New Richmond Bridge Stage 2
Concept Design and REF

Hydrology Hydraulics Assessment

Transport for New South Wales

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Contents

Abbreviations i
Glossary ii
Adopted Terminology i
1 Introduction 1
1.1 Proposal overview 1
1.1.1 Background 4
1.2 Proposal objectives 4
1.3 Purpose and scope of this report 4
2 Legislative and policy context 6
2.1 NSW State Legislation 6
2.1.1 Water Management Act 2000 6
2.2 Other policies and guidelines 6
2.2.1 Flood Prone Land Policy (2023) 6
2.2.2 NSW Flood Risk Management Manual (2023) 6
2.2.3 NSW State Flood Plan (2018) 7
2.2.4 Industry guidelines 7
3 Approach 9
3.1 Assessment criteria 9
3.2 Flood behaviour under pre-proposal conditions 10
3.3 Assessment of construction related impacts 11
3.4 Assessment of operational related impacts 11
4 Existing environment 12
4.1 Flood-producing mechanisms 12
4.1.1 Hawkesbury River mainstream flooding 12
4.1.2 Local catchment flooding 12
4.1.3 Emergency Response 13
4.2 Key features and infrastructure 13
4.2.1 Existing transverse culverts 13
5 Flood modelling methodology 15
5.1 Available information 15
5.1.1 Previous flood studies and models 15
5.1.2 Terrain and structure data 17
5.2 Model setup 17
5.3 Mainstream Model 18
5.3.1 Existing Model Setup and Validation 18
5.3.2 Existing Baseline Scenario 18
5.4 Local catchment model 18
5.4.1 Hydrological Modelling 19
5.4.2 Hydraulic modelling 20
5.5 Model scenarios 21
5.6 Assumptions and limitations 22
6 Existing flood behaviour 23
7 Proposed environment 25
7.1 Key features of the Proposal 25

7.1.1 New Richmond Bridge over Hawkesbury River 27
7.1.2 Richmond Bypass Bridge No. 1 27
7.1.3 Richmond Bypass Bridge No. 2 28
7.1.4 Transverse culverts 28
7.2 Proposed Design Scenario model setup 29
7.3 Model scenarios 29
7.4 Sensitivity testing scenarios 29
7.5 Climate Change considerations 30
7.6 Impact of partial blockage of major hydraulic structures 31

8 Flood behaviour with the proposal....32
9 Impact assessment 33
9.1 Impacts during construction 33
9.1.1 Potential flood risks to construction works areas 34
9.1.2 Potential flood impacts of construction activities 36
9.2 Impacts during operation 37
9.2.1 Potential flood risk to the proposal 37
9.2.2 Potential flood impacts of the proposal 39
9.2.3 Impact of future Climate Change on flood behaviour 42
9.2.4 Impact of partial blockage of major hydraulic structures 43
9.3 Summary of impacts related to proposal stages 44
9.3.1 Stage 2A 44
9.3.2 Stage 2B 44
9.4 Cumulative impacts 45

10 Management of impacts 46
10.1 Management of construction impacts 46
10.2 Management of operational impacts 46

11 Conclusion and recommendations 48
11.1 Recommendations 48

Appendices

Appendix A
Figures and Flood Maps

Figures

Figure 1-1a: The proposal
Figure 1-1b: The proposal
Figure 5-1: Local catchment hydrology validation catchments
Figure 6-1: Flood Hazard categories from ARR2019
Figure 9-1: Proposed ancillary facilities for construction
Figure 9-2: Proposed ancillary facilities for construction overlaid on flood extents

Tables

Table 3-1: Acceptable impacts for major transport infrastructure (AGRD, 2023)
Table 4-1: Existing transverse culverts
Table 5-1: Richmond Bridge Duplication and Traffic Improvements - Flood Assessment Report (WMA, July 2022) - supplied model data summary
Table 5-2: Hawkesbury-Nepean River Flood Study Interim Results (INSW, 2022) - supplied model data summary.
Table 5-3: Hawkesbury-Nepean River Flood Study data (INSW, 2023) - supplied model data summary.
Table 5-4: Local catchment Hydrology validation – TUFLOW vs DRAINS flows
Table 5-5: Existing baseline model scenarios
Table 7-1: Proposed New Richmond Bridge parameters
Table 7-2: Proposed Bypass Bridge No. 1 parameters
Table 7-3: Proposed Bypass Bridge No. 2 parameters
Table 7-4: Proposed transverse culverts
Table 7-5: Post-Development Model scenarios
Table 7-6: Post-Development Model – sensitivity testing scenarios
Table 9-1: Design flood levels at Bridges
Table 9-2: Design flood water surface levels and road freeboard
Table 9-3: Number of flood affected habitable dwellings with potential above-floor flooding – Existing scenario
Table 9-4: Number of habitable dwellings affected by flooding and an increase in flooding (afflux) – Design scenario

Abbreviations

Abbreviation	Definition
AEP	Annual Exceedance Probability
ALS	Aerial Laser Survey
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR87	Australian Rainfall and Runoff 1987 edition
ARR2019	Australian Rainfall and Runoff 2019 edition
BoM	Bureau of Meteorology
DCP	Development Control Plan
DEM	Digital Elevation Model
FPL	Flood Planning Level
FRMM	Flood Risk Management Manual
FSL	Finished Surface Level
GIS	Geographic Information System
ha	Hectare
HCC	Hawkesbury City Council
IFD	Intensity Frequency Duration
INSW	Infrastructure NSW (Flooding section now part of NSW Reconstruction Authority)
km	Kilometres
km^2	Square kilometres
LiDAR	Light Detection and Ranging survey
LGA	Local Government Area
m	Metre
m^2	Square metre
m^3	Cubic metre
mm	Millimetre
m/s	Metres per second (velocity)
m^3/s	Cubic metres per second (flow)
mAHD	Metres to Australian Height Datum
NRBS2	New Richmond Bridge Stage 2 (the proposal)
NSW	New South Wales
NSW SES	State Emergency Service

Abbreviation	Definition
DPE	NSW Department of Planning & Environment
PMF	Probable Maximum Flood
TfNSW	Transport for New South Wales
WSU	Western Sydney University

Glossary

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

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

Term	Definition
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Overland Flow	The flow of water over the ground surface either along formal flow paths such as roads and formed channels, or informal flowpaths along topographic low points and through properties and open space areas. The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
The Proposal	New Richmond Bridge and traffic improvements – Stage 2 proposed works to upgrade Bells Line of Road / Kurrajong Road between Crooked Lane, North Richmond and Old Kurrajong Road, Richmond and construct a new bypass south of Richmond town centre. The new route between Richmond and North Richmond would provide a minimum five per cent annual exceedance probability (AEP) flood resilience.
Topography	A surface which defines the ground level of a chosen area.

Adopted Terminology

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends the use of Annual Exceedance Probability (AEP) terminology to define flood event magnitudes. Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year. This is interchangeable with a 1 in 100 chance per year terminology.

Historically, terminology such as Annual Recurrence Interval (ARI) or "return period" has been used which can be misleading to the public and stakeholders. Such terms imply that a given event magnitude will only be exceeded once within the specified interval. However, there are examples of rare events such as a 1% AEP occurring within short succession, for example, in consecutive years or multiple times within a ten year period.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are different and the correlation between them.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is appropriate and the term Exceedances per Year (EY) is recommended. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 1 EY would be expected to occur on average once a year and a 2 EY event is an event that is likely to occur twice in one year. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval.

The Probable Maximum Flood is the statistically largest flood that could possibly occur in a catchment. It is related to the Probable Maximum Precipitation (PMP) which has an approximate probability assigned depending on catchment size. A PMP does not translate to a PMF of the same AEP due to the conservativeness applied to other factors influencing flooding. Therefore, an AEP is not assigned to the PMF.

This report adopts the 1 in X or % AEP terminology in line with ARR2019 recommendations.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

1 Introduction

1.1 Proposal overview

Transport for NSW (Transport) proposes to upgrade Bells Line of Road / Kurrajong Road between Crooked Lane, North Richmond and Old Kurrajong Road, Richmond and construct a new bypass south of Richmond town centre. This is known as New Richmond Bridge and traffic improvements – Stage 2 (the proposal). The new route between Richmond and North Richmond would provide a minimum five per cent annual exceedance probability (AEP) flood resilience (equivalent to the 1 in 20 chance per year flood event). The proposal is about 50 kilometres north-west of the Sydney Central Business District (CBD) and about 33 kilometres north-west of Parramatta. It is in the Hawkesbury City Council local government area (LGA).

The proposal would be delivered in two stages, known as Stage 2A and Stage 2B. Should this REF be determined, and the already committed funding by the Australian Government and NSW Government released, Stage 2A would be constructed. This is expected to be complete by 2029. The timing of Stage 2B would be subject to available funding and Transport will continue to seek funding in upcoming State and Federal budgets to deliver the rest of the upgrades.

Stage 2A of the proposal includes a new four-lane bridge over the Hawkesbury River about 30 metres downstream of the existing Richmond Bridge, widening of Bells Line of Road through North Richmond to provide two lanes in each direction between the new bridge and the Terrace Road / Grose Vale Road intersection and a new bypass to the south of the Richmond town centre. The bypass would extend about 1.7 kilometres across the floodplain between the Kurrajong Road / Old Kurrajong Road intersection and Castlereagh Road / Inalls Lane / Southee Road intersection. Stage 2A of the proposal would also provide an active transport corridor between North Richmond and Richmond. This would include a new shared path on the southern side of Kurrajong Road between Old Kurrajong Road and Chapel Street and the conversion of the existing Richmond Bridge into an active transport connection across the Hawkesbury River.

Stage 2B of the proposal includes widening of Bells Line of Road between the Terrace Road / Grose Vale Road intersection and west of Charles Street and at its intersection with Crooked Lane. The bypass would also be extended 1.3 kilometres east from Castlereagh Road to Londonderry Road and would be a new road alignment to the south of Southee Road. Southee Road would connect to the bypass opposite Valder Place. The Londonderry Road / bypass / Vines Drive intersection would also be upgraded.

Further details on the key features of the proposal are outlined in Section 7.1.

An overview of the proposal (Stage 2A and 2B) is provided in Figure 1-1a-b.

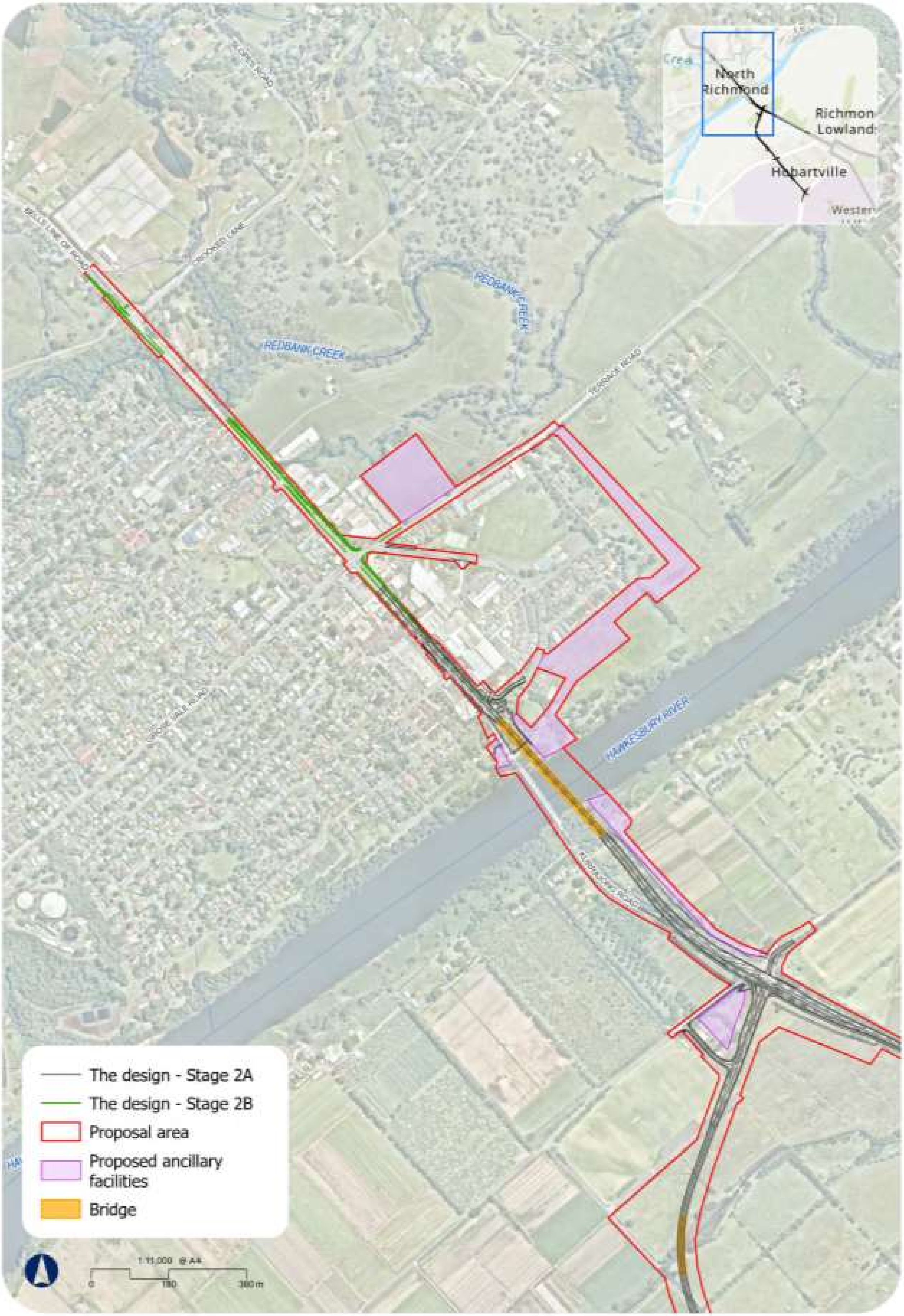

Figure 1-1a: The proposal

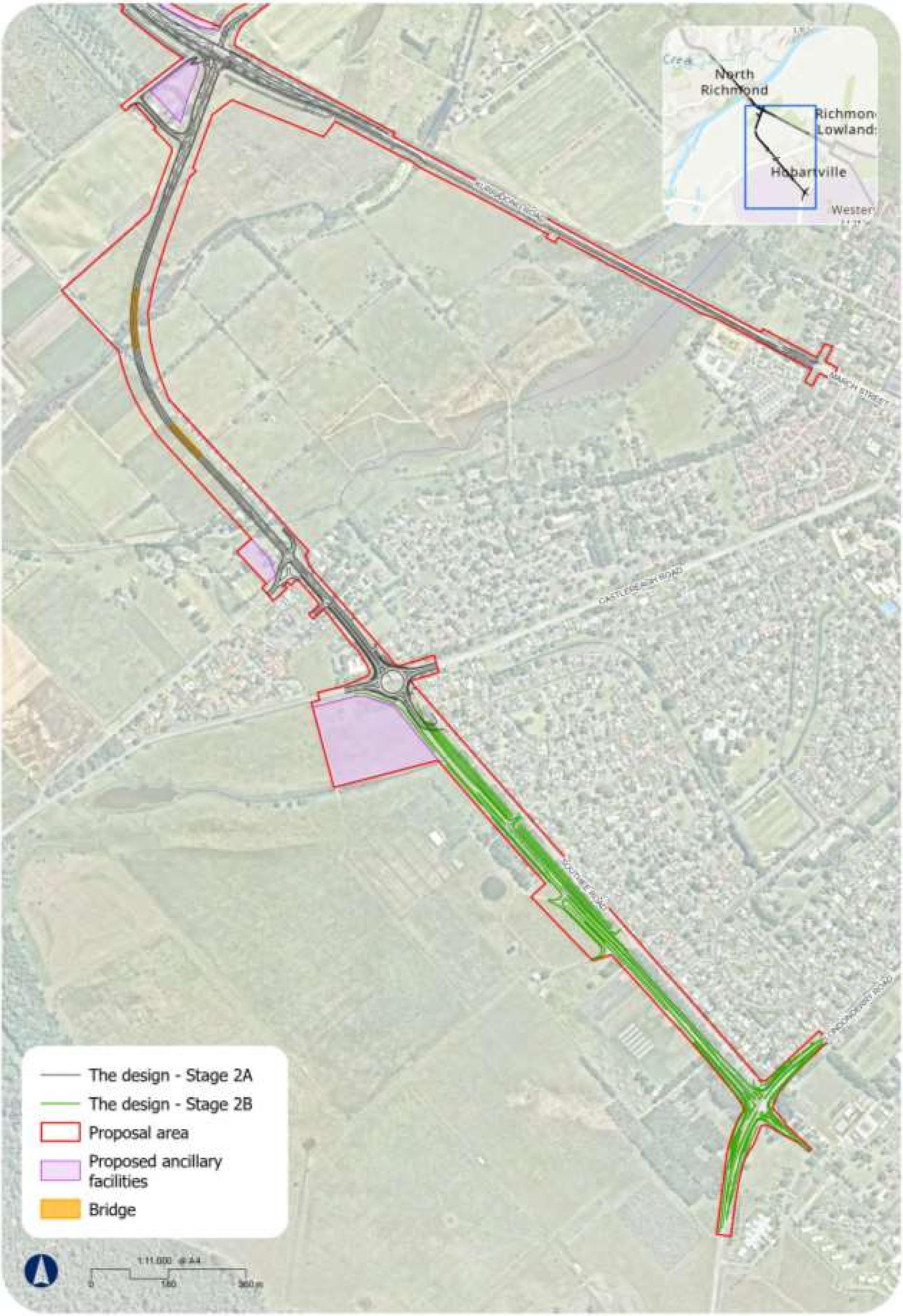

Figure 1-1b: The proposal

1.1.1 Background

Richmond Bridge is currently operating at capacity during peak periods and future traffic demand in the area will increase, driven by residential development west of the Hawkesbury River and background traffic growth. This is expected to further increase congestion and travel times along this arterial corridor.

Richmond Bridge is closed in moderate flood events when flood levels reach about eight metres Australian Height Datum (AHD), which is at about the 50 percent AEP flood level. Since 2020, Richmond Bridge has closed multiple times due to flooding. The closure of this bridge results in disruption to travel between North Richmond and Richmond and disrupts regional traffic using the Bells Line of Road corridor.

The Australian Government and NSW Government are funding traffic improvements between North Richmond and Richmond including a new bridge over the Hawkesbury River. This initiative is part of a wider program of traffic improvements between North Richmond and Richmond which includes previous intersection improvements at three key intersections on the approach to the existing Richmond Bridge, including Bells Line of Road / Grose Vale Road in North Richmond as well as Kurrajong Road / Old Kurrajong Road and March Street / Bosworth Street in Richmond. The proposal builds on the previous intersection improvements and is being carried out as part of a wider program of traffic improvements between Richmond and North Richmond which is being delivered in two stages (Stage 1 and Stage 2). They are:

- **Stage 1** involves upgrading The Driftway between Londonderry Road and Blacktown Road to improve safety and flood resilience. This project has been separately determined by Transport and is being delivered separately to the proposal.
- **Stage 2** is the proposal and it aims to improve traffic efficiency, flood resilience, active transport connections and safety of the road network between Richmond and North Richmond.

1.2 Proposal objectives

The proposal objectives are to:

- Improve travel times, journey time reliability, and cater for future demand for private, public, active and freight transport between North Richmond, Richmond and the connecting arterial road network.
- Reduce the frequency and severity of crashes on key road corridors between Richmond and North Richmond.
- Improve connectivity between Bells Line of Road and Sydney's arterial road network.
- Improve flood resilience to 1 in 20 chance per year flood or better for the entire alignment.
- Support economic development, improved liveability, and Council's long-term vision for the town centres of Richmond and North Richmond.

In doing this TfNSW would provide a road corridor that aims to:

- Improve connections to the Central West of NSW as the alternative connection to the Great Western Highway.
- Maintain the historical significance of the area.
- Best fit with the built fabric and natural patterns of the area.

1.3 Purpose and scope of this report

This *Hydrology and Hydraulics Assessment working paper* has been prepared in accordance with the relevant proposal requirements and industry standards and guidelines.

The purpose of the *Hydrology and Hydraulics Assessment working paper* is to:

- Define flood behaviour under the pre-development baseline conditions including flood levels, flood depths, velocities and flood hazard

- Define flood behaviour under the post-development operational conditions including flood levels, flood depths, velocities and flood hazard
- Identify and consider flood risk to the proposal during construction and operation including flood immunity levels
- Assess impacts of the proposal during construction and operation including assessing impacts to properties
- Identify mitigation measures considered and incorporated in the design
- Make recommendations for future assessments and considerations to further mitigate flood impacts during future design stages of the proposal.

2 Legislative and policy context

2.1 NSW State Legislation

2.1.1 Water Management Act 2000

The *Water Management Act 2000* (NSW) (WM Act) is administered by the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) (formerly NSW Department of Industry and Environment (DPIE)) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses and to protect catchment conditions.

The WM Act's intent and objectives have been considered part of this assessment. Provisions of the WM Act require the development of management plans to deal with flooding regimes and how they are managed in relation to risks to property and life and ecological impacts. The WM Act also defines approvals required for carrying out works near a river or floodplain via flood work or drainage work approvals.

2.2 Other policies and guidelines

2.2.1 Flood Prone Land Policy (2023)

The NSW Flood Prone Land Policy aims to mitigate the impacts of flooding and flood liability on communities and properties, aiming to reduce both private and public losses from such events. This is to be achieved through a merit-based approach in creating and implementing Flood Risk Management (FRM) plans that address both riverine and local overland flooding. The policy underscores the importance of using ecologically positive methods to improve community resilience against flooding, which includes undertaking flood mitigation works, emergency management measures, and applying development controls, especially in existing developed areas identified in FRM plans.

To implement this policy, a set of provisions is outlined, emphasizing the development of FRM plans that incorporate a broad mix of management measures to mitigate risks to existing and future developments, including considerations for climate change and ecological sustainability. Local councils bear the primary responsibility for managing flood-prone lands, setting development standards, and engaging with the community in the FRM process. The NSW Government supports these efforts by providing technical assistance, funding for flood studies and mitigation efforts, and developing regional land-use strategies, ensuring that FRM adheres to principles of ecologically sustainable development and aligns with higher-level strategies and legislation.

2.2.2 NSW Flood Risk Management Manual (2023)

The NSW Flood Risk Management Manual (2023) supports the NSW Flood Prone Land Policy (2023) and guides local government and industry in managing flood risks effectively. It focuses on developing and implementing sustainable strategies for human activities on floodplains, considering social, economic, ecological, and cultural factors along with community aspirations.

The manual states that Flood Risk Management is a partnership across all levels of government with local councils being primarily responsible in their local government areas (LGA) (DPE, 2022). The guideline suggests that the NSW government has a significant contribution in the area of technical assistance and financial support to the FRM process, similar to the earlier Floodplain Development Manual (2005).

The NSW Flood Risk Management Manual is accompanied by a toolkit, which includes several supporting documents, such as guidelines for administration arrangements, delivery under the flood risk management framework, understanding and managing flood risk, flood function, flood hazard, flood risk management measures, support for emergency management planning, and flood impact and risk assessment. These documents provide detailed guidance on various aspects of flood risk management to aid local governments in planning and implementation.

A list of guides supporting the new manual is found in Table 4 of guide AG01 (Administration Arrangements). The relevant new guides include:

- Flood Impact and Risk Assessment (LU01)
- Understanding and Managing Flood Risk (FB01)
- Support for Emergency Management Planning (EM01).

2.2.3 NSW State Flood Plan (2018)

The NSW State Flood Plan (2018) outlines the overall framework for flood management in New South Wales, with the State Emergency Service (SES) playing a key role supported by other relevant agencies. This Plan is written and issued under the authority of the State Emergency and Rescue Management Act 1989 (NSW) ('SERM Act'), the State Emergency Service Act 1989 (NSW) ('SES Act') and the NSW Emergency Management Plan (EMPLAN). It is a sub plan to the NSW Emergency Management Plan (EMPLAN) and is endorsed by the NSW State Emergency Management Committee (SEMC).

The Hawkesbury Nepean Valley Flood Plan (SES, 2020) provides important considerations for designing new developments to facilitate effective emergency response during floods and implementing modifications to properties that minimise flood damage.

Regional evacuation routes should have objectives that include extending the routes beyond the Probable Maximum Flood (PMF) extent, ensuring the traffic network can handle evacuation traffic without congestion, increasing capacity to reduce evacuation timelines, protecting routes from local flooding, raising the lowest points on inundated routes, establishing independent routes to avoid convergence, improving traffic management at intersections, diverting evacuation streams from the Hawkesbury River floodplain, and providing alternative routes for redundancy in case of incidents on the main route.

In summary, the NSW State Flood Plan provides the framework for flood management, the Hawkesbury Nepean Valley Flood Plan offers relevant guidance and key considerations involve land use planning and regional evacuation routes to ensure effective emergency response and minimise flood damage.

2.2.4 Industry guidelines

Australian Rainfall and Runoff: A Guide to Flood Estimation (2019)

Australian Rainfall and Runoff (AR&R) (2019) (Ball et al, 2019) is a guideline published by Engineers Australia and is a governing document for hydrological and hydraulic analysis. It provides designers and analysts with documentation, data, software and tools for the assessment of design flood estimation in Australia.

The reference is widely used throughout Australia, considered essential for many projects and practitioners such as engineers, policy makers, and managers. The website is presented by the Australian Government – Geoscience Australia, for the purpose of disseminating information for the benefit of the public.

The Guideline covers hydrology and hydraulics and is broken down into nine principal sections including:

- Scope and Philosophy
- Rainfall Estimation
- Peak Flow Estimation
- Catchment Simulation
- Flood Hydrograph Estimation
- Flood Hydraulics
- Application of Catchment Modelling Systems
- Very Rare to Extreme Flood Estimation

- Runoff in Urban Areas.

The guideline is used for a wide range of projects involving infrastructure such as roads, rail, airports, bridges, dams and stormwater systems, to name a few. Some of the updates include Flood Frequency Analyses (FFA), urban and rural loss models, Aerial Reduction Factors (ARF), design storms such as ensemble and Monte Carlo approaches, point and aerial temporal patterns, pre-burst rainfall, numerical models such as TUFLOW or HECRAS-2D, updated Intensity-Frequency-Duration (IFD) data in conjunction with the Bureau of Meteorology (BoM), baseflow estimation, blockage, and safety criteria for people and vehicles with revised hazard ratings, updates to Regional Flood Frequency Estimation (RFFE) technique, and coastal and catchment interactions. Climate change factors affecting design rainfall are also included.

Applying the procedures, inputs, and parameters set out in ARR2019 is an important component in providing reliable and robust estimates of design flood behaviour to ensure that projects such as the New Richmond Bridge and traffic improvements - Stage 2 proposal are designed to manage the impact of flooding.

Managing The Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Australian Disaster Resilience Handbook 7

This publication Australian Disaster Resilience Handbook 7 (AIDR 2017) provides a similar framework to floodplain management as that presented in the NSW Flood Risk Management Manual but prepared to include a wider audience across Australia. The Managing the Floodplain – Handbook 7 compliments the NSW Flood Risk Management Manual. Handbook 7 is one component of the Australian Disaster Resilience Handbook Collection applicable to management of floodplains.

It includes the framework for Flood Risk Management including:

- Floodplain Management Entity (FME) Level
- Floodplain specific management processes
- Data collection
- Flood studies
- Floodplain management studies
- Floodplain management plans
- Plan implementation
- With ongoing communication and consultation, and ongoing monitoring and review.

The Handbook 7 also defines government responsibility beyond the local council/ consent authority that is associated with the NSW Flood Risk Management Manual.

The handbook provides for additional chapters that cover specific aspects of floodplain risk management to assist with land use planning. These include a national generic brief for flood investigations, flood emergency response classification of the floodplain, flood hazard, project brief template, flood information to support land-use planning, assessing options, and considering flooding in land-use planning activities.

The national handbook presents General flood hazard vulnerability curves from Smith et.al. as shown in Figure 6-1 .

3 Approach

3.1 Assessment criteria

The primary objective of the flood assessment is to determine that flood immunity for critical components of the proposal is achieved and to minimise impacts of the proposal on surrounding properties. The design requirements for the proposal are set out in the Scope and Design Requirements, the proposal specifications and relevant industry standards and guidelines.

Flood immunity for the proposal is to achieve the 5% (1 in 20) Annual Exceedance Probability (AEP) event for the bridge waterway crossings and pavement wearing surfaces to retain trafficability of the bridge and bypass during the 5% AEP storm event. In addition, existing flood immunity for the local roads would be retained.

The proposal is also required to assess the performance of a range of design flood events up to the Probable Maximum Flood (PMF), including checks that the proposal would not result in any additional property damage in the 1% AEP event and no structural damage to the bridges in a 0.05% AEP event.

In addition to the above requirements, the assessment has been undertaken with consideration of the *Flood Risk Management Guide FB01: Understanding and managing flood risk.* In accordance with the *Flood Risk Management Guide LU01: Flood impact and risk assessment*, the flood assessment evaluates the impacts of the proposal for the following key considerations over a range of flood events:

- Flood level change (afflux)
- Change in duration of inundation
- Velocity change
- Change in frequency of inundation
- Change in warning and evacuation time
- Hazard categorisation change.

A merits based approach has been adopted in the assessment of the impacts the proposal would have on existing flood behaviour and in the development of a range of potential measures which are aimed at mitigating its impact on the existing environment.

Austroads Guide to Road Design Part 5: Drainage (2023) provides guidance for acceptable impacts for major transport infrastructure works on the floodplain for different land use types (reproduced in Table 3-1 below). These suggested acceptable impacts have been used as a guide for assessing impacts and a merits based approach adopted to determine the acceptable impacts based on the performance of the design, the magnitude of further mitigation measures to reduce afflux and the benefit of the proposal. In addition, the criteria of no new above floor flooding of habitable dwellings not already inundated was also adopted.

Table 3-1: Acceptable impacts for major transport infrastructure (AGRD, 2023)

	Residential buildings (mm)*	Residential yards (mm)	Industrial and Commercial buildings (mm)	Industrial and Commercial yards (mm)	Non-habitable structures (sheds) (mm)	Agricultural (mm) **	Open Space/ Forest (mm) #
Flood Levels	25 (general) 10-20 (sensitive receivers including hospitals, schools and critical infrastructure)	50	50	100	100	200 - 400	400
Change in duration of inundation	No more than the larger of 10% of the existing duration of inundation or 1hr whichever is largest for durations over 2hrs						
Flow distribution	No more than 10% change						
Velocities	Velocity increases to keep velocities less than 1m/s or if existing >1m/s than no more than 10% change						
Events to be considered	5% AEP and 1% AEP as a minimum 20% AEP or smaller for agricultural land The 0.05% or PMF should be used to check for extreme changes in flood behaviour but not for acceptable impacts						

* if impacts less than or equal to 10mm can be achieved by the project then this is recommended as the acceptable impact. This is the practical limit to which models can predict impact.
** dependent on the type of agriculture and its tolerance. Other criteria may be more important than peak level for example time of inundation.
# conditional on no ecologically sensitive communities where flooding is an issue

3.2 Flood behaviour under pre-proposal conditions

The proposal area is affected by both regional Hawkesbury River flooding from the river breaking its banks as well as backwater flooding from downstream backing up to the proposal areas. The proposal may also be impacted by local catchment flooding due to intense thunderstorms over local catchments, particularly the bypass along Southee Road between Castlereagh Road and Londonderry Road and more frequent events in the floodplain flow paths.

Regional Hawkesbury River flooding is assessed using a regional flood model which focuses on mainstream river flooding covering the main Hawkesbury River channel and floodplains including backwater effects.

Local catchment flooding is also assessed with development of a local flood model to determine flood extents and impacts for the areas of the bypass along Southee Road between Castlereagh Road and Londonderry Road and the floodplain local flow paths. This local catchment assessment targets the more intense, shorter duration events and assesses the more frequent events in the floodplain flow paths that aren't impacted by flooding from the Hawkesbury River. This includes the local catchments upstream of the bypass alignment for waterways/crossing locations.

The hydrology assessment has been undertaken using Australian Rainfall and Runoff 2019 data and guidelines to determine flows for critical duration events.

The following range of events have been modelled to assess existing flood behaviour:

- 1 in 2 (50%) AEP (Annual Exceedance Probability)
- 1 in 5 (20%) AEP
- 1 in 20 (5%) AEP
- 1 in 50 (2%) AEP
- 1 in 100 (1%) AEP
- 1 in 2000 (0.05%) AEP
- Probable Maximum Flood (PMF)

Section 5 of this report describes the model setup and assessment of existing flood behaviour.

3.3 Assessment of construction related impacts

A qualitative assessment was made of the construction related issues associated with flooding along the proposal based on indicative construction areas and activities as provided in the current design. The locations of surface works, construction ancillary sites and proposed bridge construction methods were assessed against the indicative flood extents for a range of events for the pre-development conditions. This provides an understanding of the likelihood that flooding could occur in the vicinity of construction activities.

The potential flood risk to construction activities, as well as their potential impact on existing flood behaviour were assessed based on an understanding of flood behaviour under pre-proposal conditions during a range of events up to the 1 in 100 (1%) AEP event. Consideration was also given to the potential for localised overland flooding to occur in construction areas.

Section 9.1 of this report deals with the impact that flooding could have on construction activities. It also includes an assessment of the impact that construction activities could have on flood behaviour external to the proposal footprint.

3.4 Assessment of operational related impacts

The model setup was adjusted to incorporate the design features to represent the proposal under operational conditions based on the 80% Concept Design Stage. This includes:

- the 80% Concept Design road alignment and earthworks
- water quality basins, ponds and swale earthworks
- bridge structures
- transverse drainage culverts.

The following range of events have been modelled as part of the flood impact assessment:

- 1 in 5 (20%) AEP (Annual Exceedance Probability)
- 1 in 20 (5%) AEP
- 1 in 50 (2%) AEP
- 1 in 100 (1%) AEP
- 1 in 2000 (0.05%) AEP
- Probable Maximum Flood (PMF)
- Climate Change scenarios
- Blockage scenario.

Section 7 of this report describes the proposal and model setup for the post-development scenario, **Section 8** describes the proposed flood behaviour and **Section 9.2** deals with the impacts during operation.

4 Existing environment

The study area lies within the Hawkesbury-Nepean River catchment, with most of the study area catchment draining to the Hawkesbury River and its floodplain. The eastern most area of the proposal around Londonderry Road drains towards Rickabys Creek in the south, which is a tributary of the Hawkesbury River, joining it at Windsor.

The Hawkesbury-Nepean River catchment has an area of approximately 22,000 km² and extends from Goulburn in the south to the mouth of the Hawkesbury River at Broken Bay. The catchment has varying terrain with steep and high rainfall areas in the upper catchments draining to several major tributaries, as well as the flatter river and floodplain areas. The upper reaches include numerous dams that form Sydney's drinking water supply including Cataract, Cordeaux, Avon, Nepean and Warragamba Dams. The Nepean River valley flows through a narrow gorge downstream of Wallacia where the valley widens to form the floodplain between Penrith and Castlereagh. The river has a further constriction at Castlereagh and the valley widens around Yarramundi to form a further major floodplain in the area of North Richmond, Richmond, Windsor, Pitt Town and Wilberforce, the river becoming the Hawkesbury River around the confluence with the Grose River. Further downstream, a narrow gorge around Sackville acts as a major hydraulic control to flow capacity and can cause high flood levels upstream on the floodplain due to a backwater effect. The Hawkesbury River is tidal back up to Yarramundi and may be influenced by sea level rise.

4.1 Flood-producing mechanisms

Different areas of the proposal are subject to flooding from different sources which changes with the magnitude of events. The Richmond Bridge and Kurrajong Road cross the channel and floodplain of the Hawkesbury River and are affected by mainstream river flooding primarily but will also experience less severe flooding from the local floodplain catchment. The area around Southee Road and Hobartville is elevated above the Richmond Lowlands floodplain and will primarily be affected by local catchment flooding.

4.1.1 Hawkesbury River mainstream flooding

The proposal area crosses the channel of the Hawkesbury River and the floodplain between Richmond and North Richmond, known as the Richmond Lowlands. The floodplain has a local catchment which drains to two main flowpaths through the floodplain, flowing through Mareh Mareh Lagoon and Pugh's Lagoon in the vicinity of the proposal. The floodplain connects to the Hawkesbury River just upstream of Windsor around Cornwallis and extends back upstream of Agnes Banks, just downstream of Castlereagh. In larger river flow events additional flow enters the floodplain from the river breaking its banks along the stretch of river between Yarramundi and North Richmond and is also impacted by the backwater or 'bath tub' effect which fills up the floodplain from Sackville back to Richmond and further upstream as the magnitude of events increases.

The floodplain has experienced a number of significant floods including most recently in March 2021, March 2022 and July 2022.

4.1.2 Local catchment flooding

The proposal may also be impacted by intense thunderstorms over local catchments, particularly the bypass along Southee Road between Castlereagh Road and Londonderry Road. There are a number of smaller catchments that drain both north and south across Southee Road and localised rainfall events, that do not affect the whole Hawkesbury Nepean River, will activate flooding in the floodplain flow paths and channels.

Southee Road also experienced flooding in 2021 and 2022. Flooding is largely due to the local terrain with various low points and local drainage features and capacity. Southee Road drainage near Castlereagh Road drains to a channel that runs southwest through WSU land and through 2 x 900mm pipe culverts under Castlereagh Road, the outlet of which flows to the floodplain overland. The centre of Southee Road drains via Council drainage pipes and overland towards an urban waterway that connects east to west through

Hobartville, discharging via a 900mm pipe under Castlereagh Road and south of William Cox Drive, with its outlet in the floodplain. WSU land drains towards Londonderry Road in the east which has very flat terrain. This catchment drains to a trapped low point to the southwest of the Southee Road – Londonderry Road intersection and would pond until a higher threshold level is reached to allow flow to drain towards the south via the road swales.

4.1.3 Emergency Response

The existing Richmond Bridge is a low level bridge that becomes inundated in frequent events (approximately a 50% AEP event) and is not part of an evacuation route. Flood evacuation routes for North Richmond are to the west to higher ground and for Richmond and Hobartville is to the east and south to higher ground.

4.2 Key features and infrastructure

Key features and existing infrastructure in the study area include:

- Local drainage networks within North Richmond that discharge into Redbank Creek in the northwest.
- The existing Richmond Bridge over the Hawkesbury River – the bridge is low level with a low level of flood immunity.
- A high bank/levee along the eastern bank of the Hawkesbury River separating the floodplain which is at a lower elevation than the bank/levee
- Through the floodplain there are various flowpaths and unnamed channels which flow to ponds and coastal wetlands around the proposal area. There are two main flowpaths which flow through Mareh Mareh Lagoon and Pugh's Lagoon in the proposal area.
- Five existing culverts under Kurrajong Road
- Various small culverts under other roads through the floodplain including Inalls Lane
- Two existing ponds within WSU land south of Southee Road
- Local drainage flowpaths, culverts, drainage network and urban waterway around Southee Road, Londonderry Road and Hobartville.

4.2.1 Existing transverse culverts

The existing transverse culverts along the proposal are shown in Table 4-1.

Table 4-1: Existing transverse culverts

Structure Size (mm)	Approximate Location (control line and chainage	Comment
2 x 2400 (W) x 1800 (H) box	Bells Line of Road (MCA1 CH620)	This culvert conveys flows from the upstream urban catchment under Bells Line of Road to discharge into the channel.
1050 mm RCP	Kurrajong Road/Old Kurrajong Road intersection (MCA1 CH2225)	Existing culvert conveys external catchment flows into Old Kurrajong Road intersection drainage. Connects to existing pit on the northern side which then connects under Old Kurrajong Road and discharges to swale on northern side of Kurrajong Road.
900 mm (W) x 400 mm (H) box	Kurrajong Road (MCA1 CH2640)	Culvert conveys external catchment flows under Kurrajong Road.
1050 mm pipe	Kurrajong Road MCA1 CH2765	Culvert conveys external catchment flows under Kurrajong Road.
1050 mm pipe	Kurrajong Road MCA1 CH2790	Culvert conveys external catchment flows under Kurrajong Road.
1200 mm pipe	Kurrajong Road MCA1 CH3305	Culvert conveys external catchment flows under Kurrajong Road.
600 mm pipe (Assumed)	Kurrajong Road MCA1 CH3480	Culvert conveys external catchment flows under Kurrajong Road (Pugh's Lagoon)
2 x 900mm RCP	Inalls Lane MCN1 CH3200	Culvert conveys external catchment flows under Inalls Lane (Mareh Mareh Lagoon)
900 mm (W) x 750 mm (H) box	Inalls Lane MCN1 CH3750	Culvert conveys external catchment flows under Inalls Lane.

Drainage culverts above are for the main roads only. Culverts for local drainage conveyance such as under driveways have not been listed here.

5 Flood modelling methodology

5.1 Available information

5.1.1 Previous flood studies and models

Hawkesbury-Nepean Valley Regional Flood Study - Draft (WMAwater, 2019)

The Hawkesbury-Nepean Valley Regional Flood Study (HNVRFS) was the first stage of an update to the Hawkesbury-Nepean Flood Study. The HNVRFS used a RUBICON model for the hydraulic modelling, and undertook a Monte Carlo assessment of flood probability, with a range of inputs considered – leading to 20,000 unique events being run through the model. A representative set of design flood events selected from the Monte Carlo model simulation have been used as inputs to the subsequent detailed 2-dimensional flood model assessment of the Hawkesbury Nepean River Flood Study.

Richmond Bridge Duplication and Traffic Improvements - Flood Assessment Report and Model (WMAwater, July 2022)

The study covers the flood assessment of the proposed Richmond Bridge duplication and improvement of the approaches as part of the solutions to address the congestion issues and accommodate future traffic in the area. The report documented the impacts of the 8 design options (namely Options 1, 2, 3, 4, 5, 6, 7, 6A and 2021) on the flood risk of the study area which were assessed using a quasi-calibrated TUFLOW hydraulic model of the Hawkesbury-Nepean River Basin. The study only investigated a limited number of design flood events, namely 20% AEP, 5% AEP and 1% AEP for the options assessment. Option 6A in this study is the adopted option that forms the basis of the strategic design on which the Concept Design is being developed.

Table 5-1 provides a summary of the supplied model data parameters.

Table 5-1: Richmond Bridge Duplication and Traffic Improvements - Flood Assessment Report (WMA, July 2022) - supplied model data summary

Description	Parameters
Model	Quasi-calibrated TUFLOW Model
Terrain Data	2017 LiDAR data with 0.8 metres (horizontal) and 0.3 metres (vertical) spatial resolution 2011 LiDAR data was used to supplement some areas, specifically the Upper Colo River and Hawkesbury River segment downstream of Wisemans Ferry Hydrosurvey of the downstream Hawkesbury River and Warragamba River representing bed levels were also incorporated in the TUFLOW model
Grid	20-metre grid
Result output	10-metre resolution

Hawkesbury-Nepean River Flood Study Interim Results (INSW, 2022)

The NSW Reconstruction Authority (formerly part of INSW) are currently undertaking an update to the Hawkesbury Nepean River Flood Study. The study was nearing completion in 2022, however, with two significant flood events occurring in March and July 2022, it was decided to undertake additional calibration of the model with data collected during these flood events. INSW supplied the interim results from the Hawkesbury-Nepean River Flood Study (Rhelm & Catchment Simulation Solutions, April 2022) to provide macroscale flood information for the existing condition flood information. No reports were provided together with the model results. The data contain the following maps:

- Depth
- Flood Extents
- Flood Function
- Hazard
- Levels
- Velocity

Results for the following design events were provided:

- 1 in 2 (50%) AEP
- 1 in 5 (20%) AEP
- 1 in 10 (10%) AEP
- 1 in 20 (5%) AEP
- 1 in 50 (2%) AEP
- 1 in 100 (1%) AEP
- 1 in 200 (0.5%) AEP
- 1 in 500 (0.2%) AEP
- 1 in 1000 (0.1%) AEP
- 1 in 2000 (0.05%) AEP
- Probable Maximum Flood (PMF)

The above information was used to inform the early stages of the concept design.

Table 5-2 provides a summary of the model grid data parameters corresponding to the supplied interim results.

Table 5-2: Hawkesbury-Nepean River Flood Study Interim Results (INSW, 2022) - supplied model data summary.

Item	Description
Spatial Reference	GDA2020 (MGA Zone 56)
Grid Size	15-metre grid
Result output	7.5-metre resolution
Remapped results output	4-metre resolution

Hawkesbury-Nepean River Flood Study (INSW, 2023)

At the time of this assessment, INSW was in the process of finalising the Hawkesbury-Nepean River Flood Study 2d TUFLOW flood model, however, it was not yet complete. INSW agreed to provide the baseline data from the model to Aurecon and this data has been used to re-establish a baseline TUFLOW flood model for the NRBS2 proposal using the provided INSW data. INSW Hawkesbury Nepean River Flood Study 2d TUFLOW model data provided includes:

Table 5-3: Hawkesbury-Nepean River Flood Study data (INSW, 2023) - supplied model data summary.

Description	Parameters
Terrain Data	15m resolution grid data based on LiDAR and bathymetric survey for the area downstream of Lapstone to Sackville 10m resolution grid data based on LiDAR and bathymetric survey for the area downstream of Lapstone to Sackville
Model Roughness	10m resolution grid data and polygon shapefiles
Flow hydrographs	10min timestep resolution (from hydrologic modelling) as hydraulic model inflows within the study area model extent for a range of events listed above.
Downstream Boundary Conditions	10min timestep resolution for the range of events downstream of Sackville Gorge
Structures Layers	Culverts and bridge model layers for the broader model that may impact hydraulic behaviour.

This data has been used to establish a revised flood model to undertake flood modelling for the REF and design development for the 80% Concept Design as described in **Section 5.2**.

5.1.2 Terrain and structure data

The following information has been provided by TfNSW (unless noted otherwise) and was used to inform the drainage design and flood modelling of the proposal:

- TfNSW Survey:
  - Pit and Pipe survey dated 26 July 2023 and 08 September 2023.
  - Detailed Ground Feature Survey dated 23 November 2023.
- LiDAR survey data dated April 2019 sourced in May 2023 from Geoscience Australia.
- RMS Stewardship Maintenance Contract - Sydney West. Richmond Bridge Approaches project drainage model (.12da) designed by Jacobs received 19 May 2023.
- Drainage GIS data received from Hawkesbury City Council dated 26 July 2023.

5.2 Model setup

Mainstream flooding is assessed through the New Richmond Bridge Stage 2 (NRBS2) Hawkesbury-Nepean River flood model developed for the proposal. As discussed above, Aurecon has used the baseline data from the INSW Hawkesbury Nepean River model to re-establish an existing scenario TUFLOW flood model for the NRBS2 proposal at the 80% Concept Design Stage. Assessment of mainstream flooding using this model, based on the same data as the INSW model, was done to facilitate consistency of results with the INSW model when it is available for use in future design stages of the proposal.

Local catchment flooding is assessed with development of a local flood model to determine flood extents and impacts for the areas of the bypass along Southee Road between Castlereagh Road and Londonderry Road and the floodplain local flow paths. This local catchment assessment targets the more intense, shorter duration events and assesses the more frequent events in the floodplain flow paths that aren't impacted by flooding from the Hawkesbury River. This includes the local catchments upstream of the bypass alignment for waterways/crossing locations.

5.3 Mainstream Model

5.3.1 Existing Model Setup and Validation

For the NRBS2 proposal, a cut down model extent of the Hawkesbury-Nepean River has been used to focus on the flood behaviour in the study area. The NRBS2 Hawkesbury River model extends from Castlereagh 10km upstream of Richmond Bridge to approximately 43km downstream to the Sackville Gorge which controls water levels in the area (**Appendix A Figure 1-1**). The model was setup to match the INSW model as closely as possible in order to undertake validation of the model performance. As such, the validation model setup uses a 15m grid based on the 10m terrain grid provided, the provided model roughness parameters and bridge and culvert structures within the model extent. Inflow hydrographs supplied have been used at the upstream boundary and at internal inflow points along the river and tributaries. The supplied time series water level has been applied at the downstream boundary.

Hydrology for the Hawkesbury-Nepean River catchment has been undertaken as part of the Hawkesbury Nepean River Regional flood study as documented in the Hawkesbury-Nepean River Regional Flood Study (HNVRFS) report (WMAWater, July 2019) undertaken for Infrastructure NSW (INSW). It is understood that there have been some refinements to the hydrology for the current INSW H-N River 2d TUFLOW Flood Model. Flows derived from the (HNVRFS) hydrology model have been used as inflows to the Hawkesbury-Nepean River TUFLOW model and INSW have provided to Aurecon/TfNSW flow hydrographs from the TUFLOW model.

One set of flow hydrographs was provided for each AEP event which were for the critical 72-hour duration event that produces the highest flood peak at Richmond for each flood event. This includes flows from local catchments and main tributaries along the River from upstream of Penrith Lakes to Sackville Gorge, including the Grose River, South Creek and Cattai Creek inflows. Timing of hydrographs for inflows from different tributaries was also supplied which result in the highest flood peak at Richmond.

The model was run for a range of events including the 10% AEP, 5% AEP, 1% AEP and Probable Maximum Flood (PMF) and good correlation was found between the NRBS2 model water level results and the INSW H-N River Model results provided. The NRBS2 water levels were typically 60-100mm higher than the INSW results along the River and in the floodplain which is a close correlation given the significant flood depths of typically greater than 12m in the River and typically greater than 4m in the floodplain. This close correlation confirms that the model is validated and consistent with the INSW results and appropriate for use on this study.

5.3.2 Existing Baseline Scenario

Following validation with the INSW model, modifications have been made to the NRBS2 model to make it fit for purpose for the objectives of the NRBS2 proposal. Modifications include:

- Use of the latest TUFLOW model version
- Changing the grid resolution from 15 m to 10 m to achieve a higher resolution terrain grid to better represent the design and flow through bridge structures in particular
- Incorporating ground feature survey, bathymetric survey and drainage survey collected for the proposal.
- Addition of existing culverts within the Richmond floodplain around Inalls Lane and Kurrajong Road.

5.4 Local catchment model

A local catchment flood model was also setup to determine flood extents and impacts for the areas of the bypass along Southee Road between Castlereagh Road and Londonderry Road and the floodplain local flow paths. A TUFLOW 2-dimesional grid model has been used and a direct rainfall approach was used in TUFLOW to allow runoff simulation within the hydraulic model. This method was chosen to allow flowpaths within the smaller catchments to be determined in the hydraulic model rather than using inflows from a separate hydrology model at the catchment outlet. In addition, the local overland flowpaths have some more complex interaction of catchments that change over the range of events which make exact delineation of catchments difficult. The model setup is described below.

5.4.1 Hydrological Modelling

The hydrological model has been setup using ARR2019 data and methods and a direct rainfall approach was used in TUFLOW to allow runoff simulation within the hydraulic model. It was decided to use a direct rainfall approach to allow rainfall over the whole domain to most accurately represent the interactions between adjacent catchments and storage effects which are coupled with the hydraulic model. These features are not necessarily well represented by a traditional hydrology model with discrete inputs to the hydraulic model.

Intensity Frequency Duration (IFD) data has been obtained from the Bureau of meteorology website. An Initial Loss/Continuing Loss model has been adopted in line with ARR2019 recommendations. Due to a lack of available flow gauges for calibration of the local catchments flows, losses have been adopted from the ARR2019 DataHub and the probability neutral burst initial losses have been used.

Validation of flows

A DRAINS hydrology model was also established using RAFTS runoff routing and an Initial Loss/Continuing Loss model to determine flows for the local catchments. The same rainfall and loss model parameters were adopted for the DRAINS model as per the TUFLOW hydrology setup. Catchments were delineated using the terrain model and catchment parameters such as area, grades and catchment roughness (PERN) input to the model.

Flows to critical locations (bridges, culverts and basins along the proposal area) were checked for consistency between the TUFLOW results and the DRAINS hydrology model and showed good comparison as shown in Table 5-4. Comparisons were undertaken for simple individual catchments which were not obviously impacted by storage effects or flows from upstream catchments (Figure 5-1). Catchments with large roads and culverts or dams are not necessarily well represented in the DRAINS model due to storage effects. Comparisons presented below are for a thirty minute duration storm. The reasonable match gives confidence in the runoff volumes and flows generated in the TUFLOW model.

Table 5-4: Local catchment Hydrology validation – TUFLOW vs DRAINS flows

Event (AEP)	Catchment	Peak Flow (m^3/s)	
		TUFLOW	DRAINS
5%	C14	1.79	1.88
	C15	1.52	1.25
	C19	1.05	0.94
1%	C14	4.32	4.01
	C15	3.07	2.67
	C19	1.85	1.96

Figure 5-1: Local catchment hydrology validation catchments

Determination of critical durations and temporal patterns

The 1% AEP and 5% AEP events were run for a full suite of durations from 20 mins to 48 hours with an ensemble of ten temporal patterns for each duration. Analysis of the results was used to establish the critical durations providing peak flood levels at key locations along the proposal alignment at culverts, bridges and basins. The peak flow hydrographs for these durations were compared with DRAINS model hydrographs. In order to reduce the number of model runs in TUFLOW, the adopted temporal pattern for each event was determined from the DRAINS model. The temporal pattern with peak flow closest to and higher than the mean flow was selected. Hence the TUFLOW model was run with direct rainfall for the full suite of durations from 20 mins to 48 hours using one temporal pattern for each duration for each event as determined from the DRAINS model.

5.4.2 Hydraulic modelling

The local catchment TUFLOW Model extent covers the floodplain area bounded by the Hawkesbury River bank to the west, from Castlereagh in the south to a short distance downstream (north) of Kurrajong Road and extends east to cover the local catchments through the WSU land and the Hobartville area, extending to east of Londonderry Road (**Appendix A Figure 1-2**). The TUFLOW model has been setup with a 5m grid using 2019 LiDAR data and the feature survey terrain data and incorporating surveyed culverts. Model roughness has adopted the same roughness parameters for different land use types as the mainstream model.

Hydrology has been setup using ARR2019 data and methods and a direct rainfall approach was used in TUFLOW to allow runoff simulation within the hydraulic model. A DRAINS hydrology model was also established using RAFTS runoff routing to determine flows for the local catchments. Flows to critical locations were checked for consistency between the TUFLOW results and the DRAINS hydrology model and showed good correlation.

5.5 Model scenarios

The models were re-run for the full range of flood events to establish the Existing Baseline Scenario flood levels, depths, velocities, and other appropriate parameters.

Table 5-5: Existing baseline model scenarios

Events	Mainstream	Local
1 in 2 (50%) AEP	✓	N/A*
1 in 5 (20%) AEP	✓	✓
1 in 10 (10%) AEP	✓	✓
1 in 20 (5%) AEP	✓	✓
1 in 50 (2%) AEP	✓	✓
1 in 100 (1%) AEP	✓	✓
1 in 2000 (0.05%) AEP	✓	N/A**
PMF	✓	N/A**

* Only the mainstream model has simulated the 50% AEP to define the current flood immunity of the existing Richmond Bridge and this event has not been mapped as it is confined to the Hawkesbury River.

**The local model has not been simulated for the 0.05% AEP or the PMF event as the mainstream flood levels inundate the Southee Road area and are the dominant event in determining flood levels within the local model extent.

As noted above, the TUFLOW model was run with direct rainfall for the full suite of durations from 20 mins to 48 hours. From this set it was determined that the critical durations to key locations for culverts, bridges and basins/storages were:

- 20% AEP - 30 min and 45 min for local flowpaths, 18 hours and 48 hours through floodplain and WSU storage areas.
- 10%, 5% AEP - 20 min and 30 min for local flowpaths. 24 hour through floodplain, 36 hour and 48 hour for WSU storage areas
- 2%, 1% AEP- 20 min for local flowpaths. 24 hour through floodplain, 48 hours for WSU storage areas

5.6 Assumptions and limitations

The following assumptions and limitations apply to the flooding and drainage assessments:

- The hydrology and flows used in the TUFLOW model are calibrated as described in the Hawkesbury-Nepean River Regional Flood Study report (WMAWater, July 2019).
- For this study, Aurecon have been provided with the critical storm event (duration and temporal pattern) which produces the highest peak flood levels at Richmond. The assessment is limited to results for those events only.
- The resolution of the terrain data provided is a 10m grid. This limits the resolution achievable by the TUFLOW results to a 10 m grid unless further survey is undertaken or the INSW base survey data is obtained.
- Localised flooding impacts in areas far away from the proposal related to local hydraulic controls not being represented in the model are beyond the scope of the proposal to resolve.

6 Existing flood behaviour

The floodplain between Richmond and North Richmond, known as the Richmond Lowlands, is inundated in relatively frequent flood events, overtopping Kurrajong Road and Richmond Bridge. In frequent flood events with AEPs of 50% and 20%, flow is generally confined to within the main Hawkesbury River channel at the Richmond Bridge with a backwater effect from downstream flooding extending back up through the Richmond Lowlands floodplain to Kurrajong Road in the 20% AEP.

In these events, flows from rainfall over the floodplain catchment are largely confined to the main channels running through the proposal area in the floodplain.

It is noted that the existing Richmond Bridge will be inundated in approximately the 50% AEP event including the approach road areas and hence connectivity/access across the Hawkesbury River is cut off for this and larger events.

With larger events, the flood level from the backwater rises and begins to overtop Kurrajong Road between the 20% AEP and the 10% AEP. Flows also begin to spill into the floodplain from the river via the existing eastern bridge approach road which is in a cutting in the terrain, which provides a flowpath to the floodplain.

In the 5% AEP the river begins to break its banks directing flows through the floodplain and the backwater level continues to increase in depth. Similar behaviour is seen in the 2% and 1% AEP events, with the river and floodplain margin to become a connected water level.

The majority of the floodplain is inundated by an average depth of around 1 m during the 20% AEP event, this increases to an average depth of 6-7 m during the 1% AEP event. Flood depths are some 12m in the 0.05% AEP and increase to more than 20 m in the PMF event and flooding in these events extends over Hobartville and WSU lands connecting to the floodwaters in Rickabys Creek.

20% AEP

For the 20% AEP flood event, flow is generally confined to the channel of the Hawkesbury River. Flood levels at Richmond Bridge are approximately 12.40 m AHD and less than 11.0m AHD in the floodplain flowpaths (**Appendix A Figure 3.1**) and peak flood velocities are 1.8m/s in the Hawkesbury near the Richmond Bridge. Floodwaters from the Hawkesbury River form a backwater through Richmond Lowlands, past Kurrajong Road towards Inalls Lane.

The existing dams along Southee Road are full and overflowing, inundating the road in the 20% AEP. The culverts under Castlereagh Road are at capacity and create ponding within the channel across the Western Sydney University land from Southee Road to Castlereagh Road with a water surface level (WSL) of 20.60 m AHD. There is overland flooding through Hobartville with flooding of Bell, Valder and Hughes Avenues and flows from Hill Street through to Cromwell Avenue as well as ponding in the sag on Clarke Avenue. There is also ponding on Bell and Hughes Avenues.

5% AEP

This is a notable event as it is where the Richmond Lowlands becomes substantially inundated. Flows break out of the Hawkesbury River near Yarramundi, and at various points along the bank. In the 5% AEP event, flood depths are greater than 4m in parts of the floodplain. The peak flood level at Richmond Bridge is 15.5 m AHD (**Appendix A Figure 2.3**) with levels in the floodplain lower at around 13.8m AHD.

While the Hawkesbury River is still the primary conveyance of floodwater, with velocities reaching a maximum of 3.01 m/s in the river and the floodplain experiences velocities up to 1.22 m/s (**Appendix A Figure 4.3**).

The flooding on Southee Road adjacent to 9 Southee Road, Hobartville is connected to the channel across the WSU land with a peak WSL of 21.00 m AHD. Depths in the overland flowpaths and ponded areas through Hobartville continue to increase. There is ponding in the sag on Clarke Avenue with approximately 0.3 m in depth.

1% AEP

The Hawkesbury River completely breaks its banks and water flows in a north easterly direction across the floodplain. The peak flood level at Richmond Bridge and in the floodplain is 17.51 m AHD (**Appendix A Figure 2.5**) and peak velocities in Hawkesbury River are approximately 2.8 m/s. The majority of the flow is conveyed through the river, however, the floodplain receives approximately 40% of the flow that is directed along the river. There is also a complex interaction with the Windsor floodplain, whereby peak velocity of the flow in the Richmond Floodplain does not coincide with peak water levels. This is due to the backwater affect which drives the peak water levels later in the flood event.

The channel across the WSU land has a peak WSL of 21.13 m AHD with flooding extending across Southee Road into the properties across the road. Depths on Southee Road and in the overland flowpaths and ponded areas through Hobartville continue to increase. Ponding in the sag on Clarke Avenue has approximately 0.35 m in depth.

Flood hazard

Flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations. Hazard categorisation has been developed as defined in ARR2019 (Book 6: Flood Hydraulics, Section 7.2.7) and utilises six categories on velocity and depth combination based on the stability of children, adults, the elderly, vehicles and buildings in flood waters.

The ARR2019 hazard curves are shown below in Figure 6-1.

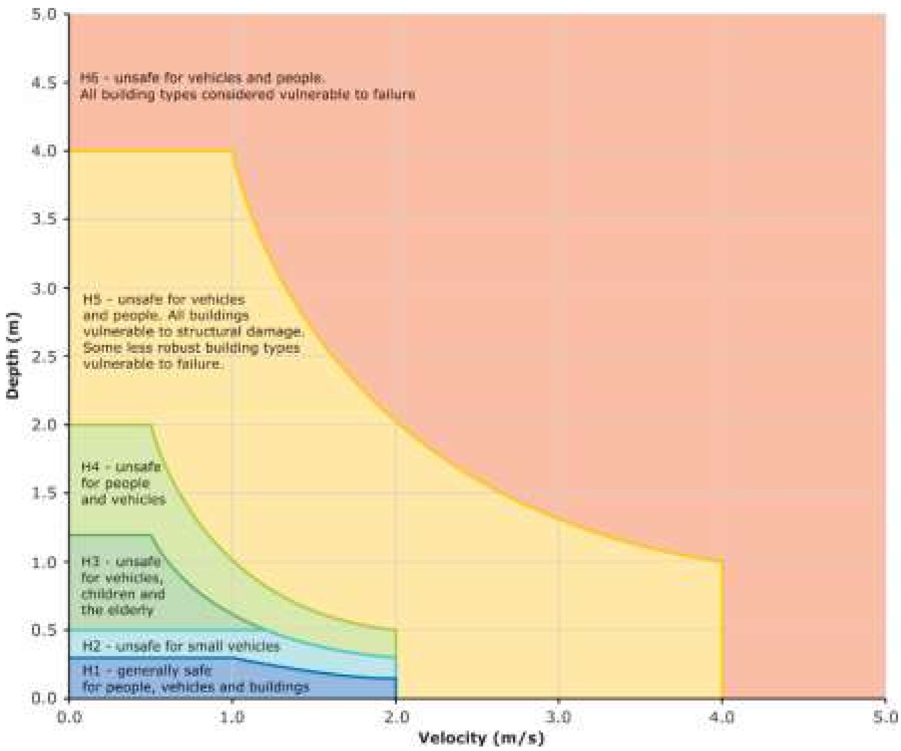

Figure 6-1: Flood Hazard categories from ARR2019

In the proposal area, the Hawkesbury River is categorised as H6 hazard due to both depth and velocity being high in all events, (**Appendix A Figure 5.1 - 5.7**). Through the floodplain area, flood hazard ranges from H1 at the fringes of the flood extent to H5 and H6 in the main flowpaths through the floodplain varying in hazard level between the different AEP events. In events larger than the 2% AEP, the floodplain is primarily classed as H6, being dominated by flood depths greater than 4m.

Around Southee Road hazard is relatively low at H2 to H3 for all events with higher hazard in the deeper ponded areas through WSU land.

7 Proposed environment

7.1 Key features of the Proposal

The key features of Stage 2A of the proposal would include:

- a new four-lane bridge over the Hawkesbury River (about 360 metres long) about 30 metres downstream of the existing bridge, with two eastbound and two westbound lanes and the road level at a height to provide a five per cent AEP flood immunity
- widening of Bells Line of Road and Kurrajong Road to two lanes in each direction from the Terrace Road / Grose Vale Road intersection in North Richmond to just east of the Kurrajong Road / Old Kurrajong Road intersection in Richmond
- a new two-lane bypass south of Richmond town centre (one lane in each direction) between the Kurrajong Road / Old Kurrajong Road intersection and just east of the Castlereagh Road / Inalls Lane / Southee Road intersection, including:
  - a three-way signalised intersection connecting Kurrajong Road and the new bypass, including closure of the existing northern and southern legs of Old Kurrajong Road at Kurrajong Road
  - a two-way gated emergency driveway access connecting the northern leg of Old Kurrajong Road and Kurrajong Road, to be opened during flood evacuation events
  - a 150-metre-long bridge over a tributary to Mareh-Mareh Lagoon (near Inalls Lane)
  - a 120-metre-long bridge over the floodplain parallel to Inalls Lane
  - a roundabout at the Castlereagh Road / Inalls Lane / bypass intersection, with a local road connection to Southee Road
  - local road connections to Yarramundi Lane and Victoria Place from the bypass
  - truncation of Inalls Lane near Mareh-Mareh Lagoon, with local road connections to Inalls Lane from the bypass via Yarramundi Lane and near Drift Road
  - closure of the existing Drift Road intersection with Inalls Lane, with a new local road connection to Drift Road from the bypass
  - footpaths along the southern side of the of the bypass between Drift Road and Castlereagh Road and on each side of the roundabout
- an upgraded active transport network between Richmond and North Richmond, including:
  - a new shared path along the southern side of Kurrajong Road between the existing Richmond Bridge and Chapel Street, Richmond, a distance of about two kilometres, connecting to existing paths along March Street, Richmond
  - conversion of the existing Richmond Bridge and approaches into an active transport only connection
  - active transport connections from the existing Richmond Bridge through Hanna Park to an upgraded shared path on the northern side of Bells Line of Road until east of the Bells Line of Road / Terrace Road / Grose Vale Road intersection
- retention of bus stops along Bells Line of Road and Kurrajong Road
- new drainage infrastructure, including swales and water quality basins
- utilities connections and upgrades (including electrical, gas, water and telecommunications)
- new intelligent transport systems including closed-circuit television (CCTV) cameras to monitor traffic flow and assist with emergency management
- new maintenance access to the three new bridge structures

- permanent retaining walls near the approach to the new four-lane bridge in North Richmond and along Kurrajong Road near the new shared path
- driveway adjustments and tie-ins, including along Bells Line of Road, Beaumont Avenue, Kurrajong Road, Old Kurrajong Road, Inalls Lane, Drift Road and Castlereagh Road
- eight new parking spaces on the northern side of Beaumont Avenue, near its intersection with Terrace Road to replace parking spaces removed on Bells Line of Road
- finishing works, including kerb and gutters, signs, landscaping, lighting and line marking
- construction activities, including:
  - early work, including the establishment of a new compliant handrail on the existing Richmond Bridge
  - geotechnical, contamination and utility investigations which may be carried out as early work
  - a temporary roundabout at the Kurrajong Road / Chapel Street intersection
  - civil earthworks, bridge structural works, retaining walls, drainage work, utilities relocations and tie-in work and adjustments to adjoining sections of road
  - establishment of temporary ancillary facilities to support construction, including compound sites, site offices, stockpile and laydown locations, temporary access tracks and water quality devices
  - demolition work for structures and property features that fall in the proposal area.

The key features of Stage 2B of the proposal would include:

- localised widening of Bells Line of Road to provide a dedicated right-turn lane into Crooked Lane
- widening of Bells Line of Road to two lanes in each direction from west of Charles Street to the Terrace Road / Grose Vale Road intersection in North Richmond
- additional capacity improvements to the Bells Line of Road / Terrace Road / Grose Vale Road intersection, including an additional eastbound through lane at the intersection
- an upgraded shared path on the northern side of Bells Line of Road from west of Charles Street to the Terrace Road / Grose Vale Road intersection in North Richmond
- extension of the bypass (one lane in each direction) between the Castlereagh Road roundabout and just south of the Londonderry Road / Southee Road intersection, including:
  - a new signalised intersection at the junction of Londonderry Road, the new bypass and Vines Drive
  - closure of the Southee Road local road connection from Castlereagh Road and closure of Southee Road at Londonderry Road
  - a new local road connection to Southee Road opposite Valder Place, with left and right turn lanes provided at this intersection.
  - two new bus stops along the bypass near Hill Avenue (one eastbound and one westbound), with a footpath connection to Southee Road
- retention of bus stops along Bells Line of Road and Londonderry Road
- new drainage infrastructure, including swales and a water quality basin on Londonderry Road
- noise screening mounds, walls and/or additional attenuation between the bypass and Southee Road along the extended section of the bypass between Castlereagh Road and Londonderry Road
- utilities connections and upgrades (including electrical, gas, water and telecommunications)
- new intelligent transport systems at the Londonderry Road / bypass / Vines Drive intersection including closed-circuit television (CCTV) cameras to monitor traffic flow and assist with emergency management
- driveway adjustments and tie-ins, including along Bells Line of Road, the bypass and Londonderry Road
- finishing works, including kerb and gutters, signs, landscaping, lighting and line marking
- construction activities, including:

- geotechnical, contamination and utility investigations which may be carried out as early work
- civil earthworks, retaining walls, drainage work, utilities relocations and tie-in work and adjustments to adjoining sections of road
- establishment of temporary ancillary facilities to support construction, including compound sites, site offices, stockpile and laydown locations, temporary access tracks and water quality devices
- demolition work for structures and property features that fall in the proposal area.

The flood modelling for the full Stage 2 proposal scope includes all features of the proposal relevant to hydraulic flow behaviour including the proposal earthworks for the road, basins, ponds and swales, noise mounds and noise walls bridge structures and culverts.

The following sections describe the major structures relevant to the flood model setup.

7.1.1 New Richmond Bridge over Hawkesbury River

The New Richmond Bridge will have an overall length of 321.5 m consisting of 9 x 33 m and 1 x 24.5 m spans with 1515 mm deep Super-T girders. The new bridge will have a width of 18.5 m will comprise 4 x 3.5 m lanes for eastbound traffic & westbound traffic, 2 x 1.2 m shoulders, a 1.0 m median and 0.53 m wide medium performance barriers.

The bridge has Blade Piers (4 m long x 2 m wide), with a pile cap at water level supported on 3 No. 1200 mm diameter circular piles.

Table 7-1: Proposed New Richmond Bridge parameters

Bridge location	Pier Configuration	Number of Spans	Span length	Deck Soffit	Handrail Height
45 metres downstream of existing bridge	Blade Pier (4 m long x 2 m wide) 3 No. 1200 mm diameter circular piles	9	33.0 m	Varies along the span of the bridge (lowest at 17.27 m)	1.4 m
		1	24.5 m		

7.1.2 Richmond Bypass Bridge No. 1

The first bridge on the Richmond Bypass is located east of Inalls Lane from CH3080 to CH3230 along control line MCA1. The 16.06 m wide bridge will comprise 2 x 3.5 m lanes for eastbound traffic & westbound traffic, a 3.0 m shoulder on the eastbound carriageway, a 2.5 m shoulder on the westbound carriageway, a 1.0 m median and 0.53 m wide medium performance barriers.

The overall bridge length is 149.35m comprising of 7 spans of 16.6 m and 2 spans of 16.575 m. The bridge cross section will consist of 19 No 700 mm deep TfNSW planks girders with the deck soffit level sitting above the 5% (1 in 20) AEP flood level. The deck will consist of 180 mm reinforced concrete deck and 80mm wearing surface.

Table 7-2: Proposed Bypass Bridge No. 1 parameters

Bridge location	Pier Configuration	Number of Spans	Span length	Pier width	Deck Soffit	Handrail Height
Inalls Lane from CH3080 to CH3230 along control line MCA1	2 No. 1200 mm diameter circular columns (2 No. 1500 mm diameter piles)	7	16.6 m	1.2 m	Varies along the span of the bridge (lowest at approx.14.6 m AHD)	1.4 m
		2	16.575 m			

7.1.3 Richmond Bypass Bridge No. 2

The Richmond Bypass Bridge No. 2 is located from CH3420 to CH3540 along control line MCA1. This bridge will have the same cross-section as the Richmond Bypass Bridge No.1, except with a two-way cross fall of 3%. The bridge consists of 5 spans of 17.15 m and 2 spans of 17.125 m spans with an overall length of 120 m and a cross section consisting of 19 No. 700 deep prestressed concrete planks with the deck soffit level sitting above the 5% (1 in 20) AEP flood level.

Table 7-3: Proposed Bypass Bridge No. 2 parameters

Bridge location	Pier Configuration	Number of Spans	Span length	Pier width	Deck Soffit	Handrail Height
Inalls Lane from CH3420 to CH3540 along control line MCA1	2 No. 1200mm diameter circular columns (2 No. 1500mm diameter piles)	5	17.15 m	1.2	Varies along the span of the bridge (lowest at approx. 14.2 m AHD)	1.4 m
		2	17.125 m			

7.1.4 Transverse culverts

All design transverse culverts shown on the 80% Concept Design phase civil drawings have been included in the flood model. The proposed transverse culverts along the proposal are shown in Table 7-4.

Table 7-4: Proposed transverse culverts

Structure Size (mm)	Approximate Location (control line and chainage	Comment
900 mm (W) x 400 mm (H) box	MCA1 CH2640	Existing retained, proposed extension (MAC03)
1050 mm pipe	MCA1 CH2765	Existing retained, proposed extension (MAC04)
1050 mm pipe	MCA1 CH2790	Existing retained, proposed extension (MAC05)
1200 mm pipe	MCA1 CH3305	Existing retained, proposed extension (MAC06)
600 mm pipe (Assumed)	MCA1 CH3480	Existing retained, proposed extension (MAC07)
1200 mm RCP	MCA1 CH1950	New (MAC01)
1050 mm RCP	MCA1 CH2225	New (MAC02) (connects to existing)
600 mm RCP	MCN1 CH2645	New (BCP01)
3 x 900mm RCP	MCN1 CH2890	New (BCP17)
3 x 900mm RCP	MCN1 CH2975	New (BCP02)
5 x 2400 (W) x 2400 (H) RCBC (Flood relief)	MCN1 CH3750	New (BCP03)
2 x 600 mm RCP	MCN1 CH4425	New (BPC13/BPC14)
450 mm RCP	MCN1 CH4870	New (BPC18)

Drainage culverts above are for the main carriageway only. Culverts for local drainage conveyance such as under driveways and access roads are shown on drawings and have not been listed here.

7.2 Proposed Design Scenario model setup

The Existing Baseline model setup described in **Section 5** was adjusted to incorporate the design features to represent the full Stage 2 proposal at the 80% Concept Design Stage. This includes:

- the 80% Concept Design road alignment and earthworks
- noise mounds and noise walls
- water quality basins, ponds and swale earthworks
- bridge structures
- transverse drainage culverts.

The model includes changes to the roughness grid as appropriate to represent the change in land use with the road surface and embankments. Relocated ponds in WSU land have been incorporated in the terrain. All other parameters and boundary conditions remain unchanged from the Existing Baseline model.

7.3 Model scenarios

The proposed design models were run for the full range of flood events (as for the baseline scenario) to define the operational flood behaviour and assess impacts of the proposal including levels, depths, velocities, and other appropriate parameters.

Table 7-5: Post-Development Model scenarios

Events	Mainstream	Local
20% AEP	✓	✓
10% AEP	✓	✓
5% AEP	✓	✓
2% AEP	✓	✓
1% AEP	✓	✓
0.05% AEP	✓	N/A**
PMF	✓	N/A**

** As per the existing baseline scenario, the local model has not been simulated for the 0.05% AEP or the PMF event as the mainstream flood levels inundate the Southee Road area and are the dominant event in determining flood levels within the local model extent.

7.4 Sensitivity testing scenarios

In addition to the above design flood event scenarios, a number of sensitivity scenarios were undertaken to assess the sensitivity of flood behaviour, risk to the proposal and impacts associated with climate change and blockage of hydraulic structures (Table 7-6). The development of these scenarios is further discussed in Section 7.5 and 7.6.

Table 7-6: Post-Development Model – sensitivity testing scenarios

Sensitivity Scenario Events	Mainstream	Local
5% AEP CC RCP4.5 2090 (9.5% rainfall increase + 0.9m Sea Level Rise)	✓	✓
5% AEP CC RCP8.5 2090 (19.7% rainfall increase + 0.9m Sea Level Rise)	✓	✓
1% AEP CC RCP4.5 2090 (9.5% rainfall increase + 0.9m Sea Level Rise)	✓	✓
1% AEP CC RCP8.5 2090 (19.7% rainfall increase + 0.9m Sea Level Rise)	✓	✓
5% AEP with Blockage	✓	✓
1% AEP with Blockage	✓	✓

RCP = Representative Concentration Pathways (see Section 7.5)

7.5 Climate Change considerations

It is widely accepted that Climate Change will lead to increases in global temperatures which will lead to increases in the intensity of rainfall along with sea level rise. The NSW Government's Flood Risk Management Manual (NSW Government, 2023) requires that flood risk assessments consider the impact of climate change (rainfall increase and sea level rise) on flood behaviour. This study has assessed the sensitivity of impacts on flooding due to a combination of both climate change induced rainfall increases and sea level rise using current industry guidelines.

To address climate change considerations, a relative assessment has been undertaken to evaluate the potential change in expected flood levels due to the effects of Climate Change in accordance with ARR guidance and *TfNSW Draft Technical Guide – Climate Change Adaptation for the Road Network*, Table 3 and Appendix A.

Climate Change predictions are made based on modelling changes to temperature and rainfall in global climate models for various Representative Concentration Pathways (RCPs), which consider projected increases in greenhouse gas concentrations. Interim Climate Change factors for temperature and rainfall for low, medium and high carbon emissions scenarios for years up to 2090 are provided in the ARR2019 Data Hub. ARR2019 (Ball et al., 2019) recommends the use of RCP 4.5 and RCP 8.5 values. These values are available as a percentage that the rainfall should be factored by from the ARR2019 Data Hub. Based on a projection date of 2090, ARR 2019 shows that:

- for an RCP of 4.5, the predicted rise in temperature is 1.86 ^{o}C, which corresponds to an increase in rainfall intensity of 9.5 per cent, and
- for an RCP of 8.5, the predicted rise in temperature is 3.68 ^{o}C, which corresponds to an increase in rainfall intensity of 19.7 per cent.

Both RCP 4.5 and RCP 8.5 rainfall increase have been run for the 2090 future scenario for both the 5% AEP and 1% AEP events. This provides a range of potential impacts with RCP8.5 scenario considered as the worst case scenario.

The Hawkesbury River is tidal up to approximately Yarramundi and flooding at the study area may be subject to Sea Level Rise. Hence, for mainstream flooding, based on the above considerations, the models have been simulated with both rainfall increase in combination with the expected corresponding sea level rise for the year 2100, which is approximately 0.9m increase above 1990 sea levels.

7.6 Impact of partial blockage of major hydraulic structures

The assessment of the impact that a partial blockage of major hydraulic structures may have on flood behaviour was based on guidance provided in ARR 2019. ARR 2019 recommends that the adopted blockage factor be based on the size of the largest 10% of debris relative to the size of the waterway opening; the availability, mobility and transportability of the debris; and the magnitude of the flood event.

Applying the guidelines for each culvert structure, typically, most catchments for the proposed culverts have well maintained agricultural land with limited trees. As a result, the potential for blockage from large debris is generally low and culverts less than 600mm have applied a minimum 20% blockage factor while all culverts 600mm or greater have a minimum of 10% applied.

For the bridge structures, the impact of an accumulation of debris against the piers was assessed to determine the percentage blockage factor to be applied. For each bridge, it was assumed that a raft of debris three times the pier width may become lodged on the upstream side of each pier. Given the typically floating nature of the debris, for the New Richmond Bridge, it was considered that applying this blockage for the full depth of flow was overly conservative. Hence, it was assumed that this debris raft may be assumed to occupy the top three metres of the pier depth (similar to the debris mat thickness used in bridge loading calculations), which equates to a blockage of approximately 5% of the waterway area. While for the floodplain bridges, it was assumed that this debris raft may be assumed to occupy the top third of the pier depth, which equates to a blockage of approximately 10% of the waterway area.

8 Flood behaviour with the proposal

The modelling results presented in this section and the associated mapping is for the full Stage 2 proposal.

In general, flow behaviour is not dramatically different from the existing baseline model. There are, however, a few areas where changes do occur to the flood behaviour.

Flood mapping results for the developed scenario are provide in **Appendix A**:

- Flood Levels – **Figures 6.1** to **6.7**
- Flood Depths – **Figures 7.1** to **7.7**
- Flood Velocities – **Figures 8.1** to **8.7**
- Flood Hazard – **Figures 9.1** to **9.7**

In general, the construction of the bridge and bypass across the floodplain presents an impediment to flow. The New Richmond Bridge spans the Hawkesbury River and flow extents for events up to the 10% AEP event, after which the approach embankment starts to constrict flows through the bridge opening. There are hydraulic losses at the bridge caused by the reduction in flow area and the shape of the piers in the river which results in higher flood levels upstream of the bridge. In the floodplain, bridge structures and culverts have been provided at the major flowpaths and hence the flow behaviour remains similar to existing for events up to the 10% AEP event. For larger events, the presence of the embankment and structures concentrates flow through the structures resulting in higher velocities through the structures. The 5% AEP flood levels remain below the edge of road and bridge soffits and the bridge and bypass would remain trafficable. Velocities through the floodplain are low and hence there are no significant hydraulic losses through the structures due to the backwater flooding. In the 2% AEP event, there is overtopping of the bypass road embankment and the floodplain bridge soffits become impacted, constricting flow and causing higher velocities downstream of the bridge structures of approximately 3 m/s.

For the 1% AEP up to the PMF, the floodplain is largely backwater dominated with large flow depths and the presence of the embankment and structures do not alter flood behaviour significantly from pre-development conditions. The New Richmond Bridge superstructure would become impacted by flows in the 1% AEP and greater.

The construction of the bypass adjacent to Southee Road creates an embankment across the existing flowpaths which cross the alignment both south and north. This is an impediment to flow and represents a small reduction in flood storage area. Culverts and diversion channels have been provided to maintain these flowpaths and/or divert flows as necessary. For all events, flow behaviour remains similar to pre-development conditions other than some changes to ponding location and storage being relocated further south on WSU land. The design creates larger storage depths on the southern side of the bypass and some reductions in flood depths through Hobartville. Velocities have localised changes with new drainage swales while Hazard categories are typically H2 to H3, which may pose a risk to vehicles and pedestrians.

Assessment of the impacts of the proposal are presented in the next section.

9 Impact assessment

The impact assessment presented in the following sections is for the full Stage 2 proposal.

9.1 Impacts during construction

In general, the land within the project boundary along the alignment will be used for construction activities. In addition, a range of ancillary facilities would be required to support construction, including:

- site compounds that incorporate site offices, car parking, sheds, workshops and storage
- areas for the delivery and storage of bridge structural elements and construction of the bridge over the Hawkesbury River
- areas for capturing and treating water from construction areas
- stockpile sites for materials, spoil and mulch.

The use of and layout for each ancillary facility would be finalised prior to construction.

Ancillary facilities would be temporary and developed for the sole purpose of the construction of the proposal. They would be returned to pre-existing conditions or rehabilitated upon completion of construction, in agreement with the landowner.

Seven potential ancillary facilities have been identified within the proposal area (Figure 9-1). These sites were identified in areas that maximised the use of existing vacant land. These ancillary facilities are as follows:

A. Terrace Road, North Richmond – laydown and storage area, stockpiling and site offices
B. North Richmond Park & Hanna Park (east) – bridge construction, laydown and storage area
C. Hanna Park (west) – laydown and storage area
D. Eastern side of the Hawkesbury River – bridge construction, laydown and storage area
E. Old Kurrajong Road – laydown and storage area
F. Inalls Lane – laydown and storage area
G. Castlereagh Road, Richmond – laydown and storage area, stockpiling and site offices

The inundation of the construction work areas and ancillary sites by floodwater has the potential to:

- pose a safety risk to construction workers
- cause damage to the proposal works and delays in construction program
- impact the downstream waterways through the transport of sediments and construction materials by floodwater
- obstruct the passage of floodwater and overland flow through ancillary works such as site sheds, stockpiles and some types of temporary fencing, which has the potential to exacerbate flooding conditions outside the construction footprint.

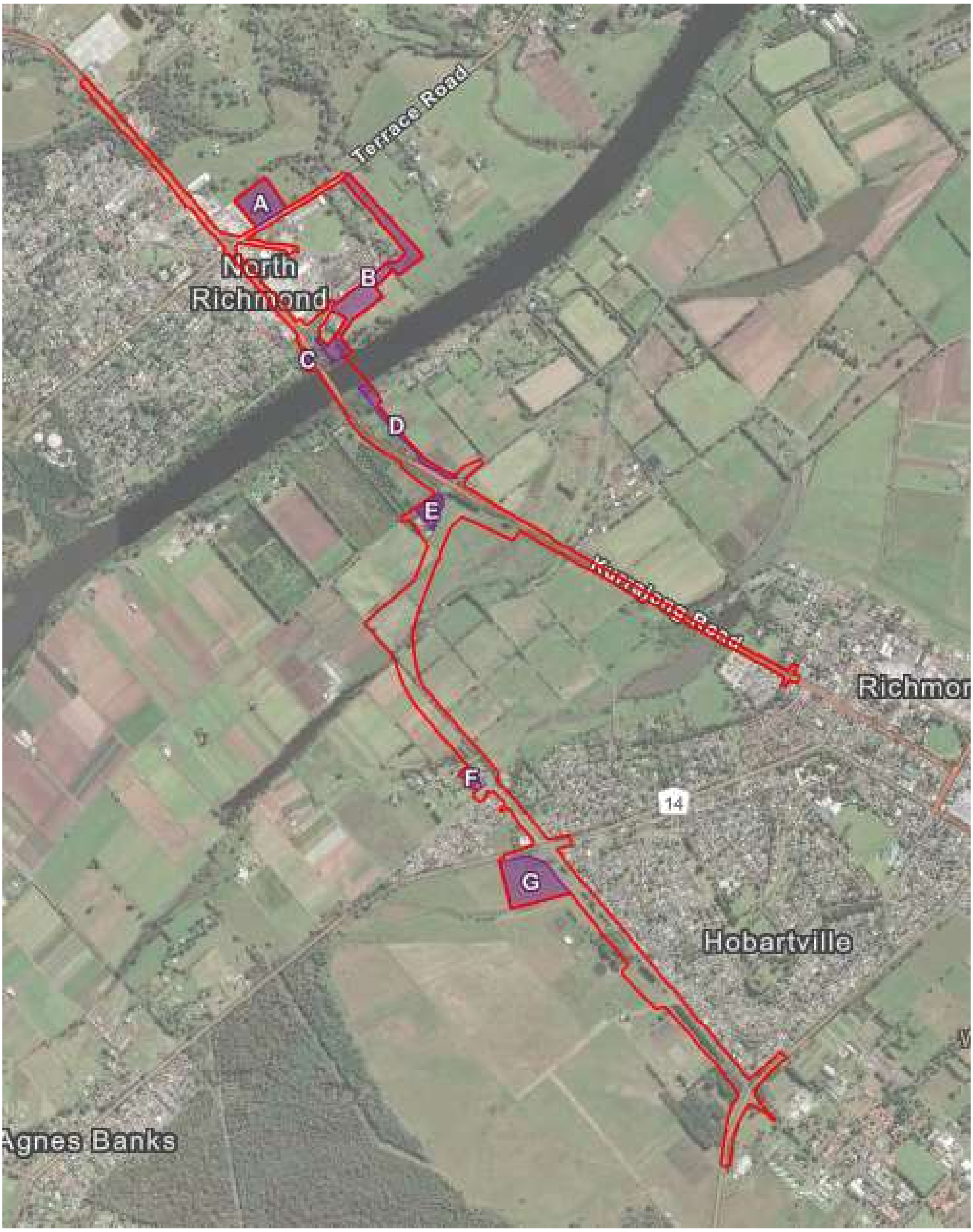

Figure 9-1: Proposed ancillary facilities for construction

9.1.1 Potential flood risks to construction works areas

The ancillary facilities have been overlaid on the flood extents for the range of flood events to assess the risks to the construction work areas and ancillary facilities (Figure 9-2).

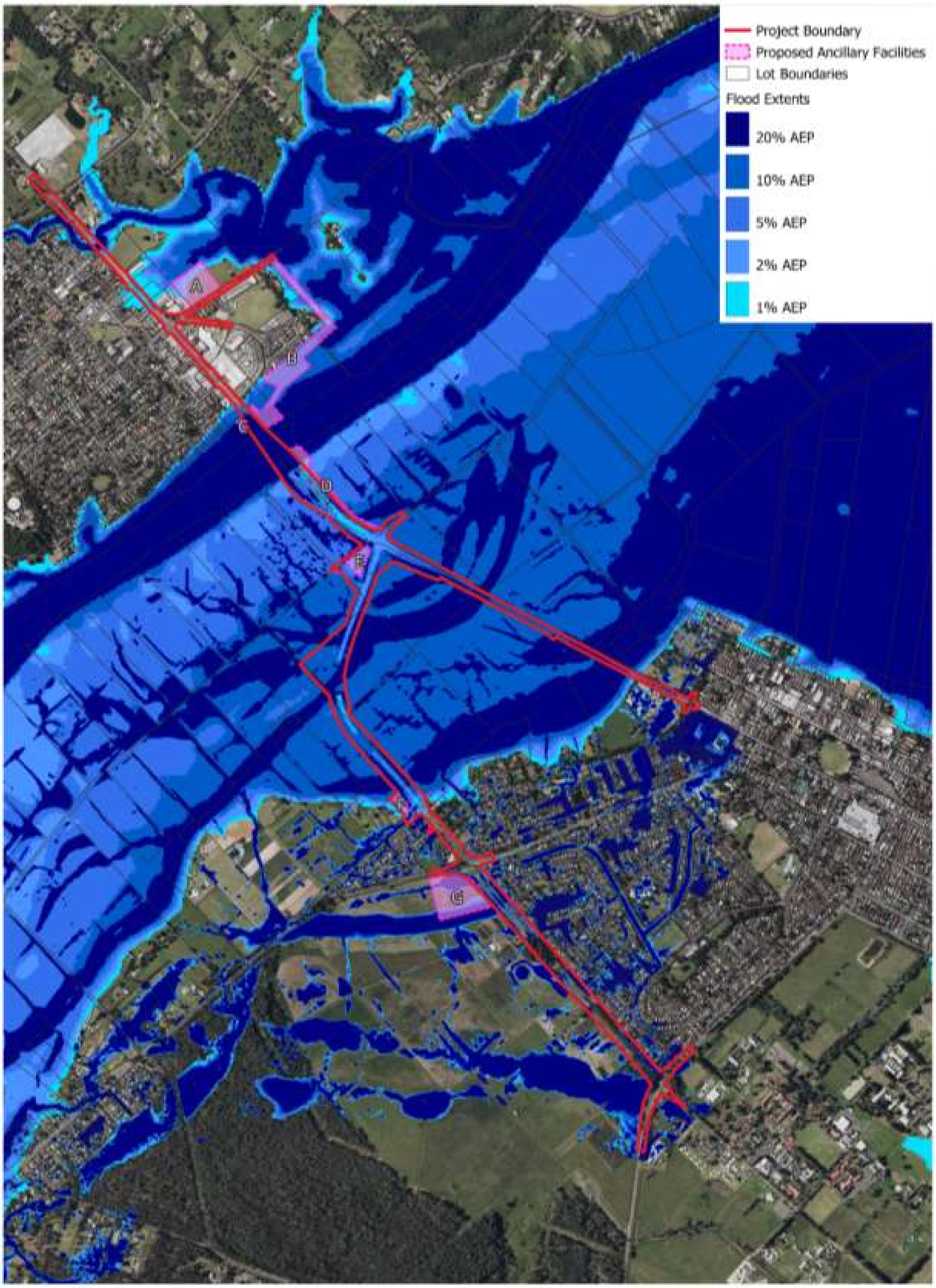

Figure 9-2: Proposed ancillary facilities for construction overlaid on flood extents

In frequent flood events with AEPs of 50% and 20%, flooding is confined to within the main Hawkesbury River channel at the Richmond Bridge. In these events, local flooding from the floodplain catchments is largely confined to the main channels running through the proposal area where the bypass is to be constructed.

It is noted that the existing Richmond Bridge will be inundated in approximately the 50% AEP event including the approach road areas and hence connectivity/access across Hawkesbury River would become cut off, limiting access and movement of construction traffic.

The location of site compounds would largely remain outside the flood extents for events up to the 20% AEP event. However, part of facilities B, C, D and G lie within the 20% AEP flood extents. Part of all site compounds would be susceptible to flooding in the 10% AEP flood event and construction works through the floodplain would be impacted by the backwater flooding, with Kurrajong Road also inundated and cut off to traffic. All larger events would similarly inundate construction works and site compounds.

Stockpiles within compounds should be located in areas above the 20% AEP flood levels.

Appropriate management measures should be implemented that give consideration to the location and level of the construction work areas and compounds and ensure that an appropriate flood warning emergency response plan is implemented utilising upstream gauge information and flood warnings and alerts issued by the Bureau of Meteorology. This would allow sufficient time for evacuation and movement of or securing of equipment within flood risk areas and barges in the river.

9.1.2 Potential flood impacts of construction activities

In general, it is expected that construction activities and ancillary sites would have minor footprints relative to the permanent works and would have no significant impact on flooding. In 10% AEP and rarer events due to the backwater flooding and the volume of the floodplain, site works are minor by comparison and would not alter flowpaths.

Earthworks

Earthworks for the proposal predominantly consists of the construction of fill embankments across the floodplain. As a result, the progressive embankment lifts will largely follow the same footprint of the permanent works and hence would have a smaller or equal impact on flooding. There are some minor cutting areas at the eastern extent of Kurrajong Road which does not impact flooding. Consideration should be made for potential impacts to flooding in areas where surcharge loading of embankments is required which would have a higher embankment height than the finished road level. This would only be of consideration for events larger than the 5% AEP event. Again, due to the isolated locations, it is expected that any impacts would be negligible and very localised.

Temporary waterway/flowpath diversions may need to be implemented during construction of culverts along waterway/flowpath alignments to ensure positive drainage is maintained.

Bridge Construction

For the New Richmond Bridge, construction of land piers will be undertaken with cranes and piling rigs from the land and adjacent ancillary works sites at Hanna Park (Site B) and on the eastern bank of the river (Site D). Piers in the river are to be constructed using a barge and there are currently no plans for temporary piling platforms in the river.

For the floodplain bridges, construction will be undertaken with cranes and piling rigs on land within the floodplain.

Works would be largely outside the flood extents for floods up to the 20% AEP event with the exception of the bridge pier works within waterways. All of these works and footprints of construction activities align with the permanent works with no significant additional temporary works that would be expected to cause any impacts. This is due to their small footprint relative to the volume of the floodwaters that would be experienced in large events.

9.2 Impacts during operation

9.2.1 Potential flood risk to the proposal

In general, potential flood risks to the proposal include:

- Flood levels inundating the road requiring closure
- Flood flows overtopping the road and causing damage to the roadway and embankment
- Flood forces impacting the bridge structures causing damage
- High velocities causing scour of bridge structures, culvert inlets and outlets and scour of embankments.

The proposal has been designed to meet the required flood immunity levels of the bridges and the roadway as demonstrated in the following sections. The roadway would remain flood free for flood events up to and including the 5% AEP and would maintain connectivity of North Richmond to Richmond (**Appendix A Figure 7.3**).

Velocities through the floodplain are typically low being around 1.5m/s or less, except localised higher velocities through bridges and culverts. Bridges have been designed to account for the calculated scour depths and scour protection is provided in the design for the bridge piers and abutments and for culvert inlets and outlets to counteract the potential for scour. For events larger than the 5% AEP, the bridge soffits would begin to be impacted and the roadway would start to overtop posing a risk of damage to the road surface. Velocities across the roadway typically remain low (<1.5m/s) and issues with scour are not expected until an extreme event greater than the 1% AEP, such as the 0.05% AEP which would have high velocities of 3m/s or more which would likely cause significant damage to the roadway embankments.

Bridge immunity

In accordance with New Richmond Bridge Stage 2 Scope and Design Requirements, bridge soffits are to achieve 5% AEP flood immunity as a minimum. Further, Super T girders are required to be above the 2% AEP event flood level. The water surface elevation (WSE) during the flood events determines the flood resilience level of the infrastructure being designed.

For the purpose of this proposal, the INSW Interim flood results were used in setting the design road immunity and bridge soffit levels for the 20% Concept Design. Flood levels have then been confirmed through flood modelling for the 80% Concept Design development.

Table 9-1 below outlines the bridge soffit levels and the design flood levels based on the latest flood modelling results. As demonstrated in the table, the New Richmond Bridge soffit is above the 2% AEP flood level and the Bypass bridge soffits are above the 5% AEP flood level.

Table 9-1: Design flood levels at Bridges

Bridge	Bridge soffit RL (m AHD	Flood Level (m AHD)				
		0.05% AEP	1% AEP	2% AEP	5 % AEP	20 % AEP
New Richmond Bridge	16.79 to 17.74	22.03	17.51	16.32	15.60	12.38
Bypass Bridge No. 1	14.61 to 15.33	23.04	17.54	16.05	13.86	N/A
Bypass Bridge No. 2	14.22 to 15.34	23.03	17.53	16.05	13.86	N/A

Road flood immunity

In accordance with New Richmond Bridge Stage 2 Scope and Design Requirements "the design is to provide minimum 300 mm freeboard at the edge line of road to the 1 in 20 chance per year flood level" (i.e. a 5% AEP event). Table 9-2 details the low points of each road section and the freeboard at the location. There is one location that fails to meet this criterion – at the tie-in of design works with the existing Kurrajong Road levels which is below the existing conditions 5% AEP flood level. Hence it is not possible to comply in this location, without raising the full length of Kurrajong Road to the limit of works, about 880 m further east towards Richmond.

Table 9-2: Design flood water surface levels and road freeboard

Road	Chainage & String Name	Road Edge line RL (mAHD)	5% AEP Flood Level (mAHD)	Freeboard (m)
Bells Line of Road at western abutment of Richmond Bridge	Ch 1435 MCB1	19.87	15.69	4.18
Intersection of Kurrajong Road and Bypass	Ch 2280 MCA1	14.67	13.86	0.81
Kurrajong Road at tie in to existing *	Ch 3310 MCA1	10.43	13.86	**-3.43 ***
Bypass between intersection and Richmond Bypass Bridge No. 1	Ch 2620 to Ch 2900 MCN1	14.55	13.86	0.69
Bypass between Bypass Bridge No. 1 and Bypass Bridge No. 2	Ch 3420 MCN1	15.47	13.86	1.61
Bypass east of Richmond Bypass Bridge No. 1	Ch 3375 MCN1	14.36	13.86	0.50
Bypass between Bypass Bridge No. 1 and Bypass Bridge No. 2	Ch 3420 MCN1	15.47	13.86	1.61
Bypass near Castlereagh Road	Ch 4400 MCN1	21.25	20.83	0.42
Bypass near WSU Access Road #	Ch 4880 MCN1	22.10	21.75	**0.35 #**
Londonderry Road Intersection	Ch 428 MCW1	24.29	23.92	0.37

* Existing Kurrajong Road becomes inundated between the 20% (1 in 5) AEP and 10% (1 in 10) AEP event.

It is noted that the bypass design as documented near the WSU access near Hill Avenue currently does not achieve the required flood immunity, however, an outstanding item in the design is to refine the road vertical geometry in this section of the Bypass to achieve the required immunity. The final levels required will need to be determined through future design stages after discussion and agreement is reached with WSU regarding the relocated pond configuration and impacts of detention storage on WSU land. Some bunding is proposed on the southern side of the road to form the pond which would provide immunity to the road as well.

Flood hazard

The ARR2019 hazard curves are shown in Figure 6-1.

In the vicinity of the proposal alignment, the Hawkesbury River is categorised as H6 hazard due to both depth and velocity being high in all events (**Appendix A Figure 9.1 - 9.7**). Through the floodplain area, flood hazard ranges from H1 at the fringes of the flood extent to predominantly H5 in the floodplain and H6 in the main flowpaths through the floodplain up to the 5% AEP event. In the events larger than the 2% AEP, the floodplain is primarily classed as H6, being dominated by flood depths greater than 4m.

Around Southee Road hazard remains relatively low at H2 to H3 for all events with higher hazard in the deeper ponded areas through WSU land.

9.2.2 Potential flood impacts of the proposal

Flood Level Impact

Flood level impacts are calculated as afflux - the change in flood level between the post-development scenario and the existing (pre-development) baseline scenario. Positive afflux values indicate that the flood level is higher as a result of the proposal. Negative afflux values indicate flood levels are reduced as a result of the proposal. Afflux maps have been generated for 20% AEP to 0.05% AEP events for this report (**Appendix A Figure 10.1 to 10.6**).

There are no criteria for acceptable flooding outlined in the proposal requirements and the proposal is to determine acceptable impacts as part of the REF process. A merits based approach has been adopted as described in **Section 3.1** to determine the acceptable impacts based on the performance of the design, the magnitude of further mitigation measures to reduce afflux, and the benefit of the proposal.

In general, there is an afflux in all modelled storm events of typically up to 35mm upstream of the proposal area, due to the bridge and bypass design. There are hydraulic losses at the bridge caused by the reduction in flow area and the shape of the piers in the river which results in higher flood levels upstream of the bridge. The presence of the bypass embankment in the floodplain also constricts flow through the floodplain bridge and culvert structures.

For more frequent events up to the 5% AEP event, flows are more constrained to the Hawkesbury River channel and afflux is mainly due to the new Bridge, with limited afflux in the floodplain. For the 2% AEP and rarer events, more flow breaks out of the River through the floodplain, with afflux in the floodplain due to the bypass and bypass structures.

The peak afflux occurs during the 2% AEP event due to the floodplain bridge soffits becoming impacted, constricting flow and coupled with the small amount of overtopping of the bypass road embankment, this represents the greatest impediment to flow.

Due to the backwater nature of flooding in the river and floodplain, the afflux in the 1% AEP extends back to Yarramundi and Castlereagh to the upstream model extent with slightly more than 10mm afflux near the upstream model boundary. The flood impacts primarily affect agricultural land which is less sensitive to flood level changes with limited impacts to residential properties.

Afflux is typically less than 35 mm in all events and falls within the acceptability criteria with three areas outside the proposal boundary of exception:

- Western Sydney University (WSU) land (Lot 10 DP1293174) has two areas with afflux exceeding 50 mm, however, both areas are on agricultural land where 200-400mm afflux is acceptable:
  - In the northern corner of the site near Castlereagh Road, where there is an existing pond. The design includes a relocated pond, an outlet channel and a bund separating the road drainage. This area experiences a maximum of 85 mm increase in water levels in the 5% AEP event.
  - The second area is located adjacent to the proposed WSU access off Southee Road, where the afflux is 160mm, 175 mm and 355 mm for the 20%, 5% and 1% AEP events, respectively.

- Mapping indicates an area with afflux up to 95mm in Agnes Banks south of Crowley's Lane, with a peak of 83mm of afflux affecting dwelling locations. This appears to be related to some local hydraulic controls in this area which have not been represented in the model due to lack of available information is this area. There are several culverts under roads and lands that cross the flow paths of the floodplain in this area that without the culverts modelled may cause artificially higher water levels.

There is also afflux of less than 12mm on Southee Road limited to the road reserve. The current design also has decreases in flood levels of up to 100mm through Hobartville around Hill, Potts, Cromwell and Rutherglen Avenues, Clarke Avenue and Atkins Crescent. This is due to the complex interaction of the Bypass, relocated ponds on WSU land and the connected channel and outlet structures which cause storage on WSU land. The final afflux in this area may need to be optimised through further design development of these connected systems in consultation with WSU.

Property Impacts

An initial assessment was undertaken of impact of habitable dwellings located within the 1% AEP flood extent in Richmond, North Richmond and up to Agnes Banks and Yarramundi. No floor level information is available, so identification of which properties have above floor flooding is not able to be determined. The exact number of affected properties will need to be confirmed with floor level survey and site inspections in future design stages. While many of the affected dwellings may have the habitable floor level elevated above the ground level, Table 9-3 provides a breakdown of those dwellings with less than 250mm flood depth as it is assumed that these dwellings would not have above floor flooding, even for a slab on ground construction. Those properties with greater than 250mm flood depth do not necessarily have above-floor flooding, as noted above, floor levels will need to be confirmed through survey.

Table 9-3: Number of flood affected habitable dwellings with potential above-floor flooding – Existing scenario

Depth of Existing Flooding	1%	2%	5%	10%
0.01m to 0.25m	19	28	21	16
Greater than 0.25m (potential above-floor flooding)	61	30	6	0
Total	80	58	27	16

* Properties within the 1% AEP flood extent upstream of the proposal area most susceptible to impacts from the proposal. Properties within the 1% AEP flood extent downstream of the proposal in areas not impacted by the proposal are not included.

Table 9-4: Number of habitable dwellings affected by flooding and an increase in flooding (afflux) – Design scenario

AEP Storm Event	1%	2%	5%	10%
Number of Dwellings Affected by flooding	80	58	27	16
Number of Dwellings Affected by more than 10mm of afflux	65	24	7	2
Number of Dwellings Affected by more than 50mm of afflux	0	15	0	0
Maximum Afflux (mm)	38	83	30	19

There would be no change to the number of habitable properties affecting by flooding as a result of the proposal. In addition to the above impacts there would also be benefits of decreases in flood levels of up to 100mm through Hobartville around Hill, Potts, Cromwell and Rutherglen Avenues, Clarke Avenue and Atkins Crescent:

- In the 5% AEP flood event, there are 7 properties affected by more than 10mm of afflux with a maximum afflux of 30mm experienced upstream of the Bridge. 38 properties would have reduced flood levels of up to 100mm through the Hobartville area.
- In the 2% AEP flood event, there are 39 properties affected by more than 10 mm of afflux with a maximum afflux of 83 mm, while some 41 properties would have reduced flood levels of up to 100mm through the Hobartville area.
- In the 1% AEP flood event, there are 65 properties affected by more than 10 mm of afflux with a maximum afflux of 38 mm, while some 47 properties would have reduced flood levels of up to 100mm through the Hobartville area.

In the 2% AEP event, of the 39 habitable dwellings affected by afflux, 15 dwellings have an afflux of more than 50mm, with a maximum of 83mm. All of these properties are located in Agnes Banks to the south of Crowley's Lane. This appears to be related to some local hydraulic controls not represented in the regional model and further investigation during detailed design may result in lower impacts in this area. The majority of these properties experiencing more than 50mm afflux are already impacted by more than 500mm depth of flooding and the property with afflux of 83mm has more than 1.7m of flooding depth in the 2% AEP event.

Overall, the impacts as a result of the proposal are reasonably small and are typically 30-40 mm with impacts to habitable dwellings that already have existing inundation. There is not expected to be any significant increase in flood damages to habitable dwellings that have existing inundation, however, this will need to be confirmed once floor level survey of affected buildings is undertaken. As noted above, the current design also has decreases in flood levels through Hobartville around Hill, Potts, Cromwell and Rutherglen Avenues.

Following floor level survey and assessment of over-floor flooding impacts, any residual flood impacts to properties that cannot be mitigated during detailed design will require consultation with property owners to inform them of the impacts and whether any increase in damage would be expected at their property.

Velocity Impact

The design velocity mapping (**Appendix A Figure 9.1 to 9.9**) shows that peak flood velocities are typically around 2.0 – 4.0 m/s in the Hawkesbury River and 1.0 – 1.5 m/s in the floodplain. This is largely due to the high downstream water levels creating ponding in the floodplain with low velocities resulting.

In general, flood velocities under the proposal scenario remain similar to existing velocities in the River and floodplain areas. Comparing **Appendix A Figure 4.1** to **4.7** and **Appendix A Figures 8.1** to **8.7**, there are localised increases in velocity downstream of both bypass bridges in the events greater than the 5% AEP this is due in part to the concentration of flows as a result of the reduced flow area through the bridges. The post development velocities are still typically below 1.5m/s for events up to the 1% AEP throughout the floodplain which is considered acceptable to not cause scour to affected areas being largely vegetated/grassed agricultural land. The exception to this is the 2% AEP event where localised velocities of up to 3m/s are seen to extend for a short distance downstream of the bridges. Scour protection is provided in the design at bridge abutments and piers along with culvert outlets to manage scour from localised higher velocities to prevent loss of sediment and to protect the proposal infrastructure.

Further design optimisation during detailed design may be required for the vertical alignment to mitigate velocity impacts. This may include raising the soffit of the bridges to provide a greater waterway area under the bridges during the 2% AEP event and/or optimising the location of floodplain bridges and culverts to better align the existing flowpaths to keep velocities within the same area as existing.

Hazard Impact

There is no identifiable change to hazard categories as a result of the proposal (comparing **Appendix A Figure 5.1** to **5.7** and **Appendix A Figures 9.1** to **9.7**). This is largely because the impacts of the proposal are small relative to the flood depths and flowpaths are typically maintained to maintain flow regimes. The floodplain is also a backwater volume driven system and hence the hazard categories are predominantly defined by depth only change by a minor amount (typically less than 50mm).

The design requirements for cycleways including shared paths state that they must be limited to low hazard as defined in Australian Rainfall and Runoff (ARR) during a 1% AEP event.

As shown in **Appendix A Figure 3.5** the existing Richmond Bridge and Kurrajong Road are well below the 1% AEP flood level placing it in the H6 hazard category (**Appendix A Figure 9.5**). As the ATC is to be on the existing bridge and at existing grade along the existing Kurrajong Road it is not possible to limit its hazard level to H1 or H2. This is due to the depth of water in this location being greater than 4 m during the 1% AEP event. For the cycleway/shared user path to be classed as H1 or H2 during the 1% AEP event, it would need to be raised to near or above the 1% AEP flood level.

Appendix A Figure 5.1 to **5.7** and **Appendix A Figures 9.1** to **9.7** show that the design does not worsen the hazard categories along the existing Kurrajong Road or Bells Line of Road alignment.

Time of Inundation

The proposal causes a small amount of afflux within the Hawkesbury River channel which in events greater than the 5% AEP event causes break out through the overbank to the floodplain area to a greater level earlier in the flood event. The constriction of flow through the floodplain bridges results in the flood event rising faster, however, the start time of the breakout from the River is comparable and inundation due to local catchment flooding has already begun. Given the overall length of the flood event being over 5 days any minor changes to time of inundation is not considered significant. In each event, there is only a minor increase in flood level and stored volume relative the full volume of the flood hydrograph which would not take any appreciable additional amount of time to drain. Hence changes to time of inundation are not considered significant.

There is not expected to be any impact on flood evacuation with the minor changes to the timing of the flood hydrograph. While the Richmond Bridge and bypass are not part of the flood evacuation route, the increased level of immunity would allow additional time for residents to be able to evacuate to the surrounding network for a longer period of time before the bypass becomes inundated.

9.2.3 Impact of future Climate Change on flood behaviour

Flood level sensitivity to climate change mapping for both the mainstream and local catchment flood events has been provided in **Appendix A Figures 11.1** to **11.16**.

The two scenarios examined were:

- for a Representative Concentration Pathway 4.5 (RCP4.5) emissions scenario projected for the year 2090, a 9.5 per cent increase in rainfall intensity, and
- for a Representative Concentration Pathway 8.5 (RCP8.5) emissions scenario projected for the year 2090, a 19.7 per cent increase in rainfall intensity.

These scenarios were assessed for both the 5% AEP and the 1% AEP events and have been modelled in combination with the corresponding sea level rise projections for 2090.

In general, there are appreciable changes to flood behaviour as a result of Climate Change, with increased rainfall leading to increased flows, with greater overtopping into the floodplain and depths across the floodplain with associated increased velocities. Flood hazard through the floodplain remains largely unchanged due to the existing depths being already significant.

In the 5% AEP RCP4.5 scenario, flood levels at the New Richmond Bridge increase by approximately 150mm while in the floodplain the flood level would increase by some 800mm to RL 14.66 mAHD. The bypass would largely maintain flood immunity, however, would start to impact the current design edge line of road levels (shown in Table 9-2) in some locations. The Floodplain bridge soffits would also start to be impacted. Around Southee Road, flood levels on Southee Road and WSU land are expected to increase by around 50mm.

In the 5% AEP RCP8.5 scenario, flood levels at the New Richmond Bridge increase by 400mm to RL 16.0m RL while in the floodplain the flood level would increase by some 1.9m to RL 15.70 mAHD. This would cause overtopping of the bypass road levels across the alignment with depths of between 300mm to 1.2m. Around Southee Road, flood levels on Southee Road and WSU land are expected to increase by around 100mm.

In the 1% AEP RCP4.5 scenario, flood levels at both the New Richmond Bridge and in the floodplain increase by approximately 850mm to RL 18.40 mAHD. Around Southee Road, flood levels are expected to increase by around 30mm near Castlereagh Road and up to 80mm on WSU land opposite Hill Avenue. In the 1% AEP RCP8.5 scenario, flood levels at both the New Richmond Bridge and in the floodplain increase by 1.75m to RL 19.27 mAHD while in the floodplain. This corresponds to greater depths of overtopping of the bypass road levels across the alignment. Around Southee Road, flood levels are expected to increase by around 60mm near Castlereagh Road and up to 150mm on WSU land opposite Hill Avenue.

The potential consequences to the proposal due to climate change is therefore deemed to be “medium” risk. The increased rainfall intensity caused by climate change would reduce the long-term flood immunity service level of the bypass. Presently, climate change has not been included in the design flood event flows and has been presented as a sensitivity assessment only. Consideration may be given to refining the road elevation levels during detailed design to provide flood immunity for at least an RCP4.5 5% AEP scenario with no freeboard. The flood immunity of the Bypass between Castlereagh Road and Londonderry Road is not significantly impacted by increased rainfall intensity due to Climate Change.

9.2.4 Impact of partial blockage of major hydraulic structures

As discussed in **Section 7.6**, it has been determined that the potential for blockage is reasonably low due to the nature of the catchments being largely agricultural land with limited trees. As such, ARR2019 blockage assessment has provided low blockage percentages to be applied to most structures. Culverts typically have 10 – 20 % blockage applied with the exception of some smaller culverts less than 600mm diameter which have 50% blockage.

Impacts due to partial blockage of hydraulic structures were assessed for both the 1% AEP and the 5% AEP. The results show that the impact caused by partial blockages are minimal in both the floodplain and the river, with values below 10mm in both events. This is largely due to the backwater nature of flooding in the 5%AEP with limited upstream flow passing through the structures. Hence blockage is not significant in reducing flow conveyance area. In the 1% AEP, while there is significant flows across the floodplain, there is also overtopping of the bypass embankment by 2-3m, a large backwater and relatively low velocities. Hence the relatively small reduction of flow area due to blockage applied to the bridges has a minor effect of additional flow distributed across the floodplain.

Blockage of culverts under the bypass adjacent to Southee Road have a more appreciable impact with reduced capacity leading to impacts in the order of 100-150mm increase in water level were blockage to occur. This indicates consideration should be given to allowance for blockage in the final sizing of culverts under the bypass including near Castlereagh Road (BCP13/BCP14) and at the WSU pond outlet culvert (BPC18), once the final arrangement of the pond, basin and road is refined during detailed design.

Blockage of culverts in the floodplain may have a more appreciable localised impact for the local catchment flows, however, this has not been investigated for this assessment.

9.3 Summary of impacts related to proposal stages

Flood mapping, behaviour and impacts presented above are for the full New Richmond Bridge Stage 2 proposal. While no revised flood mapping has been undertaken with the revised Stage 2A design, the following section outlines the impacts expected under both stages.

9.3.1 Stage 2A

The expected changes related to the Stage 2A scope of works are as follows:

- New Richmond Bridge additional span – the additional span would provide some additional flow area through this span, however, due to the sloping ground in this area, there is limited height and the additional flow area is small in comparison to the total flow area of the bridge/river. Sensitivity testing was conducted for the additional span, however, only minor localised changes were observed with no appreciable change to afflux results and flood mapping has not been updated to reflect this.
- Old Kurrajong Road intersection – the northern leg of the intersection sits within the floodplain and would not have a significant impact of flowpaths being largely within the backwater affected area of the floodplain. The design footprint in this area has been reduced and hence there is expected to be no change or minor localised improvement to flood impacts.
- Southee Road tie-in – removal of the bypass between Castlereagh Road and Londonderry Road means there would be no change to existing flood behaviour and no flood impacts as there are no proposed earthworks in this area. The only impact would be to the local overland flow path from the catchment north of Southee Road adjacent to Castlereagh Road which needs to pass under the proposed bypass tie-in to Southee Road. An appropriately sized culvert has been provided to convey the 1% AEP local catchment flows. This area of the proposal sits above the 0.5% AEP flood extent for the mainstream river flooding. Flood modelling in this area was undertaken with the local catchment model and hence all mapped flood impact results through this area would no longer apply as there will be no change to flood behaviour due to no design earthworks in this area.

The property impacts expected in Stage 2A would be the same as those in the full Stage 2 scope, except that there would not be impacts on WSU land between Castlereagh Road and Londonderry Road and the associated benefits through the Hobartville area.

9.3.2 Stage 2B

The expected impacts related to the Stage 2B scope of works are as follows:

- North Richmond – this area is on higher ground outside the 1% AEP flood extent and there would be no flood impacts associated with this area in the Stage 2 flood modelling. Hence there would be no impacts related to the Stage 2B design scope in this area.
- Bypass between Castlereagh Road and Londonderry Road – the impacts related to the Stage 2B scope for this section of the bypass would include the impacts on WSU land near the WSU access and the associated flood level reductions through the Hobartville area around Hill, Potts, Cromwell and Rutherglen Avenues as well as ponding in the sag on Clarke Avenue.

There would be no additional property impacts with Stage 2B of the proposal compared with the full Stage 2 scope.

9.4 Cumulative impacts

This section presents an assessment of the potential impacts the proposal would have on flood behaviour in combination with other projects in its vicinity.

The Grose River Bridge project is upstream of the New Richmond Bridge within the Grose River and is not expected to have any impacts on flows arriving at the New Richmond Bridge area. The New Richmond Bridge impacts do extend up Grose River and may influence hydraulics of the Grose River bridge.

There are no other known developments being planned or constructed in the vicinity of the project between Windsor and Yarramundi. This area is highly flood affected with high hazard and there is unlikely to be any future development approved within the floodplain in this area.

As such, there are no projects in the vicinity that would lead to cumulative impacts in addition to the project impacts expected.

10 Management of impacts

The assessment of flood impacts outlined in this report provides an understanding of the flood risk to the proposal and the potential impacts on the surrounding environment during construction and operation. The proposed road upgrade will be designed, as practicable and feasible, to minimise the flood impact on properties whilst maintaining the required flood immunity for the proposed road upgrade. As the design develops further during the detailed design stage, flood modelling will be undertaken to confirm flood impacts of subsequent design changes.

The following sections outline measures which would be considered to manage the flood risk and impacts during the construction and operational phases of the proposal.

10.1 Management of construction impacts

Measures which will be considered for incorporation into the Construction Environment Management Plan (CEMP) in order to manage construction related flood risk and impacts are outlined below.

As ancillary facilities and construction work areas would be subject to potential high hazard flooding and isolation due to surrounding roads becoming cutoff, it will be necessary to implement measures to identify how risks to personal safety and damage to construction facilities and equipment will be managed.

The layout of the ancillary sites and material storage areas will need to be designed to:

- Limit the extent of works located in floodway areas
- Divert overland flow either through or around work areas in a controlled manner
- Locate stockpile areas at the highest points within compounds above at least the 10% AEP event
- Manage storage of hazardous material is to ideally be confined to ancillary sites that are not subject to flooding during a 1% AEP extent.

A Flood Management Plan would be developed for the construction area and ancillary facilities that would include details and procedures to minimise the potential for construction activities to adversely impact on flood behaviour in neighbouring properties and a set of procedures for the evacuation of construction personnel.

Measures to manage residual flood risk and impacts during construction would include:

- a procedure to monitor weather conditions (existing and forecast conditions), including minor rain events, local weather warnings and flood alerts and river water level data
- processes to make sure construction equipment and materials are removed from floodplain areas when a weather warning of impending flood-producing rain is issued
- a communication protocol to disseminate warnings to construction personnel of impending flood producing rain or predicted flooding and actions required to make construction areas stable and safe
- flood emergency response procedures to remove temporary works during periods of heavy rainfall
- an evacuation plan for construction personnel should a severe weather warning or flood alert for the Hawkesbury River be issued

10.2 Management of operational impacts

The proposal provides for improved flood immunity and connectivity of road access between Richmond and North Richmond via the new Hawkesbury River Bridge and Bypass with trafficability up to at least the 5% AEP event.

A number of management measures have been incorporated into the design to mitigate impacts of the proposal. This includes maximising the span of the new Hawkesbury River Bridge, lowering the bypass embankment, designing the size, position and levels of floodplain structures to minimise afflux, provision of scour protection measures.

The afflux due to the proposal during operation is deemed to be generally acceptable, however, further flood modelling will be undertaken to confirm flood impacts of subsequent design changes as the design develops.

Management of operational impacts may include the following measures:

- Investigate further design measures during detailed design to reduce afflux such as optimisation of bridge piers and the size and location of structures through the floodplain
- Consultation with affected property owners
- Floor level survey of affected buildings to determine whether the proposal would increase flood damages at residential properties with above floor flooding
- Provide local mitigation measures for affected properties
- Property modifications for affected properties.

11 Conclusion and recommendations

This assessment has investigated and outlined the potential impact the proposed road upgrade would have on flood levels, velocities, hazard and inundation times. The assessment is based on available data obtained and received and reflects the existing environment as currently stands.

The outcomes of the assessment show that the proposal would:

- Provide flood immunity for the New Richmond Bridge and Bypass for at least the 5% (1 in 20) AEP flood level plus 300mm of freeboard to allow trafficability during this event.
- Not worsen flooding outcomes for private properties compared to the existing case. It is noted that a number of dwellings have afflux impacts of typically 35mm with impacts occurring at properties that have existing inundation. During the 2% AEP event, 15 properties may have up to 83mm impact. No floor level survey is available, so identification of which habitable dwellings have above floor flooding is not able to be determined at this stage. The exact number of affected properties will need to be confirmed with floor level survey and site inspections in future design stages.
- Not increase erosion and scour risk caused by concentration of flows downstream of transverse drainage bridges and culverts. Scour potential inside the project boundary would be managed by rock protection around the culvert outlets.

Further flood modelling will be undertaken to confirm flood impacts of subsequent design changes as the design develops.

There are a number of isolated locations where afflux is greater than 50mm in the 2% AEP event, however, it is expected that such impacts can be further mitigated through design refinement and/or model refinement in these areas during future design stages.

Embankment height and bridge and culvert structures have been sized to balance the flood immunity requirements of the bridges and roadway, the size of structures and the afflux. Further optimisation of the size and location of flood relief culverts and design road elevation levels during detailed design may provide further reductions in flood impacts to upstream areas. Refinement of the main bridge over the Hawkesbury River may also be considered during detailed design which may further reduce hydraulic losses associated with the piers to reduce afflux.

Given the benefits of the bridge and bypass to the community in increasing flood immunity for improved connectivity during larger floods, the relatively minor impacts are deemed acceptable. There is not expected to be any significant increase in flood damages to properties with existing inundation. Some amount of afflux is unavoidable with a new bridge structure due to the reductions in waterway area due to piers and bridge deck (for events where the bridge deck becomes submerged). The additional cost to the proposal in attempts to further reduce the flood level impacts would outweigh the benefit of minor reductions in afflux achievable.

11.1 Recommendations

The following recommendations are made for further investigation during future design stages:

- Further investigate and refine the flood model in isolated locations where model results show afflux is greater than 50mm (such as around Agnes Banks)
  - It is expected that such impacts may be mitigated through further design refinement of the systems that control the hydraulic behaviour in these areas. Impacts that are seen within the floodplain around Agnes Bank are thought to be in part due to the model representation in this area not accurately capturing the flow between the River and floodplain or including culverts through road embankments in this area. Inclusion of such features may improve the accuracy of the flood model results in this area to confirm hydraulic capacity and impacts. Alternatively, design refinements to the embankment and structures during detailed design may be able to achieve incremental improvements in afflux which may mitigate the impacts observed in the model results in this area.

- Flood modelling during detailed design to further consider velocity impacts and design optimisation to mitigate such impacts such as adjustment/optimisation of structures along the bypass through the floodplain.
  - The flood modelling results are limited to the one critical design storm event supplied by INSW for each AEP which results in the peak flood levels at Richmond Bridge. There may be other storm events which are more critical for velocity with lower tailwater levels which may become evident during detailed design when the Hawkesbury-Nepean River Flood Study model and additional storm events become available. Interim INSW model results indicate higher velocities through the floodplain than determined through the NRBS2 assessment. This indicates there may be another critical event for velocity that results in higher velocity changes through structures which may require mitigation.
- Consider adjustment/optimisation of structures along the bypass through the floodplain including road vertical alignment levels.
  - The bypass bridges and culverts concentrate flows which causes high velocities downstream of the floodplain bridge and culvert structures, particularly in the 2% AEP event. The Richmond Bypass Bridge No. 2 is concentrating flows in an area away from the existing flow path which is at the low point in the floodplain at the location of the 5 x 2.4m x 2.4m box culverts. In future design stages, consideration may be given to repositioning the Richmond Bypass Bridge No. 2 to the east towards the low point which may provide greater alignment with the existing flow path and greater flow area through the bridge opening. This may replace the flood relief box culvert which may be relocated to provide flood relief culverts at other strategic locations along the bypass to maintain flowpaths as required.
- Further consultation with WSU is required to understand and agree on the final arrangement of the relocated ponds on WSU land and acceptable impacts. The operation and preferred location and size of the proposed relocated ponds is not currently known.
  - Flood modelling currently shows flood impacts on WSU land in the vicinity of the eastern relocated pond location (WSU002). This is largely as a result of the current design assumptions regarding their location, levels, associated outlet arrangements and bunds.
  - It is expected that these impacts can be optimised/balanced between different areas with further design refinement. Discussion is required regarding the acceptable flood impacts on WSU land and utilising the ponds and associated outlet infrastructure to manage flood impacts to downstream areas. For example, the eastern pond (WSU002) may have a different arrangement to utilise the low point in the land currently showing flood impacts to provide detention storage in this area which can benefit the Hobartville community downstream.
- The vertical road alignment of the bypass opposite Hill Ave, Hobartville should be raised to provide flood immunity. The flood modelling has included the following mitigations near the WSU access which will need to be included as a minimum in future design stages to provide 5% AEP flood immunity and mitigate the impacts affecting the Hobartville community:
  - The Bypass raised between approx. CH4830 to CH4900 to have edge line at RL 22.1m AHD and maintain a crown at approx. RL 22.4m with two way cross fall to provide 300mm freeboard to the edge line of road in the 5% AEP.
  - Culvert BPC18 changed to be separated from downstream Council drainage network, changed to 2 x 600mm RCP and discharge to surface at the Southee Road roadside swale.
  - Provision of a bund between the WSU low point and the Bypass road swale – approximately 60m at RL 22.5 mAHD (CH4790 to CH4850).
  - Inclusion of a clean water culvert (450mm diameter RCP) under the WSU Access Road between the WSU low point and BPC18 culvert inlet.
  - The vertical alignment for this section to Londonderry Road intersection requires further design development to ensure the coordination of road geometry, flooding and drainage requirements.
- Climate Change Adaptation:

- Consideration may be given to refining the bypass road elevation levels in localised sections during detailed design to provide flood immunity for at least a 5% AEP RCP4.5 climate change scenario (with no freeboard). This would allow minimum of 300mm freeboard above current day 5% AEP flood levels while future proofing to maintain the desired 5% AEP flood immunity with the predicted future RCP4.5 2090 5% AEP flood levels.
- Consideration may be given to adopting a rainfall intensity increase of 10% due to Climate Change in the design of pavement drainage and local catchment culverts.

A

Appendices

Appendix A
Figures and Flood Maps

List of Figures

Figure ID	Figure description
Model Setup	
Figure - 1.1	Mainstream Flooding Model Extents
Figure - 1.2	Local Catchment Model Extents
Existing Scenario Results	
Figure - 2.1	20% AEP Peak Flood Level - Existing Condition
Figure - 2.2	10% AEP Peak Flood Level - Existing Condition
Figure - 2.3	5% AEP Peak Flood Level - Existing Condition
Figure - 2.4	2% AEP Peak Flood Level - Existing Condition
Figure - 2.5	1% AEP Peak Flood Level - Existing Condition
Figure - 2.6	0.05% AEP Peak Flood Level - Existing Condition
Figure - 2.7	PMF Peak Flood Level - Existing Condition
Figure - 3.1	20% AEP Peak Flood Depth - Existing Condition
Figure - 3.2	10% AEP Peak Flood Depth - Existing Condition
Figure - 3.3	5% AEP Peak Flood Depth - Existing Condition
Figure - 3.4	2% AEP Peak Flood Depth - Existing Condition
Figure - 3.5	1% AEP Peak Flood Depth - Existing Condition
Figure - 3.6	0.05% AEP Peak Flood Depth - Existing Condition
Figure - 3.7	PMF Peak Flood Depth - Existing Condition
Figure - 4.1	20% AEP Peak Flood Velocity - Existing Condition
Figure - 4.2	10% AEP Peak Flood Velocity - Existing Condition
Figure - 4.3	5% AEP Peak Flood Velocity - Existing Condition
Figure - 4.4	2% AEP Peak Flood Velocity - Existing Condition
Figure - 4.5	1% AEP Peak Flood Velocity - Existing Condition
Figure - 4.6	0.05% AEP Peak Flood Velocity - Existing Condition
Figure - 4.7	PMF Peak Flood Velocity - Existing Condition
Figure - 5.1	20% AEP Hazard - Existing Condition
Figure - 5.2	10% AEP Hazard - Existing Condition
Figure - 5.3	5% AEP Hazard - Existing Condition
Figure - 5.4	2% AEP Hazard - Existing Condition
Figure - 5.5	1% AEP Hazard - Existing Condition
Figure - 5.6	0.05% AEP Hazard - Existing Condition
Figure - 5.7	PMF Hazard - Existing Condition
Post Development Scenario Results	
Figure - 6.1	20% AEP Peak Flood Level - Developed Condition
Figure - 6.2	10% AEP Peak Flood Level - Developed Condition
Figure - 6.3	5% AEP Peak Flood Level - Developed Condition
Figure - 6.4	2% AEP Peak Flood Level - Developed Condition
Figure - 6.5	1% AEP Peak Flood Level - Developed Condition
Figure - 6.6	0.05% AEP Peak Flood Level - Developed Condition
Figure - 6.7	PMF Peak Flood Level - Developed Condition
Figure - 7.1	20% AEP Peak Flood Depth - Developed Condition
Figure - 7.2	10% AEP Peak Flood Depth - Developed Condition
Figure - 7.3	5% AEP Peak Flood Depth - Developed Condition
Figure - 7.4	2% AEP Peak Flood Depth - Developed Condition
Figure - 7.5	1% AEP Peak Flood Depth - Developed Condition
Figure - 7.6	0.05% AEP Peak Flood Depth - Developed Condition
Figure - 7.7	PMF Peak Flood Depth - Developed Condition
Figure - 8.1	20% AEP Peak Flood Velocity - Developed Condition

Figure ID	Figure description
Figure - 8.2	10% AEP Peak Flood Velocity - Developed Condition
Figure - 8.3	5% AEP Peak Flood Velocity - Developed Condition
Figure - 8.4	2% AEP Peak Flood Velocity - Developed Condition
Figure - 8.5	1% AEP Peak Flood Velocity - Developed Condition
Figure - 8.6	0.05% AEP Peak Flood Velocity - Developed Condition
Figure - 8.7	PMF Peak Flood Velocity - Developed Condition
Figure - 9.1	20% AEP Hazard - Developed Condition
Figure - 9.2	10% AEP Hazard - Developed Condition
Figure - 9.3	5% AEP Hazard - Developed Condition
Figure - 9.4	2% AEP Hazard - Developed Condition
Figure - 9.5	1% AEP Hazard - Developed Condition
Figure - 9.6	0.05% AEP Hazard - Developed Condition
Figure - 9.7	PMF Hazard - Developed Condition
Flood Impacts - Afflux	
Figure - 10.1	20% AEP Peak Flood Level Afflux
Figure - 10.1a	20% AEP Peak Flood Level Afflux (Proposal Area)
Figure - 10.2	10% AEP Peak Flood Level Afflux
Figure - 10.2a	10% AEP Peak Flood Level Afflux (Proposal Area)
Figure - 10.3	5% AEP Peak Flood Level Afflux
Figure - 10.3a	5% AEP Peak Flood Level Afflux (Proposal Area)
Figure - 10.4	2% AEP Peak Flood Level Afflux
Figure - 10.4a	2% AEP Peak Flood Level Afflux (Proposal Area)
Figure - 10.5	1% AEP Peak Flood Level Afflux
Figure - 10.5a	1% AEP Peak Flood Level Afflux (Proposal Area)
Climate Change Sensitivity	
Figure - 11.1	5% AEP 2090 RCP 4.5 Peak Flood Level - Developed Condition
Figure - 11.2	5% AEP 2090 RCP 8.5 Peak Flood Level - Developed Condition
Figure - 11.3	1% AEP 2090 RCP 4.5 Peak Flood Level - Developed Condition
Figure - 11.4	1% AEP 2090 RCP 8.5 Peak Flood Level - Developed Condition
Figure - 11.5	5% AEP 2090 RCP 4.5 Peak Flood Depth - Developed Condition
Figure - 11.6	5% AEP 2090 RCP 8.5 Peak Flood Depth - Developed Condition
Figure - 11.7	1% AEP 2090 RCP 4.5 Peak Flood Depth - Developed Condition
Figure - 11.8	1% AEP 2090 RCP 8.5 Peak Flood Depth - Developed Condition
Figure - 11.9	5% AEP 2090 RCP 4.5 Peak Flood Velocity - Developed Condition
Figure - 11.10	5% AEP 2090 RCP 8.5 Peak Flood Velocity - Developed Condition
Figure - 11.11	1% AEP 2090 RCP 4.5 Peak Flood Velocity - Developed Condition
Figure - 11.12	1% AEP 2090 RCP 8.5 Peak Flood Velocity - Developed Condition
Figure - 11.13	5% AEP 2090 RCP 4.5 Hazard - Developed Condition
Figure - 11.14	5% AEP 2090 RCP 8.5 Hazard - Developed Condition
Figure - 11.15	1% AEP 2090 RCP 4.5 Hazard - Developed Condition
Figure - 11.16	1% AEP 2090 RCP 8.5 Hazard - Developed Condition
Blockage Sensitivity	
Figure - 12.1	5% AEP Peak Flood Level - Developed Condition - Blockage
Figure - 12.2	5% AEP Peak Flood Level Afflux - Developed Condition - Blockage
Figure - 12.3	5% AEP Peak Flood Depth - Developed Condition - Blockage
Figure - 12.4	5% AEP Peak Flood Velocity - Developed Condition - Blockage
Figure - 12.5	5% AEP Hazard - Developed Condition - Blockage
Figure - 12.6	1% AEP Peak Flood Level - Developed Condition - Blockage
Figure - 12.7	1% AEP Peak Flood Level Afflux - Developed Condition - Blockage
Figure - 12.8	1% AEP Peak Flood Depth - Developed Condition - Blockage

Figure ID	Figure description
Figure - 12.9	1% AEP Peak Flood Velocity - Developed Condition - Blockage
Figure - 12.10	1% AEP Hazard - Developed Condition - Blockage

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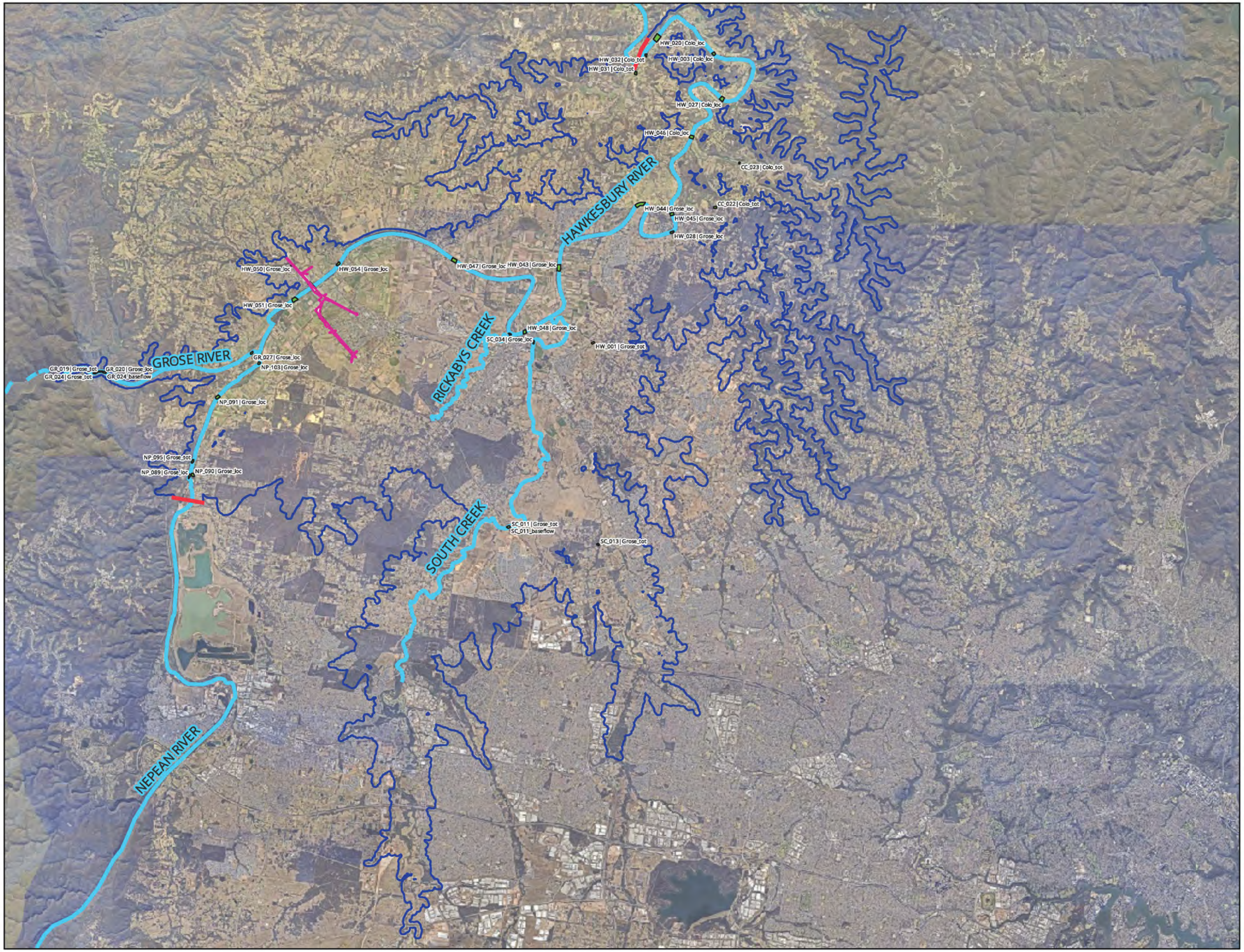


Legend

- Project Boundary
- Bridges
- Downstream Bounday Conditions
- Model Extents
- Inflow Locations
- Hydroline

Notes:

Map by: TT

A3 Scale: 1:160,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 1.1: Mainstream Flooding Model Extents

aurecon

Legend

- Project Boundary
- Culverts
- Downstream Bounday Conditions
- Model Extents
- Design Strings
- Hydroline
- Bridges

Notes:

Map by: TT

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 1.2: Local Flood Plain Model Extents

Legend

- Project Boundary
- Cadastre

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

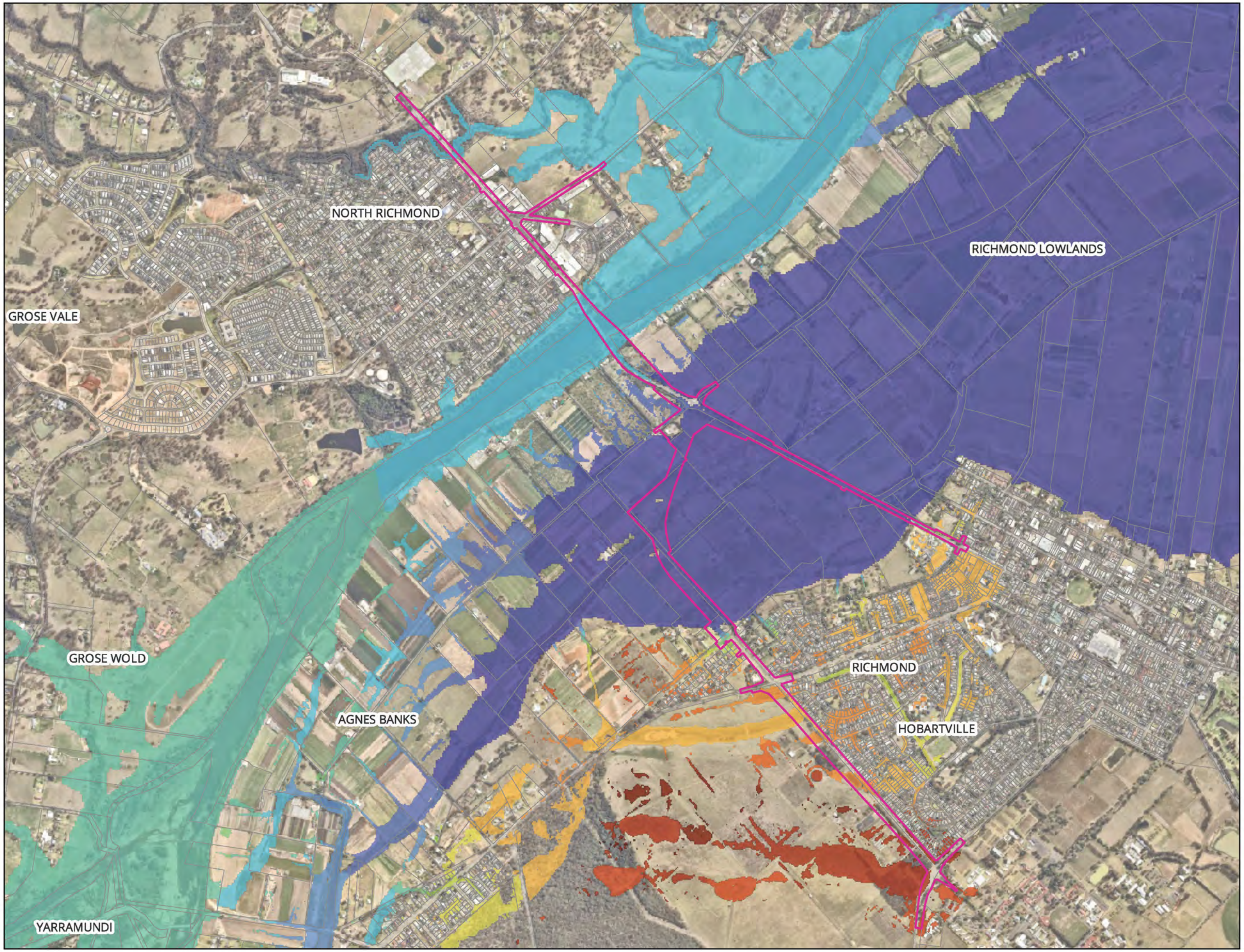
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.1: 20% AEP Peak Flood Level - Existing Condition



aurecon

Legend

Project Boundary
Cadastre

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

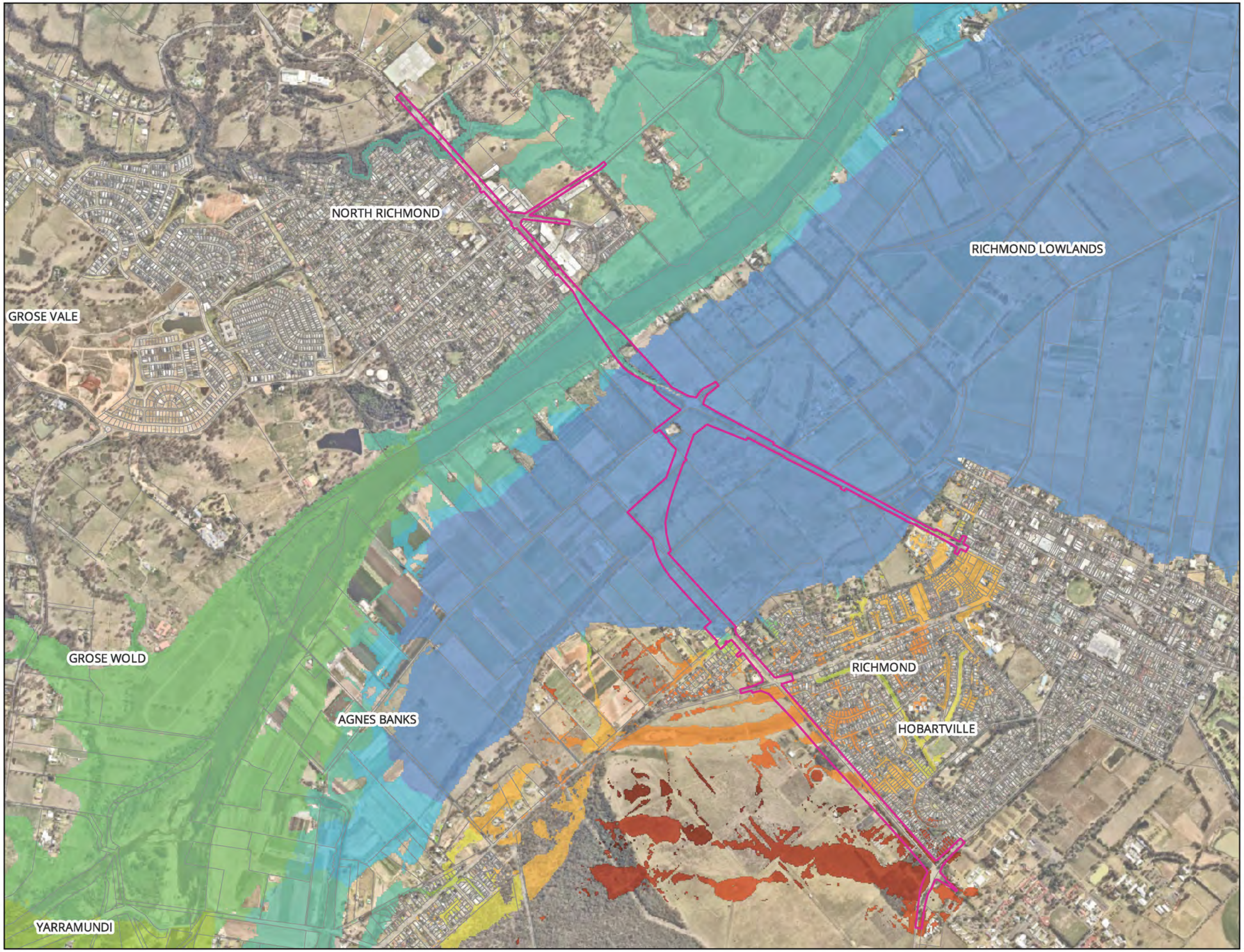
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.2: 10% AEP Peak Flood Level - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.3: 5% AEP Peak Flood Level - Existing Condition

aurecon

Legend

Project Boundary

Cadastre

Peak Flood Level (mAHD)

<= 11.00
11.00 - 12.00
12.00 - 13.00
13.00 - 14.00
14.00 - 15.00
15.00 - 16.00
16.00 - 17.00
17.00 - 18.00
18.00 - 19.00
19.00 - 20.00
20.00 - 21.00
21.00 - 22.00
22.00 - 23.00
23.00 - 24.00
24.00 - 25.00
> 25.00

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.4: 2% AEP Peak Flood Level - Existing Condition

aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

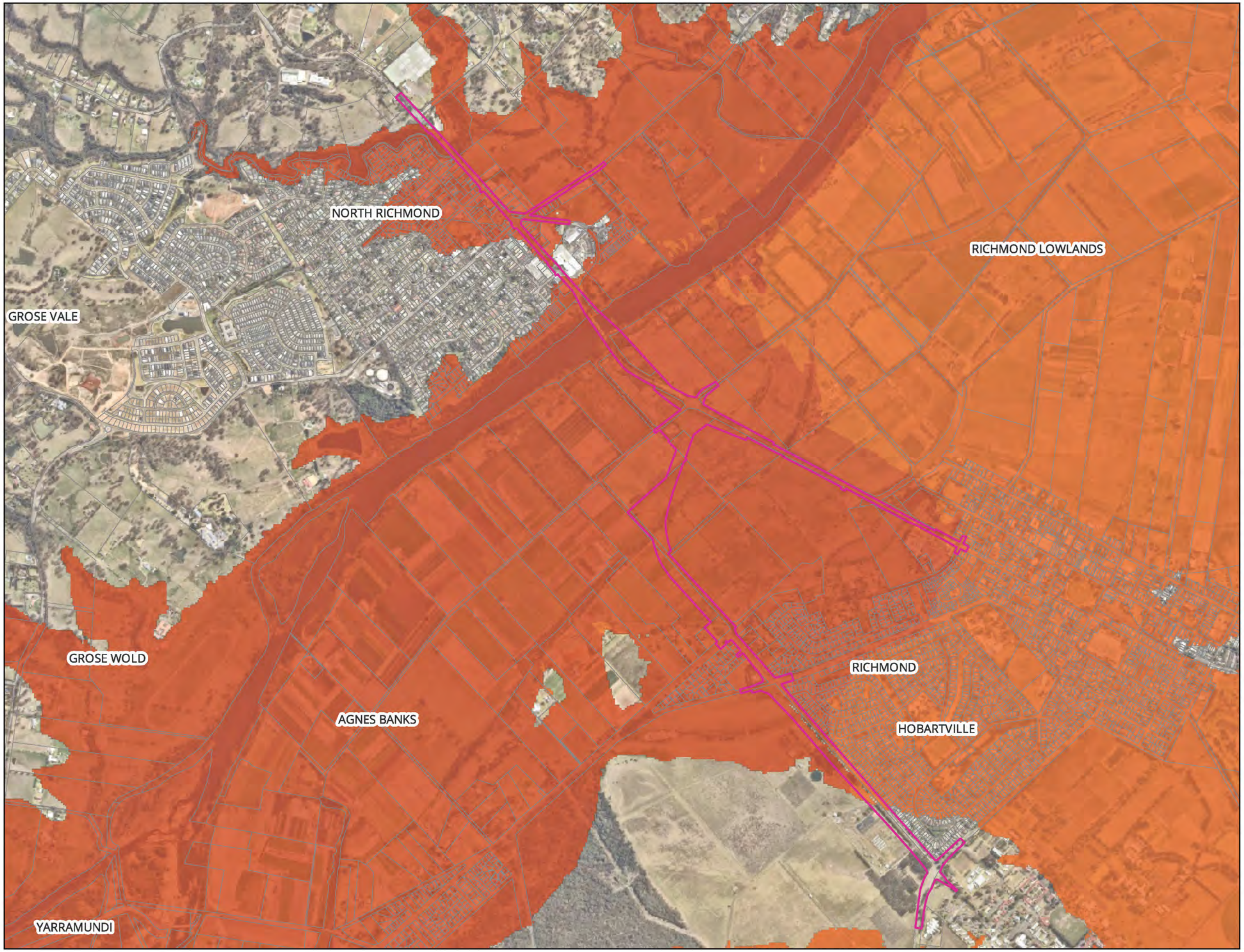
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.5: 1% AEP Peak Flood Level - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

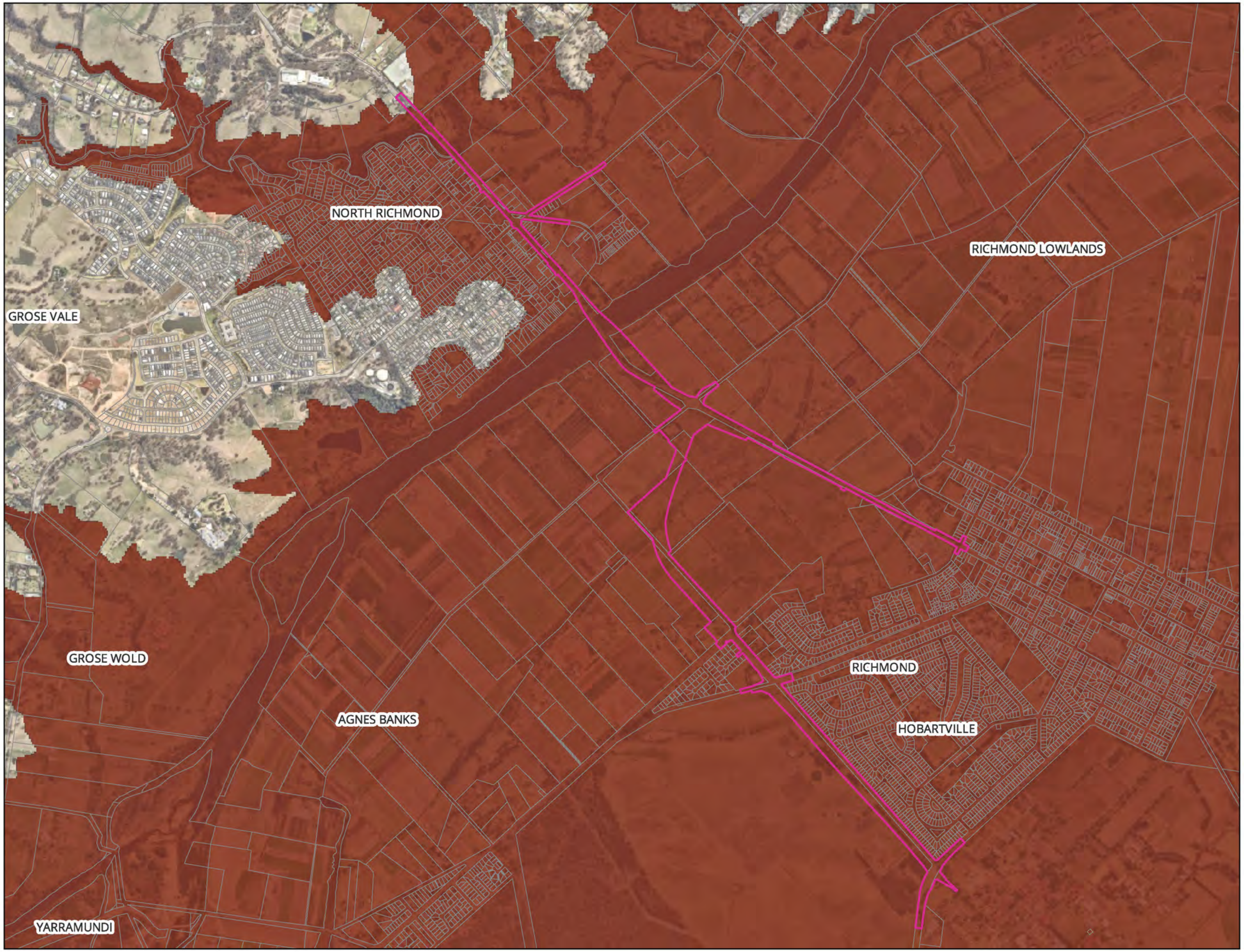
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.6: 0.05% AEP Peak Flood Level - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

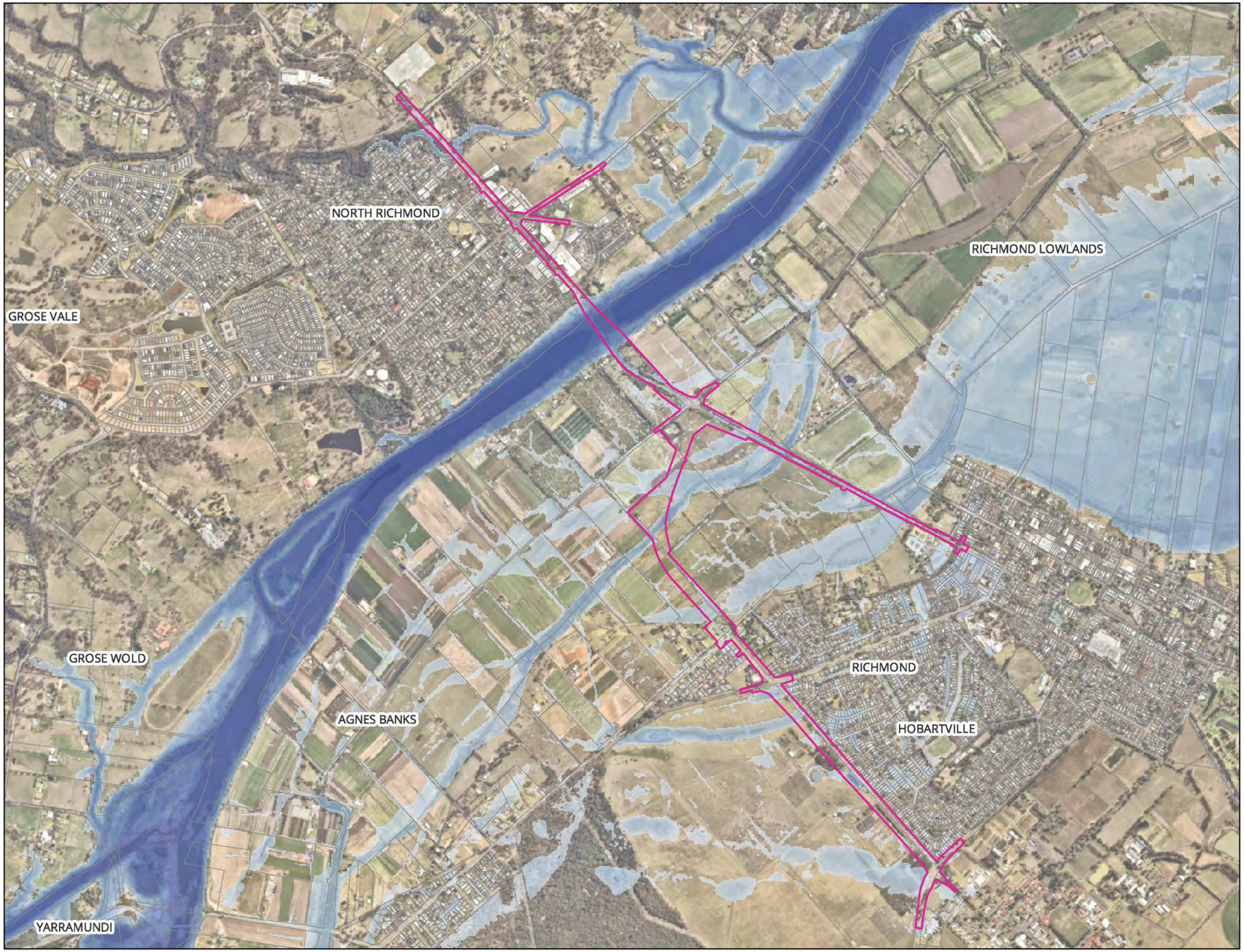
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 2.7: PMF Peak Flood Level - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

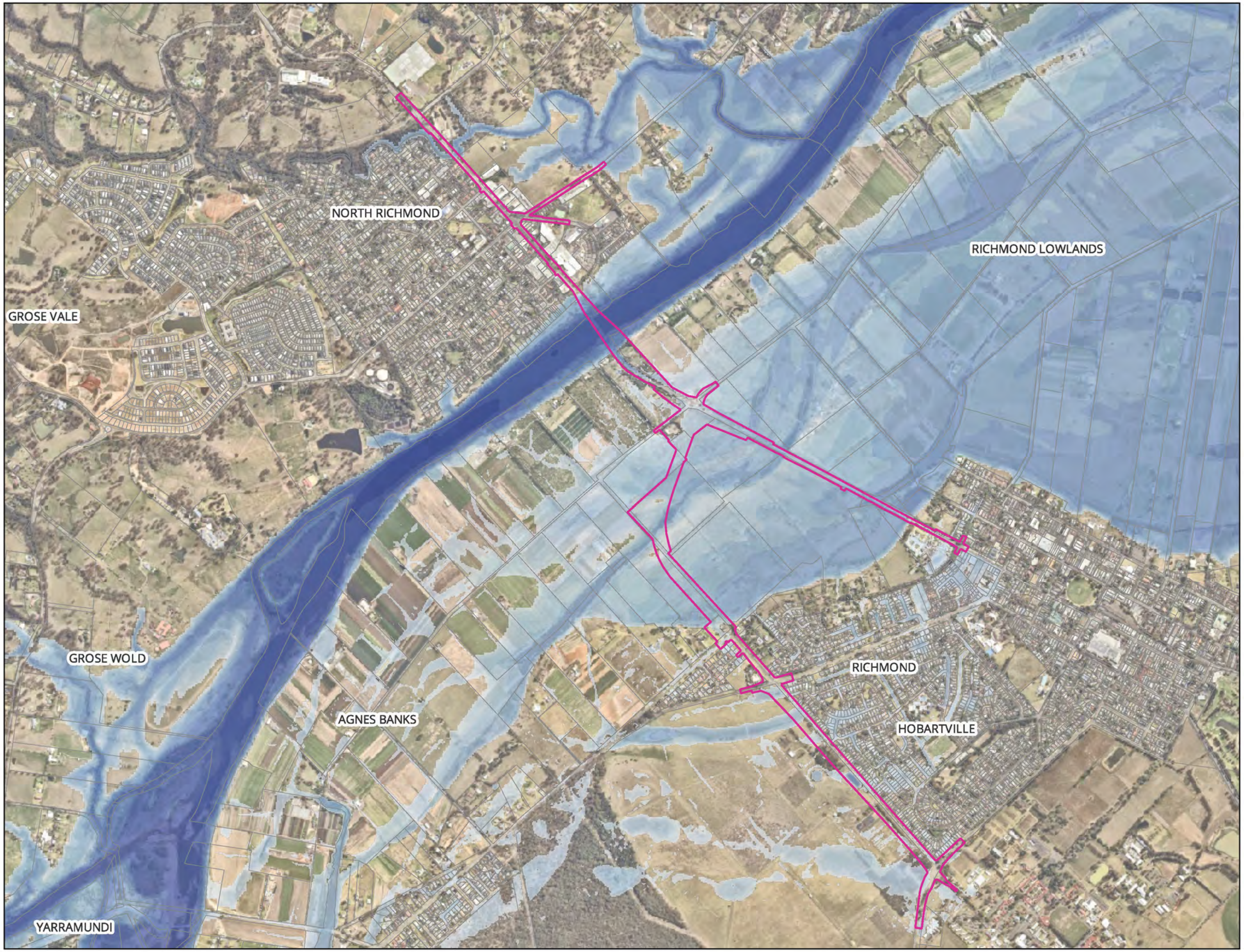
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.1: 20% AEP Peak Flood Depth - Existing Condition



aurecon

Legend

Project Boundary
Cadastre

Peak Flood Depth (m)

<= 0.10
0.10 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 3.50
3.50 - 5.00
5.00 - 7.50
7.50 - 10.00
10.00 - 15.00
15.00 - 20.00
20.00 - 25.00
> 25.00

Notes:

Map by: TT

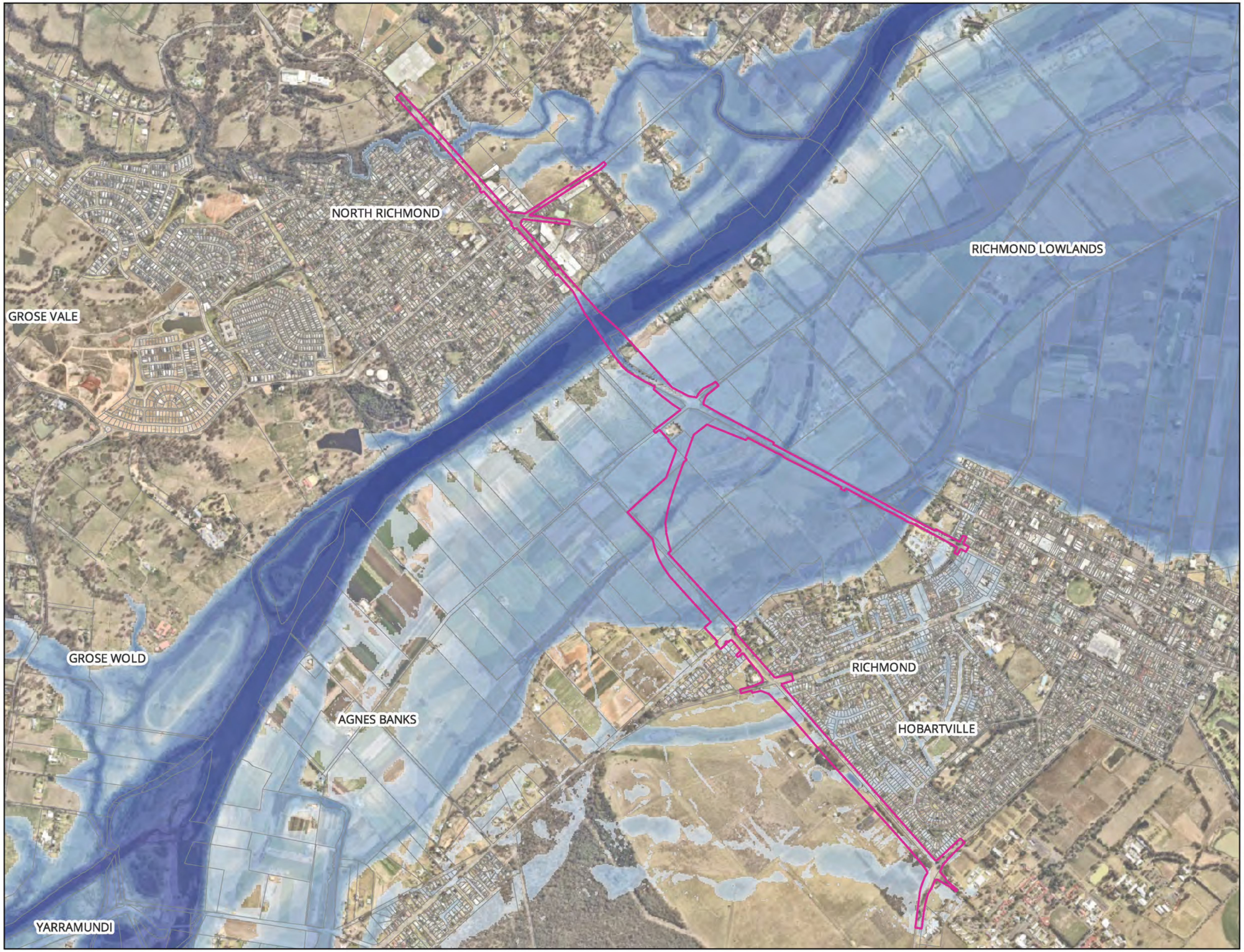
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.2: 10% AEP Peak Flood Depth - Existing Condition



aurecon

Legend

Project Boundary
Cadastre

Peak Flood Depth (m)

<= 0.10
0.10 - 0.30
0.30 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 3.50
3.50 - 5.00
5.00 - 7.50
7.50 - 10.00
10.00 - 15.00
15.00 - 20.00
20.00 - 25.00
> 25.00

Notes:

Map by: TT

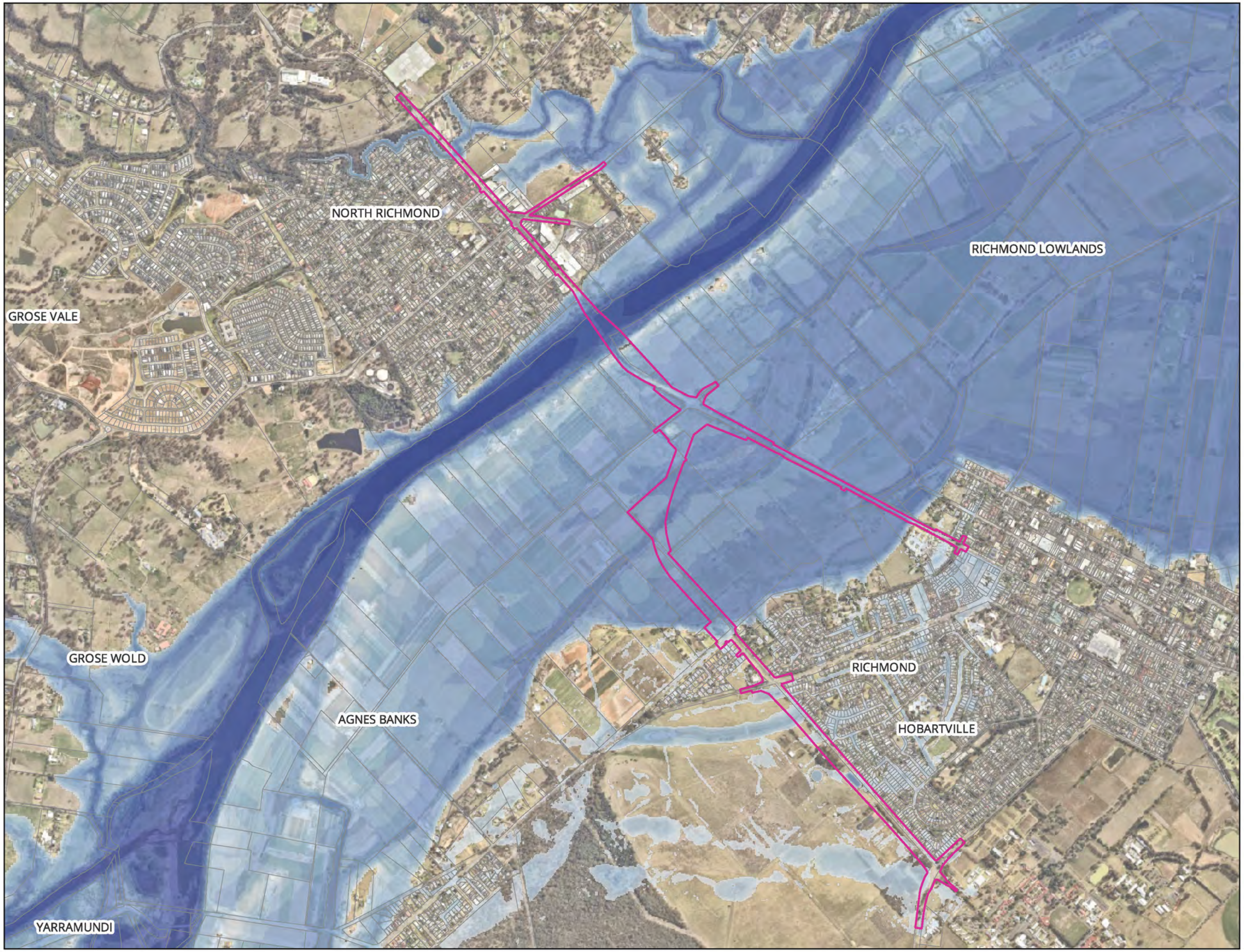
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.3: 5% AEP Peak Flood Depth - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

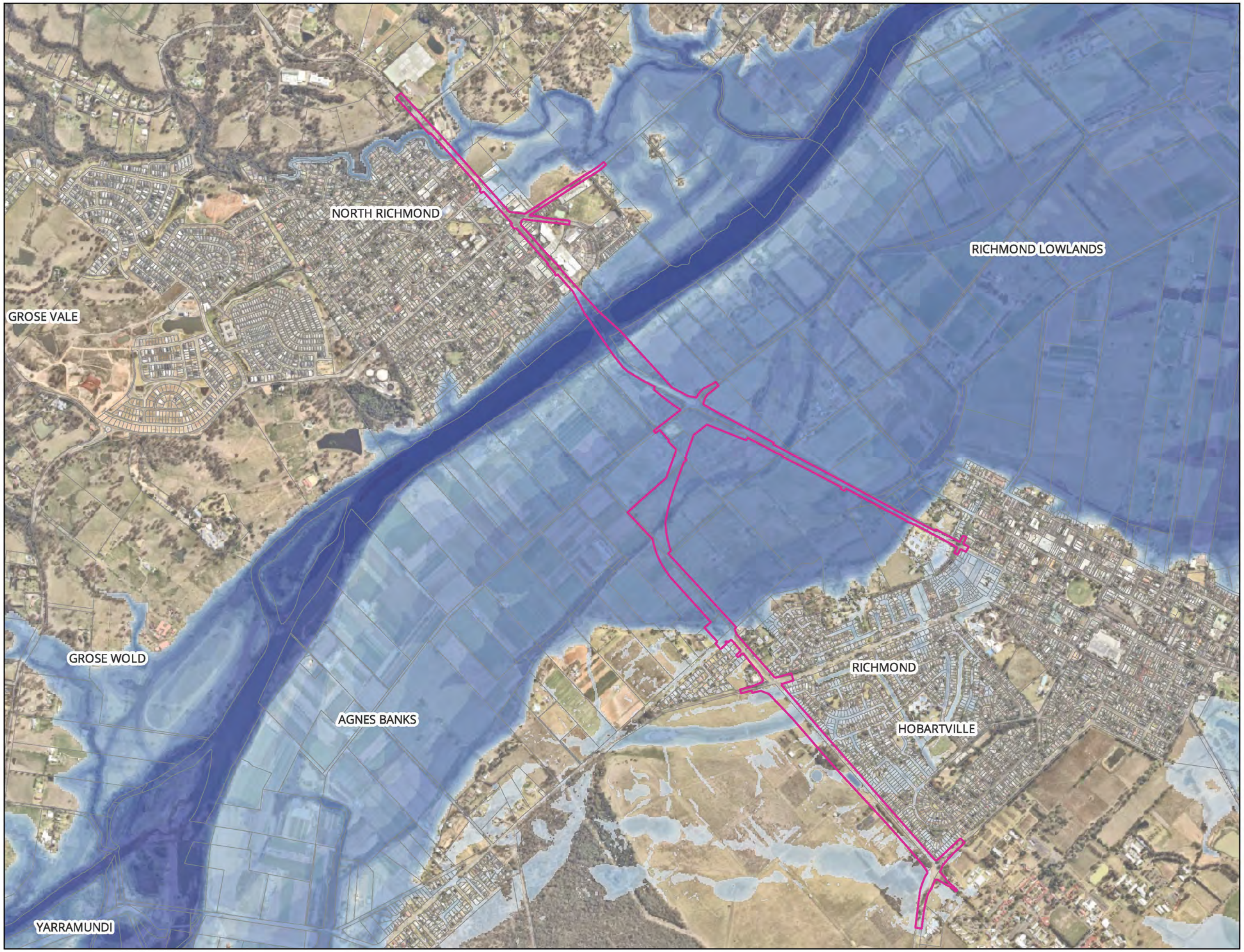
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.4: 2% AEP Peak Flood Depth - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

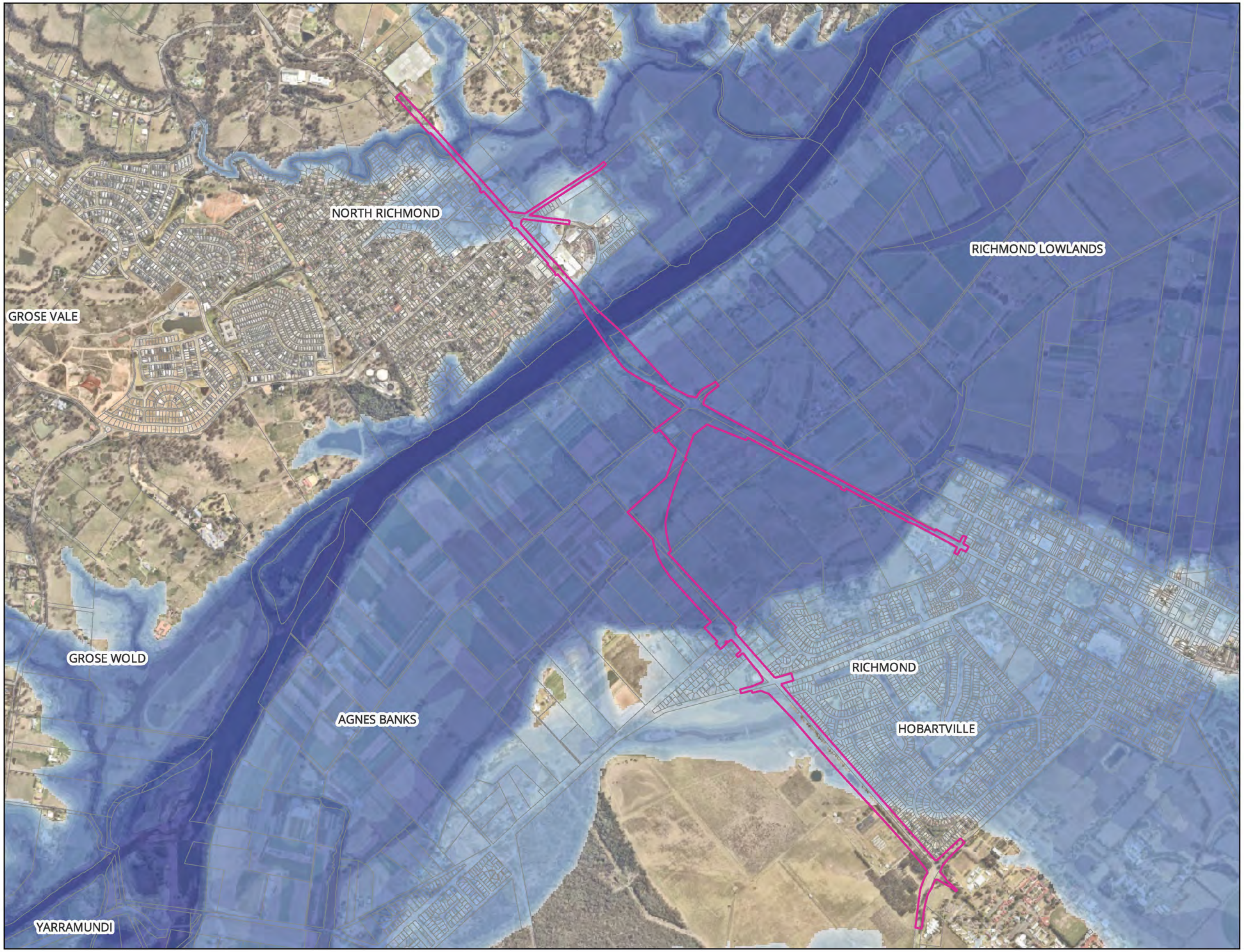
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.5: 1% AEP Peak Flood Depth - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

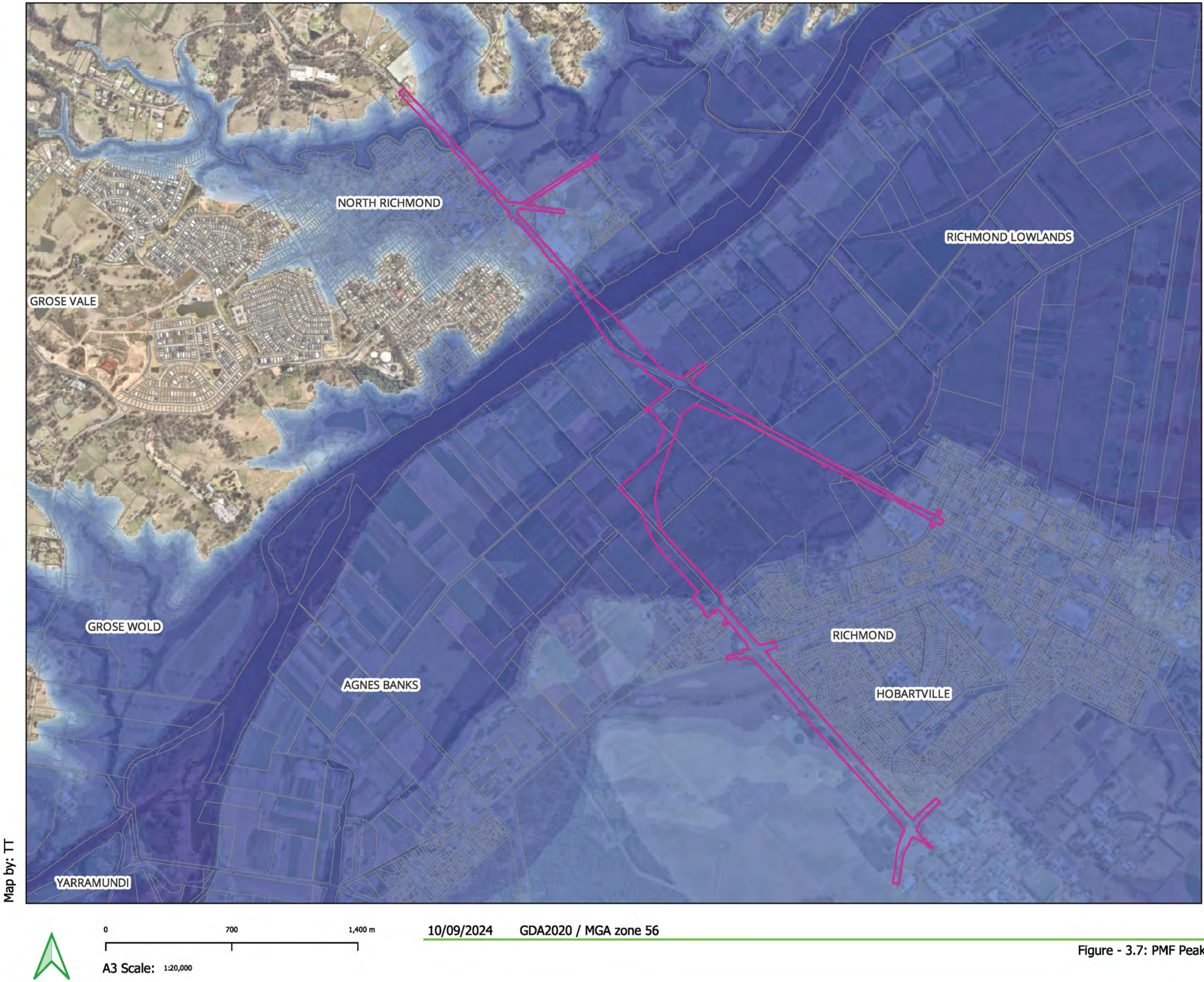
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.6: 0.05% AEP Peak Flood Depth - Existing Condition



aurecon

Legend

Project Boundary
Cadastre

Peak Flood Depth (m)

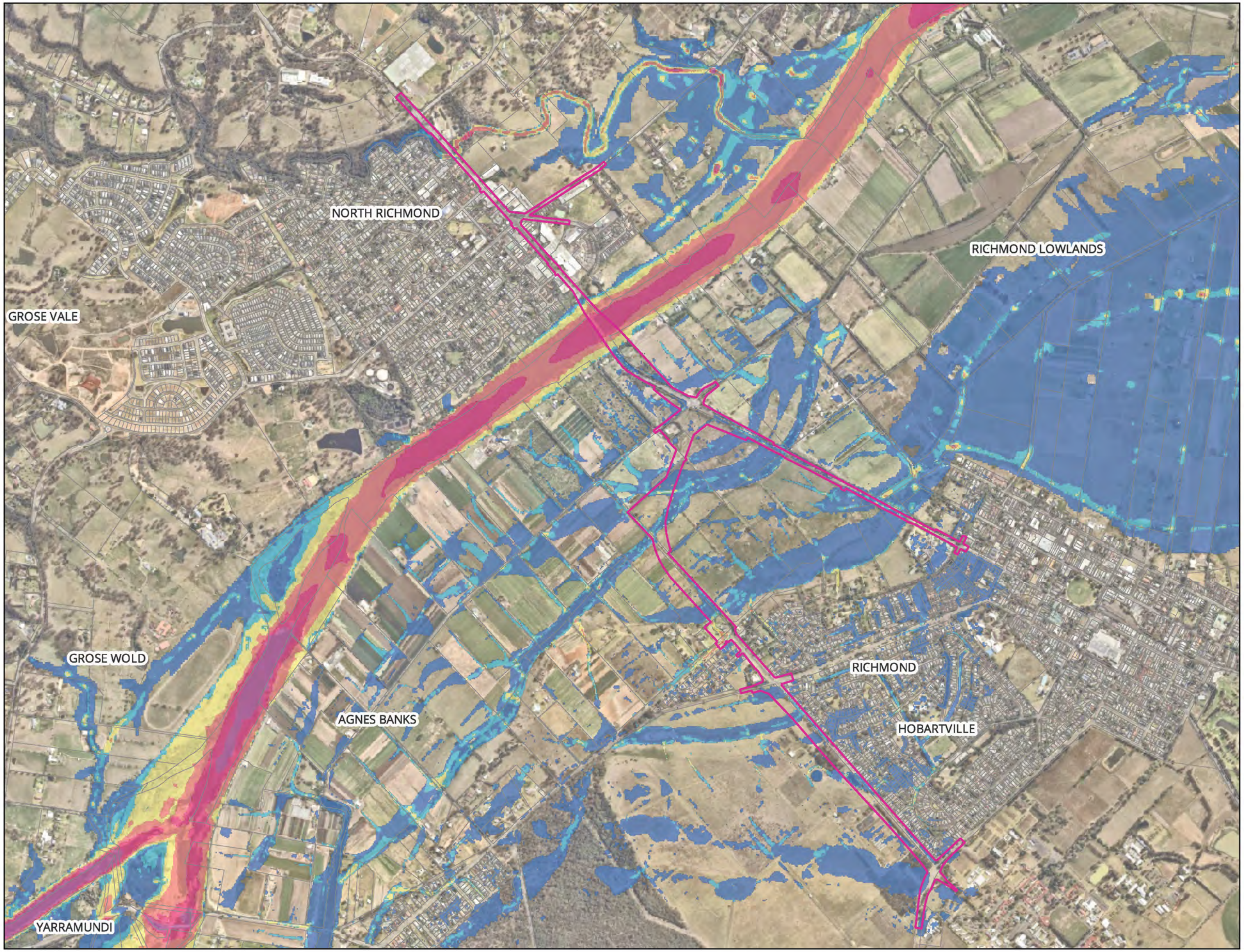
- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 3.7: PMF Peak Flood Depth - Existing Condition



aurecon

Legend

Project Boundary
Cadastre

Peak Flood Velocity (m/s)

<= 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 3.0
3.0 - 4.0
>4.0

Notes:

Map by: TT

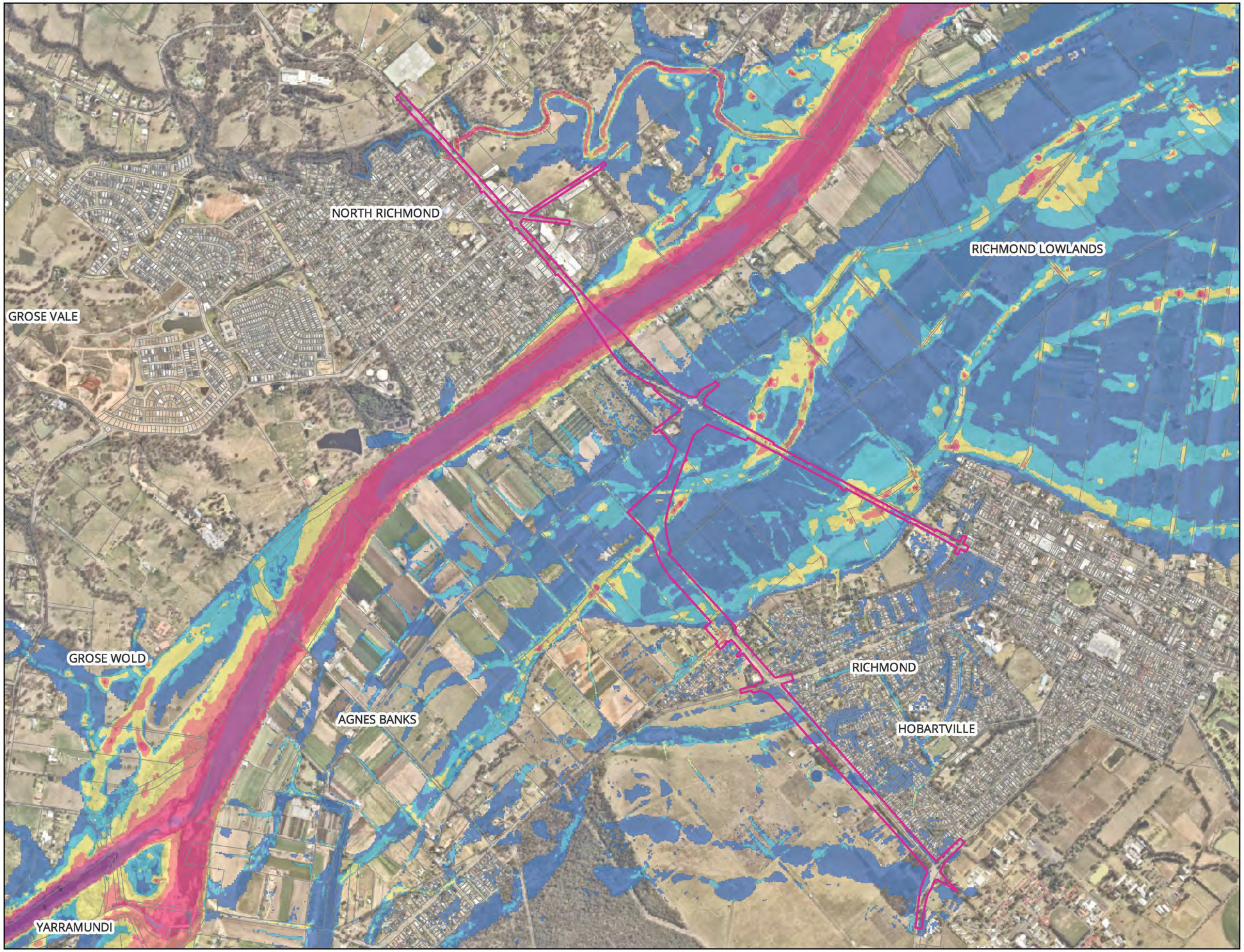
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.1: 20% AEP Peak Flood Velocity - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

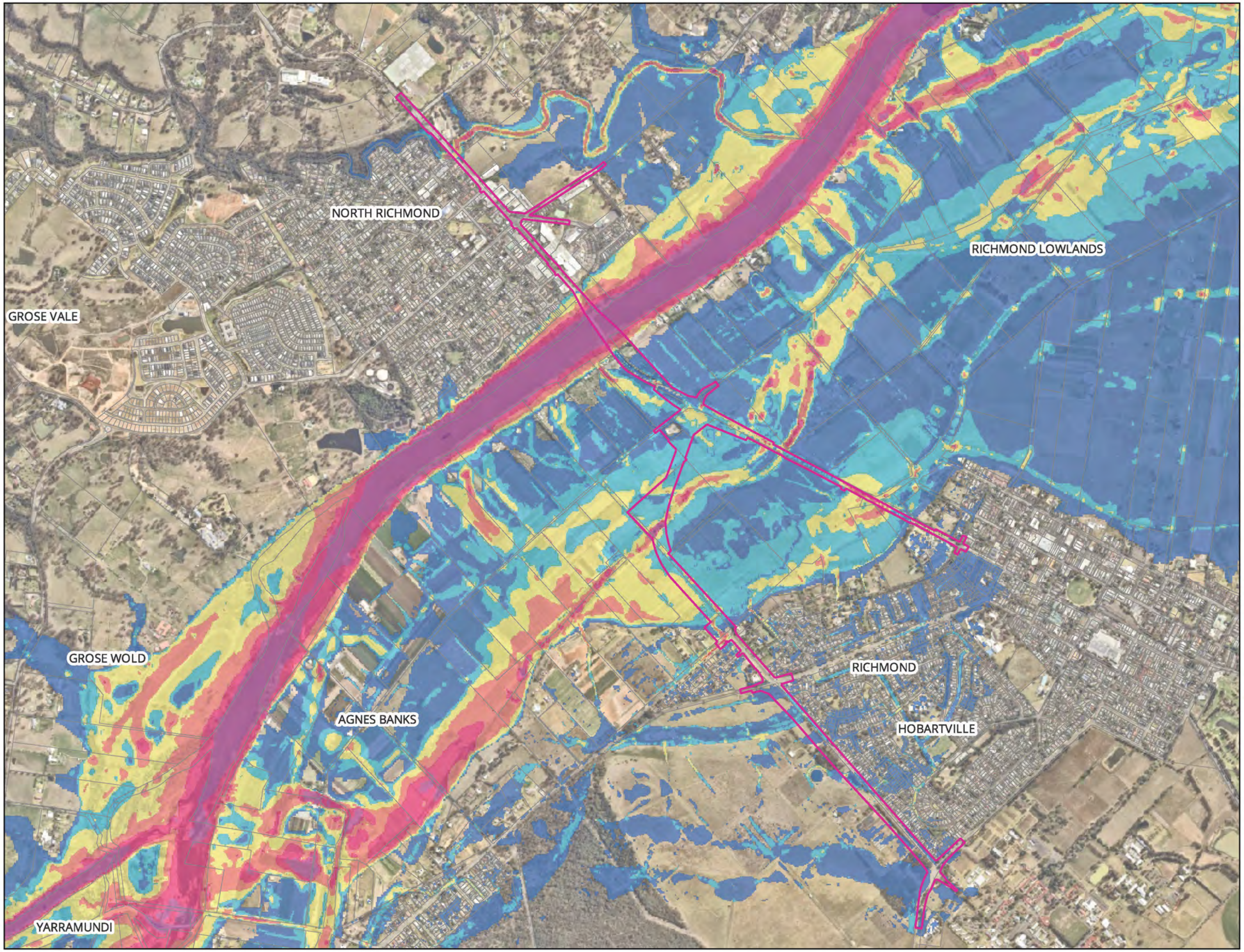
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.2: 10% AEP Peak Flood Velocity - Existing Condition



Legend
- Project Boundary
- Cadastre

Peak Flood Velocity (m/s)
- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

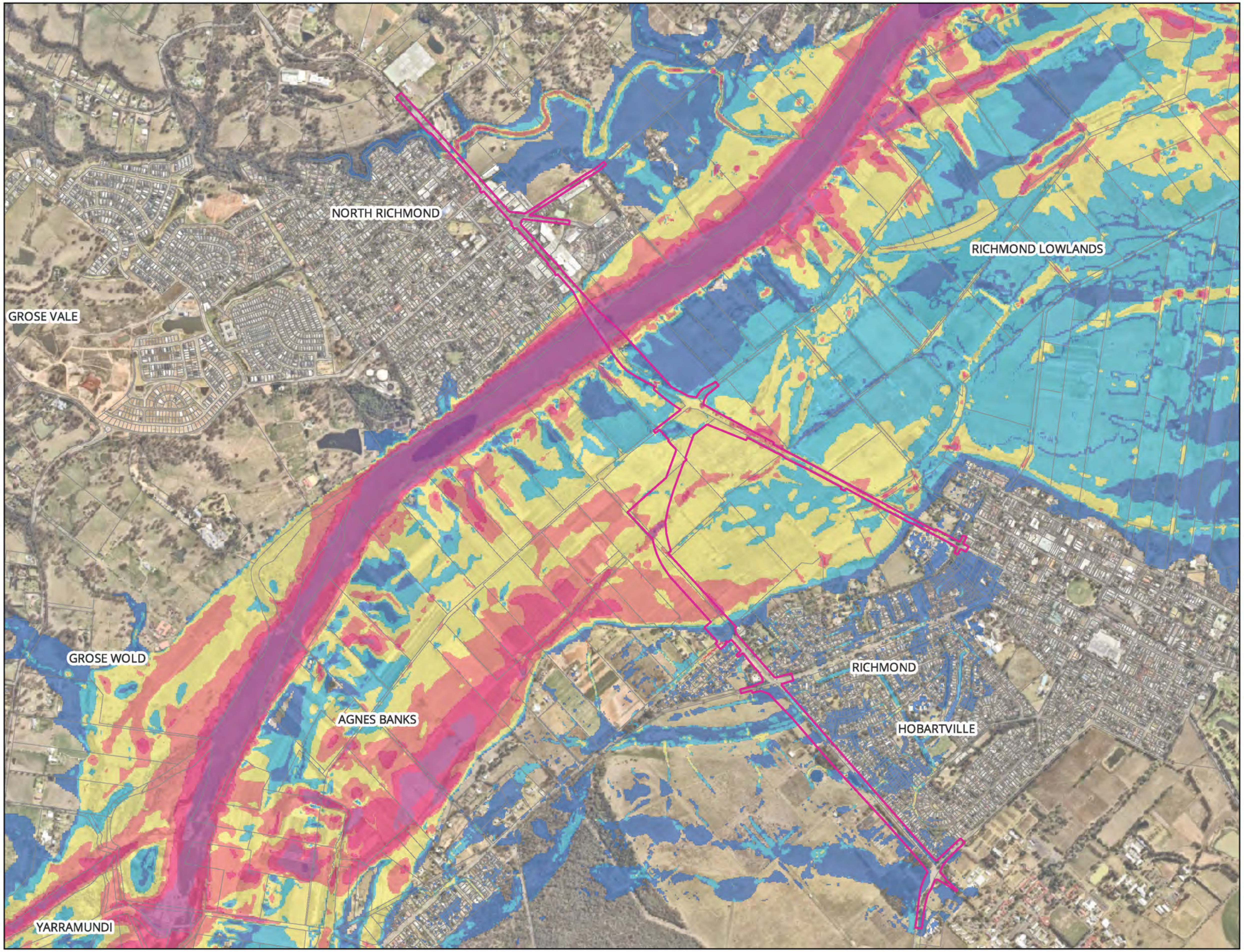
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.3: 5% AEP Peak Flood Velocity - Existing Condition



aurecon

Legend

Project Boundary

Cadastre

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

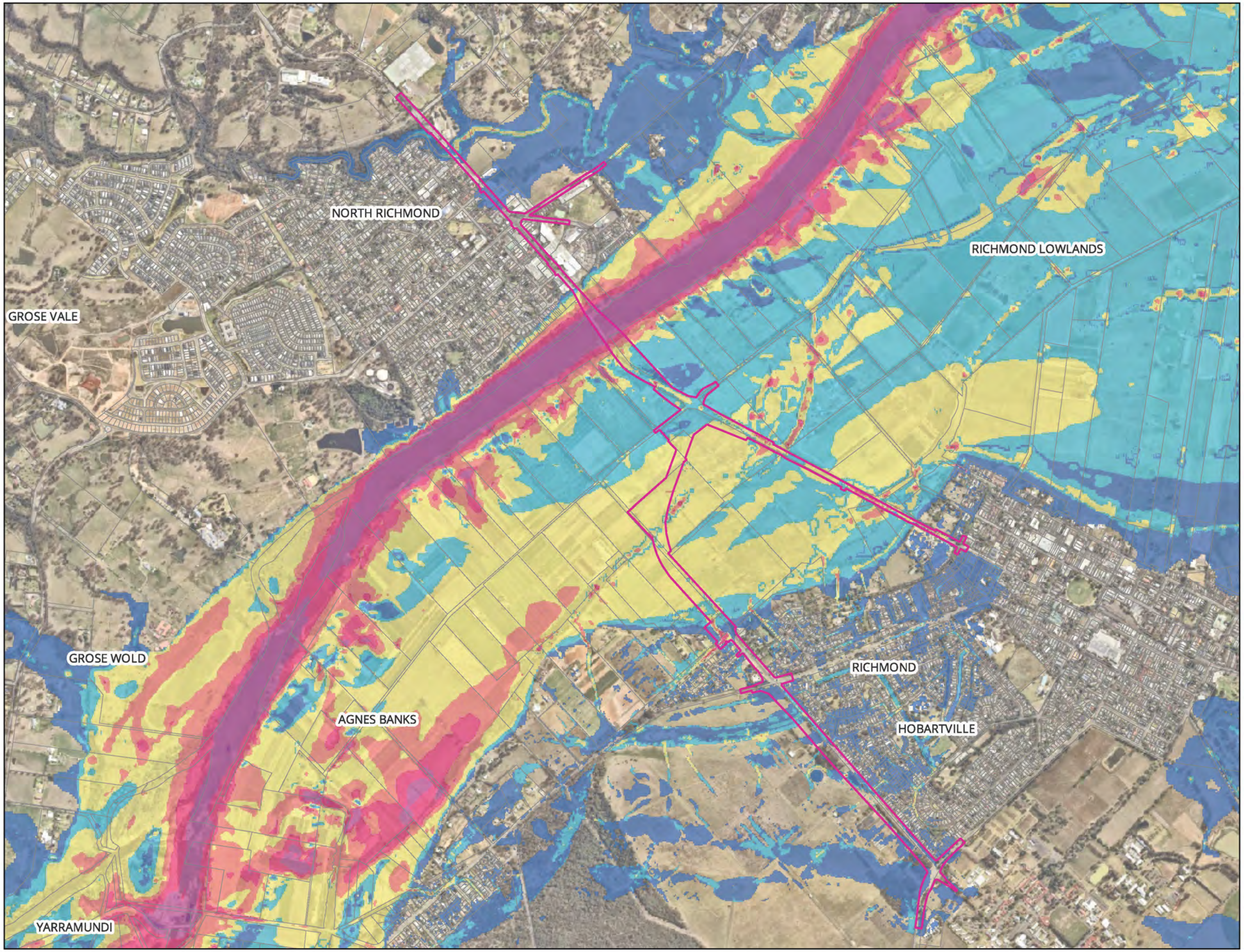
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.4: 2% AEP Peak Flood Velocity - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

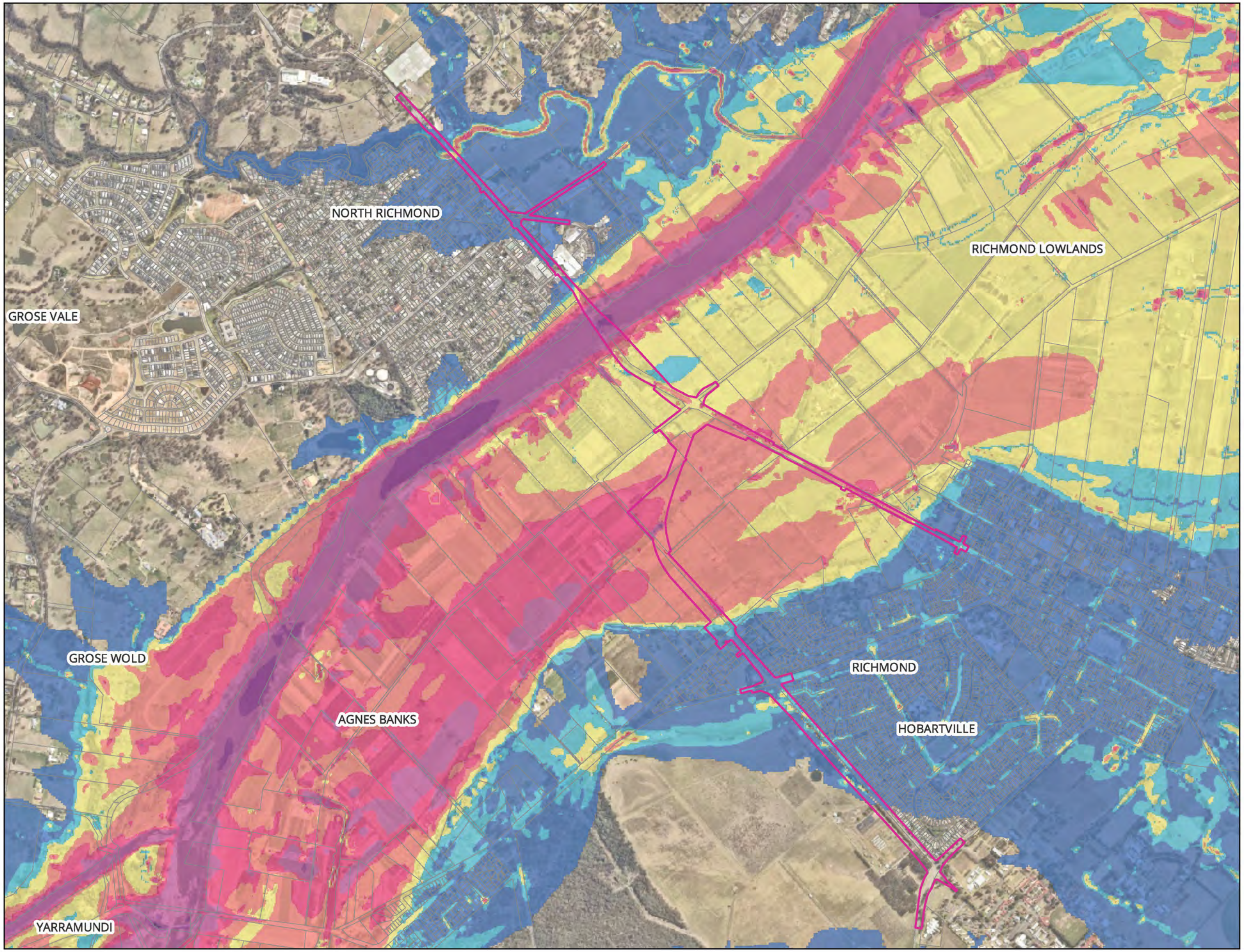
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.5: 1% AEP Peak Flood Velocity - Existing Condition



aurecon

Legend

Project Boundary

Cadastre

Peak Flood Velocity (m/s)

<= 0.25

0.25 - 0.5

0.5 - 1.0

1.0 - 1.5

1.5 - 2.0

2.0 - 3.0

3.0 - 4.0

>4.0

Notes:

Map by: TT

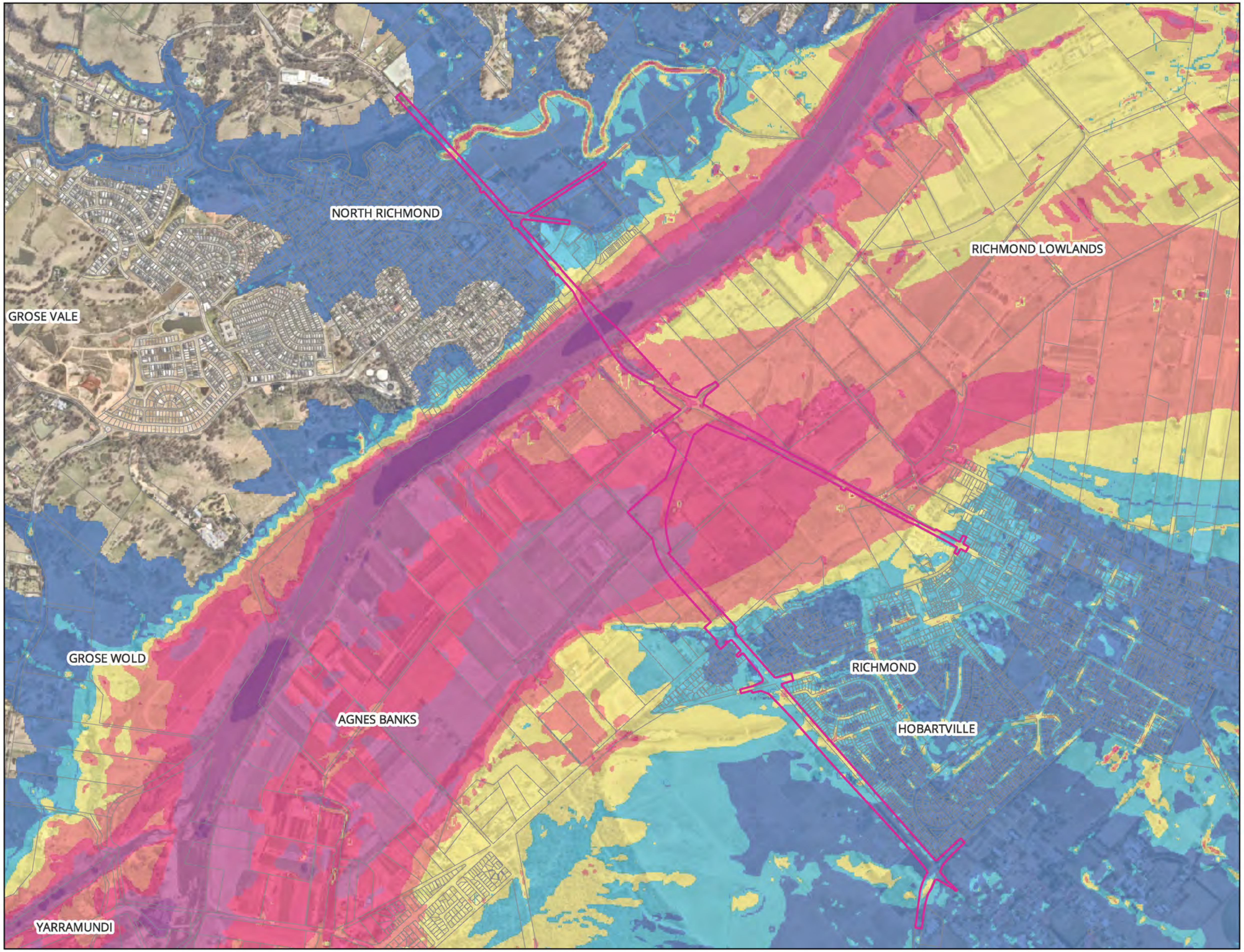
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.6: 0.05% AEP Peak Flood Velocity - Existing Condition



aurecon

Legend

Project Boundary

Cadastre

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 4.7: PMF Peak Flood Velocity - Existing Condition

aurecon

Legend

Project Boundary

Cadastre

Peak Flood Hazard

H1

H2

H3

H4

H5

H6

Notes:

Map by: TT

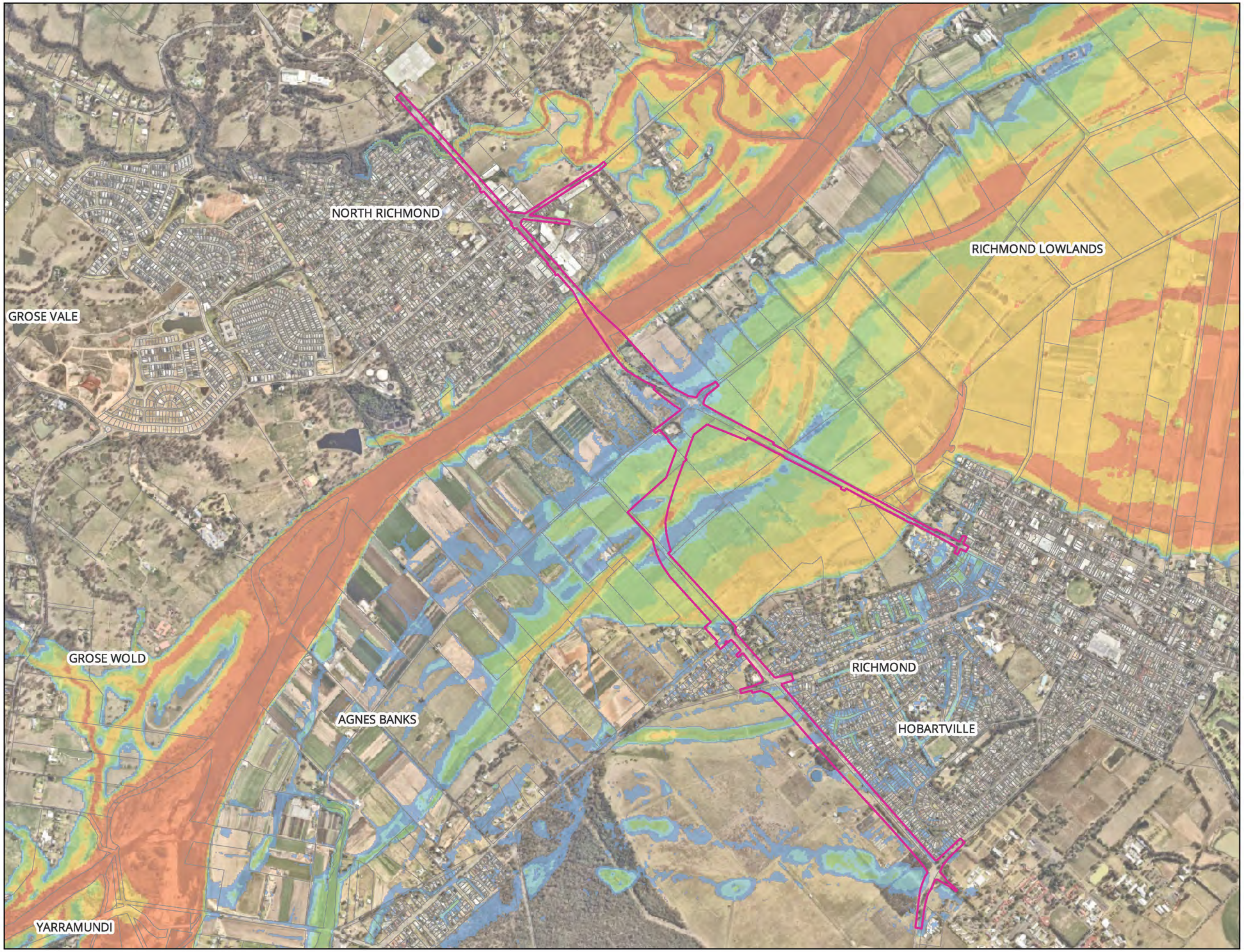
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.1: 20% AEP Hazard - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

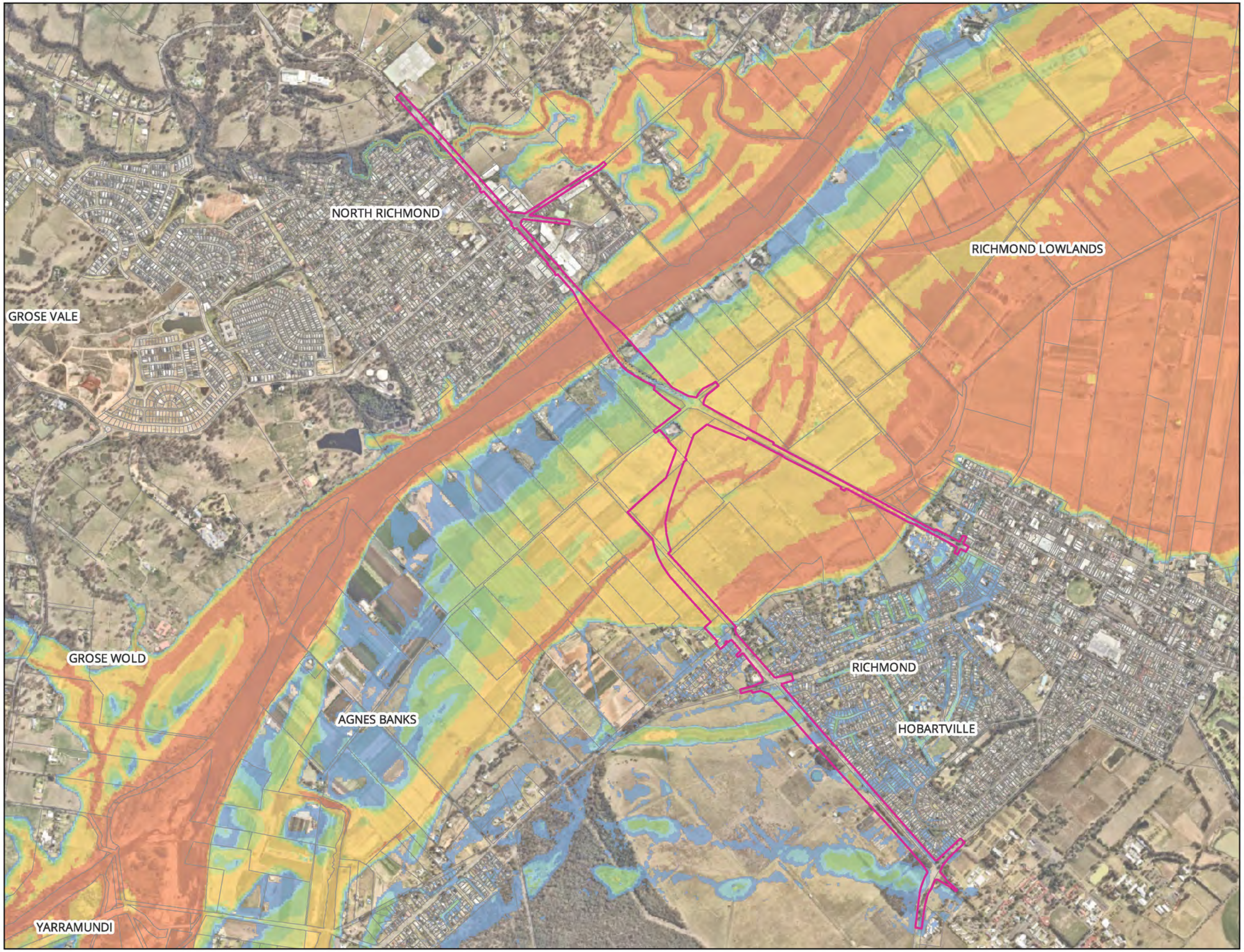
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.2: 10% AEP Hazard - Existing Condition



aurecon

Legend

Project Boundary

Cadastre

Peak Flood Hazard

H1

H2

H3

H4

H5

H6

Notes:

Map by: TT

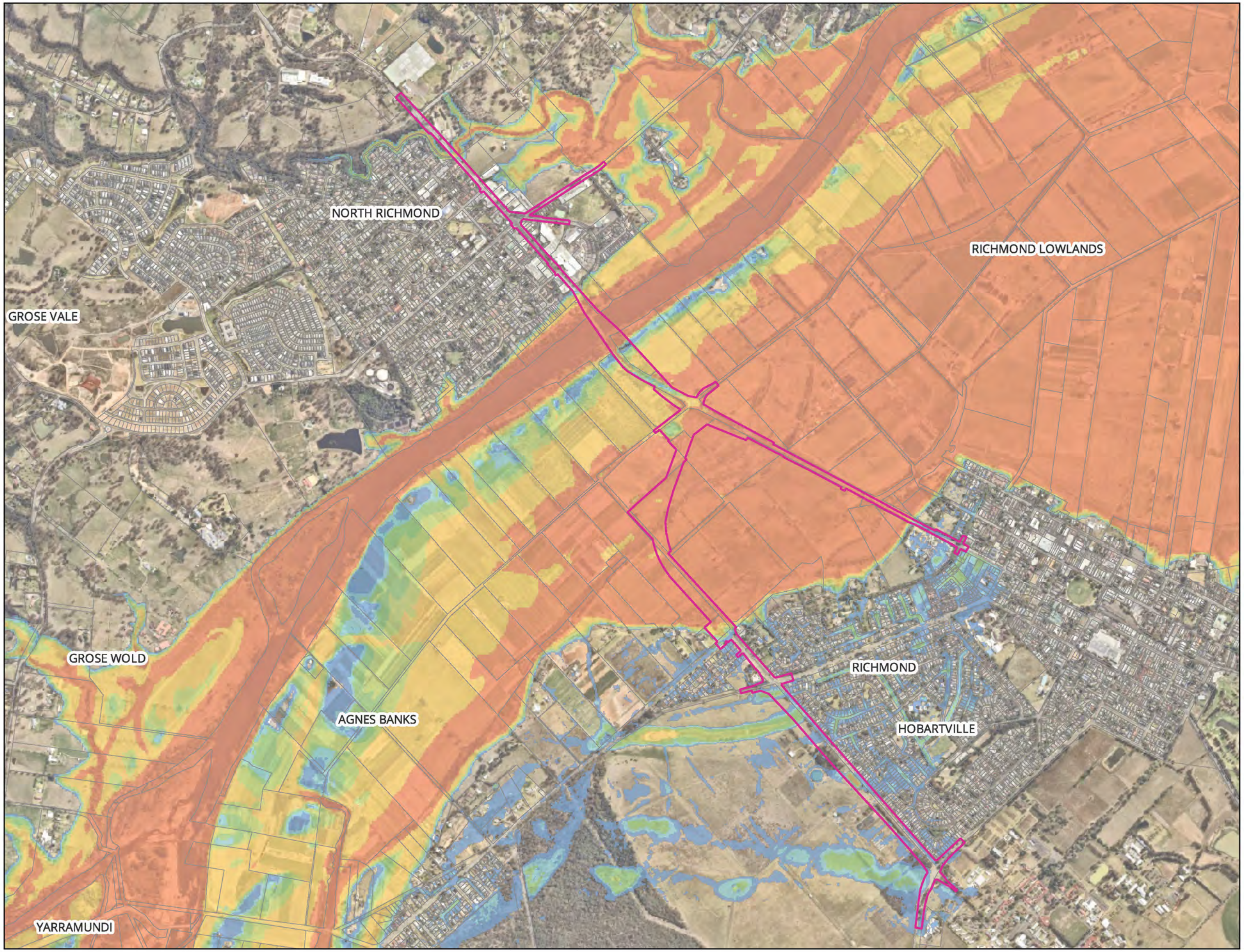
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.3: 5% AEP Hazard - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

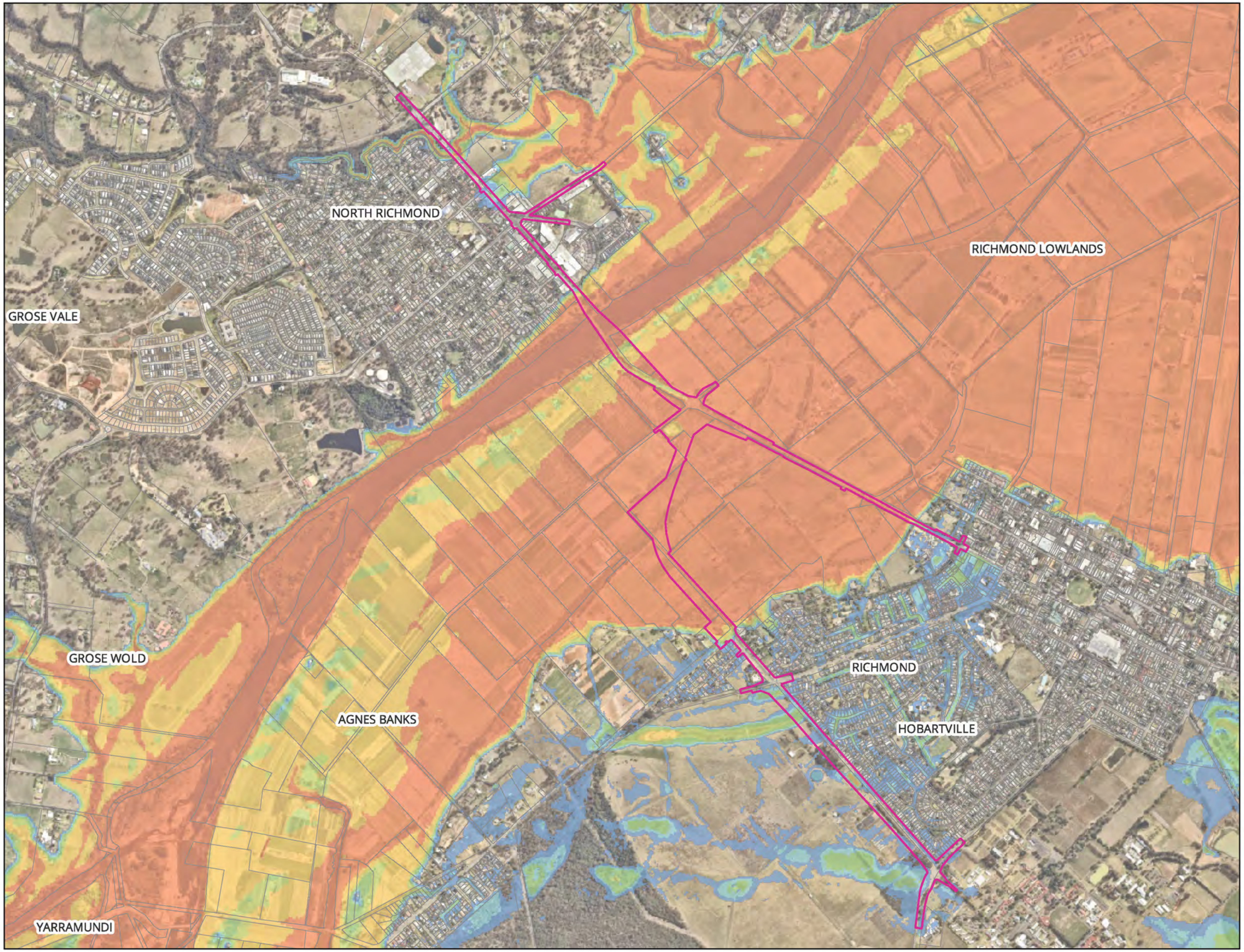
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.4: 2% AEP Hazard - Existing Condition



aurecon

Legend

Project Boundary
Cadastre

Peak Flood Hazard

H1
H2
H3
H4
H5
H6

Notes:

Map by: TT

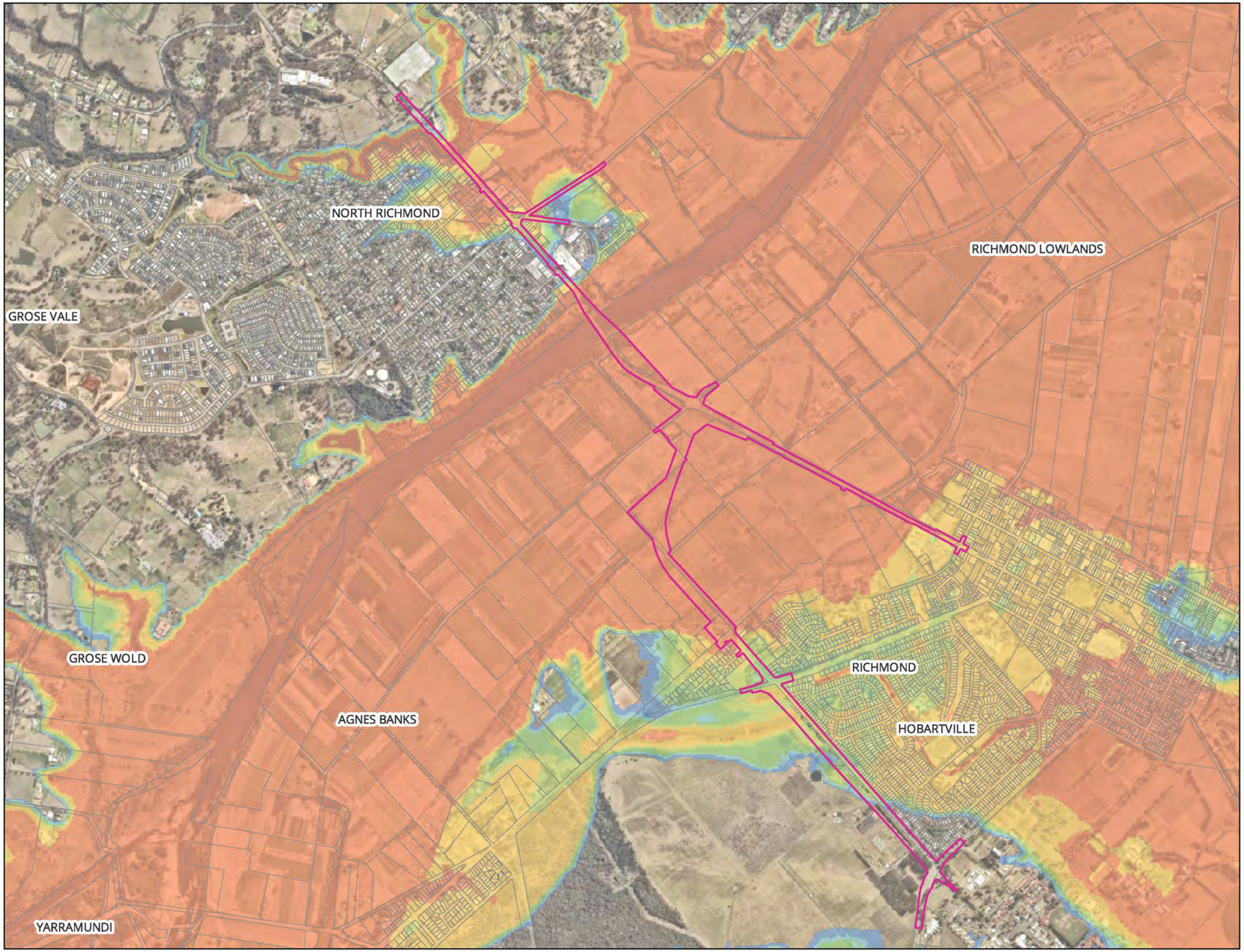
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.5: 1% AEP Hazard - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

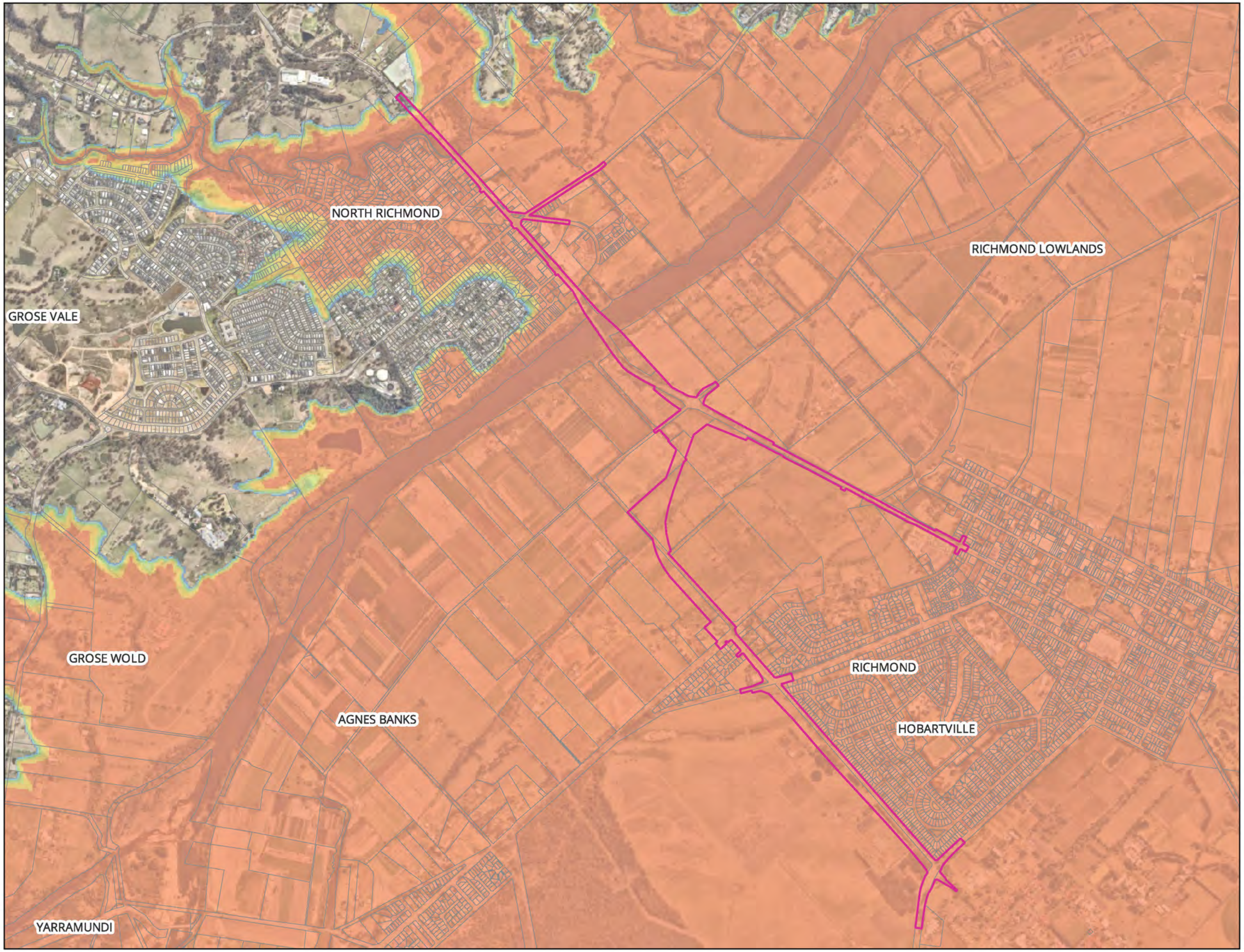
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.6: 0.05% AEP Hazard - Existing Condition



aurecon

Legend

- Project Boundary
- Cadastre

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

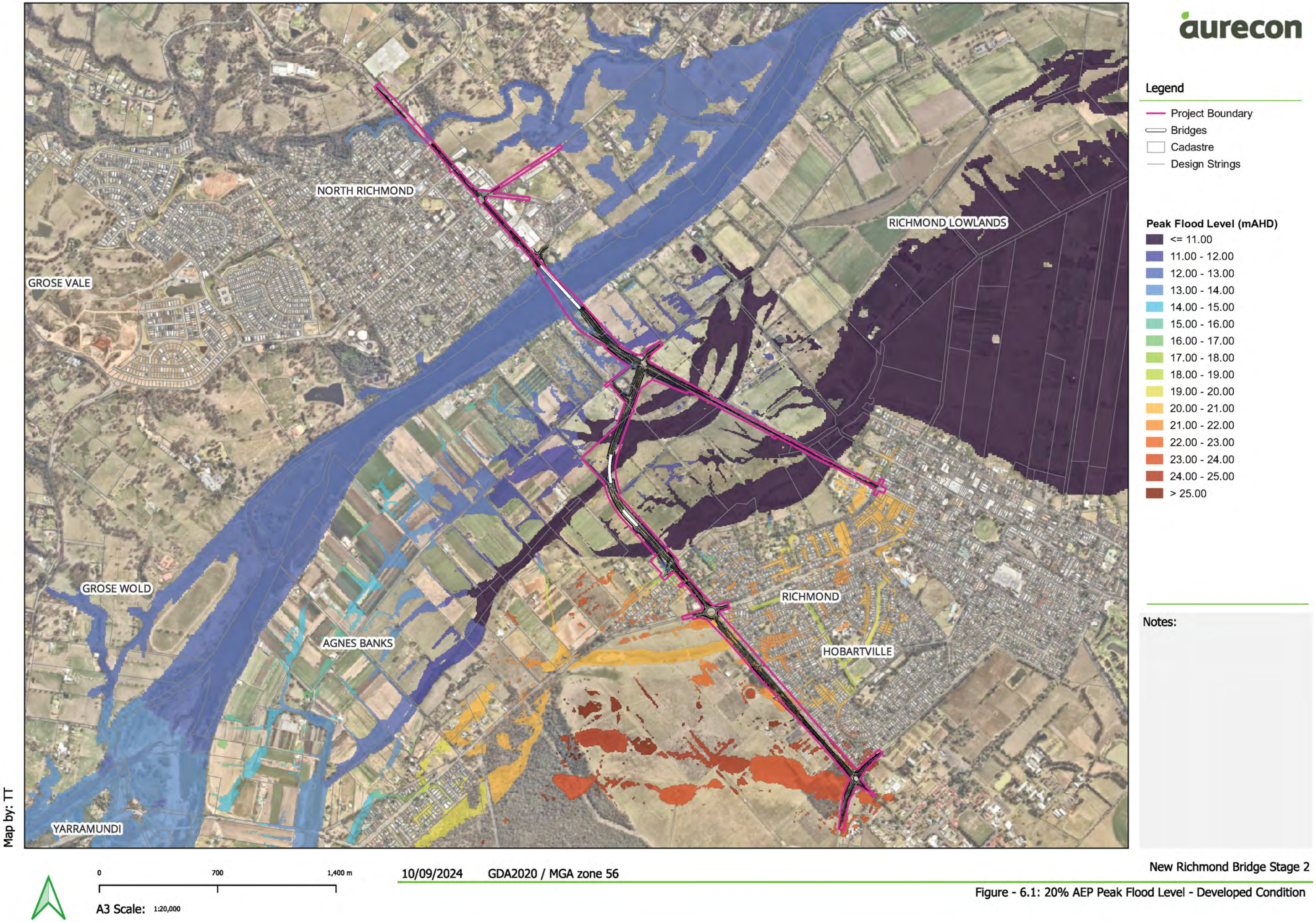
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 5.7: PMF Hazard - Existing Condition



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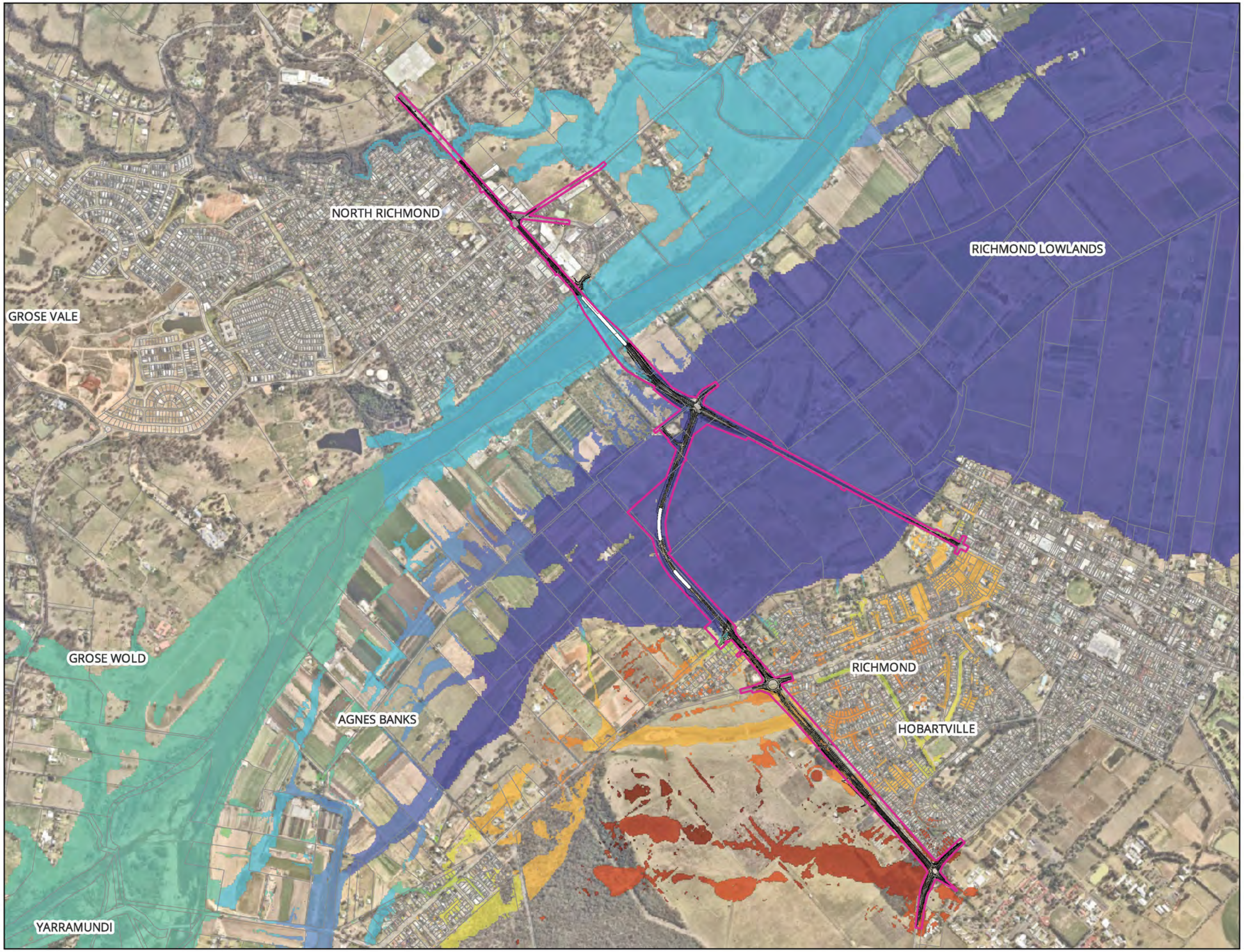
New Richmond Bridge Stage 2

Figure - 6.1: 20% AEP Peak Flood Level - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

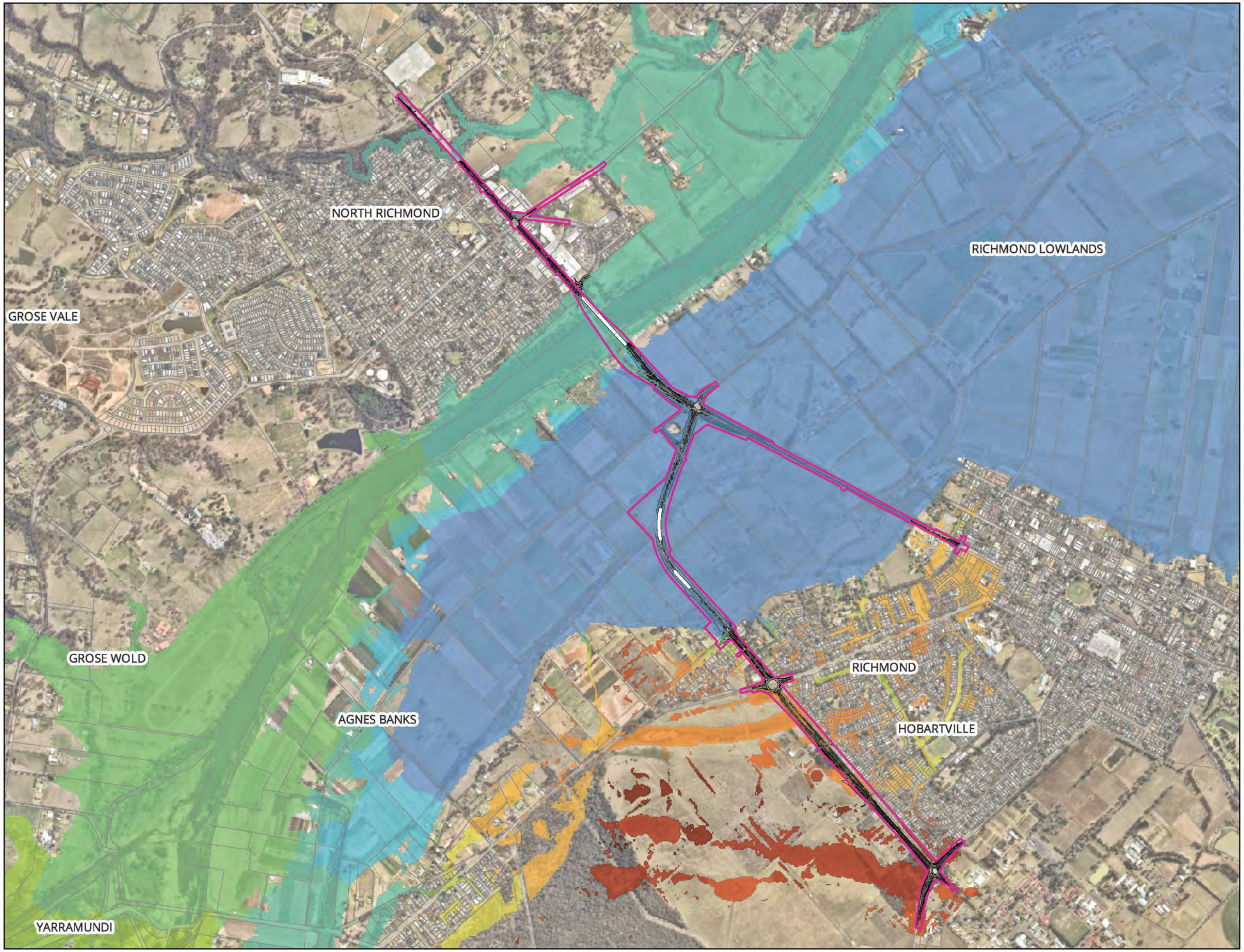
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 6.2: 10% AEP Peak Flood Level - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 6.3: 5% AEP Peak Flood Level - Developed Condition

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 6.4: 2% AEP Peak Flood Level - Developed Condition

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

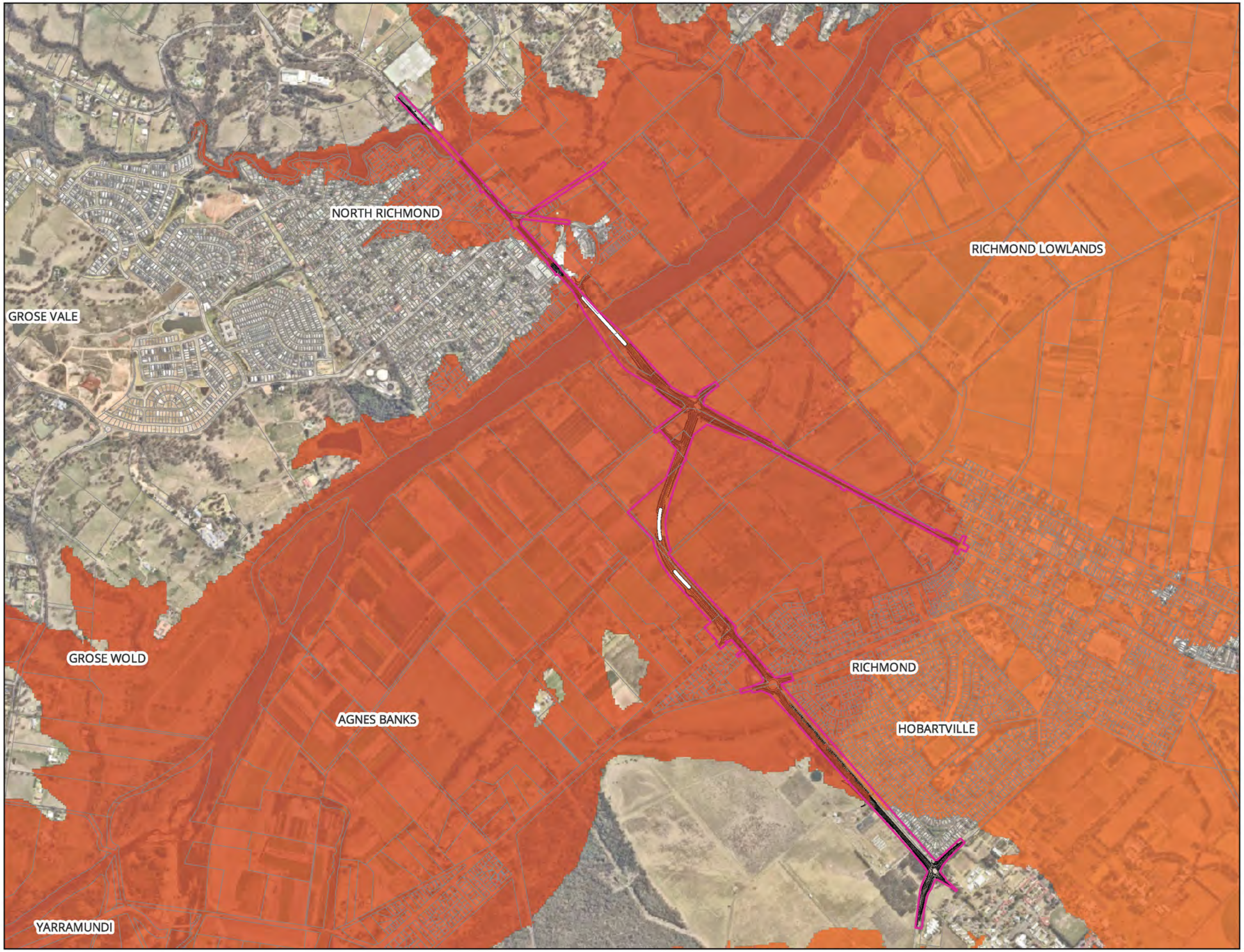
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 6.5: 1% AEP Peak Flood Level - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

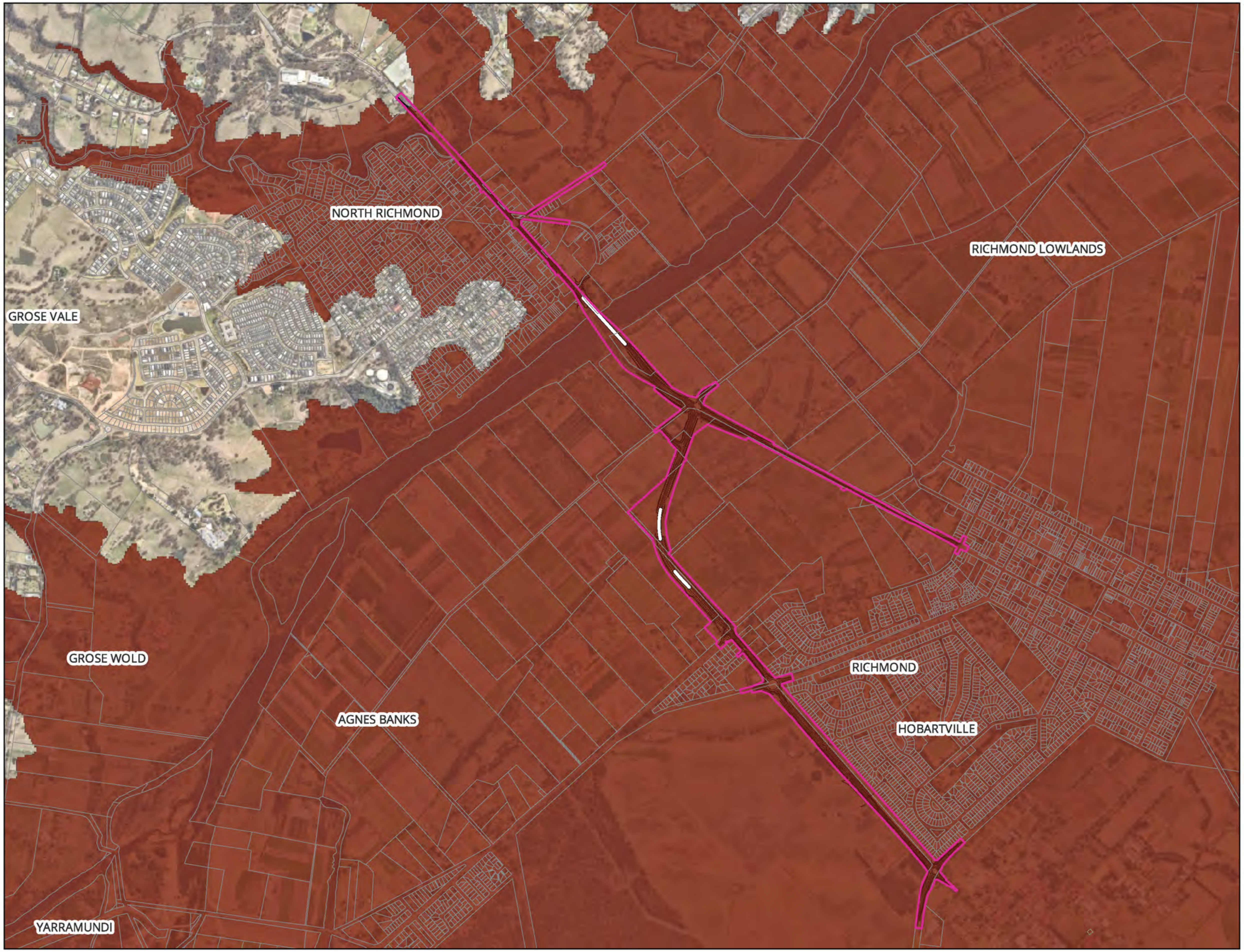
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 6.6: 0.05% AEP Peak Flood Level - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

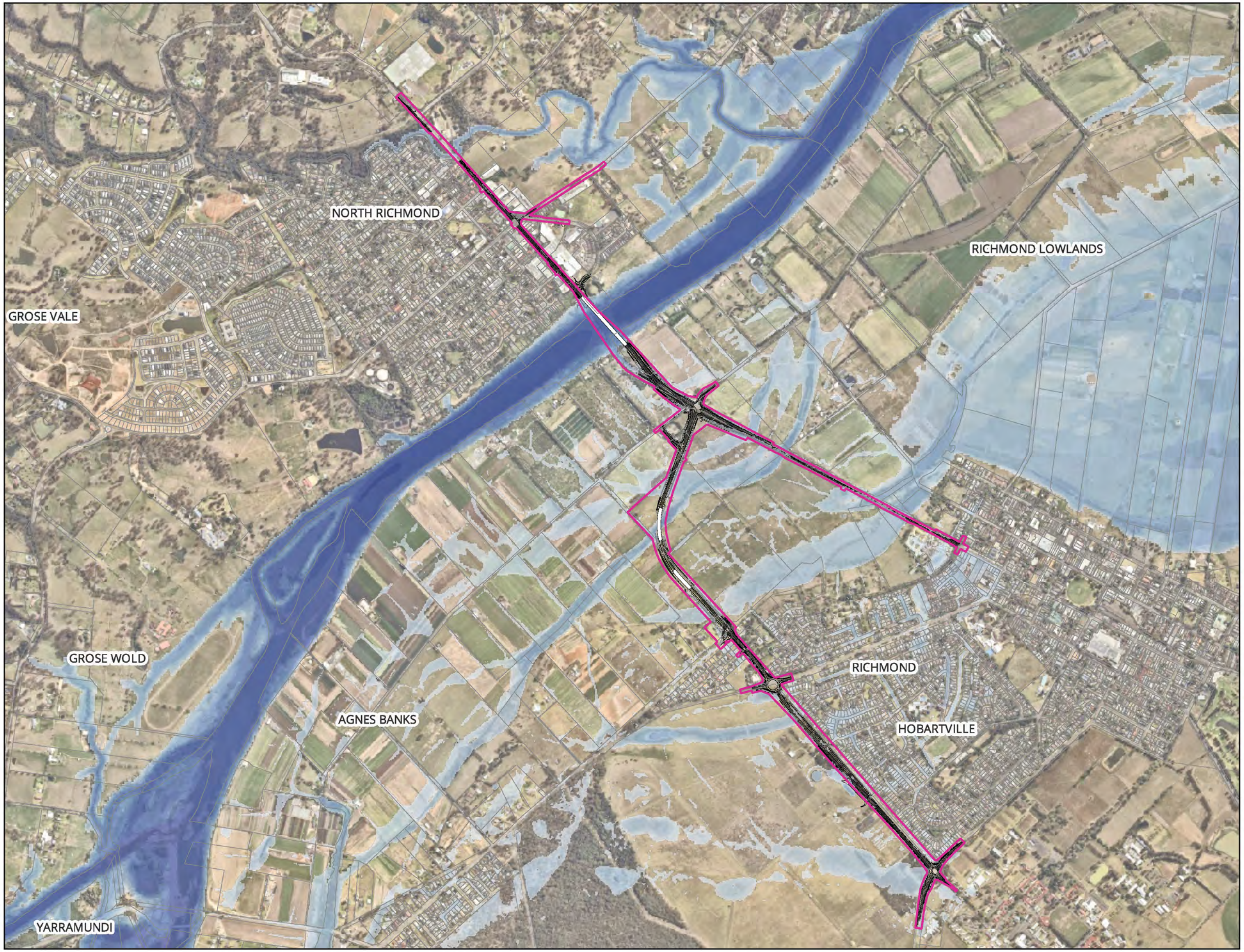
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 6.7: PMF Peak Flood Level - Developed Condition



aurecon

Legend
- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)
- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

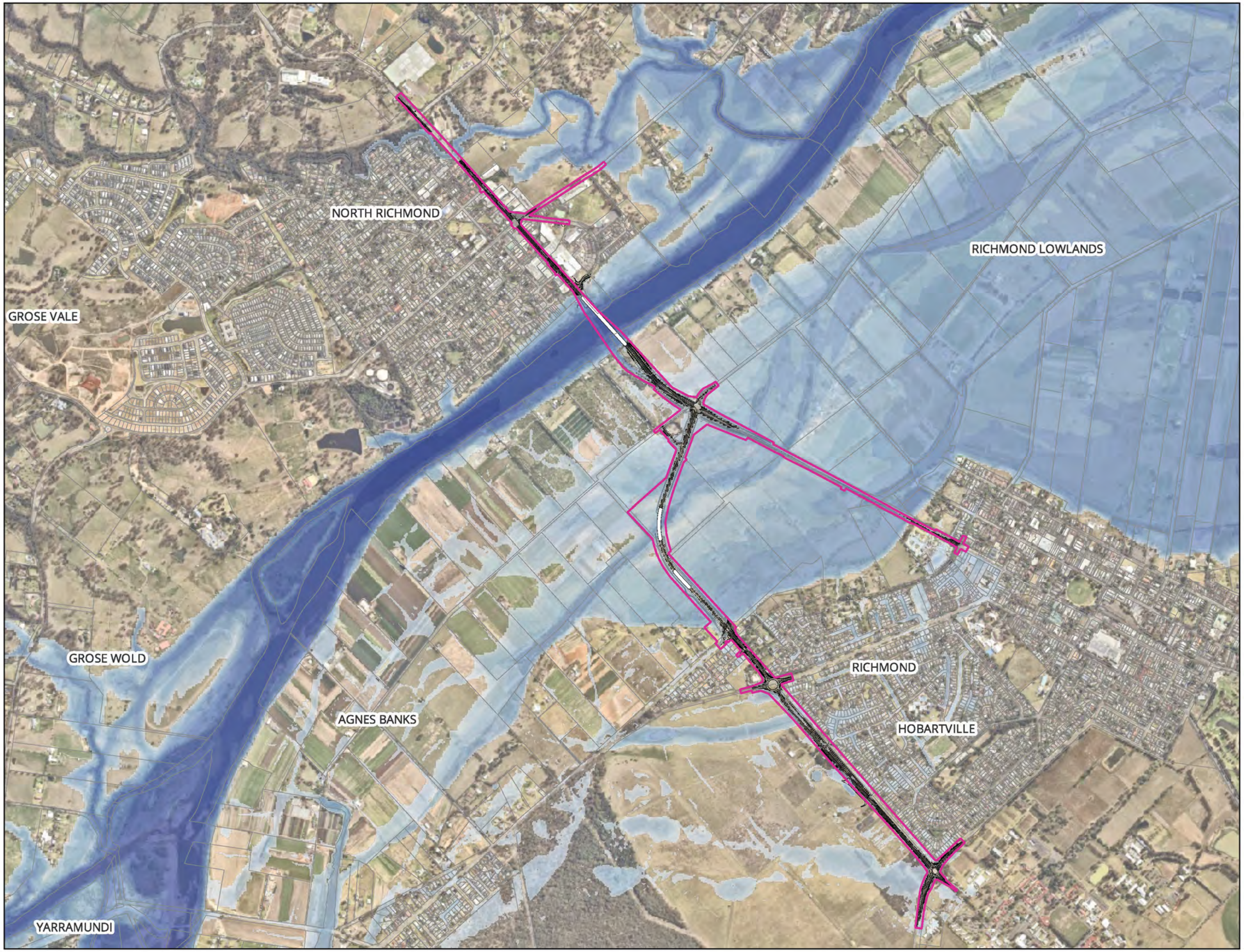
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.1: 20% AEP Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

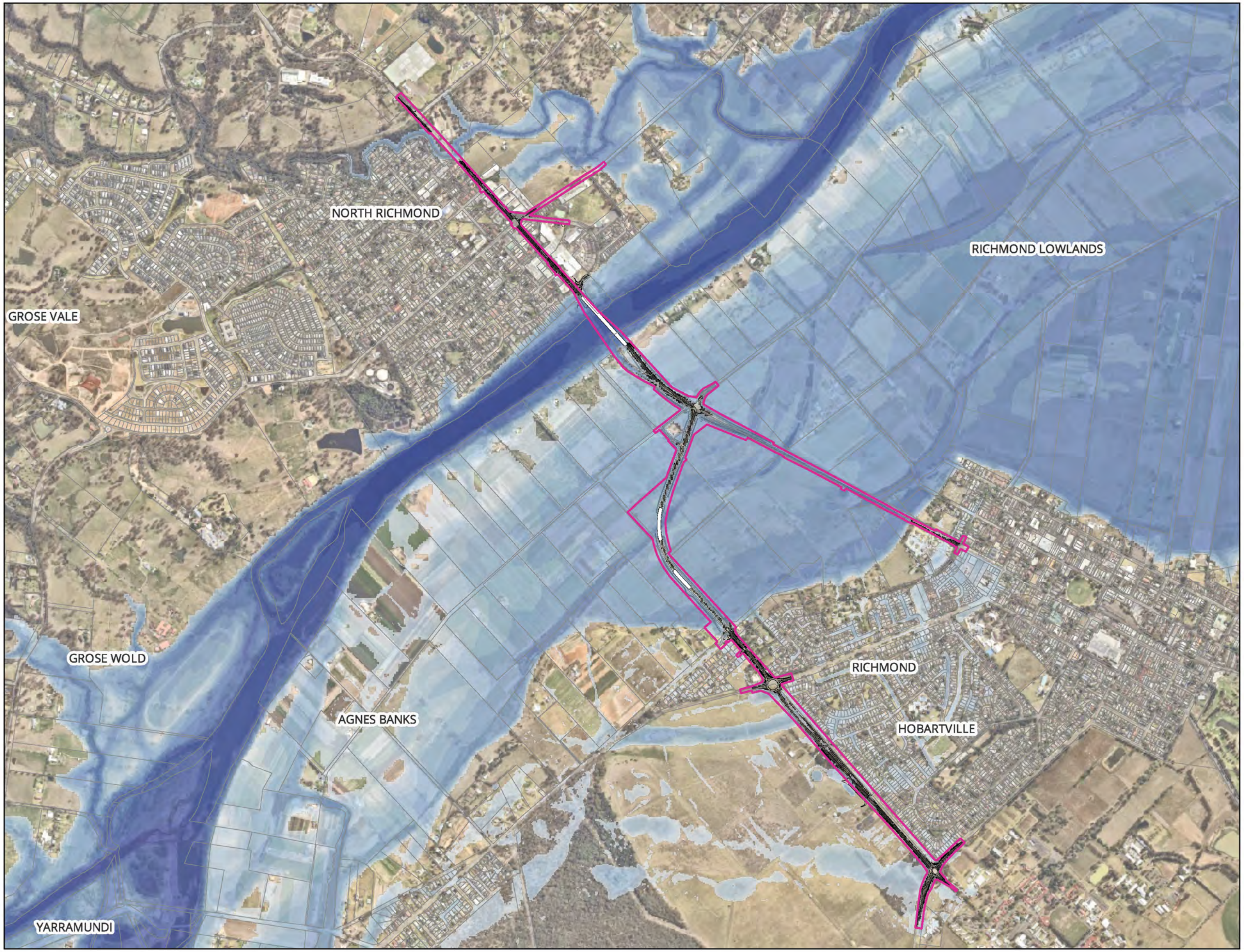
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.2: 10% AEP Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

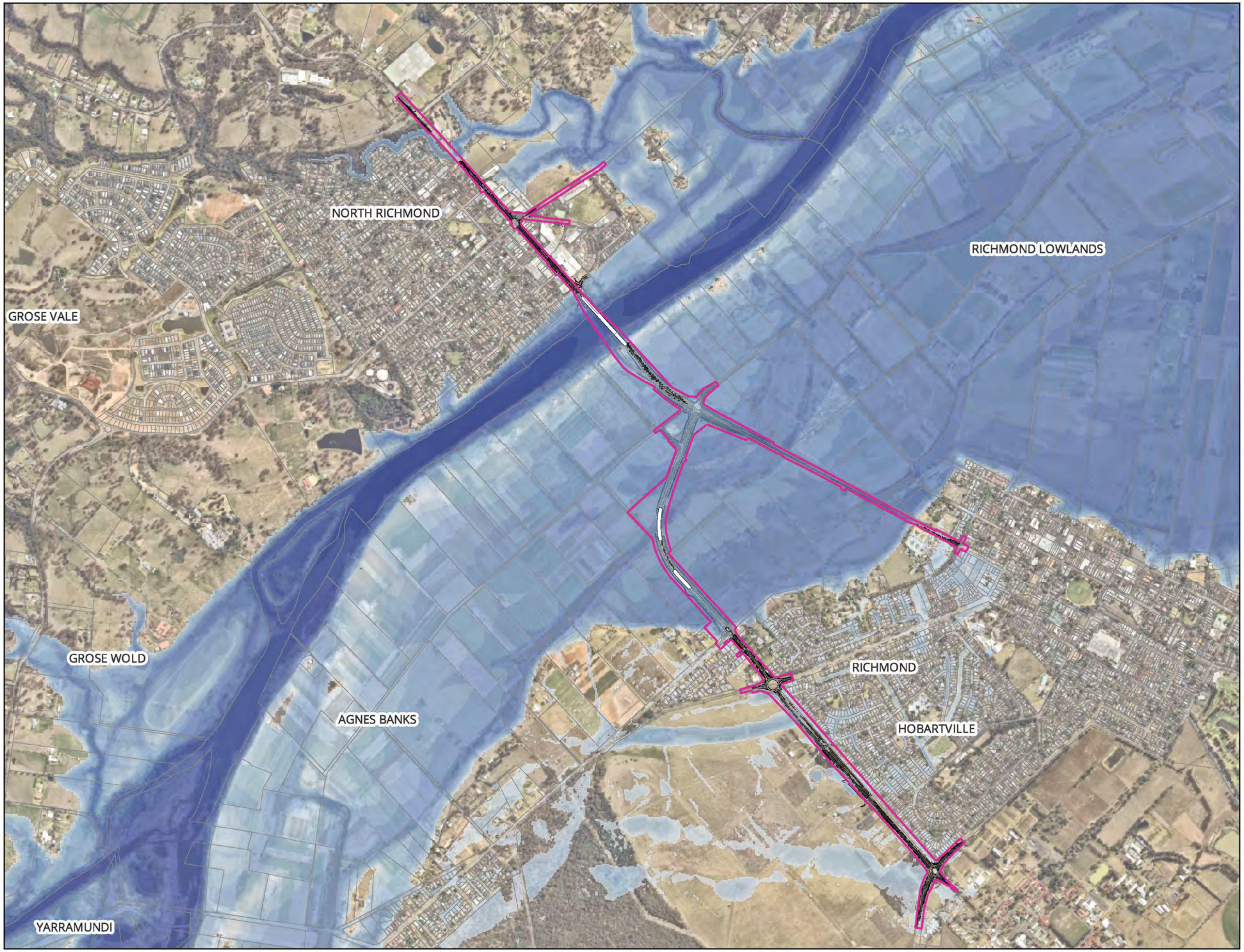
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.3: 5% AEP Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

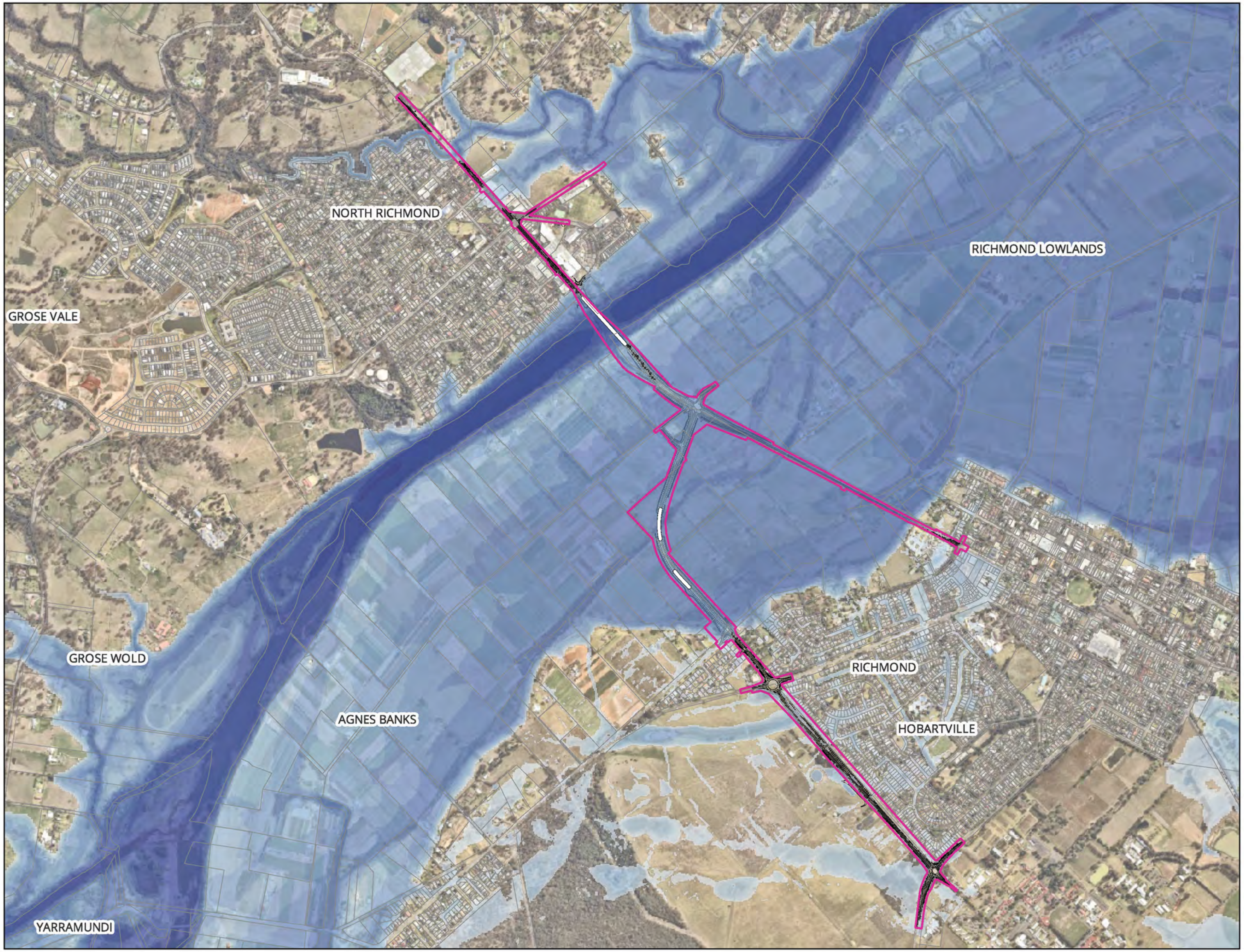
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.4: 2% AEP Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

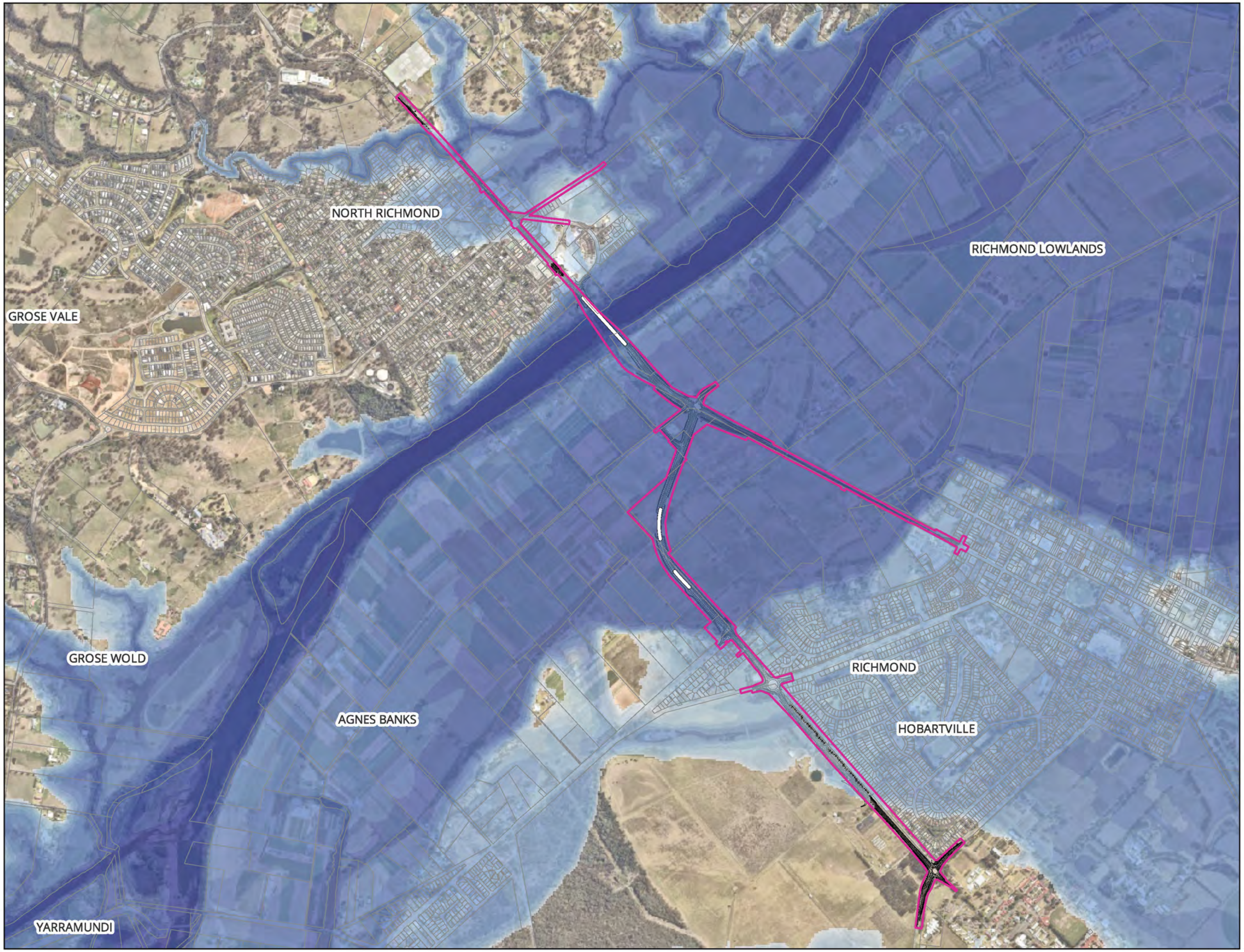
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.5: 1% AEP Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

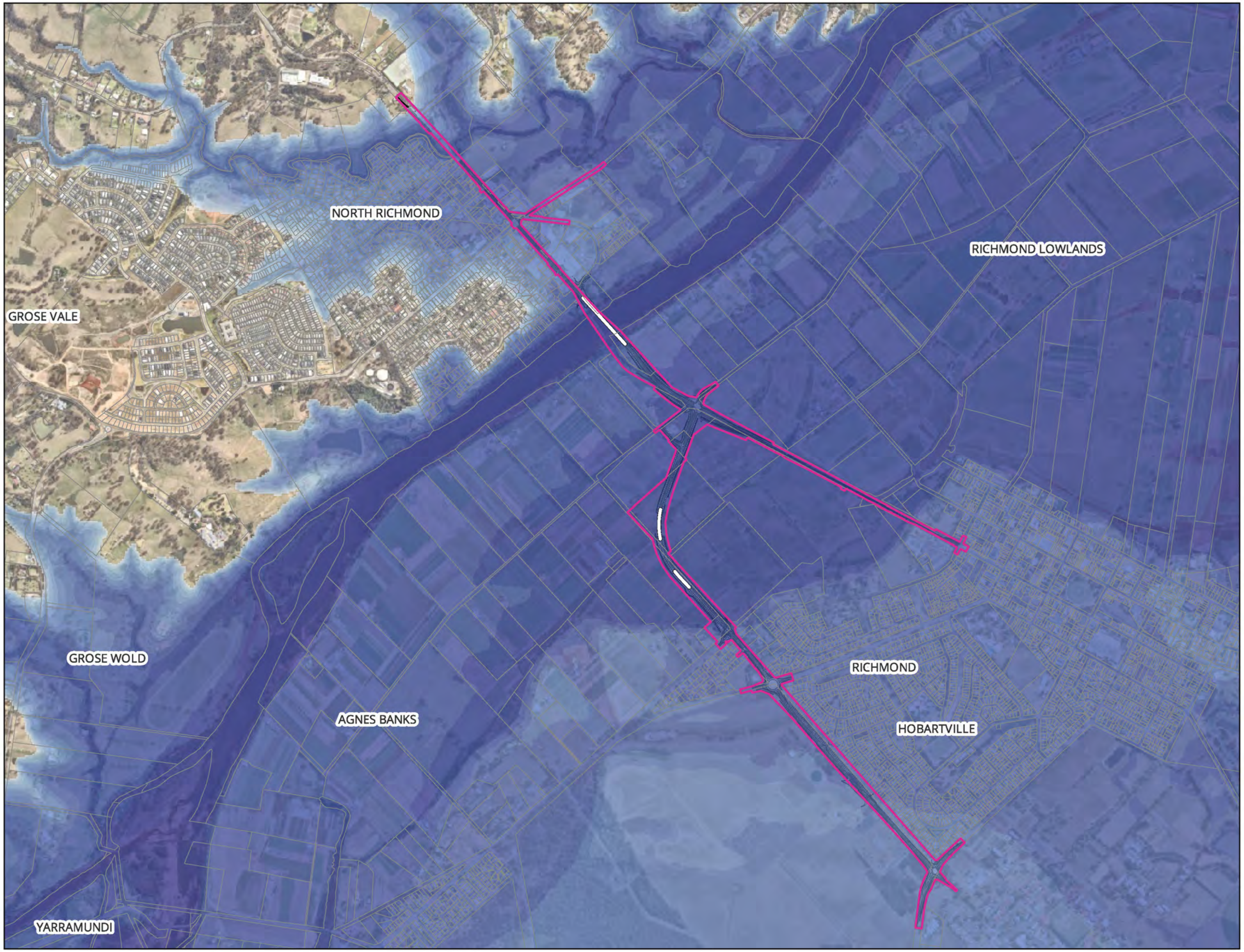
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.6: 0.05% AEP Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

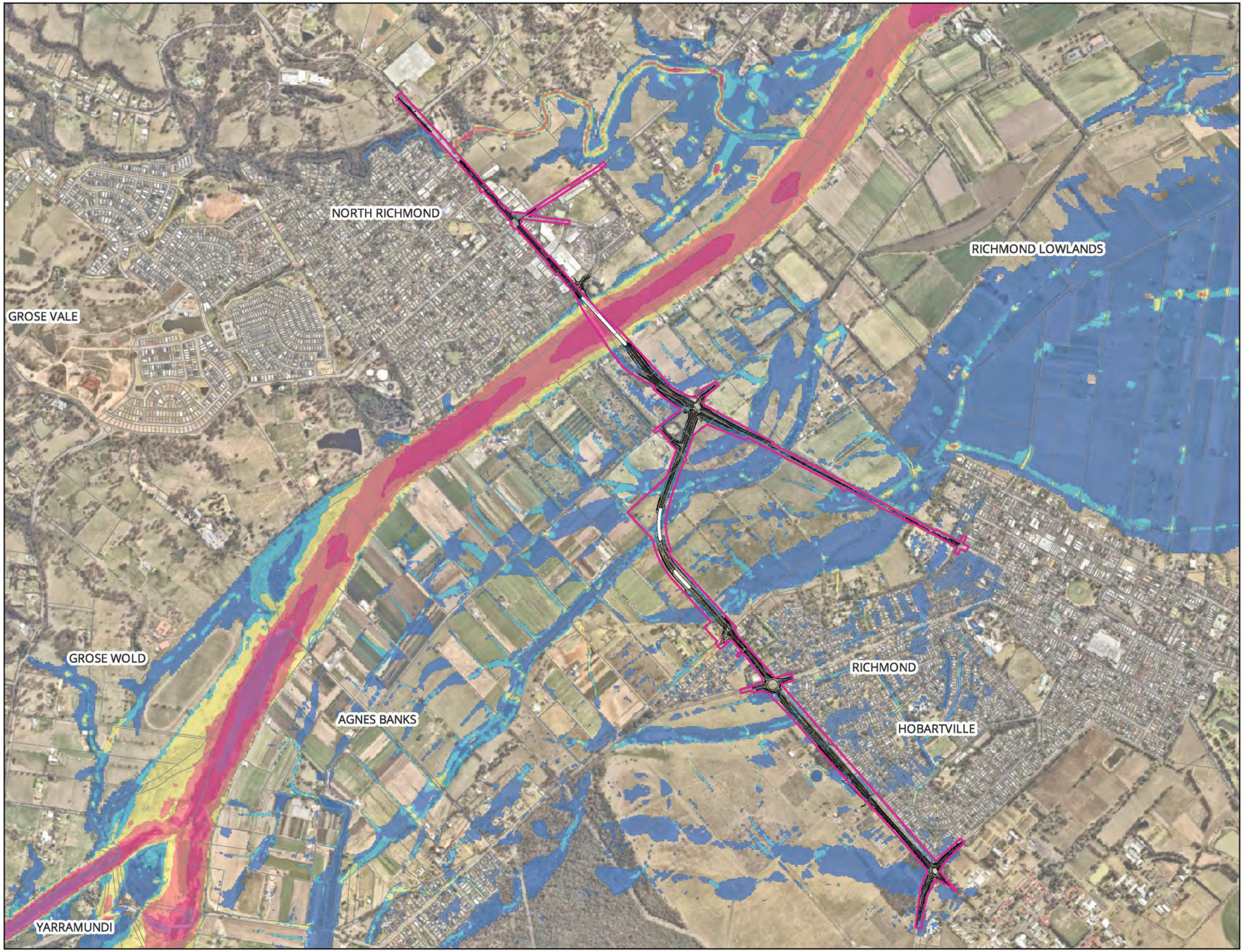
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 7.7: PMF Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

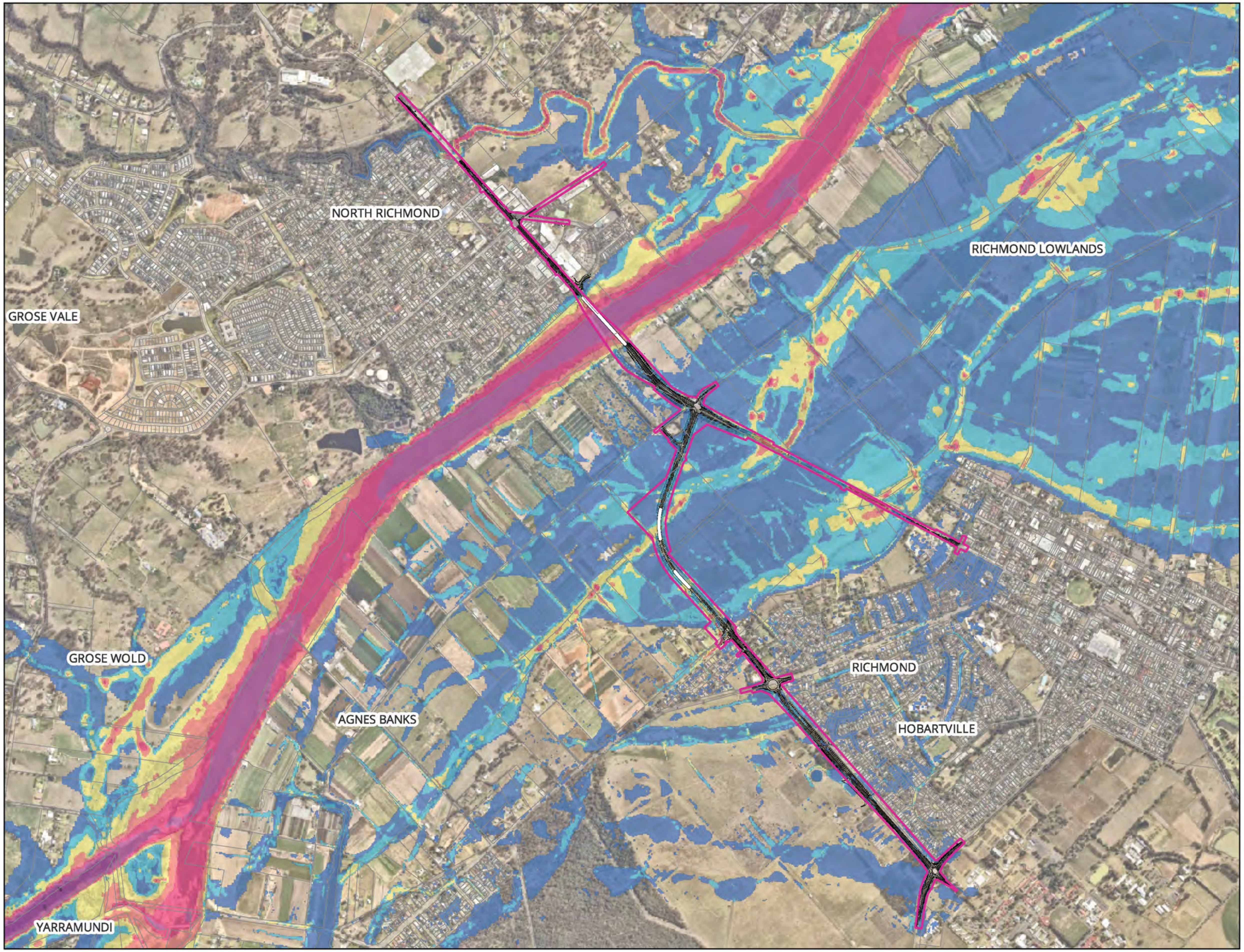
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.1: 20% AEP Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

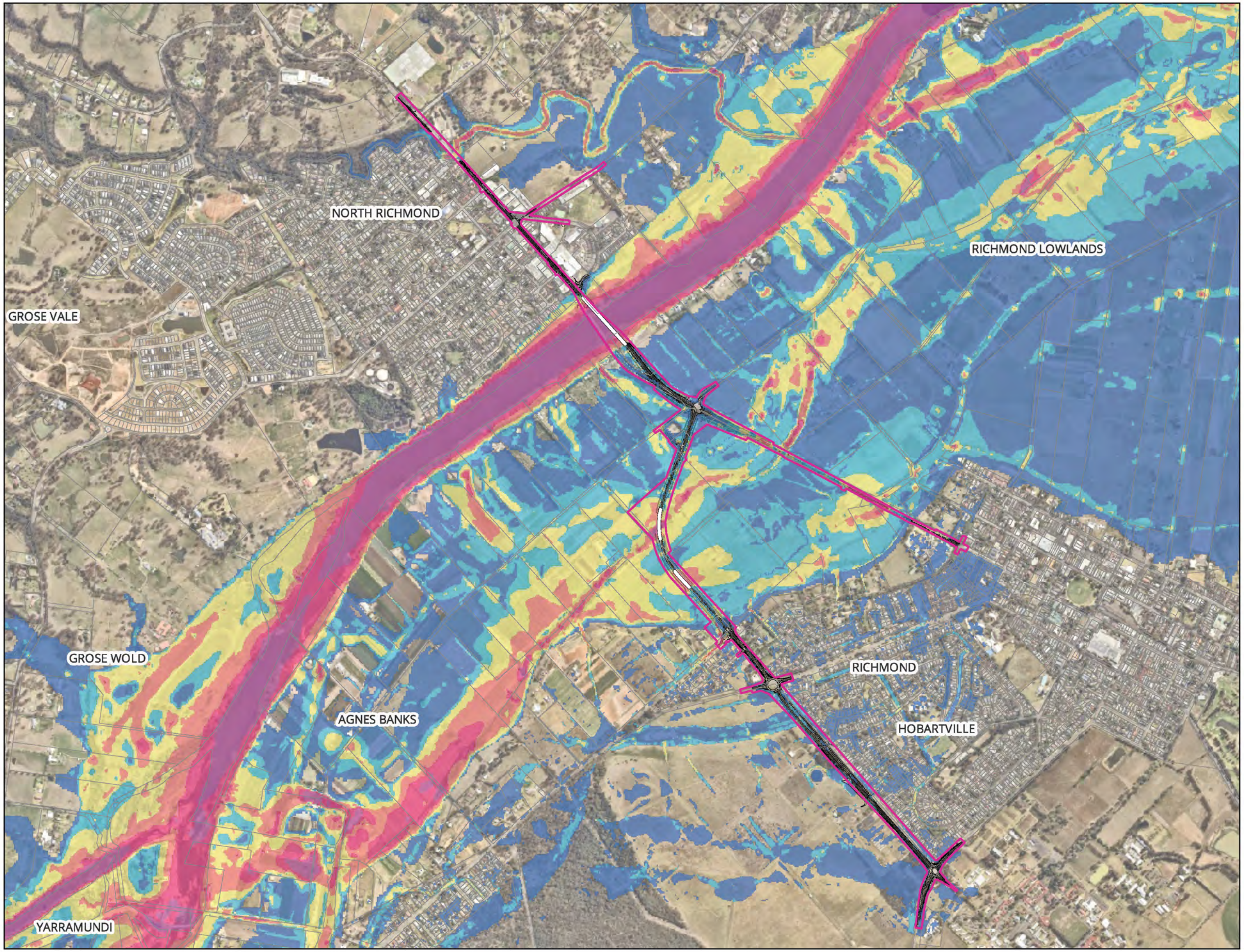
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.2: 10% AEP Peak Flood Velocity - Developed Condition



Map by: TT

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

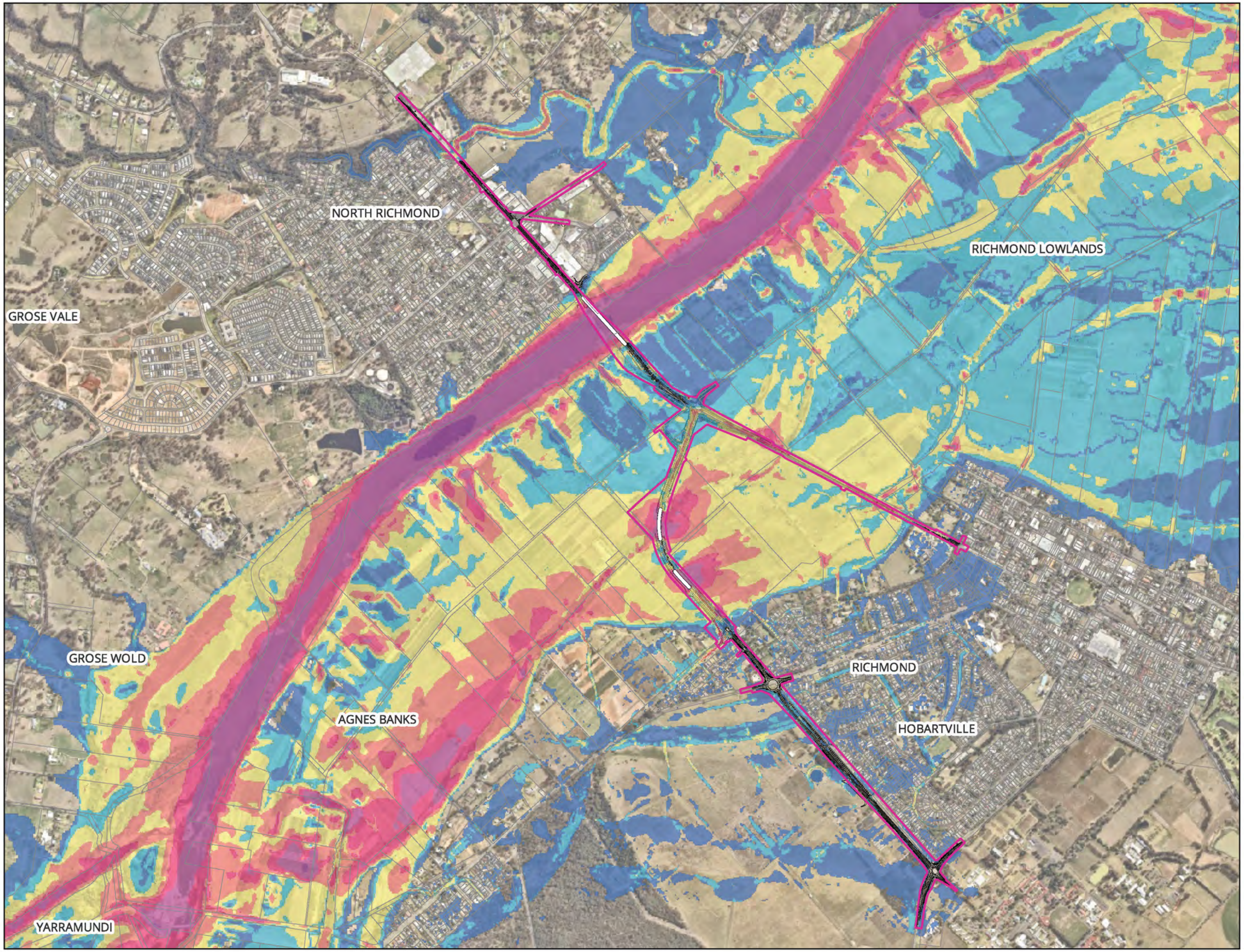
0 | 700 | 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.3: 5% AEP Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

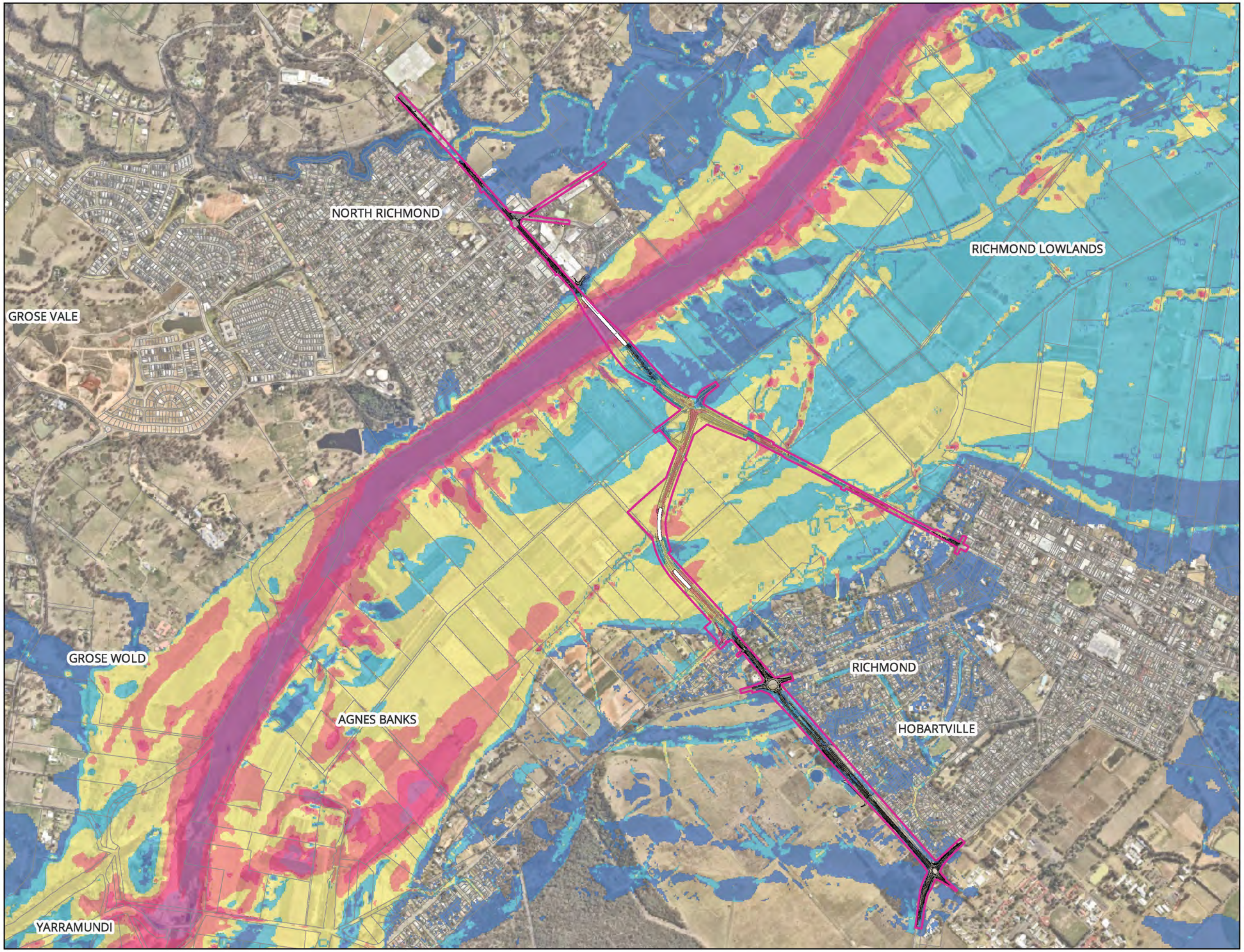
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.4: 2% AEP Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

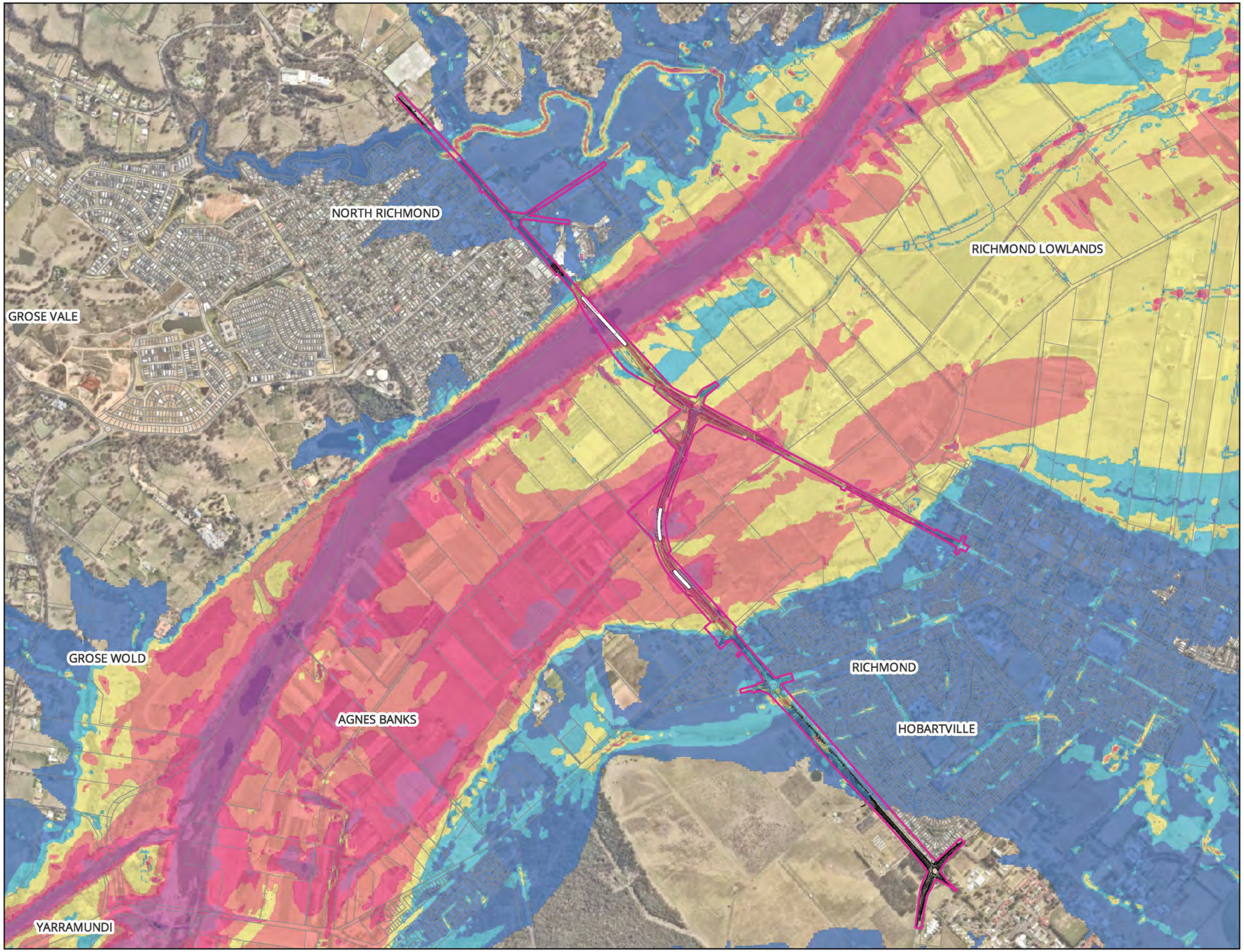
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.5: 1% AEP Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

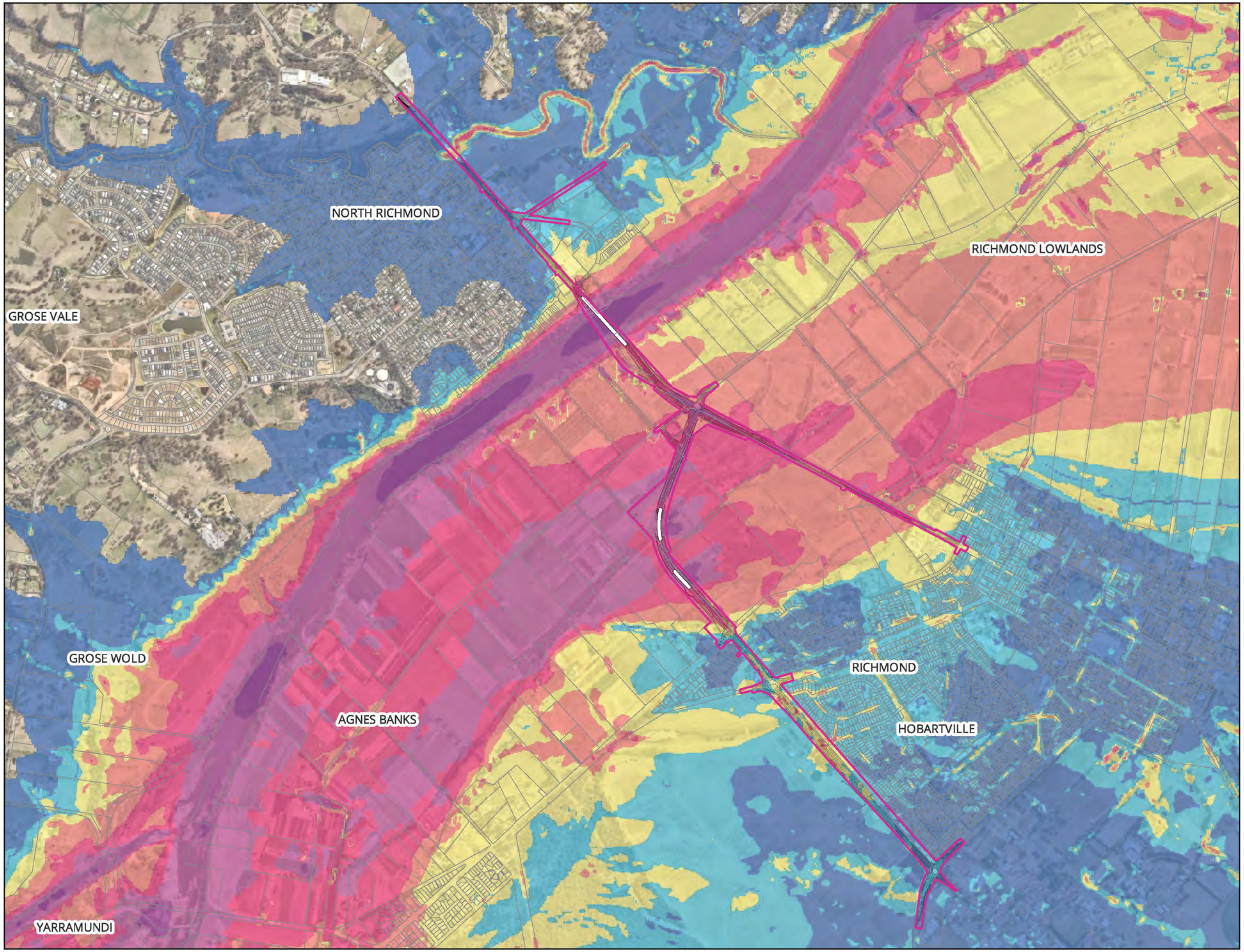
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.6: 0.05% AEP Peak Flood Velocity - Developed Condition



Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

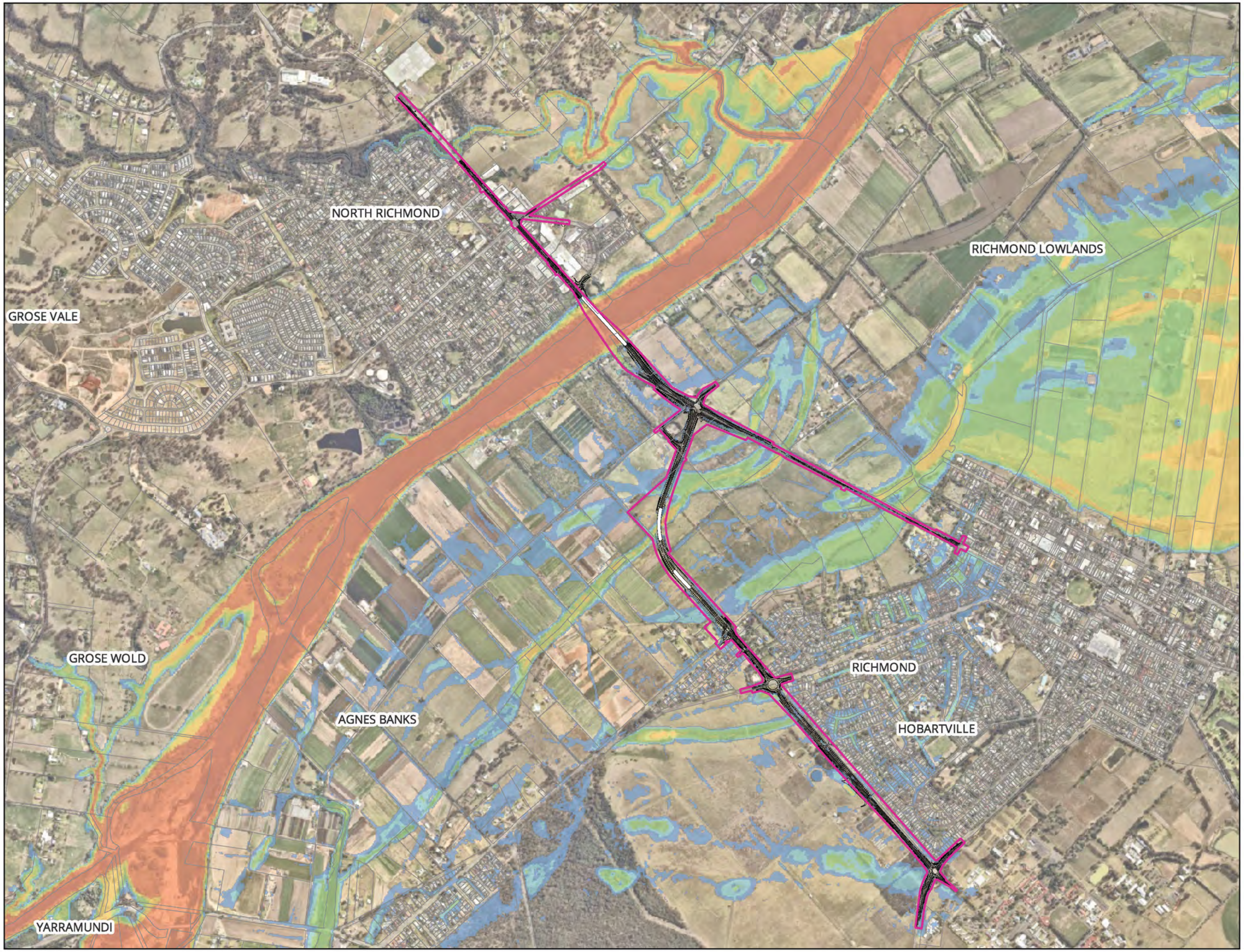
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 8.7: PMF Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

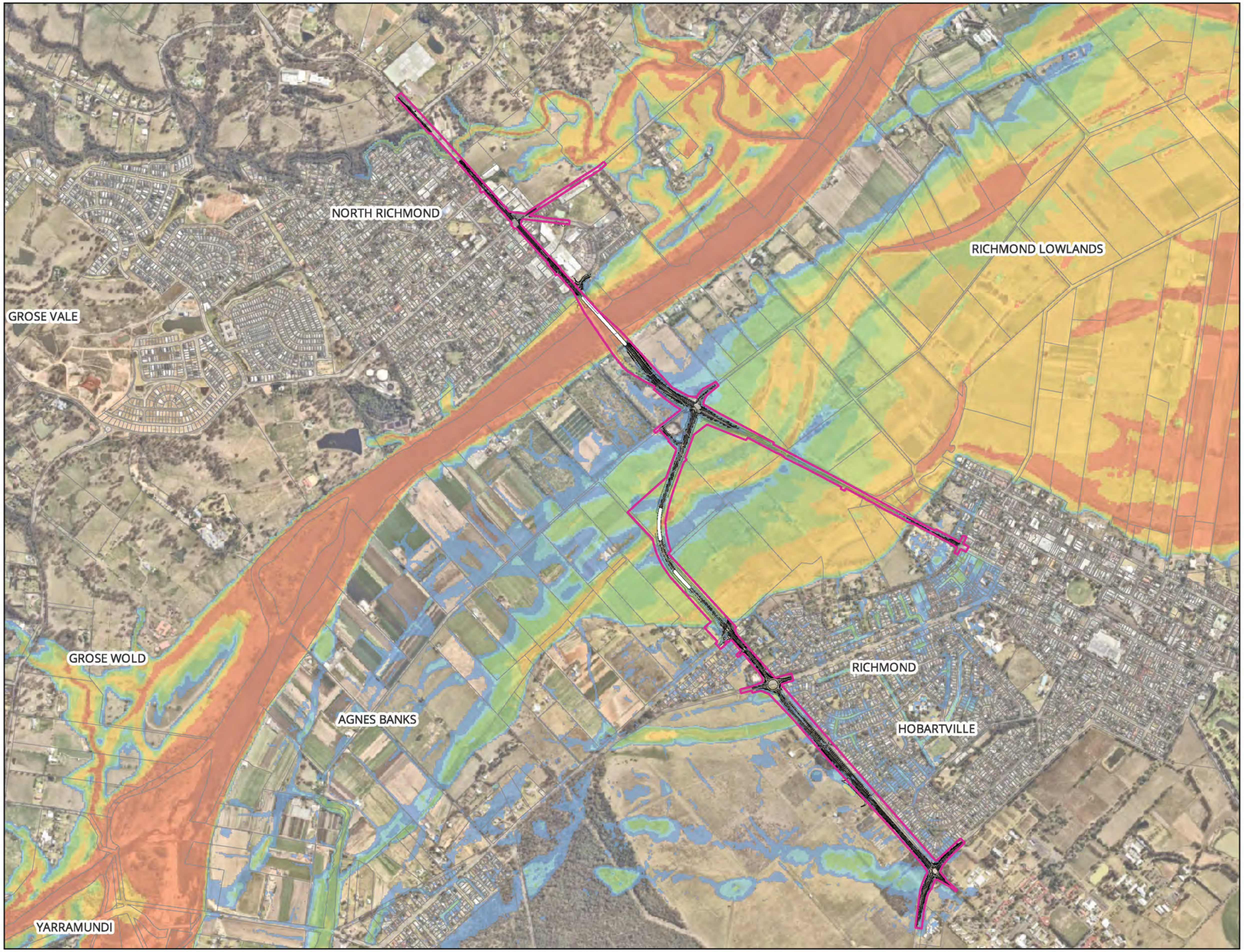
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.1: 20% AEP Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

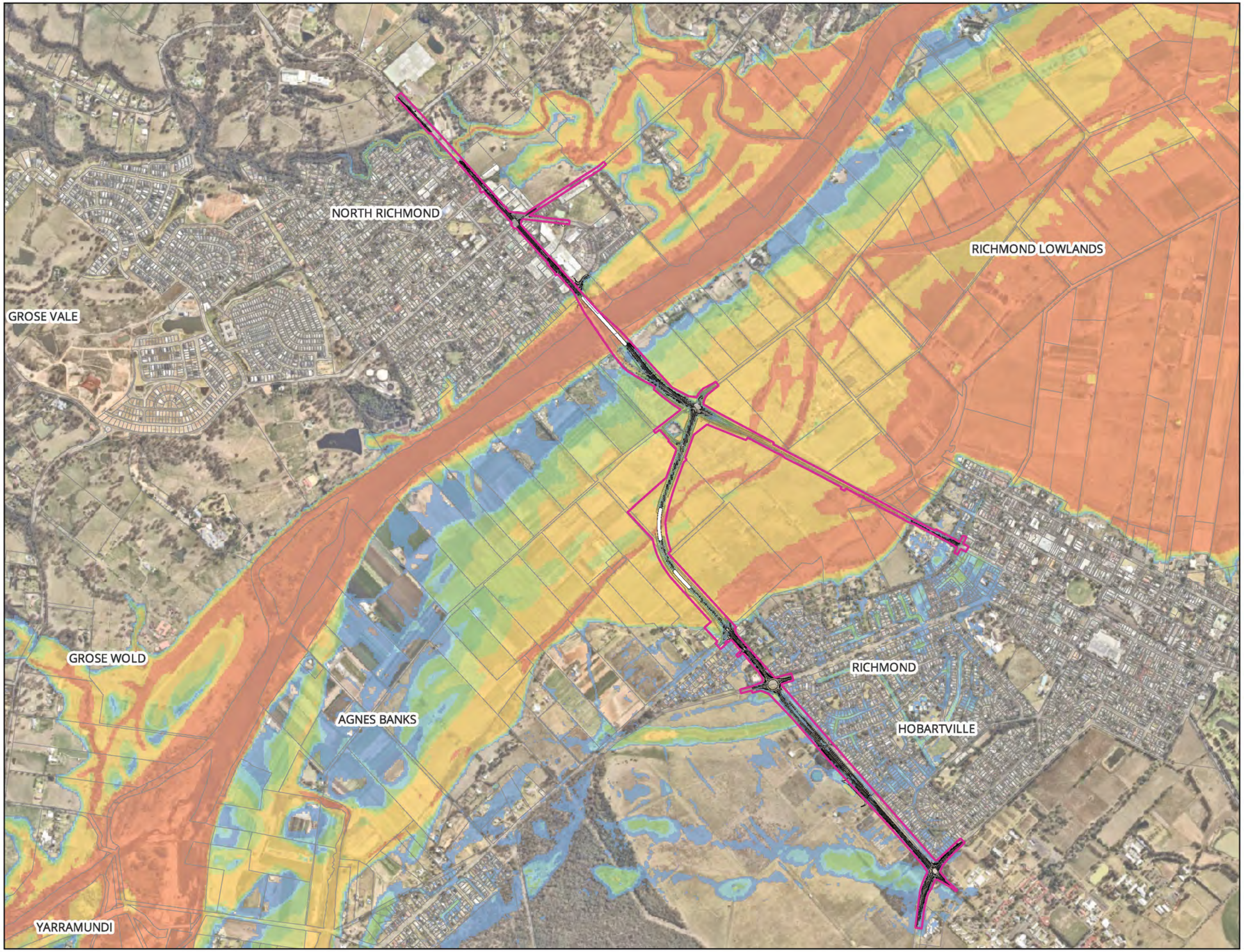
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.2: 10% AEP Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

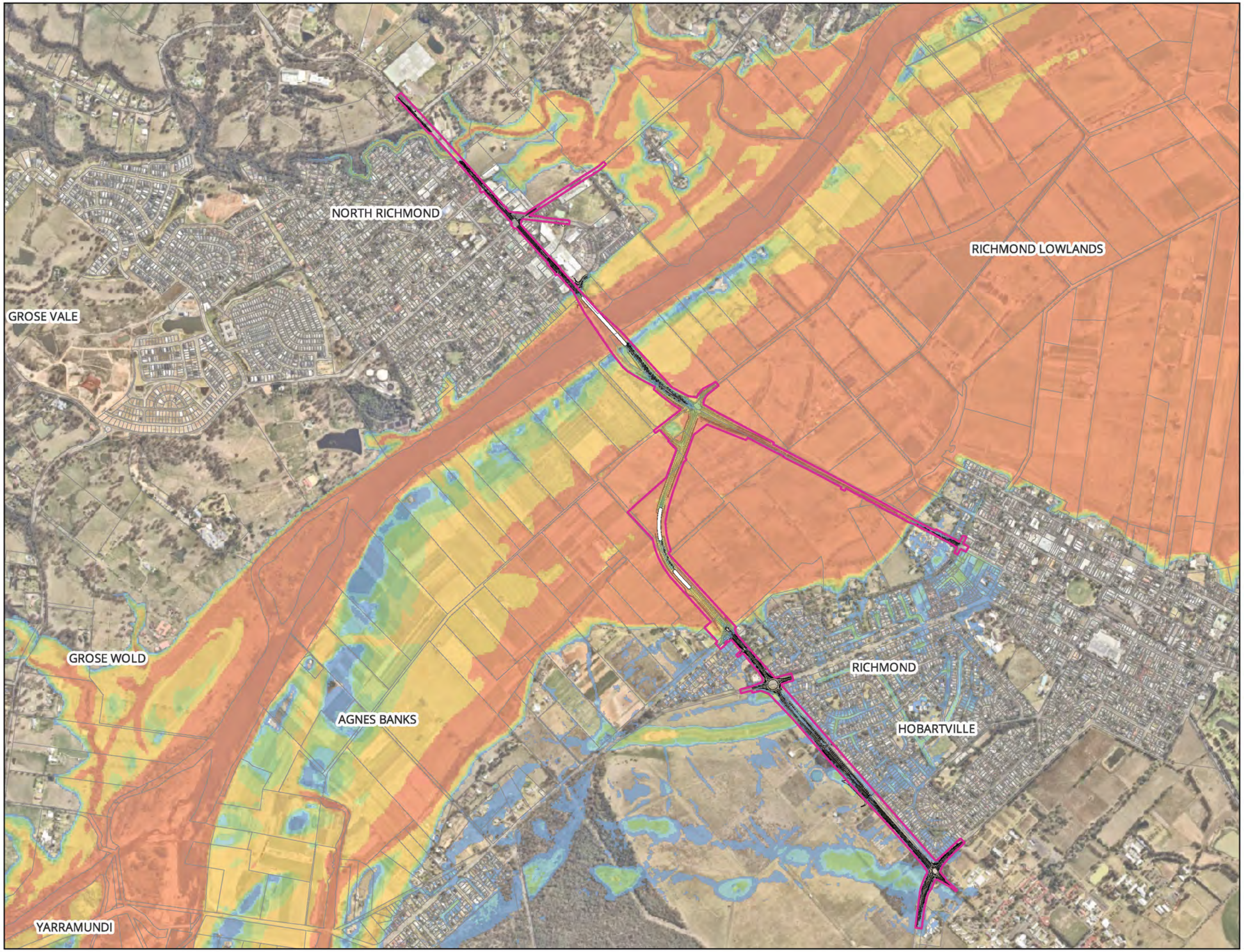
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.3: 5% AEP Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

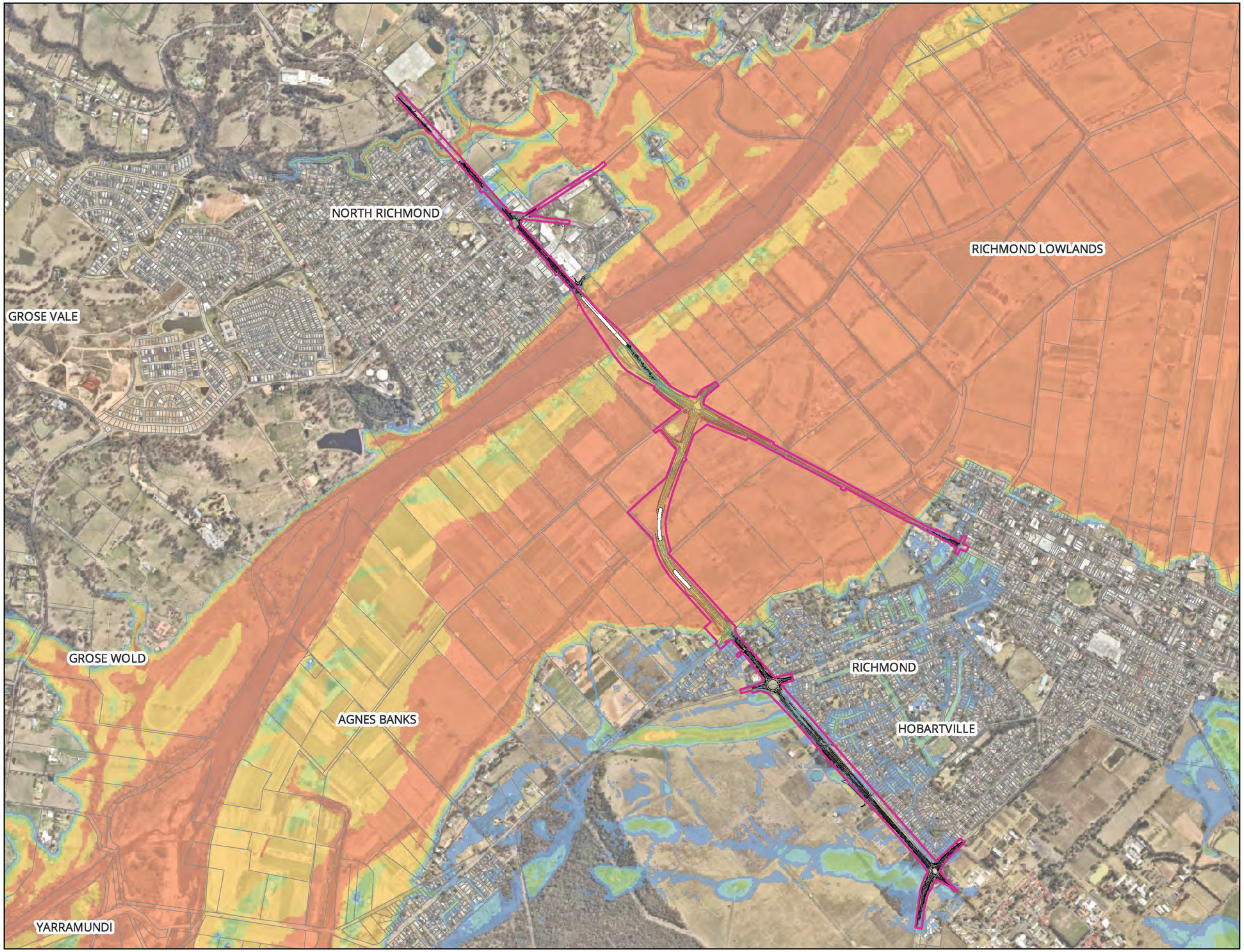
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.4: 2% AEP Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

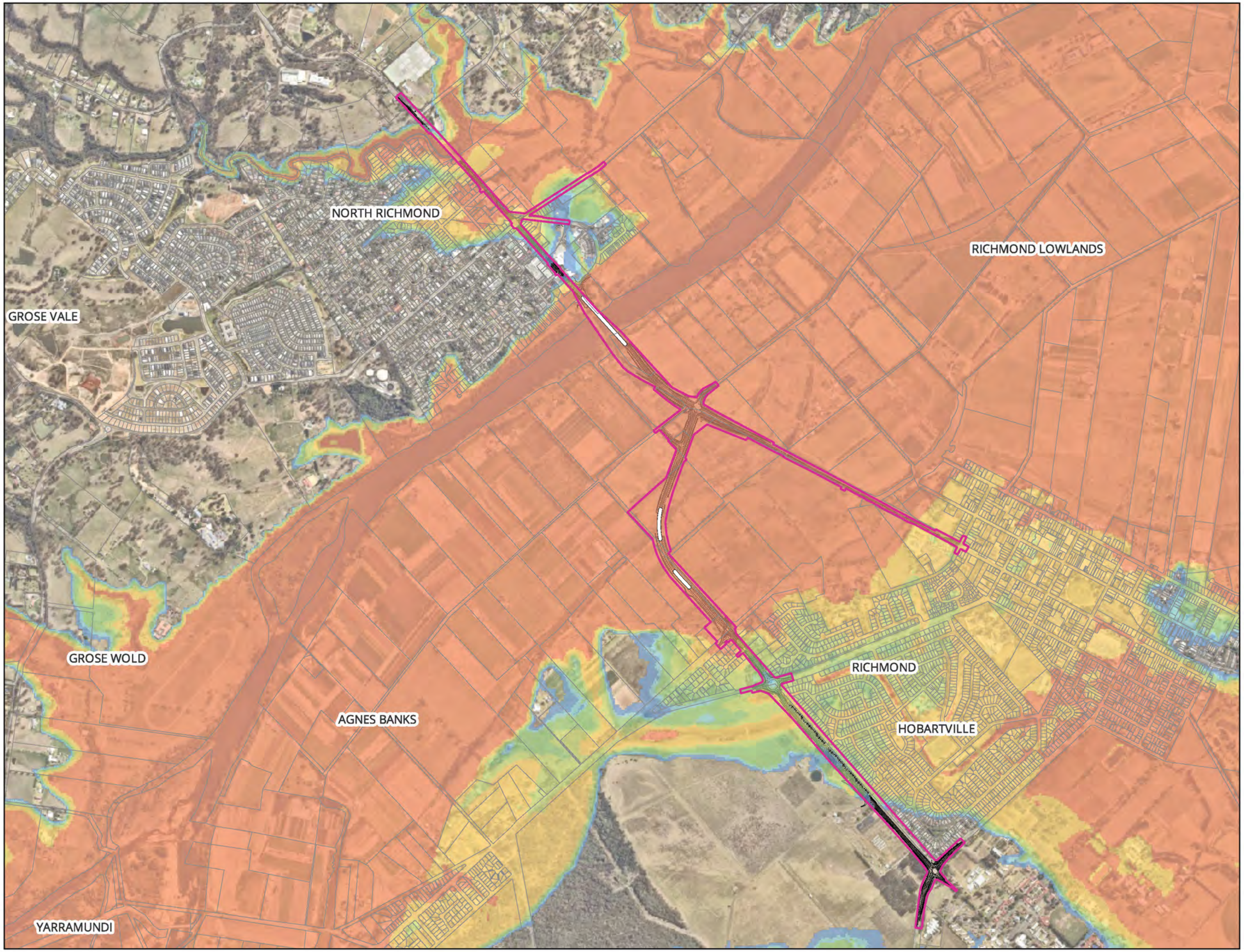
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.5: 1% AEP Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

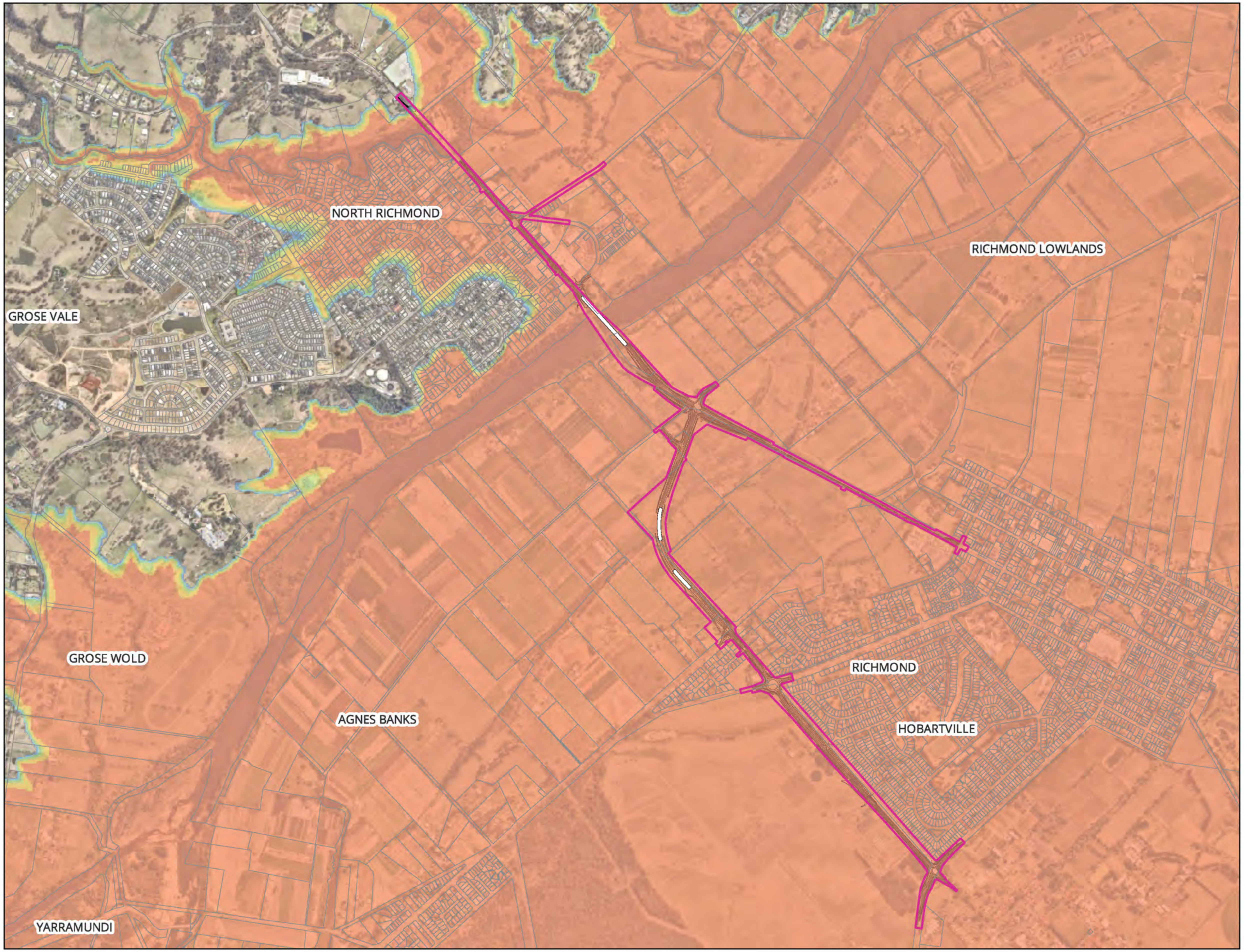
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.6: 0.05% AEP Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

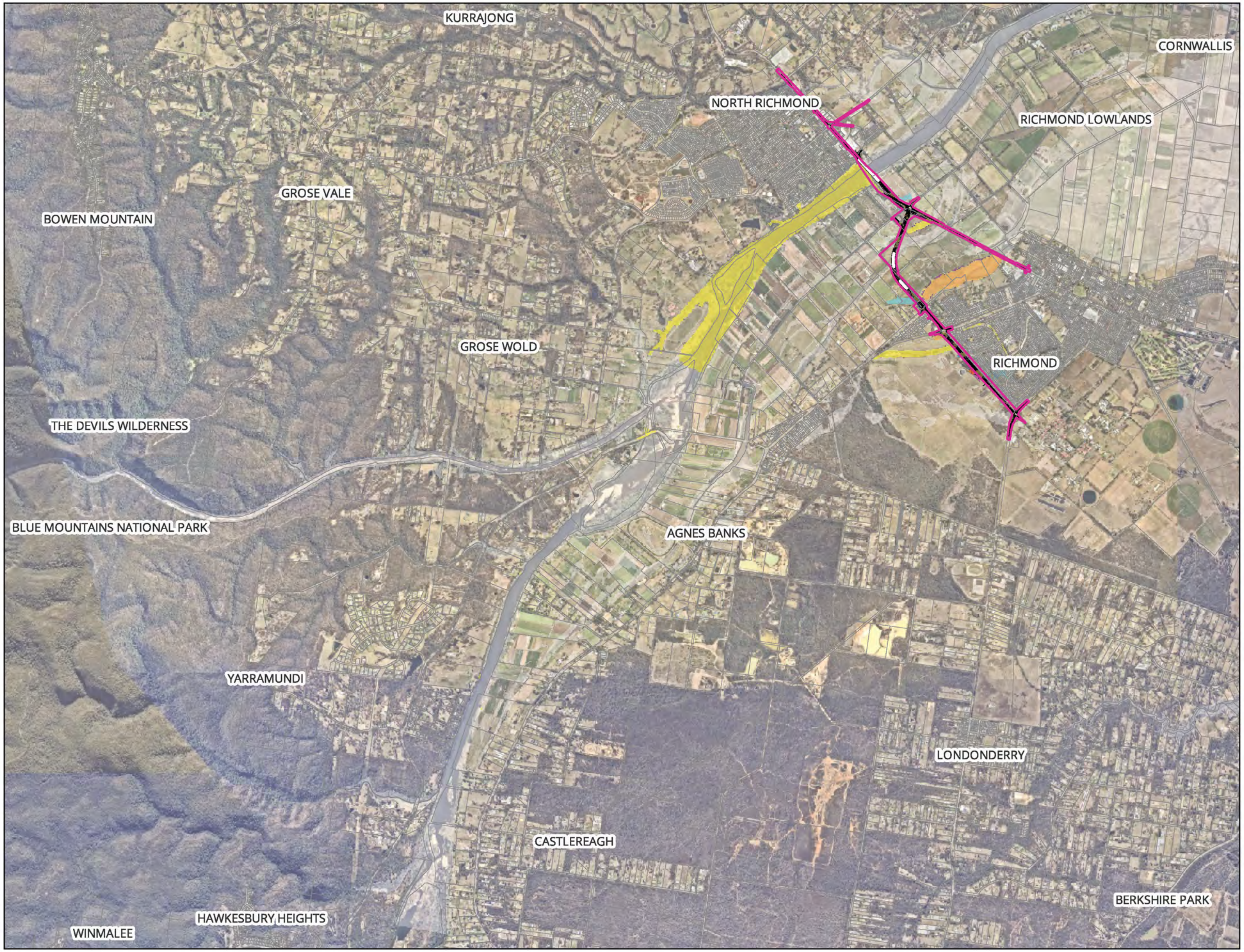
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 9.7: PMF Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

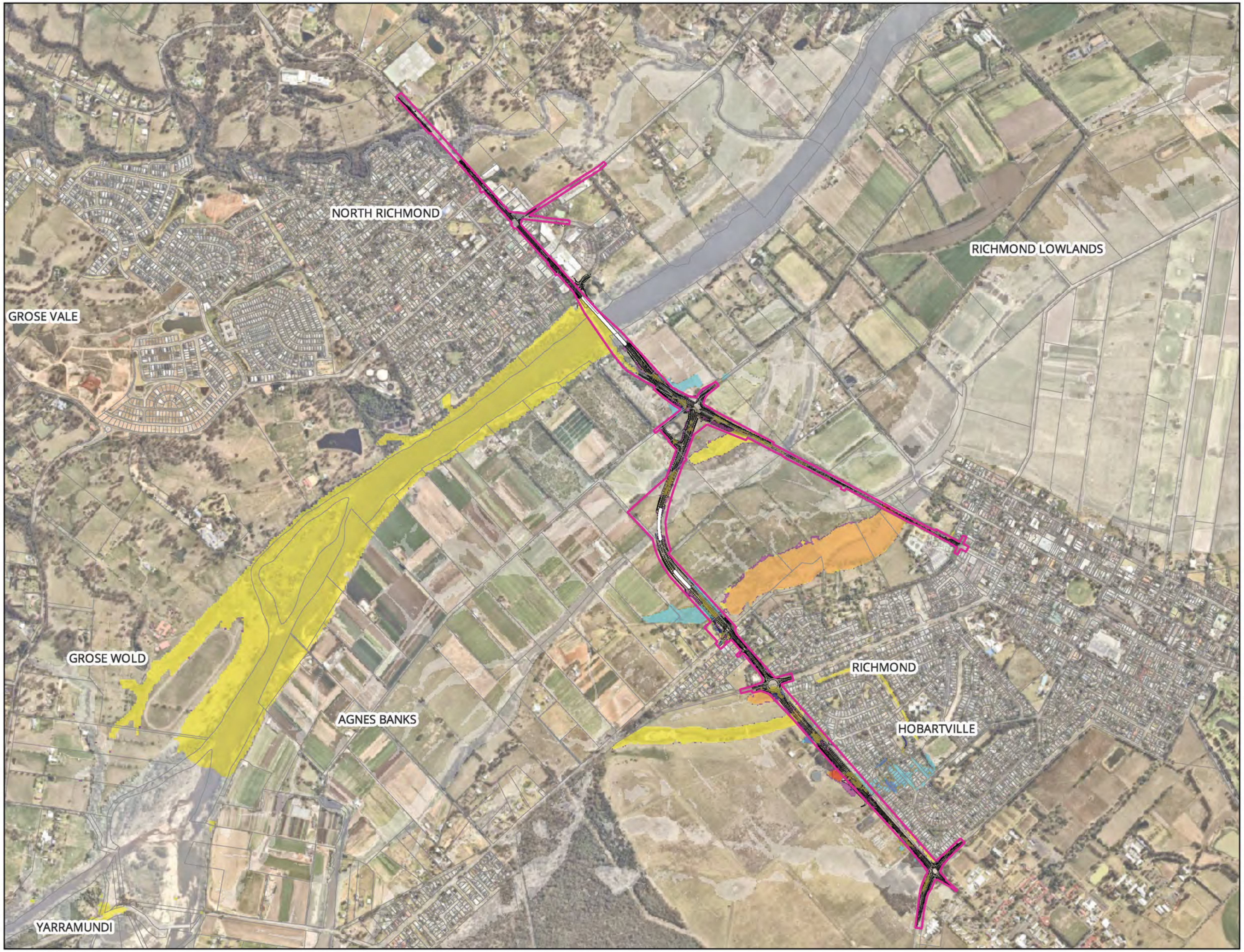
0 1,700 3,400 m

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.1: 20% AEP Peak Flood Level Afflux



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

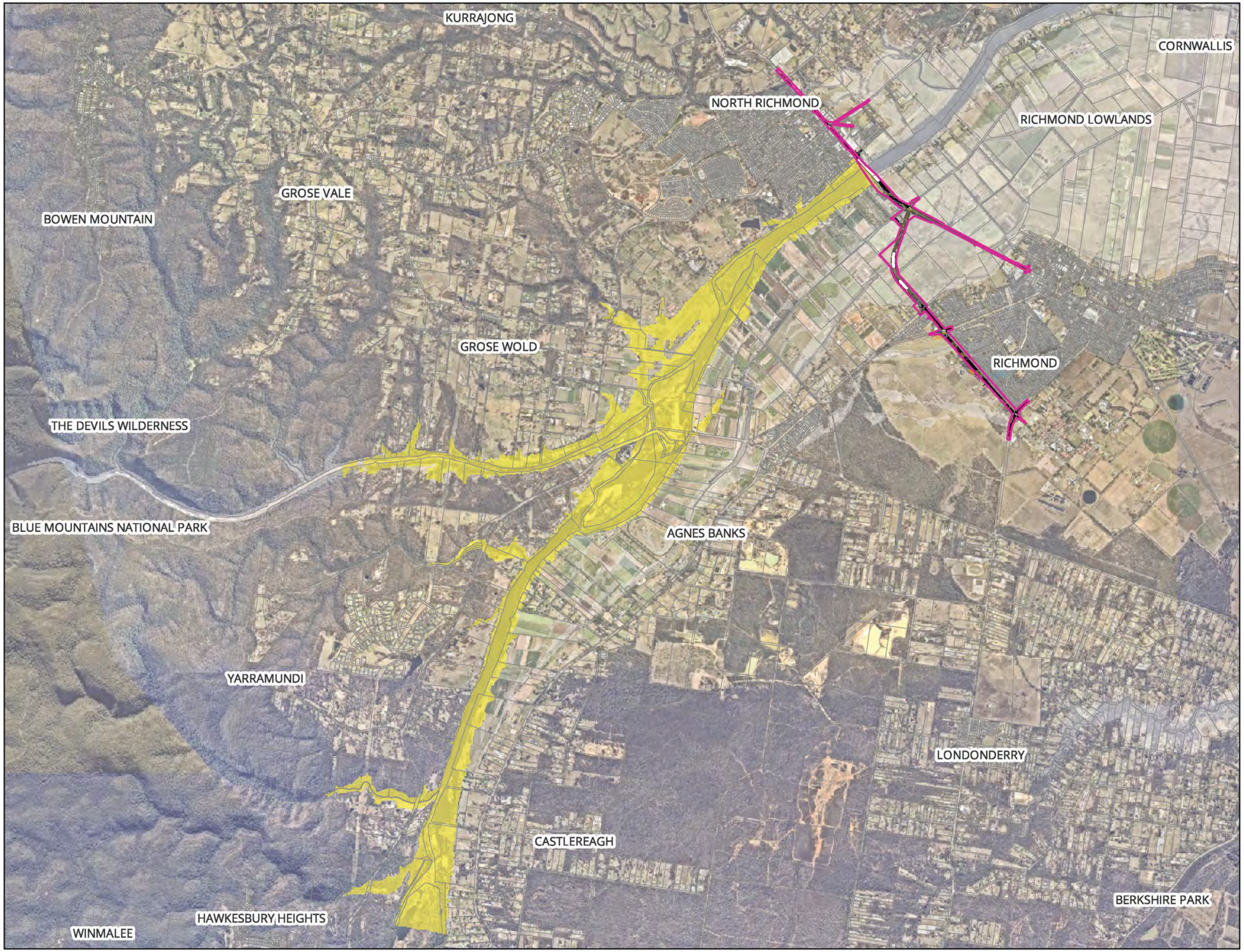
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.1A: 20% AEP Peak Flood Level Afflux (Proposal Area)



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

0 1,700 3,400 m

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.2: 10% AEP Peak Flood Level Afflux

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

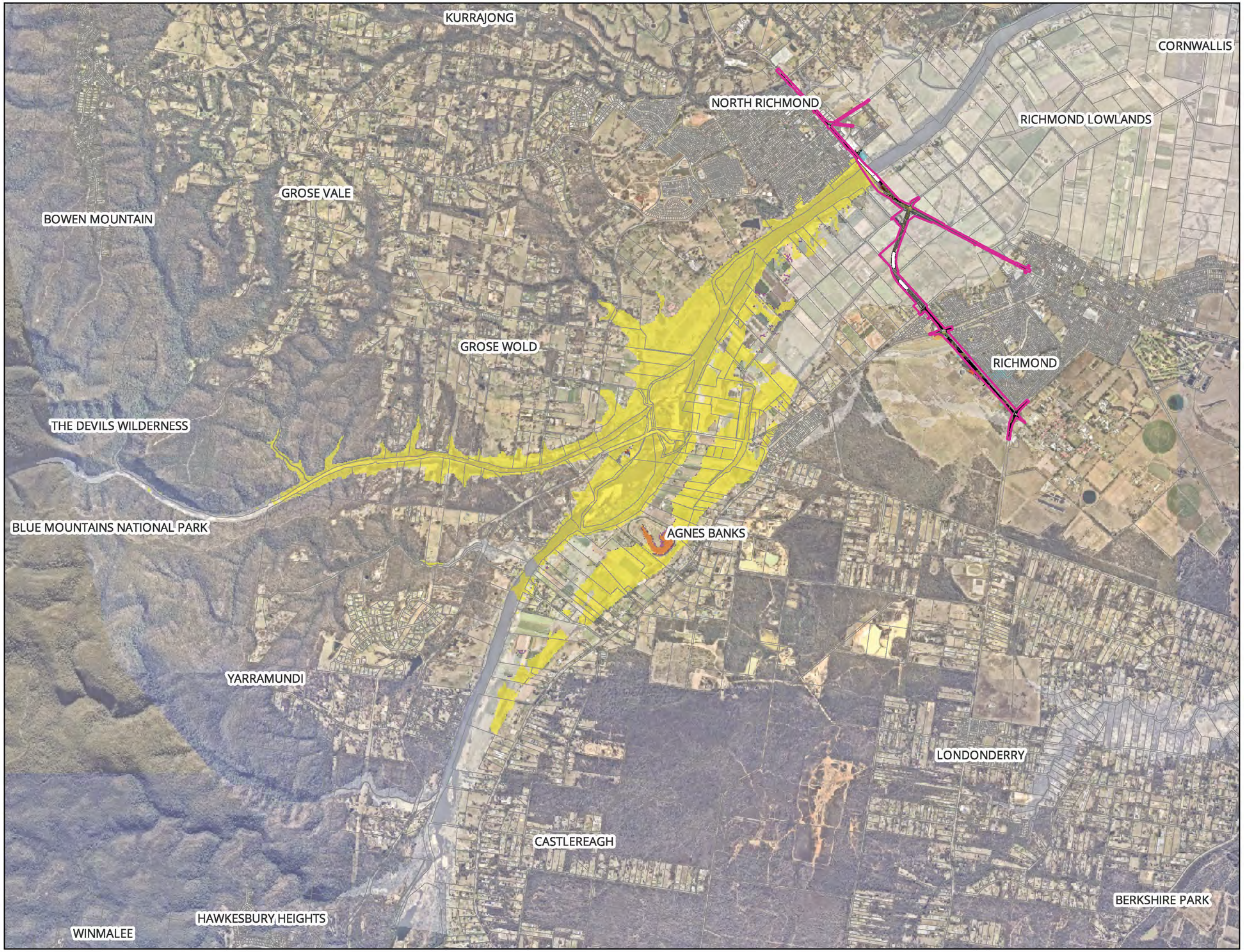
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.2A: 10% AEP Peak Flood Level Afflux (Proposal Area)



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

0 1,700 3,400 m

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.3: 5% AEP Peak Flood Level Afflux

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

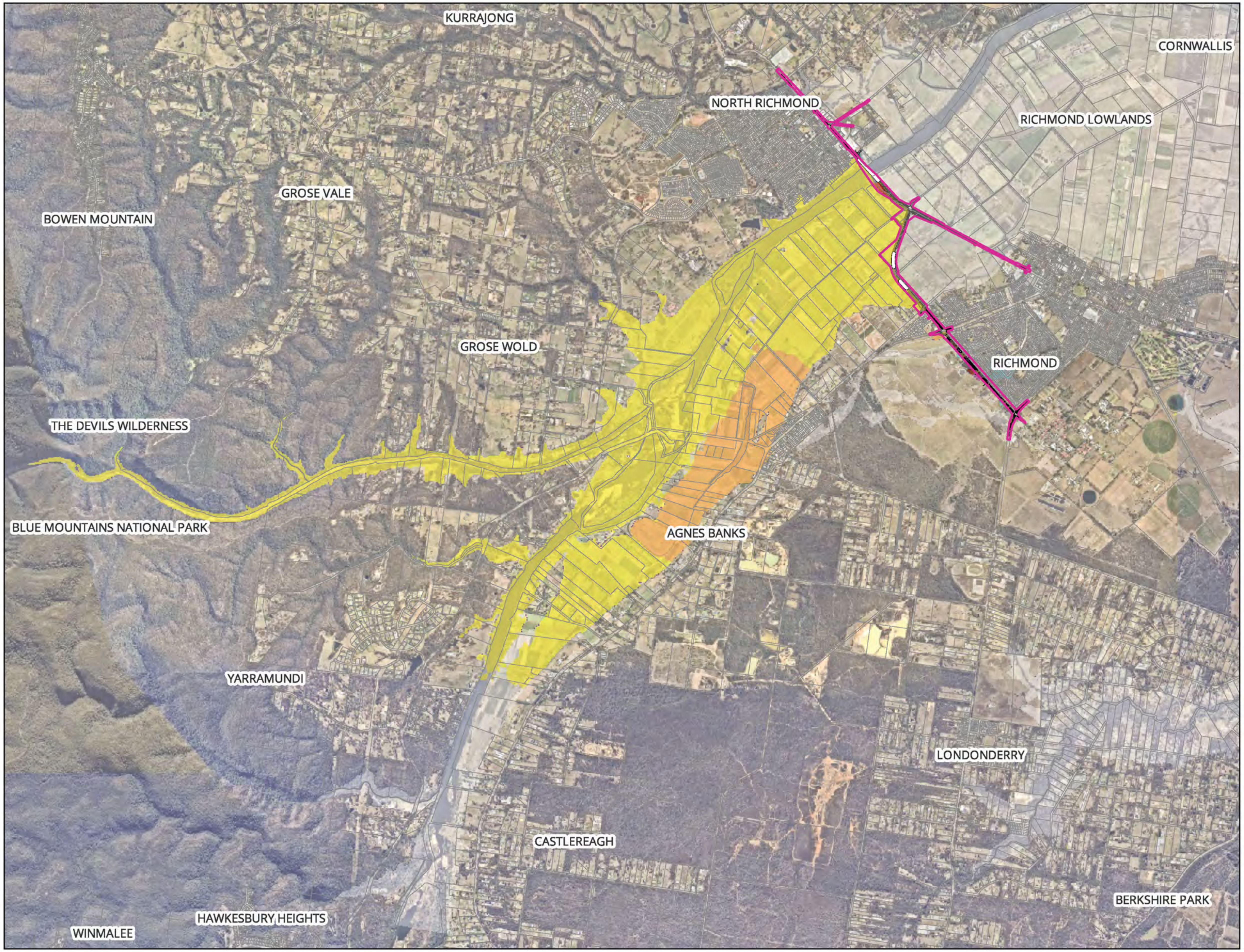
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.3A: 5% AEP Peak Flood Level Afflux (Proposal Area)



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

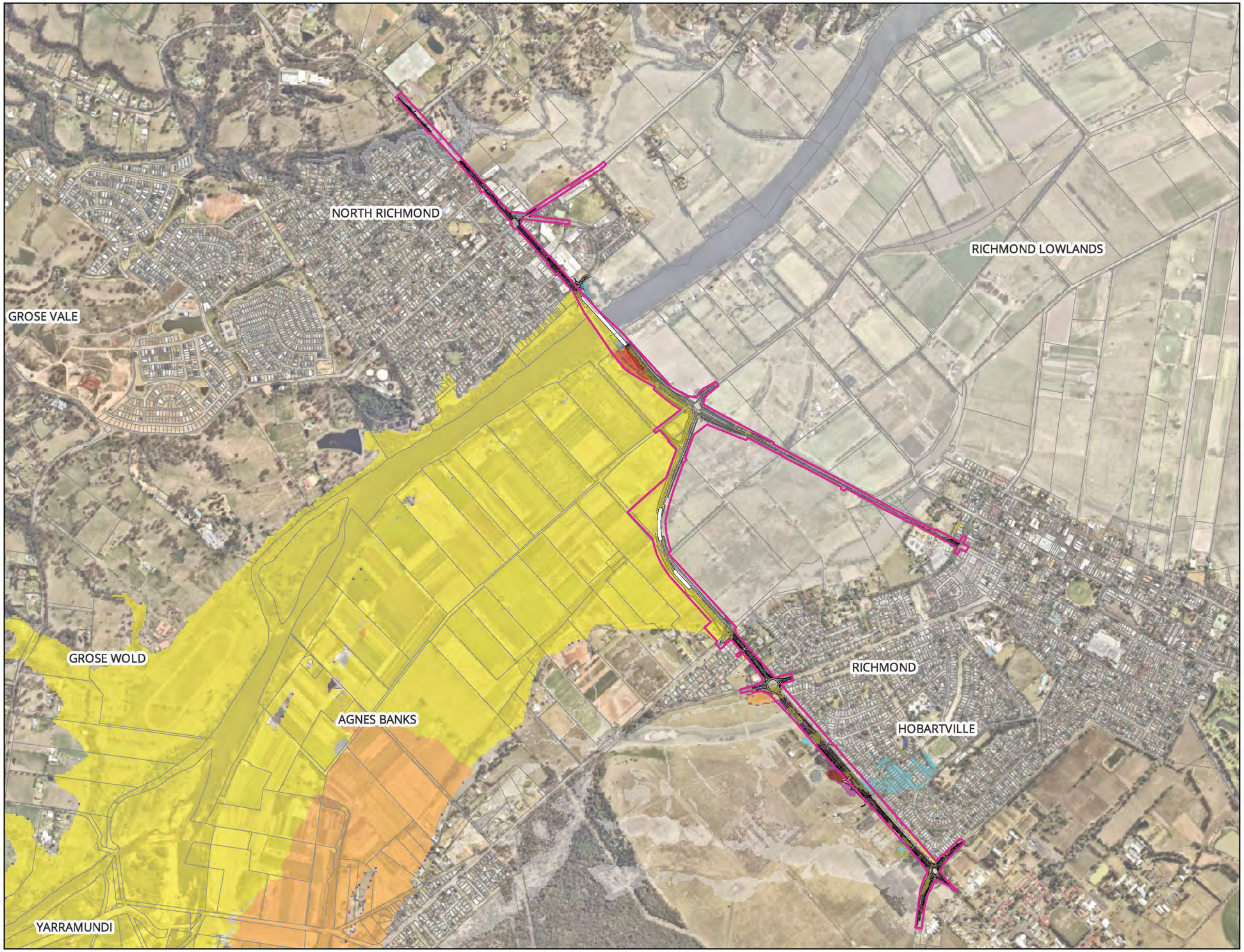
0 1,700 3,400 m

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.4: 2% AEP Peak Flood Level Afflux



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

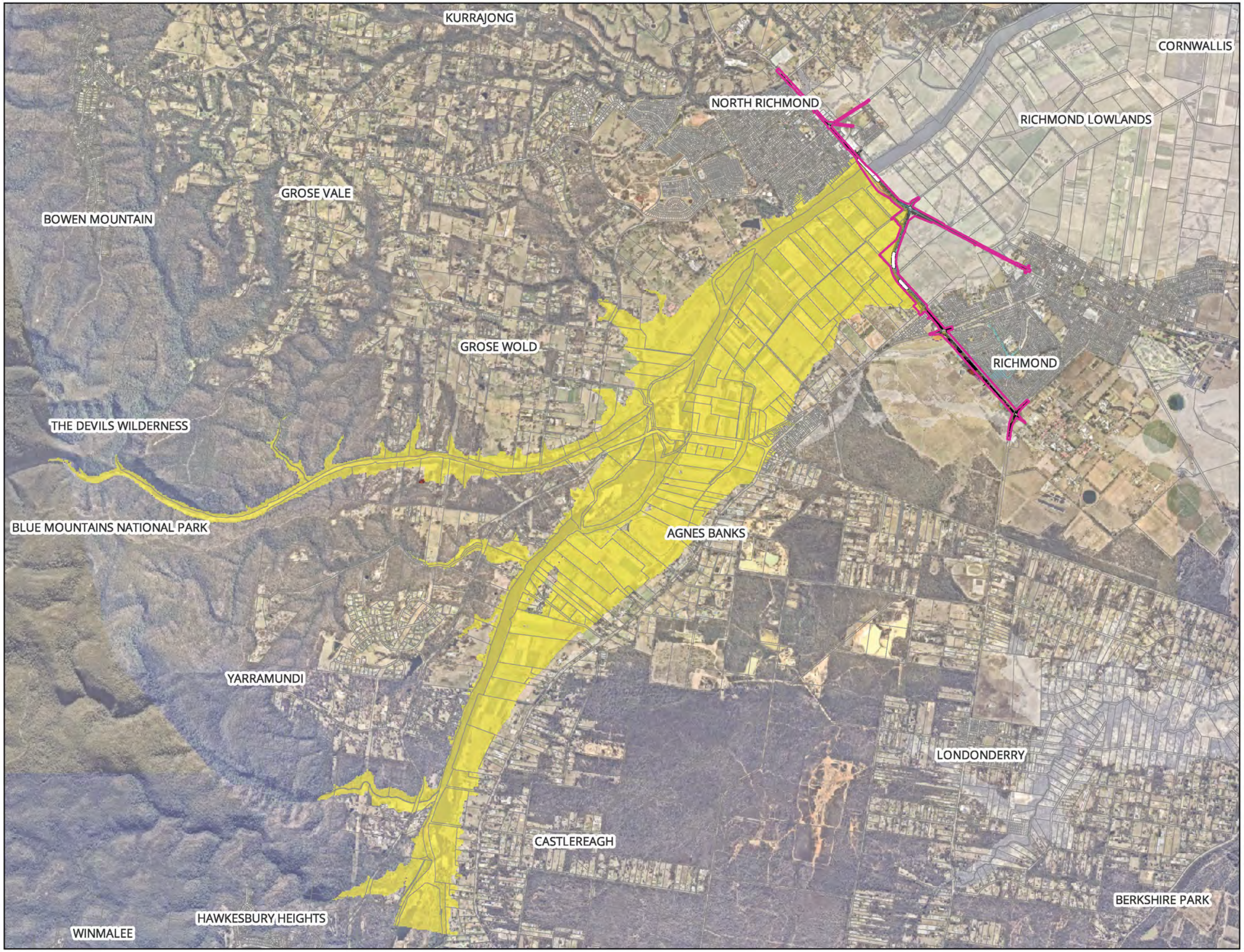
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.4A: 2% AEP Peak Flood Level Afflux (Proposal Area)



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

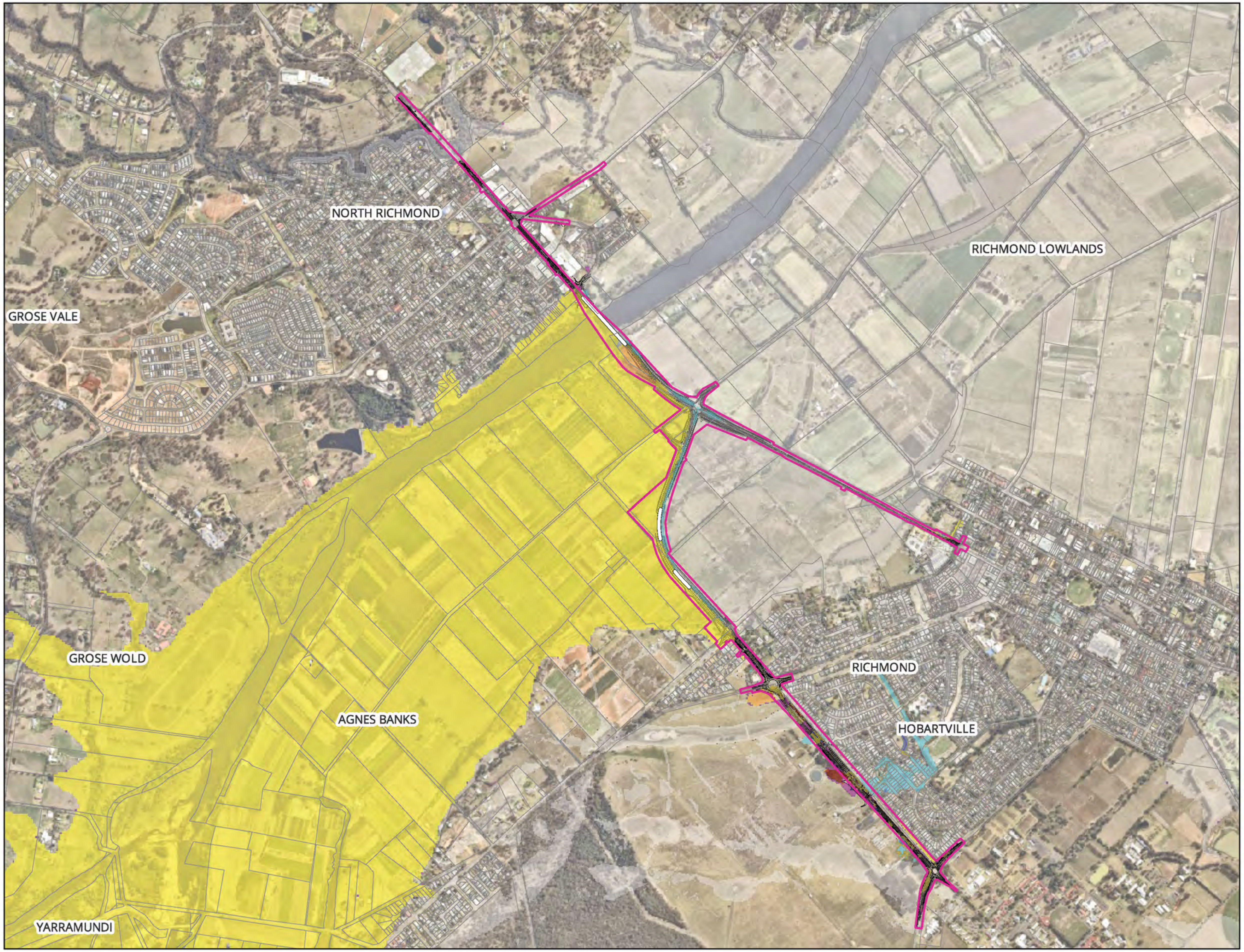
0 1,700 3,400 m

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.5: 1% AEP Peak Flood Level Afflux



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

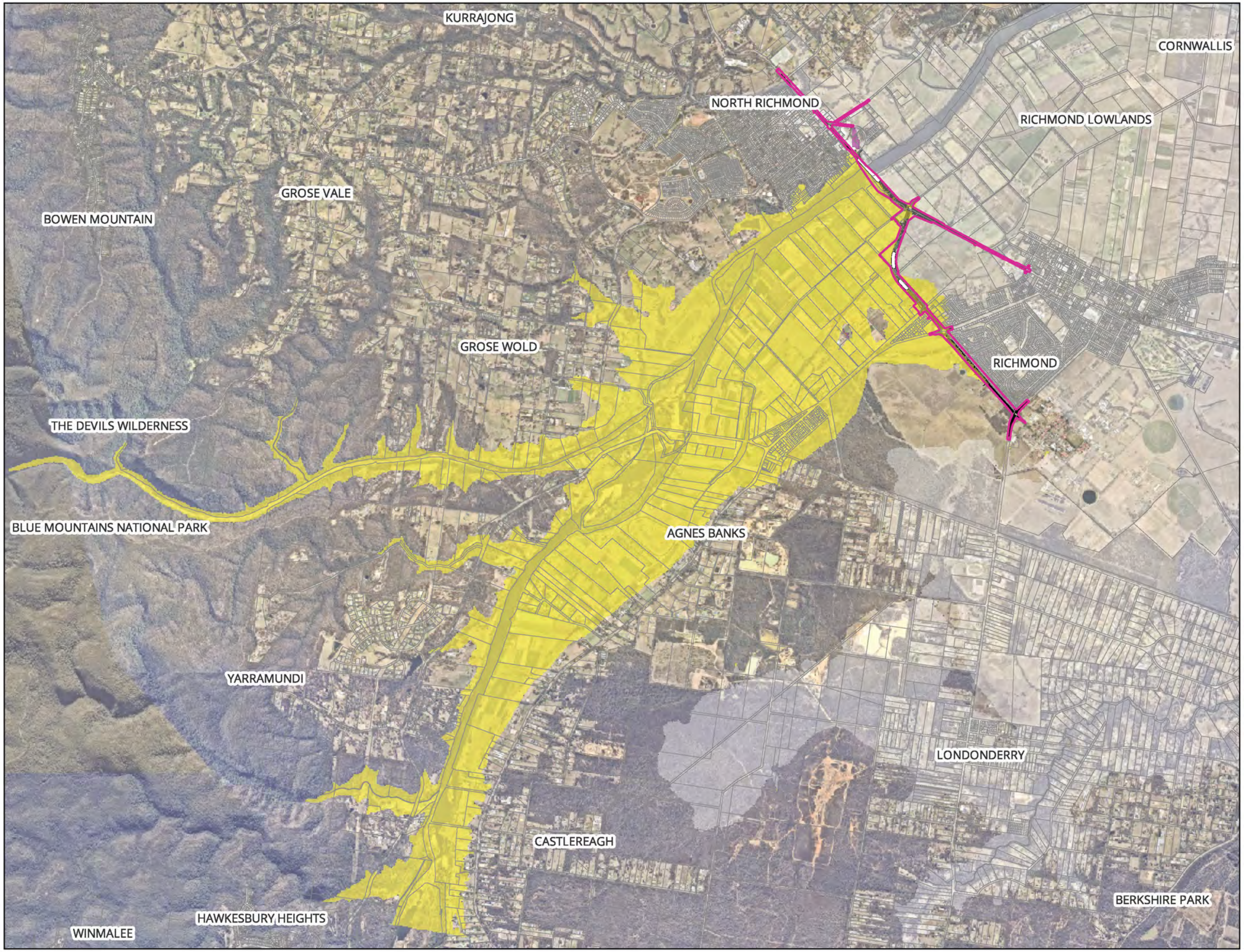
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.5A: 1% AEP Peak Flood Level Afflux (Proposal Area)



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

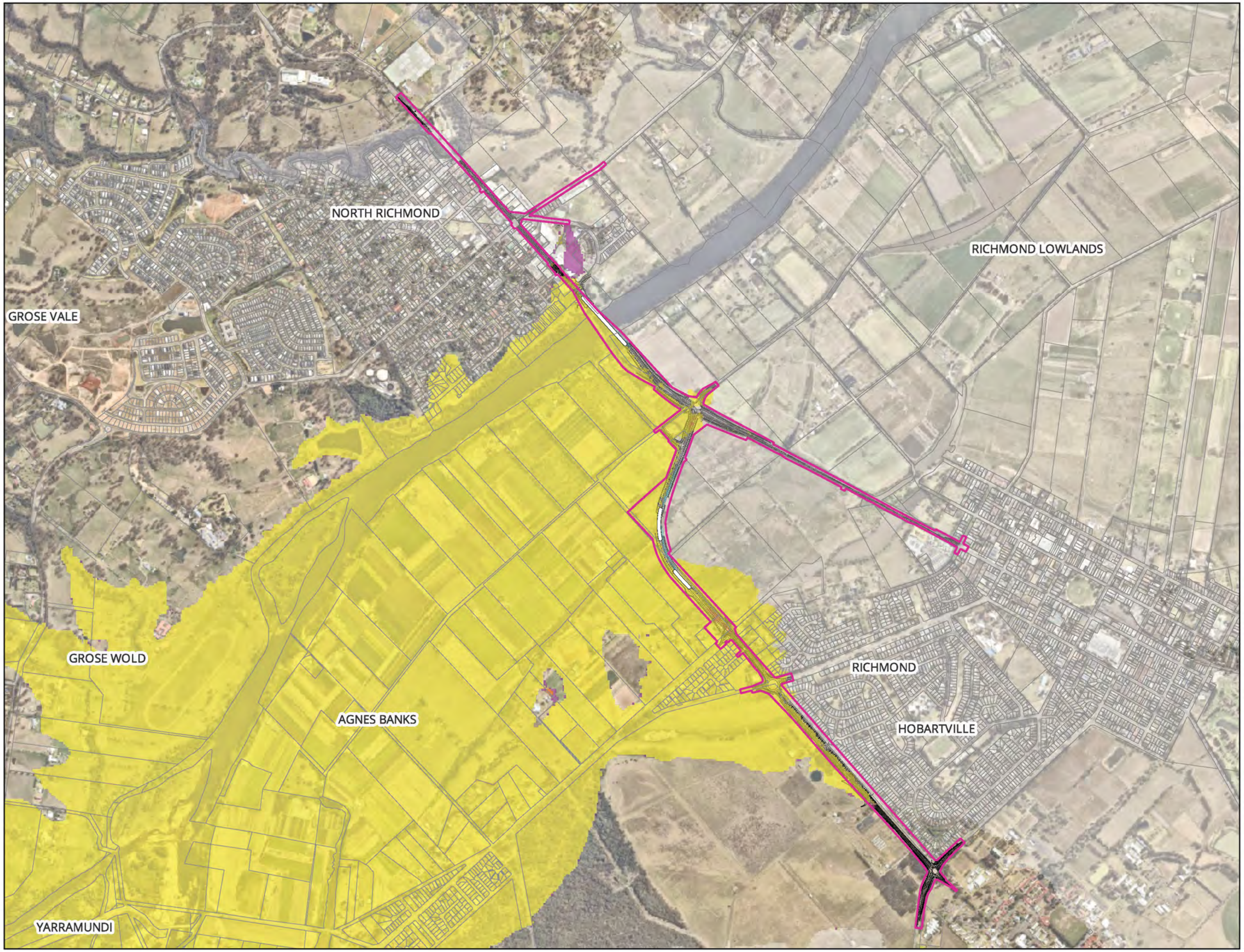
0 1,700 3,400 m

A3 Scale: 1:45,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.6: 0.05% AEP Peak Flood Level Afflux



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

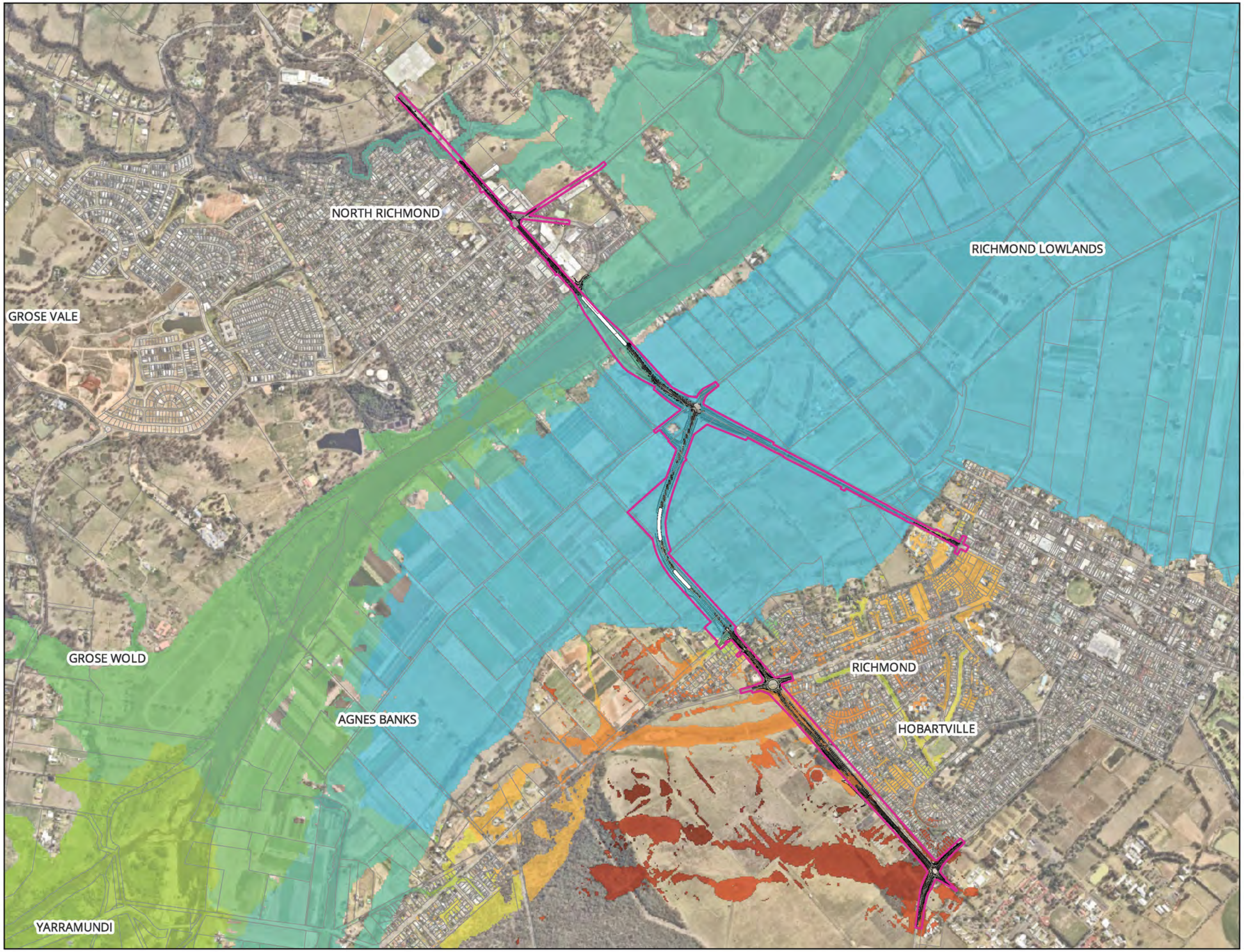
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 10.6A: 0.05% AEP Peak Flood Level Afflux (Proposal Area) aurecon



Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

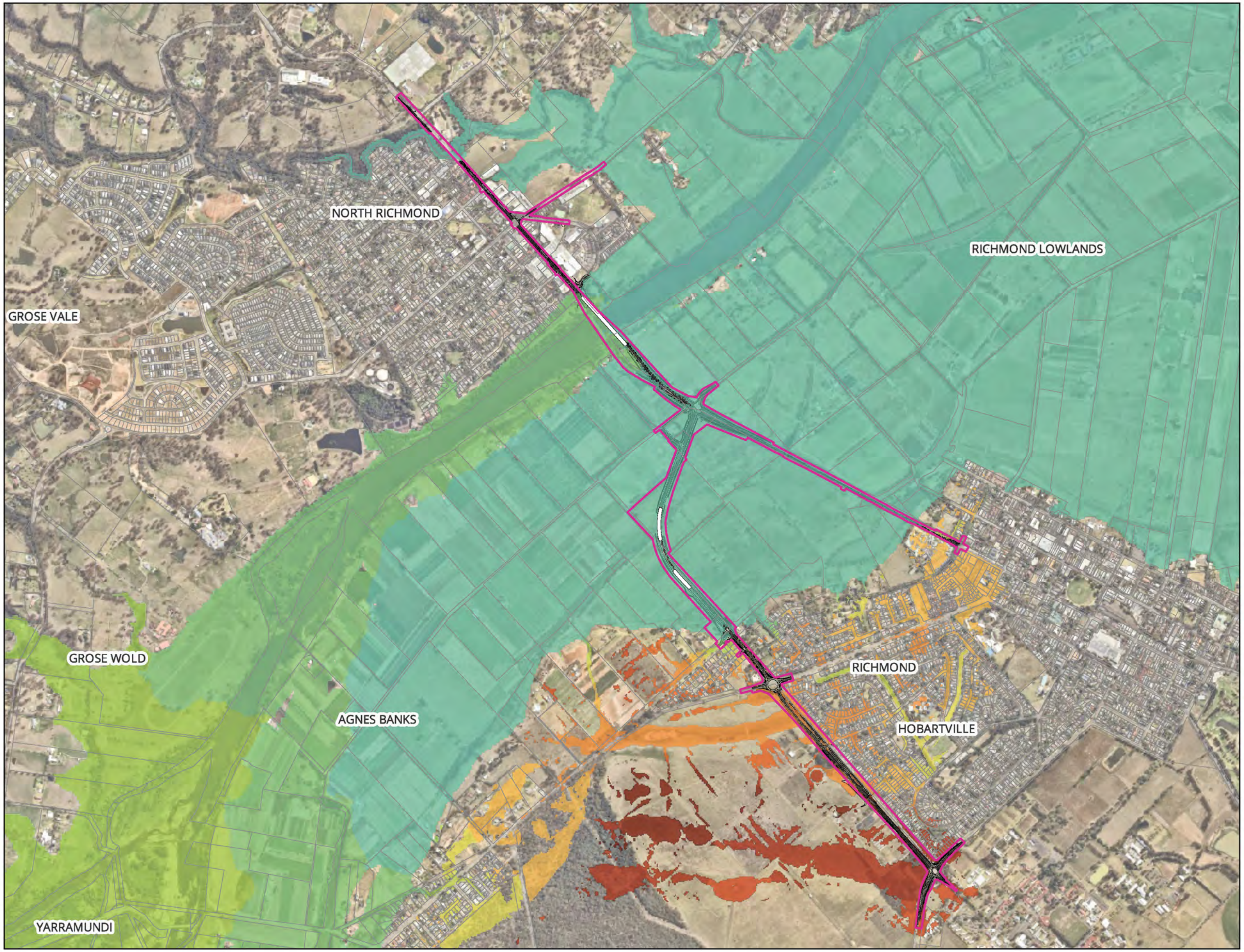
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.1: 5% AEP 2090 RCP 4.5 Peak Flood Level - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

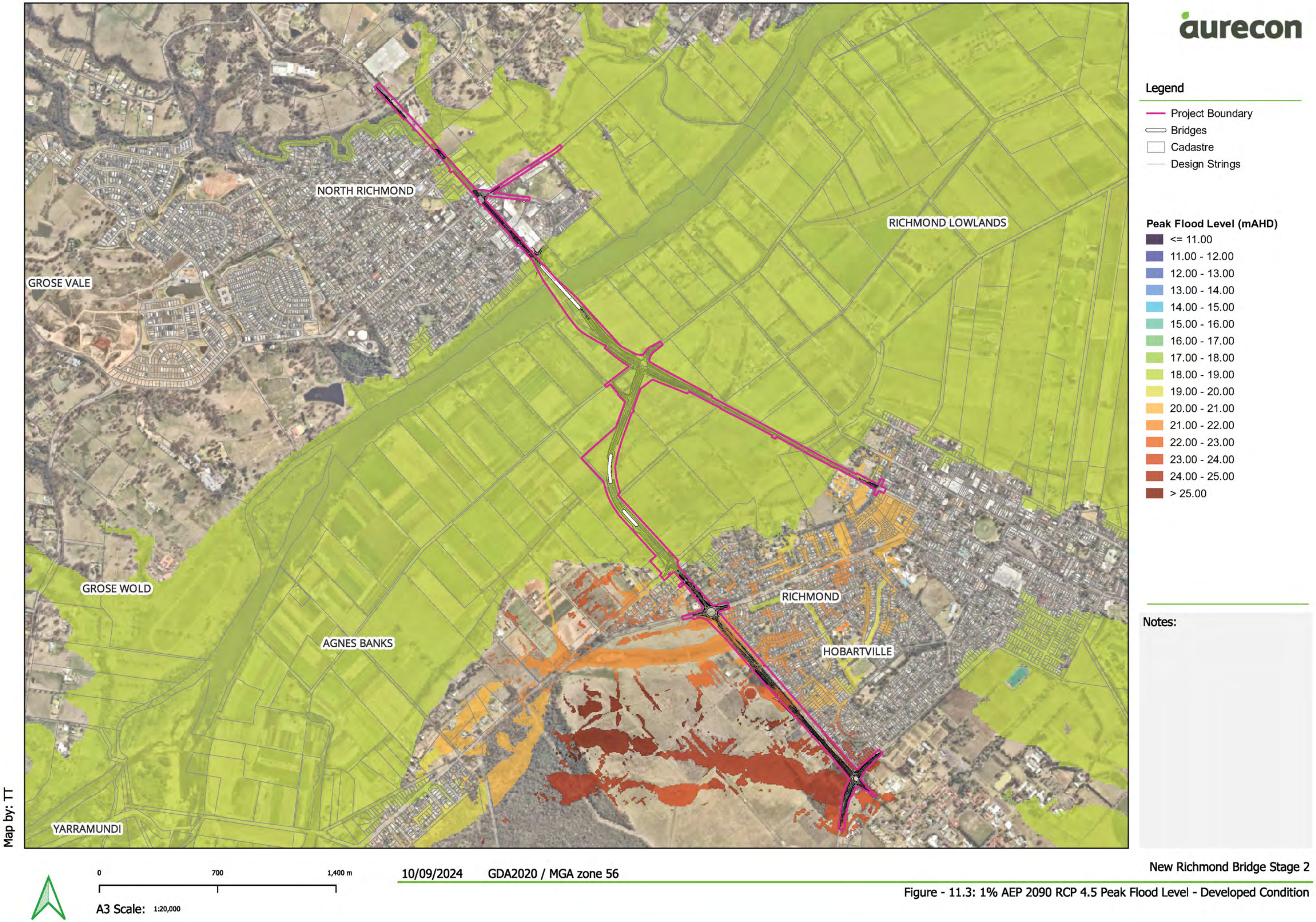
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.2: 5% AEP 2090 RCP 8.5 Peak Flood Level - Developed Condition



Notes:

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.3: 1% AEP 2090 RCP 4.5 Peak Flood Level - Developed Condition

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

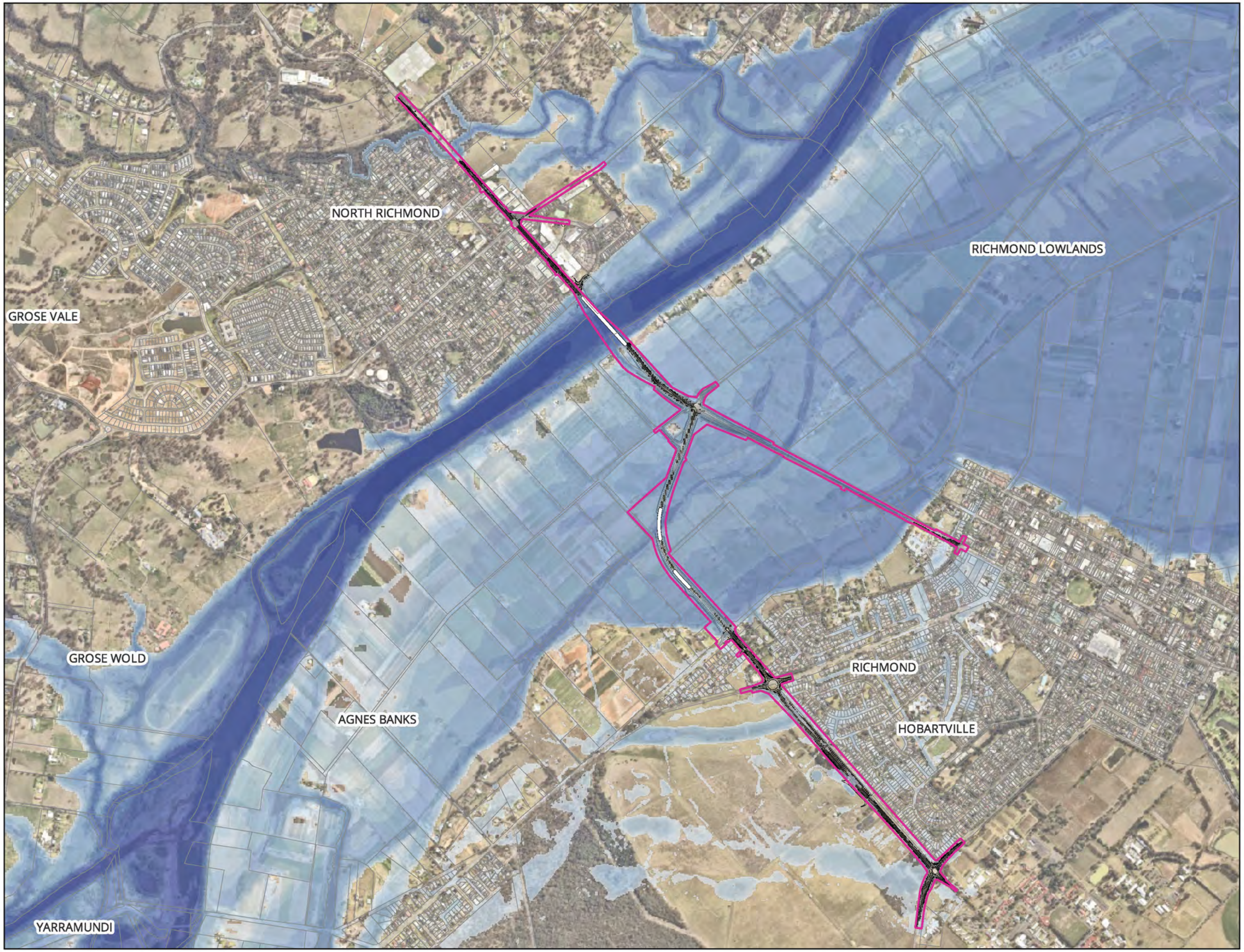
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.4: 1% AEP 2090 RCP 8.5 Peak Flood Level - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

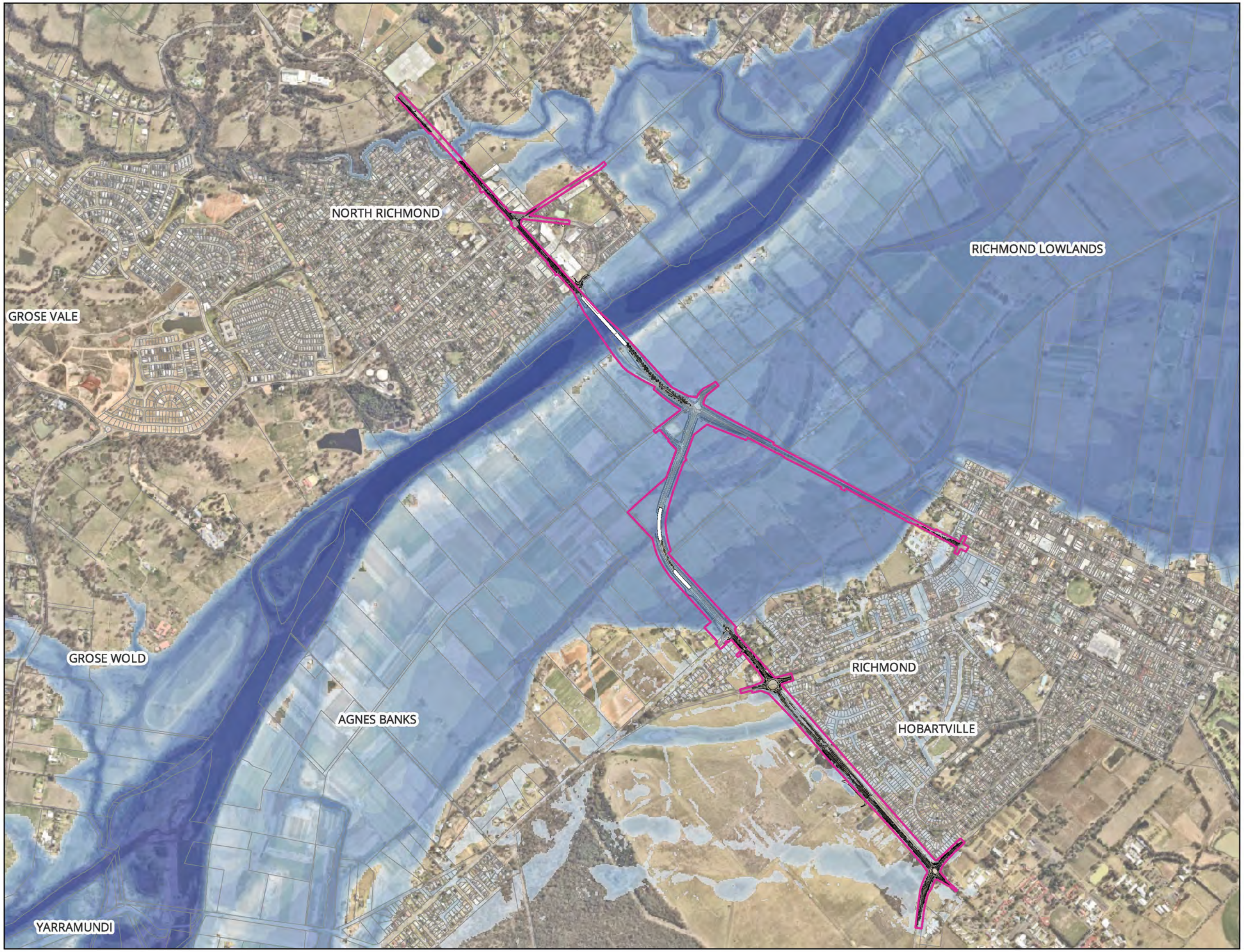
Map by: TT

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.5: 5% AEP 2090 RCP 4.5 Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

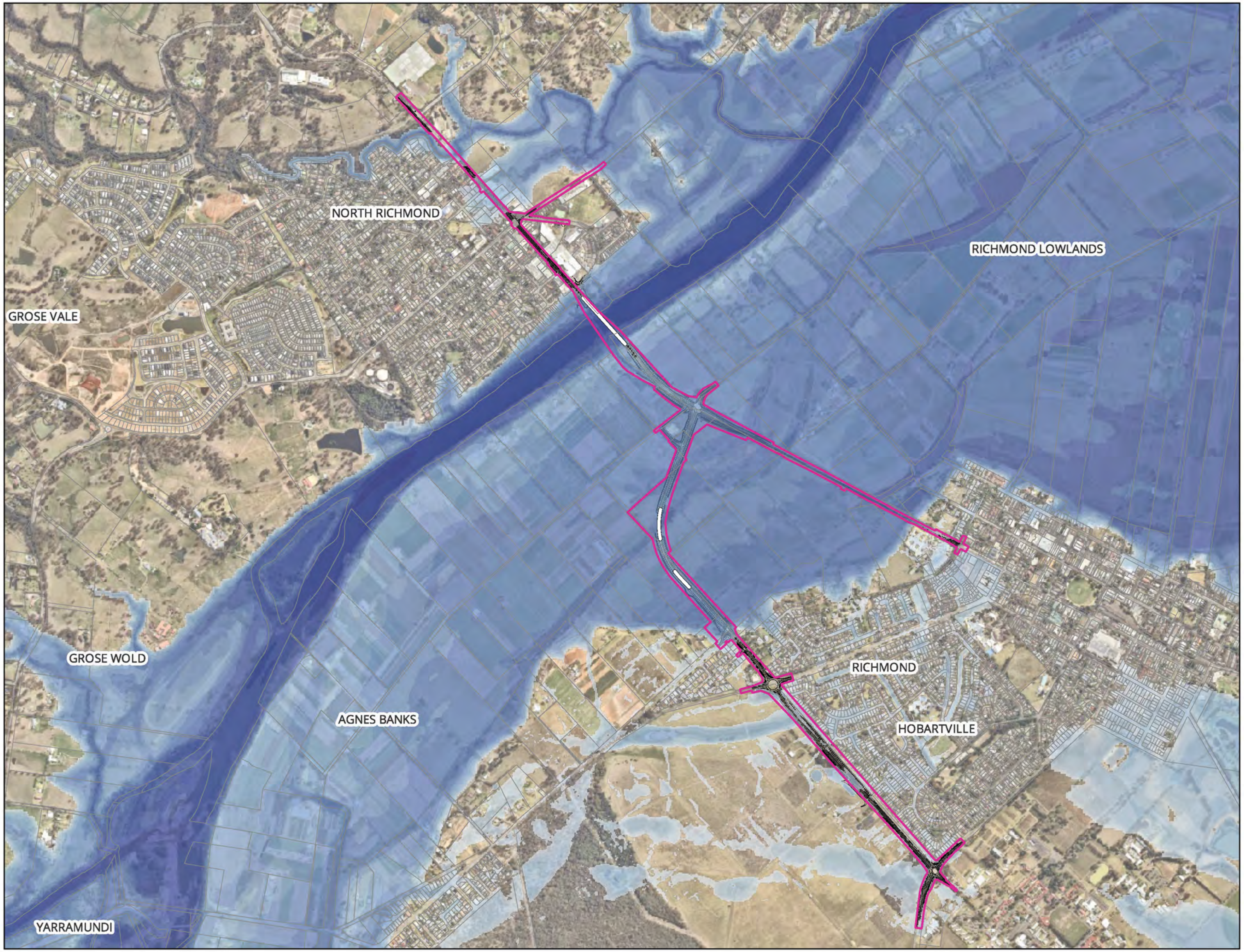
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.6: 5% AEP 2090 RCP 8.5 Peak Flood Depth - Developed Condition



Map by: TT

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

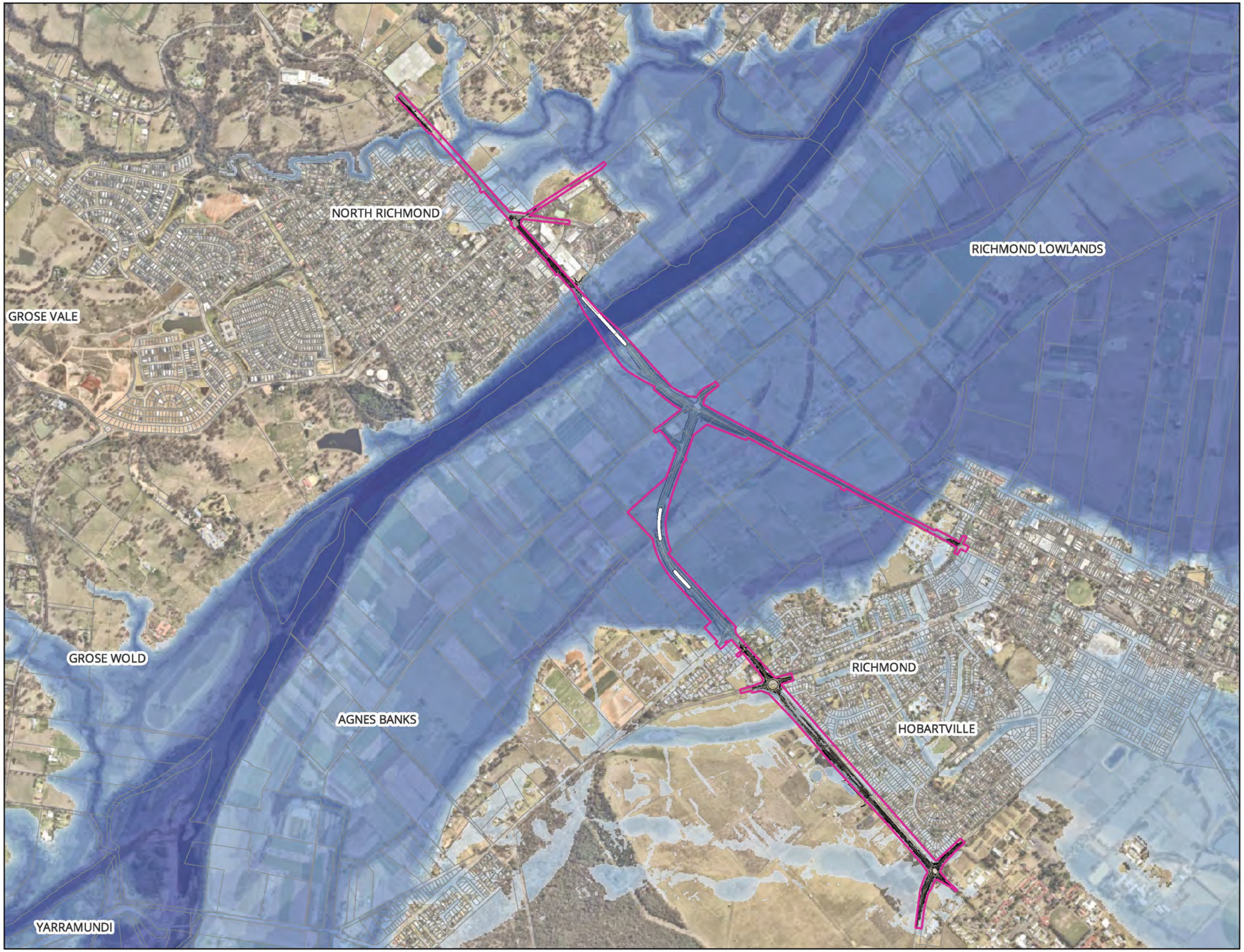
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.7: 1% AEP 2090 RCP 4.5 Peak Flood Depth - Developed Condition



Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

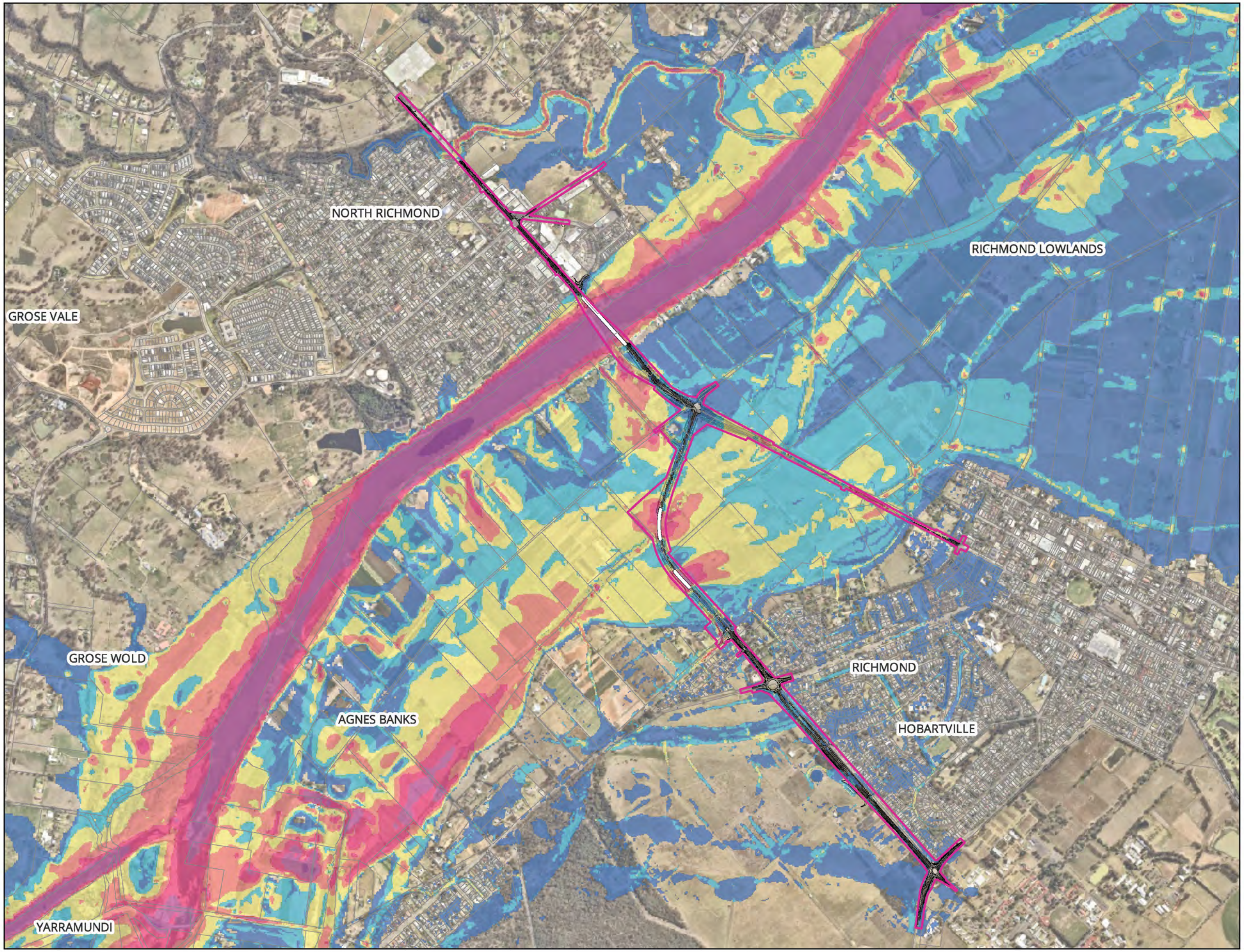
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.8: 1% AEP 2090 RCP 8.5 Peak Flood Depth - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

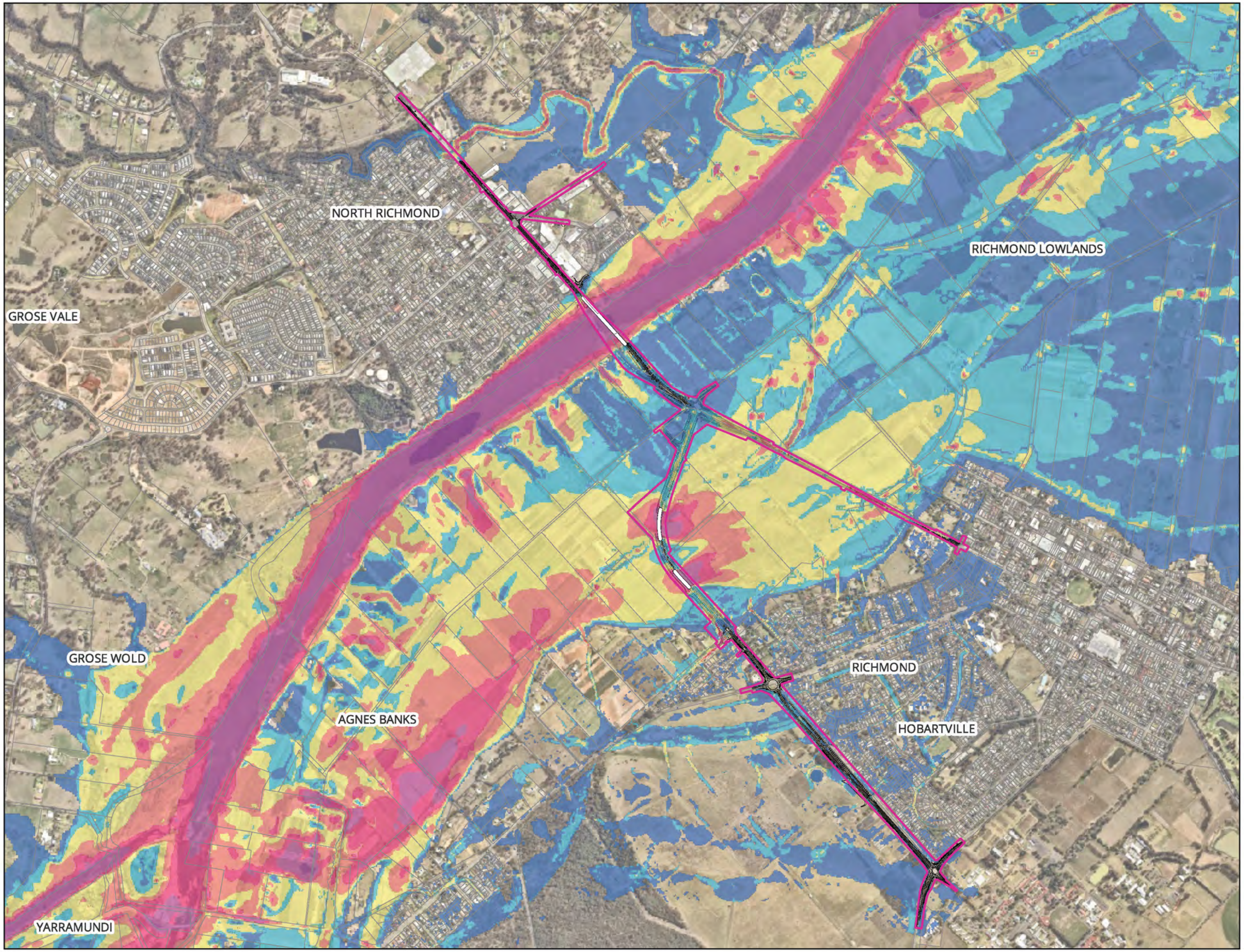
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.9: 5% AEP 2090 RCP 4.5 Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

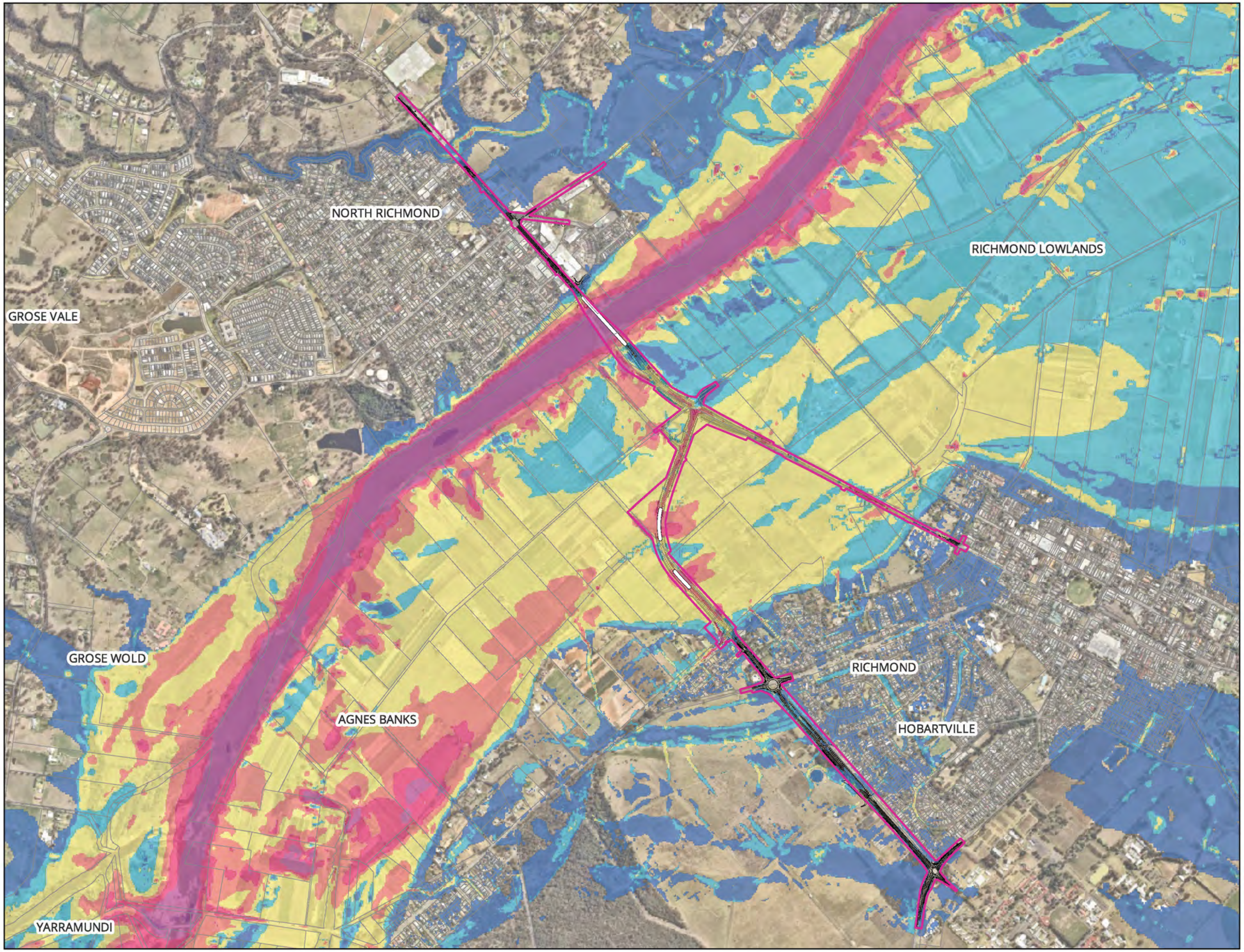
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.10: 5% AEP 2090 RCP 8.5 Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

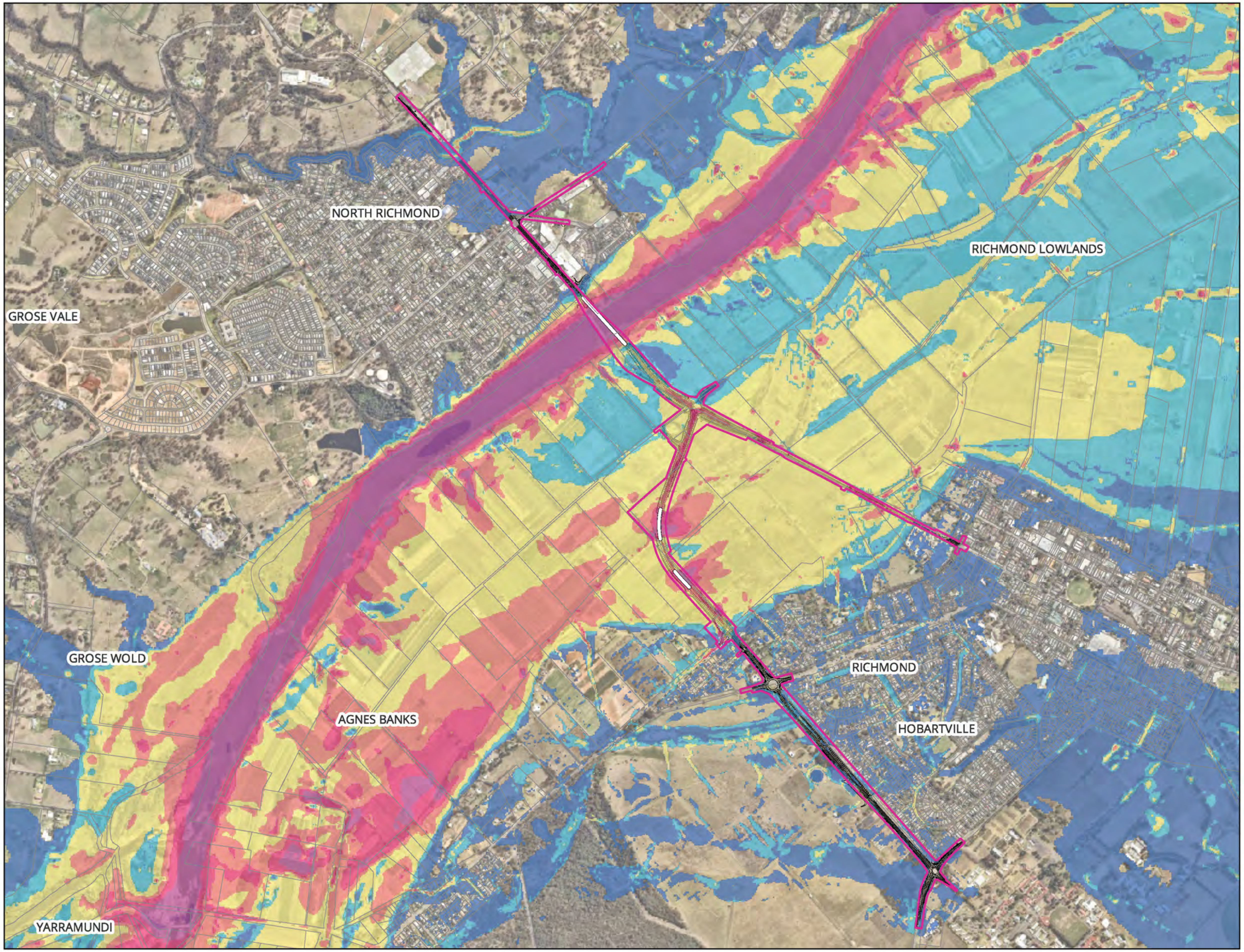
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.11: 1% AEP 2090 RCP 4.5 Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

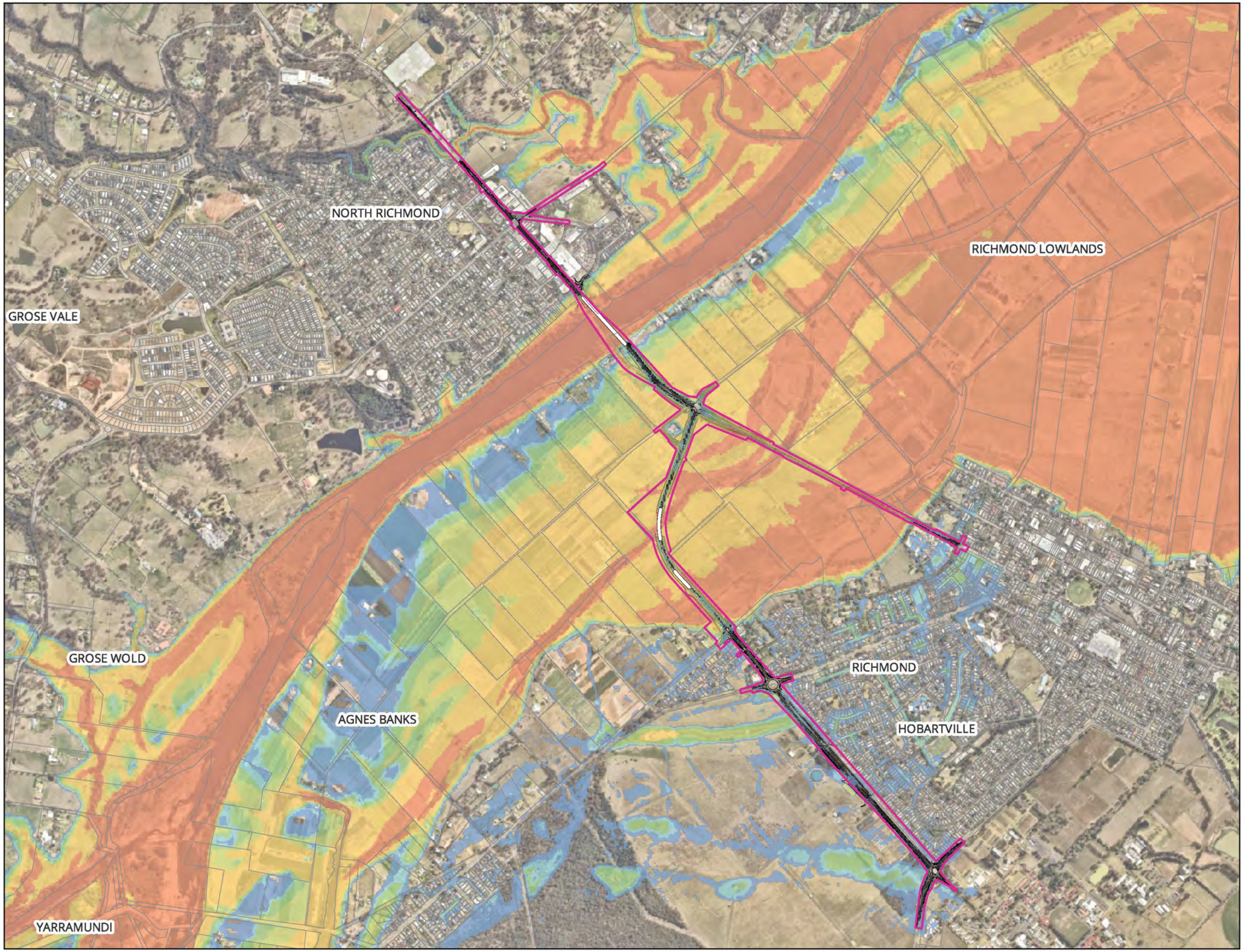
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.12: 1% AEP 2090 RCP 8.5 Peak Flood Velocity - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

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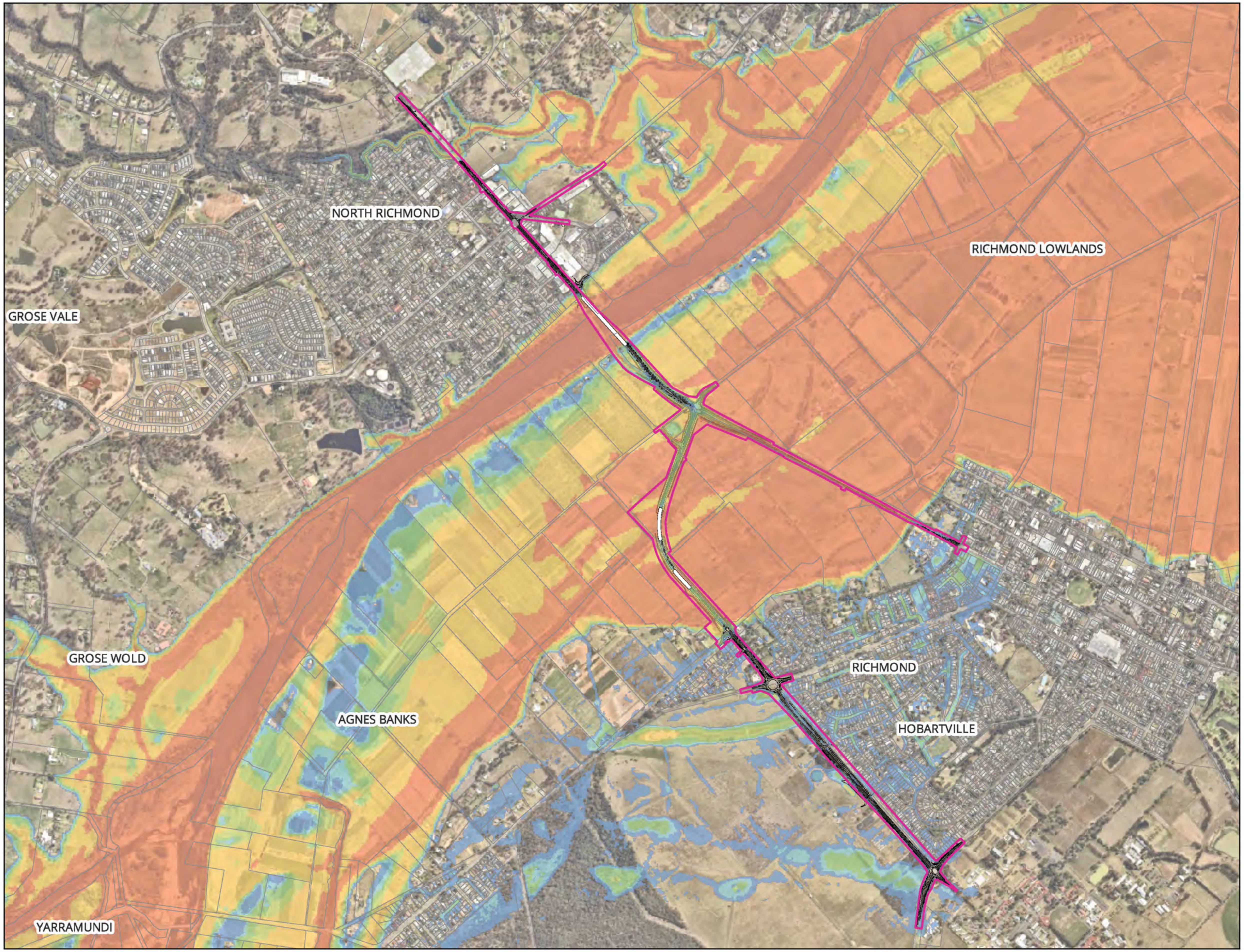
New Richmond Bridge Stage 2

Figure - 11.13: 5% AEP 2090 RCP 4.5 Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

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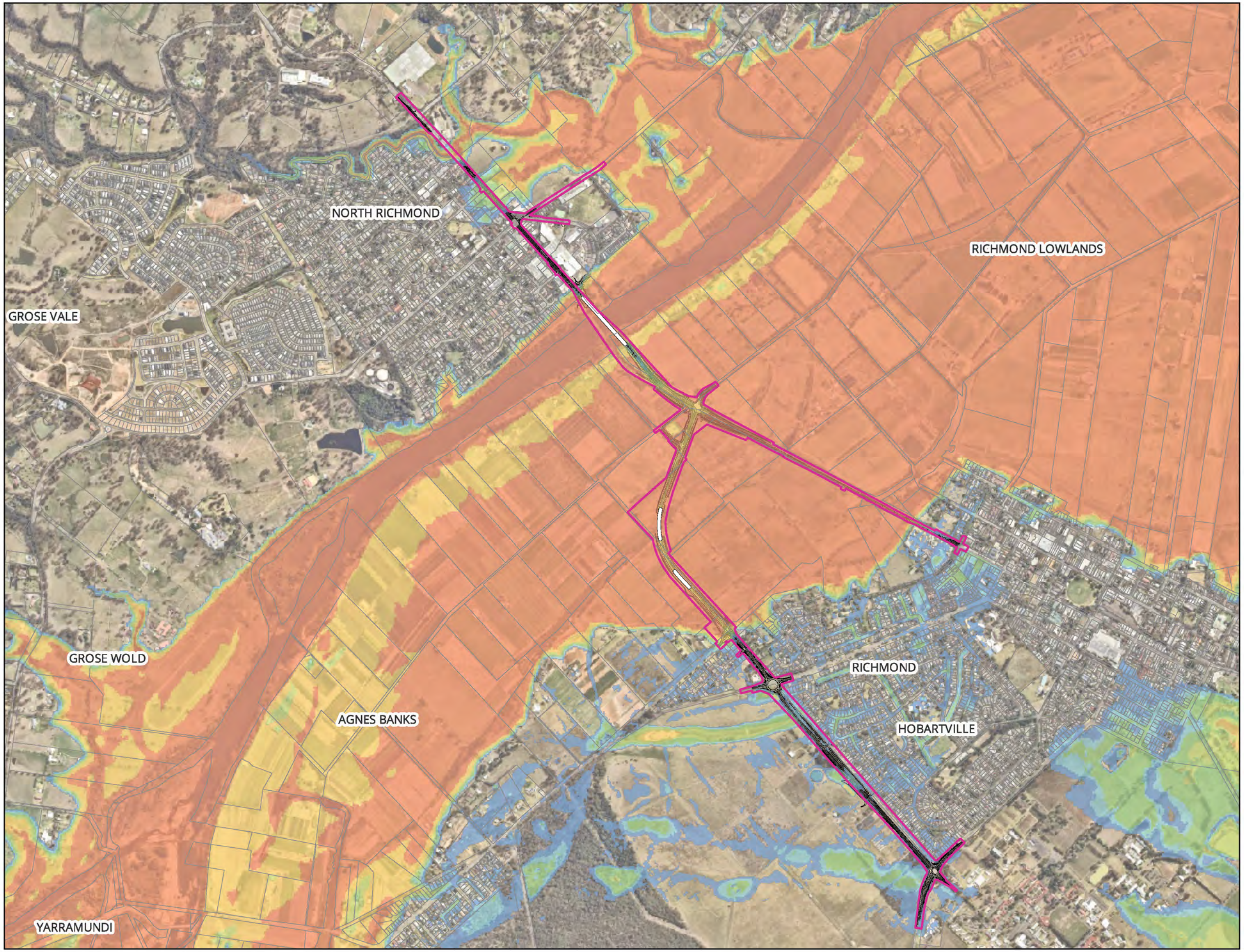
New Richmond Bridge Stage 2

Figure - 11.14: 5% AEP 2090 RCP 8.5 Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

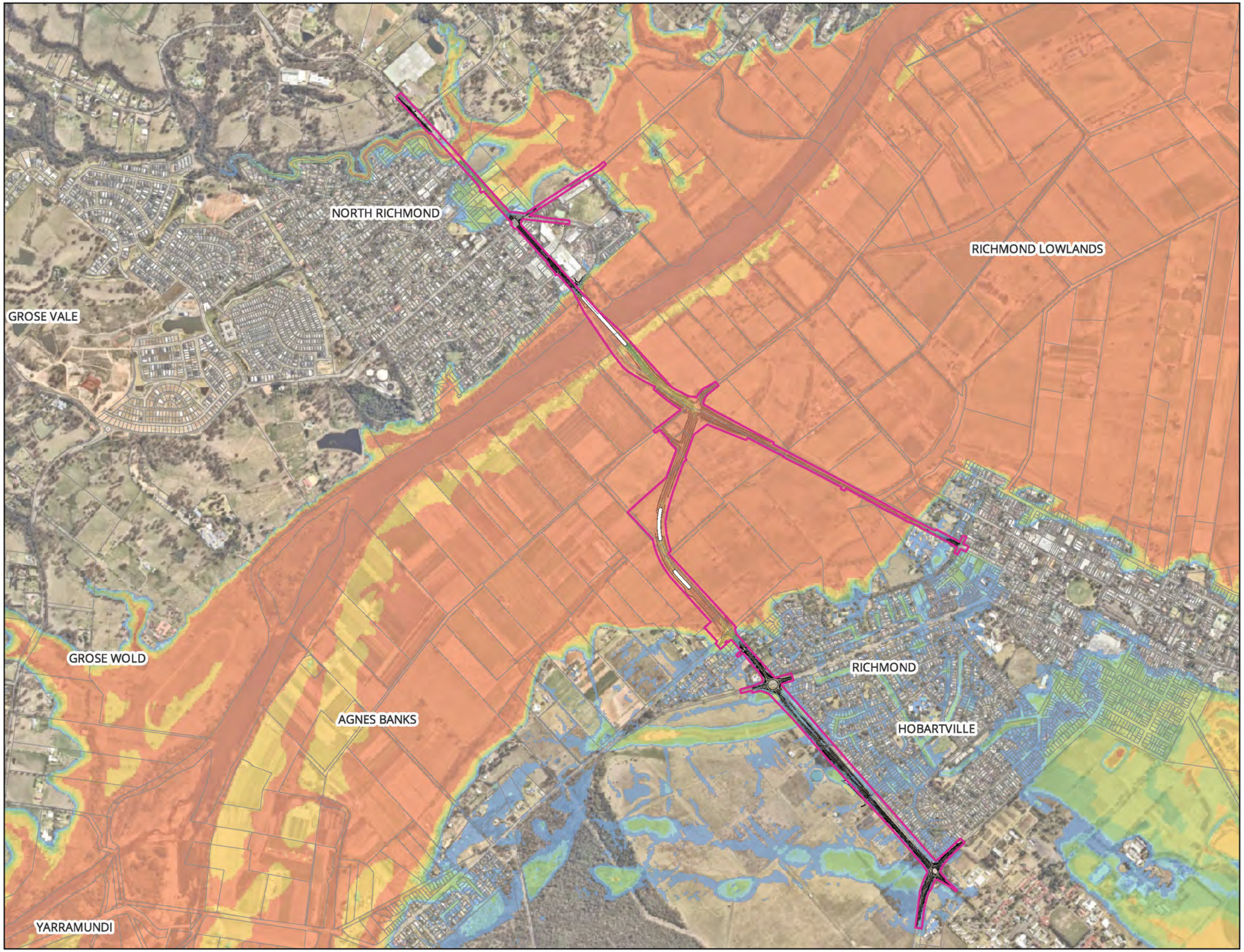
Notes:

Map by: TT

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.15: 1% AEP 2090 RCP 4.5 Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

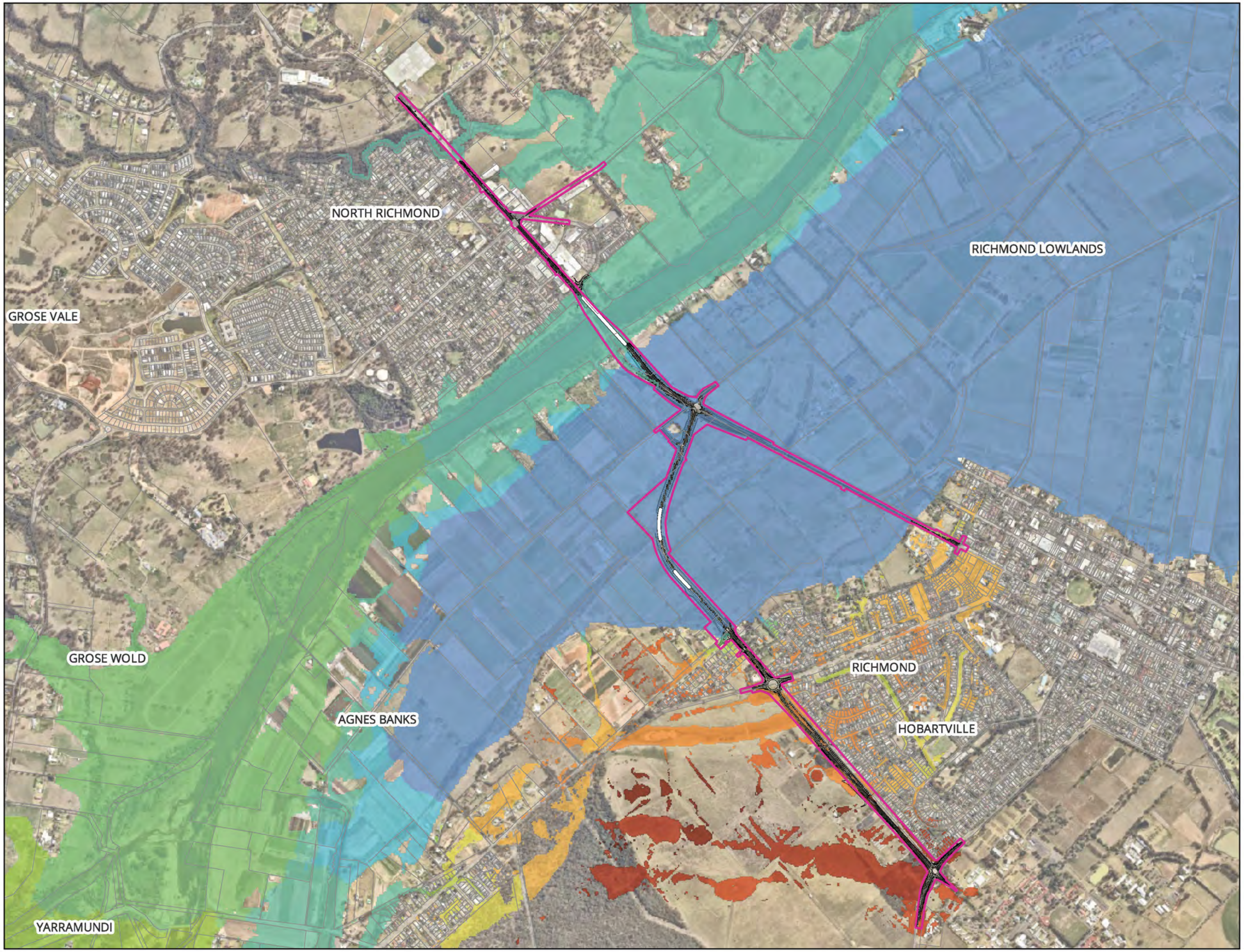
- H1
- H2
- H3
- H4
- H5
- H6

Notes:

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 11.16: 1% AEP 2090 RCP 8.5 Hazard - Developed Condition



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.1: 5% AEP Peak Flood Level - Developed Condition - Blockage

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

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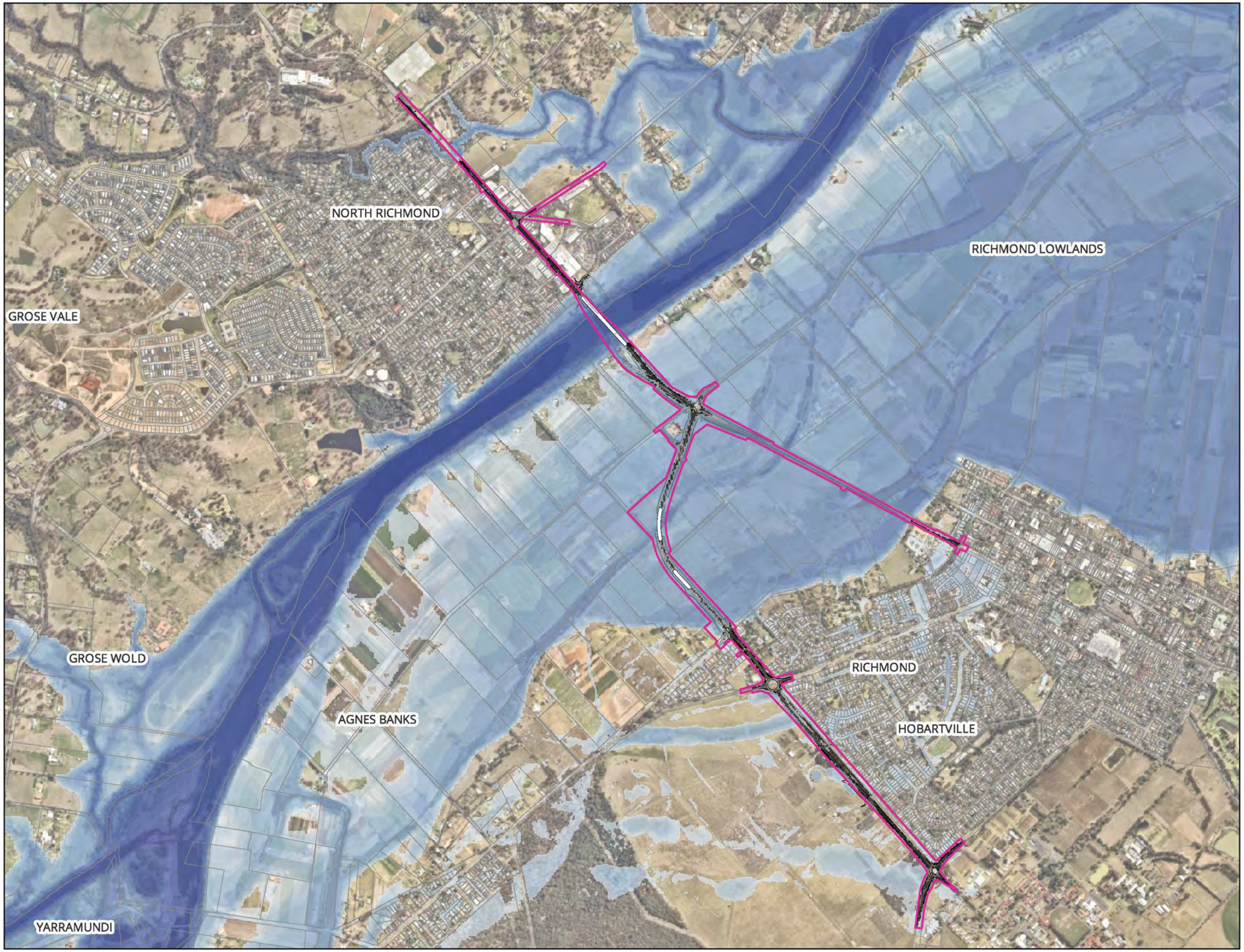
New Richmond Bridge Stage 2

Figure - 12.2: 5% AEP Peak Flood Level Afflux - Developed Condition - Blockage



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

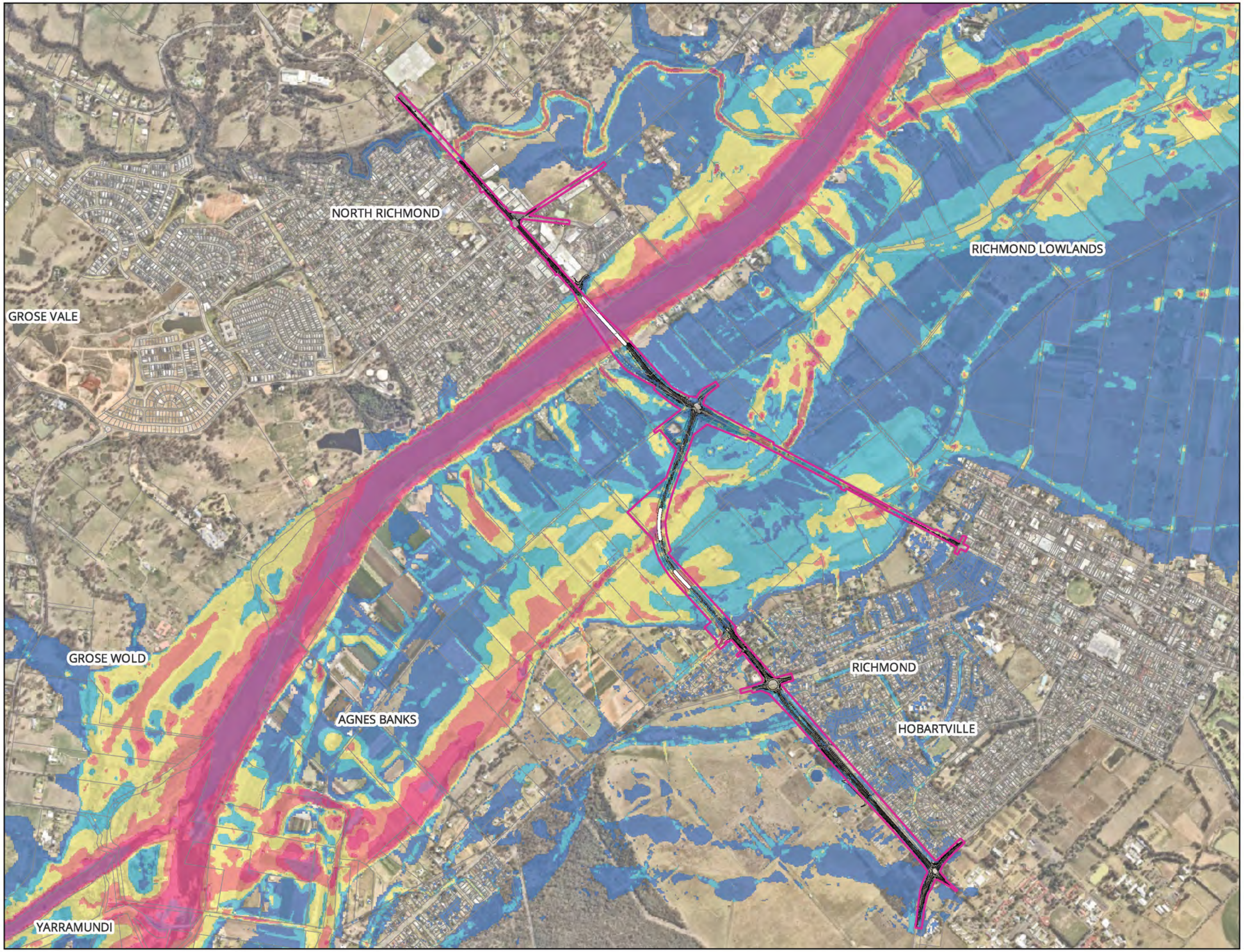
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.3: 5% AEP Peak Flood Depth - Developed Condition - Blockage



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

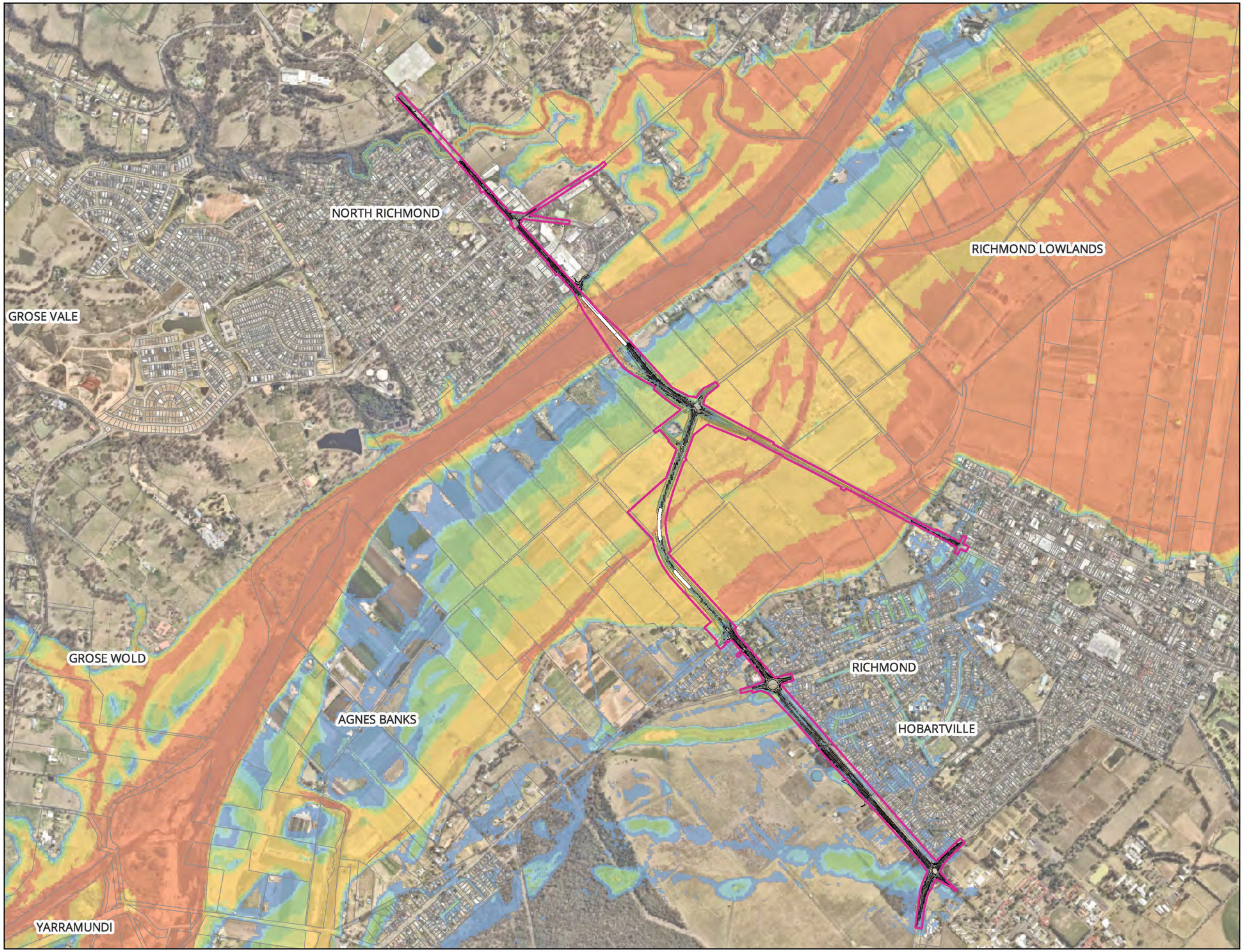
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.4: 5% AEP Peak Flood Velocity - Developed Condition - Blockage



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.5: 5% AEP Hazard - Developed Condition - Blockage

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Level (mAHD)

- <= 11.00
- 11.00 - 12.00
- 12.00 - 13.00
- 13.00 - 14.00
- 14.00 - 15.00
- 15.00 - 16.00
- 16.00 - 17.00
- 17.00 - 18.00
- 18.00 - 19.00
- 19.00 - 20.00
- 20.00 - 21.00
- 21.00 - 22.00
- 22.00 - 23.00
- 23.00 - 24.00
- 24.00 - 25.00
- > 25.00

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.6: 1% AEP Peak Flood Level - Developed Condition - Blockage

aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Changes in Water Level

- Area no longer inundated
- Less than -0.25
- -0.25 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.15
- 0.15 to 0.25
- Greater than 0.25
- New area of inundation

Notes:

Map by: TT

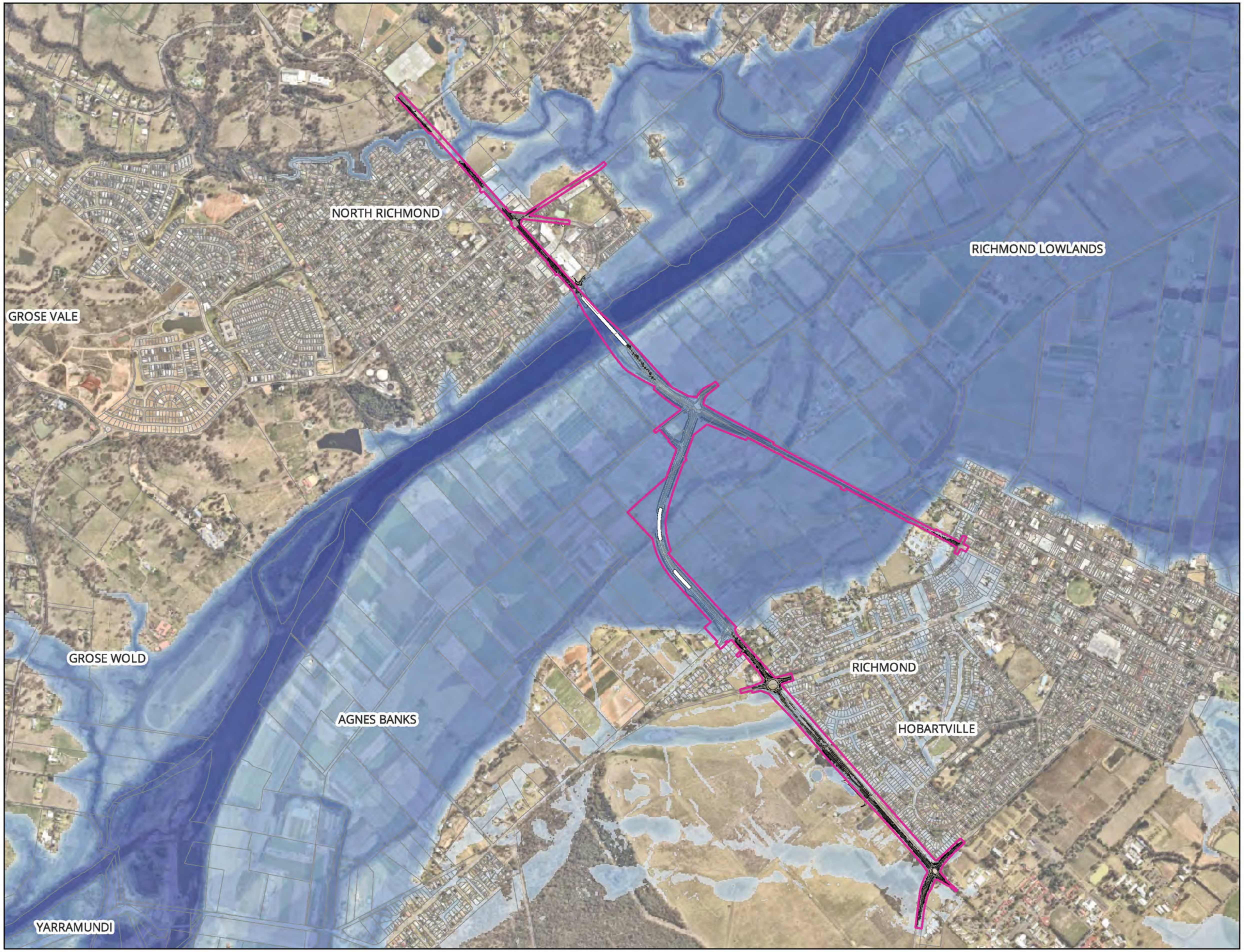
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.7: 1% AEP Peak Flood Level Afflux - Developed Condition - Blockage



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Depth (m)

- <= 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.50
- 3.50 - 5.00
- 5.00 - 7.50
- 7.50 - 10.00
- 10.00 - 15.00
- 15.00 - 20.00
- 20.00 - 25.00
- > 25.00

Notes:

Map by: TT

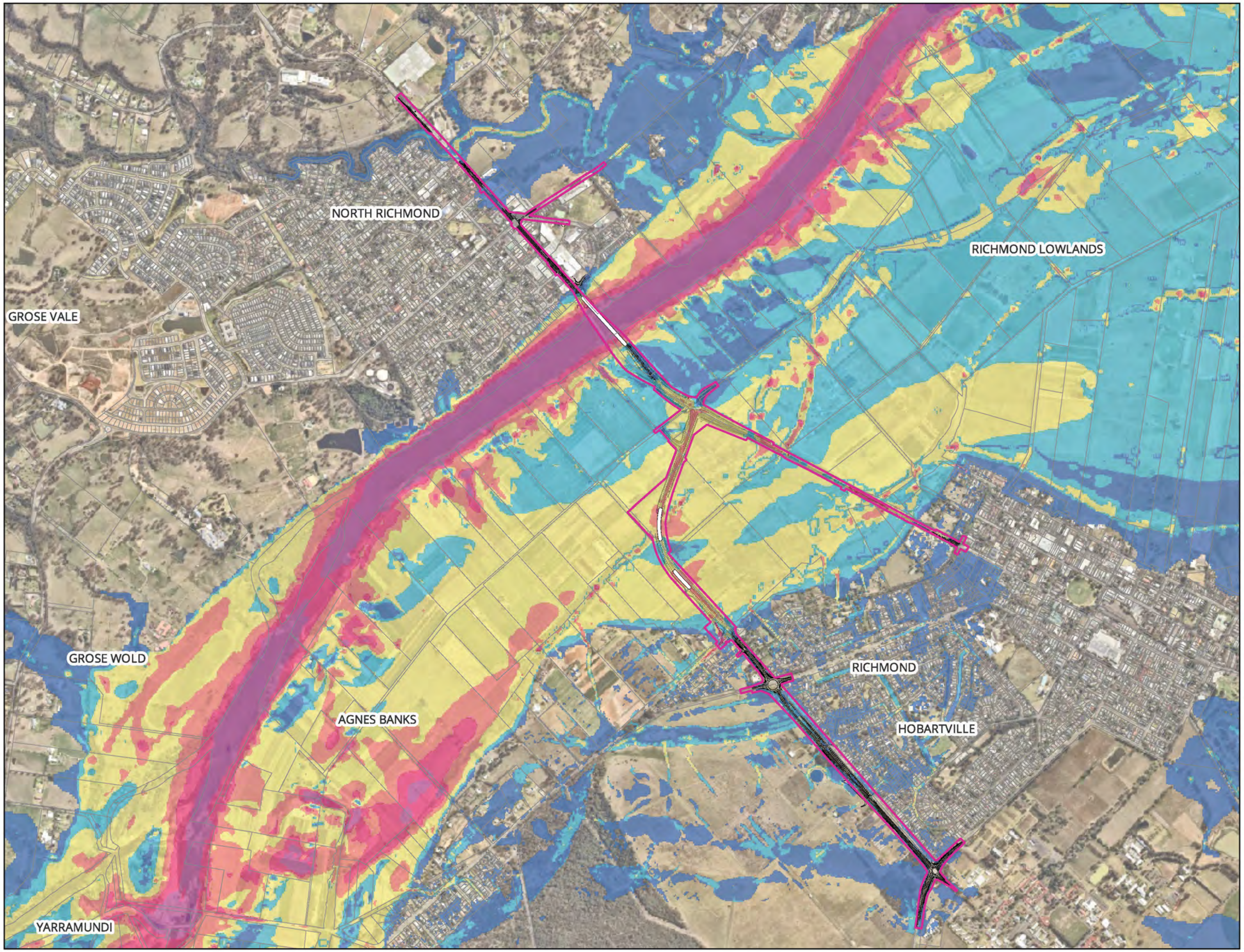
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.8: 1% AEP Peak Flood Depth - Developed Condition - Blockage



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- >4.0

Notes:

Map by: TT

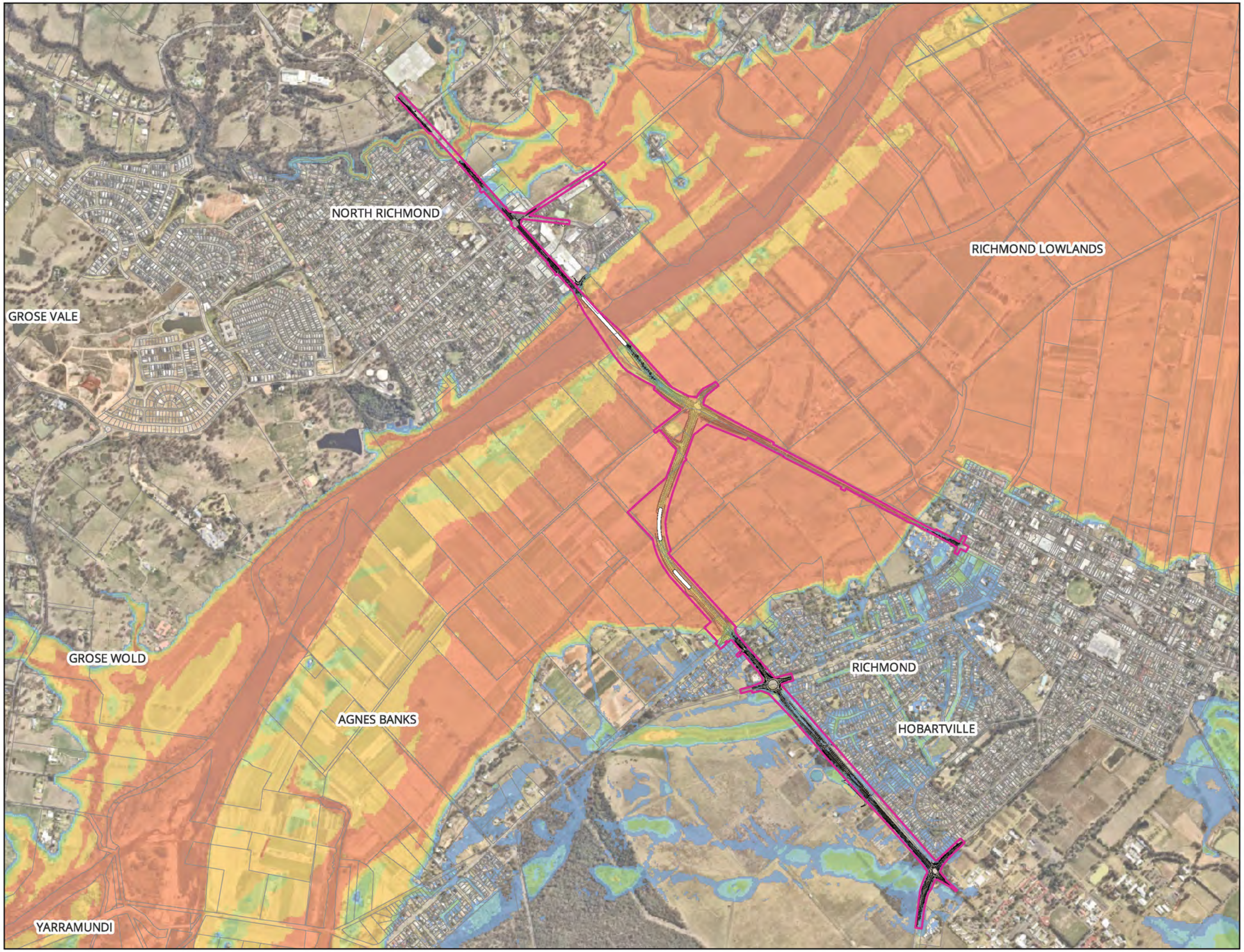
0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.9: 1% AEP Peak Flood Velocity - Developed Condition - Blockage



aurecon

Legend

- Project Boundary
- Bridges
- Cadastre
- Design Strings

Peak Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Notes:

Map by: TT

0 700 1,400 m

A3 Scale: 1:20,000

10/09/2024 GDA2020 / MGA zone 56

New Richmond Bridge Stage 2

Figure - 12.10: 1% AEP Hazard - Developed Condition - Blockage

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