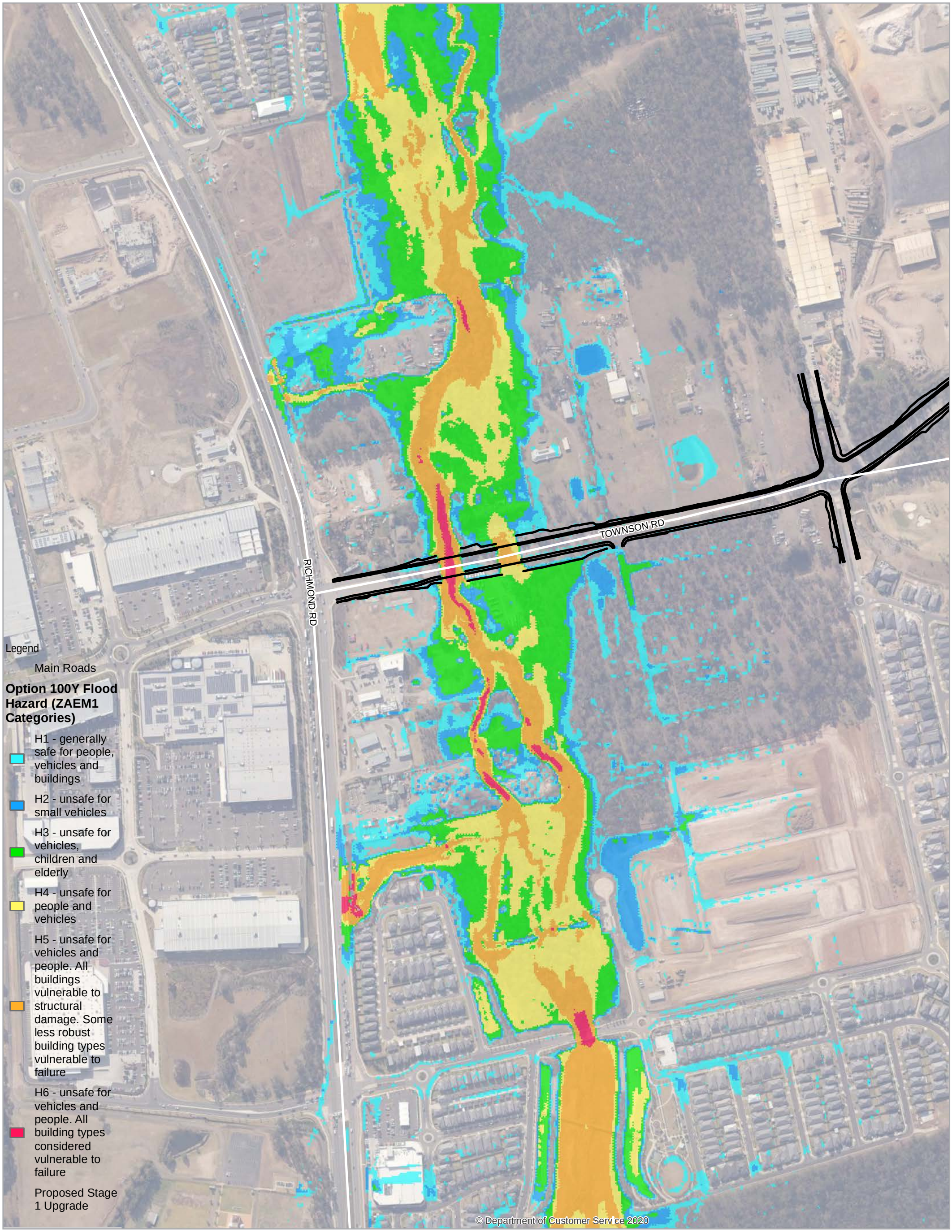

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Kilometers

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Hazard Category ZAEM1
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-21

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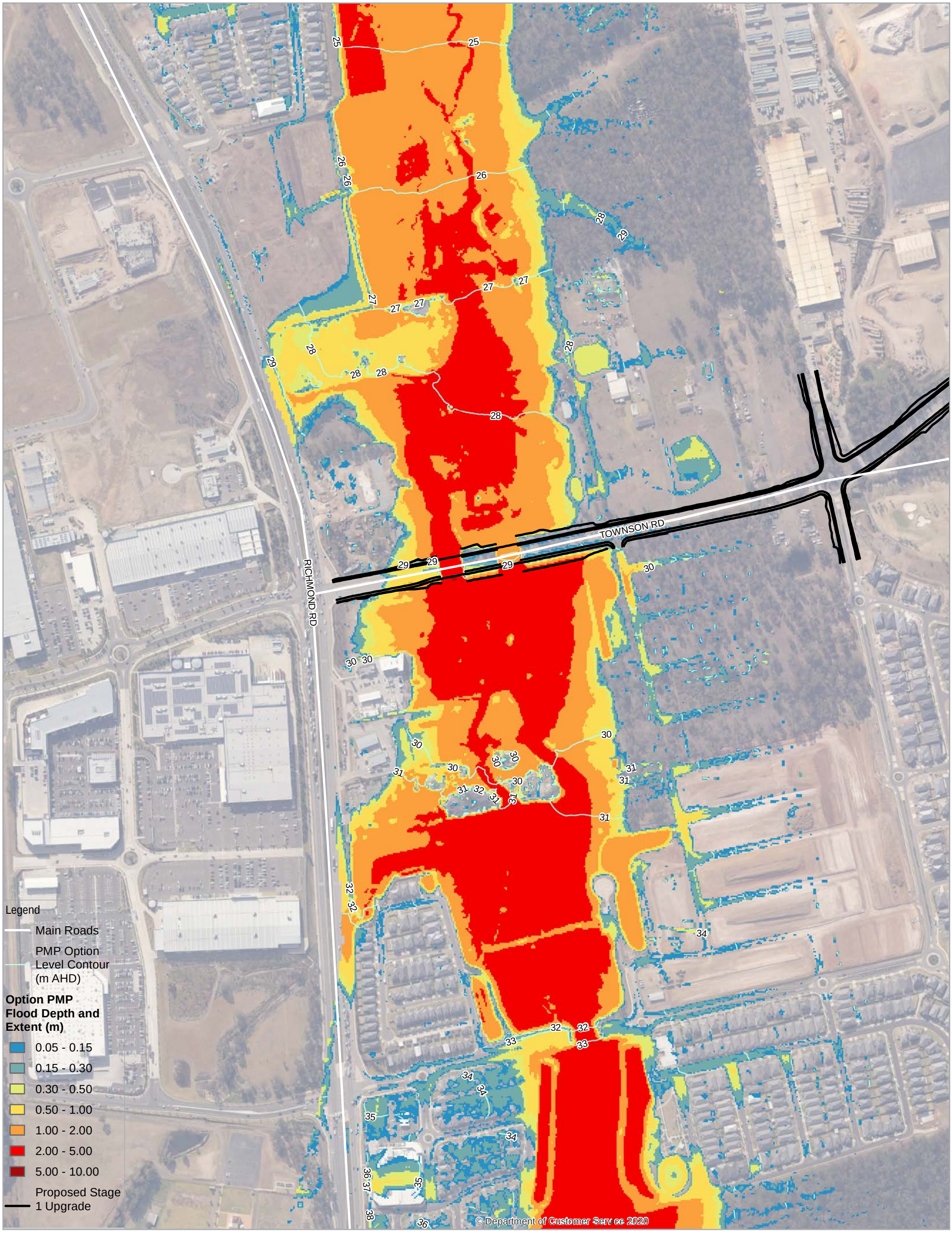

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Kilometers

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

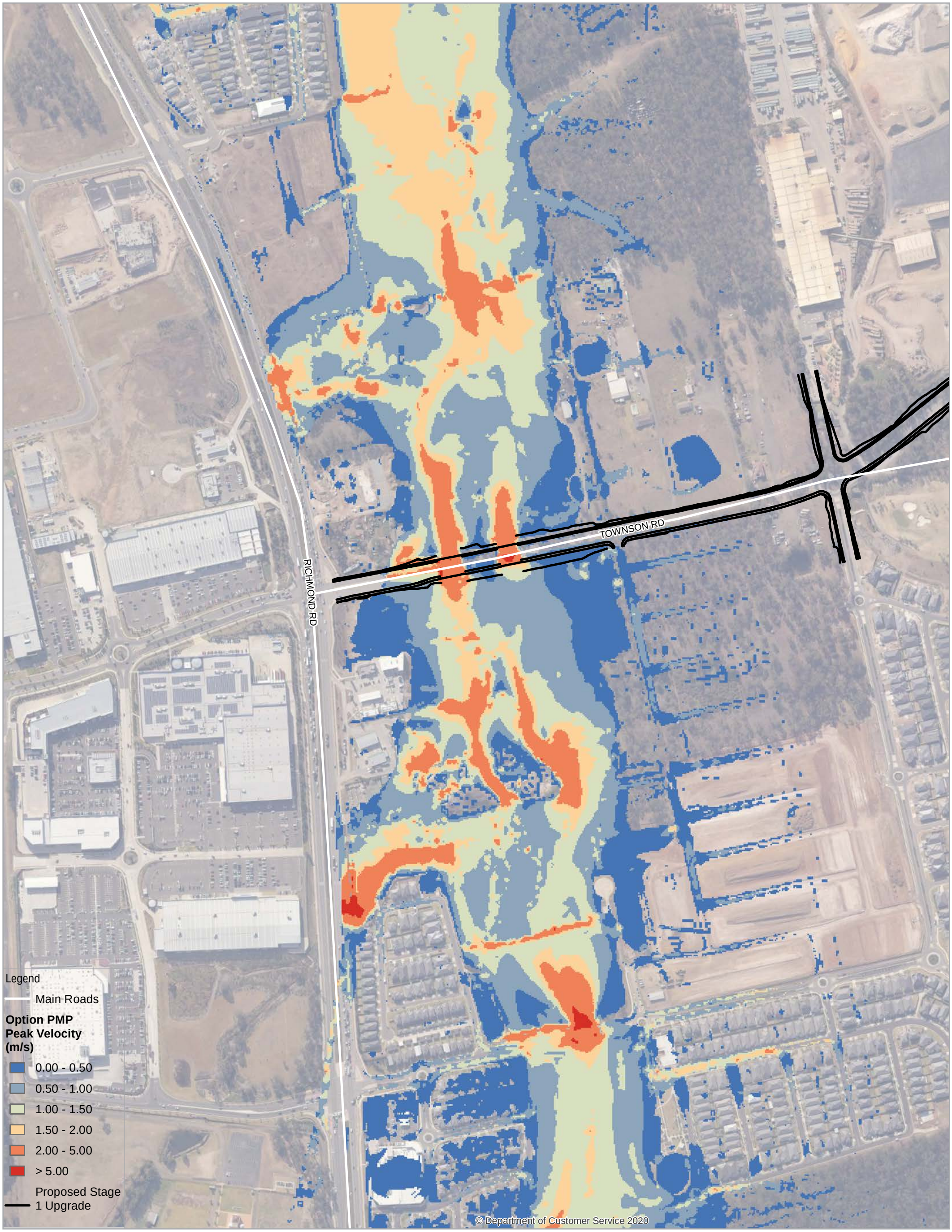
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Depth and Level Contours
PMP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-22

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 11 Nov 2020 - 10:46 (SMA record: 24)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

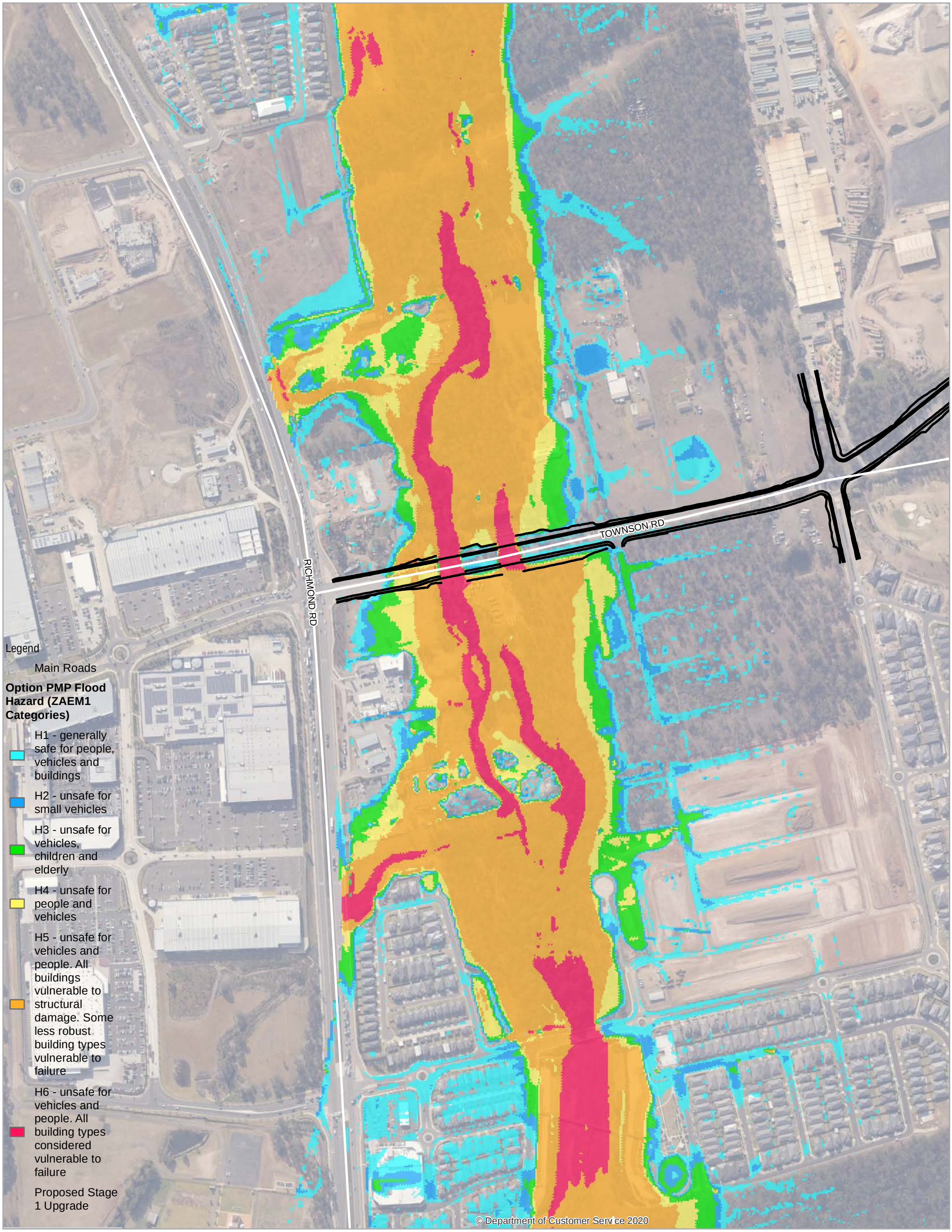
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flooding Velocity
PMP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-23

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 11 Nov 2020 - 10:46 (SMA record: 25)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

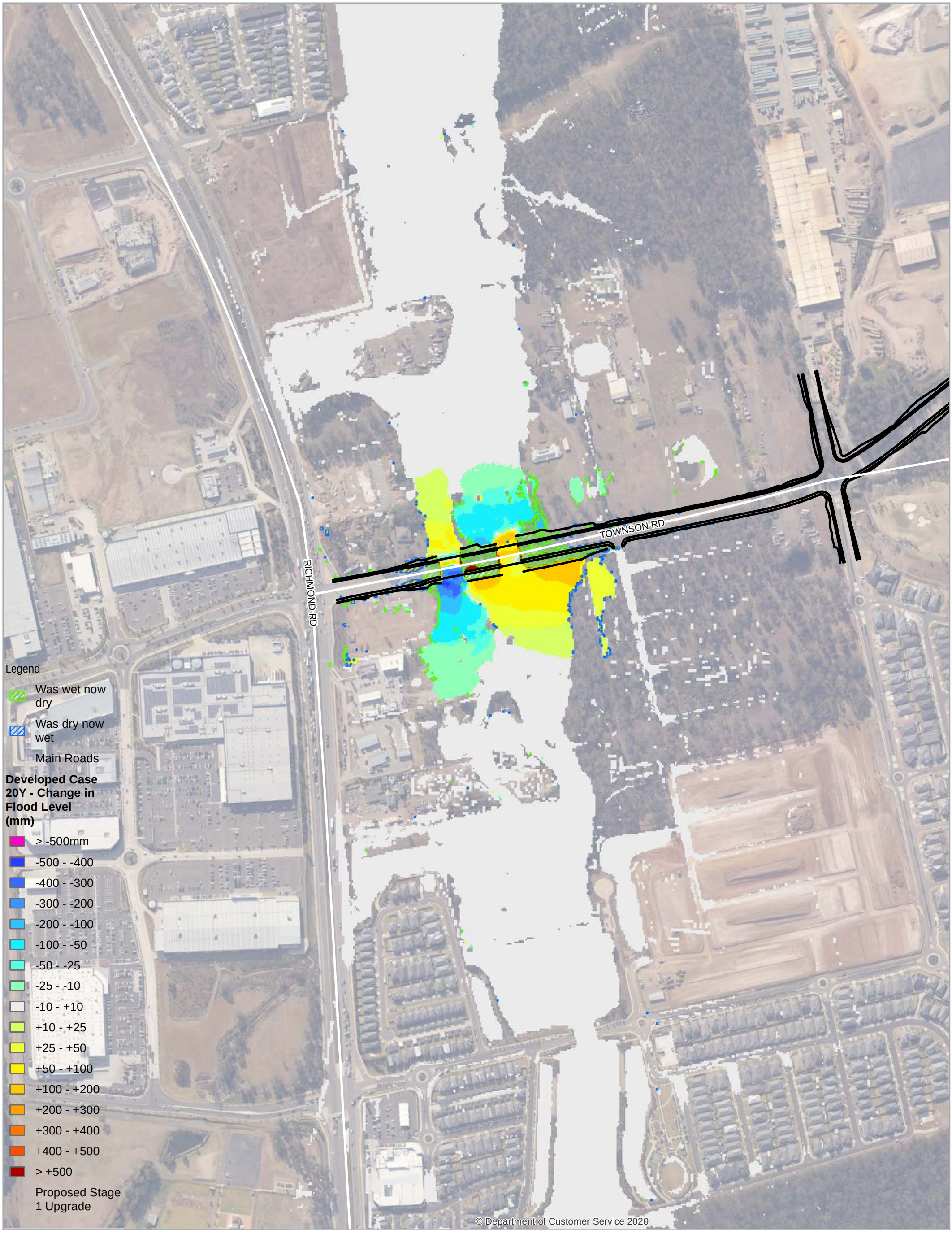
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Hazard Category ZAEM1
PMP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-24

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 11 Nov 2020 - 10:46 (SMA record: 26)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

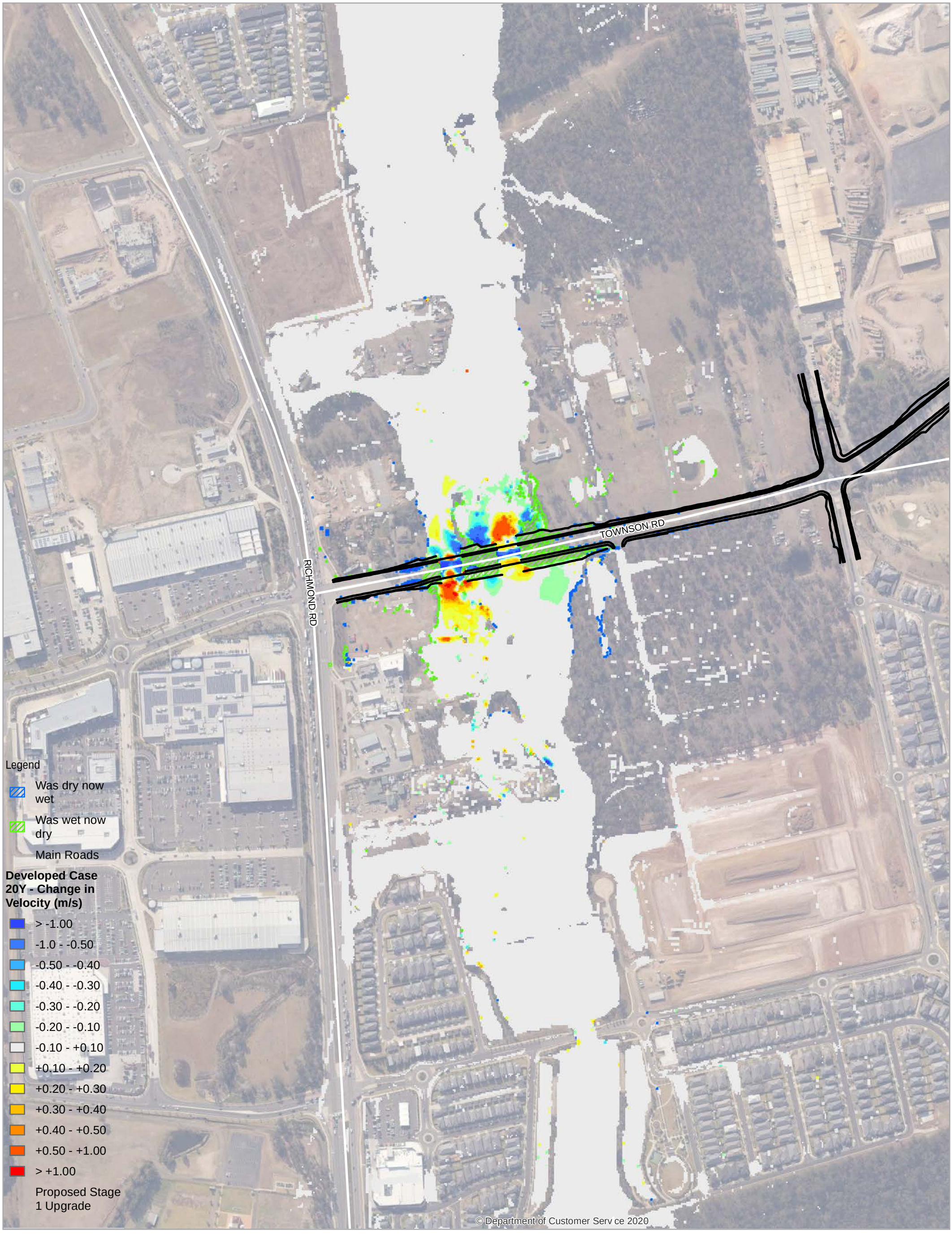
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Level Impact
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-25

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 19:58 (SMA record: 27)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

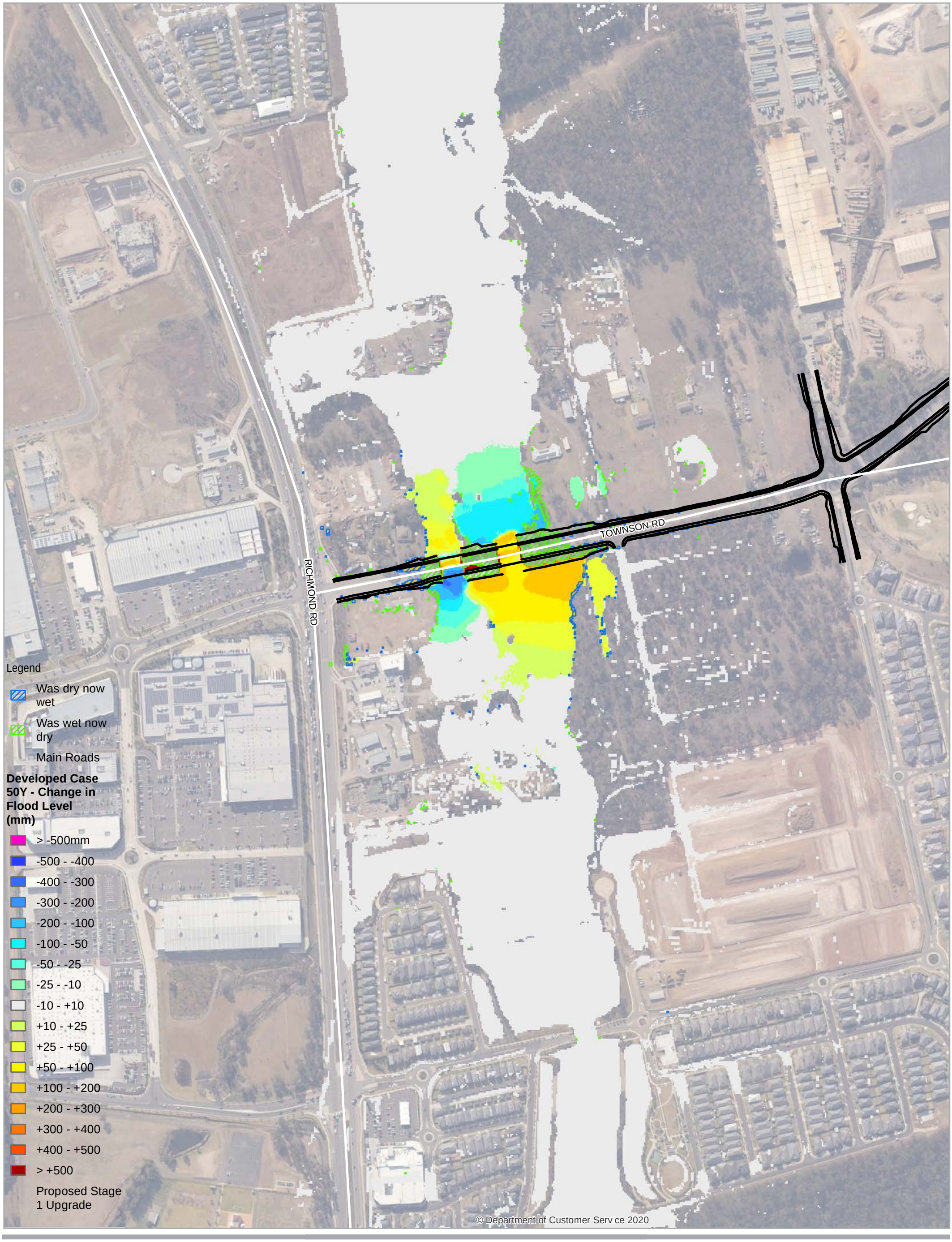
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Velocity Impact
5% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-26

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 19:59 (SMA record: 28)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Level Impact
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-27

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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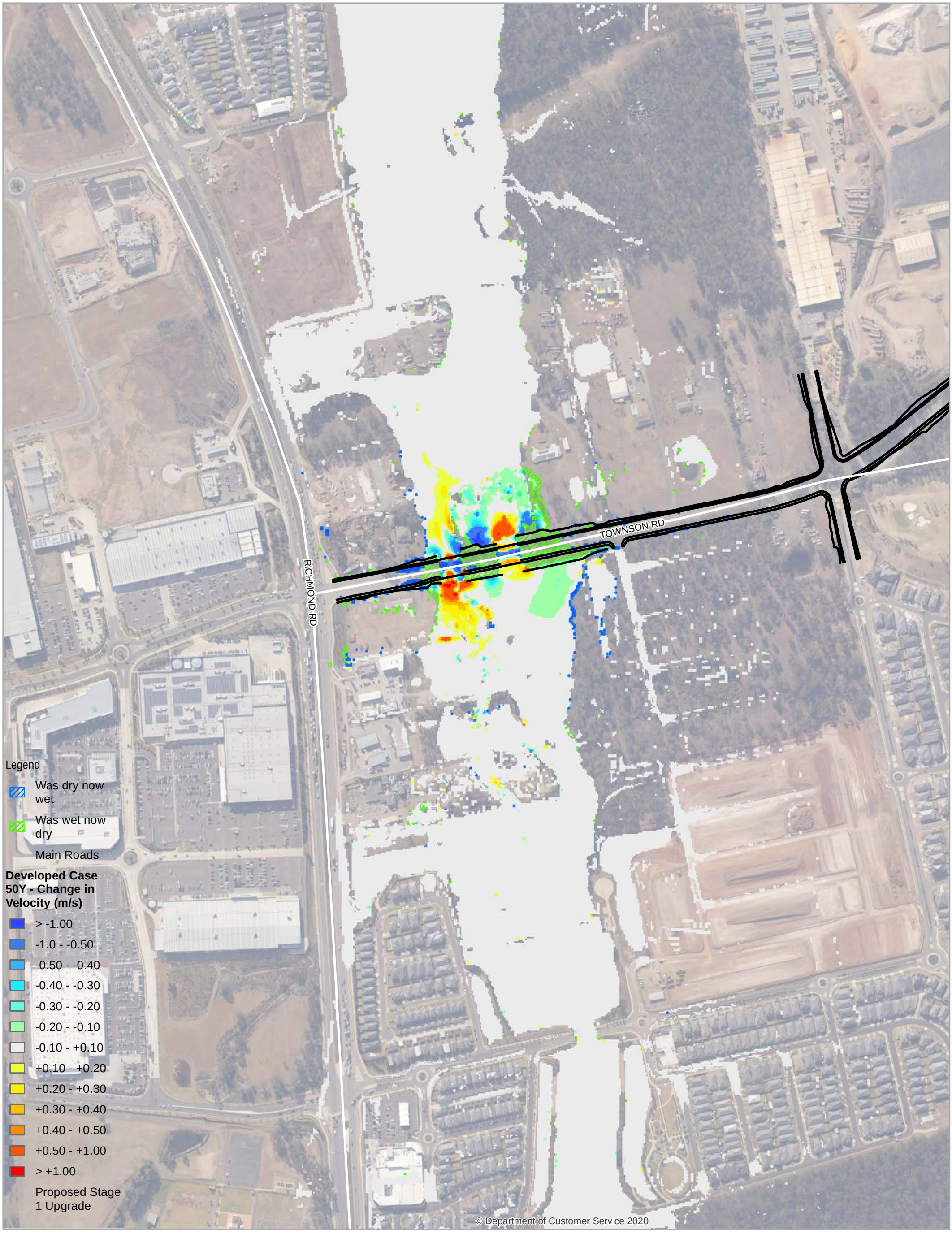


Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

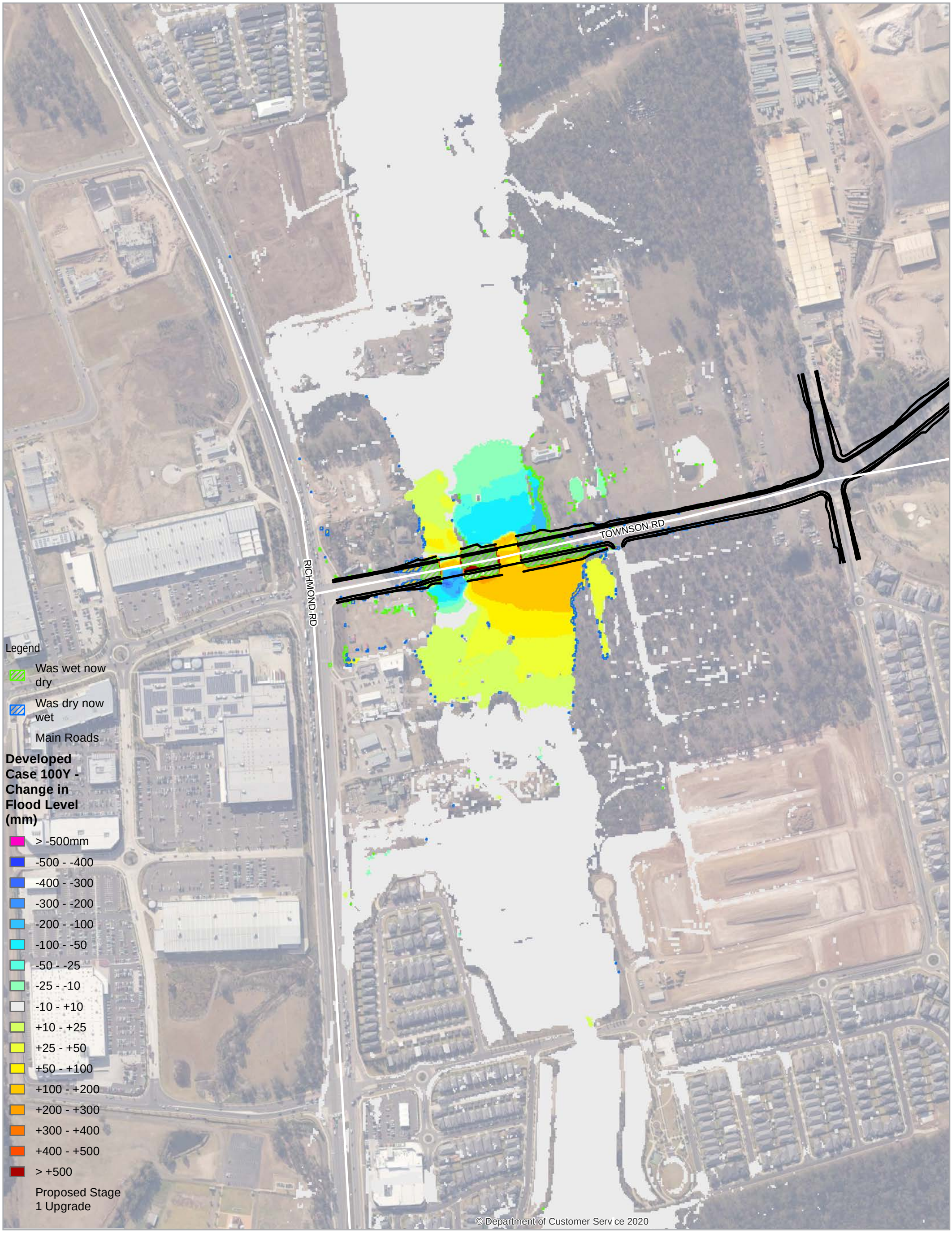
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Velocity Impact
2% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-28

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:00 (SMA record: 30)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

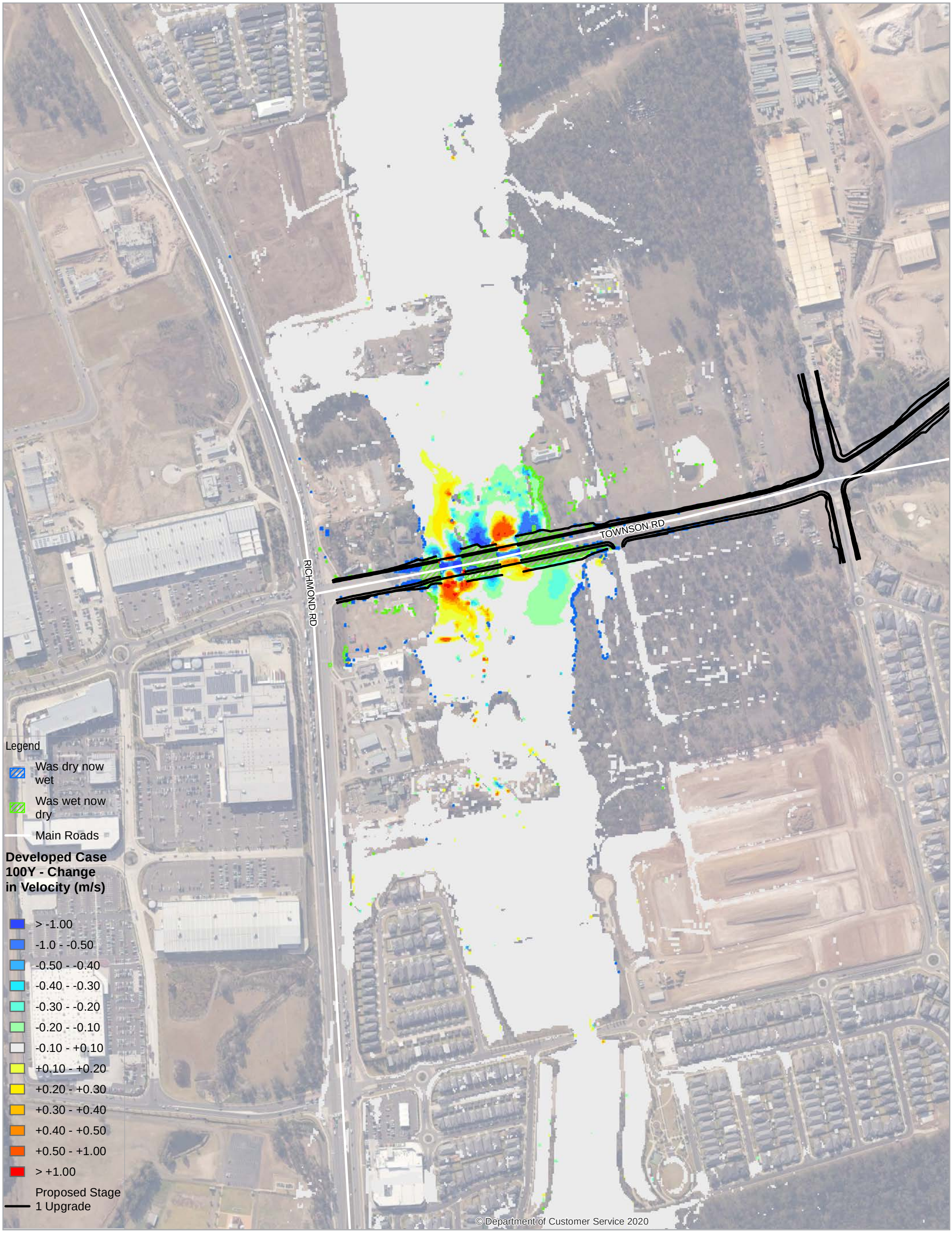
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Level Impact
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-29

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:00 (SMA record: 31)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

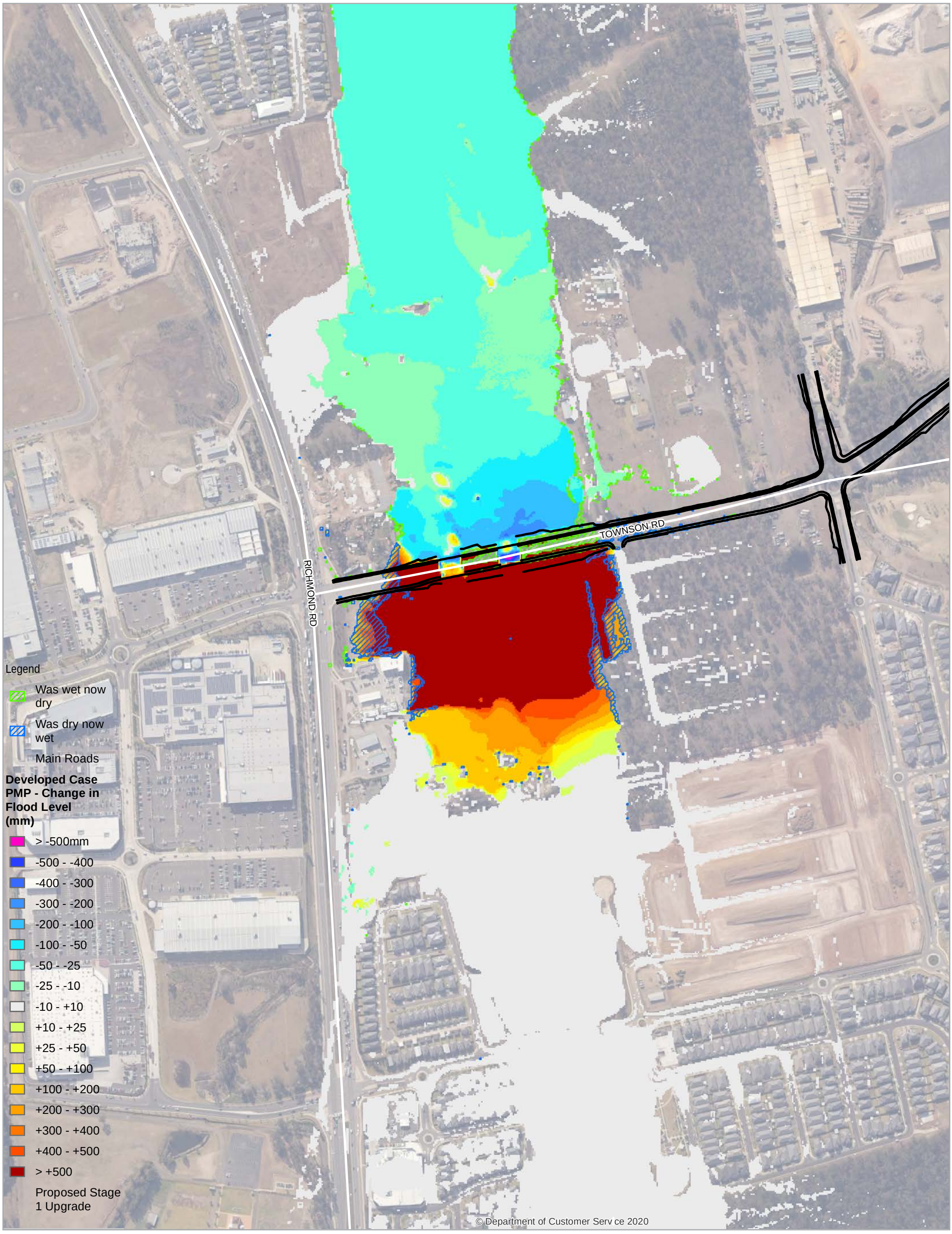
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Velocity Impact
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-30

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:01 (SMA record: 32)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

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

N

GHD

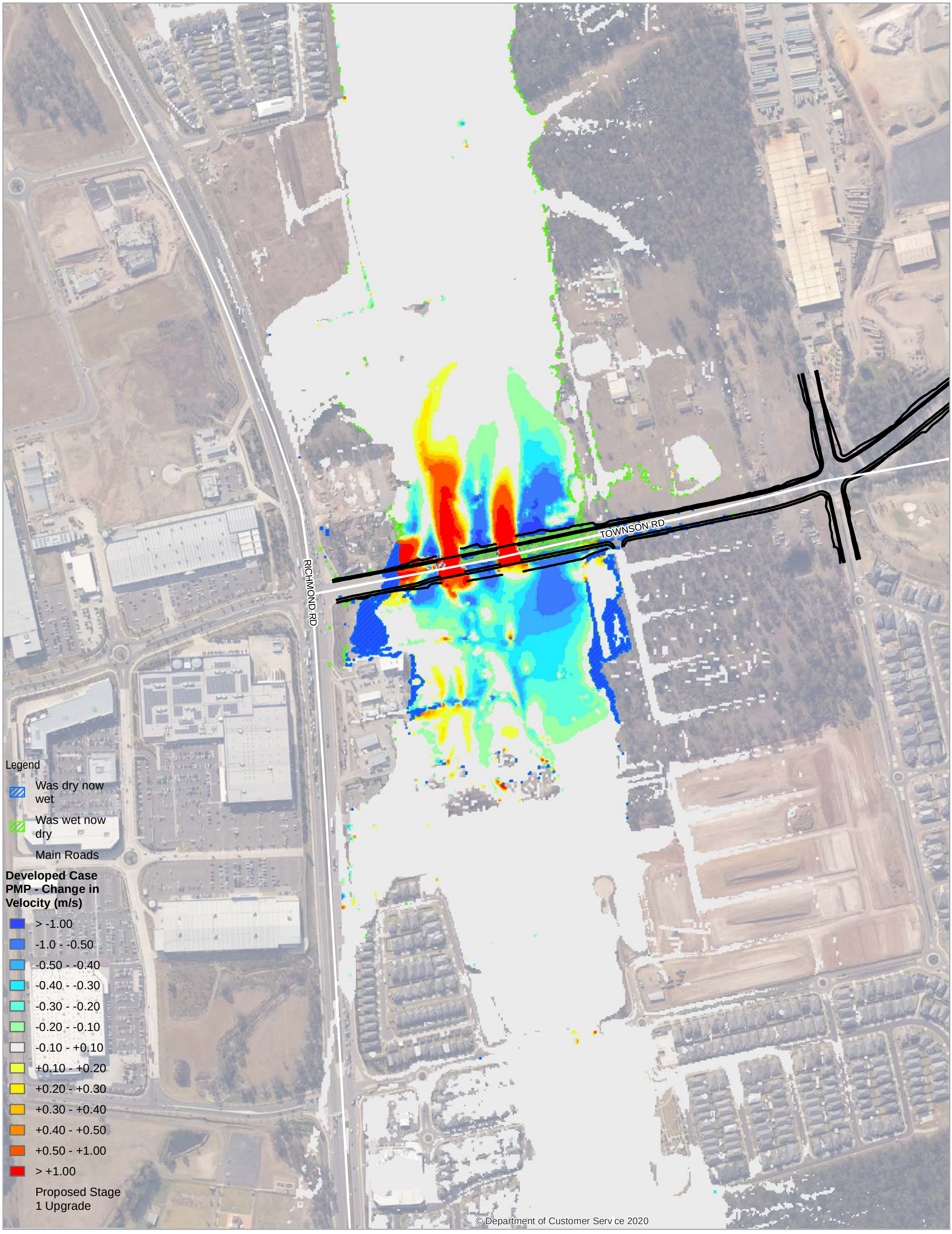
Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Level Impact
PMP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-31

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:01 (SMA record: 33)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Velocity Impact
PMP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-32

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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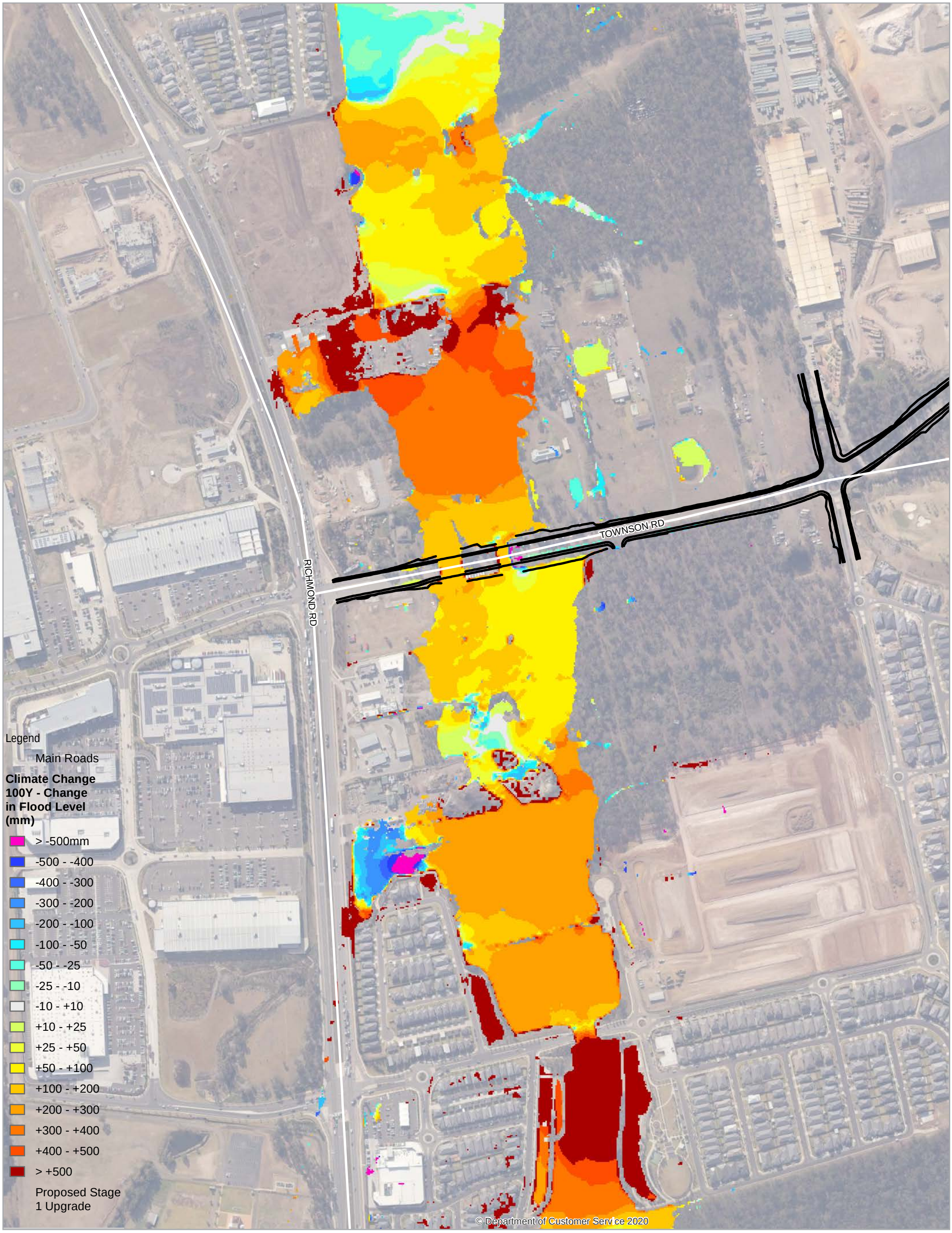

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Level Impact
1% AEP Event (Climate Change)

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-33

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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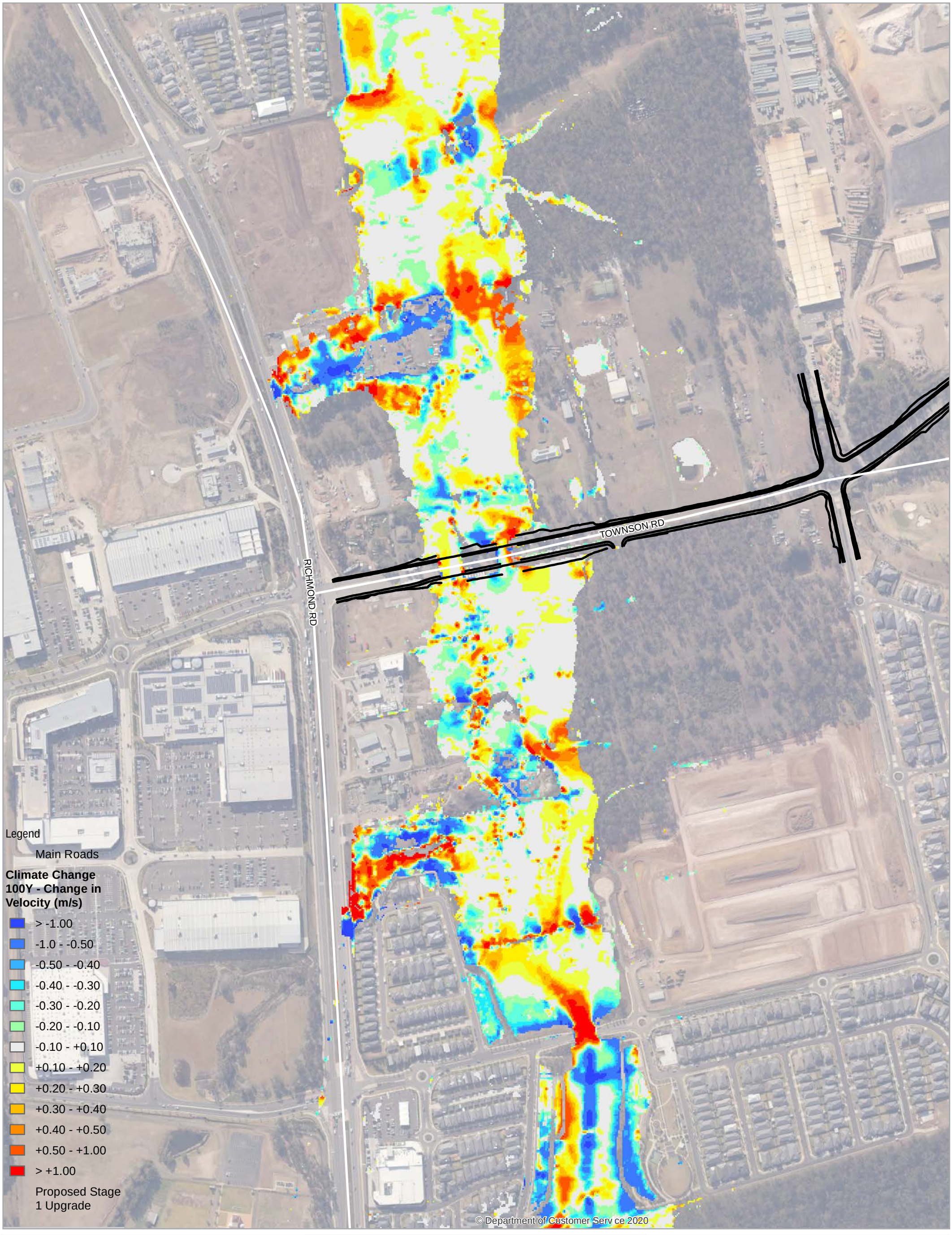

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Velocity Impact
1% AEP Event (Climate Change)

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-34

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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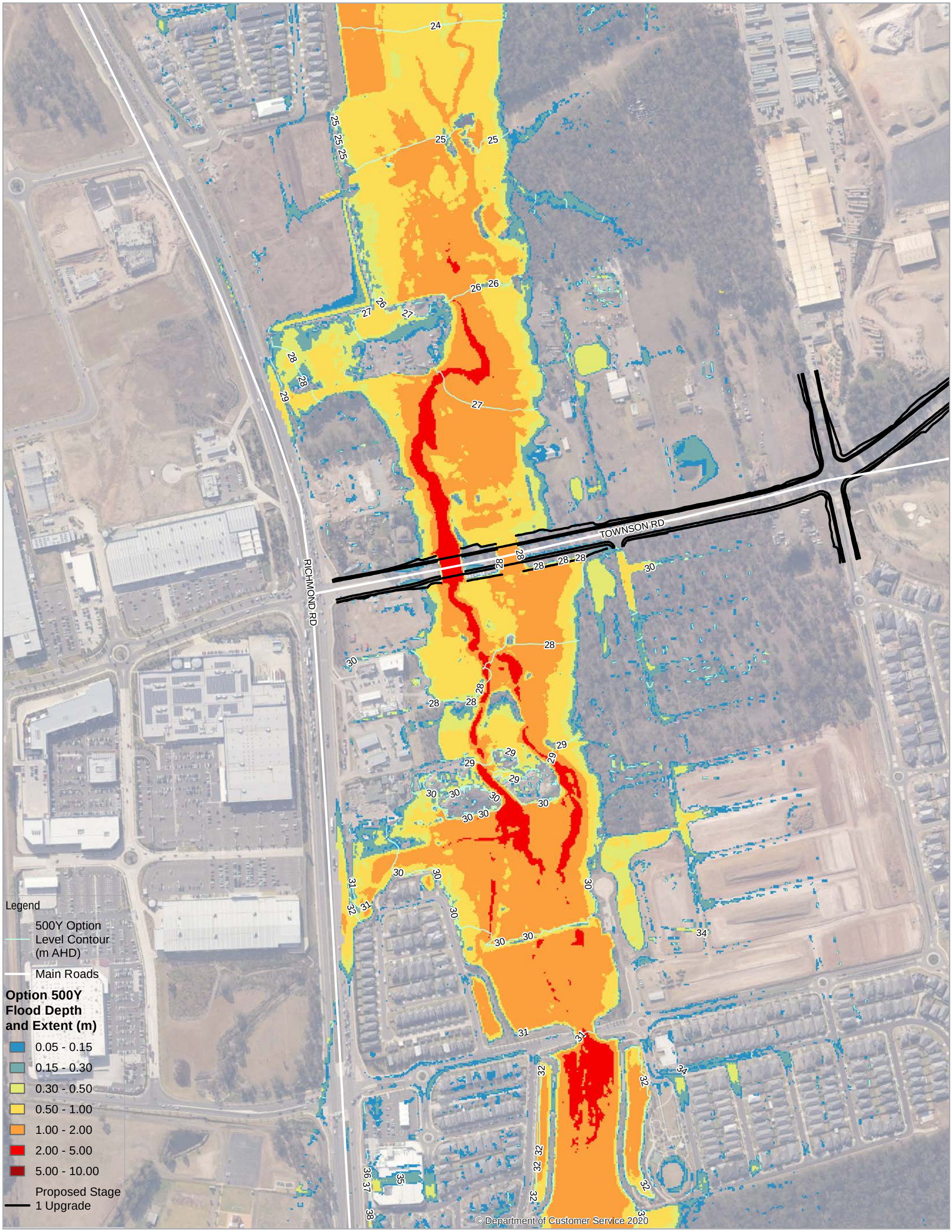

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Post Development Option
Flood Depth and Level Contours
0.2% AEP Event

Project No. 21-12511195
Revision No. A
Date 11 Nov 2020

Figure A-35

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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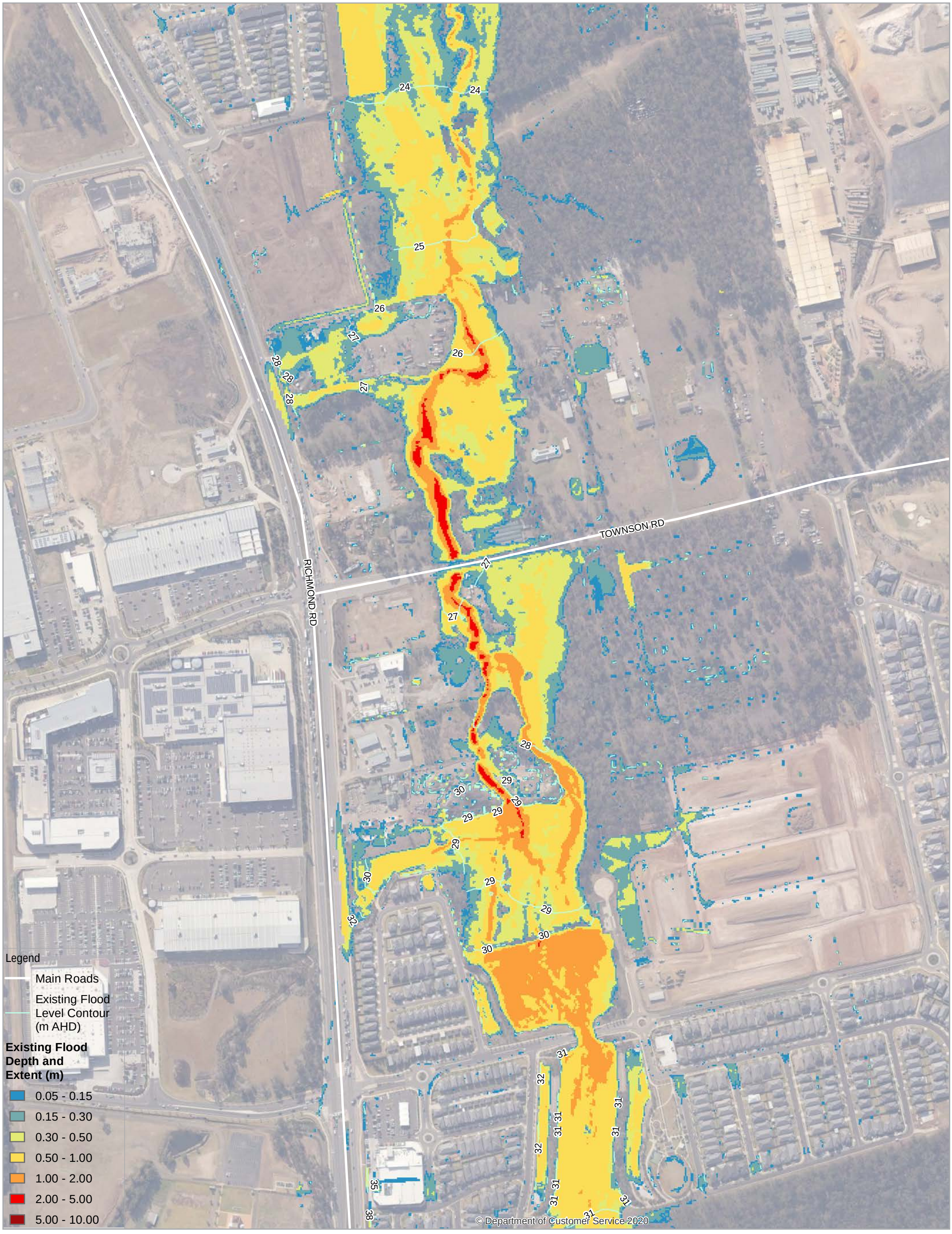

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Depth and Level Contours
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-36

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:13 (SMA record: 38)

TOWNSON RD

RICHMOND RD

Legend

Main Roads

Existing Peak Velocity (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- > 5.00

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flooding Velocity
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-37

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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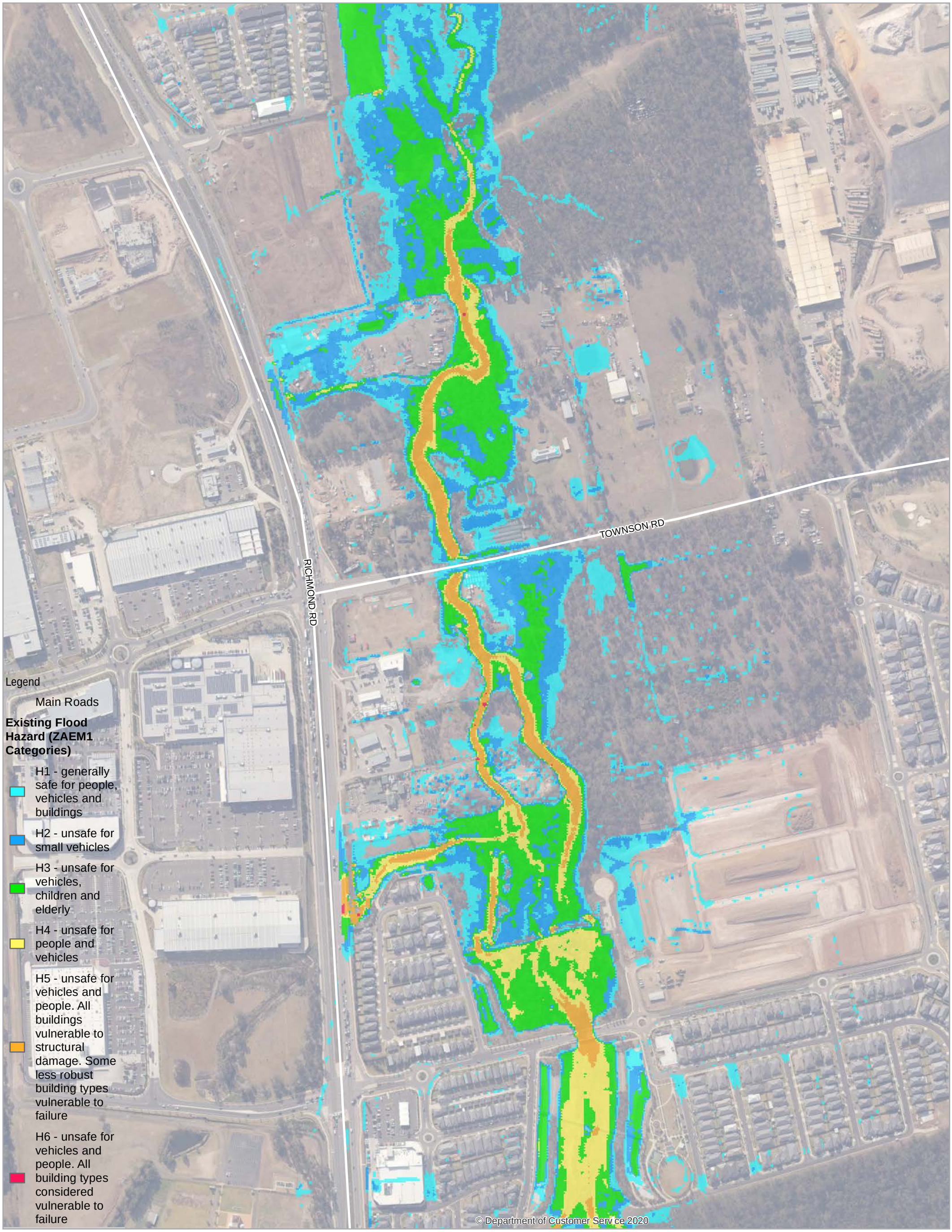

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Hazard Category ZAEM1
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-38

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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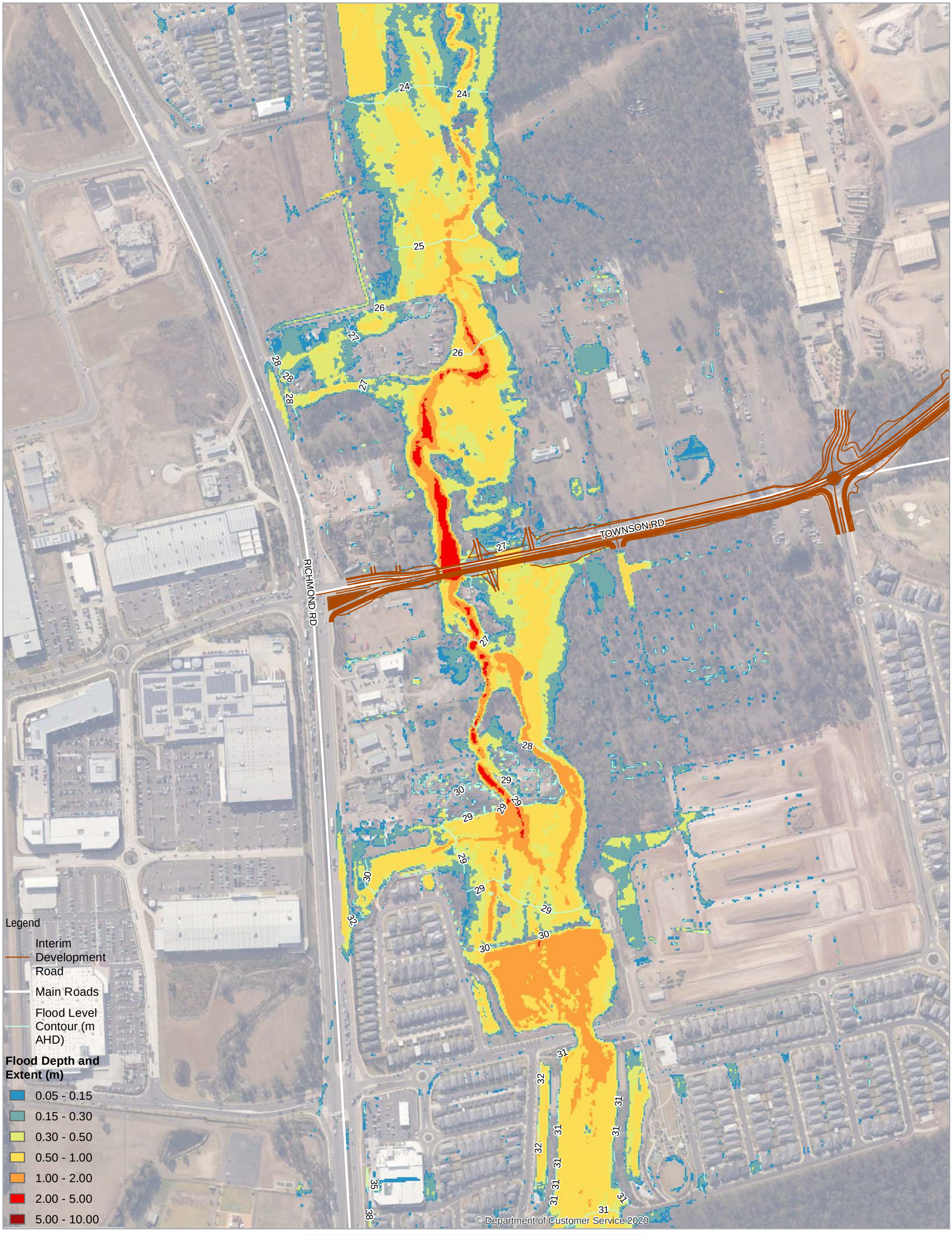


Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Depth and Level Contours
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-39

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:14 (SMA record: 41)

TOWNSON RD

RICHMOND RD

Legend

Interim Development Road

Main Roads

Peak Velocity (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- > 5.00

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

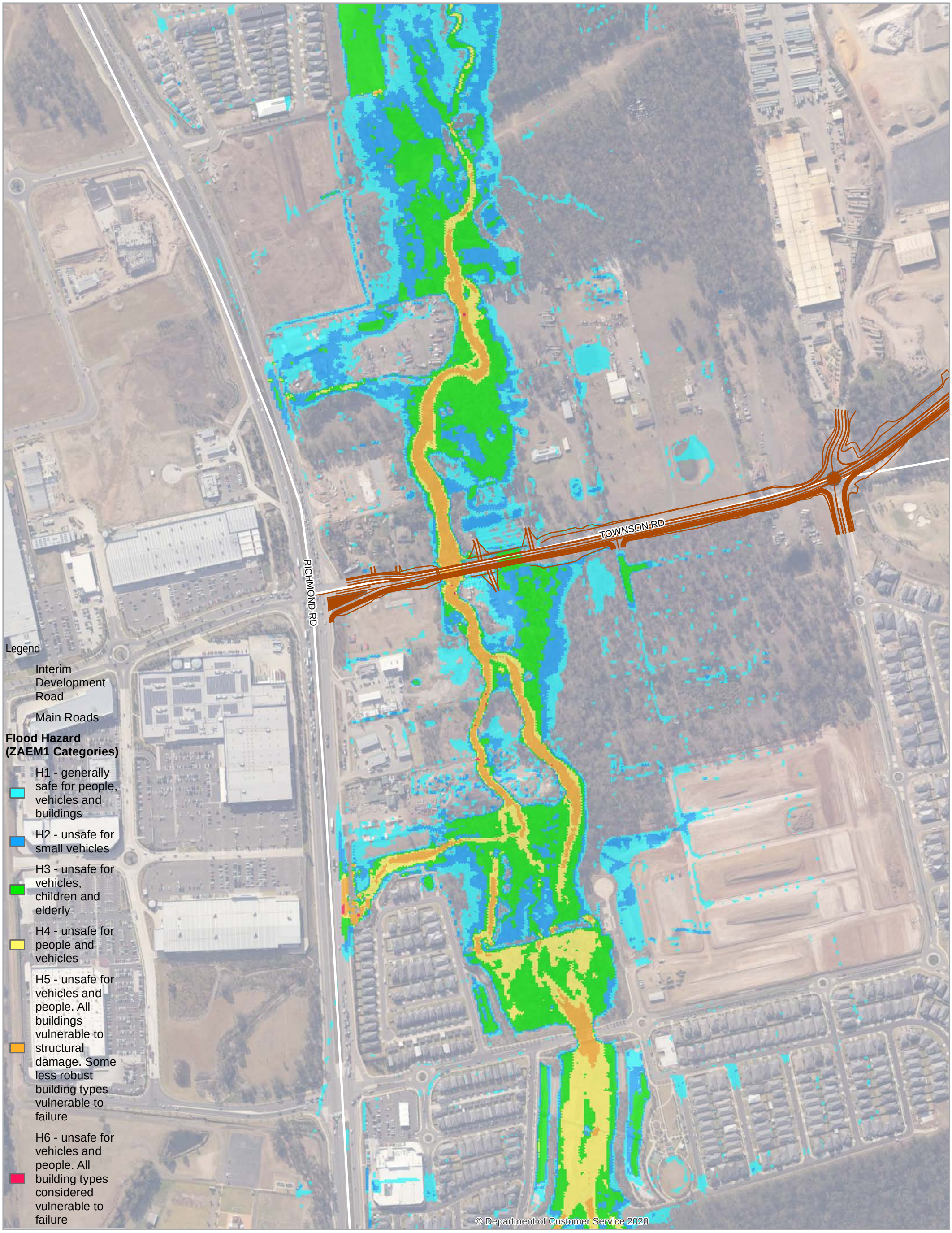
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development Flooding Velocity 50% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-40

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:14 (SMA record: 42)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

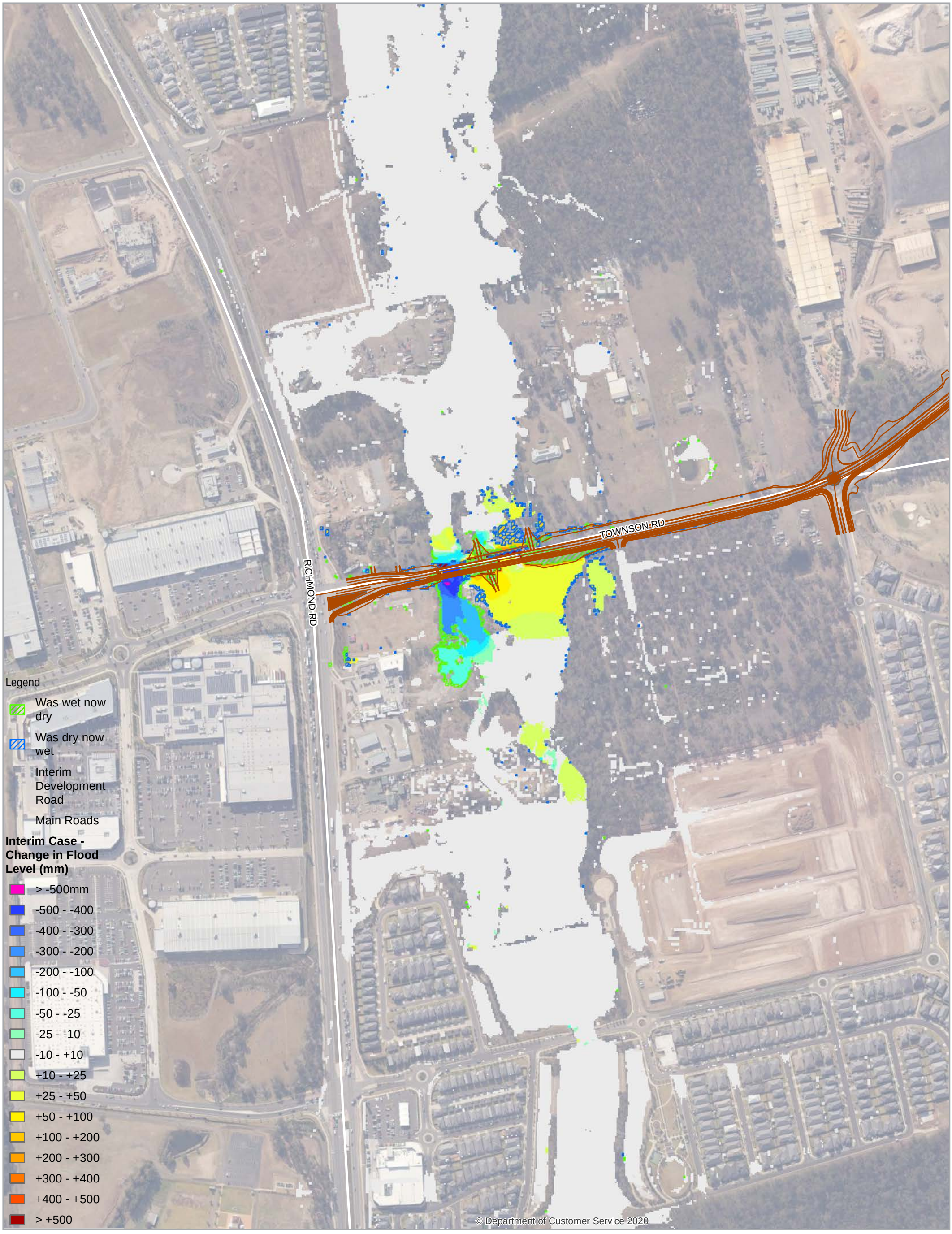
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Hazard Category ZAEM1
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-41

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:15 (SMA record: 43)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Level Impact
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-42

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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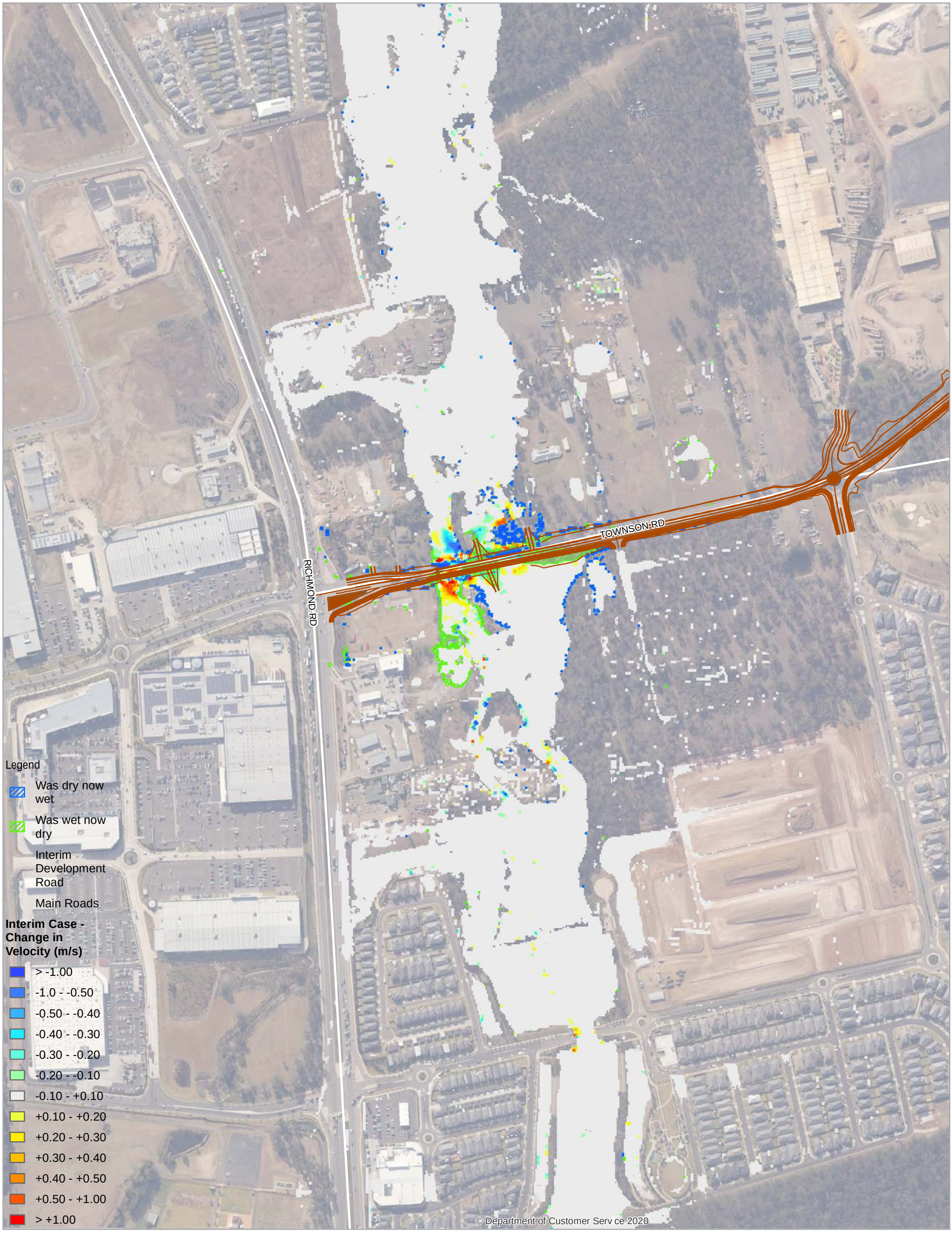

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

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

N

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Velocity Impact
50% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-43

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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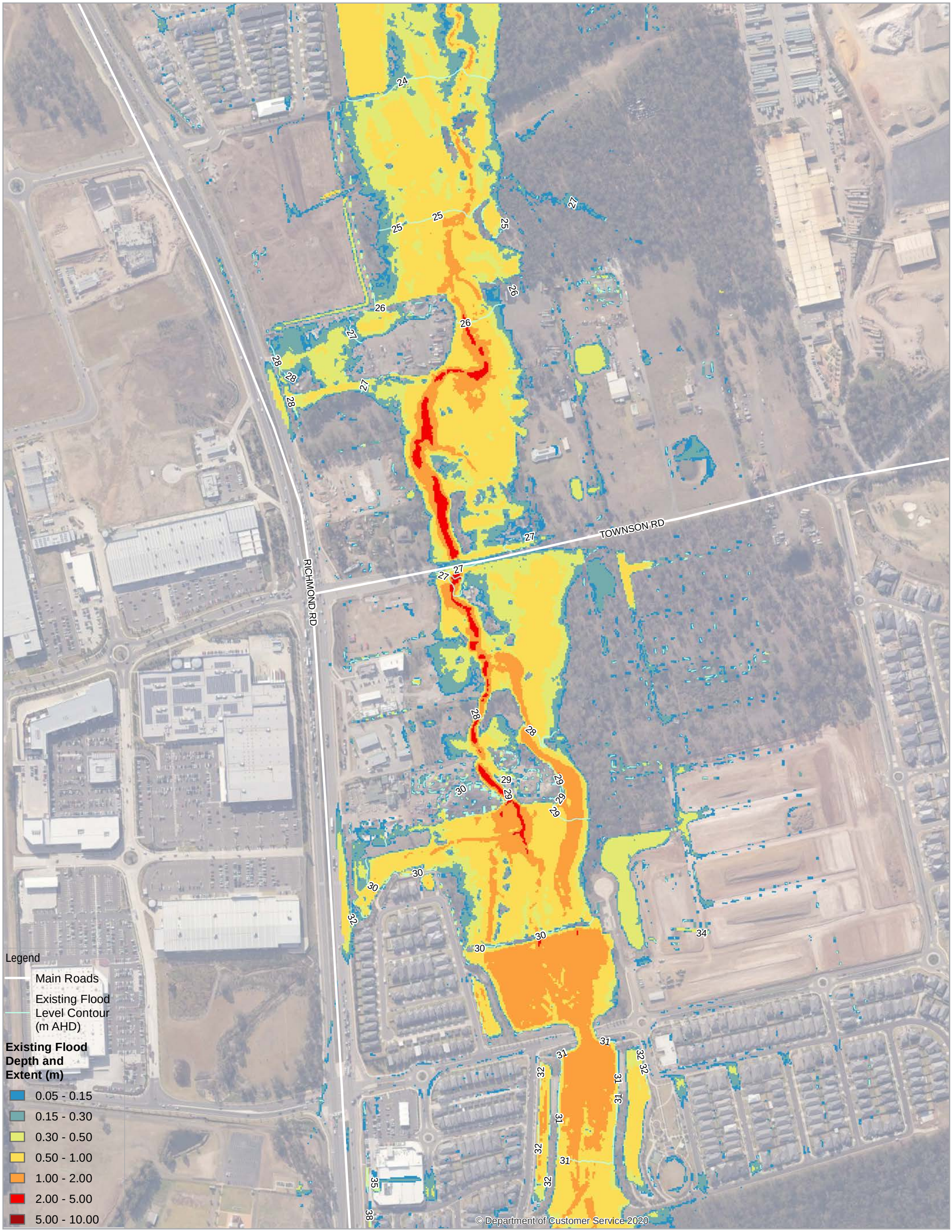

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

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

N

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Depth and Level Contours
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-44

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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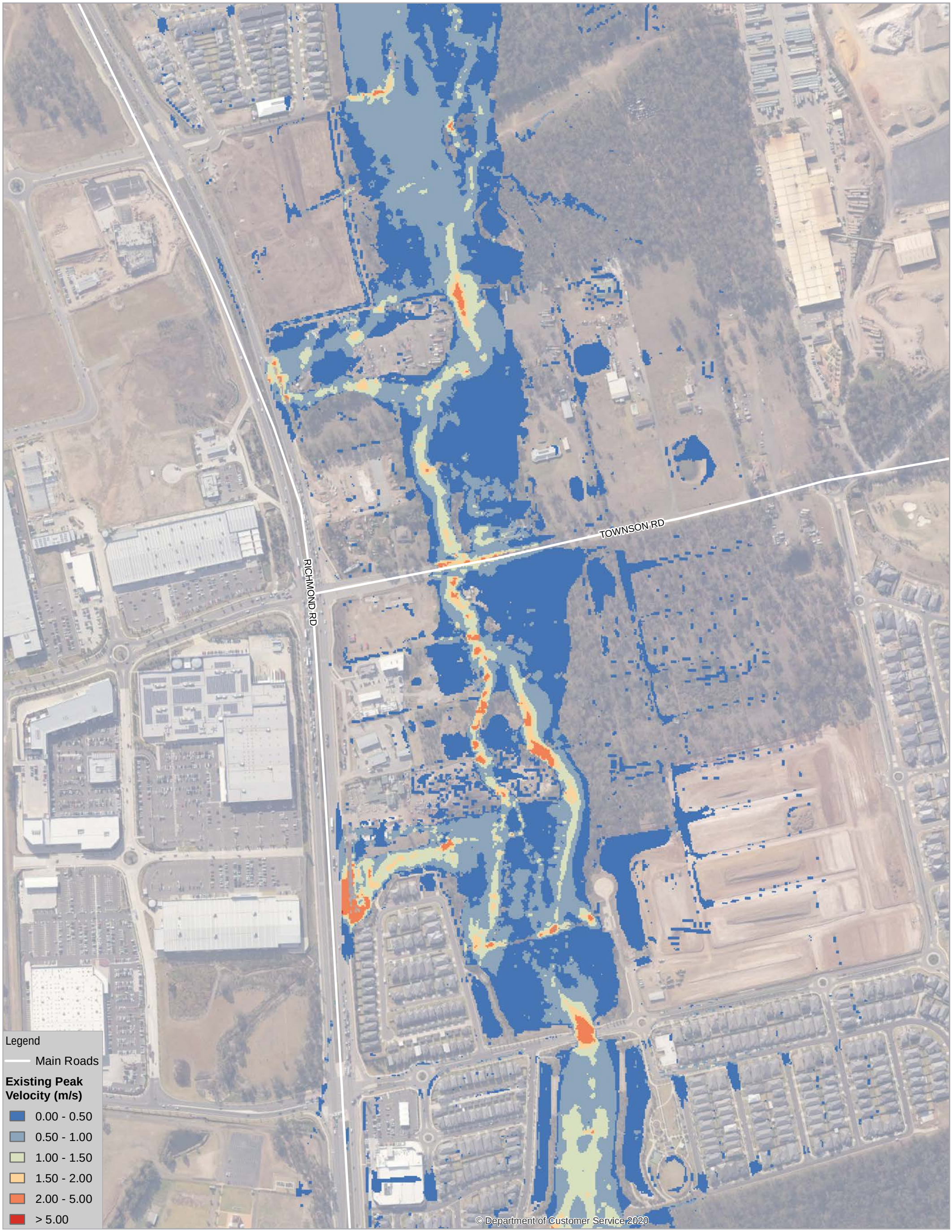

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flooding Velocity
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-45

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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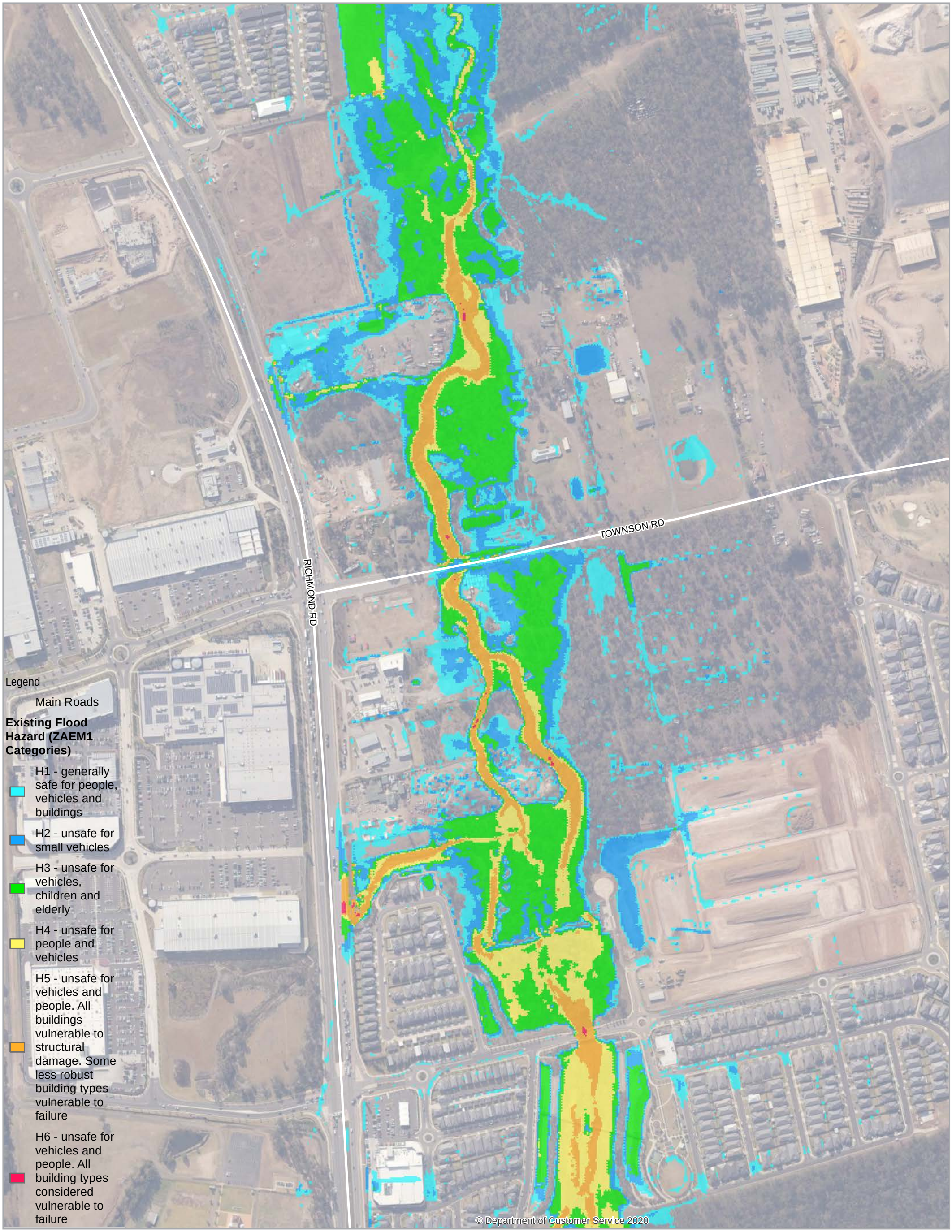

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Existing Condition Scenario
Flood Hazard Category ZAEM1
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-46

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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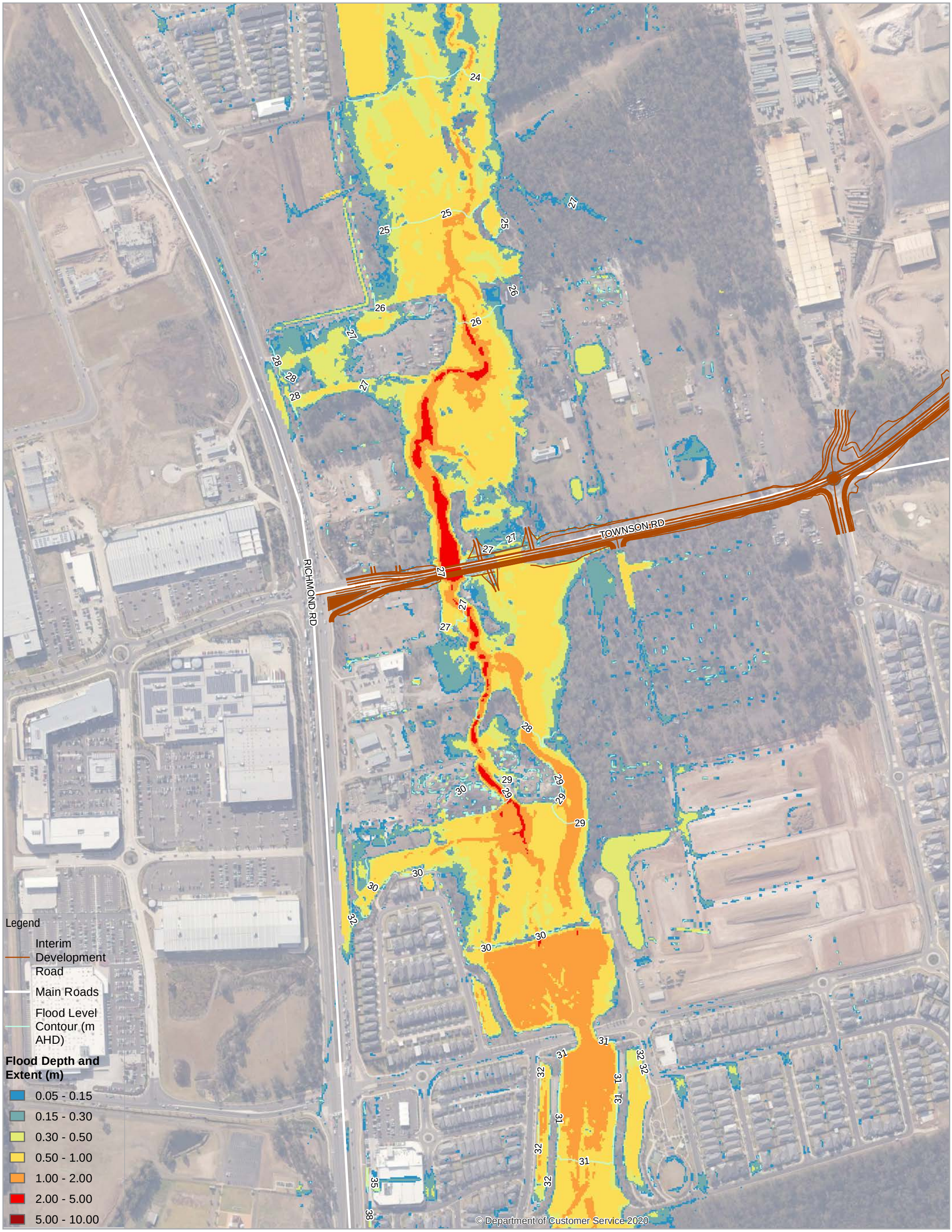

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Depth and Level Contours
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-47

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
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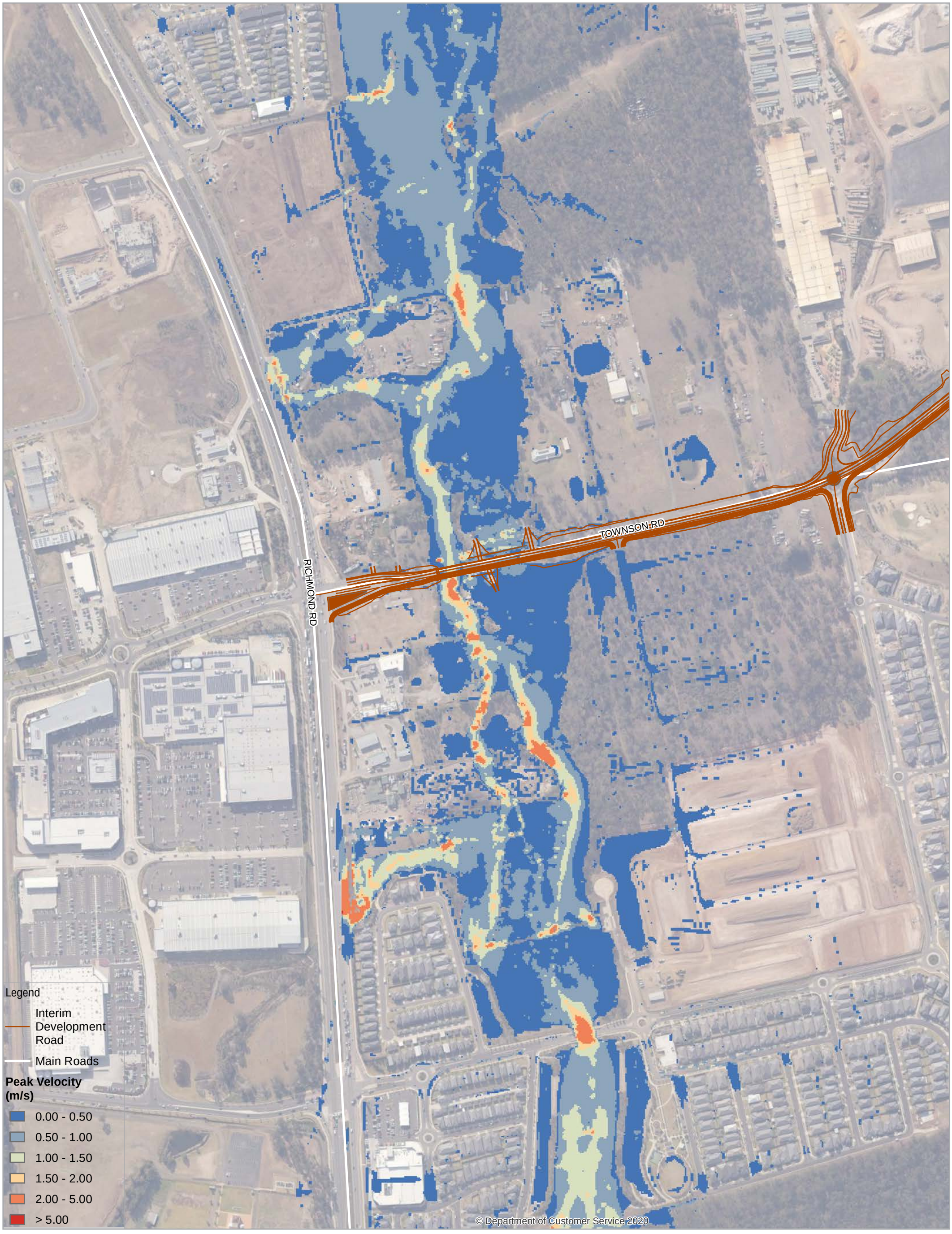


Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

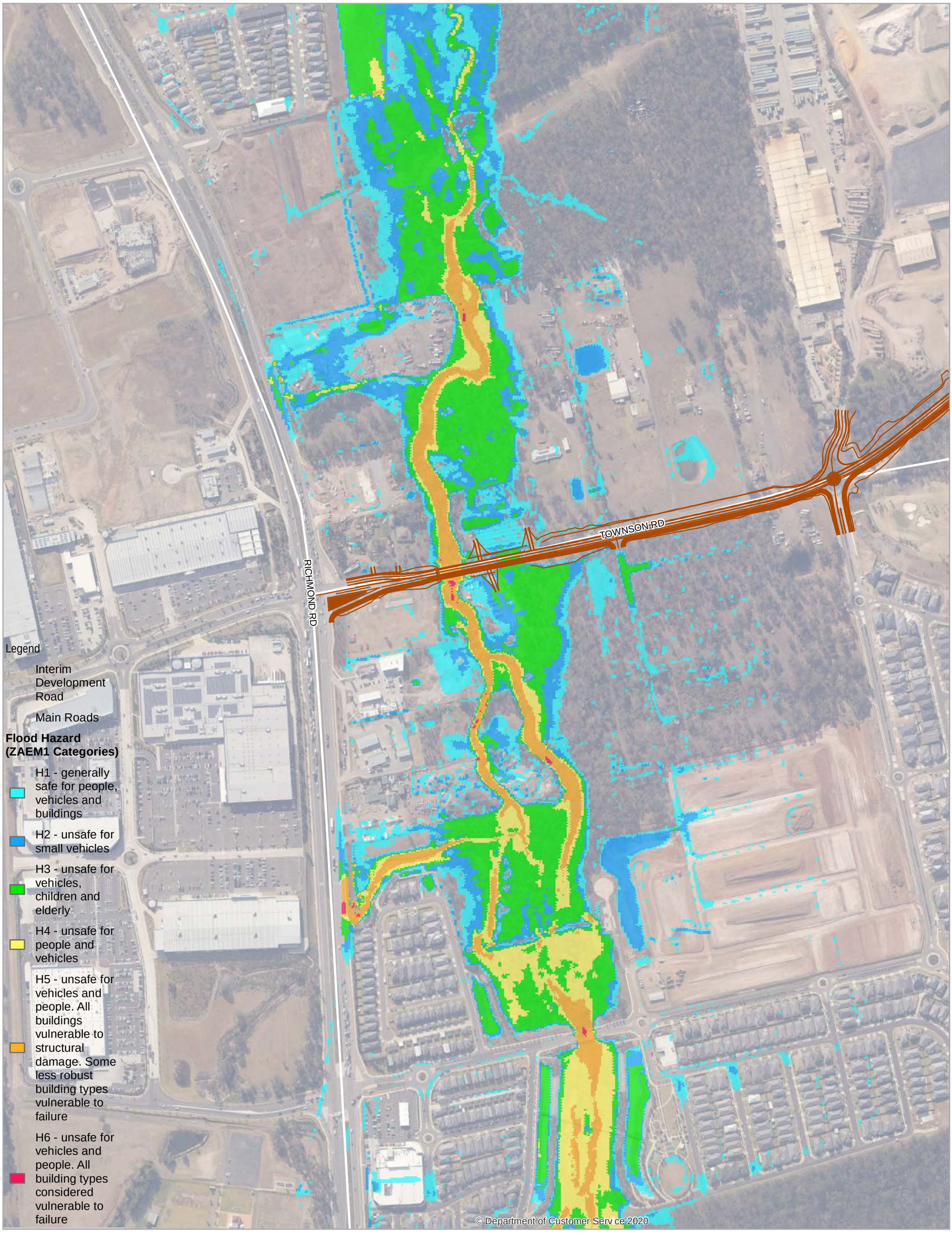
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flooding Velocity
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-48

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:17 (SMA record: 50)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Hazard Category ZAEM1
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-49

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:17 (SMA record: 51)

TOWNSON RD

RICHMOND RD

Legend

- Was dry now wet
- Was wet now dry
- Interim Development Road
- Main Roads

Interim Case - Change in Flood Level (mm)

- > -500mm
- -500 - -400
- -400 - -300
- -300 - -200
- -200 - -100
- -100 - -50
- -50 - -25
- -25 - -10
- -10 - +10
- +10 - +25
- +25 - +50
- +50 - +100
- +100 - +200
- +200 - +300
- +300 - +400
- +400 - +500
- > +500

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

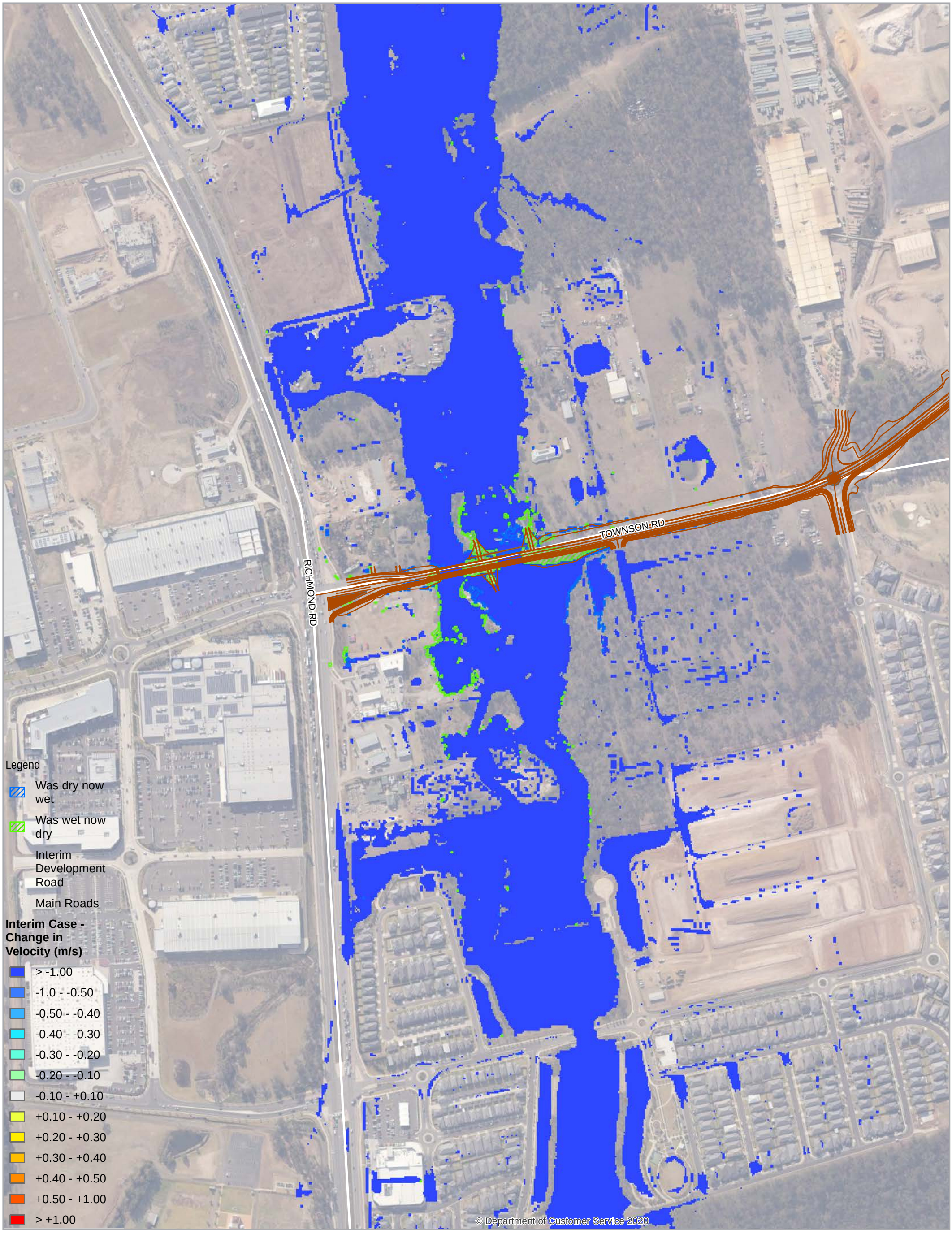
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Level Impact
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-50

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:03 (SMA record: 52)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

GHD

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Velocity Impact
20% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-51

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:04 (SMA record: 53)

RICHMOND RD

TOWNSON RD

Legend

Interim Development Road

Main Roads

Flood Level Contour (m AHD)

Flood Level Contour (m AHD)

Flood Depth and Extent (m)

- 0.05 - 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

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

N

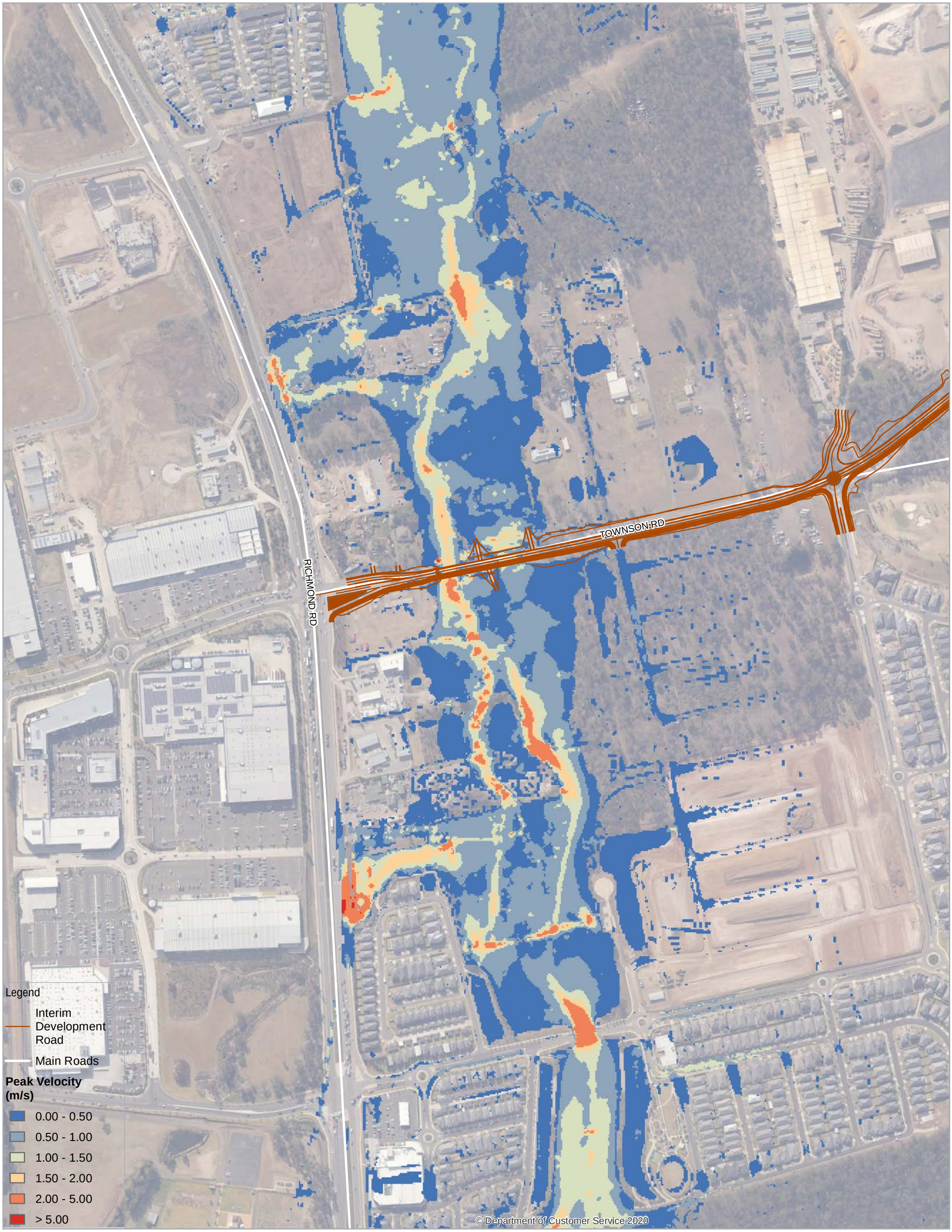
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Depth and Level Contours
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-52

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:18 (SMA record: 54)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

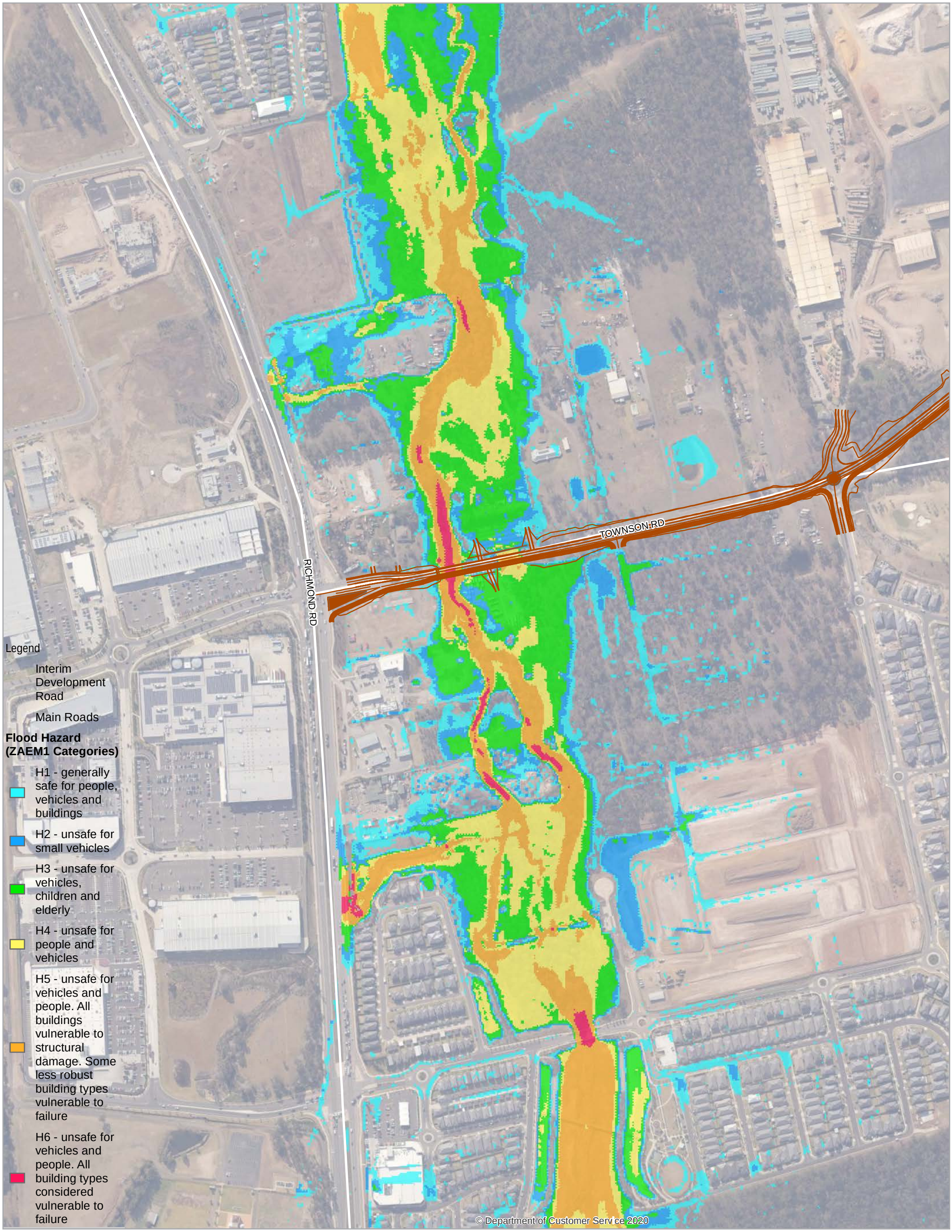
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flooding Velocity
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-53

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:19 (SMA record: 55)



Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

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

N

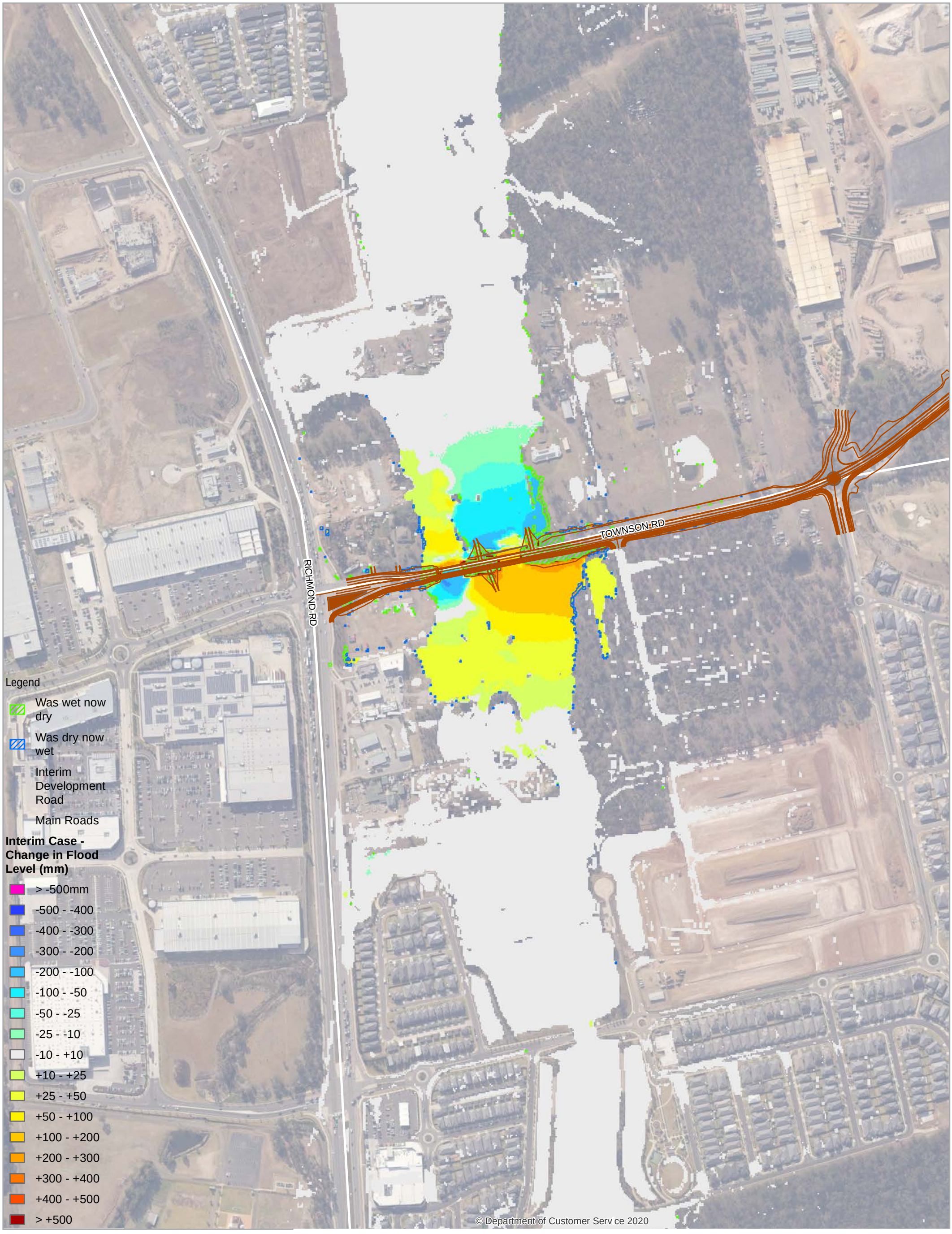
Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Hazard Category ZAEM1
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 12 Nov 2020

Figure A-54

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 12 Nov 2020 - 15:19 (SMA record: 56)



G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:04 (SMA record: 57)

RICHMOND RD

TOWNSON RD

Legend

- Was dry now wet
- Was wet now dry
- Interim Development Road
- Main Roads

Interim Case - Change in Velocity (m/s)

- > -1.00
- -1.0 - -0.50
- -0.50 - -0.40
- -0.40 - -0.30
- -0.30 - -0.20
- -0.20 - -0.10
- -0.10 - +0.10
- +0.10 - +0.20
- +0.20 - +0.30
- +0.30 - +0.40
- +0.40 - +0.50
- +0.50 - +1.00
- > +1.00

Paper Size ISO A3

0 0.03 0.06 0.09 0.12

Kilometers

N

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

Roads and Maritime Services
Townson and Burdekin Road Project

Interim Development
Flood Velocity Impact
1% AEP Event

Project No. 21-12511195
Revision No. A
Date 19 Nov 2020

Figure A-56

G:\21\12511195\GIS\Resources\Templates\21-12511195-Z001_SMA.mxd
Print date: 19 Nov 2020 - 20:05 (SMA record: 58)

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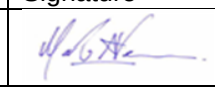
Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	D Bannigan	R Berg		M Ferreira		13/11/2020

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