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NSW GOVERNMENT

M1 Pacific Motorway extension to Raymond Terrace

Hydrology and Flooding Working Paper

Transport for NSW | July 2021

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Executive summary

Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Purpose of this report

This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSI 7319) relating to flooding and water (hydrology). In addition, the desired performance outcomes for the project in relation to flooding and water (hydrology) as outlined in the SEARs (SSI 7319) is to:

- Flooding (SEAR 5) are to:
  - Minimise adverse impacts on existing flooding characteristics
  - Avoid, or minimise the risk of adverse impacts from infrastructure flooding, flooding hazards, or dam failure during construction and operation of the project.
- Water – hydrology (SEAR 7), are to:
  - Minimise long term impacts on surface water and groundwater hydrology, including drawdown, flow rates and volumes
  - Maintain (where values are achieved) or improve and maintain (where values are not achieved) the environmental values of nearby connected and affected water sources, groundwater and dependent ecological systems, including estuarine and marine water
  - Provide for the sustainable use of water resources.

Overview of potential hydrology and flooding impacts

The concept design for the project was developed considering a range of engineering, environmental, social, land-use and economic criteria. The project represented the best balance after a multi-criteria analysis of all known constraints and opportunities. By adopting a viaduct instead of an embankment across the Hunter River floodplain, the project has avoided substantial upstream flooding impacts (including impacts to drainage capacity, flood storage and conveyance) as well as groundwater impedance and level impacts. Other impacts, such as local afflux and erosion and scour directly downstream of the project were also minimised during the design development.

Once operational, the project would improve the accessibility of the Pacific Highway between Black Hill and Raymond Terrace including across the Hunter River floodplain during flood events by improving the flood immunity of the roadway from existing road condition. This is particularly significant as the Pacific Highway forms an important flood evacuation and emergency access route during floods.

Impacts on flooding and hydrology from the project would mainly be associated with minor increases in flood levels and impact on some properties. A summary of the impacts of the project on surface water and groundwater hydrology, and flooding are provided below.

Surface water hydrology impacts

Operational phase hydraulic modelling results indicate that the project may result in a moderate increase to the rate, volume and velocity of stormwater discharged downstream of the project. Although modelling was not completed for the construction phase of the project, potential changes to stormwater discharges are expected to follow the same trend of increased rates, volumes and velocity.

As a result of these quantified changes to stormwater discharge, the project is likely to result in the following additional changes to existing receiving environment flow regimes during operation:

- A minor reduction in baseflow and moderate increase to quickflow contributions
- Minor to moderate increases to the rates of water level rise and fall
- Minor changes to the number, duration and magnitude of low flow events.

Changes to existing flow regimes identified above may result in impacts to local receiving waterway processes and health, immediately downstream of project discharge locations from storm events. Impacts include increased erosion and water turbidity, reduced bank stability and minor increases to the duration and depth of inundation for overbank events. Monitoring of the impacts identified above is proposed for the areas immediately surrounding the project stormwater discharge locations.

Groundwater hydrology impacts

The project is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including groundwater dependent ecosystems and other groundwater users. No impacts are expected to the nearby Tomago Sandbeds Catchment drinking water supply.

Flooding impacts

During construction, flood level increases are generally between 0.02–0.1 metres in the 5% annual exceedance probability (AEP) event. There are 19 lots and five habitable buildings, including one dwelling near the Tarro interchange, identified as experiencing afflux exceeding the adopted criteria during construction.

During operation, flood level increases generally between 0.02–0.04 metres in the 5% and 1% AEP events are expected to occur. A dwelling near the Tarro interchange experiences an increase of up to 0.06 metres, which exceeds the afflux design objective criterion during a 5% AEP flood event. Flood levels in vegetated local catchments on the eastern side of the project and between the viaduct and Heatherbrae change by up to +/- 0.1 metres as a result of changed transverse drainage capacity. Flood levels in the probable maximum flood generally increase by up to 0.08 metres across the Hunter River floodplain during operation. There are 10 lots and one habitable building identified as experiencing afflux exceeding the adopted criteria during operation.

Broadly, the project achieves the flood management objectives and criteria including for afflux, flood hazard and flood duration. The large majority of existing flood-affected residential, commercial and industrial properties experience at most a negligible in flood depth (defined as a 0.01 metre change), hazard and time of inundation (defined as a change of up to three hours) during operation of the project.

Localised increases in flow velocities, flood hazard and duration of inundation are expected, with overall negligible to minor impacts. The absence of widespread increases in flood hazard indicate that there is negligible change to flood hydraulic characteristics, including floodways and flood storages.

Negligible to minor impacts are expected to agricultural and grazing activities, emergency services (including evacuation routes), future development potential of affected lands, existing roads and rail infrastructure.

The project would impact on the Hunter Valley Flood Mitigation Scheme as a result of access roads to be constructed immediately next to the existing flood levees on the western Hunter River floodplain. While these roads may modify the structure and maintenance of the levees, they are not expected to impact operation, function or structural integrity of the scheme (including the floodgates). Transport will continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

Climate change impacts on flooding

Sensitivity analysis of flood levels and project flood immunity to climate change has been carried out.

Under the main alignment of the project remains flood-free in the 5% AEP flood (existing climate) with a year 2100 sea level rise of 0.9 metres, and hence would continue to meet the key design criterion of an existing climate 5% AEP Hunter River flood immunity.

Raising the proposed project road levels is not considered practical to achieve increased flood immunity in the climate change scenarios as raised road levels would exacerbate the potential flooding impacts resulting from the project. Raising of the proposed road levels would also result in increased project footprint, increased resources for construction and operation, and increased property and environmental impacts in many locations along the project alignment.

Management measures

Prior to construction, environmental management measures will be implemented to mitigate or manage hydrological impacts including the preparation of a flood management plan, detailed construction staging plans to minimise flood risk during construction and further refining temporary and permanent works including embankments and structures in detailed design to minimise impacts to the Hunter Valley Flood Mitigation Scheme.

During construction, environmental management measures will include detailed erosion and sediment control plan as part of the Construction Soils and Water Management Plan, inclusion of temporary waterway crossings and regular monitoring of key waterways downstream of project discharge locations.

During operation, hydrological impacts will be managed through the inclusion of permanent erosion and scour protection, flow dissipation (where required) and through the design of permanent waterway crossings. Regular monitoring of key waterways immediately downstream of project discharge locations will be conducted for a minimum period of twelve months or until establishment and stabilisation to identify evidence of erosion and scour (if present) and initiate appropriate remediation measures.

Further flood investigations and hydrological and hydraulic modelling will be carried out during detailed design to confirm any changes in flood impacts as a result of design changes. Should the updated flood modelling show the project detailed design results in further adverse flooding impact to existing development, Transport will consult with landowners about appropriate management measures to be implemented in relation to each individual property impacted by the project. Transport will also continue to consult with operators of the Hunter Valley Flood Mitigation Scheme to inform design development.

Conclusions

The project design aims to ensure that predicted increases to rates, volumes and velocity of stormwater are managed at each discharge location such that potential impacts to the geomorphic integrity of waterways immediately downstream of project discharge locations are minimised.

Potential impacts to existing surface water and groundwater flow regimes, levels and availability, and to flooding of properties, infrastructure and sensitive receivers from the construction and operation of the project are generally expected to be low. Increases in peak flood levels are generally within the maximum tolerable limits in the adopted flood management objectives. There is expected to be no or low impact to the drainage capacity of adjusted waterway channels. Monitoring will be carried out during construction and operation of the project at stormwater discharge sites at all stormwater discharge locations.

Predicted increases in peak flood levels during construction exceed the maximum tolerable limits in the adopted flood management objectives, noting that this would be for a short period of time during construction of the project. Project construction phase activities would ensure that modified traffic arrangements do not impact on flood evacuation routes.

The project would improve the trafficability of the road access for all road users, in comparison to the existing case. Modelling indicates that in the 10% AEP event, the New England Highway is currently cut off at Hexham, while the Pacific Highway is currently cut off at Hexham and Tomago. Beneficial outcomes from the project include provision of a new flood emergency and evacuation access route (the project itself) between Black Hill and Raymond Terrace with a minimum 5% AEP flood immunity.

Management measures to further reduce the impacts of the project and include ongoing design development of project elements in the detailed design stage have been identified, where reasonable and feasible. In addition, the project will include detailed construction planning and regular monitoring of waterways post-construction with appropriate remedial measures to be implemented if waterway erosion is observed. Transport will continue to consult with affected property owners during detailed design to manage land use and property impacts.

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1. Introduction

1.1 Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The project would connect the existing M1 Pacific Motorway at Black Hill and the Pacific Highway at Raymond Terrace within the City of Newcastle and Port Stephens Council local government areas (LGAs). The project would provide regional benefits and substantial productivity benefits on a national scale. The project location is shown in **Figure 1-1** within its regional context.

1.2 Project description

The project would include the following key features:

- A 15 kilometre motorway comprised of a four lane divided road (two lanes in each direction)
- Motorway access from the existing road network via four new interchanges at:
  - Black Hill: connection to the M1 Pacific Motorway
  - Tarro: connection and upgrade (six lanes) to the New England Highway between John Renshaw Drive and the existing Tarro interchange at Anderson Drive
  - Tomago: connection to the Pacific Highway and Old Punt Road
  - Raymond Terrace: connection to the Pacific Highway.
- A 2.6 kilometre viaduct over the Hunter River floodplain including new bridge crossings over the Hunter River, the Main North Rail Line and the New England Highway
- Bridge structures over local waterways at Tarro and Raymond Terrace, and an overpass for Masonite Road in Heatherbrae
- Connections and modifications to the adjoining local road network
- Traffic management facilities and features
- Roadside furniture including safety barriers, signage, fauna fencing and crossings and street lighting
- Adjustment of waterways, including at Purgatory Creek at Tarro and a tributary of Viney Creek
- Environmental management measures including surface water quality control measures
- Adjustment, protection and/or relocation of existing utilities
- Walking and cycling considerations, allowing for existing and proposed cycleway route access
- Permanent and temporary property adjustments and property access refinements
- Construction activities, including establishment and use of temporary ancillary facilities, temporary access roads, haul roads, batching plants, temporary wharves, soil treatment and environmental controls.

A detailed project description is provided in Chapter 5 of the environmental impact statement (EIS). The locality of the project is shown in **Figure 1-1**, while an overview of the project is shown in **Figure 1-2**.

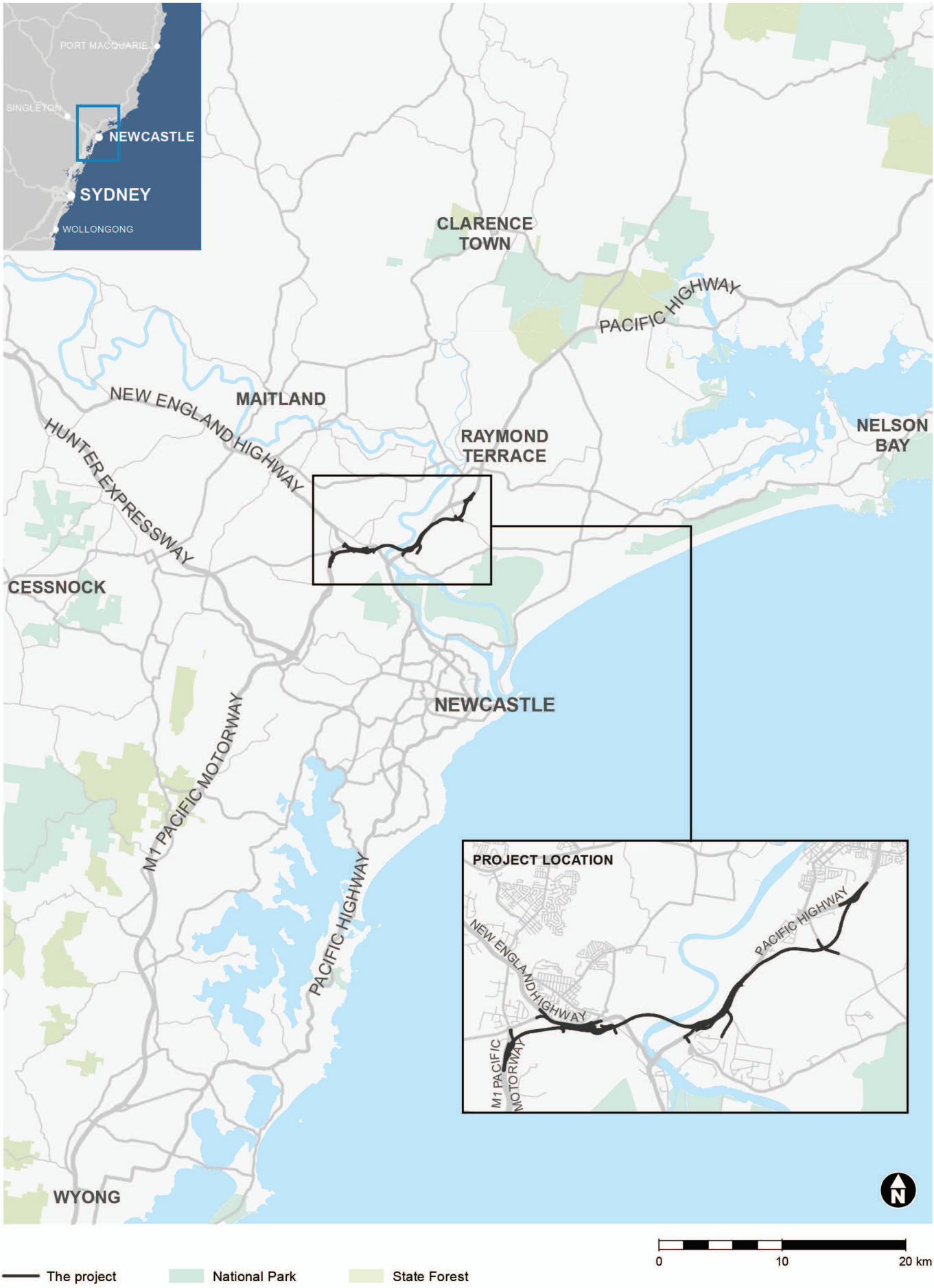

Figure 1-1 Regional context of the project

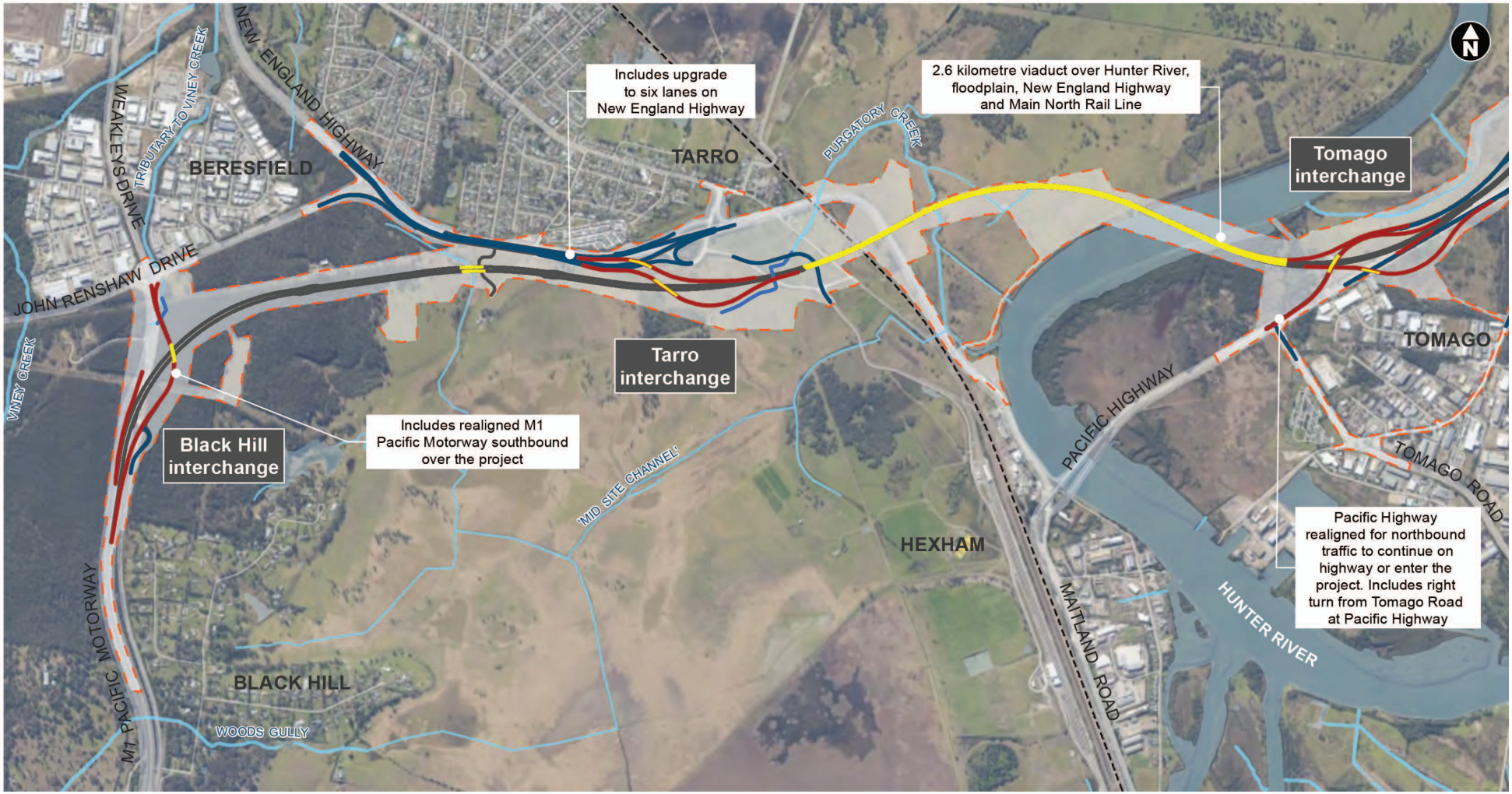

Figure 1-2 Project key features (map 1 of 2)

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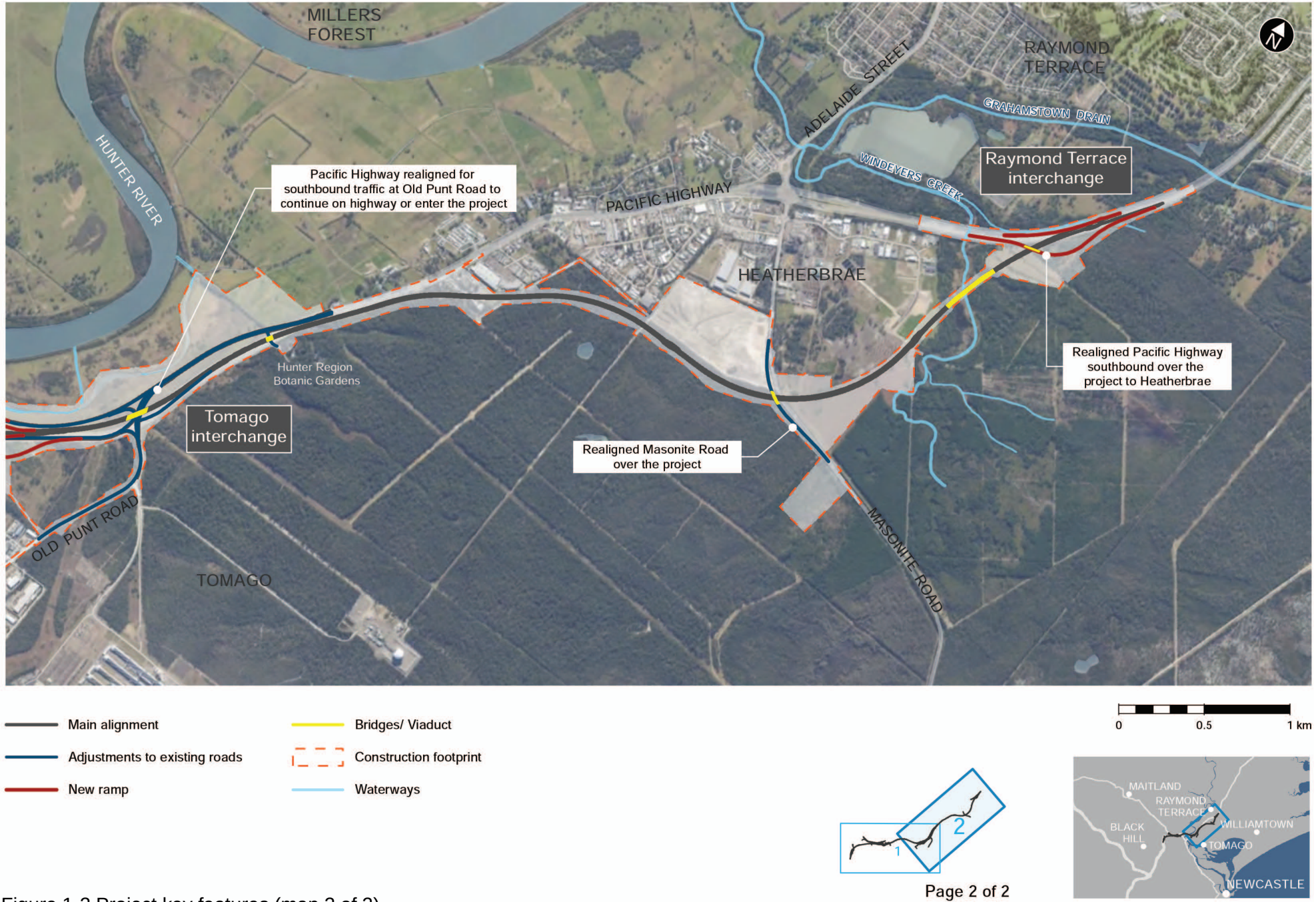

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Figure 1-2 Project key features (map 2 of 2)

1.3 Performance outcomes

The desired performance outcomes for the project relating to flooding (Secretary's Environmental Assessment Requirement [SEAR] 5) are to:

- Minimise adverse impacts on existing flooding characteristics (see **Section 5.2.7**, **Section 5.3.8** and **Chapter 8**)
- Avoid, or minimise the risk of, adverse impacts from infrastructure flooding, flooding hazards, or dam failure during construction and operation of the project (see **Section 5.1, Section 5.2.7** and **Section 5.3.8** and **Chapter 8**).

The desired performance outcomes for the project relating to water – hydrology (SEAR 7) are to:

- Minimise long term impacts on surface water and groundwater hydrology, including drawdown, flow rates and volumes (see **Section 5.2.2**, **Section 5.3.1** and **Section 5.3.2** for surface water and **Section 5.2.3** and **Section 5.3.3** for groundwater)
- Maintain (where values are achieved) or improve and maintain (where values are not achieved) the environmental values of nearby connected and affected water sources, groundwater and dependent ecological systems, including estuarine and marine water (see the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS)
- Sustainable use of water resources (see **Chapter 7**, the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS) and the Sustainability Working Paper (Appendix T of the EIS).

1.4 Secretary's Environmental Assessment Requirements

This assessment forms part of the EIS for the project. The EIS has been prepared under Division 5.2 of the EP&A Act. This assessment has been prepared to address the SEARs (SSI 7319) relating to hydrology and flooding and will assist the Minister for Planning and Public Spaces to make a determination on whether or not to approve the project. It provides an assessment of potential impacts of the project on hydrology and flooding and outlines proposed management measures.

In 2019 revised SEARs were issued for the project, which included hydrology and flooding as a key issue. **Table 1-1** outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-1 SEARs relevant to hydrology and flooding

Secretary's requirement	Where addressed in this report
5. Flooding	
1. Identification of potential impacts and benefits of the proposal on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources 2005), with an assessment of the potential changes to flooding behaviour (levels, velocities, storage and direction) and impacts on bed and bank stability, through flood modelling (using a validated model), including:	**Section 2.3.5** – identifies the relevant provisions of the Floodplain Development Manual (Department of Natural Resources 2005). **Section 3.3.3** – describes the flood modelling approach. **Section 5.2.2** – details the construction impacts on bed and bank stability. **Section 5.2.7** – includes an assessment of the construction impacts on flood regimes and behaviour. **Section 5.3.2** – provides the operational impacts on bed and bank stability. **Section 5.3.8** – includes an assessment of operational impacts on flood regimes and behaviour.

Secretary's requirement	Where addressed in this report
(a) detailed description, justification and assessment of the flood management objectives, and other design objectives and design (including bridge, culvert and embankment design);	**Section 1.2** – provides an overview of the project design, Chapter 3 of the EIS includes the project justification and Chapter 5 of the EIS provides a detailed description of the design, including drainage infrastructure. **Section 3.6.3** – includes the flood design criteria and justification of the flood management objectives that have been applied to the project.
(b) flood assessment and modelling undertaken for a range of flood events, including (as a minimum) the 1 in 10 year, 1 in 100 year flood events and the probable maximum flood, or an equivalent extreme event. The assessment is to demonstrate how the assessment, including the use of the modelled events listed above, provides consideration of blockage, climate change and impacts of land use change on flood hydrology, noting below;	**Section 3.3.3** – describes the design events assessed, including the 10% annual exceedance probability (AEP) (i.e. approximately the 1 in 10 year), the 1% AEP (i.e. the 1 in 100 year) flood events, and the probable maximum flood. **Section 5.3.8** – discusses blockage of hydraulic structures and climate change proxy scenarios i.e. 0.5% AEP (1 in 200 year) and 0.2% AEP (1 in 500) year flood events. **Section 5.2.7**, **Section 5.3.8** and **Chapter 6** – discuss changes in land use on flood hydrology.
(c) modelling of the effect of the proposal (including fill) on current and future flood behaviour for the range of design events identified above, with use of the 1 in 200 year and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity due to climate change;	**Section 5.2.7**, **Section 5.3.8** and **Appendix B** – discusses the effects of the project (including areas of fill) on existing flood behaviour in the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events. **Section 5.3.8** – discusses future climate flood behaviour including using the 0.5% AEP (i.e. 1 in 200) and 0.2% AEP (i.e. 1 in 500) events as proxies for an increase in rainfall intensity due to climate change.
(d) an assessment of afflux and flood duration (inundation period) on land, infrastructure, property and business operations (including agricultural land and stock movement to flood refuges and evacuation routes), hazard, evacuation and emergency service provision within the affected area, and future development potential of upstream and access affected land;	Afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario. **Section 5.2.7** and **Section 5.3.8** – discusses the change in flood levels on land in the construction and operational phases. These sections also provide discussions on the assessment of flood hazard on land, duration of inundation on land, impacts to major land uses and property (including business operations), impacts to road and railway infrastructure, impacts to sensitive receivers including agricultural operations, evacuation and emergency service provision and future development potential of lands in the construction and operational phases.
(e) an assessment of impacts associated with the Hunter Valley Flood Mitigation Scheme;	**Section 3.3.3** and **Section 4.5.4** – discuss flood modelling. The Hunter Valley Flood Mitigation Scheme has been included in the existing case flood modelling and its effects on flooding are represented in the existing case. **Section 5.2.7** and **Section 5.3.8** – discuss impacts to sensitive receivers, this includes consideration of the impacts of the project and the resultant changes in flooding and drainage on the Hunter Valley Flood Mitigation Scheme.
(f) an assessment of flooding during construction of the proposal;	**Section 5.2.7** – provides an assessment of flooding impacts during the construction phase.
(g) a cumulative flood assessment of the impact of other major projects recently completed, approved or preparing for construction; and	**Chapter 6** – includes a cumulative assessment of impacts associated with construction of the project and other major projects located nearby.

Secretary's requirement	Where addressed in this report
(h) an assessment of emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event).	**Section 2.3.10** – reviews existing flood emergency management. **Section 3.3.3** – describes the results of flood modelling and includes an assessment of flood events up to the probable maximum flood for the operational phase. **Section 4.5.7** – discusses existing flood affectation of major roads, including evacuation and access routes. **Section 5.2.7** and **Section 5.3.8** – discuss flooding impacts to major roads in the construction and operational phases, respectively and includes discussion on emergency evacuation and access. **Section 5.3.8** – discusses impacts to roads and sensitive receivers. **Chapter 8** – provides flood-related management measures.
7. Water – Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the Framework for Biodiversity Assessment (FBA).	**Section 4.3** – includes a description and map of existing surface water resources. **Section 4.4** – describes groundwater resources and the reliance by users and for ecological purposes. Chapter 8 of the Biodiversity Assessment Report (Appendix I of the EIS) assesses the biodiversity impacts of the project in accordance with the FBA.
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration.	**Chapter 7** – includes a water balance for surface and groundwater.
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	**Section 5.2** and **Section 5.3** – include an assessment of the construction and operation of the project and ancillary facilities on surface and groundwater hydrology, while considering guidelines identified in **Section 2.3**.
(a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	**Section 5.2.2, Section 5.3.1** and **Section 5.3.2** – describe the impact of the project during construction and operation on existing surface water processes and health. Impacts from the project to riparian vegetation, aquatic connectivity and access to aquatic habitats for spawning and refuge are assessed in Chapter 8 of the Biodiversity Assessment Report (Appendix I of the EIS).
(b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	**Section 5.2.3** and **Section 5.3.3** – assess the temporary and permanent impact of the project on groundwater flow.
(c) impacts on regional hydrology, in particular the Tomago Sandbeds Catchment Area drinking water supply;	**Section 5.2.4** and **Section 5.3.4** – assess the impact of the project on regional hydrology, in particular the Tomago Sandbeds Catchment Area drinking water supply.
(d) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	**Section 5.2.5** – assesses impacts of the project to environmental water availability and flows and includes consideration of regulated/licensed and unregulated/rules-based sources.

Secretary's requirement	Where addressed in this report
(e) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or waterways;	**Section 5.2.2** – assesses the impacts of the project on riparian processes and geomorphology. Impacts from the project to riparian vegetation are assessed in Chapter 8 of the Biodiversity Assessment Report (Appendix I of the EIS).
(f) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	**Section 5.2.2**, **Section 5.3.1** and **Section 5.3.2** – assess the impact of the project during construction and operation on stormwater and wastewater discharge. **Chapter 8** – provides management measures. Wastewater management is assessed in the Waste Working Paper (Appendix S of the EIS).
(g) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	**Section 5.2.6** and **Section 5.3.6** – discusses water take during construction and operation**.**
4. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	**Appendix K** and **Appendix L** – identify baseline monitoring data and requirements for surface and groundwater.
5. The assessment must include details of proposed surface and groundwater monitoring.	**Appendix K** and **Appendix L** – identifies the proposed methods for surface and groundwater monitoring during construction and operation of the project.

1.5 Report structure

The report is structured as follows:

- Chapter 1 – Introduces the project with a summary of the project background, project description and SEARS
- Chapter 2 – Provides an overview of the policy and planning setting
- Chapter 3 – Provides a summary of the assessment methodology used to inform the assessment
- Chapter 4 – Details the existing environment
- Chapter 5 – Provides an assessment of potential impacts
- Chapter 6 – Provides a cumulative assessment
- Chapter 7 – Details of the site water balance assessment
- Chapter 8 – Details the proposed management measures and monitoring program for the project
- Chapter 9 – Conclusions
- References
- Terms and acronyms.

2. Policy and planning setting

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act is the main piece of environmental legislation that provides the legal framework to protect and manage Matters of National Environmental Significance (MNES) including nationally and internationally important flora, fauna, ecological communities, cultural heritage and water resources.

Threatened and migratory species, ecological communities and a wetland of international importance (Ramsar) identified as MNES are located near the project.

Subtropical and Temperate Coastal Saltmarsh is a federally listed Threatened Ecological Community (TEC) protected under the EPBC Act that has been mapped within the study area, refer to the Biodiversity Assessment Report (Appendix I of the EIS). This TEC is located on riverbanks and has the potential to be impacted by changes in surface water and groundwater hydrology and flooding from the project. The EPBC Act also identifies important wetlands that are Ramsar listed and are collectively known as the Hunter Estuary Wetlands within the surface water study area (refer to **Figure 2-1**) and includes the following:

- Kooragang Nature Reserve, located a minimum distance of about 1.9 kilometres south-east of the project and over 2.8 kilometres from the main alignment
- Shortland Wetland to the south of Hexham Swamp Nature Reserve, located about 3.8 kilometres south of the project.

These Ramsar listed wetlands are downstream of the project and are identified as sensitive receiving environments in this assessment as these wetlands have the potential to be impacted by changes in surface water and groundwater hydrology and flooding from the project. Further details on MNES are presented in the Biodiversity Assessment Report (Appendix I of the EIS).

2.2 State legislation

2.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act and the Environmental Planning and Assessment Regulation 2000 (the Regulation) provide the framework for development assessment in NSW. The EP&A Act and the Regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process before proceeding to construction. The project is declared state significant infrastructure (SSI) and an EIS has been prepared under Division 5.2 of the EP&A Act. The SEARs have been issued and this report considers those requirements as relevant to hydrology, flooding and climate change.

Section 5.22 of the EP&A Act specifies that environmental planning instruments, including State Environmental Planning Policies (SEPPs), do not apply to projects that are declared SSI. As such, the Coastal Management SEPP (2018) (Coastal Management SEPP) does not apply, although the sensitivity of Coastal Management Areas identified in the Coastal Management SEPP that are within or near to the project have been considered in the assessment.

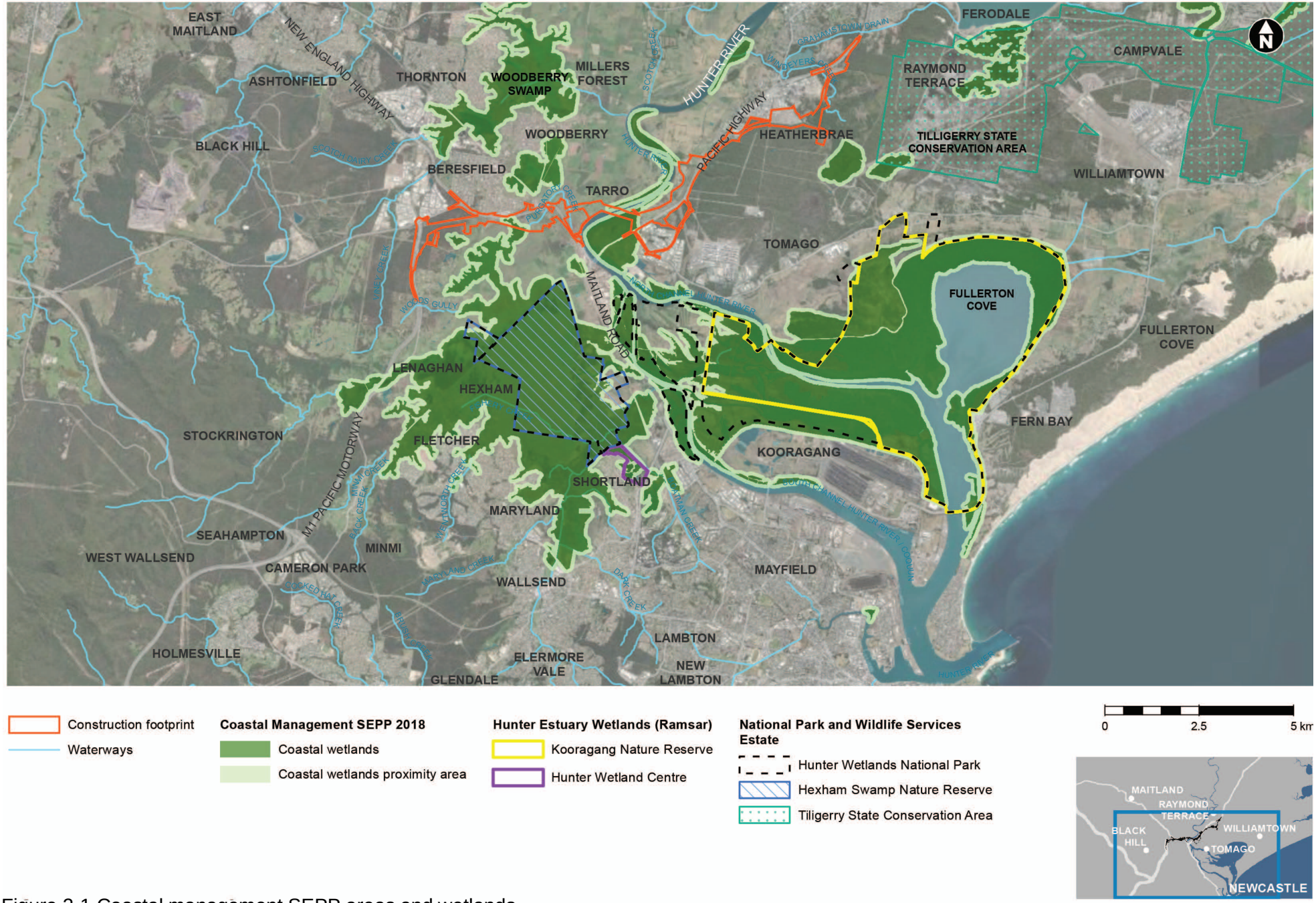


Figure 2-1 Coastal management SEPP areas and wetlands

2.2.2 Water Management Act 2000 and Water Act 1912

Groundwater and surface water

The *Water Management Act 2000* (WM Act) and the *Water Act 1912* are the two key pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. The Acts are administered by the NSW Department of Planning, Industry and Environment (Water) (DPIE (Water)), with WaterNSW as the regulator and DPIE (Water) as the policy maker. The *Water Act 1912* is being progressively phased out and replaced by the WM Act.

The WM Act establishes a system of licensing and approvals whereby access to water is generally regulated by way of water access licences (WALs). The WM Act enables the State's water resources to be managed under water sharing plans, which establish the rules for sharing of water in a particular water source between water users and the environment, and rules for the trading of water in a particular water source.

The majority of water access licences are issued under the WM Act, however where there is no water sharing plan, some access rights are still issued in the form of licences or permits under the *Water Act 1912* which are tied to the land.

The project lies within the following water sources and water sharing plans (refer to **Figure 2-2**):

- Newcastle Water Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government, 2009) (applicable for groundwater and surface water)
- Sydney Basin–North Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government, 2016a) (applicable for groundwater)
- Tomago Groundwater Source of the Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government, 2016b) (applicable for groundwater).

Volumetric water takes for the project are assessed in this report, however, as a roads authority, and in accordance with Division 2 of the Water Management (General) Regulation 2018, Transport are exempt from requiring a water access licence in relation to water required for road construction and road maintenance.

Under the WM Act, all activities that interfere with an aquifer require assessment and approval under the NSW Aquifer Interference Policy (AIP). The WM Act defines an aquifer interference activity as that which involves any of the following:

- The penetration of an aquifer
- The interference with water in an aquifer
- The obstruction of the flow of water in an aquifer
- The taking of water from an aquifer in the course of carrying out mining or any other activities prescribed by the regulations
- The disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The AIP (DPI, 2012) and its applicability to the project is discussed in **Section 2.3.1**.

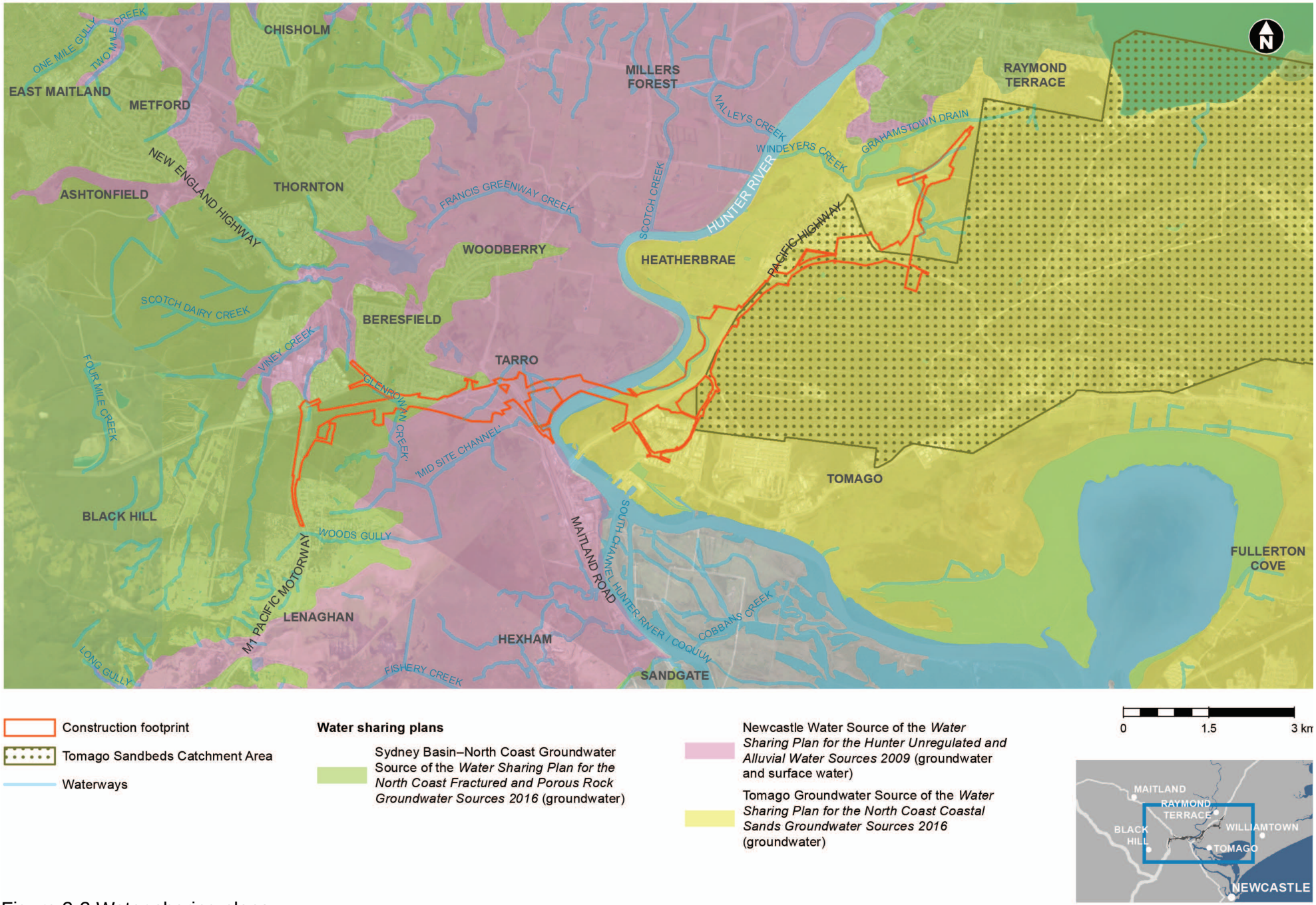


Figure 2-2 Water sharing plans

Flooding

A controlled activity approval under section 91 of the WM Act is required for certain types of developments and activities that are carried out in or near waterfront land. Under the EP&A Act, a controlled activity approval is not required for SSI, such as the project and so the NSW Office of Water's guidelines for controlled activities on waterfront land have not been considered further.

Development on floodplains is now managed under the WM Act, including the provisions of floodplain management plans and 'flood works' i.e. works that affect, or are likely to affect, flooding and/or floodplain functions. Under Section 256 of the WM Act approval is required for construction of a building, fence or structure in, on, or adjacent to a levee bank or for the construction of a flood work on the Hunter River floodplain. The Hunter Valley Flood Mitigation Scheme (refer to **Figure 2-3**) includes levee banks and other drainage controls that are near to the project. Some project stormwater controls would tie into existing levees such as the Heatherbrae Levee, while some construction access roads would be located alongside existing levees. The project also involves adjustment of Purgatory Creek, which forms part of the Hunter Valley Flood Mitigation Scheme. Consent under Section 256 of the WM Act would be required.

2.2.3 Hunter Water Act 1991

The *Hunter Water Act 1991* (Hunter Water Act) and associated Hunter Water Regulation 2015 (Hunter Water Regulation) controls activities that can be carried out in special areas. The special area of relevance to the project is the Tomago Sandbeds Catchment Area.

Clauses in the Hunter Water Regulation which are of relevance include Clause 55(1) of the Act, that requires notification to DPIE prior to work commencing in a special area; Clause 10 that states no pollution of any water in a special area; and Clause 15 of the Act that addresses no engaging in extractive industries in the Tomago Sandbeds Catchment area unless approved by the DPIE.

2.2.4 Biodiversity Conservation Act 2016

The purpose of the *Biodiversity Conservation Act 2016* (BC Act) is to maintain a healthy, productive and resilient environment for the greatest wellbeing of the community, now and into the future, consistent with the principles of ecologically sustainable development (described in the *Protection of the Environment Administration Act 1991* (NSW) and Section 516A of the EPBC Act).

Schedule 4 of the BC Act lists key threatening processes and includes reference to the potential alteration of existing flow regimes which are applicable to this assessment:

> *Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands (as described in the final determination of the Scientific Committee to list the threatening process).*

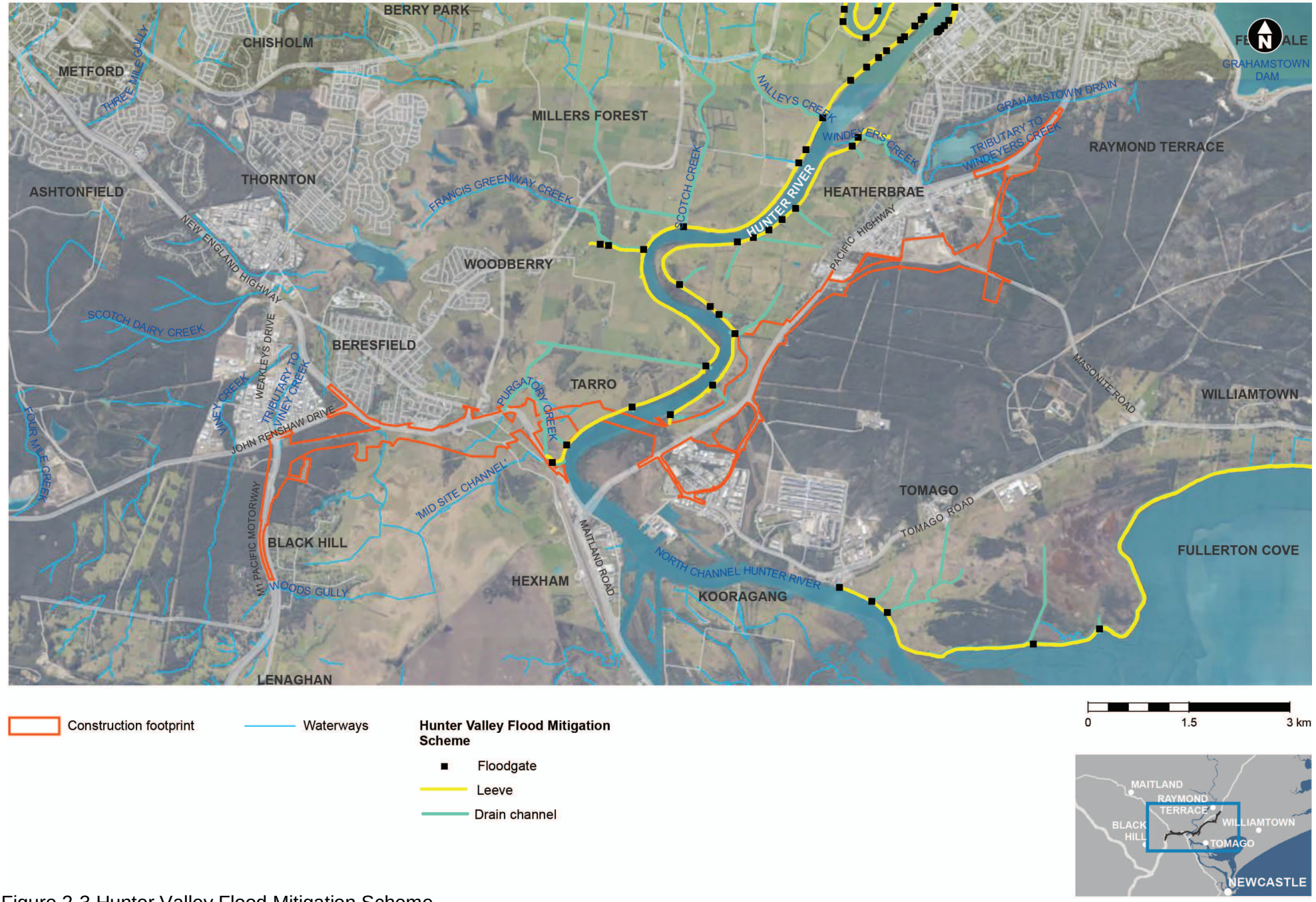


Figure 2-3 Hunter Valley Flood Mitigation Scheme

2.3 Relevant guidelines and policies

2.3.1 NSW Aquifer Interference Policy

The AIP (DPI, 2012) is the instrument for the assessment of aquifer interference activities administered by the WM Act. Key components to the policy are:

> *all water taken must be properly accounted for the activity must address minimal impact considerations with respect to water table, water pressure and water quality planning measures in the event that actual impacts are greater than predicted, including making sure there is sufficient monitoring in place.*

The AIP (DPI, 2012) outlines minimal impact considerations for water table and groundwater pressure drawdown for high priority GDEs (as identified in the WSP), high priority culturally significant sites (as identified in the WSP) and existing groundwater supply bores. Water quality impact considerations are also outlined in the AIP.

For the purpose of minimal impact consideration criteria, the AIP considers the type of water source (alluvial, coastal sands, porous rock, or fractured rock), and the productivity of the groundwater source as either highly productive or less productive. Highly productive groundwater sources are defined by the AIP to have total dissolved solids concentrations of less than 1,500 milligrams per litre and yields greater than five litres per second at bores.

The project is assessed against the AIP minimal impact considerations with respect to water level and pressure in **Section 5.2.3** and **Section 5.3.3**. An assessment of the project against the AIP minimal impact considerations with respect to water quality is provided in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

2.3.2 Australian Groundwater Modelling Guidelines

The Australian Groundwater Modelling Guidelines (Barnett, et al, 2012) are the current standard for groundwater modelling in Australia. The guidelines are a point of reference for best practice approaches to groundwater modelling. It is noted that the guidelines are not regulation or law, as they have not received endorsement from any jurisdiction, but are referenced in the AIP. This assessment has considered these guidelines in the development of the groundwater model. The groundwater model developed for the project (**Appendix A**) has been developed with consideration for the Australian Groundwater Modelling Guidelines.

2.3.3 NSW Wetlands Policy

The NSW Wetlands Policy (DECCW, 2010) replaces the NSW Wetlands Management Policy of 1996 and reflects the development of natural resource management and planning that affect wetlands. The purpose of the NSW Wetland Policy is to complement relevant legislation, including the EP&A Act, *National Parks and Wildlife Act 1974* (NPW Act), FM Act, and EPBC Act by:

- Providing a more explicit definition of wetlands, including recognition of their dry phases, to assist the application of legislation to wetlands
- Aiding the decision making when interpreting the provisions of relevant legislation
- Providing direction where legislation lacks a consistent approach.

2.3.4 Guidelines for Controlled Activities on Waterfront Land

Controlled activities carried out in, on or under waterfront land are regulated by the WM Act (2000). This Act defines waterfront land to include the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary. Under section 5.23 of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the WM Act is not required for SSI and so waterfront land has not been considered further in this assessment. The former Department of Industry (Water) (now DPIE (Water)) prepared guidelines for controlled activities which provide information on the design and construction of a controlled activity, and other ways to protect waterfront land.

Despite the exemption, the design and construction of the project would take into account the Guidelines for Controlled Activities on Waterfront Land (Department of Industry - Water, 2018).

2.3.5 NSW Floodplain Development Manual and Flood Prone Land Policy

The NSW Flood Prone Land Policy is produced within section 1.1 of the Floodplain Development Manual (NSW Government, 2005). The manual highlights the requirements consistent with the *Water Act 1912* to manage the risks resulting from natural hazards. Its purpose is to reduce the impact of flooding on individual owners and occupiers of flood-prone property and to reduce private and public losses resulting from floods. The manual "*promotes the use of a merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable*". This policy also recognises the benefits of the use, occupation and development of flood prone land.

The project recognises existing users of the floodplain and the existing flooding risks that apply to these users. Consideration has been made in the design development of the project to minimise impacts as a result of the project and hence not increase private and public losses resulting from floods. In doing so, the project is being carried out in compliance with the provisions in the Floodplain Development Manual and the NSW Flood Prone Land Policy.

2.3.6 NSW Climate Change Policy Framework

The NSW Climate Change Policy Framework (OEH, 2016) summarises how the NSW Government intends to support the reduction of emissions to reduce the effects of climate change, and measures to adapt to the risks associated with climate change.

One of the policy directions is to reduce risks and damage to public and private assets in NSW arising from climate change. This has been considered in the design and assessment of the project by considering projections for future climate when carrying out the flood modelling (refer to that climate change assessment in **Section 5.3.8**).

2.3.7 Practical Consideration of Climate Change

Practical Consideration of Climate Change (DECC, 2007) is a floodplain risk management guideline that aims to assist in floodplain risk management. It describes the impacts of climate change and the associated ramifications upon the vulnerability of floodplain risk management and mitigation options. This guideline was considered when preparing the climate change assessment in **Section 5.3.8**.

2.3.8 Floodplain Risk Management Guideline: Incorporating sea level rise benchmarks in flood risk assessments

The Floodplain Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments (DECCW, 2010) provides advice on approaches that can be used to incorporate sea level rise benchmarks into flood risk assessments for waterways in NSW. This guideline was considered when preparing the climate change assessment in **Section 5.3.8**.

2.3.9 Floodplain risk management plans

Floodplain risk management plans are generally prepared for urban floodplains to address the existing, continuing and future flood risk in accordance with NSW Government's Flood Prone Land Policy (**Section 2.3.5**). The floodplain risk management plans which are relevant to the project and surrounding floodplain areas are:

- Williamtown Salt Ash Floodplain Risk Management Study and Plan (BMT WBM, 2017) for Port Stephens Council
- Newcastle City Wide Floodplain Risk Management Study and Plan (BMT WBM, 2012a) for City of Newcastle
- Hunter River Floodplain Risk Management Study and Plan (WMAwater, 2015) for Maitland City Council.

Key flood risk management works and measures recommended in the Williamtown Salt Ash Floodplain Risk Management Study and Plan for Port Stephens Council LGA include a Hunter River Levee Review including review of function and performance. The existing Hunter River flood levees provide existing protection for lower order flood events (<5% AEP) for the floodplain areas in the vicinity of Tomago and Fullerton Cove. There may be potential interactions of flood impacts between the project and any modifications to Hunter River levees.

Other works based measures were identified in the Williamtown Salt Ash Floodplain Risk Management Study and Plan but are considered unlikely to affect flooding behaviour at the project.

Measures identified in the Newcastle City Wide Floodplain Risk Management Study and Plan may influence flooding conditions at the project including (investigation of) raising the Pacific Highway if voluntary purchase of residential properties in Hexham is unsuccessful. This was listed as a lower priority/longer term measure.

No measures in the Hunter River Floodplain Risk Management Study and Plan for Maitland City Council were considered likely to affect flooding behaviour at the project.

2.3.10 Local flood plans

Local flood plans, prepared by the State Emergency Service (SES) as part of broader local disaster plans, outline the preparations, responses and recovery actions that are to be carried out before, during and following a major flood event. Local flood plans prepared for the area near to the project include:

- City of Newcastle Flood Emergency Sub Plan (SES, 2013a)
- Port Stephens Flood Emergency Sub Plan (SES, 2013b).

These local flood plans outline the broad procedures and responsibilities for planning and responding to flood events. Specific activities and key evacuation routes and centres are not publicly available. For the purposes of this assessment, the main roads in the study area have been assumed to form the evacuation routes. Refer to **Section 4.5.7**, **Section 5.2.7** and **Section 5.3.8** for discussion on flooding of the evacuation routes in the existing case, during construction and during operation respectively.

2.3.11 Australian Rainfall and Runoff

Australian Rainfall and Runoff (Ball et al., 2019) is a national guideline for the estimation of design flood characteristics in Australia. The approaches presented in Australian Rainfall and Runoff (ARR) are essential for policy decisions and projects involving:

- Infrastructure such as roads, rail, bridges, dams and stormwater systems
- Floodplain risk management plans for urban and rural communities
- Flood warnings and flood emergency management
- Estimation of extreme flood levels.

Reference was made to ARR 2019 (Ball et al, 2019) in developing the methodological framework for assessing potential impacts of the project on hydrology, flooding and water quality.

2.3.12 Flood hazard

Flood preparedness, flood hazard and emergency management guidelines have been developed and are available in Australian Disaster Resilience Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Australian Institute for Disaster Resilience, 2017). **Figure 2-4** presents the flood hazard classification from the guidelines which describe the varying flood hazard ratings according to flood depth and flow velocity as the following:

- H1 – Generally safe for people, vehicles and buildings
- H2 – Unsafe for small vehicles
- H3 – Unsafe for vehicles, children and the elderly
- H4 – Unsafe for people and vehicles
- H5 – Unsafe for people and vehicles. Buildings require special engineering design and construction
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

These guidelines were considered in defining existing flood hazard (H1 to H6 identified in **Figure 2-4**) for the full range of flood events for the project. In order to provide a consistent and simplified commentary on impacts of the project on flood hazard, flood hazard categories H1 and H2 are referred to as “low” hazard and flood hazard categories H3 to H6 are referred to as “high” hazard.

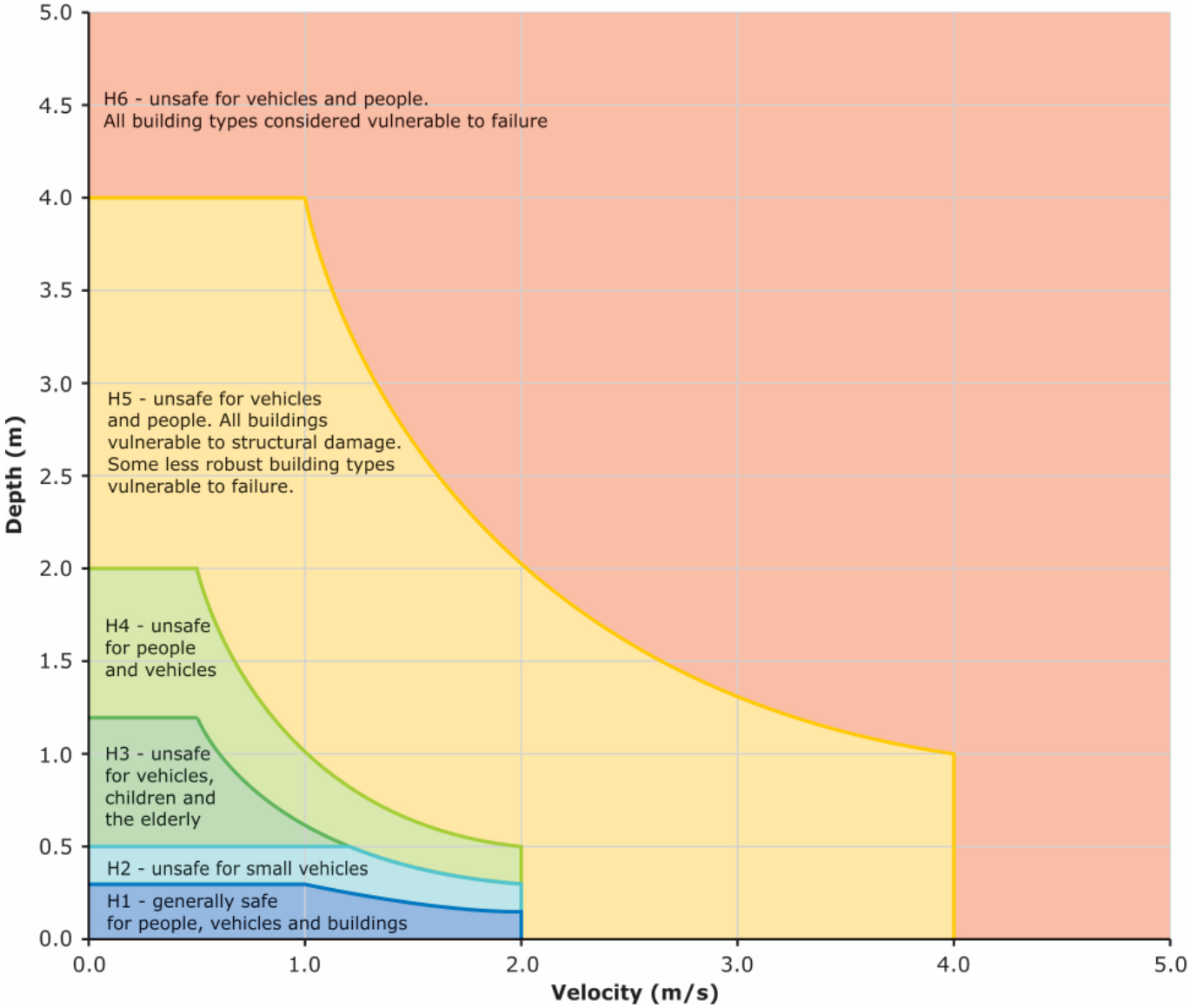


Figure 2-4 Combined flood hazard curves (ARR, 2019)

2.3.13 NSW Water Quality and River Flow Objectives

The NSW Water Quality and River Flow Objectives (DECCW, 2006) are the environmental values and long term goals for NSW surface waters. The NSW Water Quality and River Flow Objectives (DECCW, 2006) are in two parts, the NSW water quality objectives and NSW river flow objectives, which are distinct because they relate to different environmental attributes of a waterway that are important for long-term functionality. Project impacts to NSW river flow objectives nominated for waterways within the surface water study area have been described and addressed in this report. NSW water quality objectives have been described and addressed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS). From herein, this report will only refer to the NSW river flow objectives (DECCW, 2006).

The NSW river flow objectives are the agreed high-level goals for surface water flow management which have been developed by the NSW Government (DECCW, 2006). They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses. Each objective aims to improve river health by recognising the importance of natural river flow patterns. A set of objectives have been developed for the Hunter River.

There are four key surface water management zones identified in the Hunter River and which are relevant to the project and the surface water study area. These are:

- Town water supply sub-catchments: The streams in town water sub-catchments or groundwater aquifers typically feed into a town's water supply storage. Tomago Sandbeds are potentially directly affected by the project
- Mainly forested areas: Streams in mainly forested areas are often valued for their conservation or recreational values. They often have relatively natural flows and water quality. The objectives apply to streams running through state forests, national parks and nature reserves and through other forested areas, if any are defined locally (private land or Crown land). Hunter Wetlands National Park and Hexham Swamp Nature Reserve are included in this category
- Waterways affected by urban development: Waterways within urban areas that are often substantially modified and generally carry poor quality stormwater. Many local communities are keen to see these waterways returned to more natural conditions. There are several urban-affected waterways in Tarro, Hexham, Raymond Terrace and Tomago which are relevant
- Estuary: Being dominated by saline conditions, estuaries have hydraulic and water quality characteristics, and potential problems, that are often very different from those of freshwater systems. The entire Hunter River estuary, which extends from the ocean up to the Paterson River and includes adjoining mangrove areas and minor tributary inflow channels and waterways, is included in this category.

In total, there are twelve coastal River Flow Objectives, each dealing with a critical element of natural river flows and estuarine processes. Nine of these are relevant and are used in the impact assessment, refer to **Section 5.2.2** and **Section 5.3.2**.

3. Assessment methodology

3.1 Overview

The methodology for this assessment included definition of the study areas (**Section 3.2**), desktop assessment (**Section 3.3**) and field investigations (including community and stakeholder consultation, which is discussed in **Section 3.4.1**). Criteria by which the environmental impacts were assessed are discussed in **Section 3.6**.

3.2 Study areas

Three different study areas are applicable for this report, including:

- **Surface water study area** – defined as the project construction and operational footprints and a 500 metre buffer around the construction footprint. The surface water study area was chosen to encapsulate the inferred area that may be affected (directly or indirectly) by the project. The surface water study area is shown on **Figure 3-1**
- **Groundwater study area** – defined by a two kilometre buffer applied to the construction footprint. The groundwater study area boundary was adopted to encapsulate surrounding registered groundwater users near to the project, including the nearby Hunter Water Corporation Tomago Sandbeds borefield, to increase the amount of bore data available for analysis. While the two kilometre buffer study area was used for analysis relating to existing groundwater users, predicted impacts relating to the project are expected to be localised and limited to the immediate area of the construction footprint. The groundwater study area is shown on **Figure 3-1**
- **Flooding study area** – the flooding study area has been identified to assess the potential adverse impacts to flooding from the project and covers waterways located in floodplain areas of the Hunter River, Williams River and Tilligerry Creek that surround the project. The study area extends north of the project along the Hunter River and Williams River from the junction of the two rivers at Raymond Terrace and extends to the south along the Hunter River to the city of Newcastle and the river's outlet to the Tasman Sea. The flooding study area also extends to the east over Fullerton Cove onto the Tilligerry Creek floodplain to the Tilligerry Creek outlet into Port Stephens and terminates at Williamtown. The flooding study area is shown on **Figure 3-2**, and relevant flood and water level gauges are also shown.

Surface water hydrology and flooding analysis focussed on waterways and associated floodplains that the project would cross or potentially impact on, which includes major waterways and floodplains in the Hunter River and Williams River catchments.

The surface water study area and the groundwater study area referred to above are the same study areas applied in Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

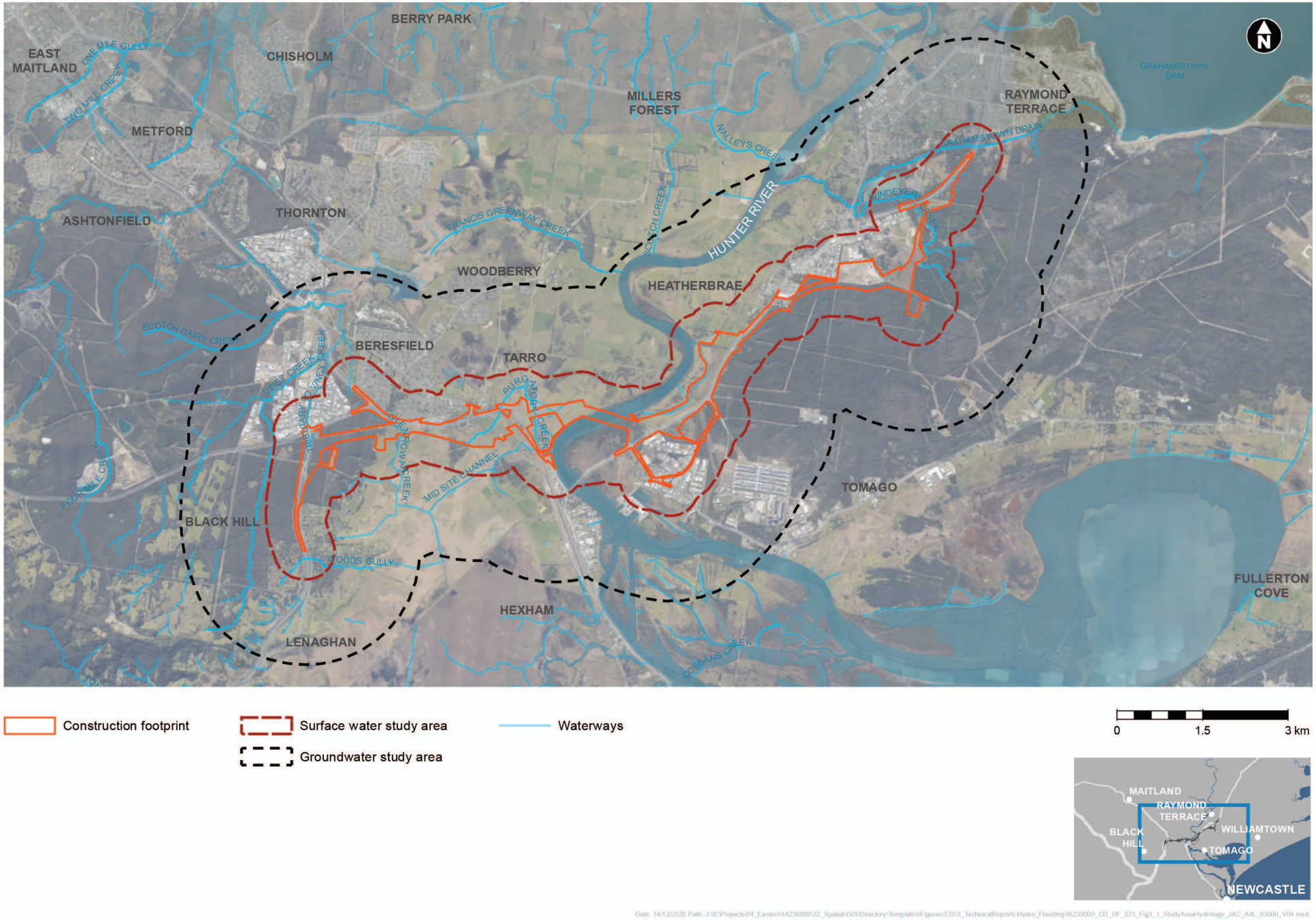


Figure 3-1 Study area – surface water hydrology and groundwater assessment

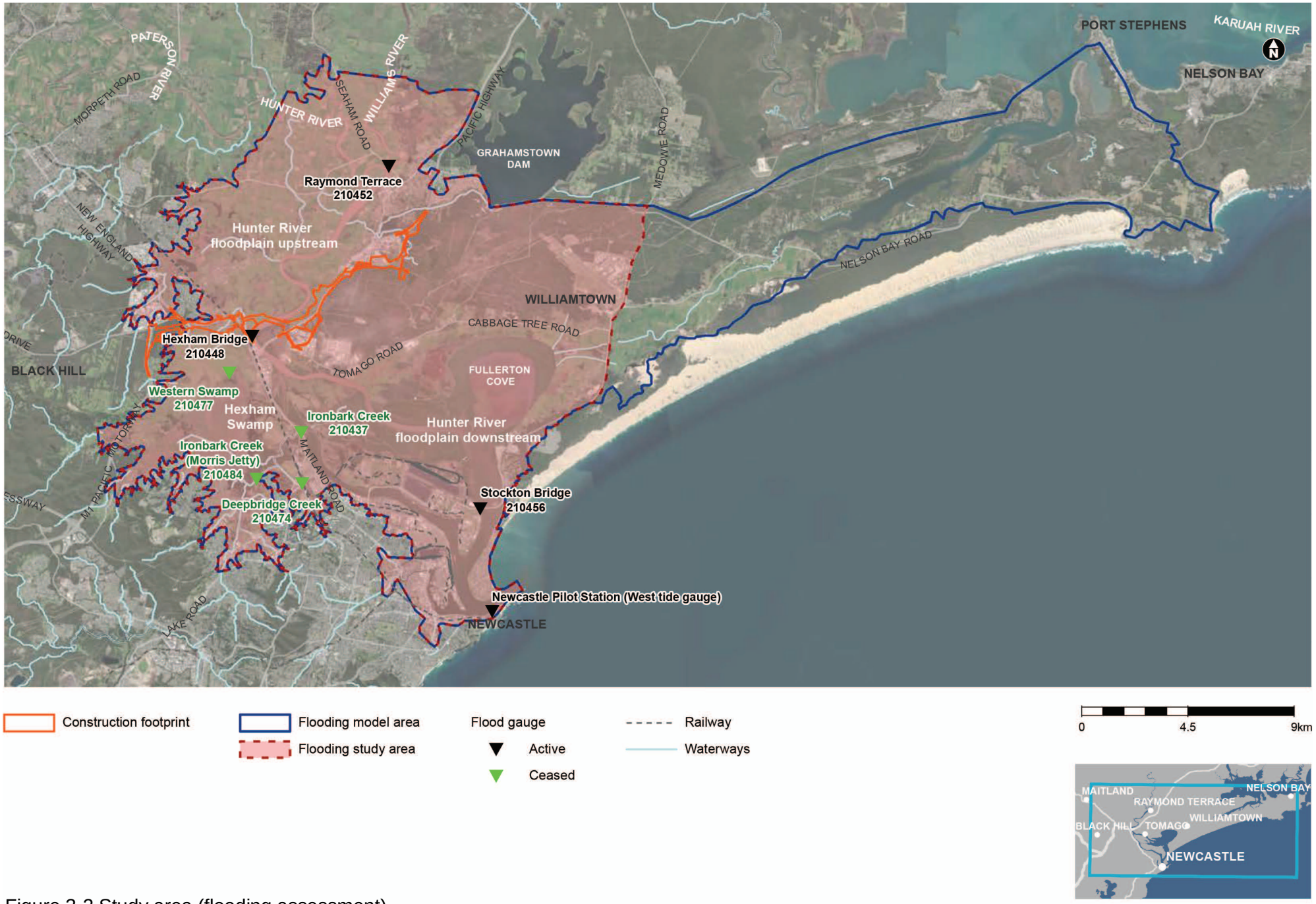


Figure 3-2 Study area (flooding assessment)

3.3 Desktop assessment

A desktop assessment was carried out to assess the likely and potential impacts of the project on surface water and groundwater quantity and flooding within the respective study areas described in **Section 3.2**. The purpose of the desktop assessment was to:

- Develop an understanding of the existing physical environment and hydrological regime near the project and within the respective study areas
- Identify waterways within the surface water and groundwater study areas which are considered sensitive receiving environments (SREs) with respect to hydrology and flooding
- Assess flooding and groundwater quantity risks through numerical modelling (as discussed in **Section 3.3.3**).

3.3.1 Desktop review

The desktop review involved a collation of available literature, databases, aerial photography, topographic mapping and existing land use to aid in interpreting the existing hydrological conditions of waterways, groundwater systems and floodplains within the respective study areas. Literature sources included:

- Minview – Rivers (DPIE, 2019)
- Soil landscape and hydrological soil group mapping – eSPADE v2.0 interactive NSW Soil and Land Information mapping (DPIE, 2020)
- Climate and rainfall data from the Bureau of Meteorology (BoM, 2020a, 2020b)
- Bore data from the BoM's (2020c) Australian Groundwater Explorer and data provided by Water NSW
- The BoM's (2020d) Groundwater Dependent Ecosystem (GDE) Atlas
- Groundwater level data for selected Hunter Water Corporation bores
- Geological mapping (Newcastle Coalfield Regional Geology, Sheet 9321, NSW Department of Mineral Resources).

3.3.2 Identification of sensitive receiving environments

Sensitive receiving environments (SREs) are environments that have high conservation or community value or support ecosystems/human uses of water that are particularly sensitive to changes in quantity of surface water and groundwater. SREs within the surface water study area are identified in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS) and those that are relevant to the flooding and hydrology assessment were identified based on the following considerations:

- Features or users on the floodplain which are particularly sensitive to changes in flood behaviour
- Drinking water supply – aquifers
- Groundwater users
- Groundwater and surface water dependent vegetation and fauna communities listed under the BC Act and EPBC Act
- Proximity to wetlands and protected areas such as Ramsar listed wetlands and National Parks and Nature Reserves.

3.3.3 Technical modelling assessment

Quantitative numerical modelling has been completed for the assessment of existing flooding, stormwater discharge and groundwater quantity conditions, and to assess the potential impacts of the project on flooding and groundwater quantity. Details on the modelling are provided in **Appendix A** for groundwater quantity and **Appendix B** for flooding. A summary of the modelling is provided in the following sections.

Groundwater modelling

Three-dimensional numerical groundwater modelling was carried out using MODFLOW-NWT, an industry standard saturated groundwater flow model code.

Objectives of the groundwater model were to:

- Match historical groundwater levels
- Predict change in groundwater level due to the project
- Predict change in groundwater contribution to proximate surface watercourse and wetlands due to the project.

Target model confidence level classification, in accordance with Australian Groundwater Modelling Guidelines (AGMG) (Barnett et. al., 2012) is Class 2.

The groundwater model was applied to predict water level responses due to soft sediment consolidation, groundwater inflow and drawdown in relation to excavations for water quality basins and the Purgatory Creek adjustment. Dewatering requirements for smaller scale excavations (such as for bridge pier foundations) were assessed analytically due to limitations of the groundwater model resolution.

Details of the numerical groundwater modelling, including construction, calibration and model results are provided in **Appendix A**. An assessment of potential impacts due to predicted groundwater level change is provided in **Section 5.2.3** and **Section 5.3.3.**

Flood modelling

Detailed flood modelling was completed to inform the concept design and the environmental impact assessment. The modelling was carried out in a TUFLOW two-dimensional flood hydraulic model of the Lower Hunter River. The model extends five kilometres upstream on the Hunter River and four kilometres upstream on the Williams River from the junction of the Hunter River and the Williams River at Raymond Terrace, and includes the floodplains of those rivers. The model extends in the downstream direction to the river's outlet into the Tasman Sea to the east of the city of Newcastle. The model also extends to cover:

- The Hunter River floodplain west to Thornton and Beresfield
- Swamp areas around Hexham in the west and to the south-east of the Hunter River, this includes some areas of Coastal Wetlands and areas within Hexham Swamp Nature Reserve that are referred to in this report as Hexham Swamp
- The Fullerton Cove overflow onto the Tilligerry Creek floodplain at Williamtown and Salt Ash to the south and southeast
- The Tilligerry Creek outlet to Port Stephens, in the northeast.

Figure B-1 in **Appendix B** shows the TUFLOW model configuration and results for existing conditions in the flooding study area. In summary, the flood modelling assessment included:

- Collection and review of existing flood studies and flood models from local councils, information on historic flooding (including recorded rainfall and water level data) and other data contained in existing flood studies

- Review of XP-RAFTS hydrology and hydraulic TUFLOW (BMT, 2018) flood models, reporting and background data developed for the Williamtown Salt Ash Floodplain Risk Management Study and Plan (BMT WBM, 2017)
- Update and refinement of XP-RAFTS hydrology models for Purgatory Creek and Tomago area
- Update and simulation of XP-RAFTS hydrologic models in accordance with design rainfall and guidelines in ARR 2019 (Ball et al, 2019)
- Simulation of runoff hydrographs for the flood events of April 2015 and January 2016 and design flood events including the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events on the basis of ARR 2019 (Ball et al, 2019)
- Conversion of the 20 metre grid TUFLOW Classic hydraulic model to a 20 metre grid TUFLOW HPC hydraulic model to reduce model run time
- Update and refinement of the TUFLOW model in key locations based on additional topographic survey and site reconnaissance, including improved representation of Hunter Valley Flood Mitigation Scheme and other important drainage features
- Update and refinement of the TUFLOW model in key locations based on additional topographic survey and site reconnaissance
- Verification of the updated TUFLOW model for the flood events of April 2015 and January 2016
- Modelling of the April 2015 and January 2016 flood events for existing case, and assessment of operational phase to demonstrate impacts of the project on historic flood events
- Modelling assessment of a range of design flood events including the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the existing case utilising an envelope of flooding mechanisms dominated by a combination of rainfall runoff generated over the local catchments, Hunter River inflow and tide levels
- Validation of the results was undertaken with comparison to design flood levels presented in previous studies (DHI, 2008; BMT WBM, 2012b; and BMT WBM, 2017) (refer to **Section 4.5.6**)
- Modelling assessment of a range of design flood events including the 20%, 10% and 5%AEP flood events for the construction phase
- Modelling assessment of a range of design flood events including the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the operational phase, representing the change in land use, drainage conditions and hydraulic obstructions potentially affecting flood hydrology
- Analysis of the sensitivity of flooding to blockage condition of hydraulic structures and to climate change scenarios (rainfall and flood flow increase, and sea level rise). Refer to the discussion on climate change assessment in **Section 5.3.8** for details
- Assessment of cumulative flooding impacts due to the project and other approved projects
- Independent verification reviews of the flood modelling carried out by third parties external to the project design and environmental assessment.

The models have been verified against historic flooding events, validated against existing flood studies and independently verified so they are robust and appropriate for use in this assessment.

Limitations identified in the flood modelling are summarised below:

- The extent of identified flooding impacts is in some cases limited by the extent of the available flood modelling. Impacts may extend further than the model domain
- The flood model is based on a 20 metre resolution model grid and estimates of localised impacts due to small scale features are considered indicative

- The absolute accuracy of the flood model is generally limited by vertical accuracy of LiDAR data (typically +/- 0.15 metres to one standard deviation), horizontal resolution of the model grid (20 metres), accuracy of bathymetric survey, the dynamic nature of the river bathymetry and other factors such as temporal variability of vegetation. Given these factors, the accuracy of the flood model is likely to be +/- 0.1 to 0.2 metres, with the accuracy of the LiDAR being a significant influence on the model accuracy. Other technical factors, including the numerical precision of the modelling computation scheme, also contribute to accuracy limits on all flood models. As a result, ARR 2019 guidelines (Ball et al, 2019) state that it is appropriate the modelling results (flood levels) are not reported to the nearest millimetre, and impacts less than 0.01 metre (i.e. 10 millimetres) are not reported, as they are considered to be within the precision of the numerical model and data.

Stormwater discharge modelling

An assessment of stormwater and flood discharges from the project was carried out based on DRAINS hydrologic modelling of existing and operational phase drainage conditions in accordance with ARR 2019 (Ball et al, 2019). The design rainfall data required for hydrological and hydraulic modelling has been obtained from the BOM website for Heatherbrae. Rainfall temporal pattern ensembles were obtained by downloading the data from the ARR Data Hub. The modelling was carried out using the RAFTS storage routing hydrology within DRAINS. Generally, the parameters in **Table 3-1** have been used for the RAFTS hydrology within DRAINS model.

Table 3-1 RAFTS loss model parameters adopted in DRAINS model

Description	Value
Impervious areas initial loss	1 mm
Impervious areas continuing loss	0 mm/h
Pervious areas initial loss	4 mm for 1% AEP event 6.6 mm for 5% AEP event 7.9 mm for 0.2 EY (1 in 2 year) event
Pervious areas continuing loss	1.08 mm/h
Bx (storage coefficient)	1.0

Flows were quantified at the downstream model boundary, i.e. the area immediately downstream of project stormwater discharges to receiving waterways and drainage lines. Model output was used to assess potential impacts to downstream drainage systems and natural areas and is considered indicative of conditions immediately downstream of the assessed discharge location only.

3.4 Site inspections

3.4.1 Surface water hydrology site inspection

Visual assessment of the hydrological conditions of the waterways traversed by or in close proximity to the project was carried out in conjunction with surface water quality monitoring at nominated project-specific monitoring sites. Twenty one monitoring sites were selected for surface water monitoring. These sites are listed in **Table 3-2** and shown on **Figure 4-1**.

Table 3-2 Project surface water monitoring sites

Site name	Surface water feature	Location
M12RT1	Glenrowan Creek	Within main alignment
M12RT2	Purgatory Creek (in Coastal Wetland)	Traverses main alignment
M12RT2a	Purgatory Creek (at crossing/ancillary facility location), east of the New England Highway	Traverses main alignment
M12RT2b	Purgatory Creek (west of Woodlands Close)	Downstream of main alignment
M12RT2c	Purgatory Creek downstream	Downstream of main alignment
M12RT2d	Purgatory Creek downstream at junction with Hunter River	Downstream of main alignment
M12RT3	Hunter River at crossing	Traverses main alignment
M12RT3a	Hunter River midstream	Downstream of main alignment
M12RT3b	Hunter River downstream	Downstream of main alignment
M12RT4	Hunter River Drain (upstream of Hunter River)	Downstream of main alignment
M12RT5	Unnamed tributary of Hunter River Drain (at construction sediment basin outlets)	Downstream of construction footprint
M12RT6	Windeyers Creek (at the project crossing)	Traverses main alignment
M12RT6a	Windeyers Creek upstream of tributary	Upstream of main alignment
M12RT6b	Downstream of Windeyers Creek crossing and tributary of Windeyers Creek	Downstream of main alignment
M12RT7	Tributary of Windeyers Creek at Crossing	Traverses main alignment
M12RT8	Hunter River wetland	Downstream of construction boundary
M12RT9	Drainage canal, Old Punt Road	Downstream of construction boundary
M12RT10	Grahamstown Drain	Downstream of construction boundary
M12RT11	Unnamed Coastal Wetland (east of Hunter River)	Downstream of construction boundary
M12RT11a	Unnamed tributary located in unnamed Coastal Wetland (east of Hunter River)	Downstream of construction boundary
M12RT12	Viney Creek	Downstream of construction boundary

The method of water quality monitoring at monitoring sites is detailed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS), however, for waterway hydrology, the field assessment was limited to visual observations of:

- Waterway dimensions – approximate width of the waterway at the monitoring location
- Water level – estimation of whether the waterway had low, moderate or high water level at the time of inspection
- Flow direction – noting direction of flow or if the waterway had no flow at the time of inspection
- Waterway obstructions – noting if there were any visible obstructions at the site or downstream (i.e. existing culverts or floodgates)
- Erosion potential – noting any visible signs of erosion and erosion potential.

3.4.2 Groundwater site inspection

Field assessment carried out for the project is covered comprehensively in **Appendix A**, with an investigation summary provided below. Field assessment included:

- Pore pressure dissipation tests via cone penetrometer testing (CPT)
- Establishment of a groundwater monitoring network, which included a total of 20 piezometers at 13 locations, comprising six single and seven paired (deep and shallow) installations
- Hydraulic testing at selected project piezometers
- Groundwater level monitoring at the project piezometers, which included:
  - Five groundwater level sampling rounds, spanning between September 2016 and July 2017 which is considered representative of current groundwater levels
  - Included manual dip gauging of groundwater level and download of groundwater level data loggers (six-hourly data recording frequency), which were installed at 12 of the project's 20 piezometers.

Groundwater quality sampling was also carried out as part of the field assessment as discussed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

3.5 Community and stakeholder consultation

3.5.1 Flood focus group

Transport invited community representatives to participate in a flood focus group to keep the community informed about the flood assessment progress and for the community to contribute valuable information to the flood assessment process. Community representatives and stakeholders were selected to attend the flood focus group, including:

- Six community members
- Four local business owners / managers (Weathertex, Aurizon, Koide, Port Stephens Hexham junction Pty Ltd)
- Hunter Region Botanic Gardens
- Cessnock City Council
- Maitland City Council
- City of Newcastle
- Port Stephens Council
- Hunter Water Corporation
- NSW State Emergency Services
- Department of Planning and Environment (now DPIE)
- Department of Primary Industries (now DPIE)
- Office of Environment and Heritage (now DPIE)
- The project team, including flooding, environmental, consultation and project management specialists
- Independent flood reviewers.

One flood focus group meeting has been held to date on 18 February 2016. The meeting provided the opportunity to introduce the project and describe the flood focus group process. The project team was able to discuss the flood assessment approach. The community had the opportunity to ask questions, raise concerns and provide information about the nature of flooding in regard to the project.

3.5.2 Landowner discussions

The Jacobs flooding team, independent flood reviewers and Transport representatives met with property owners near to the project to gain an understanding of the flooding issues that are faced by the residents and the behaviour of flooding and drainage. In addition to these discussions, a business owner and a business manager were also consulted. These discussions were carried out between January 2015 and August 2016.

3.6 Assessment criteria

3.6.1 Surface water hydrology assessment criteria

The NSW River Flow Objectives as outlined in **Section 2.3.13** form the basis of the assessment for surface water hydrology, and specifically the potential stormwater discharges. The NSW Blue Book requirements (DECC, 2008a and 2008b) apply to stormwater discharge velocities during the construction phase, specifically increased velocities. The project design has sought to minimise increases in discharge velocities by providing scour protection downstream of stormwater discharge outlets where outlet velocities exceed relevant industry guidelines and/or as required in accordance with the NSW Blue Book (DECC, 2008a and 2008b).

3.6.2 Groundwater assessment criteria

Potential construction and operation impacts were assessed against the AIP (DPI NOW, 2012) minimal impact considerations for groundwater level.

With consideration for project and adjacent water quality data an assessment of the productivity of the various groundwater sources near to the project is provided in **Table 3-3**. The relevant AIP minimal impact considerations are shown in **Table 3-4**.

Minimal impact considerations with respect to water quality are discussed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

Table 3-3 Water source type and productivity

Water source	Type	Productivity
Newcastle Water Source	Alluvial	Less Productive (variable yields and high salinity)
Sydney Basin–North Coast Groundwater Source	Porous Rock	Less Productive (variable yields and high salinity)
Tomago Groundwater Source	Coastal Sands	Highly Productive

Table 3-4 AIP (DPI NOW, 2012) minimal impact considerations

Water source	Minimal impact considerations
Newcastle Water Source: • alluvial • less productive	**Water table:** 1) Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2m decline cumulatively at any water supply work unless make good provisions should apply. 2) If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work, then make good provisions should apply. **Water pressure:** 1) A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work. If the predicted pressure head decline is greater than requirement 1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.
Sydney Basin–North Coast Groundwater Source: • porous rock • less productive	**Water table:** 1) Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan. A maximum of a 2m decline cumulatively at any water supply work. 2) If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2m decline cumulatively at any water supply work, then make good provisions should apply. **Water pressure:** 1) A cumulative pressure head decline of not more than a 2m decline, at any water supply work. 2) If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply

Water source	Minimal impact considerations
Tomago Groundwater Source: • coastal sands • highly productive	**Water table:** 1) Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan. A maximum of a 2m decline cumulatively at any water supply work. 2) If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work, then make good provisions should apply. **Water pressure:** 1) A cumulative pressure head decline of not more than a 2m decline, at any water supply work. 2) If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.

3.6.3 Flood related design assessment criteria

Flood design criteria

The relevant design criteria are outlined below:

- Flood immunity requirement – 5% AEP Hunter River flood for the proposed motorway. Not applicable to existing roads which are realigned as a part of the project (e.g. Pacific Highway, New England Highway and other roads). The flood immunity is achieved through design of proposed road embankments and transverse culverts
- Underside of all bridges above the 1% AEP flood plus 0.5 metres freeboard
- Transverse culverts are generally designed for 1% AEP event (local catchment flooding), and 5% AEP in the floodplain to ensure 5% AEP flood immunity is provided to the carriageway edge line
- Minimise the increases in flood levels/depths, velocity, hazard and duration of inundation due to temporary and permanent infrastructure where reasonable and feasible during flood events up to an including the 1% AEP event
- Dedicated evacuation routes would not be adversely impacted in flood events up to and including the probable maximum flood.

Based on preliminary analysis of flooding for the project, provisions in the design to achieve flood immunity of the project in future climate change flood scenarios were omitted as these would generally require a higher road finished level and result in higher impacts on flooding due to the project in both existing and future climate scenarios. However, the impact of increased flooding on the project due to climate change is assessed and discussed in **Section 5.3.8**.

Flood management design objectives

The objectives detailed in **Table 3-5** have been adopted as the project's quantitative design limits. These objectives apply outside the project boundary, for events up to and including the 1% AEP flood event. Justification for each objective is provided in **Table 3-5**.

These have been established based on policies, planning controls and guidelines (including the NSW Floodplain Development Manual, local development control plans and relevant floodplain risk management plans see **Chapter 2**) as relevant and similar infrastructure projects in NSW. Adoption of these objectives minimises the risk to public safety, buildings, existing highways and roads, existing rail lines and land uses.

Table 3-5 Quantitative flood management objectives

Parameter	Location or land use	Quantitative design objective	Justification / description
Afflux i.e. increase in flood level resulting from implementation of the project	Above floor flooding of habitable floors [1]	50 mm	For the project, the increase in flood level (afflux) should be minimal. A target maximum afflux of 50 mm has been adopted for habitable floors where there is above floor flooding. This target is unlikely to result in a significant impact to land use and hazard. A 50 mm afflux threshold is considered reasonable in relation to the magnitude of flooding in the Hunter River and the overall susceptibility of urban development in the floodplain (large majority is above the 1% AEP; most of the impacted area is rural). For the remaining areas a target of 100 mm afflux outside the project has been generally adopted. Where survey information of habitable floors was not available, a target maximum afflux of 50 mm has been adopted.
	Below floor flooding at habitable buildings	100 mm	
	Other urban and recreational	100 mm	
	Sensitive infrastructure, assumed to include: • Emergency services (e.g. hospitals, ambulance, fire, police stations) • Electricity substations • Water treatment plants.	50 mm	
	Rural and forest	100 mm	
	Named roads and railways	Less than 100 mm. Less than 10% change in length of overtopping.	Target has been adopted to minimise impacts to transport routes.
Flood hazard i.e. increase in flood hazard resulting from implementation of the project Refer to **Section 2.3.12** for definition of flood hazard	All areas outside the project	Minimise changes based on an assessment of risk with a focus on land use and flood sensitive receptors	Minimising increases in flood hazard is important for public safety. Ensuring there are no widespread increases in flood hazard also ensures there are no changes to hydraulic characteristics of the floodplain including floodways and flood storages. The project has been developed with a target of minimising increases in flood hazard

Parameter	Location or land use	Quantitative design objective	Justification / description
Flood duration i.e. increase in duration of inundation resulting from implementation of the project	All areas outside the project	Less than 10% change in duration of inundation for flood depths above 0.5 metres	Minimising increases in duration of flood inundation will mitigate potential impacts to residents that may be isolated within houses or may have evacuated and wish to return within a reasonably similar timeframe as is currently possible. It is also important in order to minimise impacts to rural and forested lands including agricultural activities. The project has been developed with a target of minimising increases in duration of flood inundation.

1 Habitable floors/rooms are defined consistent with the use of this term in the NSW Floodplain Development Manual (NSW Government, 2005). In a residential situation this comprises a living or working area such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial, commercial or other building, this comprises an area used for an office or to store valuable possessions, goods or equipment susceptible to flood damage in the event of a flood

4. Existing environment

4.1 Catchment overview

The project is located in the lower portion of the Hunter River catchment in NSW. The Hunter River catchment is east of the Great Dividing Range, bound by the Manning and Karuah catchments to the north, and by the Lake Macquarie and Hawkesbury-Nepean catchments in the south. The catchment drains a total area of about 22,000 square kilometres. The headwaters of the Hunter River are located in the Liverpool Ranges, which flows generally in a south-easterly direction for about 450 kilometres, before reaching the Tasman Sea at Newcastle. Elevations across the catchment vary from over 1,500 metres above sea level in the mountain ranges, to less than 50 metres above sea level on the floodplains of the lower valley. Four major rivers discharge into the Hunter River along its length – these are Pages River, Goulburn River, Paterson River and Williams River. The lower reaches of the Hunter River form an open, wave-dominated barrier estuary which extends about 64 kilometres inland to its tidal limits at Oakhampton (OEH, 2017). The estuary has two main channel arms (north and south) that diverge about 17 kilometres from the mouth (about three kilometres downstream of the project) and reconverge about four kilometres from the mouth.

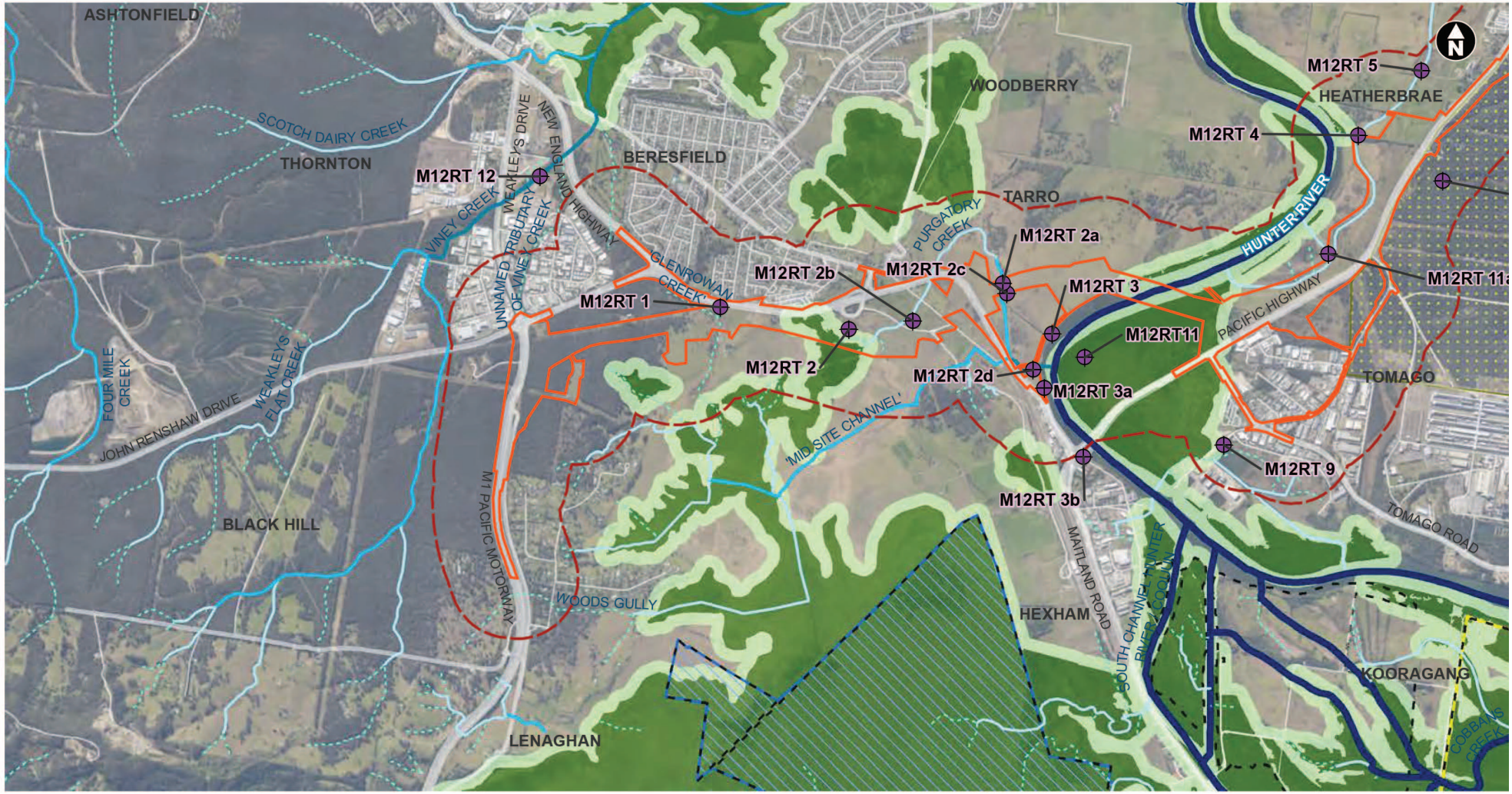
The Hunter River catchment spans over seven local government areas. The upper catchment is predominantly an agricultural landscape on floodplains dispersed with smaller urban centres. The area surrounding the lower estuary is heavily urbanised with substantial industrial, commercial and residential development and a major harbour port near the mouth of the estuary.

The project construction and operational footprints intercept waterways within the suburbs of Black Hill, Beresfield, Tarro, Heatherbrae and Raymond Terrace. Key waterways, drainage lines and tributaries with the potential to be impacted by the project are described in **Section 4.3.2** and shown in **Figure 4-1**.

4.1.1 Land use

The flooding study area described in **Section 3.2** falls within three LGAs, Maitland LGA in the northwest, City of Newcastle LGA in the southeast, and Port Stephens Council LGA in the northeast. The project itself is within City of Newcastle and Port Stephens Council LGAs. The project construction and operational footprints are in proximity to several urban centres, industrial areas, land utilised for agricultural purposes and water supply areas including the Tomago Sandbeds. Residential areas within proximity of the project include Black Hill, Tarro, Heatherbrae and Raymond Terrace, with other residential areas in Wallsend, Maryland and Birmingham Gardens located further away to the south.

Tomago, which is located on the eastern side of the Hunter River, is heavily industrialised with an Aluminium Smelter (Tomago Aluminium) and Forgacs shipyard located within 1.5 kilometres of the eastern bank of the Hunter River Estuary. The Grahamstown Water Treatment Plant is located about five kilometres east of Tomago and the Hunter River Estuary, on the north-western bank of Fullerton Cove. North east of Tomago, in the northern portion of the suburb of Heatherbrae, the Raymond Terrace Wastewater Treatment Plant discharges treated effluent to Grahamstown Drain which subsequently flows to the Hunter River via Windeyers Creek (Hunter Water, 2020). Other heavy industry areas are located in Hexham and Sandgate, in addition to Kooragang Island.



Construction footprint
Surface water study area
Tomago Sandbeds catchment area

Coastal Management SEPP 2018

Coastal wetlands
Coastal wetlands proximity area

National Park and Wildlife Services Estate

Hunter Wetlands National Park
Hexham Swamp Nature Reserve

Hunter Estuary Wetlands Ramsar

Kooragang Nature Reserve

Strahler Stream Order

SSO 1
SSO 2
SSO 3
SSO 4
SSO 9

Surface water monitoring site

Figure 4-1 Key waterways and drainage features (map 1 of 3)

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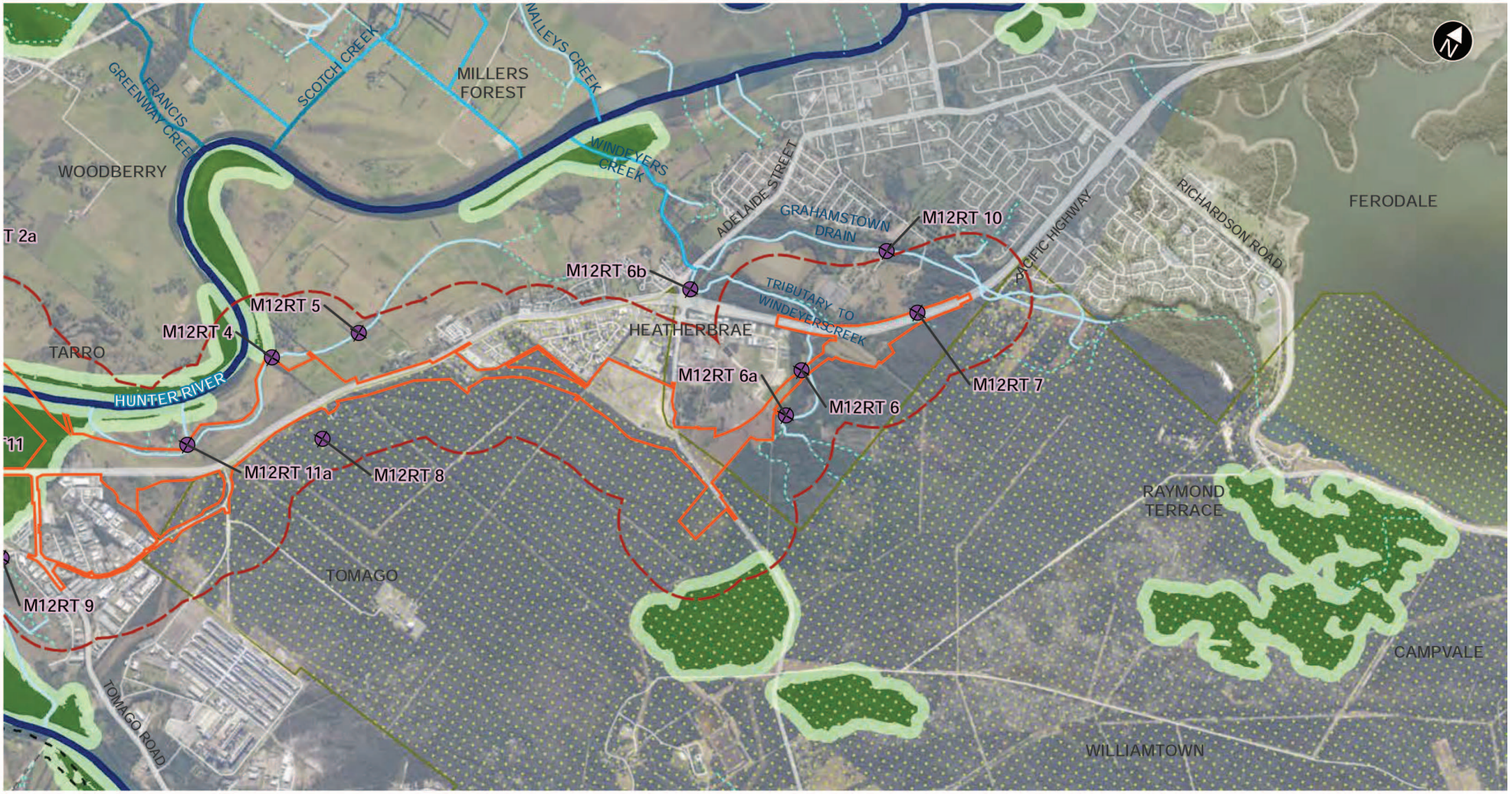

Figure 4-1 Key waterways and drainage features (map 2 of 3)

Page 2 of 3

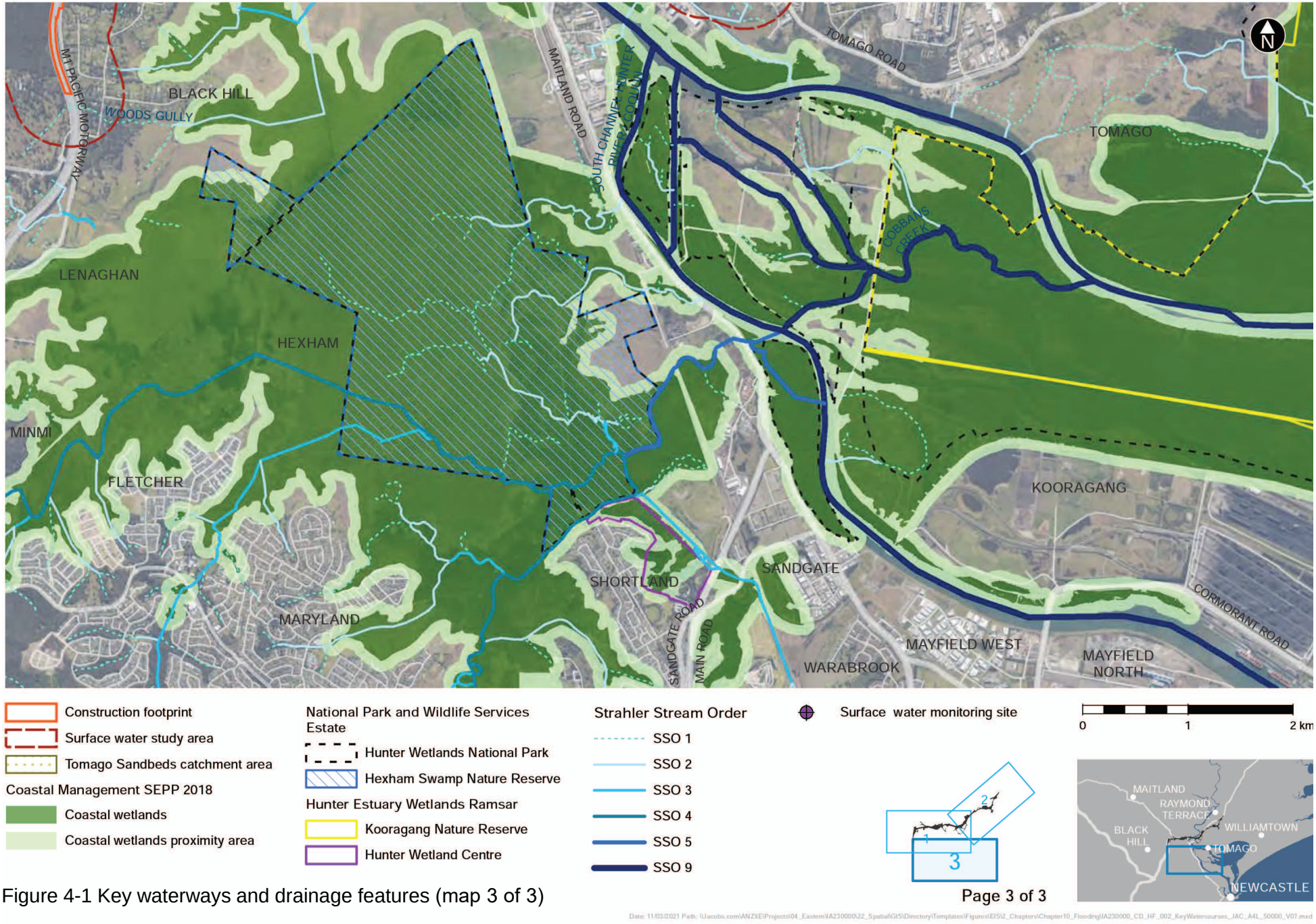

Figure 4-1 Key waterways and drainage features (map 3 of 3)

Page 3 of 3

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The project crosses the Hunter River and its floodplain. Land use outside the residential areas, on the floodplain to the north of the project is primarily rural and primary production, which consists mainly of grazing and beef production. To the south west of the project and west of the Hunter River in Hexham land is zoned for environmental conservation, national park and nature reserves. Land uses on the southern side of the project to the east of the Hunter River in Tomago include environmental conservation in wetlands and national parks, industrial and special activity areas. Land use on Kooragang Island is mainly national park and nature reserves, with industrial and port facilities at the south-eastern end of the island. Land uses on the Tilligerry Creek floodplain area are primarily rural, rural residential, primary production and national parks.

A motorway, several highways and roads are also within proximity of the project, including the M1 Pacific Motorway at Black Hill, New England Highway near Tarro, Maitland Road, the Pacific Highway (including Hexham Bridge across the Hunter River), and Tomago Road.

4.1.2 Topography

The project is located in the lower Hunter River catchment area, which is generally characterised as a low-lying, gently undulating floodplain environment (refer to **Figure 4-2**). A review of local topographic mapping indicates that the elevation and topography across the flooding study area and varies along the main alignment of the project with three distinct areas identified as follows:

- Western portion: comprising gently sloping ground between reduced level (RL) four metres Australian Height Datum (AHD) and RL 30 metres AHD (with a ridgeline oriented north to south)
- Central portion: comprising low lying, gently undulating floodplains at below RL three metres AHD
- Eastern portion: comprising mildly undulating terrain between RL two metres AHD and 10 metres AHD, with a localised area (possibly fill) adjacent to Masonite Road (western side) of about RL 12 metres AHD.

4.1.3 Climate and rainfall

The climate of the Lower Hunter River catchment is warm and temperate, generally experiencing mild to hot summers and cool to mild winters (Köppen classification is temperate, no dry season (hot summer)). Average maximum temperature approaches 30 degrees Celsius in January and average maximum July temperatures are about 18 degrees Celsius (BOM, 2020a).

Long term rainfall data for weather station 61031 (Raymond Terrace, 1894 to present) obtained from Bureau of Meteorology is presented in **Table 4-1** and **Figure 4-3**:

- Mean annual rainfall is approximately 1041 millimetres
- Annual rainfall variability is relatively low with a standard deviation of 255 millimetres and coefficient of variation of 0.24
- Monthly rainfall is moderately seasonally distributed with a wetter period from December through June and a drier period from July through November
- Median monthly rainfall is lowset in August (40.8 millimetres) and highest in March (102.1 millimetres).

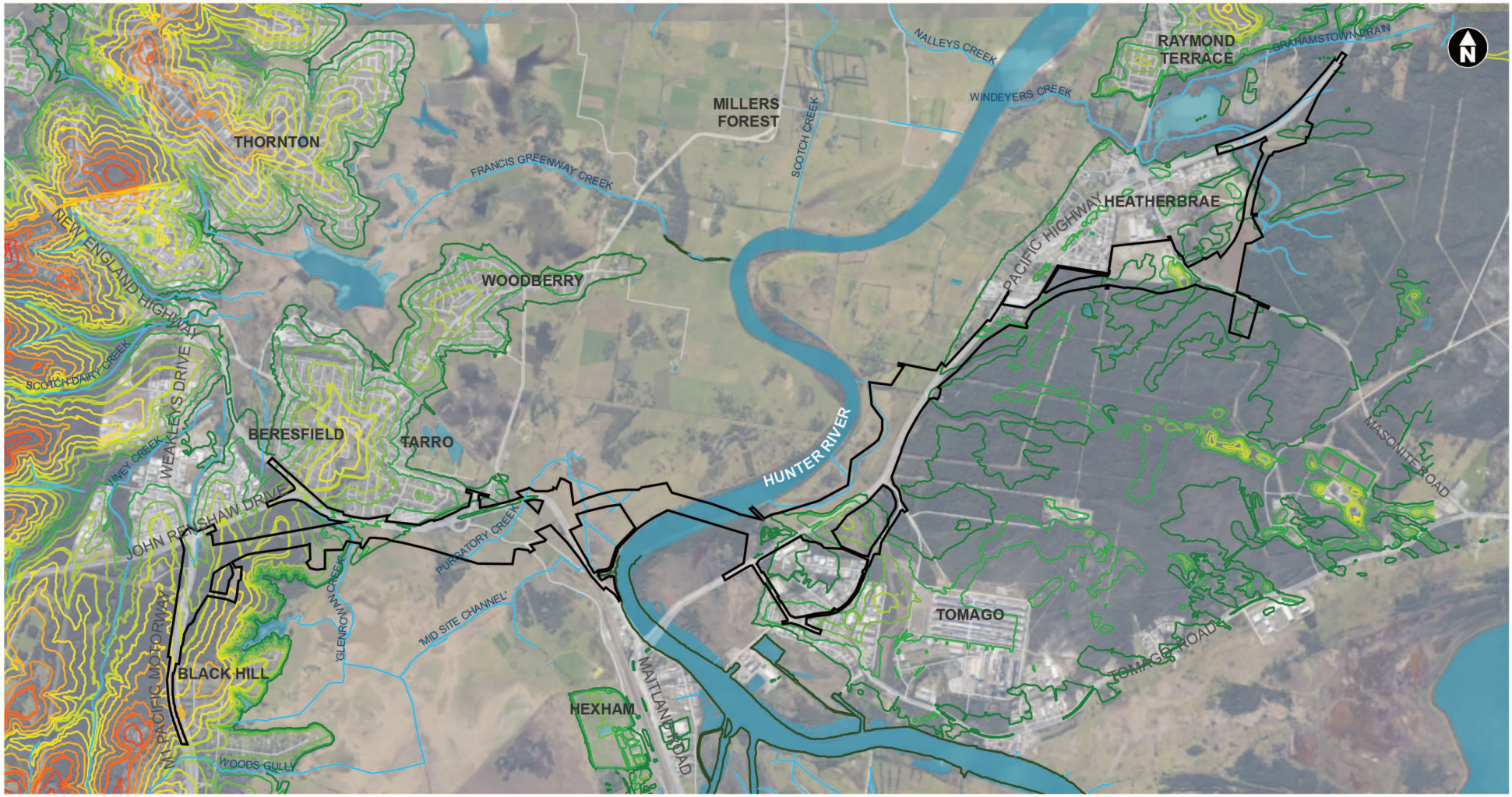
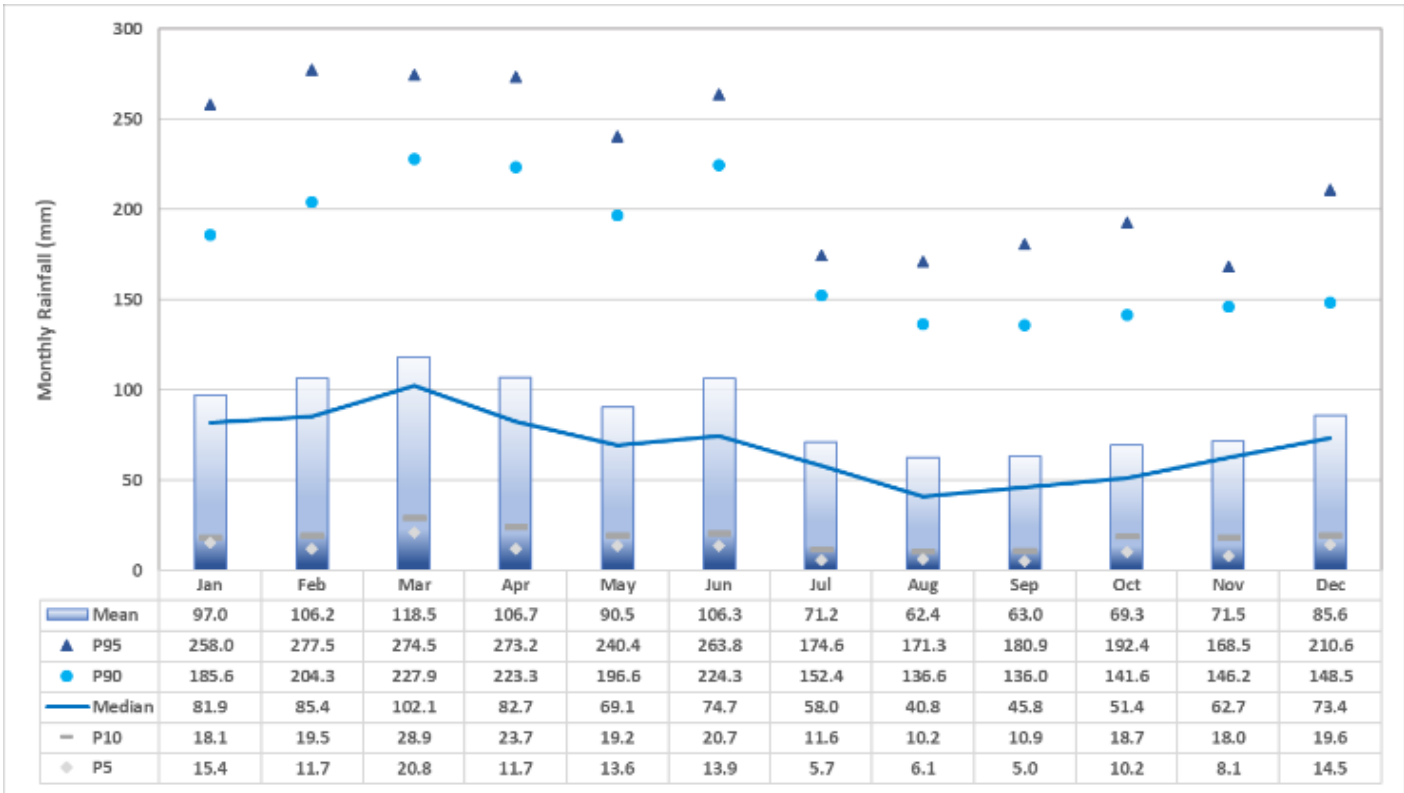


Figure 4-2 Elevation

Table 4-1 Long term annual rainfall (61031, Raymond Terrace, 1894-present)[1]

Statistic	Annual rainfall (mm)
Mean	1,041
P95	1,477
P90	1,390
P50	1,025
P10	718
P5	680
Standard deviation (mm)	255
Coefficient of variation (unitless)	0.24



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	97.0	106.2	118.5	106.7	90.5	106.3	71.2	62.4	63.0	69.3	71.5	85.6
P95	258.0	277.5	274.5	273.2	240.4	263.8	174.6	171.3	180.9	192.4	168.5	210.6
P90	185.6	204.3	227.9	223.3	196.6	224.3	152.4	136.6	136.0	141.6	146.2	148.5
Median	81.9	85.4	102.1	82.7	69.1	74.7	58.0	40.8	45.8	51.4	62.7	73.4
P10	18.1	19.5	28.9	23.7	19.2	20.7	11.6	10.2	10.9	18.7	18.0	19.6
P5	15.4	11.7	20.8	11.7	13.6	13.9	5.7	6.1	5.0	10.2	8.1	14.5

Figure 4-3 Long term monthly rainfall monthly (61031, Raymond Terrace, 1894-Present)

[1] Annual statistics do not include data from 1999-2001, 2007-2015 and 2020.

4.2 Geology and soil landscapes

4.2.1 Geology

Three main geological units lie along the project based on the 1:100,000 scale regional geology map for Newcastle (NSW Department of Mineral Resources, 1975), as shown in **Figure 4-3**. From west to east, these geological units along the project include:

- Permian Tomago Coal Measures
- Quaternary aged sediments associated with the Hunter River
- Quaternary Coastal Sands.

Further detail on the geology near the project is included in **Appendix A**.

4.2.2 Soil landscapes and characteristics

The project and surrounding area traverse several soil landscapes as described in **Table 4-2** and shown on **Figure 4-5**. Further detail on the soil landscapes and characteristics near the project is included in the Soils and Contamination Working Paper (Appendix P of the EIS).

Table 4-2 Soil landscapes around the project

Soil landscape	Description (taken from Douglas Partners, 2015)
Beresfield soil landscape	The Beresfield soil landscape group comprises undulating low hills and rises on Permian sediments with slopes between 3% to 15% and an elevation of 20m to 50m. Dominant soils comprise brown black loam (topsoils) and yellow brown sandy loam (topsoil), brown plastic mottled clays (subsoil), red brown plastic clays (subsoil) or silty clays (subsoil). Limitations include high foundation hazard, water erosion hazard, seasonal water logging and high run-on on localised low slopes, highly acidic soils of low fertility. Red-brown clays and silty clays are sodic / highly sodic and susceptible to dispersion.
Residual soil of the Hamilton landscape	The Hamilton soil landscape group comprises level to gently undulating well-drained plain on Quaternary aged deposits with slopes <2% and elevations up to 12m. Dominant soils comprise brown black loamy sand and pale coarse sand (topsoils) and brown to orange sandy pan (subsoil). Limitations include wind erosion hazard, groundwater pollution hazard, strong acidity, non-cohesive soils.
Millers Forest estuarine landscape	The Millers Forest landscape group comprises extensive alluvial plain on recent sediments with an elevation of 6m to <3m and slopes <1%. Dominant soils comprise brown black silty clay loam (topsoils) and brown silty clay (subsoil). Limitations include flood hazard, permanently high water tables, seasonal waterlogging and foundation hazard, low wet bearing strength soils. Brown silty clay subsoils are also limited by sodicity / dispersion, salinity (localised, at depth) and potential acid sulphate soils at depths below 1.5m AHD.
Fullerton Cove estuarine landscape	The Fullerton Cove landscape group comprises tidal flats and creeks in tidal inlets and estuaries with slopes <3% and elevation <3m. Dominant soils comprise black organic rich peat or saturated saline organic mud. Limitations include flooding, wave erosion hazard and foundation hazard, saturated, saline, potential acid sulphate soils.
Hexham Swamp landscape	The Hexham Swamp landscape group comprises broad, swampy, estuarine backplains on the Hunter delta with slopes <1% and elevation <2m. Dominant soils comprise black silty clay loam (topsoil) and plastic clays (subsoil). Limitations include flood hazard, permanently high water tables, seasonal waterlogging, foundation hazard, groundwater pollution hazard, localised tidal inundation, highly plastic potential acid sulphate soils of low fertility. Both topsoils and subsoils are sodic and very highly saline in localised areas.

Soil landscape	Description (taken from Douglas Partners, 2015)
Tea Gardens Landscape Variant Aeolian landscape	The Tea Gardens landscape group comprises Pleistocene beach ridges on the Tomago coastal plain with slopes <5%, elevations between 5m to 8m. Dominant soils comprise sandy peat, brown/black to brown /grey loamy sand (topsoil), saturated brown/black coarse sandy clay loam (topsoil), bleached sands (shallow subsoil), massive organic pan (loamy sand to sand), coarse smelly saturated sand. Limitations include permanently high water tables, seasonal waterlogging, groundwater pollution hazard, strongly to extremely acid soils of low fertility and low available water-holding capacity.
Blind Harrys Swamp landscape	The Blind Harrys Swamp landscape group comprises waterlogged swales and deflation areas on sands of the Tomago coastal plain with elevation <10m and slopes <2%. Dominant soils comprise black organic fibrous peat and saturated brown mottled sand. Limitations include permanently high water tables, foundation hazard, permanently waterlogged, ground water pollution hazard and strongly acid soils. Sands are also limited by salinity and localised potential acid sulphate soils.
Bobs Farm Beach Landscape	The Bobs Farm variant landscape group comprises low remnant lake shore beach deposits with up to 1m relief, 15m width and 200m in length. Dominant soils comprise dark brown loose loamy sands (topsoil) and yellow brown loose coarse beach sand (subsoil). Limitations include flood hazard, high run-on, wind erosion hazard, non-cohesive soils, groundwater pollution hazard, foundation hazard and permanently high water table.

Soft soil areas are also present along the project in areas where the soils consist of unconsolidated and compressible materials. These are typically present in the estuarine and swampy soil landscapes that are located next to the Hunter River, with the exception of a small area of estuarine soils near Tomago. These soft soil areas require specific ground improvement for road construction (specifically around Tarro and Tomago) and are discussed further in Chapter 5 of the EIS and are displayed as compressible soils (Domains B and C) in the Soils and Contamination Working Paper (Appendix P of the EIS).

Potential surface water, groundwater flow impacts associated with soft soil consolidation are discussed in **Section 5.2.2**, **Section 5.2.3**, **Section 5.2.6** and **Section 5.3.3**. Potential impacts to water quality are discussed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

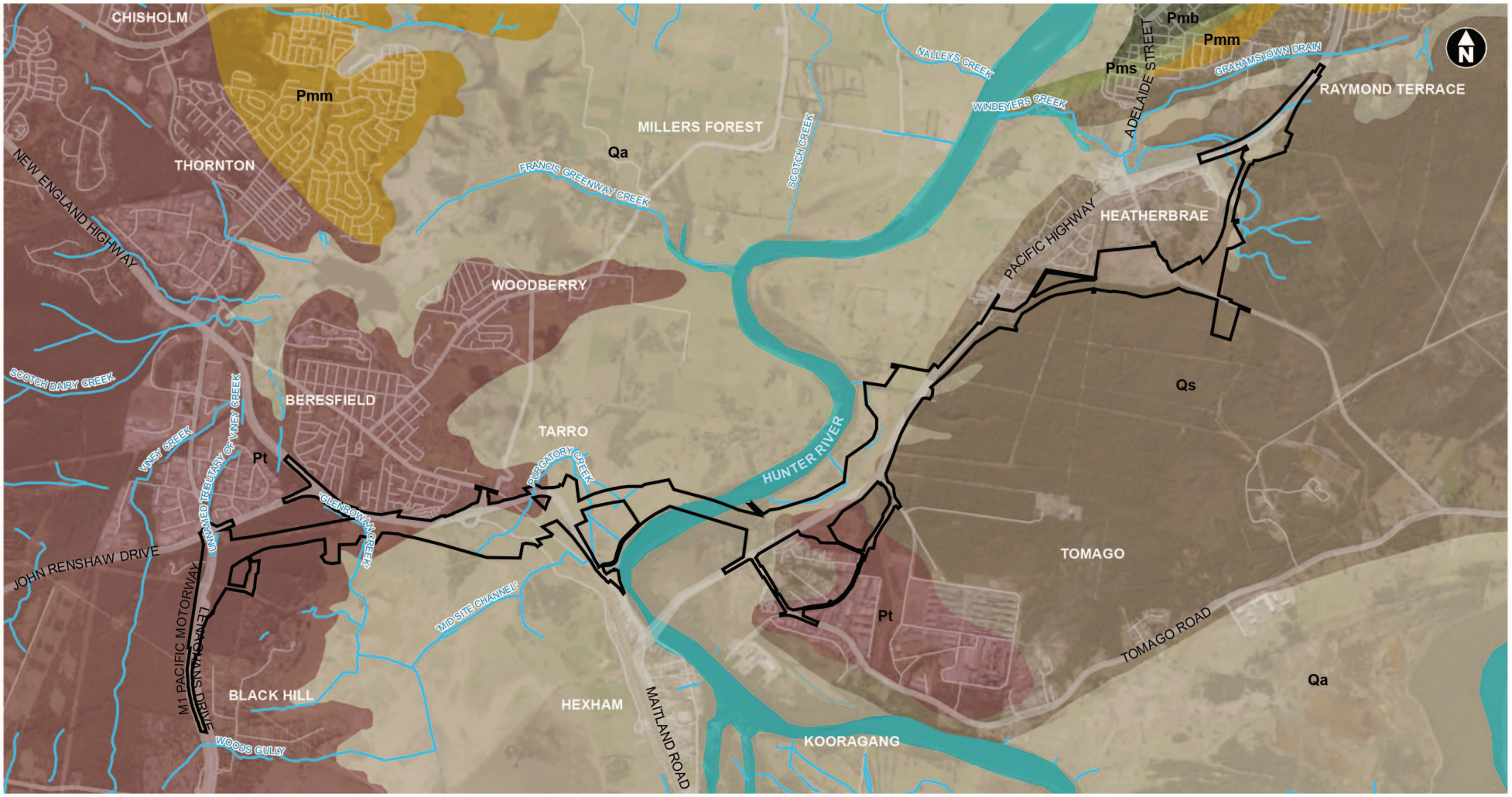


Figure 4-4 Geology

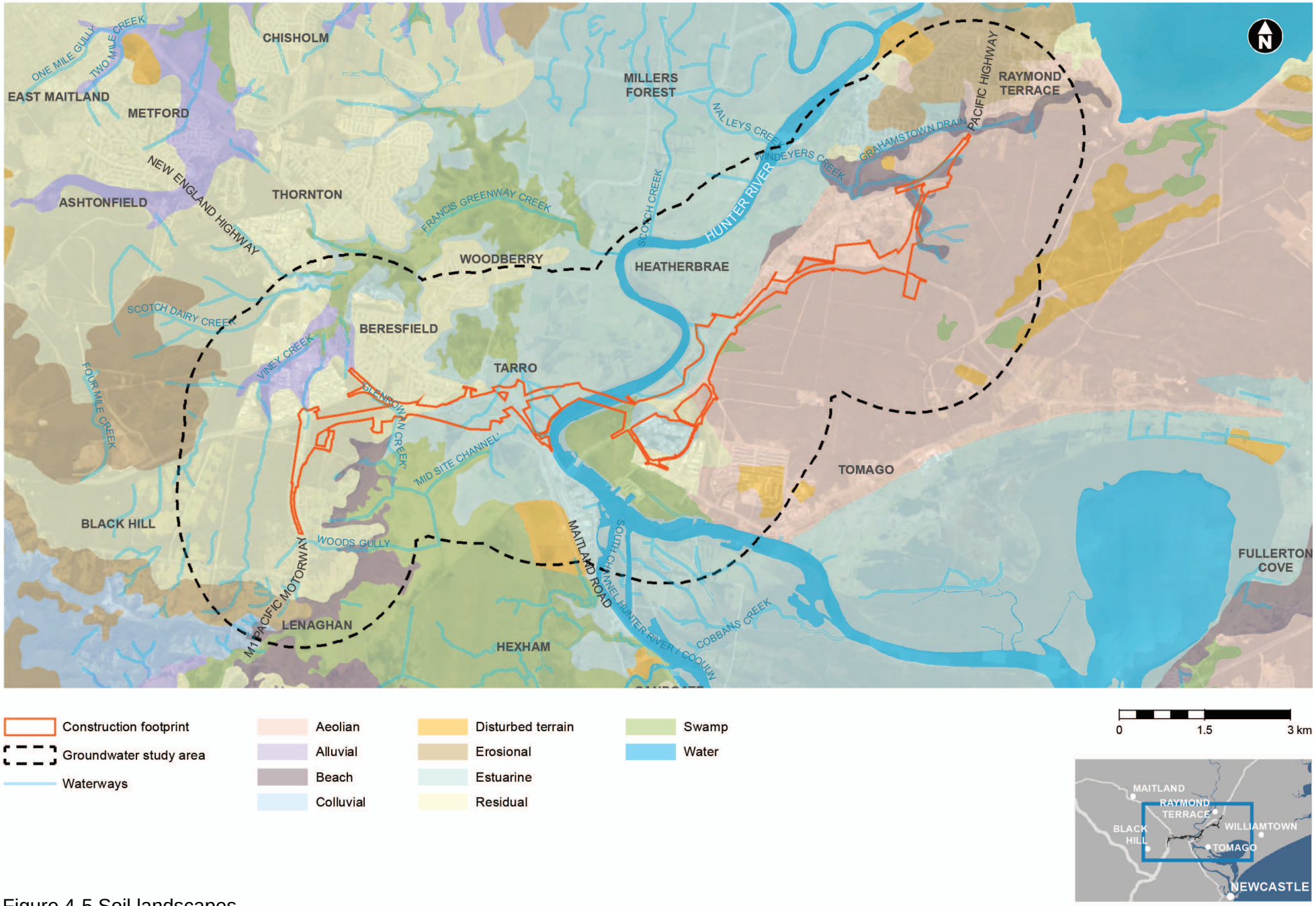


Figure 4-5 Soil landscapes

4.3 Surface water features

Hydrological flow characteristics of waterways within the catchment have been broadly described in **Section 4.3.1**. Key waterways and drains within the surface water hydrology study area and which are crossed by the alignment are shown on **Figure 4-1**. Important wetlands within the flooding study area or within proximity of the project are shown on **Figure 2-1**. These key surface water features have been described in **Section 4.3.2**. Water resources in the surface water study area have been summarised in **Section 4.3.4**.

4.3.1 Hydrological flow regimes

Above the low-lying floodplain areas, the relatively small tributary catchment areas of Viney Creek to the west of the flooding study area would typically only generate episodic flows with stream flow recessing relatively quickly and restricted to periods during and immediately after rainfall events. While baseflow is not expected to form a substantial proportion of total discharge, low channel gradients and channel geomorphology result in prolonged storage of standing water within the channel giving rise to a series of semi-permanent ponds and waterholes.

Flow is not expected to be strongly seasonal. However, some bias towards increased frequency, duration and magnitude of flows through the months of January through June is projected due to the greater rainfall experienced during these months.

Where waterways traverse the low-lying Hunter River floodplain a relatively permanent presence of water is found due to lack of streambed gradient, presence of floodgates and channel incision below the surrounding water table. Inflows from the upper catchment are likely to have long residence times resulting in prolonged inundation of the surrounding catchment after flood events. Refer to **Figure 2-3** for locations of floodgates.

The Hunter River is subject to tidal influence as it traverses the flooding study area (as are all other waterways within the Hunter River catchment downstream of the floodgates). Upstream of the tidally-influenced reach, flow in the Hunter River is partially regulated by the operation of the Hunter Regulated Water Source which comprises two large water supply dams (Glennies Creek and Glenbawn). Examination of stream gauge data for the closest gauge to the flooding study area (210064, Hunter River at Greta, around 32 kilometres north west) indicates that flow is perennial with a strong baseflow component. Mean monthly flow is moderately seasonally distributed and typically greatest from February through March and June.

4.3.2 Waterways and wetlands

Waterways, wetlands, drainage features and floodplains within the surface water study area have been described according to:

- The Strahler stream classification system where waterways are given an order according to the number of additional tributaries associated with each watercourse (Strahler, 1952 and FBA, 2014)
- Other key characteristics including natural stream type, flow direction, riparian buffer areas, and relevant features within, or in proximity to the watercourse, wetland or drainage feature
- Observations of hydrological characteristics of the watercourse, wetland or drainage feature (and any associated tributaries) noted during site visits.

Viney Creek and Woodberry Swamp Coastal Wetland

Viney Creek is an ephemeral, fourth order stream that flows in a north-easterly direction into Woodberry Swamp. Woodberry Swamp is listed as a Coastal Wetland under the Coastal Management SEPP and is located between Maitland and Hexham (refer to **Figure 2-1**). Viney Creek drains a catchment area of 670 hectares with about one fifth of the catchment fully developed (Rayner, et al, 2016). Viney Creek flows through an industrial estate and has several culverts and bridge structures present along the length of the channel which disrupt flow to Woodberry Swamp (refer to **Photo 4-1** and **Photo 4-2**). There is dense riparian and negligible submergent zone vegetation in the upper reaches of Viney Creek, however becomes sparse when the creek flows through the industrial estate.

Photo 4-1 Viney Creek looking upstream

Photo 4-2 Viney Creek looking downstream

An unmapped and unnamed artificial tributary of Viney Creek is proposed to be adjusted to accommodate the project. This tributary meets Viney Creek about 1.5 kilometres to the north of the project. The unnamed tributary of Viney Creek will need to be realigned (to accommodate the entry ramp at the Weakleys Drive and John Renshaw Drive intersection) and drainage from the south western end of the project could discharge into Viney Creek.

At the time of inspection, Viney Creek at monitoring site M12RT12 exhibited the following hydrological characteristics:

- Waterway channel was well defined but with low gradient banks and was about 13 metres wide
- Water levels were moderate and there was low flow
- There was a double culvert present about 50 metres upstream
- There was no evidence of active erosion or erosion potential.

Glenrowan Creek

An unnamed tributary of Mid Site Channel is located south of the New England Highway at Tarro (refer to **Figure 4-1**). While this creek is not formally named, for ease of identification, this creek has been referred to as Glenrowan Creek for the purposes of this assessment only.

Glenrowan Creek is an ephemeral, first order stream that first flows in an easterly direction for about 500 metres through an undeveloped roadside area (with some sparse vegetation) south of the New England Highway then flows south through cleared farm land near Black Hill (refer to **Photo 4-3** and **Photo 4-4**). The creek during dry weather drains to Mid Site Channel, however during a flood event, there are connections under the rail embankment which allows some hydrological connectivity between the northern and southern floodplains (refer to the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS) for further detail).

Glenrowan Creek drains a predominantly agricultural catchment with modified instream vegetation but also receives runoff from New England Highway and urban runoff from Tarro.

Photo 4-3 Glenrowan Creek at monitoring site M12RT1 (looking upstream)

Photo 4-4 Glenrowan Creek at monitoring site M12RT1 (looking downstream)

Twin bridges (B02) are proposed to be built across Glenrowan Creek and the waterway would receive runoff from the operation of the project.

At the time of inspection, Glenrowan Creek at monitoring site M12RT1 exhibited the following hydrological characteristics:

- Waterway had minimal channel definition and was about 15 metres wide
- The site was mostly dry with some residual pools (less than five centimetres deep)
- There was no evidence of active erosion or erosion potential.

Purgatory Creek and unnamed Coastal Wetland

Purgatory Creek is a second order stream that first flows in a north easterly direction under the existing Main North Rail Line and New England Highway, then flows south-east through predominantly cleared farmland to the Hunter River on the eastern side of the New England Highway. Purgatory Creek is ephemeral in its upper reaches, then becomes perennial about 1.5 kilometres upstream of its confluence with the Hunter River. About 450 metres upstream of the confluence with the Hunter River, a second artificial drainage channel has been dredged to connect another drainage channel (Mid Site Channel) to Purgatory Creek and the Hunter River. Floodgates have been installed on the main Purgatory Creek channel (northern channel) about 30 metres upstream of the confluence with the Hunter River and on the artificial channel about 200 metres from the confluence with the Hunter River (refer to **Figure 2-3** for floodgate locations). Below these floodgates, Purgatory Creek and the Purgatory Creek drainage channel are tidally influenced.

The ephemeral headwaters of Purgatory Creek fall within an area that is listed as ‘Coastal Wetland’ under the Coastal Management SEPP (refer to **Figure 2-1**). The creek drains a low-lying floodplain environment which has been substantially modified to accommodate the establishment of agricultural land and linear infrastructure (water mains, overhead transmission lines and associated access roads) and control flooding. In places, the creek has been artificially incised and stabilised with rocks, the majority of native riparian vegetation has been removed from the banks and there is negligible submergent zone vegetation (refer to **Photo 4-5** and **Photo 4-6**). Channel incision is likely to have resulted in altering the water table which has allowed groundwater to inflow to the channel. Given the lack of limited tidal flow, groundwater is likely to constitute a notable portion of the water in the channel. The creek is also influenced by catchment runoff and by the presence of floodgates which disrupt flow and prevent tidal flushing.

Photo 4-5: Purgatory Creek at midstream location (M12RTa) looking upstream

Photo 4-6: Purgatory Creek at midstream location (M12RTa) looking downstream

The project intercepts Purgatory Creek at two locations on the southern side of the Hunter River. Purgatory Creek is also anticipated to receive drainage from the project, while a section of upstream Purgatory Creek in Tarro is proposed to be adjusted to accommodate the project.

At the time of inspection, Purgatory Creek at monitoring sites upstream (M12RT2, M12RT2b), midstream (M12RT2a and M12RT2c) and at the confluence with Hunter River (M12RT2d) exhibited the following hydrological characteristics:

- M12RT2:
  - Waterway had minimal channel definition and was about 10 metres wide
  - Water levels were moderate and water appeared to be stagnant
  - There was no evidence of active erosion or erosion potential.
- M12RT2b:
  - Waterway had minimal channel definition and was about 10 metres wide
  - Water levels were moderate and there was low flow
  - There was a small box culvert present 10 metres upstream
  - There was no evidence of active erosion or erosion potential.
- M12RT2a:
  - Waterway channel was well defined with steep banks and was about eight metres wide
  - Water levels were moderate and there was low flow
  - There was a small box culvert present 10 metres upstream
  - There was no evidence of active erosion or erosion potential.
- M12RT2c:
  - Waterway channel was well defined with steep banks and about 13 metres wide
  - Water levels were moderate and there was low flow
  - Floodgates are located downstream
  - There was some minor active erosion at meander bends and there was moderate potential for further erosion due to lack of riparian vegetation.

- M12RT2d:
  - Waterway channel was well defined with steep banks and about 12 metres wide
  - Water levels were moderate and there was low flow
  - Floodgates are located about 100 metres upstream
  - There was no evidence of active erosion but moderate potential for erosion due to lack of riparian vegetation.

Hexham Swamp Nature Reserve

Hexham Swamp Nature Reserve forms part of the floodplain environment on the southern side of the Hunter River and is part of the Hunter Wetlands National Park. The Hexham Swamp Nature Reserve, and the surrounding wetland area that adjoins the Hexham Swamp Nature Reserve, is classified as Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-1**). Hexham Swamp Nature Reserve and the adjoining Coastal Wetland area make up the largest freshwater wetland on the north coast of NSW (Martindale, 1998).The Hexham Swamp Nature Reserve covers an area of about 900 hectares (Martindale, 1998). Hunter Wetlands Centre, which is part of the Hunter Estuary Wetlands Ramsar site, is located to the south of Hexham Swamp Nature Reserve.

The boundary of the Hexham Swamp Nature Reserve is located about two kilometres south of the project. The wetland receives water from tributaries and drainage channels situated to the south-west of the Hunter River and is maintained by rainfall, although flow is minimal. Hexham Swamp Nature Reserve drains to the south channel of Hunter River via Ironbark Creek which flows north under Maitland Road. To manage saltwater incursions, there are floodgates on Ironbark Creek at the confluence with the south channel of Hunter River.

Mid Site Channel

Mid Site Channel is an ephemeral, third order, artificial drainage channel located in proximity to the southern portion of the project between Hexham, Tarro and Black Hill. The channel flows in an easterly direction through culverts under the Main North Rail Line and New England Highway and is governed by floodgates. It discharges to Purgatory Creek (upstream of the floodgates) on the eastern side of the existing New England Highway. The majority of native riparian vegetation has been removed from the banks and submergent zone and the creek flows through predominantly cleared farmland. The channel mainly receives water from pastures in the south east portion of Tarro, however also drains residential areas in Black Hill.

Hunter River and floodplain

The Hunter River, the ultimate receiving environment for the project, is a ninth order major watercourse which forms a tidally influenced estuarine system in its lower reaches (up to 64 kilometres from the mouth of the estuary). On the western floodplain where the project is expected to cross the Hunter River Estuary, almost all native bushland and riparian vegetation has been cleared for agricultural grazing land and road infrastructure, however the northern portion of the western bank of the Hunter River is classified as Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-1**). The eastern floodplain is extensively vegetated by mangrove forests and classified as Coastal Wetland under the Coastal Management SEPP (refer to **Photo 4-7** and **Photo 4-8**). Other areas classified as Coastal Wetlands under the Coastal Management SEPP are located on the eastern floodplain of Hunter River near Tomago. One Coastal Wetland is located south east of the project footprint on the southern side of Masonite Road and the other is located further east on the floodplain north of the north channel of the Hunter River (refer to **Figure 2-1**).

The catchment area which drains to the Hunter River Estuary is heavily urbanised with industrial, commercial, agricultural and residential development. Within vicinity of the project, runoff from the surrounding urban centres, major roads including the Maitland Road and the existing Pacific Highway (which crosses Hunter River at Hexham Bridge), and treated wastewater from industry are discharged into Hunter River. The riparian zone of the western bank has been modified to construct the levee bank for the Hunter River Flood Scheme and more recently has been rock armoured to prevent scour.

Photo 4-7 Hunter River at monitoring site M12RT3a (looking upstream)

Photo 4-8 Hunter River at monitoring site M12RT3a (looking upstream)

At the time of inspection, Hunter River at monitoring sites at the proposed crossing location (M12RT3), midstream (M12RT3a) and at the confluence with Hunter River (M12RT3b) exhibited the following hydrological characteristics:

- M12RT3:
  - Waterway channel was well defined but with shallow gradient banks and was about 250 metres wide
  - Water levels were moderate and the tide appeared to be going in
  - There was some evidence of active erosion on the right bank and there was moderate potential for further erosion.
- M12RT3a:
  - Waterway channel was well defined with steep banks and was about 140 metres wide
  - Water levels were moderate and the tide was going out
  - There was no evidence of active erosion and erosion was unlikely to occur due to large rocks on the banks.
- M12RT3b:
  - Waterway channel was well defined but with shallow gradient banks and was about 205 metres wide
  - Water levels were low and the tide was going in
  - Large pylons for Hexham Bridge were located instream at the site
  - There was some evidence of active erosion on the right bank and there was moderate potential for further erosion.

Other waterways which flow into the Hunter River that were monitored for the project included Hunter River Drain (M12RT4), a tributary to Hunter River Drain (M12RT5) and the unnamed waterbody opposite Old

Punt Road (M12RT9). These sites exhibited the following hydrological characteristics at the time of inspection:

- M12RT4:
  - Waterway channel was well defined with steep banks and was about four metres wide
  - Water levels were moderate and there was low flow
  - There was no evidence of active erosion but there was moderate potential for erosion due to lack of riparian vegetation.
- M12RT5:
  - Waterway channel was well defined with steep banks and was about five metres wide
  - Water levels were moderate and there was low flow
  - There was no evidence of active erosion but there was moderate potential for erosion due to lack of riparian vegetation.
- M12RT9:
  - Waterbody was well defined with steep, artificially reinforced banks and spanned about 215 metres
  - Water levels were moderate and there was low flow
  - There was no evidence of active erosion or erosion potential.

Unnamed coastal wetland east of the Hunter River

On the eastern side of Hunter River, between Hexham Bridge and Tomago, an unnamed wetland, which is identified as a Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-1**), drains a heavily urbanised catchment. Major sources of runoff are from the surrounding agricultural land, the industrial area of Tomago to the east, the existing Pacific Highway which traverses the wetland and Hunter Region Botanic Gardens. Mangrove and wetland vegetation are abundant in this wetland, particularly in the northern area close to the Hunter River (refer to **Photo 4-9** and **Photo 4-10**), and the waterbody is immersed in a dense bed of macrophytes, although the north-eastern area is largely devoid of vegetation and consists of agricultural grassland. A second order creek (or old oxbow watercourse from the nearby river) is located outside the wetland boundary (about 200 metres) (refer to **Photo 4-11** and **Photo 4-12**). It flows west through the north-eastern portion of the wetland to Hunter River has been regulated by floodgates to control flooding (refer to **Figure 4-1**).

Photo 4-9 Waterbody in unnamed Coastal Wetland at monitoring site M12RT11 (looking upstream)

Photo 4-10 Waterbody in unnamed Coastal Wetland at monitoring site M12RT11 (looking downstream)

Photo 4-11 Second order waterway in the unnamed Coastal Wetland at monitoring site M12RT11a (looking upstream)

Photo 4-12 Second order waterway in the unnamed Coastal Wetland at monitoring site M12RT11a (looking downstream)

The eastern bridge abutment for the viaduct (B05) would be located within the unnamed Coastal Wetland (Coastal Management SEPP) and the unnamed tributary may receive discharge from the project.

At the time of inspection, an unnamed waterbody in the unnamed Coastal Wetland (Coastal Management SEPP) at monitoring site M12RT11, and an unnamed waterway in the unnamed Coastal Wetland (Coastal Management SEPP) at monitoring site M12RT11a exhibited the following hydrological characteristics:

- M12RT11:
  - Waterbody banks had minimal definition and was about 50 metres wide
  - Water level was moderate and there was low flow
  - There was no evidence of erosion or erosion potential.
- M12RT11a:
  - Waterway channel was well defined and was about seven metres wide
  - Water level was moderate and there was low flow
  - Floodgates were located about 300 metres downstream
  - There was some evidence of active erosion and moderate potential for further erosion due to lack of riparian vegetation.

Windeyers Creek

Windeyers Creek is a second order stream situated between the southern urban area of Raymond Terrace and the northern region of Heatherbrae. The creek flows north through a vegetated wetland area, crosses under the existing Pacific Highway and then flows west toward the Hunter River (refer to **Photo 4-13** and **Photo 4-14**). Tributaries to Windeyers Creek include the Grahamstown Drain and an unnamed first order tributary upstream. Windeyers Creek is largely ephemeral until its downstream reach where it is tidal (subject to floodgate operating rules) at the confluence with the Hunter River at Raymond Terrace (refer to **Figure 4-1**). The floodgate is opened during low to medium tides to allow tidal flushing. The lower portion of the creek is situated in a largely rural landscape with some riparian vegetation along the banks of the watercourse. The lower reaches of the creek are within an area that is classified as a Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-1**).

The creek receives catchment runoff from the surrounding urban centres of Raymond Terrace and Heatherbrae, as well as from treated effluent from the Raymond Terrace Wastewater Treatment Works (WWTW), which flows to Windeyers Creek via Grahamstown Drain (Hunter Water, 2020).

Photo 4-13: Windeyers Creek at monitoring site M12RT6 (looking upstream)

Photo 4-14: Windeyers Creek at monitoring site M12RT6 (looking downstream)

A single bridge (B11) is proposed to be constructed across Windeyers Creek.

At the time of inspection, Windeyers Creek upstream (M12RT6a), at the bridge crossing location (M12RT6) and downstream (M12RT6b) exhibited the following hydrological characteristics:

- M12RT6a:
  - Waterway had minimal channel definition and was about 15 metres wide
  - Water level was high and there was low flow
  - There was no evidence of active erosion and the channel had low erosion potential.
- M12RT6:
  - Waterway had minimal channel definition and was about 15 metres wide
  - Exhibited residual, isolated pools and substantial boggy wetland areas
  - There was no evidence of active erosion and the channel had low erosion potential.
- M12RT6b:
  - Waterway channel was well defined with moderately sloped banks and was about 20 metres wide
  - Water levels were high however water appeared to be stagnant
  - Erosion could not be observed due to high water level, however there appeared to be no erosion potential.

Another waterway associated with Windeyers Creek which was monitored for the project was a first order tributary of Windeyers Creek (M12RT7). This site exhibited the following hydrological characteristics at the time of inspection:

- M12RT7:
  - Waterway channel was well defined with steep bank and was about six metres wide
  - Water levels were moderate and there was low flow
  - There was no evidence of active erosion and the channel had low erosion potential.

Grahamstown Dam

Grahamstown Dam is within the flooding study area and near the project. Grahamstown Dam has a capacity of 182,305 Megalitres (ML) and is a potable water supply storage reservoir which provides about 40 per cent of the Hunter region's drinking water supply. It is classified as an off-river earth fill embankment storage dam, storing raw water that is pumped from the Williams River at Seaham Weir through the

Balickera Canal. On average, 50 per cent of inflow to Grahamstown Dam is pumped from the Williams River, the remaining half of the water collected is sourced from the surrounding catchment which has an area of about 115 kilometres squared and is primarily located on the northern and eastern shores of the dam. To the north of the catchment, Seven Mile Creek fills the dam with run-off from small farms and other minor developments. Run-off from the east comes directly from the urban settlement of Medowie through the Campvale Swamps. Water is pumped into the dam via the Campvale Pump Station and finally spills at the Irrawang Spillway (Hunter Water, 2020).

Grahamstown Drain

Grahamstown Drain is an artificial drainage channel which flows in a south-westerly direction from Grahamstown Dam to the Hunter River via Windeyers Creek. Grahamstown Drain occasionally receives flow releases from the Grahamstown Dam, however the primary source of flow to the channel is provided by the discharge of treated effluent (7.3 Megalitres per day) from the Raymond Terrace WWTW to the Hunter River (Hunter Water, 2020). The drain additionally receives runoff from the surrounding urban parklands and residential area of Raymond Terrace. Some instream and riparian vegetation is present along the banks of the channel. Several culverts and bridge structures are present along Grahamstown Drain which disrupt flow to Windeyers Creek which lies downstream (refer to **Photo 4-15** and **Photo 4-16**).

Photo 4-15: Grahamstown Drain at monitoring site M12RT10 (looking upstream)

Photo 4-16: Grahamstown Drain at monitoring site M12RT10 (looking downstream)

At the time of inspection, Grahamstown Drain at monitoring site M12RT10 exhibited the following hydrological characteristics:

- Waterway channel was well defined but appeared artificially dredged and was about six metres wide
- Water level was moderate and there was low flow
- A bridge was located about 15 metres downstream
- There was some evidence of active erosion and moderate potential for further erosion due to lack of riparian vegetation.

Hunter River wetland

A wetland (referred to as the Hunter River wetland) is located next to the Hunter Region Botanic Gardens between Tomago and Heatherbrae. The wetland is a first order, ephemeral freshwater waterbody which is densely vegetated with instream macrophytes and riparian vegetation on the banks (refer to **Photo 4-17** and **Photo 4-18**). To the east of the Hunter River wetland, the catchment is largely undeveloped, vegetated and located on the Tomago Sandbeds which is classified as ‘special area’ and closed to the public in order protect groundwater quality and water extraction infrastructure (Hunter Water, 2020). The existing Pacific Highway is located immediately to the west of the Hunter River wetland.

Photo 4-17: Wetland adjacent to Hunter Region Botanic Gardens at monitoring site M12RT8 (looking upstream)

Photo 4-18: Wetland adjacent to Hunter Region Botanic Gardens at monitoring site M12RT8 (looking downstream)

A single bridge (B09) is proposed to be constructed near the Hunter River wetland.

At the time of inspection, the Hunter River wetland at monitoring site M12RT8 exhibited the following hydrological characteristics:

- The waterbody was about 80 metres wide
- Water level was high and there was no flow
- There was no evidence of active erosion or erosion potential.

Hunter Estuary Wetland Ramsar site

The Hunter Estuary Wetlands Ramsar site is part of the Hunter Wetlands National Park (refer to **Figure 2-1**) and is comprised of two parts, these are:

- The Hunter Wetlands National Park on Kooragang Island (Kooragang Nature Reserve), which was listed under the Ramsar convention in 1984
- The Hunter Wetlands Centre Australia in Shortland (south of the Hexham Swamp Nature Reserve), which was added to the listing in 2002.

Kooragang Nature Reserve includes the island between the north and south channel of Hunter River and Fullerton Cove which is located to the north of the north channel of Hunter River. Kooragang Nature Reserve receives flow from the north channel of Hunter River which is tidally influenced. There are also several small inlets and tributaries which flow from the Hunter River through the wetland.

The Hunter Wetland Centre lies to the south of the south channel of Hunter River in the area south of the Hexham Swamp Nature Reserve. The Hunter Wetland Centre receives flow from tributaries and drainage channels situated to the south west of the Hunter River and is maintained by rainfall, although flow is minimal. The Hunter Wetland Centre drains to the south channel of Hunter River via Ironbark Creek which flows north under Maitland Road. To manage saltwater incursions, there are floodgates on Ironbark Creek at the confluence with the south channel of Hunter River.

Kooragang Nature Reserve is located a minimum distance of about 1.9 kilometres south east of the project and over 2.8 kilometres from the main alignment. The Hunter Wetlands Centre Australia in Shortland is located to the south of Hexham Swamp Nature Reserve and about 3.8 kilometres south of the project (refer to **Figure 2-1**).

4.3.3 Watercourse geomorphology

The geomorphology of key waterways within the surface water study area are described in **Table 4-3**.

Table 4-3 Watercourse geomorphology within the surface water study area

Watercourse	Geomorphological description
Viney Creek	The creek is located within a low lying wetland environment and flows toward Woodberry Swamp. The channel receives flow from several natural and artificial tributaries located to the south. The creek is heavily modified in the central portion, with flow disrupted by several culverts and bridges. The downstream channel is laterally unconfined. The instream substrate consists of silty clays.
Glenrowan Creek at B02 crossing (flows to the coastal wetland that is associated with Hexham Swamp Nature Reserve)	Glenrowan Creek is located at the western end of the project alignment originates on a small ridgeline at the junction of Tarro, Beresfield and Black Hill. The tributary drains to a back swamp which is connected to the Hunter Wetlands at Hexham. The tributary is confined within a shallow valley however there is no channel definition due to the absence of flowing water and the valley floor has formed a swamp consisting of silty clay sediments.
Purgatory Creek	The creek is situated on stripped lowland floodplain where the creek originates from a back swamp feature in the landscape (on the southern side of the New England Highway). The highly modified downstream section consists of an entrenched farm drainage channel. The channel is tidally influenced in the lower reaches and receives freshwater in the upstream portion of the creek. The downstream channel showed evidence of scouring at the meanders, likely formed during high flows from the Hunter River. Channel inundation was mediated by floodgates which are located at the confluence, however these gates are likely leaky or partially opened due to habitat restoration objectives (DPI, 2015). The instream substrate consists of silty clays.
Hunter River	A laterally unconfined meandering river subject to large sediment loads flushed from the upstream catchment. The river is a low gradient system where the lower reaches form a branching estuary which re-joins at the river mouth. The western side of the river is coastal alluvial floodplain while the east consists of coastal sands. Bank morphology at the project alignment appears graded with sand/gravel/boulder substrate. Minor erosion occurs on the left bank at the prosed bridge crossing. Substantial erosion with undercut banks is present past the meander bend at the Hexham Bridge.
Hunter River Drain	The drain is an artificial, entrenched channel situated on open floodplain, north of the project alignment between Tomago and Heatherbrae. Channel inundation is mediated by floodgates which are located in the downstream extent at the confluence with Hunter River. The channel exhibits a sandy substrate.
Tributary of Hunter River Drain	The tributary is situated on open floodplain east of the alignment at Heatherbrae. The channel is highly modified with a steep channel invert, entrenched in silt loam sediments. The tributary discharges directly to the Hunter River and serves as an agricultural drainage line.
Unnamed Coastal Wetland	The wetland is situated on the convex bank of the Hunter River at Hexham to the east of Hexham Bridge and west of Tomago. The vegetated platform has developed at the meander bend of Hunter River. The wetland spans both sides of the Pacific Highway at the Hexham Bridge ramp, as well as to north-east where it is drained by an entrenched channel. The downstream portion of the channel exhibits no meander bends. Channel inundation is mediated by floodgates which are located at the confluence with Hunter River.
Waterbody opposite Old Punt Road	The waterbody is located at Tomago, on the floodplain just south of the unnamed Coastal Wetland (east of the Hunter River), disconnected only by an infilled dirt track. The bank morphology is entrenched, consisting of sandy clay sediment. The waterbody has been modified for industrial/urban use in a pier like formation which drains to the Hunter River.

Watercourse	Geomorphological description
Hunter River wetland	The wetland is situated in a depression on the floodplain east of the Pacific Highway, adjacent to the Hunter Region Botanic Gardens. The wetland consists of a sandy substrate and is common feature on the coastal floodplain during wetter seasons. The wetland is not a Coastal Wetland as designated by the Coastal Management SEPP.
Windeyers Creek	The upstream reaches consist of a low gradient discontinuous channel that forms a swamp on the floodplain. The downstream reach, north east of the Pacific Highway, is partially confined with a steep channel invert. Sediments consisted of silty sand. Due to overbank inundation at the time of inspection, scouring and erosion could not be determined.
Tributary of Windeyers Creek	The upstream reaches form an entrenched channel which flows through a low lying floodplain environment. The channel is partially unconfined and sediments consist of silty sand.
Grahamstown Drain	Grahamstown drain is a highly modified entrenched channel with isolated patches of erosion occurring along its length. The drain traverses the open floodplain from Grahamstown Lake to the Hunter River. The steep gradient channel consists of silty clay sediments and is partially confined on the left bank. The right bank is subject to inundation during flood events.

4.3.4 Surface water resources

The main surface water resource within and near to the surface water study area consists of Grahamstown Dam, which is described in **Section 4.3.2**. There are a number of small farm dams on private rural and rural residential properties, mainly on the western floodplain of the Hunter River upstream of the project and surrounding Hexham Swamp, in the suburbs of Black Hill and Lenaghan. Ponds are located in Beresfield Golf Course and Pasadena Crescent soccer fields in Beresfield which are likely to be used for irrigation of these golf courses and sports fields.

4.4 Groundwater features

Groundwater systems, levels, flow directions and GDEs are summarised below and covered comprehensively in **Appendix A**.

4.4.1 Groundwater systems

As detailed in **Appendix A**, three main groundwater systems are present near to the project's construction footprint. These systems and key characteristics are summarised below.

Hunter Alluvium

The indicative extent of Quaternary alluvial surrounding the project is shown as unit Qa in **Figure 4-4**. The alluvial deposits commonly comprise sequences of clays, silts, sands and gravels. The deposits are highly heterogeneous and within the floodplain area are likely to be typically of low permeability. More permeable and coarser, sand and gravel materials may be found locally within discontinuous sheets of stringers, or at the base of the alluvial deposits or within palaeochannels (basal deposits). The deposits typically are fining upward sequences of sediments.

In a regional context, the Hunter River floodplain and its associated alluvial groundwater systems form a regional groundwater sink for the surrounding and underlying Permian and Triassic rocks of the Hunter Valley (Kellett, et al, 1987). Groundwater largely flows from the rocks of the Sydney Basin into the Quaternary Alluvium.

In the area near to the project, aquifer yields and utilisation are likely to be highly variable due to the generally fine grained nature of the sediments and the salinity of the Hunter River in proximity to the coast.

Tomago Sandbeds

Coastal sands are typically unconsolidated sediments comprising estuarine deposits, palaeochannels, dunes or lowland coastal sands. These aquifers are typically unconfined with a high porosity and shallow depth to water table.

Near to the project, the coastal sands aquifer consists of the Tomago Sandbeds (unit Qs in **Figure 4-4**). The Tomago Sandbeds are of Pleistocene age, consisting of fine to medium grained, well sorted, quartzose beach sand with discontinuous indurated sand layers (Woolley, et al, 1995).

The sandbeds comprise of extensive inner barrier sand ridge deposits extending from Tomago to Port Stephens (to the northeast) and about five to 15 kilometres inland from the present coastline. The Tomago Sandbeds are up to 30 metres thick and are underlain by the Medowie Clay Member. The Tomago Sandbeds are overlain (towards the coast) by the Tilligerry Mud Member and the Stockton Sand Member (Woolley et. al. 1995). The Tomago Sandbeds are locally incised by Holocene age alluvium, particularly around Windeyers Creek near the northern parts of the project and are truncated by the Hunter Alluvium around Tomago.

Since deposition, the inner barrier sand has been subjected to weathering processes and fluctuating water levels that have resulted in the varying colour and induration due to the mobilisation and deposition of iron (oxide and carbonate). This has resulted in the presence of yellow brown to black, indurated, iron cemented (by iron oxyhydroxide) layers. Where present, these cemented layers can be sufficiently continuous and of low permeability to reduce vertical hydraulic conductivity substantially.

The Tomago Sandbeds receive a relatively high percentage of recharge from rainfall runoff and infiltration. DPI Water (2016) have calculated an average infiltration rate of 25 per cent of average annual rainfall for the Tomago Sandbeds.

The Tomago Sandbeds catchment covers an area of 109 square kilometres, and incorporates multiple land uses, including:

- Tilligerry State Conservation Area (44 per cent)
- Hunter Water Corporation freehold land (21 per cent)
- Industrial (21 per cent)
- Defence (Royal Australian Air Force Base and bombing range) (11 per cent)
- Rural residential (three per cent).

The Tomago Sandbeds catchment is designated as a ‘Special Area’ in the Hunter Water Act and is protected as a public drinking water supply by Hunter Water Corporation (Hunter Water, 2020).

The Tomago Sandbeds provide about 20 per cent of the Lower Hunter’s drinking water which reduces the load on surface water sources of Chichester Dam and Grahamstown Dam, and thereby allows greater overall yield from the total Lower Hunter water supply system (Hunter Water, 2019).

Tomago Coal Measures

Hardrock groundwater systems in the area of the construction footprint occur within the Permian Tomago Coal Measures, which outcrop in the western and central portions of the project (unit Pt in **Figure 4-4**).

The coal measures are typically of relatively low permeability, particularly at depth, with the interbedded sandstones and siltstones generally of lower permeability than the coal seams. The permeability of the coal seams relative to the interburden and overburden is enhanced by the presence of cleating and joints within

the coal and can produce permeabilities typically an order of magnitude greater than the surrounding formation.

An upper weathered layer can exist in the Permian bedrock, where permeability is enhanced by weathering and un-loading.

Groundwater flow within the deeper Permian formations is conceptualised to generally be controlled by bedding and fracture networks. A shallow unconfined aquifer can also exist in the weathering zone that is often in hydraulic connection with localised colluvial aquifers and local drainage systems.

4.4.2 Flow directions and levels

Overview

Composite groundwater levels derived from available data are shown in **Figure 4-6**. The water levels represent a composite compiled from average water levels from time series data and spot levels as available (Dundon, 2006; Coffey, 2011; Douglas Partners, 2012; Hunter Water Corporation and from the Jacobs installed groundwater monitoring bores). As such the water levels are indicative, but highlight key groundwater flow directions and trends.

Figure 4-6 illustrates the groundwater sink represented by the Hunter River and its alluvial floodplain. In the west groundwater flow is from the high-ground associated with the Permian Tomago Coal Measures that outcrops eastward towards the Hunter River floodplain. In the east, elevated groundwater levels are associated with the enhanced infiltration and recharge on the Tomago Sandbeds. Groundwater flow from the Tomago Sandbeds is to the northwest, west, and south towards the Hunter River and Fullerton Cove.

Groundwater levels beneath the Hunter floodplain are typically below two metres AHD. An exception to this occurs around Hexham where a localised groundwater mound occurs, rising to about eight metres AHD. The mounding is associated with a historical coal tailings stockpile, that until recently included a tailings dam/sediment control pond at its crest. Review of historical imagery indicates that the pond was backfilled and rehabilitated in late 2015.

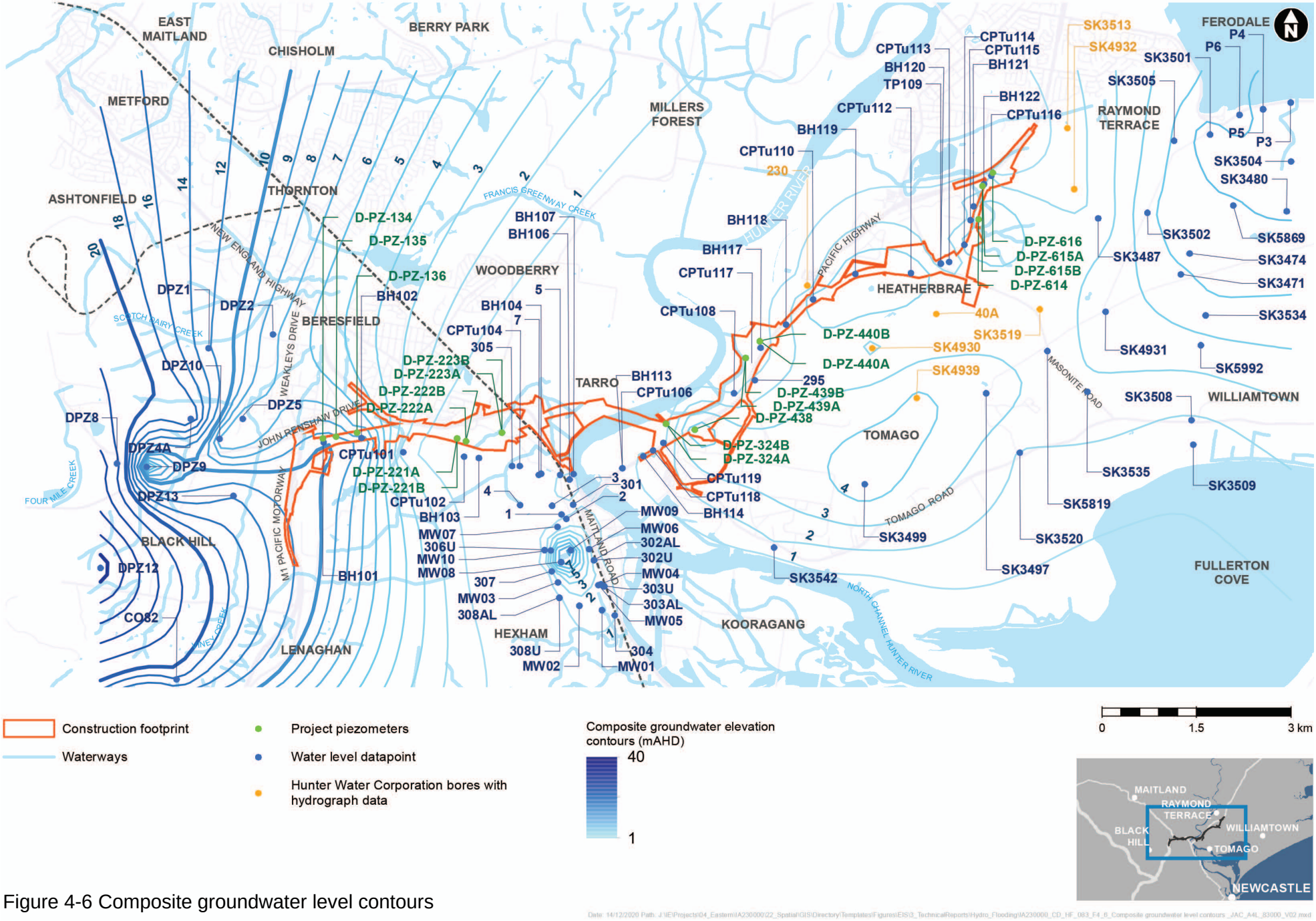


Figure 4-6 Composite groundwater level contours

Groundwater levels along the main alignment range from 11 to 12 metres AHD in the west, declining to zero metres AHD around the Hunter River. East of the Hunter River groundwater elevations are typically below two metres AHD, rising to four metres AHD in the area around Heatherbrae and declining to two metres AHD at Raymond Terrace.

Hunter Alluvium

Groundwater levels are typically very shallow and often express at surface. Project monitoring bore groundwater level data detailed in **Appendix A** indicates standing water levels of the Hunter Alluvium range from about 2.4 metres below ground level to 0.2 metres above ground level.

Tomago Sandbeds

Surrounding the project, groundwater levels are relatively shallow. Project monitoring bore groundwater level data detailed in **Appendix A** indicates standing water levels of the Tomago Sandbeds range from about 1.6 to 2.7 metres below ground level.

Tomago Coal Measures

Depth to groundwater in the Tomago Coal Measures is variable and is often a reflection of topography (depth to groundwater is greater beneath ridgelines and shallower beneath gullies).

Project monitoring bore groundwater level data detailed in **Appendix A** indicates standing water levels of the Tomago Coal Measures range from about 6.3 to 16.8 metres below ground level in the area around Black Hill. Beneath the floodplain at Tarro and confined beneath the Hunter Alluvium, potentiometric levels in the Tomago Coal Measures have been measured at 0.3 metres above ground level.

4.4.3 Groundwater dependent ecosystems

BoM mapping

GDEs are considered to be ecosystems in which the species composition and natural ecological processes are wholly or partially determined by the availability of groundwater (Serov et al.,2012). The BoM's (2020c) GDE Atlas identifies a number of known and potential GDEs. These communities are shown on **Figure 4-7** and include:

- Known aquatic GDEs:
  - Floodplain wetlands (Hexham Swamp and surrounding wetlands, Hunter Wetlands National Park)
  - Hunter River.
- High potential terrestrial GDEs:
  - Coastal Floodplain Wetlands on the floodplains of Hunter River (Tarro, Hexham and Tomago)
  - Mangrove Swamps on the margins of the Hunter River
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae).
- Moderate potential terrestrial GDEs:
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae).

A number of these potential and known GDEs coincide with the Coastal Wetlands (Coastal Management SEPP) and fall within the construction footprint. GDEs are discussed in detail in the Biodiversity Assessment Report (Appendix I of the EIS).

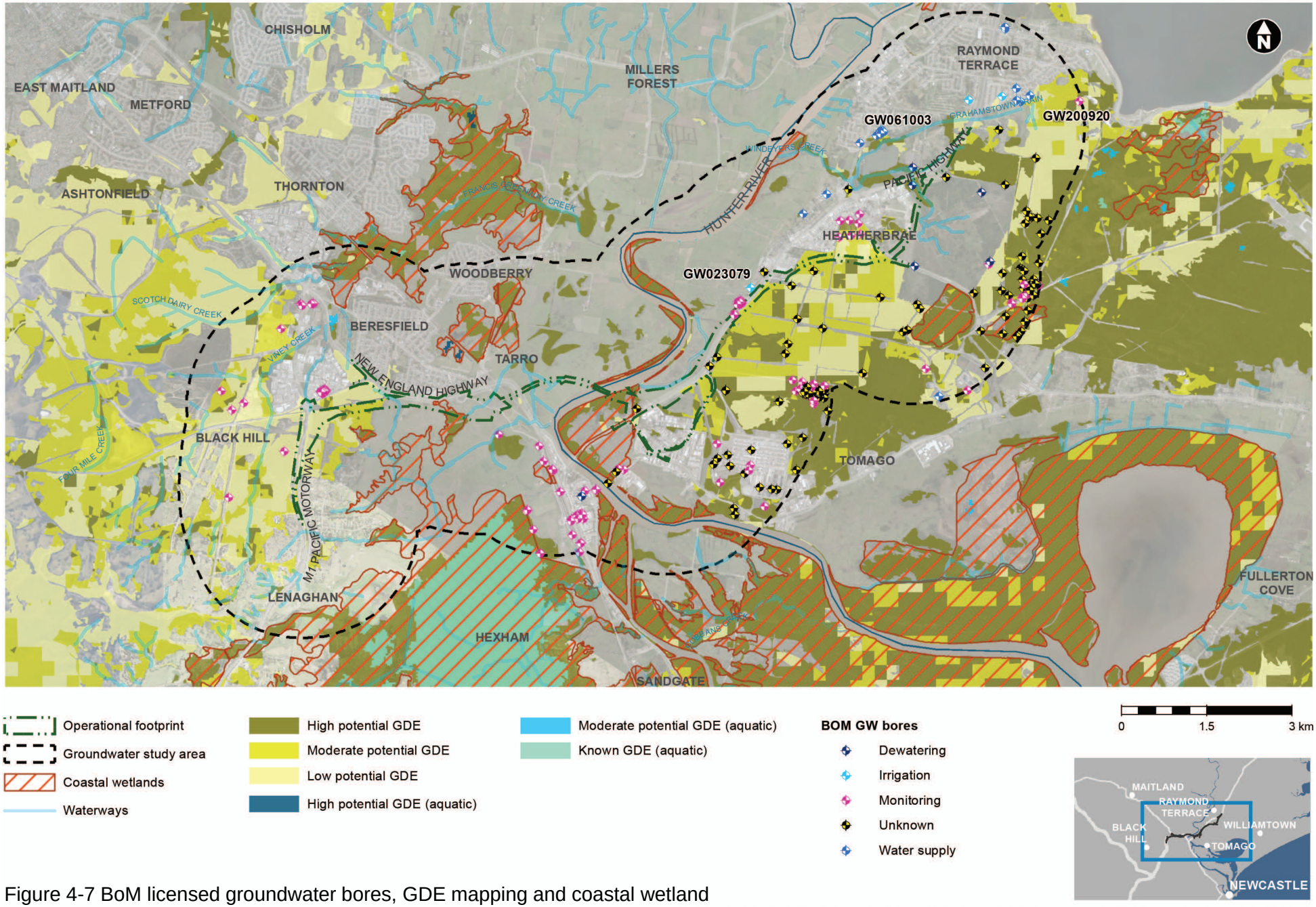


Figure 4-7 BoM licensed groundwater bores, GDE mapping and coastal wetland

High Priority GDEs

High Priority GDEs within the groundwater study area as mapped within Water Sharing Plans (WSPs) are summarised below:

- WSP for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government, 2009)
  - Hexham Swamp, located near western area of project, south of Tarro
  - Woodberry Swamp, located near western area of project in Woodberry, about 700 metres north of construction footprint.
- WSP for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government, 2016a)
  - Hexham Swamp and Woodberry Swamp
  - Wetland on boundary of groundwater study area, located about 1.8 kilometres north of the intersection of Masonite Road and Cabbage Tree Road, Tomago.
- WSP for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government, 2016b)
  - Hexham Swamp and Woodberry Swamp
  - Wetland east of Tarro and south of Woodberry Swamp
  - Narrow (about 100 metres to 300 metres wide and up to 1.2 kilometres long) isolated pockets of 'North Coast Coastal Sands GDEs' adjacent to the western side of the Hunter River and relatively large pocket of 'North Coast Coastal Sands GDEs' adjacent to western side of Hunter River near Tomago, in the area where the project crosses the Hunter River
  - Two pockets of 'North Coast Coastal Sands GDEs' south west of Heatherbrae and at least 500 metres south west of the project's construction footprint. Each pocket is about 300 metres to 400 metres in diameter.

The high priority GDEs outlined above generally coincide with areas formerly mapped as wetlands under the now repealed State Environmental Planning Policy No 14 – Coastal Wetlands. However, not all of the current Coastal Wetlands, as identified under the Coastal Management SEPP, in or near to the project are designated as high priority GDE by the relevant WSPs.

An assessment of potential groundwater level impacts at GDEs is provided in **Section 5.2.3** and **Section 5.3.3**.

4.4.4 Groundwater users

Existing licensed groundwater bores

The BoM's Australian Groundwater Explorer (2020b) was reviewed in a geographic information system (GIS) to assess existing bores in the area around the project. The analysis was restricted to within a two kilometre buffer to the project's construction footprint (i.e. the groundwater study area). Additionally, supplementary to the BoM (2020b) bore data review, bores within 500 metres of the project's operational footprint were queried in a bore data base provided by WaterNSW. This was carried out because BoM bore data omits yield data and generally omits water level and salinity data unless a bore is a state groundwater monitoring bore. Results are summarised as follows:

- 303 existing licensed bores were identified with the following purposes:
  - Monitoring – 144
  - Unknown – 134
  - Water supply – 16

  - Dewatering – six
  - Irrigation – three.

- Of these, five bores are located within the construction footprint (GW079605, GW200103, GW079447, GW079591 and GW200102). For all bores within the construction footprint except GW200102 (monitoring purpose), no specific use is recorded. Average and maximum bore depth was about nine and 54 metres respectively
- None of the bores had water level data
- Within 500 metres of the operational footprint, there were 91 bores:
  - Sixty-nine bores had water level measurements, ranging from 0.48 to 9.89 metres below ground level (bgl), with an average value of 6.90 metres bgl (WaterNSW)
  - Six bores had yield data, with yield ranging from 0.5 to 8.7 litres per second and an average of 3.3 litres per second (WaterNSW).

WaterNSW works summary reports for individual bores were not reviewed. Instead, water levels and yield were extracted from a single collated file of some, but not all, of the available water level and yield data.

Existing licensed registered groundwater bores works (bores) within the groundwater study area (BoM, 2020b) are shown in **Figure 4-7**. Licensed bores within 100 metres of the construction footprint are presented within **Appendix A**.

4.5 Flooding conditions

4.5.1 Flooding site inspection and community consultation

Site inspection of key flooding locations was carried out as a part of the flood impact assessment with observations made of the overall existing floodplain setting, drainage features and conditions, hydraulic structures and impediments to flow.

Consultation with the community and stakeholders provided information on existing flooding behaviour. A key concern was the Hexham Swamp area. Residents are aware that the swamp is highly flood-prone but felt that the flooding issue has been exacerbated by developments in and around Hexham Swamp. This was particularly evident during the recent flood event of April 2015 and to a lesser extent, January 2016. The primary concern of residents around the swamp was the duration of inundation of the land. Community concerns also focussed around Windeyers Creek and local drainage issues near the existing Pacific Highway between Tomago and Heatherbrae.

During consultation the landowners were able to describe the general flood behaviour experienced in the past including sources of floodwater, depths and velocities of floodwater, flow patterns, duration of inundation, and other information such as the performance of channels, culverts and floodgates during flood events. This information increases the understanding of the flooding issues within and near to the project. Specifically, the landowners were able to provide indicative flood levels and extents of both the April 2015 and January 2016 recent flood events that have been used to verify the flood model performance. Landowners also communicated their concerns about potential impacts of the project to their property. The landowner discussions also provided an early forum for the project team to understand the concerns of the community with relation to flooding.

4.5.2 Lower Hunter River Floodplain

Flooding on the Lower Hunter River floodplain is a result of both mainstream flooding from the Hunter River, and local catchment runoff. The Williams River joins the Hunter River just upstream of Raymond Terrace. The combined waters of these two rivers then flow in a south-westerly direction, traversing the floodplain. The floodplain within the flooding study area varies in width from around seven kilometres between Heatherbrae and Thornton to 2.5 kilometres between Tarro and Tomago. The Hunter River along this reach, from the junction with the Williams River at Raymond Terrace to Hexham Bridge, is generally bounded by levee banks. Overbank flooding occurs on the low lying areas around Raymond Terrace. A ridge line runs from Raymond Terrace to Tomago, and restricts the floodplain to a confined area once the eastern side levee bank is overtopped. The exception to this is the entry of Windeyers Creek onto the floodplain. Windeyers Creek is a prominent tributary on the Hunter River floodplain which the project crosses at its eastern extent. During flood events, the Windeyers Creek catchment experiences flooding in low lying areas from the local catchment and/or from backwater from the Hunter River.

When the western side levee bank of the Hunter River is overtopped, a substantially larger area is inundated. This broad and wide floodplain extends as far as Thornton. The floodplain is then constricted between Woodberry and Heatherbrae as the Hunter River begins to meander. Floodwaters are able to expand again and fill the floodplain to Beresfield to the west and overtop the existing Pacific Highway to extend into areas north of Tomago. The floodplain is then constricted again between Tarro and Tomago, where the project is located. Floodwater can then overtop the existing New England Highway and fill the large floodplain storage area of Hexham Swamp. Just past the existing Hexham Bridge, the floodplain is constricted to approximately 1.5 kilometres wide before branching into the north channel and south channel around Kooragang Island. Connected to the north channel is Fullerton Cove, a shallow protected estuarine lagoon about three kilometres wide. The north channel and south channel re-join downstream, between Tighes Hill and Stockton, running adjacent to the Newcastle city centre before discharging into the Tasman Sea through the Port of Newcastle breakwalls.

4.5.3 History of flooding

The Hunter River has experienced many floods during its recorded history, including 1963, 1978, 1990, 2000, 2007, 2015 and 2016. The largest flood on record occurred in 1955. Within the Lower Hunter Estuary, the 1955 flood caused extensive overbank inundation, with flood depths of up to three metres across the Kooragang Island wetlands. All the low-lying land between Fullerton Cove, Williamtown and Salt Ash was completely inundated. This flood has been estimated at about a 1% annual exceedance probability (AEP) event (Lawson and Treloar, 1994).

The most recent flood events to occur in the region include the April 2015 and January 2016 floods. The peak water level recorded in the Williams River at Raymond Terrace during the April 2015 severe storm event was 3.06 metres AHD (3:30pm on 22 April) which is between the 10% and 5% AEP design events (refer to **Section 4.5.6**). The gauge on the Hunter River at Hexham reached a peak water level of 1.88 metres AHD (1:45am on 23 April 2015), which is similar to the 10% AEP event (refer **Table 4-5** in **Section 4.5.6**). In the storm event of January 2016, the water level peaked at 2.84 metres AHD at Raymond Terrace (9:30am on 7 January) and 1.50 metres AHD (8:00am on 7 January) at Hexham Bridge.

4.5.4 Hunter Valley Flood Mitigation Scheme

Following the 1955 flood event, which claimed 14 lives, the Hunter Valley Flood Mitigation Scheme was established by the NSW Government, which has subsequently instigated 160 kilometres of levees, 3.8 kilometres of spillways, 40 kilometres of control banks, 245 floodgates and 120 kilometres of drainage canals (BMT WBM 2012b). The scheme provides flood protection to people, property and infrastructure across the Hunter floodplain.

While the scheme does not provide complete flood protection. It is designed to mitigate or reduce flood damage and provide minor flood protection for rural land and moderate flood protection for the Maitland, Lorn, Raymond Terrace, Singleton and Aberdeen areas. The scheme is still in operation, managed by DPIE, and is subject to periodic maintenance and reviews. Flood protection works near the project are shown on **Figure 2-3**.

4.5.5 Historic events

Flooding conditions for two recent flood events, the April 2015 event and the January 2016 flood event, were simulated to verify the TUFLOW flood model. The recent occurrence of these events means that they occurred in similar conditions to the existing catchment development conditions. A comparison of modelled and recorded water levels at Raymond Terrace and Hexham Bridge gauges for the flood events April 2015 and January 2016 are shown in **Figure 4-8** and **Figure 4-9** respectively. The flood level gauge sites are shown on **Figure 3-2**. The TUFLOW flood model reproduces both events satisfactorily utilising the same model parameter values. Model simulation of these historic events allows detailed mapping and analysis of an actual flooding event to be conducted.

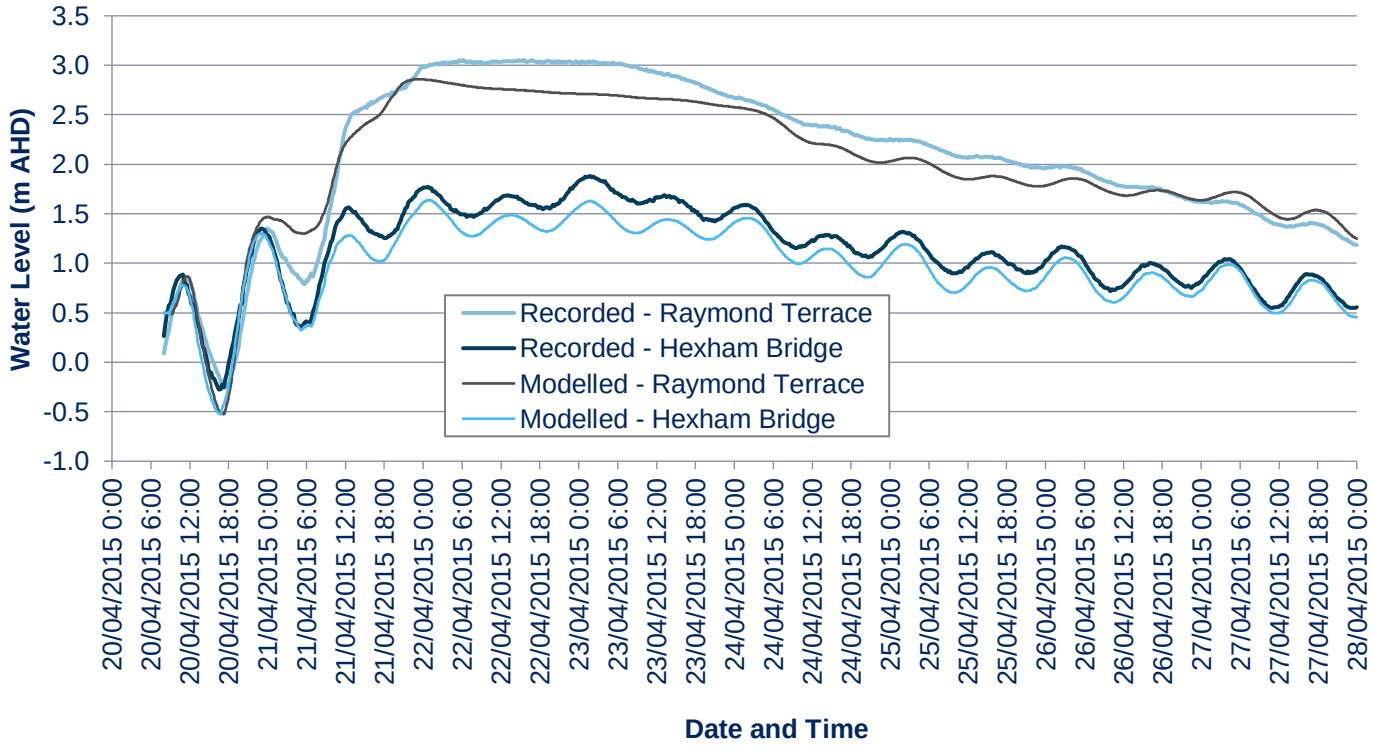


Figure 4-8 Modelled and recorded water levels for the April 2015 flood event

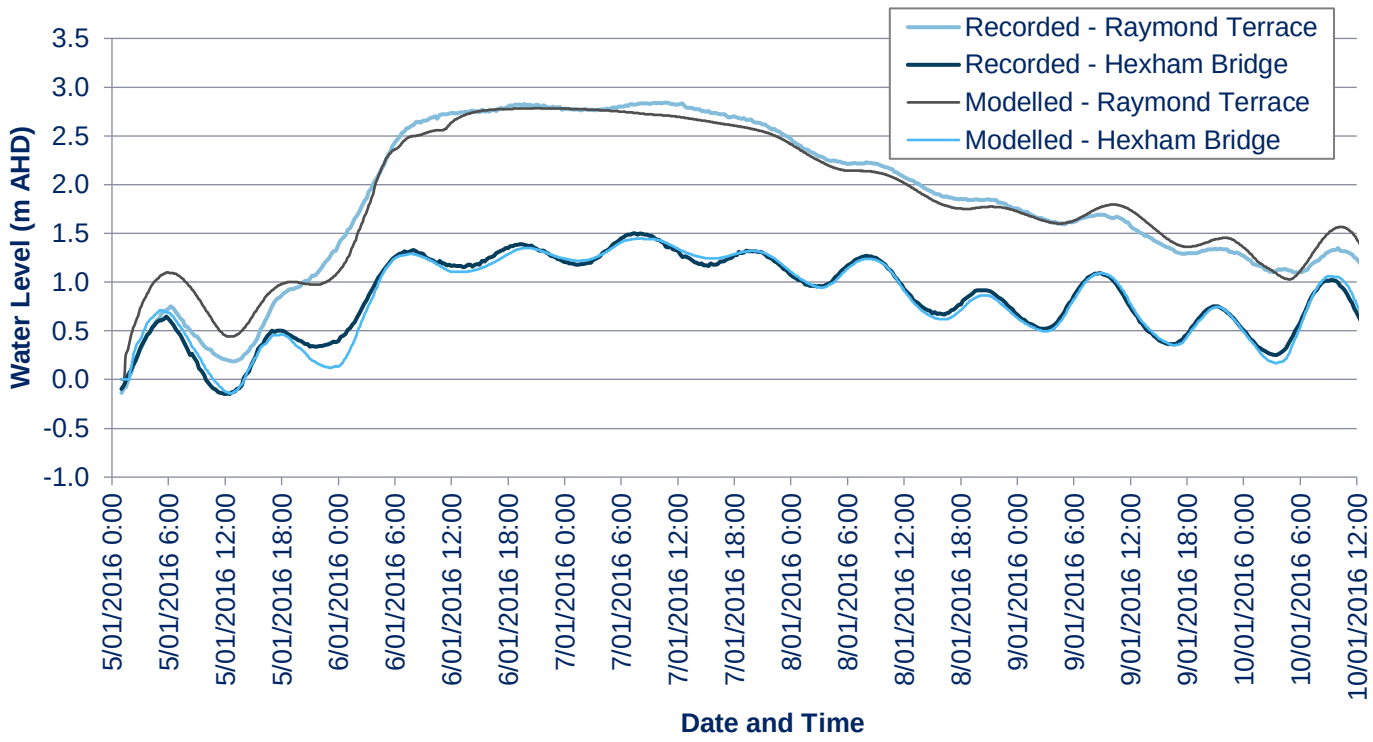


Figure 4-9 Modelled and recorded water levels for the January 2016 flood event

In the April 2015 flood event, floodwaters extended onto the Hunter River floodplain, as shown in **Figure 4-10**. It is generally the largest event experienced by many of the landowners in the area. The flood model results for the 2015 flood event indicate that the Hexham Swamp area was completely inundated, with only part of the Aurizon Hexham Train Support Facility access road in Hexham being above the peak flood level. The existing embankment which runs east-west through Hexham Swamp (formerly a railway line) was not overtopped, and flood depths in the northern part of the swamp ranged from 0.3 metres to 1.8 metres. While water usually drains from the northern portion to the southern portion through culverts in the embankment, during the April 2015 flood event, water flowed from the southern area into the north through the culverts.

The New England Highway was close to being overtopped (by about 0.1 metres) by Hunter River floodwaters that had overtopped the levee on the western bank of the Hunter River. Along the eastern bank of the Hunter River, downstream of where the constructed levee ends, the area was inundated to a depth of about one metre and just overtopped the Pacific Highway. Between Tomago and Heatherbrae the Hunter River, while overtopping the eastern levee bank, is largely contained by high ground at the edge of the floodplain. Local catchments draining through the vegetated area to the west of the Pacific Highway caused ponding on the upstream side of the Pacific Highway. The creek to the south of the Hunter Region Botanic Gardens caused minor overtopping of the Pacific Highway. There was shallow flooding in areas either side of Masonite Road, with flood depths reaching 1.5 metres in the Windeyers Creek channel, upstream of the Pacific Highway. The Pacific Highway in this location, and further north where it crosses Grahamstown Drain, was not overtopped.

Based on peak flood levels and river flows at Raymond Terrace and Hexham, the flooding in April 2015 is estimated to be between a 20% and 10% AEP flood event. In the lower reaches of the river, from Hexham downstream to the mouth, the flood coincided with a spring tide and storm surge with a peak ocean water level of 1.30 metres AHD (peak tidal level recorded by Port Authority NSW at Newcastle Port for April 2015 event), which exacerbated flooding. The flood level peaked at 1.88 metres AHD and was recorded at Hexham Bridge.

The January 2016 flood event is estimated to have slightly higher river discharge but was smaller in flood level magnitude than the April 2015 event, peaking at 1.50 metres AHD recorded at Hexham Bridge. This flood event coincided with a lower combined tide and storm surge ocean level of 0.96 metres AHD (peak tidal level recorded by Port Authority NSW at Newcastle Port for January 2016 event). The flood model results indicate that the Hunter River levees were overtopped and water spilled onto the floodplain, as shown in **Figure 4-11**. Hexham Swamp filled with water, but reached a lower peak level than in the April 2015 event. Some of the embankments in the northern portion of the swamp were above the peak flood level and the Aurizon Hexham Train Support Facility access road was not flooded.

The June 2007 flood event was another recent significant flood event in the Hunter Valley, with the major flood level being reached at Belmore Bridge (Maitland). In the vicinity of the project, peak flood levels were similar to 2015 flood levels in Ironbark Creek at the Pacific Highway and Ironbark Creek at Morris Jetty (in Hexham Swamp, adjacent to Shortland), with a difference of +/- 0.2 metres between the 2007 and 2015 events (reference: Manly Hydraulics Laboratory recorded water level data for 2007 and 2015 events. Refer **Figure 3-2** for gauge locations). No recorded water level data was available for Raymond Terrace or Hexham Bridge for the 2007 flood event.

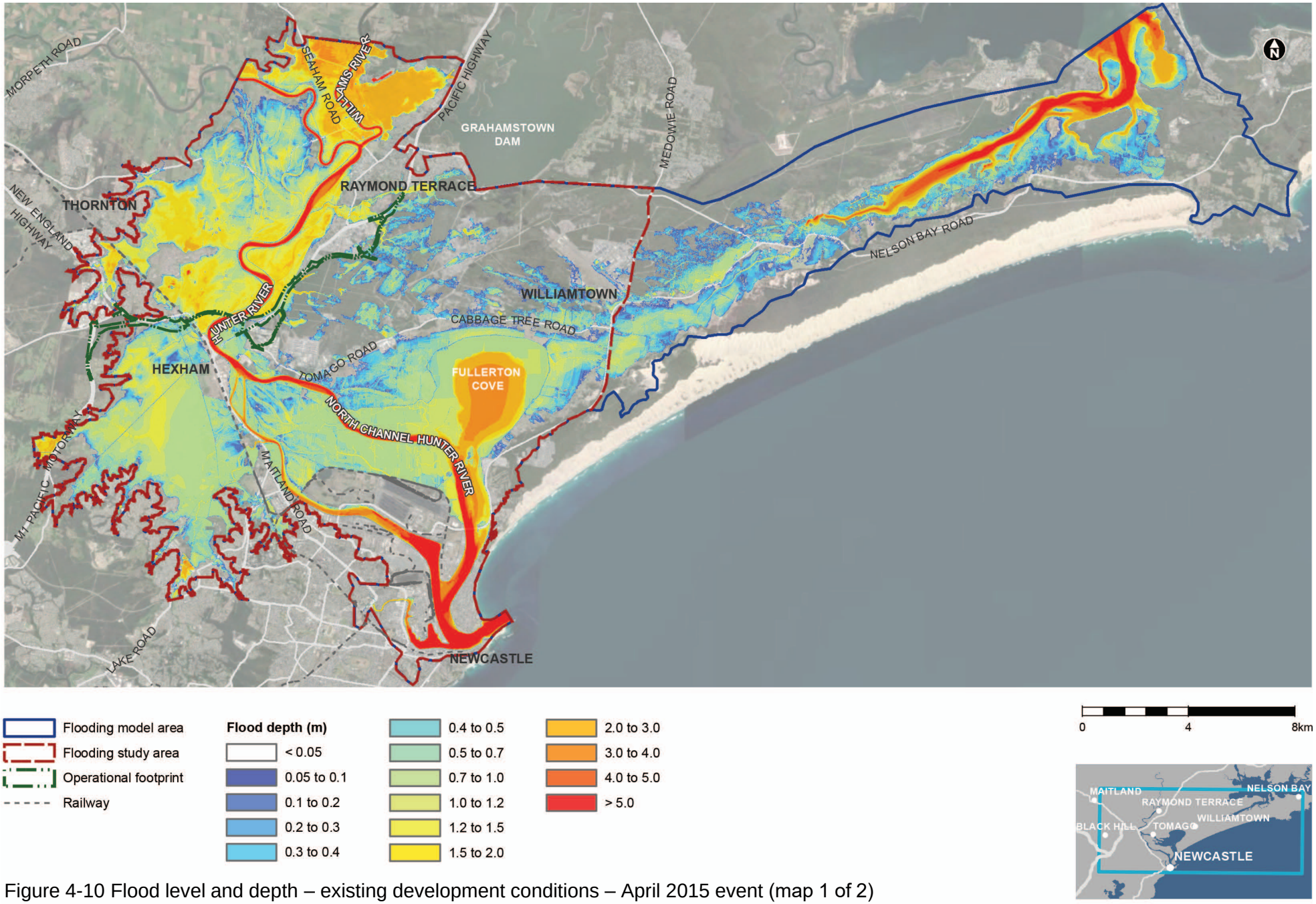


Figure 4-10 Flood level and depth – existing development conditions – April 2015 event (map 1 of 2)

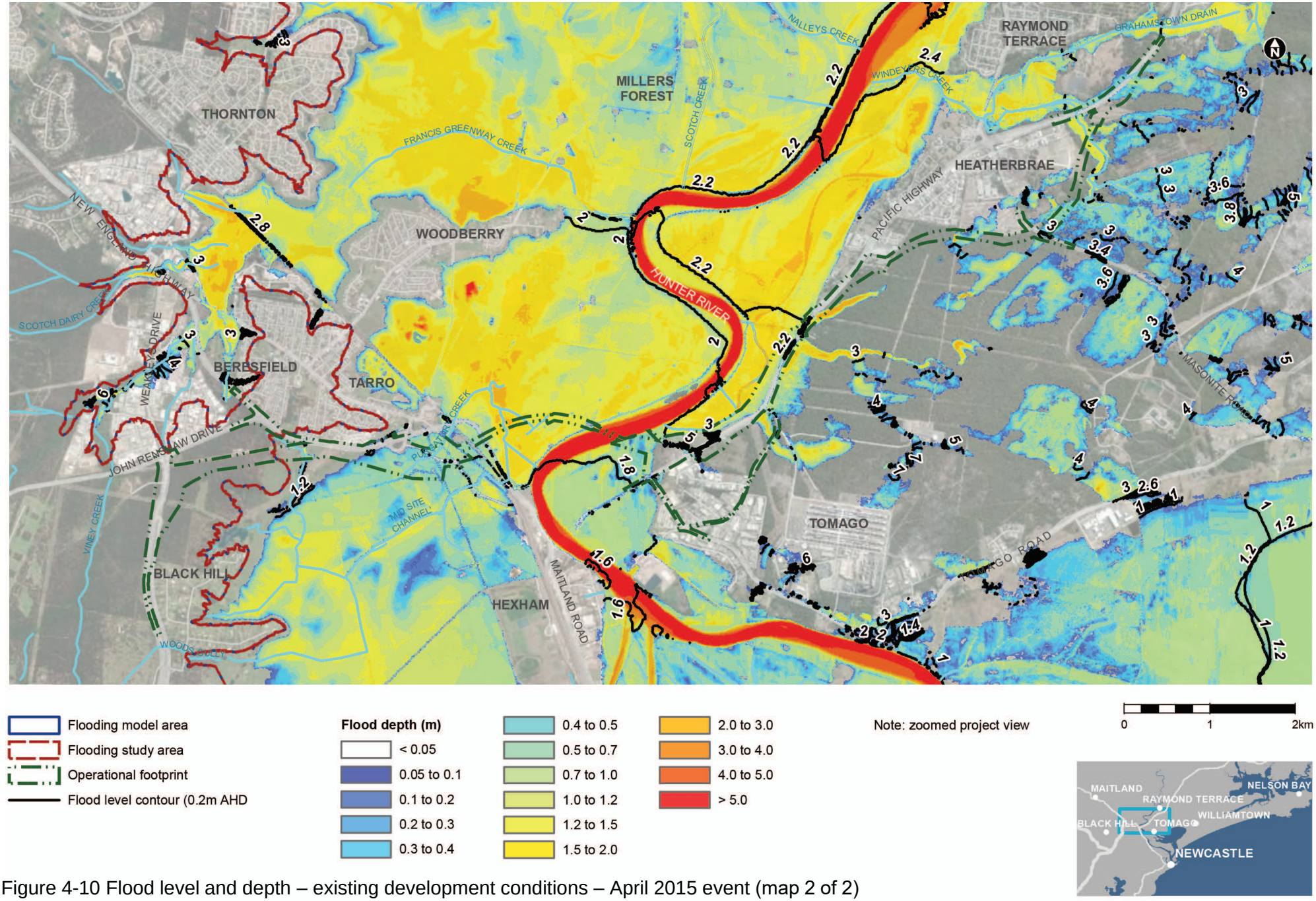


Figure 4-10 Flood level and depth – existing development conditions – April 2015 event (map 2 of 2)

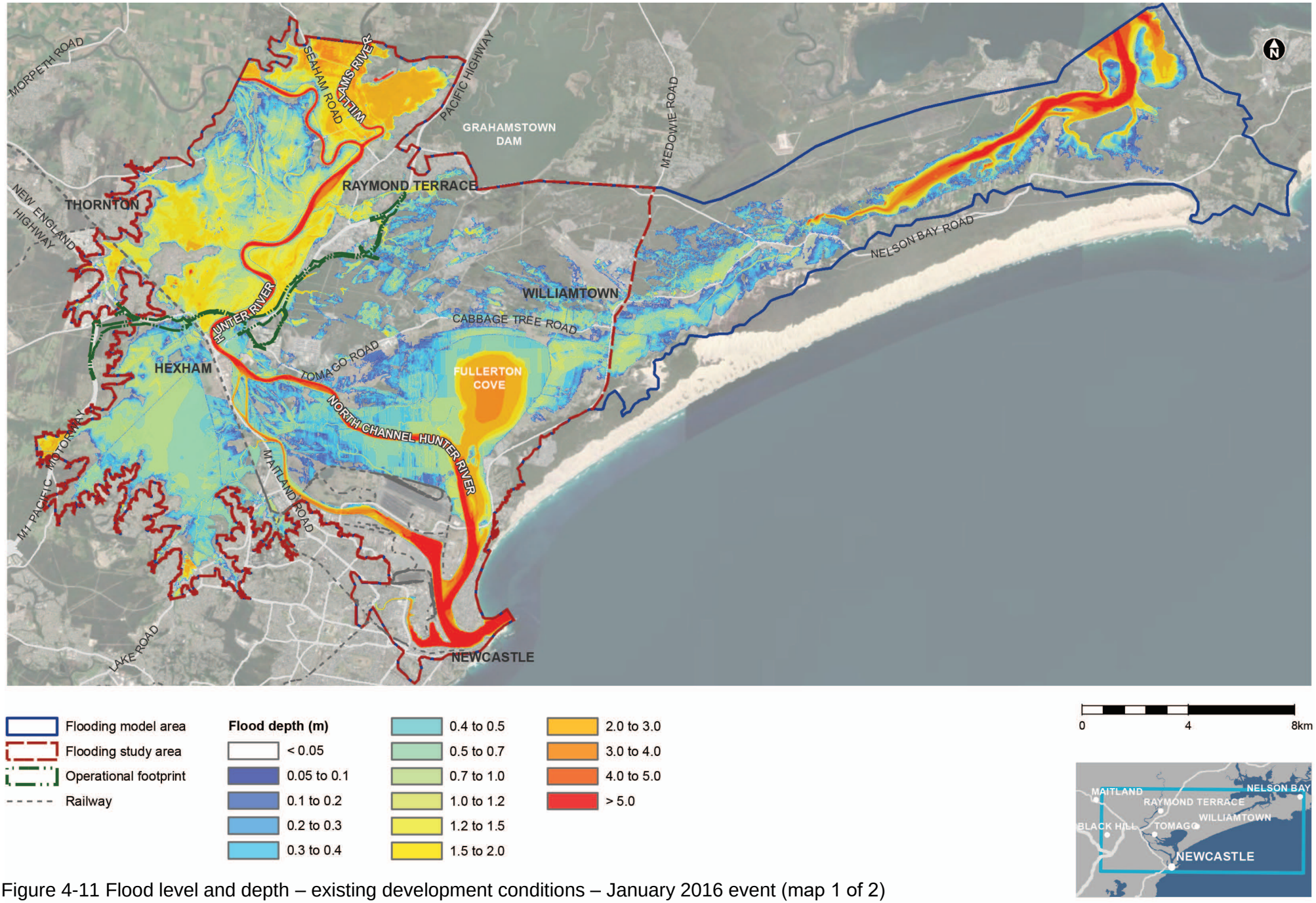


Figure 4-11 Flood level and depth – existing development conditions – January 2016 event (map 1 of 2)

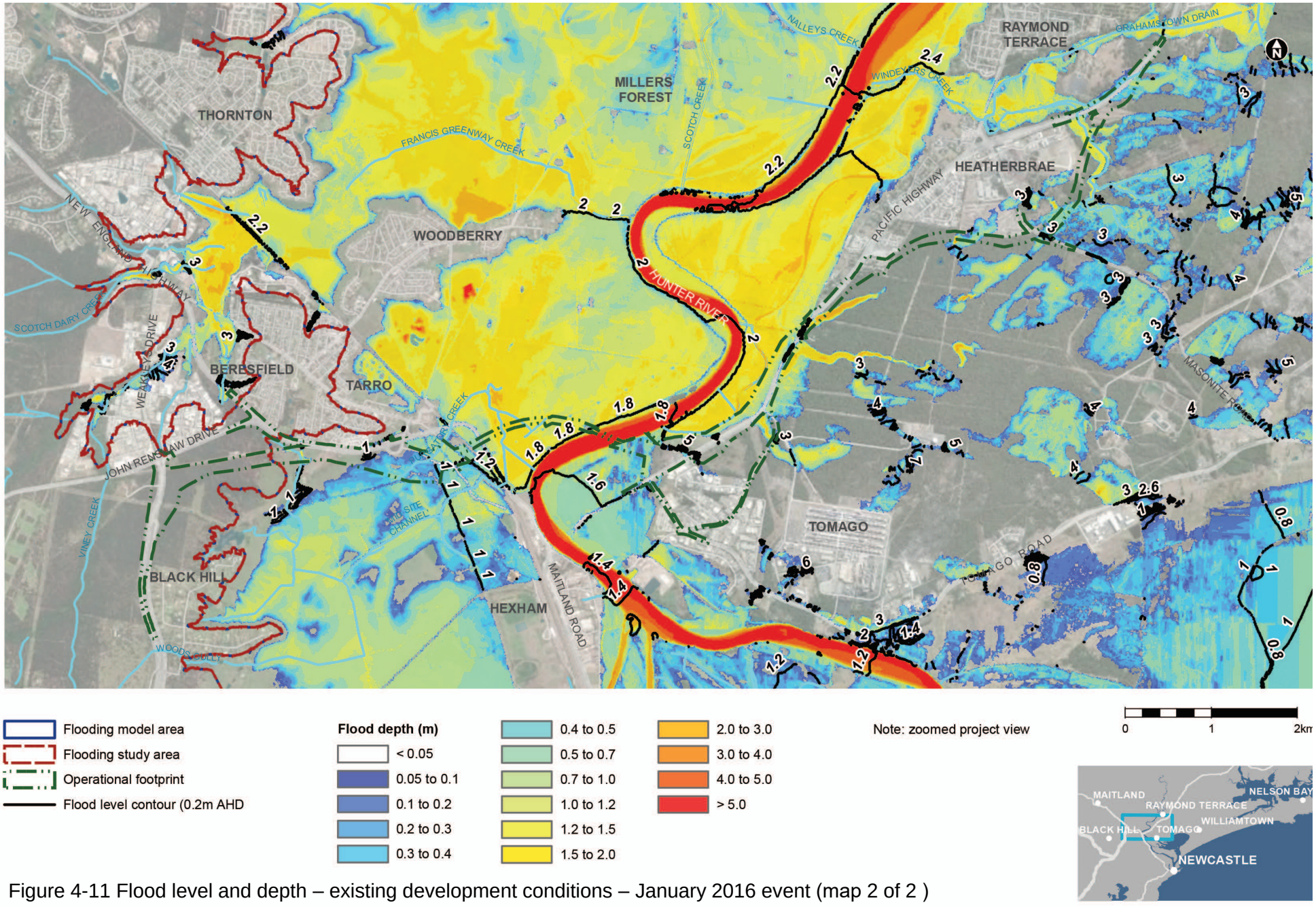


Figure 4-11 Flood level and depth – existing development conditions – January 2016 event (map 2 of 2)

4.5.6 Design events

A range of design flood events were simulated, mapped and analysed for existing catchment development conditions. These flood events include the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events. An envelope of flooding mechanisms dominated by a combination of rainfall runoff generated over the local catchments, Hunter River inflow and tide levels was assessed to define flood behaviour for each design event. A comparison between simulated peak flood levels for the design flood events and at-site flood frequency estimates (BMT WBM, 2017) for the Raymond Terrace gauge is shown in **Table 4-4**. The comparison indicates that modelled peak flood levels for the design flood events agree closely with the at-site flood frequency estimates.

Table 4-4 Comparison of flood levels (m AHD) at Raymond Terrace gauge

Design flood event	At- site flood frequency (BMT WBM, 2017)	City of Newcastle (DHI, 2008)*	This study
20% AEP	2.4	-	2.32
10% AEP	2.9	2.90	2.99
5% AEP	3.2	3.48	3.36
2% AEP	4.1	3.79	4.14
1% AEP	4.8	4.68	4.85
0.5% AEP	5.2	4.89	-
PMF	-	7.82	8.51

*Location of flood level for “Raymond Terrace” as reported in Table 9 of DHI (2008) is not correct, as such flood levels for the correct location (reported as “Hexham Bridge” in DHI (2008)) are shown for a comparison.

Table 4-5 compares the peak flood levels simulated in this study with the design flood levels adopted by City of Newcastle (DHI, 2008) at Hexham Bridge. It shows that the flood levels from this study are generally in agreement with those adopted by City of Newcastle for the 2% and 1% AEP event. The flood level for the 1% AEP event is also consistent with those from BMT WBM (2012b). There is variance between the 20% and 10% AEP and probable maximum flood levels from this study and DHI (2008) which are attributed to differences in the model configuration. The DHI (2008) represents the Hunter River and floodplain from Tomago to Fern Bay on the north side of the Hunter River as a one-dimensional drainage network, while the current TUFLOW model representing the Hunter River, other major channels and all floodplains as a two-dimensional surface, which retains finer details of the ground and river bed elevations which dictate flow patterns and is considered more accurate. These are substantial differences in model configuration which are considered likely to result in the observed variance in simulated flood levels between the DHI (2008) and the current studies.

Table 4-5 Comparison of flood levels (m AHD) at Hexham Bridge gauge

Design flood event	Modelled flood level (BMT WBM, 2012b)	Newcastle City Council (DHI, 2008)*	This study
20% AEP	-	-	1.38
10% AEP	-	2.13	1.82
5% AEP	-	2.60	2.17
2% AEP	-	2.91	2.92
1% AEP	3.8	3.94	3.84

Design flood event	Modelled flood level (BMT WBM, 2012b)	Newcastle City Council (DHI, 2008)*	This study
0.5% AEP	-	4.14	-
PMF	-	6.80	7.49

*Location of flood level for Hexham Bridge as reported in Table 9 of DHI (2008) is not correct, as such flood levels for the correct location (reported as "Hexham Swamp" in DHI (2008)) are shown for a comparison.

Each mapped and analysed flood event consists of a maximum envelope of multiple, individual scenarios which have varied combinations of different storm durations, Hunter River flooding and local catchment flooding. Peak flooding in different locations in the floodplain may be dictated by a particular flood scenario. Flood depth and level, flow velocity, flood hazard and duration of inundation is mapped for each flood AEP for the existing case and presented in **Appendix C**. A description of flood behaviour in key parts of the flooding study area which are likely to be impacted by the project are provided below.

Hexham Swamp

The flood levels in the northern portion of the swamp are controlled by the various embankments that cut across the swamp as well as by the two outlets, one of which is through Purgatory Creek. Floodwater can also be transferred to or from the southern portion of the swamp through culverts under the abandoned railway. Flooding can also occur due to rainfall-runoff on the local catchment of the swamp.

During the 20% AEP event, flooding in Hexham Swamp is influenced mainly by local catchment inflows. In the 10% AEP event, flooding in the swamp is a result of both rainfall runoff generated from local catchments and Hunter River flooding as the New England Highway and the railway are overtopped at Mid Site Channel by the Hunter River floodwaters. In the 5% AEP event, flooding in the swamp is mainly dominated by Hunter River flooding due to floodwaters overtopping the railway and New England Highway at Purgatory Creek and additional locations, particularly as the flood magnitude increases above the 2% AEP event.

Peak flood depths in Hexham Swamp are typically 0.5 to one metres in the 20% AEP event, one to three metres in the 5% AEP event and three to four metres in the 1% AEP event. During the probable maximum flood, depths are over seven metres. Residential and rural residential areas around Hexham Swamp in Black Hill, Lenaghan, Minmi, Fletcher and Maryland are generally located above and outside the fringe of flooding in the swamp in the 1% AEP event, although there are urbanised areas in Wallsend, Jesmond and Birmingham Gardens which are flood affected due to flooding in the southern end of Hexham Swamp and local catchment flooding in Ironbark Creek and Dark Creek, and are known flood problem areas. Depths of flooding in the 20% and 5% AEP events in these urban areas are up to 1.5 metres, and up to 1.8 metres in the 1% AEP event.

Flow velocities in Hexham Swamp are generally low, with velocities of 0.1 metres per second in the 20% and 5% AEP event in the main body of the swamp. Flow velocities are higher in the 1% AEP event with velocities of 0.6 metres per second and higher velocities of one to 1.5 metres per second in the northern portion of the swamp due to Hunter River overflows over the railway and New England Highway entering the swamp.

Flow velocities in the probable maximum flood are typically 0.5 to 1.5 metres per second. Higher velocities occur in the minor waterways feeding the creek, due to local catchment inflows. These are shown on the flood mapping to be up to two metres per second, although due to the broad-scale nature of the flood model these velocities are considered to be underestimates and actual flow velocities are expected to be higher, particularly in formalised and lined sections of the creeks.

The flood hazard rating is a function of the flood depth and flow velocity, with the hazard categorisation discussed in **Section 2.3.12** providing six separate hazard categories. In order to provide a consistent and simplified commentary on impacts of the project on flood hazard, flood hazard categories H1 and H2 are referred to as "low" hazard and flood hazard categories H3 to H6 are referred to as "high" hazard. In

Hexham Swamp, the flood hazard is mainly high (H3 or higher) with areas of low hazard (H1 and H2) around the fringes, in the 20% AEP event. In the 5% AEP event and larger, high hazard flooding conditions are prevalent.

Durations of inundation are typically 40 to 90 hours in the 20% AEP event, 70 to 90 hours in the 5% AEP, 80 to 90 hours in the 1% AEP event and over 144 hours in the probable maximum flood.

Hunter River floodplain upstream of the project

Flood depths on the Hunter River floodplain upstream project, on the rural and environmental conservation areas, are typically 0.3 to 0.5 metres in the 20% AEP event, two to 2.5 metres in the 5% AEP event and three to 4.5 metres in the 1% AEP event. During the probable maximum flood depths on the floodplain are seven to eight metres.

Urban areas, including residential, commercial and industrial properties, in parts of Tarro, Woodberry, Thornton, Millers Forest, Tomago and Heatherbrae are generally above the 1% AEP event, with exception of parts of Raymond Terrace where affected areas experience depths of flooding of one to 1.5 metres in the 5% AEP event and two to three metres in the 1% AEP event. Localised areas are affected in the 20% AEP event to depths of 0.5 metres.

Flooding along minor waterways, including Windeyers Creek, Purgatory Creek and Viney Creek, occurs as a result of local catchment flows, Hunter River flooding, or a combination of these two flooding mechanisms. Flood depths are typically 0.5 to two metres in the 20% AEP event, 1.5 to 2.5 metres in the 5% AEP event and two to four metres in the 1% AEP event. Maximum depths are generally due to the Hunter River flooding, although in some sections are attributed to local catchment flows ponding behind hydraulic controls such as road and rail embankments. The existing flood levees and floodgates prevent the floodwaters from overflowing from the river in flood events up to and including the 20% AEP event, which limits flooding on the floodplain to relatively low depths.

Flow velocities are typically 0.1 to 0.5 metres per second in the 20% AEP event, 0.5 to 0.8 metres per second in the 5% AEP event, 0.6 to one metres per second in the 1% AEP event and 0.7 to 2.7 metres per second in the probable maximum flood. Velocities in the river channel are above 1.5 metres per second in all events.

On the floodplain upstream of the project, the flood hazard is a mix of high and low hazard flooding in the 20% AEP event. In the 5% AEP event and larger, high hazard flooding conditions are prevalent.

Durations of inundation are typically 20 to 70 hours in the 20% AEP event, 65 to 80 hours in the 5% AEP and 75 to 90 hours in the 1% AEP event. Areas with longer durations of flooding occur at trapped low points and flood storage areas with constraint outlets, such as behind road and railway corridors and levees. Durations of inundation are over 144 hours in the probable maximum flood.

Hunter River floodplain downstream of the project

Flood depths on the Hunter River floodplain downstream of the project, including parts of Tomago, Hexham and Kooragang Island, are typically 0.5 to one metres in the 20% AEP event, one to 1.5 metres in the 5% AEP event and 1.5 to three metres in the 1% AEP event. During the probable maximum flood depths on the floodplain are five to seven metres.

Commercial and industrial properties in parts of Tomago, Hexham and Sandgate are generally above the 1% AEP event. There are some industrial properties in Tomago, between Tomago Road and the Hunter River, which are affected by shallow flooding of 0.2 to 0.4 metres due to local catchment flooding in the 20% AEP event and up to the 1% AEP event. Industrial properties in Hexham and Sandgate are affected by the 1% AEP flood to depths of 0.5 to two metres.

Flow velocities are typically 0.3 to 0.5 metres per second in the 20% AEP event, 0.5 metres per second in the 5% AEP event, 0.6 to 1.5 metres per second in the 1% AEP event and typically one to 1.5 metres per second, with localised areas up to two metres per second, in the probable maximum flood.

On the floodplain upstream of the project, the flood hazard is a mix of high and low hazard flooding in the 20% AEP event. In the 5% AEP event and larger, high hazard flooding conditions are prevalent. There are some areas of low hazard flooding between Tomago Road and the Hunter River in the 5% AEP event only.

4.5.7 Inundation of roads

Highways and major roads

Several major existing roads near the project would form the main evacuation and emergency access routes from areas that are flood prone. **Table 4-6** provides a summary of flood impacts to major roads near to the project during flood events.

Table 4-6 Flooding on existing major roads

Road	Comment
West of Hunter River	
M1 Pacific Motorway and John Renshaw Drive – Black Hill to Tarro	• Flood free except for in PMF at Lenaghan, at crossing of an unnamed creek which drains to the north-western end of Hexham Swamp.
New England Highway – Thornton to Beresfield	• Flood free except for PMF • Flooded during PMF at Viney Creek.
New England Highway – Tarro	• Flooded in 2% AEP event, immediately west of Anderson Drive overpass.
Pacific Highway – Hexham	• Existing northbound bridge crossing the Hunter River (Hexham Bridge) is flood free in all events including the PMF. • Existing southbound bridge is flood free in up to and including the 1% AEP event, and is flooded in the PMF.
New England Highway, Pacific Highway, Maitland Road – Hexham	• New England Highway heading north into Tarro flooded to 0.3m depth in 10% AEP event • Pacific Highway flooded in 10% AEP event affecting access to the south toward Hexham and Sandgate • Unlikely to be trafficable in 5% AEP event.
East of Hunter River	
Pacific Highway - Tomago	• Flooded to 0.1m depth in 20% AEP event, between Hexham Bridge and Tomago Road. Tomago Road also flooded at intersection. Unlikely to be trafficable in 10% AEP event due to depths over 0.4m. • Affected by minor flooding in 10% AEP just south of Hunter Region Botanic Gardens.
Old Punt Road	• Flooded in 20% AEP event
Tomago Road and Masonite Road	• Flooded to 0.5m depths in 20% AEP event on Tomago Road, access cut-off.
Pacific Highway – Heatherbrae and Raymond Terrace	• Remains flood free up to the 5% AEP flood event. • The Pacific Highway experiences depths of flooding over 0.5m during the 2% AEP event near Windeyers Creek, access cut-off over 1 km length. • Access cut-off at Grahamstown Drain in PMF.
Adelaide Street	• Access cut-off in 2% AEP event at Windeyers Creek and 450m section to the north.

An analysis of flooding of highways and major roads was carried out to estimate the total length on each major road in the flooding study area affected by a flood hazard rating of H2 or higher, making the roads impassable for most vehicles. An H2 rating corresponds to a flood depth of 0.3 metres for low flow velocities and is considered unsafe for small vehicles (i.e. excluding 4WDs and trucks), refer to **Section 2.3.12**.

The results are summarised in **Table 4-7**, which shows the length of road that is flood-affected in each design flood event. The analysis has extended to include all identified highways and major roads on the floodplain between Raymond Terrace and the Hunter River mouth, including a number of major roads in addition to those discussed in detail above. The lengths of road sections affected for the existing case are compared to the affected lengths during construction and operation in **Section 5.2.7** and **Section 5.3.8**, respectively, as an assessment of the impact of the project. Refer to Figures C-13 to C-18 in **Appendix C** for locations of high hazard flooding on roads.

Table 4-7 Length (kilometres) of highways and major roads subject to H2 flood hazard in existing case

Road	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Blue Gum Road	0.4	0.4	0.4	0.4	0.5	0.5
Cabbage Tree Road	0.5	0.6	0.8	0.9	1.0	4.4
Cormorant Road	0.0	0.0	0.0	0.0	0.0	4.5
Hannell Street	0.1	0.1	0.1	0.1	0.1	2.1
Hunter Street	0.3	0.3	0.4	0.4	0.5	0.8
Industrial Drive	0.0	0.0	0.0	0.0	0.0	1.1
King Street	0.0	0.0	0.2	0.2	0.2	0.2
Lenaghans Drive	0.0	0.1	0.1	0.2	0.4	0.9
Maitland Road	0.0	0.3	0.6	4.5	5.1	6.1
Nelson Bay Road	0.0	0.0	0.0	0.0	0.0	6.3
New England Highway	0.2	0.5	0.8	0.9	1.8	4.5
Newcastle Road	0.4	0.5	0.5	0.6	0.6	0.7
Pacific Highway	0.1	1.2	1.9	4.4	5.8	11.9
Raymond Terrace Road	0.7	5.4	6.1	6.8	7.1	8.1
Sandgate Road	0.4	0.5	0.5	0.7	1.0	1.4
Seaham Road	3.3	3.6	3.9	3.9	4.0	4.4
Teal Street	0.0	0.0	0.0	0.0	0.0	1.0
Thomas Street	0.0	0.0	0.0	0.0	0.0	0.2
Tillie Street	0.0	0.0	0.0	0.0	0.0	0.1
Tomago Road	0.8	0.9	1.0	1.1	1.3	7.1
Tourle Street	0.2	0.2	0.2	0.2	0.2	0.7
Wilkinson Avenue	0.1	0.1	0.2	0.2	0.5	0.6
William Bailey Street	0.0	0.0	0.3	0.4	0.4	0.5

Minor roads

The flooding affectation of all named roads in the flooding study area was analysed, for the total length of road affected by H2 flood hazard and higher. The results are presented in **Table 4-8**.

Table 4-8 Total length (kilometres) of named roads subject to H2 flood hazard and higher in existing case

Named roads	Total length (km)
20% AEP	29
10% AEP	68
5% AEP	81
2% AEP	100
1% AEP	108
PMF	218

4.5.8 Inundation of railway infrastructure

The flood model results were analysed to determine the flood affectation of railway infrastructure. The railway line spatial data are considered to be generally representative of associated railway features (stations, signalling, electrical, etc.). **Table 4-9** presents the total length of railway line overtopped by flooding within the flooding study area.

Table 4-9 Length (kilometres) of railway flooded in existing case

Road	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	Total length in study area
Main North Rail Line	2.3	3.8	5.2	11.6	12.2	13.0	14.9
Other rail lines	1.0	2.1	2.4	2.7	3.3	27.3	50.3
Aurizon facility	0.4	0.4	0.6	2.0	2.1	2.1	2.1

The Aurizon Hexham Train Support Facility site, which is located next to the eastern side of Hexham Swamp. It consists of several maintenance and administration buildings and a 1.6 kilometre long stabling yard for coal trains. The main building towards the south of the site and a maintenance building at the north of the site are not flood-affected in the 5% AEP event, while the main building remains flood-free in the 1% AEP event. The stabling yard is affected by localised flooding in the 20% AEP event to depths of 0.3 metres, while the northern one-quarter of the stabling yard is affected by depths of up to 0.5 metres in the 5% AEP event. In the 1% AEP event the entire stabling yard is affected to depths of three metres, which is consistent with the flood behaviour reported in the Hexham Train Support Facility Flood Impact Assessment (BMT WBM, 2012b). To the west of the main building is a filled area which is raised above the probable maximum flood.

The Hexham Relief Roads project supports the Aurizon Hexham Train Support Facility and is the main access road to the facility. It is flood-free in the 20% AEP event and mostly flood-free in the 10% AEP event with some localised overtopping of the road. The road is fully inundated in the 5% AEP event.

4.5.9 Inundation of major land uses

The flood affectation of major land uses was assessed, in terms of different flood depths, flood hazard and durations of inundation. Numbers of residential, commercial and industrial properties and the total area (in hectares) of various rural land uses were identified. These are summarised in Table B-1 to B-11 in **Appendix B** and is based on lots from cadastral information as properties may consist of a number of lots. In summary:

- Of residential lots:
  - 556 are flood-affected in the 20% AEP event, 696 in the 5% AEP event, 1185 in the 1% AEP event and 6983 in the probable maximum flood, between depths of 0.05 metres to over three metres
  - 274 are affected by high hazard flooding in the 20% AEP event, 417 in the 5% AEP event, 869 in the 1% AEP event and 5813 in the probable maximum flood
  - Note that “residential” properties includes those zoned general, low, medium and high density residential and large lot (rural) residential properties.
- Of commercial lots:
  - 177 are flood-affected in the 20% AEP event, 241 in the 5% AEP event, 261 in the 1% AEP event and 1048 in the probable maximum flood, between depths of 0.05 metres to over three metres
  - 126 are affected by high hazard flooding in the 20% AEP event, 193 in the 5% AEP event, 224 in the 1% AEP event and 832 in the probable maximum flood.
- Of industrial lots:
  - 113 are flood-affected in the 20% AEP event, 244 in the 5% AEP event, 328 in the 1% AEP event and 1101 in the probable maximum flood, between depths of 0.05 metres to over three metres
  - 58 are affected by high hazard flooding in the 20% AEP event, 164 in the 5% AEP event, 291 in the 1% AEP event and 1068 in the probable maximum flood.

The main rural land uses in the flooding study area are grazing, forestry and wetland/national park areas. In summary:

- Of grazing lands, 1938 hectares are affected by high hazard flooding in the 20% AEP event, 5766 hectares in the 5% AEP event, 6786 hectares in the 1% AEP event and 7451 hectares in the probable maximum flood
- Of forestry lands, 25 hectares are affected by high hazard flooding in the 20% AEP event, 107 hectares in the 5% AEP event, 320 hectares in the 1% AEP event and 362 hectares in the probable maximum flood
- Of wetlands and national park lands, 2215 hectares are affected by high hazard flooding in the 20% AEP event, 3549 hectares in the 5% AEP event, 4103 hectares in the 1% AEP event and 4786 hectares in the probable maximum flood.

Durations of inundation of up to 96 hours are typical for all land use types in the study area in up to the 1% AEP event, while durations exceeding 96 hours are common in the probable maximum flood.

4.5.10 Overview of key flooding issues raised during consultation

Review of the flooding conditions for the existing case and consultation with stakeholders and the community indicate that the following flooding issues are present in the study area:

- A large number of residential, rural, commercial and industrial properties are affected by flooding on the Hunter River floodplain, with potential for impacts to people and buildings in these areas

- Existing high flood hazard on parts of the floodplain, particularly in the 10% AEP event and greater when there are high depths of flooding on the Hunter River floodplain upstream of the project
- Current use of rural lands for primary production including beef grazing and other agriculture. Potential flooding impacts including increased flood extents and durations of inundation affecting productivity of the land, and impacts to stock flood refuge access on the floodplain
- The existing Hunter Valley Flood Mitigation Scheme includes flood mitigation works near to the project. There is potential for the project including physical features and proposed stormwater discharges to impact on the physical form or functioning of the scheme
- Sensitivity of existing flood emergency access and evacuation routes to changes in flood behaviour. Potential flood impacts may result in access and evacuation routes becoming cut-off more frequently
- Substantial existing rail infrastructure servicing passenger and freight/coal movements exists between Hunter Valley and Port of Newcastle. Potential flood impacts resulting in impacts to rail operations and maintenance.

4.6 Sensitive receiving environments

4.6.1 Drinking water supply - aquifers

The eastern section of the project study area is within the Tomago Sandbeds Catchment Area, an area classified as a Special Area under the Hunter Water Act to protect it as a drinking water supply. The catchment area is shown on **Figure 2-2**. The remainder of the study area is not classified as drinking water catchment.

The Tomago Sandbeds Catchment Area is strategically important for both ongoing and backup drinking water supply and is considered a SRE.

4.6.2 Groundwater users

Existing groundwater bores within a two kilometre radius of the project construction footprint have been extracted from the BoM's Australian Groundwater Explorer (2020) and described in **Section 4.4.4**. All groundwater users within the project construction footprint have been considered SREs.

4.6.3 Wetlands

Coastal Wetlands (Coastal Management SEPP)

Six areas identified as Coastal Wetlands under the Coastal Management SEPP (refer to **Figure 2-1**) are located within the surface area study area. Of the six Coastal Wetlands, three are located within the construction footprint:

- South of the existing New England Highway (freshwater)
- On the eastern bank of the Hunter River (estuarine)
- On the western bank of the Hunter River (estuarine).

The other three Coastal Wetlands which are outside the project construction footprint but within the surface water study area include:

- North of the project in Tarro, separated from the project by Woodberry Road

- In Tomago, located south east of the project footprint on the southern side of Masonite Road on the eastern floodplain of the Hunter River
- In Tomago, on the northern bank of the north channel Hunter River.

These Coastal Wetlands are considered likely to be, in part, supported by groundwater discharge and as such are likely to be groundwater dependent ecosystems.

Floodplain wetland

In addition, although not classified under the Coastal Management SEPP, the Hunter River wetland which is located within the Tomago Sandbeds Catchment Area, has also been considered an important wetland environment due to presence of aquatic and wetland habitat features identified on site (refer to **Figure 2-2** for Tomago Sandbeds Catchment Area and **Figure 4-1** for monitoring site M12RT8 which is located on the Hunter River wetland). This wetland is considered likely to be supported, in part, by groundwater discharge and is likely to be a groundwater dependent ecosystem.

Ramsar Wetland

As described in **Section 4.3.2**, the Hunter Wetlands National Park on Kooragang Island and the Hunter Wetlands Centre Australia in Shortland form the Hunter Estuary Ramsar listed site and these are located downstream of the study area. Kooragang Nature Reserve is located a minimum distance of about 1.9 kilometres south-east of the project and over 2.8 kilometres from the main alignment. The Hunter Wetlands Centre Australia in Shortland is located to the south of Hexham Swamp Nature Reserve and about 3.8 kilometres south of the project.

The Coastal Wetlands (Coastal Management SEPP), the Hunter River wetland and the Hunter Estuary Wetlands Ramsar Site areas are considered SREs.

4.6.4 Groundwater dependent ecosystems

As described in **Section 4.4.3**, the BoM's (2020) Groundwater Dependent Ecosystem Atlas identifies a number of known and potential GDEs. These communities are shown on **Figure 4-7** and include:

- Known aquatic GDEs
  - Floodplain wetlands (Hexham Swamp, Hunter Wetlands National Park)
  - Hunter River.
- High potential terrestrial GDEs
  - Coastal Floodplain Wetlands on the floodplains of Hunter River (Tarro, Hexham and Tomago). These areas typically coincide with the Coastal Wetland areas under the Coastal Management SEPP
  - Mangrove Swamps on the margins of the Hunter River
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (at Tomago and Heatherbrae).
- Moderate potential terrestrial GDEs
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (at Tomago and Heatherbrae).

It is noted that a number of these potential and known GDEs coincide with the Coastal Wetlands (Coastal Management SEPP) and fall within the construction footprint. These GDEs are considered SREs.

5. Assessment of potential impacts

5.1 Impacts avoided and minimised

The concept design for the project was developed using a multi-disciplinary process that identified and assessed routes against a range of engineering, environmental, social, land-use and economic criteria. This process (as described in Chapter 4 of the EIS) ultimately determined that the project alignment represented the best balance after a multi-criteria analysis of all known constraints and opportunities.

As a result of project development, the alignment has been shifted to be closer to the New England Highway and other existing infrastructure corridors, crossing the Hunter River 1.4 kilometres north of the original crossing. As a result of route option design development, the project has avoided:

- Substantial upstream flooding impacts as a result of a 2.6 kilometre long viaduct instead of an embankment across the Hunter River floodplain
- Substantial impacts to drainage capacity, flood storage and conveyance upstream in the swamp area in Hexham which would have occurred as a result of an embankment on the floodplain
- Substantial local afflux, as a result of increasing culvert flow capacity in Tomago
- Potential substantial groundwater impedance and level impacts as a result of soft soil consolidation activities that would be required to support the embankment across the floodplain
- Erosion and scour directly downstream of the project by providing rock riprap aprons downstream of all culverts.

In locations where impacts to hydrology and flooding were unable to be avoided, a number of management measures have been identified to avoid further impacts as a result of the project, refer to **Chapter 8**.

Impacts associated with the project is described in the following sections.

5.2 Construction impacts

5.2.1 Description of construction phase

Project components which have the potential to affect surface water hydrology, groundwater hydrology and flooding during construction are shown in **Figure 5-1** and include:

- Earthworks for permanent road embankments
- Bridge works including construction of piers, temporary crane pads, temporary wharves
- Temporary and permanent access roads, which are generally raised by 0.5 to one metres, and up to 2.5 metres above natural ground level. These are similar to other existing rural property access roads on the floodplain
- A total of 21 ancillary facilities located along the project alignment. Low lying areas within ancillary facilities are filled up to provide 20% AEP flood immunity. Typically raised by 0.5 to one metres, and up to 2.5 metres, above natural ground level. The ancillary facilities would seek to maintain existing drainage lines where feasible and reasonable however some redirection may be necessary
- Temporary stockpiles
- Culverts and other drainage works, including temporary waterway crossings.

Potential construction phase impacts are discussed in the sections below.

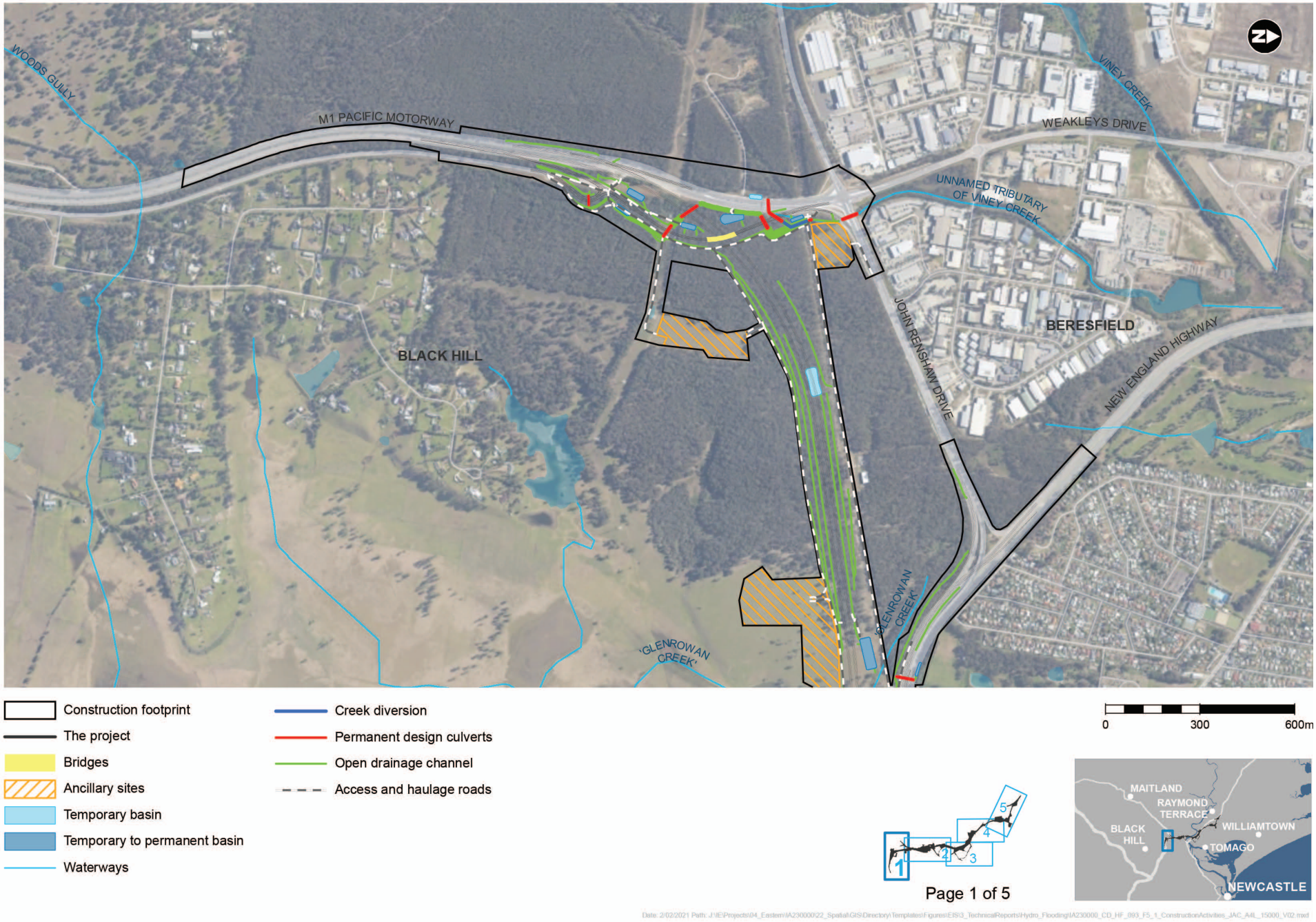
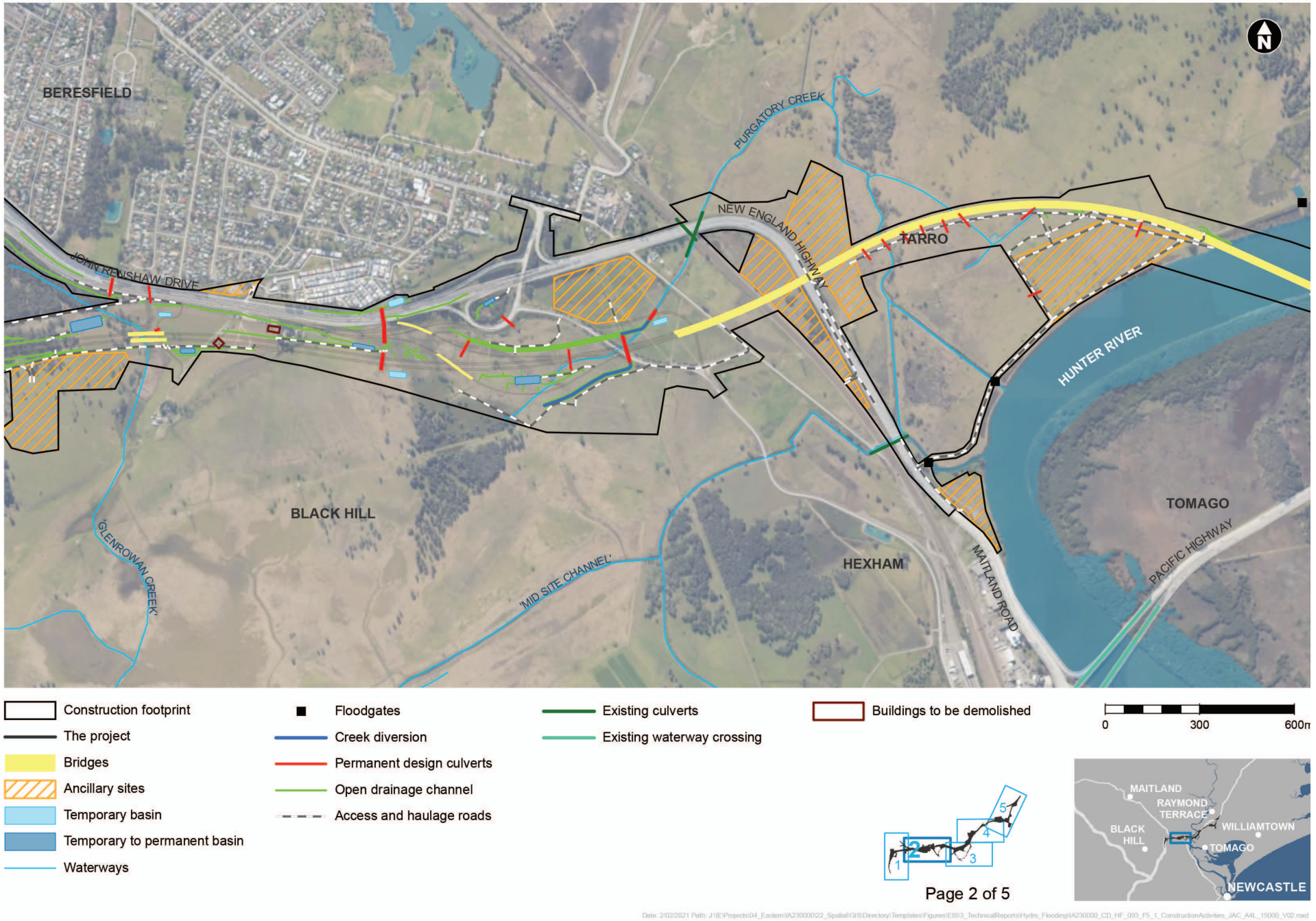


Figure 5-1 Construction activities (map 1 of 5)



Page 2 of 5

Figure 5-1 Construction activities (map 2 of 5)

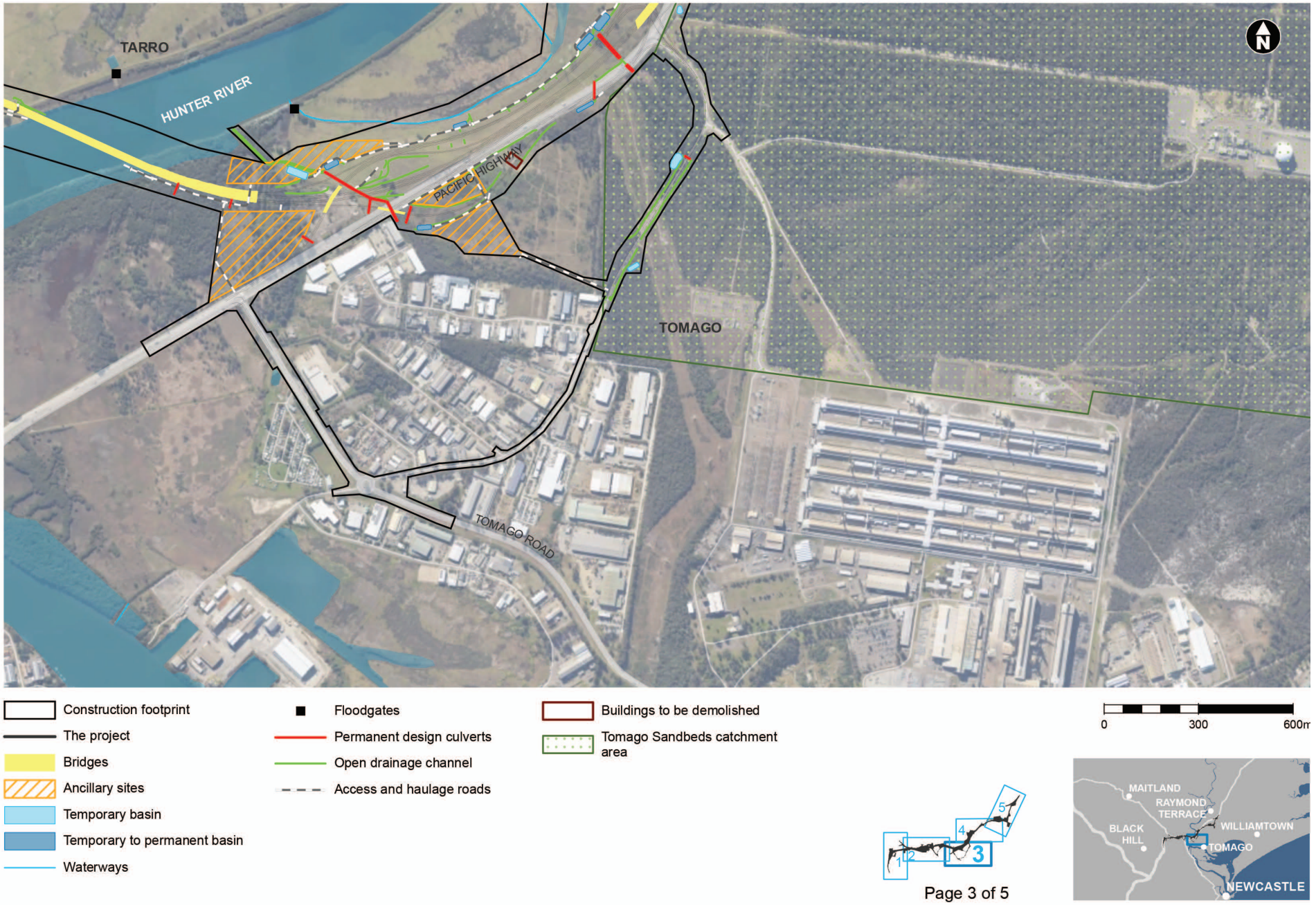


Figure 5-1 Construction activities (map 3 of 5)

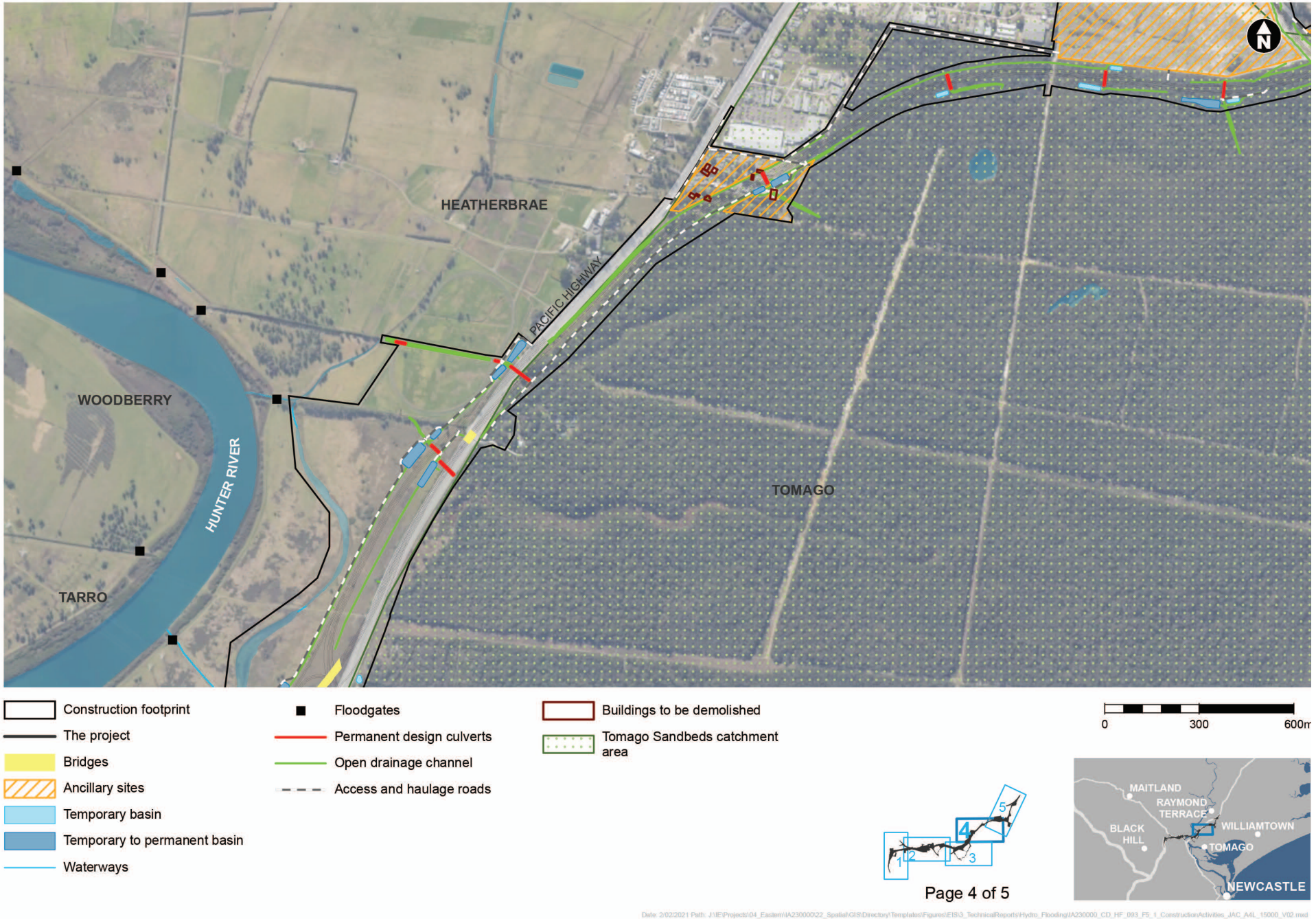


Figure 5-1 Construction activities (map 4 of 5)

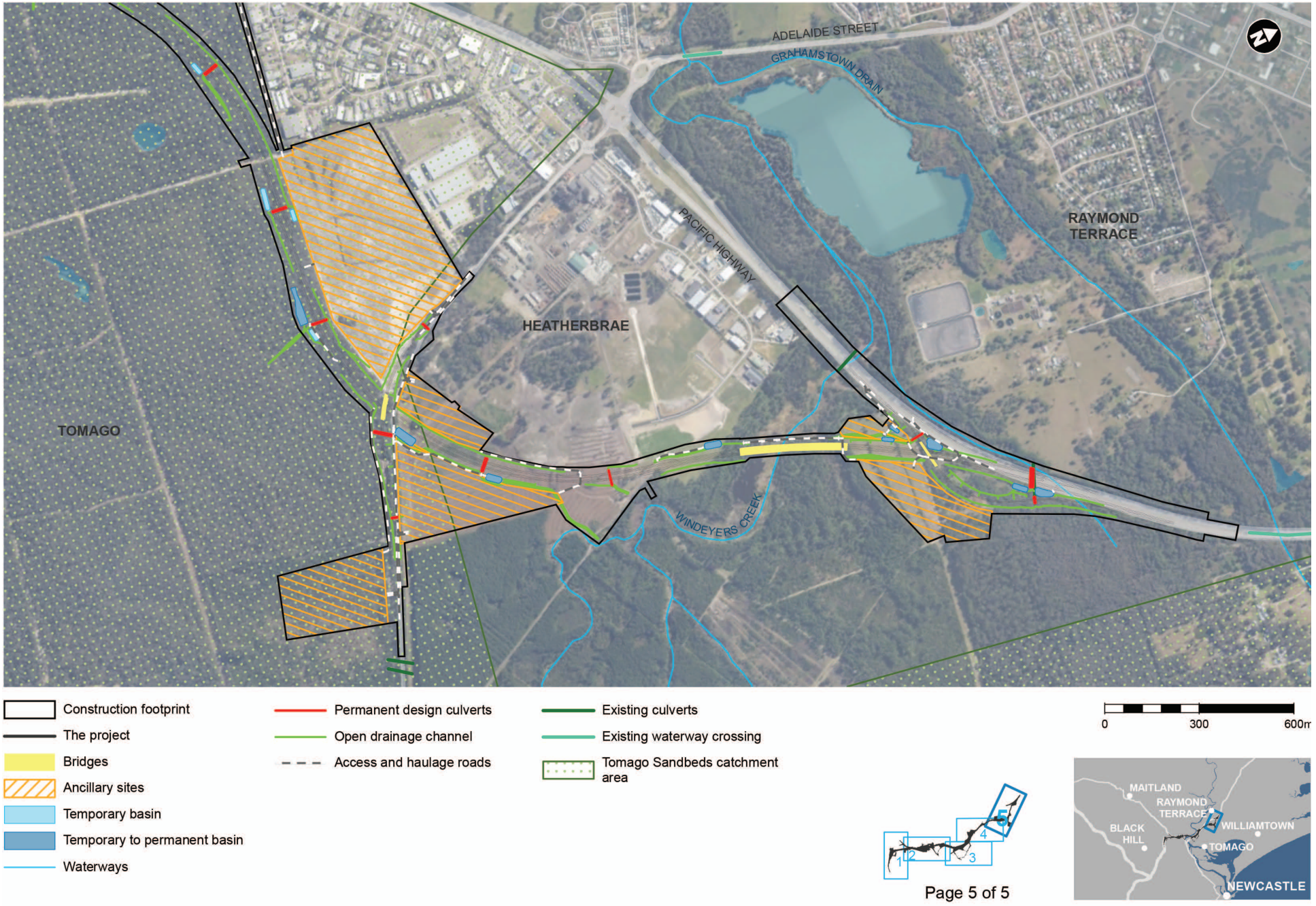


Figure 5-1 Construction activities (map 1 of 5)

5.2.2 Surface water hydrology impacts - construction

Potential impacts to surface water hydrology - construction

Key activities during construction of the project that may impact the nature (volume, rate, timing, duration, velocity, etc.) of stormwater discharges include:

- Vegetation clearance (of trees, understorey and ground cover) and reduced infiltration associated with soil compaction and paving within the road corridor and for the development of associated temporary ancillary facilities, access roads and tracks. Ancillary facilities would seek to maintain existing drainage lines where feasible and reasonable however some redirection may be necessary
- Temporary dewatering of groundwater ingress to construction excavations
- Temporary and permanent alteration or impedance (due to temporary creek crossings including crossings at Purgatory Creek and Windeyers Creek, in-stream works, etc.) of existing drainage paths and waterways which have the potential to result in localised increases in flow velocities around instream features. In particular:
  - The construction of bridges and the viaduct, (i.e. temporary waterway structures and wharves and the permanent piers themselves)
  - Adjustment of Purgatory Creek and the unnamed tributary of Viney Creek as well as temporary and permanent culverts
  - Temporary haulage road across Glenrowan Creek.
- Attenuated or delayed discharge of stormwater captured in temporary construction sediment basins and permanent water quality basins which have been designed to capture all runoff from an 80th or 85th percentile (depending on receiving environment sensitivity) 5-day rainfall event
- Reuse of stormwater captured in temporary construction sediment basins and permanent water quality basins.

Potential changes to the rates and volume of stormwater discharged from the project during the construction phase have not been assessed quantitatively. However, they are considered to be broadly similar to the operational phase DRAINS modelling outlined in **Section 5.3.1** and are expected to include minor to moderate increases to rates of stormwater discharge, volume and velocity. These changes are not expected to result in a material impact to the receiving environment as:

- A construction phase Erosion and Sediment Control Plan (ESCP) will be developed as part of the Construction Soils and Water Management Plan (CSWMP) and will identify appropriate erosion and sediment control measures in accordance with the NSW Blue Book requirements (DECC, 2008a and 2008b) for temporary stormwater discharge locations
- The project design includes appropriate mitigations including scour protection in the form of rock transition aprons and energy dissipation at culvert outlets
- Increased discharges of stormwater from the project and dewatering of construction sediment basins would largely be consistent with variations in existing conditions and occur during or following naturally occurring flow events. Potential changes to the number, timing and duration of flow events in the receiving environment are likely to be minor and not of a material impact.

Potential changes to existing flow regimes - construction

Waterways within the study area are ungauged and a quantitative assessment of existing and construction phase flow regimes has not been completed. Operation phase design event DRAINS hydraulic modelling has been completed (**Appendix** J) for locations where stormwater is discharged from the project to the receiving environment (refer to **Figure 5-2** for discharge locations and Table J-1 to Table J-4 in **Appendix J**).

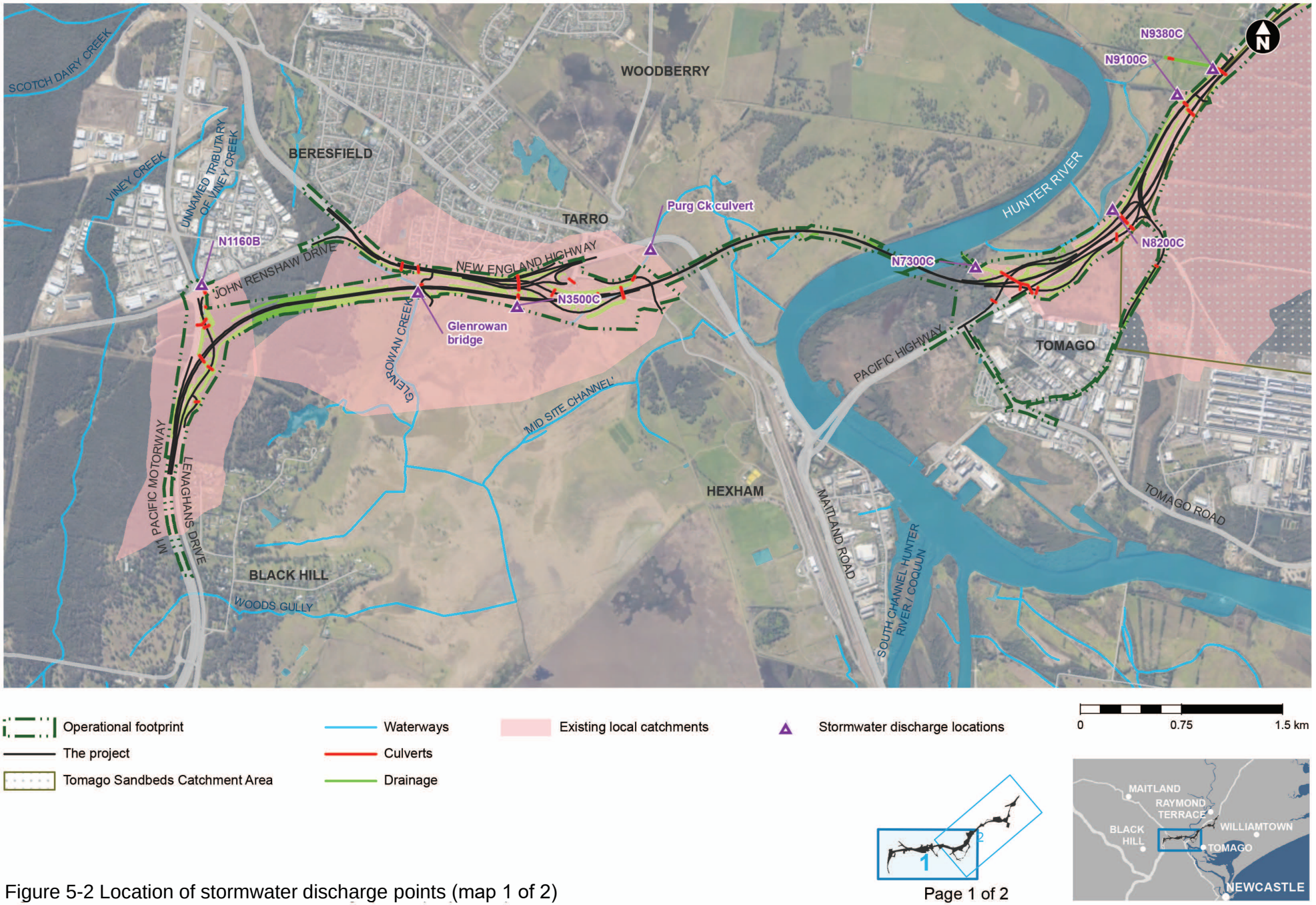


Figure 5-2 Location of stormwater discharge points (map 1 of 2)

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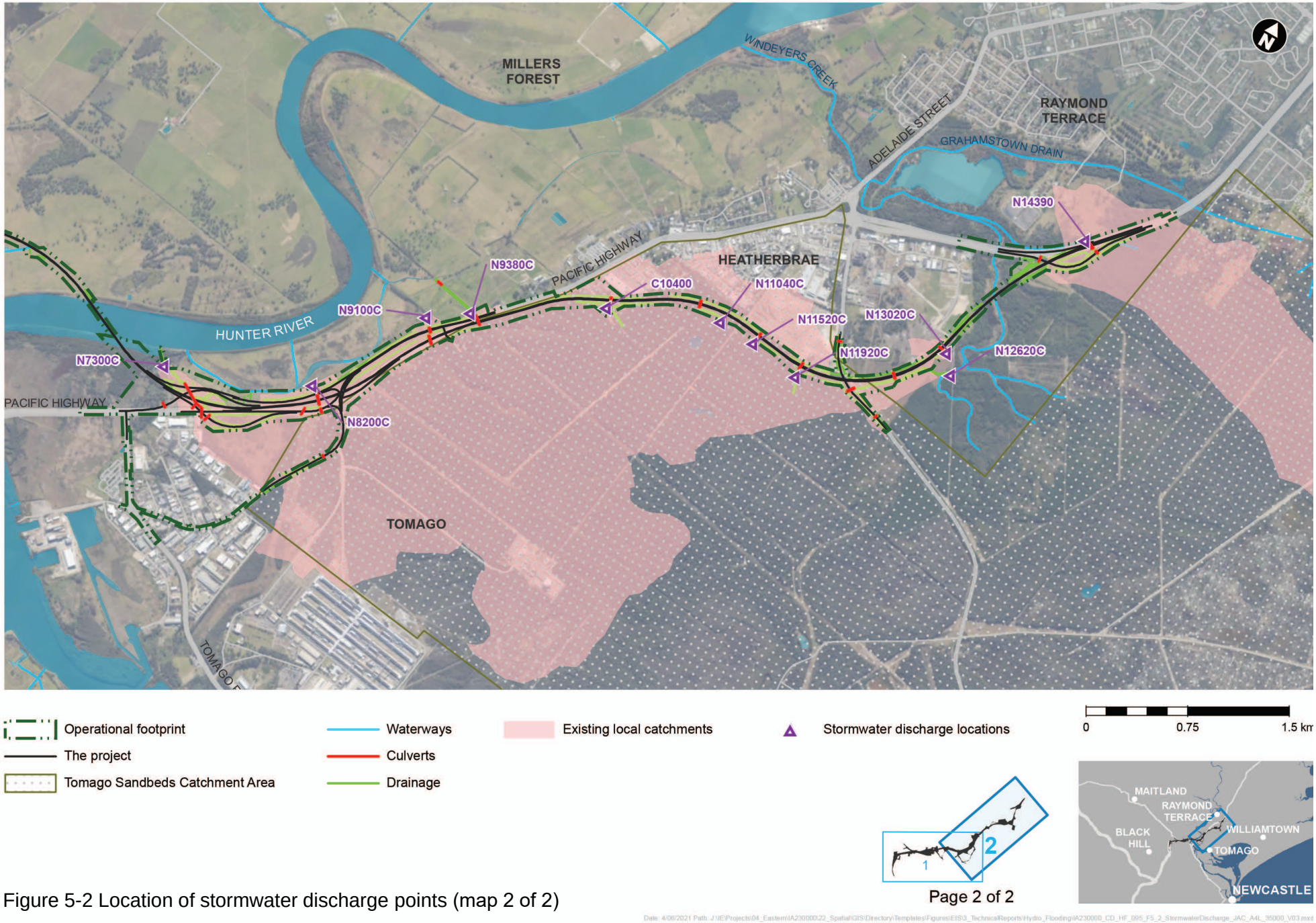


Figure 5-2 Location of stormwater discharge points (map 2 of 2)

The DRAINS results summarised in **Section 5.3.1** are considered to be broadly representative of expected changes in stormwater discharge conditions during the construction phase (where possible, the locations of temporary sediment basins and permanent water quality basins have been consolidated so that construction phase basins can be converted into operational basins following completion of construction). Receiving waterways potentially impacted by discharges of stormwater from the project during construction are as follows:

- Unnamed tributary of Viney Creek
- Purgatory Creek
- Drainage line through coastal wetland to Hunter River
- Unnamed tributary of coastal wetland
- Hunter River Drain
- Tributary to Hunter River Drain
- Diffuse drainage lines that terminate into the Tomago Sandbeds Catchment
- Windeyers Creek.

The DRAINS operational phase modelling (**Appendix J**) and TUFLOW flood modelling (**Appendix B**) indicates that the following potential changes are expected to the existing flow regime at or immediately downstream of discharge locations during construction:

- Minor reductions in baseflow and moderate increases to quickflow contributions to total streamflow as a result of lowered rates of rainfall infiltration, increase in effective rainfall depth and formalisation of drainage conveyance
- Minor to moderate increases to the rate, volume and velocity of stormwater discharged from the project and subsequent inferred alteration (minor increases) to rates of water level rise and fall
- Minor increases to the duration and depth of inundation for overbank events
- Modelling results completed for the operation phase and applied to the construction phase indicate there would be a minor increase (less than 20 per cent increase) in the rate of stormwater at discharge:
  - Discharge point N1160B at unnamed tributary of Viney Creek
  - Discharge point N8200C at the unnamed tributary of coastal wetland
  - Discharge point N9100C at the Hunter River Drain
  - Discharge point N9380C the tributary to the Hunter River Drain.
- Modelling results completed for the operation phase and applied to the construction phase indicate there would be a moderate increase (more than 20 per cent increase) in the rate, volume and velocity of stormwater at:
  - Discharge point N3500C at Purgatory Creek
  - Discharge point N7300C at the drainage line through coastal wetland to the Hunter River
  - Discharge point N11920C drains into diffuse drainage lines that feed into the Tomago Sandbeds Catchment
  - Discharge points N13020C and N12620C at Windeyers Creek.

DRAINS and TUFLOW flood modelling have been completed on a design event basis and potential changes to the frequency, duration and temporality of flow events were not assessed. However, construction of the project may also result in minor changes to the number, duration and magnitude of low flow events as a result of the construction sediment basins and changed rates of rainfall infiltration.

Impacts to waterway and riparian processes from changes in flow regime - construction

The amount of energy and type of material (such as gravel, bedrock, sand, or fine sediments such as clay and silt) are key drivers of the physical form of a watercourse. The supply and movement of material is typically in a form of dynamic equilibrium. However, they fall out of balance if they are changed dramatically or intensively over a short time period (compared with the natural rate of change). This can subsequently lead to the acceleration of processes that are detrimental to the long-term condition of the watercourse's natural geomorphic character. It is this imbalance, or potential for change that is outside of what appears to be the natural regime within the catchment, that would be considered an adverse impact on the system.

Geomorphic assessment of waterways within the study area (as discussed in **Section 4.3.3**) indicate that waterways are typically stable, low energy, show little evidence for lateral migration and are hence considered low risk from stormwater discharges from the project. Notwithstanding this, some residual risk exists for the estimated changes to flow regimes to result in the following impacts to waterway health and instream processes during construction:

- Reduced bank stability (scouring, undercutting, slumping, etc) immediately downstream of project discharge locations as a result of increased streamflow discharge and velocities
- Increased rates of removal and transport of eroded bed and bank material leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation
- Increased water turbidity due to suspended material and subsequent reduction in light infiltration potentially impacting sensitive aquatic vegetation
- Potential for fish passage obstruction due to increased flow velocities, reduced water levels or physical obstructions.

The project seeks to minimise or avoid these impacts by adopting appropriate erosion and sediment controls in accordance with the NSW Blue Book requirements (DECC, 2008a and 2008b), site-specific drainage design for construction areas and temporary and permanent erosion and scour protection and flow dissipation where required. Further, temporary waterway crossings have been designed to be in accordance with the Why do Fish need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003) NSW Fisheries guidelines in order to ensure conditions for fish passage are maintained (where required). Regular monitoring of key waterways for evidence of initiation of erosion and scour will be conducted for the duration of construction and, if required, appropriate remediation measures carried out (refer to **Appendix K** for further detail).

Impacts to waterway health and ecological processes in important wetlands are further discussed in the Biodiversity Assessment Report (Appendix I of the EIS) and the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

NSW river flow objectives - construction

Table 5-1 below summarises potential construction phase impacts to waterways in the surface water study area in consideration of the NSW river flow objectives relevant to the project. The project construction phase is expected to result in some changes to the timing, rate and volume of stormwater discharge however these changes are only expected to moderately alter the existing flow regime.

Table 5-1 River flow objectives relevant to project construction phase impacts

NSW river flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Maintain wetland and floodplain inundation	×	×	✓	✓	Construction of the project does not call for the damming of any waterway or extraction of surface water flows. Some changes to the depth and duration of floodplain inundation are expected however these changes are not anticipated to substantially impact the existing regime.
	Mimic natural drying in temporary waterways (and wetlands)	×	×	✓	×	Continuous or prolonged releases of water to ephemeral receiving waterways are not planned or required by the project. However, some localised, minor changes are expected to the timing, frequency and duration of low flow events. These are expected to result from both temporary and permanent alteration of existing drainage paths during construction, changes to the extent of catchment imperviousness and discharge of stormwater via temporary construction sediment basins and permanent water quality basins.
	Maintain natural rates of change in water levels	×	×	✓	×	Some localised changes are anticipated to rates of rise and fall in water levels due to expected increases to rate of and volume of stormwater discharged during the construction phase. Where required, bed and bank stability issues have been addressed through implementation of erosion and scour management measures such as rock transition aprons and energy dissipation as culvert outlets. Regular monitoring of key waterways for evidence of initiation of erosion and scour will be conducted and, if required, appropriate remediation measures will be carried out, refer further to **Chapter 8**.
	Protect pools in dry times	×	✓	×	×	No extraction of surface water from natural pools during the construction phase is proposed.
	Protect natural low flows	×	✓	×	×	No extraction of surface water from watercourses during the construction phase is proposed. Excavation dewatering during the construction phase is not considered to have a significant impact on surface water flows due to the small extraction volumes and short durations of dewatering at each location.

NSW river flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Maintain natural flow variability	×	✓	✓	✓	No damming of waterways, surface water extraction or prolonged discharge of water is proposed for the construction phase of the project. Discharge of stormwater from the project would largely be coincident with existing flows in receiving waterways and is not expected to negatively impact existing flow variability.
	Manage groundwater for ecosystems	✓	✓	×	✓	Localised extraction of groundwater inflow or seepage to cuttings and water exuded from wick drains during the construction of embankments in soft soils is required. In addition, changes to the hydraulic properties of soft soils during construction can result in both increases and decrease in groundwater water levels. However, the total predicted change of groundwater contribution to surface water features are not considered to be substantial, would be localised and would not materially impact on wetlands and waterways.
	Minimise effects of weirs and other structures	×	✓	✓	✓	The project construction does not call for the use of weirs or any other permanent waterway obstruction. Construction phase waterway crossings (including the viaduct access road) and minor realignments of Purgatory Creek and the unnamed tributary of Viney Creek may result in some minor temporary obstruction to flows however any impacts are likely to be small, temporary and reversible. The viaduct access road also includes a number of culverts to maintain flow.
	Maintain or rehabilitate estuarine processes and habitats	×	×	×	✓	The project does not call for the damming, obstruction or interference of any estuarine waterway and the existing tidal flow regime is expected to be maintained.

Risk assessment - construction

The potential changes to flow regime and subsequent waterway impacts identified above are considered to be minor and unlikely because:

- The project design does not call for the damming, blocking or extraction of water from waterways. Any impacts during the construction phase resulting from the construction of temporary access roads, water crossings and ancillary facilities would be localised, temporary and reversible
- The assumed opportunistic re-use of water captured in the temporary construction sediment basins (assumed to be no more than 25 per cent, as detailed in **Chapter 7**) for construction activities would only take place during the construction phase and is not considered to represent a substantial reduction in water availability to the receiving environment
- Discharges of stormwater from the project would largely be consistent with flows in receiving waterways and prolonged or permanent discharges of water are not proposed
- A substantial proportion of the project is location adjacent to an existing road corridor and other infrastructure corridors
- Watercourse catchments and existing flow regimes across the project study area are already heavily affected by urban, industrial, commercial and agricultural development as well as flood mitigation infrastructure
- No downstream flora or fauna communities sensitive to minor, localised alteration of the existing flow regime have been identified
- The accumulation of additional catchment inflows with distance downstream of any discharge point would progressively ameliorate any potential impacts
- Improvements to the quality of sediment-laden stormwater water discharged via construction sediment basins substantially outweigh any potential localised changes to receiving environment flows
- Project construction is not expected to have any impact on the Hunter River flow regime.

5.2.3 Impacts to groundwater flow and levels - construction

Impacts to groundwater flow have potential to occur where activities intersect the water table and require dewatering or alter the hydraulic characteristics of the sub-surface. Key activities with potential to alter groundwater flow include temporary construction dewatering, temporary sediment below the water table, and soft soil consolidation areas.

Temporary construction dewatering would be required where excavations occur below the water table. This is likely to include:

- Excavation of temporary and permanent water quality basins
- Excavations for bridge piers
- Excavations for the Purgatory Creek adjustment.

The adjustment of the tributary of Viney Creek, and shallow excavations for culverts and utilities, are generally expected to be above the water table, however there is potential that some may intercept groundwater. In the event that the water table is encountered, significant dewatering is not anticipated and impacts are expected to be minor.

A number of temporary sediment basins would be required to be constructed below the water table, in addition to dewatering during construction. This has potential to disrupt local groundwater flow.

Soft soil consolidation has potential to permanently affect groundwater levels and flow due to a reduction in the effective porosity and hydraulic conductivity of the sediment caused by consolidation. This has potential to result in water level mounding (rise in water level) on the upgradient margin of the consolidated area, and water level shadowing (lowering of water level) on the down-gradient margin of the consolidated area.

Basin dewatering - construction

Predicted groundwater level drawdown due to temporary construction dewatering is commensurate with the depth of excavation. Numerical groundwater modelling results (**Appendix A**) indicate a maximum localised drawdown magnitude of about 2.4 metres, and maximum distance from a basin to the 0.2 metre drawdown contour of about 500 metres. Modelled drawdown extents are considered to be very conservative as the model assumes that all basins are dewatered concurrently and for a period 30 days (the groundwater model applies a monthly stress period). However, in reality basin excavation and dewatering would be staggered and individual basin dewatering is expected to range from two to 10 days depending on the size of the basin.

At Tarro, drawdowns from temporary construction dewatering are predicted to encroach on an area of high potential GDE, with a drawdown of up to 0.75 metres, and Coastal Wetlands (Coastal Management SEPP), with drawdowns of up to 2.0 metres (refer to Figure 4.17c in **Appendix A**). It is noted, however, that the majority of the Coastal Wetlands (Coastal Management SEPP) predicted to be within the area of drawdown would be cleared by the construction activities and embankment formation, with the remaining drawdown anticipated to be short term (less than 10 days) in duration (as opposed to the 30 days simulated in the groundwater model). As a result, there would be no substantial interference drawdown between adjacent temporary sediment basins and no material impacts are anticipated from short-term drawdown associated with the temporary construction dewatering.

At Tomago, drawdown of up to 0.4 metres is predicted at groundwater work GW079591 (Figure 4.17e in **Appendix A**). At Heatherbrae, drawdown of the order of 0.6 to 0.8 metres is predicted at GW200102 and GW200103, with drawdown in the range 0.4 to 0.6 metres predicted at a number of clustered groundwater works (Figure 4.17f in **Appendix A**). GW079591 at Tomago has no recorded purpose or use, and all of the bores at Heatherbrae within the area of predicted drawdown are noted as monitoring bores and, as such, are unlikely to be impacted by the short-term drawdown.

Based on the relatively short period of dewatering and drawdown, and limited drawdown propagation, changes to groundwater flow are not anticipated to materially affect GDEs, including High Priority GDEs, baseflows, existing groundwater users or surrounding land due to settlement.

Pier dewatering - construction

Drawdowns associated with bridge pier foundations are minimal and not expected to exceed 1.8 metres. Anticipated drawdown distances are also small and would be limited to about 40 metres from any excavation. A relatively short dewatering period of about 10 to 20 days is anticipated for any given excavation.

Based on the small drawdowns and short dewatering period, changes to groundwater flow are not anticipated to materially affect GDEs, including high priority GDEs, baseflows, existing groundwater users or surrounding land due to settlement.

Purgatory Creek adjustment - construction

Numerical groundwater modelling results (refer to **Appendix A**) indicate a maximum drawdown magnitude of approximately 0.8 metres and maximum drawdown propagation (as indicated by the 0.2 metre drawdown contour) of about 100 metres. Modelled drawdown extents are considered conservative as the model assumes continuous dewatering for 30 days. However, dewatering is only anticipated to be required for up to 10 days.

Based on the small drawdowns and very short dewatering period, changes to groundwater flow are not anticipated to materially affect GDEs, including high priority GDEs, baseflows, existing groundwater users or surrounding land due to settlement.

Temporary sediment basins below the water table - construction

A total of thirty basins have been assessed as having groundwater levels above the basin invert. This means that following construction the basins would fill with groundwater to approximately the height of the surrounding groundwater level. Where basins are unlined the basins would represent a through-flow groundwater feature and are not expected to significantly interfere with groundwater flow. In cases where the temporary sediment basins are lined, there is potential for very minor and localised flow disruption around the basin. In the context of regional groundwater flow and in comparison to potential mounding at soft soil consolidation areas, potential flow disruption would be minor to negligible and would not impact on other groundwater users or GDEs.

Soft soil consolidation - construction

Numerical groundwater modelling results (Figure 4-18 and Figure 4-19 in **Appendix A**) indicate that groundwater levels are predicted to rise in response to soft soil consolidation while shadowing effects are negligible. Model results indicate groundwater levels would rise in the Tarro interchange area of soft sediment consolidation by up to about 0.3 metres, reducing to an increase of about 0.05 metres at the margin of the area located to the south mapped as High Priority GDE.

At Tarro, the mounding is not considered to be substantial. The magnitude of mounding of up to 0.3 metres is very localised, considered to be well within season fluctuations and is in an area where there is frequent surface expression of groundwater.

At the Old Punt Road intersection, near the Hunter Region Botanic Gardens, model results indicate a potential rise in groundwater levels of up to 0.2 metres is predicted over most of the upstream area of soft sediment consolidation, increasing up to 0.8 metres in the central area (Figure 4-19 in **Appendix A**). The mounding effect diminishes to about 0.05 metres within about 50 to 80 metres upgradient of the embankment. Predicted mounding in the range 0.2 to 0.8 metres occurs beneath an area mapped as high potential GDE.

The greater magnitude of mounding predicted at the Old Punt Road intersection compared to the Tarro interchange is attributed to the larger through-flow of groundwater from the Tomago Sandbeds. However, this level of mounding, at its highest point, remains at least two metres below ground surface and as such is not expected to result in noticeable surface effects.

Based on the relatively small groundwater level increases at depth below ground level, and the localised area of mounding, changes to groundwater level or flow are not anticipated to materially affect GDEs, including high priority GDEs, baseflows or existing groundwater users.

Assessment against NSW AIP - construction

During the construction phase, the level one minimal impact considerations of the AIP (DPI NOW, 2012) are met for groundwater level and pressure as summarised in **Table 5-2**.

Table 5-2 Assessment against AIP water level minimal impact considerations

Water source	Assessment
Newcastle Water Source • alluvial • less productive	Water table: 1) Meets level one consideration with respect to drawdown at High Priority GDEs and water supply works. Water pressure: 1) Meets level one consideration with respect to pressure head at water supply works.

Water source	Assessment
Sydney Basin–North Coast Groundwater Source • porous rock • less productive	Water table: 1) Meets level one consideration with respect to drawdown at High Priority GDEs and water supply works. Water pressure: 1) Meets level one consideration with respect to pressure head at water supply works.
Tomago Groundwater Source • coastal sands • highly productive	Water table: 1) Meets level one consideration with respect to drawdown at High Priority GDEs and water supply works. Water pressure: 1) Meets level one consideration with respect to pressure head at water supply works.

An assessment of the project construction against the AIP minimal impact considerations for water quality is provided in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

Assessment of the project operation against the AIP minimal impact considerations is covered in **Section 5.3.3**.

5.2.4 Impacts to regional hydrology - construction

Surface water hydrology - construction

The project does not result in the damming, blockage or extraction of water of any waterways in the study area during construction and hence no impacts to regional hydrology (Hunter River catchment) are predicted. Adjustment of smaller creeks and minor waterways in addition to upgraded and new highway transverse drainage is proposed. While these adjustments have the potential to affect local hydrologic conditions, the design of the channel adjustments and hydraulic structures is adequately sized to minimise impacts to drainage capacity and avoid diversion of flows. Refer to **Section 5.3.7** for operational case impacts, which are also relevant to construction phase.

Groundwater hydrology - construction

As outlined in **Section 5.2.3**, impacts to groundwater levels during the construction phase are negligible to minor and are localised to the area immediately next to the project.

During construction, the project is predicted to result in only minor and temporary drawdown and minor alteration of groundwater flows outside of the construction footprint and would not impact the Tomago Sandbeds Catchment Area drinking water supply or other downgradient water users.

Groundwater quality impacts are discussed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

5.2.5 Changes to environmental water availability and flows - construction

Surface water hydrology - construction

The project is not expected to materially impact environmental water availability. No damming or permanent blockage of major watercourses is proposed, and extraction of surface water is not required. The proposed minor adjustments of Purgatory Creek and the unnamed tributary of Viney Creek would only have a minor impact to environmental water availability as downstream contributions to streamflow would largely be maintained during construction.

A small proportion of water captured in construction sediment basins may be subject to opportunistic re-use for construction activities. As outlined in **Section 5.3.1**, rates, volumes and velocities of stormwater discharged by the project are expected to increase however this is not expected to adversely impact existing environmental water availability and flows.

Groundwater - construction

As outlined in **Section 5.2.3**, during construction changes to groundwater levels and flows due the project are negligible to minor and are localised to the area immediately next to the project. Potential changes are not anticipated to materially affect GDEs, including high priority GDEs, baseflows or existing bores.

Groundwater take during construction of the project is discussed in **Section 5.2.6**.

5.2.6 Water take - construction

Surface water - construction

Direct take of water from natural waterways for construction is not proposed. However, runoff from the construction footprint that accumulates in construction sediment basins may be used opportunistically for construction activities (subject to meeting water quality criteria as discussed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS)). An assessment of potential water use from construction sediment basins, and associated assumptions, is provided in **Chapter 7** and **Appendix I**.

Under a relatively conservative base case scenario (assuming up to 25 per cent of accumulated basin runoff is able to be used opportunistically) the notional surface water take over the duration of project construction is assessed to be approximately 10.45 megalitres or 3.5 megalitres per year. Given that the availability of water within the basins (for 5 days following a significant rainfall event) would generally coincide with reduced water demand for dust suppression and fill conditioning, the assumption of 25 per cent water use is considered to be very conservative.

Indirect surface water take due to groundwater drawdown and subsequent baseflow reduction at creeks is anticipated to be negligible. This is because construction dewatering periods are short (typically about 10 days), maximum drawdown heights are small and areal drawdown extents are small and generally not near creeks or rivers.

Groundwater - construction

Groundwater take is anticipated during the construction phase due to temporary construction dewatering for basins, piers and the Purgatory Creek adjustment, and via wick drains in soft soil consolidation areas. Shallow excavations, such as for culverts and utilities, are not anticipated to require any substantial dewatering. The dewatering period for individual excavations is anticipated to be in the order of 10 to 20 days. The take associated with soft soil consolidation is anticipated to occur over a maximum period of about nine months.

A summary of estimated groundwater take is provided in **Table 5-3**, with total groundwater take over 25 months for groundwater sources estimated as follows:

- Newcastle Water Source – 68.6 megalitres
- Sydney Basin-North Coast Groundwater Source – 5.6 megalitres
- Tomago Groundwater Source – 92.7 megalitres.

It is noted that Transport, as a Roads Authority, is exempt from the requirement to hold a Water Access License under Part 1, Schedule 4 of the Water Management (General) Regulation 2018.

Table 5-3 Estimated groundwater take during construction phase

Water source and WSP	Element	Estimated take (ML)	Source and calculation
Newcastle Water Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government, 2009)	Temporary construction dewatering for basins	5.86	• Temporary construction dewatering period of 10 days per basin • Groundwater model daily dewatering rate for 8 basins in this groundwater source was 0.586 ML/d • 10 days x 0.586 ML/d = 5.86 ML
	Temporary construction dewatering for piers	31.52	• 10 to 20 days dewatering per excavation • Refer water balance (**Chapter 7**) for further details
	Temporary construction dewatering for Purgatory Creek adjustment	0.71	• Temporary construction dewatering period of 10 days • Groundwater model daily dewatering rate of 0.071 ML/d • 10 days x 0.071 ML/d = 5.860 ML
	Soft soil consolidation	30.50	• Refer water balance (**Chapter 7**)
	All	Total = 68.59	• All elements summed
Sydney Basin–North Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government, 2016a)	Temporary construction dewatering for basins	1.02	• Temporary construction dewatering period of 10 days • Groundwater model daily dewatering rate for 4 basins in this groundwater source was 0.102 ML/d • 10 days x 0.102 ML/d = 1.02 ML
	Temporary construction dewatering for piers	4.54	• 10 days dewatering per excavation • Refer water balance (**Chapter 7**) for further details
	Soft soil consolidation	N/A	• N/A
	All	Total = 5.56	• All elements summed

Water source and WSP	Element	Estimated take (ML)	Source and calculation
Tomago Groundwater Source of the Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government, 2016b)	Temporary construction dewatering for basins	76.44	• Temporary construction dewatering period of 10 days • Groundwater model daily dewatering rate for 23 basins in this groundwater source was 7.644 ML/d • 10 days x 7.644 ML/d = 76.44 ML
	Temporary construction dewatering for piers	1.92	• 10 days dewatering per excavation • Refer water balance (**Chapter 7**) for further details
	Soft soil consolidation	14.37	• Refer water balance (**Chapter 7**)
	All	Total = 92.73	
TOTAL		**166.88**	**Total estimated water take**

Water supply bores

While the current proposed construction water supplies are reliant on imported water supplemented with the opportunistic use of surface water captured in temporary sediment basins and groundwater extracted for temporary construction dewatering (**Section 7.2**), there remains the potential that groundwater bores may also be used for construction water supplies where site conditions and water demands are agreeable. The assessment of potential impacts associated with the use of water supply bores are not addressed in this assessment.

Water supply potential for the project within the Hunter Alluvium and Tomago Coal Measures is considered to be relatively limited with relatively low yields and / or poor water quality expected. Although moderate potential may exist in the Tomago Coal Measures away from the floodplain or in the Hunter Alluvium adjacent to the Tomago Sandbeds. Suitable permeability that may be indicative of moderate water supply potential was encountered at monitoring bore D-PZ-223B, screened from eight to 13 meters below ground in the Tomago Coal Measures (**Appendix A**). However, D-PZ-223B is located on the floodplain and the groundwater salinity is elevated, with a median salinity of 17,946 µS/cm, making the water un-usable for most construction activities. More prospective supplies of good quality water would be achievable from the Tomago Sandbeds, or from Hunter Alluvium immediately adjacent to the sandbeds. Any prospective water bore locations would require further consideration at the detailed design stage. Appropriate groundwater work and groundwater use approvals (where required) would need to be sought at that time with due consideration for existing water uses including the Hunter Water Corporation borefield.

It is noted that under Schedule 4, Part 1 of the Water (General) Regulation 2018, Transport, as a roads authority, are exempt from the requirement to hold an access licence in relation to water required for road construction and road maintenance. The exemption also extends to the requirement to hold a water use approval. Transport would, however, need to acquire the appropriate water supply works approval under the Water Management (General) Regulation 2018 for the construction and operation of any water supply bores in the event that water supply bores are utilised. Transport would also need to satisfy the Minister (WaterNSW) that that the potential impacts associated with any water abstraction are considered acceptable under the AIP.

5.2.7 Flooding - construction

An overview of the overall construction phase activities and features is provided in **Section 5.2.1**. The construction phase of the project was represented and analysed in the TUFLOW model to estimate the flooding impacts. A worst-case “snapshot” of the construction phase was modelled, with key assumptions including:

- All work for the operational phase (i.e. embankments in place, bridge piers constructed, culverts operational) are close to completion and all construction works are on the ground. The operational phase road design is to provide a 5% AEP flood immunity from Hunter River mainstream flooding, and the road embankments during construction have been elevated accordingly in combination with transverse drainage with adequate capacity
- Temporary and permanent access roads, which are generally raised by 0.5 to one metre, and up to 2.5 metres above natural ground level, are in place
- Temporary wharves at the viaduct construction site are in place
- Temporary stockpiles are not represented
- Crane pads are not represented
- Low lying areas within ancillary facilities are filled up to provide 20% AEP flood immunity, typically raised by 0.5 to one metre, and up to 2.5 metres, above natural ground level
- Culverts through the road formation and provision of flow paths through ancillary facilities, have been included to address adverse flood impacts. The presence of these features was assumed at locations where required to provide adequate drainage and conveyance of floodwaters.

Refer to Figure B-2 in **Appendix B** for the construction phase TUFLOW model configuration.

The 20%, 10% and 5% AEP events were assessed and the impacts to flooding mapped in **Appendix D**. Potential impacts may result due to construction and permanent works obstructing flood flows, change in drainage capacity for local catchments and loss of floodplain storage. All construction infrastructure is temporary and the assessment should be read in context of the likelihood of a flood of a given AEP occurring during construction. In addition, given the short duration of construction relative to the life of the project during operation, these impacts should be considered in context of the predicted operation impacts detailed in **Section 5.3.8**. The chance of occurrence of a given AEP flood event during construction (i.e. five years) is substantially lower than during operation (i.e. 100 years) of the project. The chance of occurrence of a 1% AEP flood event during construction and operation of the project are around 4.9 per cent and 63.4 per cent respectively, while the chance of occurrence of a 20% AEP flood event during construction and operation are approximately 67.2 per cent and 100 per cent respectively. Based on these probabilities, it was considered appropriate to limit assessment to up to the 5% AEP event for the construction phase.

In terms of overall effects of the project construction on flood behaviour, a review of the impacts indicates that the raised construction access roads around the viaduct obstructs floodplain flows and causes increases in flood levels upstream of the access roads, which result in increased flows into Hexham Swamp particularly in the 10% AEP event and larger. The viaduct piers, wharf structures and permanent road embankments also contribute to the flooding impacts. The increased flood levels translate into corresponding increases in flood hazard and durations of inundation.

The impacts during the construction phase are discussed below.

Changes to design flood levels - construction

Afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario. Figures D-1 to D-3 in **Appendix D** show the change in flood levels (or afflux) for the 20%, 10% and 5% AEP events respectively, for the construction phase. In the 20% AEP event, flood levels increase by up to

0.03 metres on the western bank of the Hunter River around Tarro, in the Hunter River itself upstream of the project and extending up past the Williams River junction, and in Windeyers Creek in Raymond Terrace. Flood levels on the eastern bank of the river between the new viaduct crossing and Raymond Terrace increase by about 0.05 metres. Flood levels in local catchments on the eastern (upstream) side of the project and between the new viaduct and Heatherbrae decrease by over 0.4 metres as a result of increased transverse drainage capacity. Reductions in flood levels are also expected in localised areas around Masonite Road. There are localised increases in flood levels around a number of ancillary facilities along the project, with increase of over 0.4 metres near Tarro interchange and Masonite Road.

In the 10% AEP event, flood levels increase by up to 0.08 metres on the western bank of the Hunter River around Tarro and Purgatory Creek, which are attributed to the access roads in this area. These increases result in flood level increases in Hexham Swamp of 0.01 to 0.02 metres as additional flows appear to overtop the railway and New England Highway and into Hexham Swamp. This also results in reductions in flood levels of up to 0.05 metres downstream of the viaduct. Flood level increases of 0.03 to 0.04 metres extend along the western floodplain of the Hunter River up to the Williams River junction and Millers Forest, and these increases also occur up Windeyers Creek and Grahamstown Drain. Flood levels in local catchments on the eastern (upstream) side of the project and between the viaduct and Heatherbrae decrease by up to 0.8 metres as a result of increased transverse drainage capacity. There are localised increases in flood levels around a number of ancillary facilities along the project, with increase of over 0.4 metres near the western and eastern ends of the viaduct and at Masonite Road, and increases of up to 0.8 metres at Tarro interchange and 1.8 metres in wetland areas at Tarro interchange.

The areas affected by 0.05 to 0.1 metre flood level increases in the 5% AEP event are similar to those affected by the 10% AEP event, with a larger area of impact including part of the eastern Hunter Riverbank. There are increases of 0.08 metres affecting rural residential properties in Tarro, close to the western viaduct approach embankment. This incremental increase exceeds the adopted flood management criteria. Flood level increases in Hexham Swamp are also higher, with increases around 0.06 metres. Flood levels in local catchments on the eastern (upstream) side of the project and between the viaduct and Heatherbrae experience increases of 0.02 metres, instead of reductions as in the 10% AEP event. Flood level increases in Windeyers Creek are also slightly higher, at 0.03 metres, than the 10% AEP event (0.02 to 0.03 metres). There are localised increases in flood levels around a number of ancillary facilities along the project, with an increase of over 0.4 metres near the western and eastern ends of the viaduct and at Masonite Road, and increases of 0.6 metres at Tarro interchange and up to 1.4 metres in wetland areas near Tarro interchange. Flood levels in the Hunter River downstream of the project are reduced by 0.01 to 0.1 metres.

Temporary creek crossings would be required at some of the creeks including Purgatory Creek and Windeyers Creek to enable bridge construction. Potential flood impacts would be managed with installation of temporary transverse drainage.

Impacts of afflux on properties and buildings during construction are further discussed later in this section.

Changes to design flow velocities - construction

Figures D-4 to D-6 in **Appendix D** show the change in flow velocities for the 20%, 10% and 5% AEP events, respectively, for the construction phase. Broadly, there are no large areas with substantial changes in velocities across the floodplain, with the majority of changes localised around the construction footprint.

In the 20% AEP event, changes in velocities are generally expected to be localised to areas around transverse drainage and downstream drainage channels, and where filled formations associated with the project may partially impede existing flow patterns. Flow velocity increases are expected downstream and upstream of the project construction boundary with increases of 0.3 to 0.5 metres per second being typical, with isolated increases over one metre per second. The increases are accompanied by reductions in flow velocities with typical decreases of 0.1 to 0.3 metres per second. The changes in velocities in the 20% AEP event are particularly evident on the eastern bank of the Hunter River, upstream of the viaduct crossing location. Changes are also present around the proposed temporary wharves around the new viaduct

construction site, with increases and decreases in velocities of 0.2 metres per second. There are numerous locations within the construction boundary where velocity increases are over one metre per second due to flows interacting with the ancillary facilities.

In the 10% and 5% AEP events the changes in velocities on the Hunter River eastern bank upstream of the viaduct crossing are smaller than in the 20% AEP event, as the depth of flooding on the bank areas drowns out the impacts on the flow velocities. Changes in velocities are more accentuated, with increases and decreases of up to 0.3 metres per second in the 10% AEP and up to 0.5 metres per second in the 5% AEP event around the bridge construction site due to increased interaction of flood flows with access roads, temporary wharves and other features. There is also increased interaction with the New England Highway and ancillary facilities around the western end of the viaduct crossing with increased velocities of 1.5 metres per second. In the 5% AEP event, there are increase velocities of up to two metres per second over the Main North Rail Line embankment due to increased overtopping depths of 0.1 metres. Note that due to the relatively coarse resolution (20 metre grid) of the TUFLOW model in comparison to small scale features of the project influencing flow velocities, the changes in flow velocities around these localised features are considered indicative only.

Changes to design flood hazard - construction

Figures D-7 to D-9 of **Appendix D** show the change in flood hazard for the 20%, 10% and 5% AEP events, respectively, for the construction phase. For the purposes of the assessment, H1 and H2 flood hazard are referred to a “low” hazard and H3 to H6 referred to as “high” hazard. Refer to **Section 2.3.12** for discussion. The changes in hazard are expressed in terms of changes between dry, low hazard and high hazard condition, or no change.

There would be typically localised increases only in flood hazard on the floodplain on either side of the Hunter River upstream of the project crossing, particularly in the 20% and 10% AEP events, corresponding to the increases in flood levels for those events. There are no large increases in extent of the high hazard areas, which would indicate a new floodway or flow path being formed as a result of the construction phase. There are some larger areas of increased flood hazard in the 5% AEP in Hexham Swamp, corresponding to increases in flood levels, although these are also relatively localised.

There are reductions in flood hazard in local catchments on the eastern side of the project and between the new viaduct and Heatherbrae corresponding with decreases in flood levels in these areas.

Overall, the change in flood hazard for the construction phase is localised and as such does not have adverse impact on flood conveyance, floodways, flow direction and flood storage.

Changes to design flood duration of inundation - construction

Figures D-10 to D-12 in **Appendix D** show the per cent change in the duration of inundation for depths over 0.5 metres for the 20%, 10% and 5% AEP events, respectively, for the construction phase. In the 20% AEP event the change in duration of inundation is typically within +/- five per cent from the existing case (up to 0.5 hour increase) in locations including in the Hunter River and Hexham Swamp, with the exception of increases in the duration of inundation on the western bank of the Hunter River (in Purgatory Creek) and the eastern bank of the Hunter River upstream of the viaduct crossing of typically 10 to 20 per cent, with increases over 100 per cent on the fringes of the flooding extents (up to 10 hour increase). On the eastern bank of the Hunter River the increase in duration of inundation is attributed to the increase in flood levels of 0.05 metres over relatively shallow flood depths of 0.5 metres, due to increased transverse drainage capacity, required to achieve 1% AEP flood immunity of the project from local catchment flooding, discharging greater flow volumes into these areas. In Purgatory Creek the increase in duration of inundation is attributed to interaction of flooding with proposed access roads and reduced drainage capacity posed by proposed culverts under the access roads, and potential reduction in floodplain storage due to the ancillary facilities.

In the 10% and 5% AEP events the change in duration in inundation is relatively uniform in distribution and typically within +/- five per cent of existing conditions, with the exception of localised increases in durations of 10 to 20 per cent (six to 15 hour increases) along the fringes of the flooding extent and along embankment areas, generally upstream of the viaduct crossing and in Hexham Swamp where increases in flood levels are expected. Downstream of the bridge crossing there are decreases in durations of 10 to 20 per cent (up to 0.5 hour decrease) where reductions in flood levels are expected.

Impacts to roads - construction

Main roads and other named roads were assessed for the total length of road affected by H2 flood hazard and higher during construction. The per cent change in total length when compared to the existing case is presented in **Table 5-4** for highways and major roads, and **Table 5-5** for other named roads. The results in the tables reflect the change in trafficability of the roads from the existing case. H2 flood hazard and above indicates that the road is not trafficable due to flooding conditions.

Table 5-4 Change in length (per cent) of highways and major roads subject to H2 flood hazard, comparison of construction phase to existing case

Road	20% AEP	10% AEP	5% AEP
Blue Gum Road	0	0	0
Cabbage Tree Road	0	0	0
Cormorant Road	0	0	0
Hannell Street	0	0	0
Hunter Street	6	0	0
Industrial Drive	-	-	-
King Street	-	-	0
Lenaghans Drive	0	0	0
Maitland Road	-10	4	-12
Nelson Bay Road	-	-	-
New England Highway	0	23*	6
Newcastle Road	0	0	0
Pacific Highway	91**	-6	-19
Raymond Terrace Road	2	2	0
Sandgate Road	0	0	0
Seaham Road	1	0	0
Teal Street	-	-	-
Thomas Street	0	0	0
Tillie Street	-	-	-
Tomago Road	0	0	0
Tourle Street	0	0	0
Wilkinson Avenue	0	0	0
William Bailey Street	-	-	0

Note: "-" indicates that road is not affected by H2 flood hazard in existing and construction phase.
* Increase on the New England Highway is a minor extension of H2 flooding affecting a minor road on ramp and not the main alignment
** An increase of 91 per cent from existing inundated length is experienced on the Pacific Highway in the 20% AEP event, where the total length affected increases from 51 metres to 97 metres.

Table 5-5 Change in length (per cent) of named roads subject to H2 flood hazard and higher in existing case, comparison of construction phase to existing case

Named roads	% change in total length affected by H2 and higher
20% AEP	0.0
10% AEP	0.0
5% AEP	0.0

For highways and major roads, there is typically minor (less than five per cent) increase, nil increase or a decrease in the total length of each major road affected by H2 flood hazard or higher. The increases in inundated length occur and existing locations which are inundated. An increase of 91 per cent from existing inundated length is experienced on the Pacific Highway in the 20% AEP event, where the total length affected increases from 51 metres to 97 metres. A new 46 metre section of the Pacific Highway within the construction footprint is affected by H2 flood hazard at Tomago Road intersection, but not Tomago Road itself, due to a change in the modelled road levels. This is considered a minor increase. Opportunities to adjust the design to minimise the flood impact to this localised section will be investigated at detailed design, although generally the design aims to match existing levels for local roads. On the New England Highway there is a 23 per cent increase in the length of road affected, due to a new four metre section being affected by H2 flood hazard. This affects the start of a minor entry ramp lane and not the main alignment. Overall trafficability is not substantially affected in this location.

For the other named roads, it is observed that the change in total road length affected by H2 flood hazard is less than 0.01 per cent. Hence, there is negligible impact of the construction phase to flooding of minor roads.

Impacts to railway infrastructure - construction

Railways and railway facilities were assessed for the total length of rail overtopped by floodwater during construction. The per cent change in total length when compared to the existing case is presented in **Table 5-6**.

Table 5-6 Change in length (per cent) of railways overtopped by floodwater, comparison of construction phase to existing case

Railway	20% AEP	10% AEP	5% AEP
Main North Rail Line	0.0	0.0	0.1
Other rail lines	0.0	0.0	0.0
Aurizon facility	0.0	0.0	0.0

There is a negligible impact of the construction phase on railways, with a maximum 0.1 per cent increase in affected length on the Main North Rail Line. As discussed in **Section 5.3.8** there is a 0.1 metre increase in the 5% AEP depth of overtopping of the Main North Rail Line at Mid Site Channel, but this is expected to translate to a negligible reduction of the existing case flood immunity of 10% AEP.

The Aurizon access road would be affected by nil change in flood level in the 20% AEP event, up to 0.09 metres increase in flood level in the 10% AEP event but with no change to localised overtopping of the road, and up to 0.07 metres increase in flood level in the 5% AEP event, where the whole road is overtopped in the existing case.

Impacts to major land uses - construction

The flood impacts to major land uses are discussed in this section for the 20%, 10% and 5% AEP events for the construction phase. Increases in flood hazard occur where there are increases in flood depths and levels, while decreases in flood hazard occur where there are reductions in flood depths and levels. The results are tabulated in the following tables in **Appendix B** and it is noted that the analysis was based on lots from cadastral information as properties may consist of a number of lots:

- Table B-12 to Table B-14: Number of residential, commercial and industrial lots, respectively affected by change in peak flood depth
- Table B-15 to Table B-17: Number of residential, commercial and industrial lots, respectively affected by change in peak flood hazard
- Table B-18: Area (hectares) on main rural land uses affected by different changes in peak flood hazard. The main rural land uses identified for the study area include grazing, forestry and wetlands and national park areas
- Table B-19 to Table B-21: Number of residential, commercial and industrial lots, respectively affected by change in peak duration of inundation
- Table B-22: Change in area (hectares) on main rural land uses affected by different changes in peak flood duration of inundation.

The following observations are made:

- The large majority of flood-affected residential, commercial and industrial lots in the existing case experience negligible change in flood depth (+/- 0.01 metres change), hazard and time of inundation (+/- three hours) during operation
- In the 5% AEP event, up to 1.5 per cent of residential lots, 4.7 per cent of commercial lots and 6.9 per cent of industrial lots are affected by an increase in flood depths of over 0.01 metres[2]
- In the 5% AEP event, up to 0.6 per cent of residential lots and 0.8 per cent of industrial lots are affected by an increase in flood depths of over 0.05 metres[2]. This includes a number of lots which are indicated to experience increases in maximum depths over 0.2 metres
- No commercial/industrial buildings were identified to be affected by an increase in flood depth of 0.05 metres or greater in up to and including the 5% AEP event
- The change in flood hazard and change in duration of inundation effects are similar to the change in flood depth effects for the residential, commercial and industrial lots, with the large majority of lots experiencing no change. There are some lots with an indicated increase in the flood hazard rating and increase in duration of inundation
- The flood hazard on the main rural land uses including grazing, forestry and wetlands/national park areas does not change from existing for the large majority of these land use areas. For grazing lands, there would be an increase in flood hazard on 0.6 to 0.8 per cent of the land in all flood events assessed, while there would also be a decrease in flood hazard on 0.5 to 0.8 per cent of the land in all flood events assessed
- Some areas of forestry lands would experience an increase in flood hazard on up to four per cent of the total area and other areas would experience a decrease in flood hazard on up to four per cent of the total area. Some portions of wetland and national park areas (up to 0.2 per cent of the total area) would experience an increase in flood hazard, while there would be decreases in flood hazard in other portions of the wetland and national park areas (also up to 0.2 per cent of the total area).

The tables indicate that some properties may be subject to high (>24 hours) increases in the peak duration of inundation on the property. These are generally localised effects, while the majority of the property would

[2] Compared to 15,841 residential lots, 1,533 commercial lots and 1,315 industrial lots in the flooding study area.

be subject to minimal increases in duration of inundation. The flood mapping in Figure D-10 to D-12 in **Appendix D** indicate that, broadly, there is minimal change in the duration of inundation on the overall floodplain. Higher increases would occur mainly on the fringes of flooding where shallow areas of flooding with short inundation times (depths of less than 0.5 metres and inundation times of up to one day) are sensitive to increases in flood levels and durations of inundation.

The results indicate that some properties may be subject to high increases in flood depth (greater than 0.1 metre increase), hazard and duration of inundation (greater than 3 hour increase), in addition to change in flood extent. These estimates of localised impacts are due to small scale drainage features in comparison to the relatively coarse (20 metres) flood model resolution. However, as noted in the discussion below on property and building impacts from afflux, no commercial/industrial buildings and five residential dwellings are identified as being affected by afflux exceeding the 0.05 metre flood criteria.

Refinement to the construction phase design will be considered for detailed design changes and any associated flood modelling. This would include refinement to temporary access roads to reduce flood afflux where reasonable and feasible. Transport will consult with landowners about reasonable and feasible management measures to be implemented in relation to impacts to individual properties from the project including those identified in this assessment, refer further to **Chapter 8**.

Properties and buildings impacted by afflux – construction

Properties and buildings affected by afflux exceeding the adopted criteria in **Section 3.6.3** were identified from the change in flood level (i.e. afflux) mapping for construction, presented in **Appendix D**. The analysis is based on lots from cadastral information as properties may consist of a number of lots. Exceedance of the afflux criteria outside the construction boundary and across all flood events assessed has been considered, and all land use zoning property types are included. The impacted lots are listed in Table B-23 in **Appendix B**. The large majority of residential, commercial and industrial properties would experience no change in duration of inundation and flood hazard. There are 19 lots identified as experiencing afflux exceeding the adopted criteria.

Impacted buildings are identified based on afflux at the building exceeding 50 millimetres in any of the flood events assessed during construction. The 50 millimetre threshold relates to buildings with above habitable floor flooding (100 millimetre threshold for no above habitable floor flooding), however, in the absence of floor level data the more conservative criterion has been adopted for the buildings count. The impacted buildings are listed in Table B-24 in **Appendix B**. There are five buildings identified as experiencing afflux exceeding the adopted criteria. Only buildings identified with habitable floors are included.

Impacts to sensitive receivers - construction

Agricultural and grazing activities - construction

Agricultural and grazing activities, including movement and evacuation of stock during flood events, are expected to be impacted by increases in flood levels during the construction phase. Specifically, up to 0.1 metres in the 5% AEP event on the Hunter River floodplain and in the coastal wetlands in Hexham are expected, with lower impacts in the 20% and 10% AEP events. In the 5% AEP event, the increased flood levels translate to a typical increase in the width of the flood extent by 10 to 20 metres in localised areas. The increased extent of inundation may increase the risk of damage and die-off of pastures on a small section of the floodplain. As shown in **Appendix D**, the area affected by greater than 50 per cent increase in inundation duration in the 5% AEP flood is less than one per cent of the overall floodplain

Minor changes in the duration of inundation (typically up to one hour increase) for flood depths over 0.5 metres are expected, with flood mapping indicating up to +/- five per cent change in the duration during construction. Increased flood levels are expected to have a minor impact on warning time for stock to be moved before a flood event, as the rate of floodwater rise is not expected to change substantially due to the limited increase in flood level (a maximum of 0.1 metres). The negligible change in duration of inundation for flood depths over 0.5 metres means that the duration of isolation of stock flood refuges would not be

substantially impacted. It is expected that the time to drain the floodplains for water depths under 0.5 metres will be similar to existing (maximum five per cent increase).

Emergency service facilities and evacuation routes - construction

The highways and major roads are expected to form the main emergency access and flood evacuation routes within the study area. As indicated in the discussion on impacts to roads above in this section, there are typically minor (less than five per cent) increases, nil increase or a decrease in the total length of each major road affected by H2 flood hazard or higher during the construction phase. The increases in inundated length occur at existing locations which are inundated in the existing case. A new 46 metre section of the Pacific Highway at Tomago Road intersection would become cut-off in the 20% AEP event.

On minor roads, there is negligible change in the flood-affectation of these roads during construction.

The minor change in the length of roads affected by H2 flood hazard, combined with broadly minor change in duration of inundation indicates that there would be negligible impact of flooding on emergency access and evacuation routes in up to the 5% AEP event during the construction phase.

Physical works during the construction phase including changed traffic conditions and roadworks could reduce the traffic capacity of existing evacuation routes including sections of the existing M1 Pacific Motorway, Pacific Highway, New England Highway and other main roads connecting to the project. Management of these impacts to evacuation route capacity during the construction phase is recommended for the detailed construction planning phase.

Identified emergency service facilities in the study area and potential flood impacts during construction phase are described in **Table 5-7**. Nil or negligible flood impact during construction is expected.

Table 5-7 Existing emergency service centres and construction flood impacts

Description	Potential construction flood impact
Raymond Terrace Police Station	On the fringe of the PMF extent and outside the 5% AEP extent. Direct flood impact to the police station due to the project is not expected in events up to 5% AEP
Morpeth Police Station	Located outside study area and within floodplain. Potentially impacted by a flood level increase of less than 0.01m in the 5% AEP event during construction phase
Shortland Wastewater Treatment Works	Partly within PMF but not directly impacted by flood level increases from the project, which includes flood level increases of 0.08m in the 5% AEP event as it is above the 5% AEP flood
Raymond Terrace Wastewater Treatment Works	Fully within PMF extent and partly within 1% AEP extent. Indirectly affected by increases of 0.02m in the 5% AEP event
Morpeth Wastewater Treatment Works	Located outside study area and within floodplain. Potentially impacted by flood level increase of less than 0.01m in the 5% AEP event during construction phase

Hunter Valley Flood Mitigation Scheme - construction

A number of ancillary facilities in addition to temporary wharves and access roads would be situated immediately adjacent to or on the levees, channels and drainage infrastructure which are part of the Hunter Valley Flood Mitigation Scheme. Access roads for the project would be constructed immediately next to Hunter Valley Flood Mitigation infrastructure, namely existing flood levees on the western Hunter River Floodplain. While these access roads may modify the structure and maintenance of the levees, they are not expected to result in changes to flows or capacity, and as such are not expected to impact operation, function or structural integrity of the scheme (including the floodgates). Transport will continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

A section of Purgatory Creek would be adjusted as a part of construction to accommodate the construction of the western approach to the viaduct over the Hunter River and floodplain. The adjustment would be permanent and flooding impacts are assessed in **Section 5.3.8**.

5.2.8 Summary of construction impacts

Summary of surface water construction impacts

The project would have the following impacts to surface water hydrology during construction:

- Increased runoff associated with vegetation clearance, soil compaction, paving of the new road corridor and construction of the temporary ancillary facilities, access roads and tracks
- Temporary and permanent alteration or impedance of existing drainage paths and waterways resulting from:
  - The construction of the viaduct, (i.e. temporary waterway structures and wharves and the permanent piers themselves)
  - Adjustment of Purgatory Creek and the unnamed tributary of Viney Creek as well as temporary and permanent culverts
  - Minor increase (less than 20 per cent increase) in the rate of stormwater at discharge from the project at the unnamed tributary of Viney Creek, the unnamed tributary of coastal wetland, the Hunter River Drain and the tributary to the Hunter River Drain
  - Moderate increase (more than 20 per cent increase) in the rate of stormwater at discharge from the project at Purgatory Creek, the drainage line through coastal wetland to the Hunter River, diffuse drainage lines that feed into the Tomago Sandbeds Catchment Area and Windeyers Creek
  - Siting and design of the ancillary facilities would seek to maintain existing drainage lines where feasible and reasonable however some redirection may be necessary.
- Changes to stormwater discharge is likely to result in the following additional changes to existing receiving environment flow regimes:
  - A minor reduction in baseflow and moderate increase to quickflow contributions
  - Minor increases to rates of water level rise and fall
  - Minor changes to the number, duration and magnitude of low flow events.
- Changes to existing flow regimes identified above may have the potential to result in the following impacts to local receiving waterway processes and health:
  - Reduced bank stability (scouring, undercutting, slumping, etc.) immediately downstream of project discharge locations
  - Possible increases to the rate of removal and transport of eroded bed and bank material during storm events
  - Risk of increased water turbidity during and after storm events due to discharge of suspended material
  - Minor increases to the duration and depth of inundation for overbank events.

Summary of groundwater construction impacts

The project is likely to intersect the groundwater table in some locations during the following construction activities:

- Excavation of temporary sediment basins and permanent water quality basins
- Excavations for bridge piers
- Excavations for the Purgatory Creek adjustment.

Temporary dewatering of basins and piers would be required during construction as some temporary sediment basins would have an invert lower than the surrounding groundwater level and they would infill. Groundwater modelling has shown that the predicted groundwater level drawdown would be proportionate with the depth of excavation and ranges between 0.4 metres to 2.4 metres. The drawdown would be localised but would impact on some sensitive receiving environments, including high potential GDE and areas of Coastal Wetlands, however, impacts at basins and the diversion of Purgatory Creek would typically be less than 10 days, and between 10 and 20 days at the bridge piers.

Groundwater produced during project construction, through temporary construction dewatering or via wick drains, would be re-used where possible for dust suppression and fill conditioning as a measure of sustainable use of the groundwater resource. This approach would minimise, as far as practical, the need for the project to import water for construction activities. A total groundwater take of 164.9 ML across the three water sources and WSPs is anticipated.

The project would also likely result in soft soil consolidation in some areas that would potentially impact on groundwater levels and flow. This may result in water level mounding (rise in water level) on the upgradient margin of the consolidated area, and water level shadowing (lowering of water level) on the down-gradient margin of the consolidated area.

Although the project would have some localised drawdown and mounding impacts it is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including groundwater dependent ecosystems and other groundwater users. No impacts are expected to the nearby Tomago Sandbeds Catchment Area drinking water supply.

Summary of flooding construction impacts

Flooding impacts during construction include flood level increases of generally 0.02 to 0.1 metres in the 5% AEP event. There are 19 lots and five habitable buildings identified as experiencing afflux exceeding the adopted criteria. Flood level increases of up to 0.02 metres reach Raymond Terrace and beyond the current flood model extent.

A new 46 metre section of the Pacific Highway within the construction footprint is affected by H2 flood hazard at Tomago Road intersection, but not Tomago Road itself, due to a change in the modelled road levels. Opportunities to adjust the design to minimise the flood impact to this localised section will be investigated at detailed design, although generally the design aims to match existing levels for local roads.

Access roads for the project would be constructed immediately next to Hunter Valley Flood Mitigation infrastructure, namely existing flood levees on the western Hunter River Floodplain. While these roads may modify the structure and maintenance of the levees, they are not expected to impact operation, function or structural integrity of the scheme (this includes the floodgates). Transport will continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

5.3 Operational impacts

5.3.1 Surface water hydrology impacts - operation

Potential impacts to surface water hydrology - operation

Key activities during project operation that may impact the nature (volume, rate, timing, duration, velocity, etc.) of stormwater discharges that may impact on surface water hydrology include:

- Road paving and soil compaction leading to reduced or effectively eliminated rates of infiltration
- Alteration or restriction of existing drainage paths and catchments

- Attenuated or delayed discharge of stormwater captured in water quality basins which have been designed to meet the design criteria shown in **Table 5-8** below. Note that where construction phase sediment basins are proposed to transition to operational phase water quality basins the larger of the construction or operational basin would be built and retained.

Table 5-8 Pollutant reduction criteria for operational water quality basins (EPA, 1997)

Pollutant	Minimum reduction of the annual average loads
Total suspended solids (TSS)	80%
Total phosphorus (TP)	45%
Total nitrogen (TN)	45%

Note: These criteria are not the criteria by which the project is assessed, rather the criteria that have driven the basin design. Assessment criteria are discussed in Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS)

Potential changes to the rates and volume of stormwater discharged from the project (refer to **Figure 5-2** for discharge locations) during the operational phase were assessed using DRAINS hydraulic modelling of existing and operational phase drainage conditions. Design flow rates for the assessment were determined using the RAFTS Storage Routing Loss hydrological model. Discharges to the receiving environment were quantified at the downstream model boundary (immediately downstream of project stormwater discharges to receiving waterways and drainage lines) to assess impacts to downstream drainage systems and natural areas. Where permanent water quality basins form part of the drainage flow path, the basins were conservatively modelled as drainage nodes with no storage capacity being considered in the modelling. **Appendix J** provides a detailed summary of the DRAINS stormwater discharge modelling including details of changes to catchment areas and impervious percentage. **Table 5-9** provides a summary of the results and estimated changes to rates, volumes and velocity of stormwater discharges included in **Appendix J**, which are summarised as follows:

- Total catchment areas are not proposed to substantially change in area with a maximum increase of 3.2% for catchment draining to culvert N3500C and a maximum reduction of -2.1% for the catchment draining to culvert N1160B (refer to **Appendix J** for detailed results and **Figure 5-2** for discharge locations)
- The relative change in percentage of impervious area within each catchment ranges from 0 to 577.5 per cent as a result of the road development although the relative change for the majority (14 from a total of 16) of catchments is 55.1 per cent or lower
- The results indicate that discharge rates would generally increase as a result of the project which is consistent with the increase in impervious area within each catchment. The mean magnitude of the relative increase is greatest for the 50% AEP (19 per cent) and lowest for the 1% AEP (13 per cent)
- Similarly, discharge volumes are typically predicted to increase as a result of the project with the mean relative increase ranging from 5% for the 50% AEP event and 5% for the 1% AEP event
- Estimated velocities are also expected to increase with the mean relative increase ranging from 54 per cent (50% AEP event) to 89 per cent for the 5% AEP event. While the magnitude of relative increases is high, the estimated velocities for all proposed conditions and events remains below three metres per second.

The DRAINS modelling indicates that stormwater discharge rates, volume and velocities are generally expected to increase as a result of the increased percentage of impervious area within each reporting catchment. These changes are not expected to result in a material impact to the receiving environment as:

- Increased discharges of stormwater from the project and dewatering of water quality basins and permanent water quality basins would largely be consistent with variations in existing conditions and

occur during or following naturally occurring flow events. Changes to the number, timing and duration of flow events in the receiving environment are likely to be minor and not of a material impact

- Where stormwater discharges are made from the project, drainage design includes appropriate mitigations including scour protection in the form of rock transition aprons and energy dissipation at culvert outlets
- Estimated increases to discharge rates and velocities are likely to be reduced as a result of stormwater attenuation provided by the water quality basins that were not included in the DRAINS modelling.

Table 5-9 Summary of estimated changes to stormwater discharges

Storm Event	Change	Change (absolute)			Change (relative)		
		Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
50% AEP	Mean	0.69	990	0.31	19%	5%	54%
	Min	0.01	-5,011	-0.81	-24%	-14%	-25%
	Max	3.26	7,199	1.09	91%	16%	150%
5% AEP	Mean	0.83	1,079	0.66	16%	4%	89%
	Min	-1.15	-8,099	-0.25	-12%	-8%	-14%
	Max	3.30	8,110	1.42	89%	12%	227%
1% AEP	Mean	1.00	5,967	0.60	13%	5%	70%
	Min	-2.30	-11,360	-0.34	-17%	-8%	-11%
	Max	4.50	19,687	1.41	82%	17%	226%

5.3.2 Impacts to waterway processes and health - operation

Potential changes to existing flow regimes - operation

As discussed in **Section 5.2.2**, waterways within the study area are ungauged and a quantitative assessment of existing and construction phase flow regimes has not been completed. Operation phase design event DRAINS hydraulic modelling has been completed (**Section 5.3.1**) for locations where stormwater is discharged from the project to the receiving environment (refer to **Figure 5-2** for discharge locations). Waterways which receive discharges of stormwater from the project during operation include:

- Unnamed tributary of Viney Creek
- Purgatory Creek
- Drainage line through Coastal Wetland to Hunter River
- Unnamed tributary of Coastal Wetland
- Hunter River Drain
- Tributary to Hunter River Drain
- Drainage lines draining to the Tomago Sandbeds Catchment Area
- Windeyers Creek.

The results of the DRAINS operational phase modelling (detailed in **Appendix J**) and TUFLOW flood modelling (refer to **Section 5.2.7** and **Appendix B**) indicates that the following potential changes are expected to the existing flow regime at each discharge location during operations:

- Minor reductions in baseflow and a moderate increase to quickflow contributions to total streamflow as a result of lowered rates of rainfall infiltration, increase in effective rainfall depth and formalisation of drainage conveyance
- Minor to moderate increases to the rate, volume and velocity of stormwater discharged from the project and subsequent inferred alteration (minor increases) to rates of water level rise and fall
- Minor increases to the duration and depth of inundation for overbank events
- A minor increase (less than 20 per cent increase) in the rate, volume and velocity of stormwater at:
  - Discharge point N1160B at unnamed tributary of Viney Creek
  - Discharge point N8200C at the unnamed tributary of coastal wetland
  - Discharge point N9100C at the Hunter River Drain
  - Discharge point N9380C the tributary to the Hunter River Drain.
- A moderate increase (more than 20 per cent increase) in the rate, volume and velocity of stormwater at:
  - Discharge point N3500C at Purgatory Creek
  - Discharge point N7300C at the drainage line through coastal wetland to the Hunter River
  - Discharge point N11920C drains into diffuse drainage lines that feed into the Tomago Sandbeds Catchment
  - Discharge points N13020C and N12620C at Windeyers Creek.

DRAINS and TUFLOW flood modelling have been completed on a design event basis and potential changes to the frequency, duration and temporality of flow events were not assessed. However, project operation may also result in minor changes to the number, duration and magnitude of low flow events as a result of the permanent water quality basins and changed rates of rainfall infiltration.

Impacts to waterway and riparian processes - operation

As noted in **Section 5.2.2**, fluvial geomorphic processes are typically in a form of dynamic equilibrium where the energy and material drive the physical watercourse form. Waterways across the study area are generally considered stable, low energy, show little evidence for lateral migration and are hence considered low risk from stormwater discharges from the project. However, the estimated operational phase changes to flow regimes may result in the following impacts to waterway health and instream processes and may extend beyond the immediate discharge location:

- Reduced bank stability (scouring, undercutting, slumping, etc) as a result of increased streamflow discharge and velocities
- Increased removal and transport of eroded bed and bank material leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation
- Increased water turbidity due to suspended material and subsequent reduction in light infiltration potentially impacting sensitive aquatic vegetation
- Potential for fish passage obstruction due to increased flow velocities or reduced water levels.

The project seeks to minimise or avoid these impacts listed above by adopting appropriate erosion and sediment controls in accordance with the NSW Blue Book requirements (DECC, 2008a and 2008b), site-specific drainage design, scour protection and flow dissipation where required. Further, waterway crossings have been designed to be in accordance with NSW Fisheries guidelines - Why do Fish need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003) in order to ensure conditions for fish passage are maintained (where required). Regular monitoring of key waterways immediately downstream of project discharge locations for evidence of initiation of erosion and scour will be

conducted for a minimum of twelve months post construction and, if required, appropriate remediation measures would be carried out (refer to **Appendix K** for further detail).

Impacts to waterway health and ecological processes in important wetlands are further discussed in the Biodiversity Assessment Report (Appendix I of the EIS) and the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

NSW river flow objectives - operation

Potential operational phase impacts to waterways have been assessed against relevant river flow objectives are summarised in **Table 5-10**.

Table 5-10 River flow objectives relevant to project operational phase impacts

River flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Maintain wetland and floodplain inundation	×	×	✓	✓	Project operation does not require waterway damming or extraction of surface water flows. Some changes to the depth and duration of floodplain inundation are expected however these changes are only expected to have a minor impact to the existing regime.
	Mimic natural drying in temporary waterways (and wetlands)	×	×	✓	×	Continuous or prolonged releases of water to ephemeral receiving waterways are not planned or required by the project. However, some localised, minor changes are expected to the timing, frequency and duration of low flow events. These are expected to result from the alteration of existing drainage paths, changes to the extent of catchment imperviousness and discharge of stormwater via permanent water quality basins.
	Maintain natural rates of change in water levels	×	×	✓	×	Some localised changes are anticipated to rates of rise and fall in water levels due to the expected increases to rate of and volume of stormwater discharged during the operational phase. Where required, bed and bank stability issues have been addressed through implementation of erosion and scour management measures such as rock transition aprons at culvert outlets, refer further to **Chapter 8**.
	Protect pools in dry times	×	✓	×	×	No extraction of surface water is proposed.
	Protect natural low flows	×	✓	×	×	No extraction of surface water is proposed.
	Maintain natural flow variability	×	✓	✓	✓	No damming of waterways, surface water extraction or prolonged discharge of water is proposed for the operational phase of the project. Discharge of stormwater from the project would largely be coincident with existing flows in receiving waterways and are not expected to negatively impact existing flow variability.

River flow objective	Description	Hunter River sub-catchment type				Project impacts
		Town water supply sub-catchments	Mainly forested areas	Waterways affected by urban development	Estuary	
	Manage groundwater for ecosystems	✓	✓	×	✓	The total predicted change of groundwater contribution to surface water features is not considered to be substantial and would not detrimentally impact on wetlands and waterways.
	Minimise effects of weirs and other structures	×	✓	✓	✓	No weirs or any other waterway obstruction are proposed. Minor realignments of Purgatory Creek and the unnamed tributary of Viney Creek are not expected to impact flows once completed.
	Maintain or rehabilitate estuarine processes and habitats	×	×	×	✓	The project does not call for the damming, obstruction or interference of any estuarine waterway and the existing tidal flow regime is expected to be maintained.

Risk assessment - operation

The potential changes identified above are only considered to have a minor impact to the receiving waterways as:

- The project design does not call for the damming, blocking, diversion or extraction of water from waterways
- Discharges of stormwater from the project would largely be consistent with flows in receiving waterways and prolonged or permanent discharges of water are not proposed
- A majority of the main alignment is located within an existing road corridor and receiving waterways are already experiencing altered drainage conditions
- Waterway catchments and flow regimes across the study area already experience substantial impact from existing urban, industrial, commercial, utility and agricultural development and flood mitigation infrastructure
- No downstream floral or faunal communities sensitive to minor, localised alteration of the existing flow regime have been identified within close proximity to the project
- The accumulation of additional catchment inflows with distance downstream of any discharge point would progressively ameliorate potential impacts
- Improvements to the quality of stormwater water discharged from the project as a result of the proposed system of permanent water quality basins substantially offset any potential localised changes to receiving environment flows
- The project operational phase is not expected to have any impact on the Hunter River flow regime.

5.3.3 Impacts to groundwater flow and levels - operation

Groundwater dewatering would not be required during operational phase. With the exception of areas of soft soils consolidation, there is negligible potential for the project to materially impact groundwater flow or levels during project operational phase.

While there would be no further soft soil consolidation during operation, groundwater impacts, including mounding impacts and shadowing effects, would be similar to those predicted for soft soil consolidation during construction (as discussed in **Section 5.2.3**) due to the relatively rapid equilibration of groundwater levels. Negligible additional mounding, other than might be expected from seasonal fluctuation, is expected to occur during project operation.

Based on the relatively small groundwater level increases and the localised area of mounding, changes to groundwater level or flow are not anticipated to materially affect GDEs, including high priority GDEs, baseflows or existing groundwater users.

Assessment against NSW AIP - operation

During operational phase, the minimal impact considerations of the AIP (DPI NOW, 2012) are met with respect to groundwater level.

5.3.4 Impacts to regional hydrology - operation

Surface water - operation

Similar to the construction phase (**Section 5.2.2**), the project does not result in the damming, blockage or diversion of major waterways during construction which dictate regional hydrology and hence no impacts to regional hydrology are predicted. Adjustment of smaller creeks and minor waterways in addition to upgraded and new highway transverse drainage is proposed which has the potential to affect local hydrologic conditions, although the design of the channel adjustments and hydraulic structures accounts for adequate sizing to minimise impacts to drainage capacity and avoid diversion of flows. Refer to **Section 5.3.7** for operational impacts to drainage capacity.

Groundwater - operation

As outlined in **Section 5.3.3**, impacts to groundwater levels during the operational phase are negligible and localised to the vicinity of the project.

During the operational phase, the project would not impact the Tomago Sandbeds Catchment Area drinking water supply due to reduced groundwater levels or flows. Potential groundwater quality impacts are covered in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

5.3.5 Changes to environmental water availability and flows - operation

Surface water - operation

The project is not expected to materially impact environmental water availability. No damming, permanent total blockage or diversion of major waterways is proposed, and extraction of surface water is not required. As outlined in **Section 5.3.1**, rates, volumes and velocities of stormwater discharged by the project are expected to increase. However, these increases are not expected to adversely impact existing environmental water availability and flows.

Groundwater - operation

As outlined in **Section 5.3.3**, during the operational phase, changes to groundwater levels and flows from the project are negligible and localised. Potential changes are not anticipated to materially affect GDEs, including high priority GDEs, baseflows or existing groundwater users.

As indicated in **Section 5.3.6**, no groundwater take is anticipated during the operational phase of the project.

5.3.6 Water take - operation

Surface water or groundwater take is not anticipated during the operational phase of the project.

5.3.7 Impacts to drainage capacity - operation

The project would impact on a number of existing drainage lines and waterways due to the embankments and other features being built over the current alignment of the drainage lines. This includes adjustment of Purgatory Creek (**Figure 5-3**) and the unnamed tributary of Viney Creek (refer to **Figure 5-4**), to accommodate the project road embankments.

The alignment of a section of Purgatory Creek (refer to **Figure 5-3**) would be adjusted to accommodate the western approach to the viaduct over the Hunter River and floodplain. This section of the creek drains a part of the northern section of Hexham Swamp via a maintained, unlined earth drain and through several existing culverts under the Aurizon facility access road, other embankments and the Main North Rail Line. The creek adjustment would also involve construction of new culverts through the viaduct approach embankment and the Aurizon facility access road.

Hydraulic modelling was carried out for preliminary assessment of existing case and operational phase drainage capacity. The model was run for a range of steady flows from 0.2 cubic metres per second up to one cubic metre per second and the water levels plotted at key points along the Purgatory Creek, as shown **Figure 5-5**. The modelling indicates that the existing and operational case creek channels have a low drainage capacity of between 0.2 and 0.4 cubic metres per second due to the flat terrain in this part of Hexham Swamp. The modelling also demonstrates that the water level at the upstream end of the creek is lower in the operational phase compared to the existing case for flows up to 0.5 cubic metres per second, meaning that the channel drainage capacity is improved in the operational phase as a result of larger channel cross section and larger culvert crossings compared to the existing case. For a flow of one cubic metre per second the water levels are similar, suggesting a similar change to the drainage capacity. Hence, there is expected to be a beneficial impact to the drainage capacity at the upstream end of the creek resulting from the Purgatory Creek adjustment.

A slight increase in water level and hence slightly reduced drainage capacity for flows of 0.5 cubic metres per second is modelled between Woodlands Close and the Aurizon access road. Opportunities to reduce impacts on drainage capacity at Purgatory Creek would be considered during detailed design.

The adjustment of the unnamed tributary of Viney Creek (refer to **Figure 5-4**) would be designed with a 1% AEP flow capacity. Natural creeks typically have a capacity well below the 1% AEP event. Hence, no impact on flow capacity is expected on the unnamed tributary of Viney Creek.

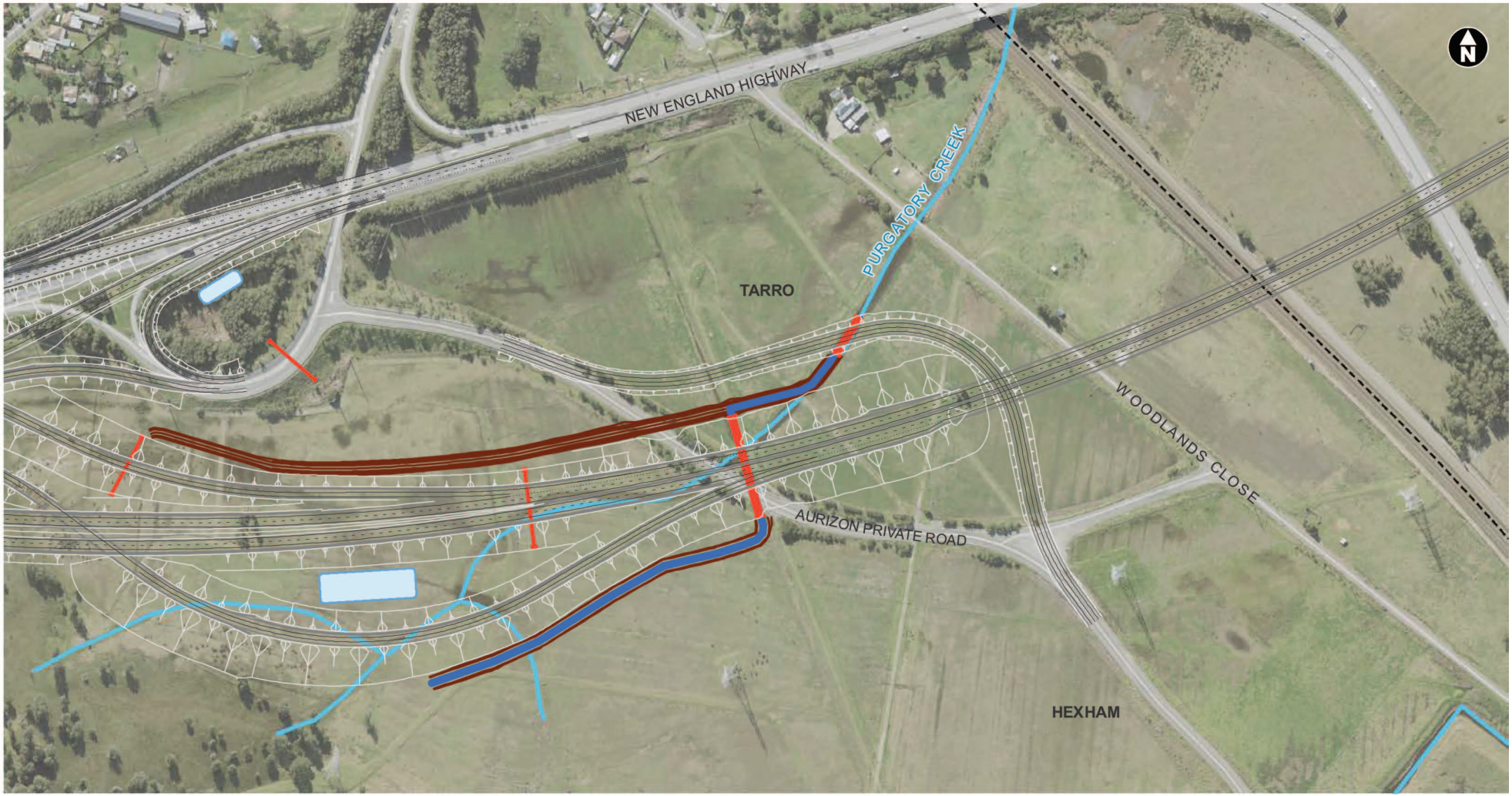


Figure 5-3 Purgatory Creek adjustment

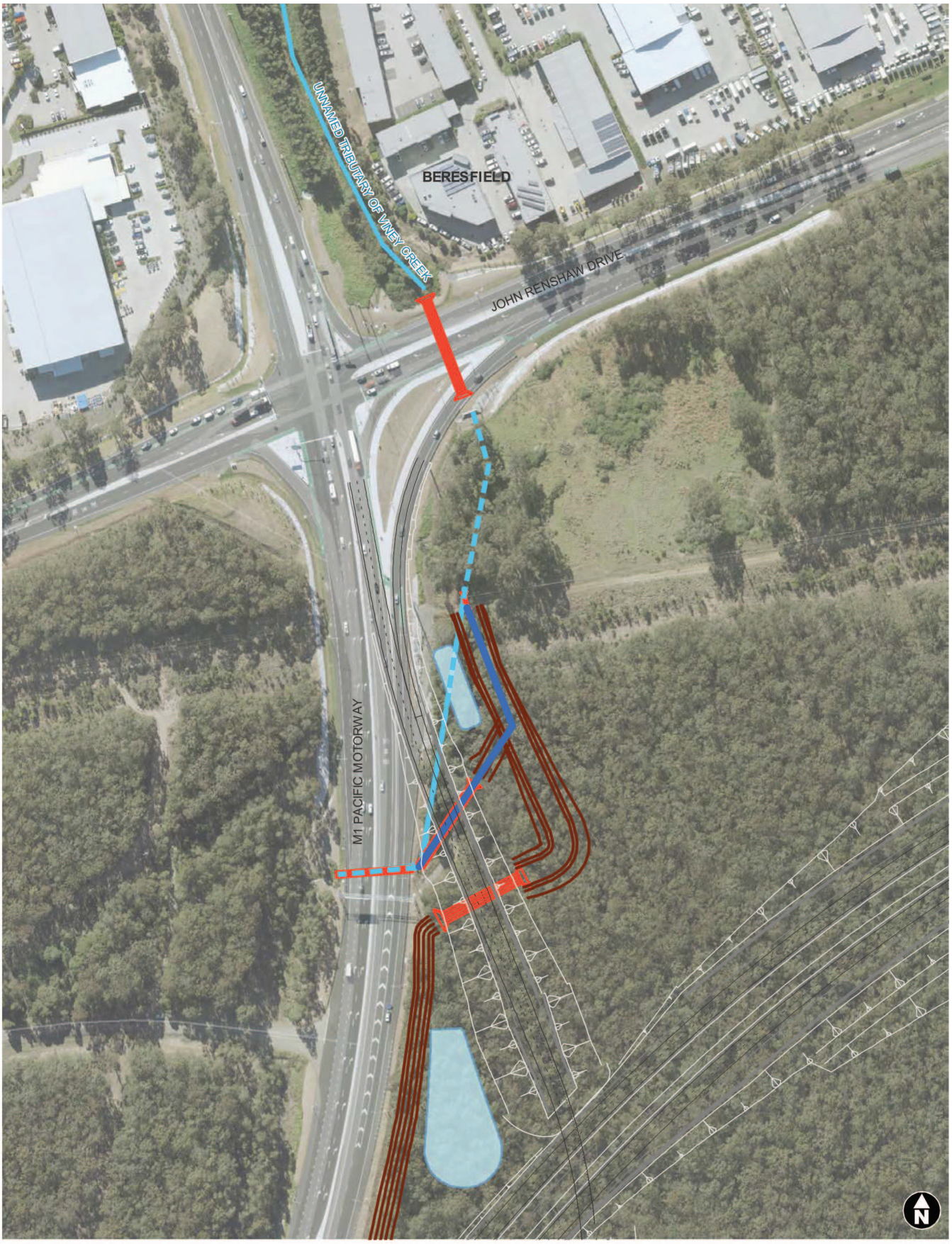


Figure 5-4 Unnamed tributary of Viney Creek adjustment

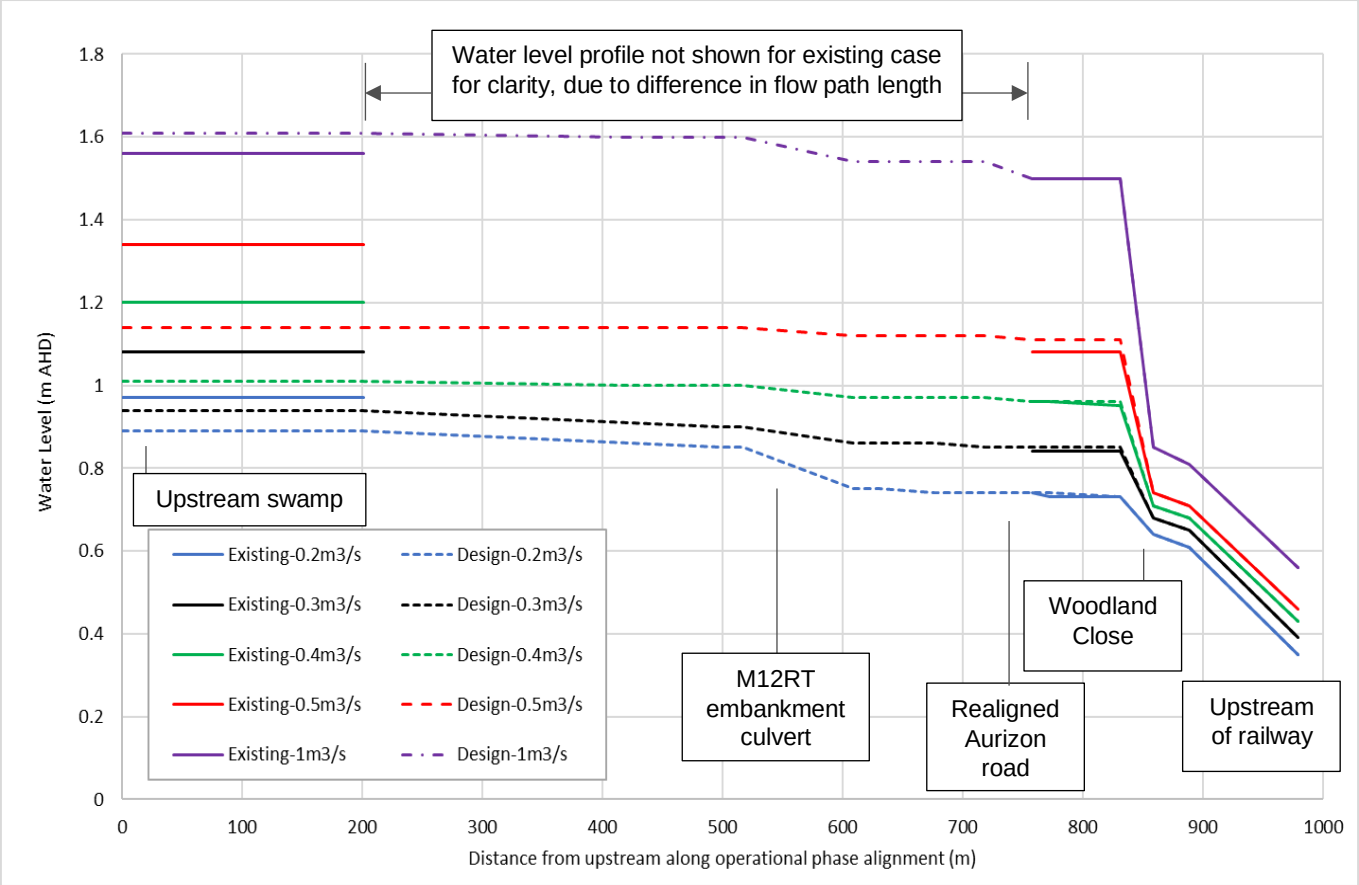


Figure 5-5 Steady flow water level profiles - Purgatory Creek adjustment

Drains which may require capacity upgrade were identified based on review of the stormwater and surface water hydrology impacts (refer **Section 5.3.1**) and the concept design. Downstream drains experiencing an increase in peak discharge rate of 20 per cent or higher at discharge points (refer **Figure 5-2**) were considered for capacity upgrade. Additionally, where the concept design provided upgraded open drains, any further downstream drainage were identified for potential upgrade.

Drainage identified for potential upgrade is shown on **Figure 5-6**. These include a private drain and a drain and floodgate operated by the Hunter Valley Flood Mitigation Scheme. These are located downstream of drainage which is to be upgraded as a part of the concept design of the project. The increment in the upgrade in capacity would be confirmed in detailed design to confirm if it is within the project thresholds, as the proposed drainage design may change.

Other locations that discharge to natural drainage lines or directly to the Hunter River were identified where the peak discharge rate increased by 20 per cent or greater. Upgrades to the capacity of these natural systems are not proposed.

Figure 5-6 Drainage requiring potential upgrade in capacity

5.3.8 Flooding - operation

Project operation was represented and analysed in the TUFLOW model to estimate the flooding conditions and flooding impacts. All work for the operational phase were represented including permanent embankments, Hunter River and floodplain viaduct, other bridges, culverts, permanent water quality basins and permanent access roads. The operational phase road design is to provide a 5% AEP flood immunity from Hunter River mainstream flooding, and the road embankments have been elevated accordingly in combination with transverse drainage with adequate capacity.

The 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events were assessed and the impacts to flooding mapped in **Appendix E**. Potential impacts may result from permanent works obstructing flood flows, change in drainage capacity for local catchments and loss of flood storage. The modelled impacts during project operation are discussed below.

Flood modelling has assumed the removal of all ancillary facilities and any associated elevated hardstand areas. The main influence on flooding impacts are the retention of raised maintenance access roads around the viaduct which obstruct floodplain flows and cause increases in flood levels upstream of the roads. These in turn result in increased flows into Hexham Swamp particularly in the 10% AEP event and larger. The flooding impacts during operation are of lesser magnitude and extent than during construction, due to less access roads being required during operation compared to the construction. Refer to **Figure 5-1** and Figure B-2 and Figure B-3 in **Appendix B**, which show the extents of the construction and operational access roads. Additionally, the horizontal extent of the access roads is less (i.e. operation access roads are required to be as wide as construction access roads), particularly in a number of locations close to the Hunter River banks near the viaduct. Hence, there is reduced interaction and obstruction of flood flows.

The viaduct itself also contributes to the flooding impacts as a result of piers causing hydraulic energy losses to the flood flows. In some locations, the permanent water quality basins result in impacts due to obstruction of flows and loss of flood storage in minor storage areas, but these are expected to be localised impacts only. Together these increased flood levels translate into corresponding increases in flood hazard and durations of inundation.

Flood immunity of project infrastructure

The project would meet the 1% AEP local flood immunity criterion between Black Hill and Tomago, and most of Tomago to Raymond Terrace, with the exception of:

- A 46 metre section of the Pacific Highway at the Tomago Road intersection
- A 300 metre section of the main alignment halfway between Tomago Road and Old Punt Road in Tomago
- A 120 metre section of the main alignment south of the Hunter Region Botanic Gardens access road in Heatherbrae
- A 450 metre section of the main alignment to the east of Masonite Road at Heatherbrae.

The main alignment has been designed to achieve a minimum 5% AEP Hunter River flood immunity.

Impacts of the project based on the April 2015 and January 2016 flood events

The historic flood events of April 2015 and January 2016 were assessed against the project in operation. Given that the community is familiar with the flood behaviour during these historic events, it was considered beneficial to analyse and discuss the effects of the project based on data from recent flood events. The change in flood levels are presented on **Figure 5-7** and **Figure 5-8** for the April 2015 and January 2016 events, respectively. The potential impacts of the project based on the historic flood events are summarised below:

- Both the April 2015 and January 2016 exhibit similar impacts on flood behaviour
- Increases in flood levels of 0.01 to 0.02 metres extend upstream from the project up to Millers Forest. These flood level increases mainly occur on the western floodplain of the Hunter River and westward to the Main North Rail Line. The impacts are mainly due to partial obstruction of flood flows by permanent access road and other features around the viaduct crossing of the river and floodplain
- There are some increases in flood levels west of the Main North Rail Line, but they do not extend far into the Hexham Swamp area. These increases include:
  - Increases in flood levels of 0.01 to 0.02 metres between the Main North Rail Line and the Aurizon Hexham Train Support Facility access road, south of the project
  - Increases in flood levels of 0.04 metres in the area bounded by the northern side of the project, New England Highway and the western side of Woodlands Close. This increase does not impact on the rural residential development on the eastern side of Woodlands Close.
- Localised increases in flood levels exceed 0.4 metres within the project operational footprint in the Tarro interchange area, which are attributed to changes in ground levels around the interchange. These impacts do not affect existing private development
- On the eastern side of the river from Tomago to Raymond Terrace there are both increases and decreases in flood levels from local catchment flooding, due to changed transverse drainage arrangements. The increases are up to 0.07 metres around Masonite Road, and decreases exceeding 0.4 metres in the local catchment to the east of Tomago Road
- There is no impact of the project on mainstream flooding on the eastern side of the river in Heatherbrae and Raymond Terrace
- There is no impact of the project on flooding on the Hunter River downstream of the proposed viaduct and permanent access roads, including in Hexham and other areas downstream.

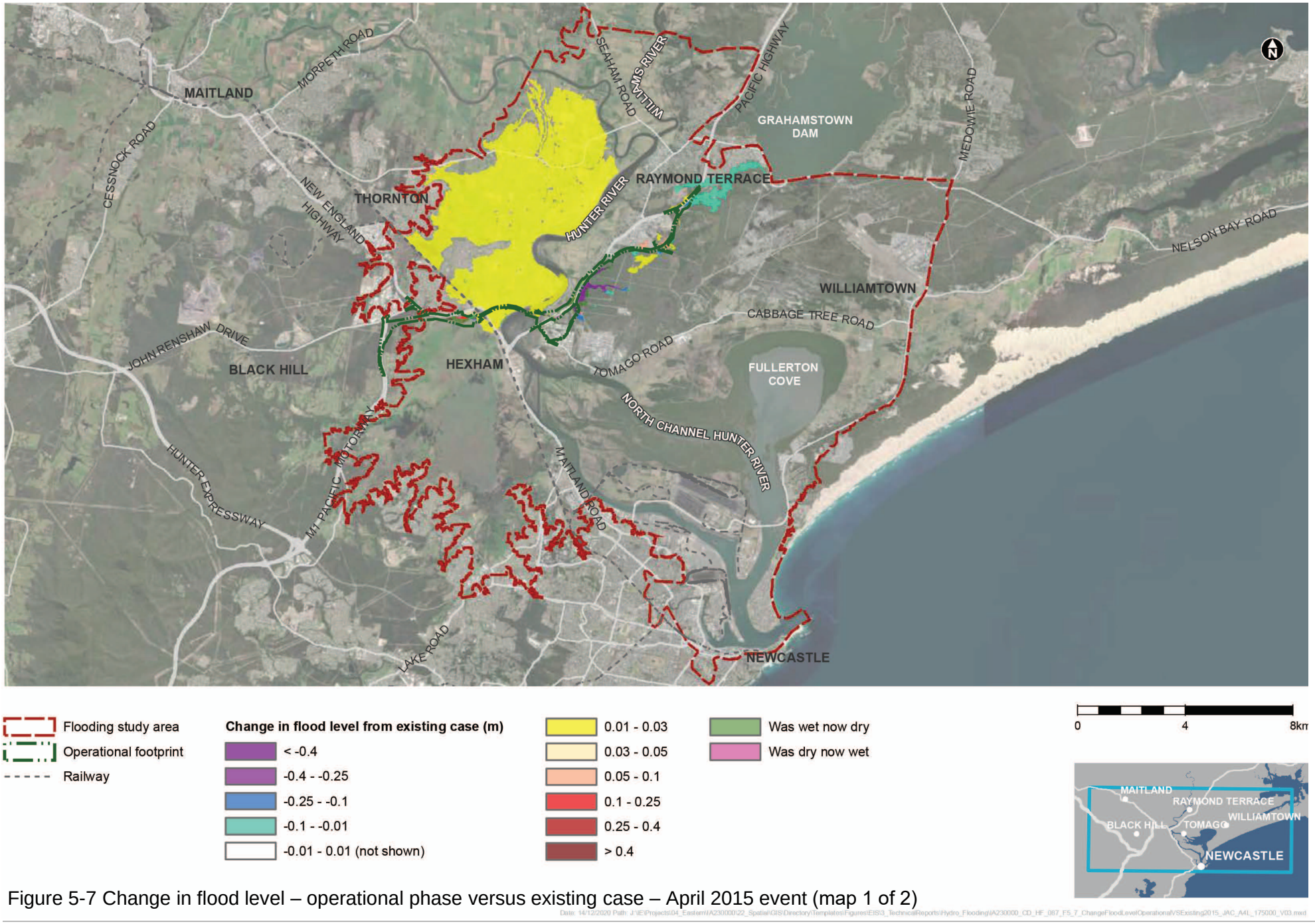


Figure 5-7 Change in flood level – operational phase versus existing case – April 2015 event (map 1 of 2)

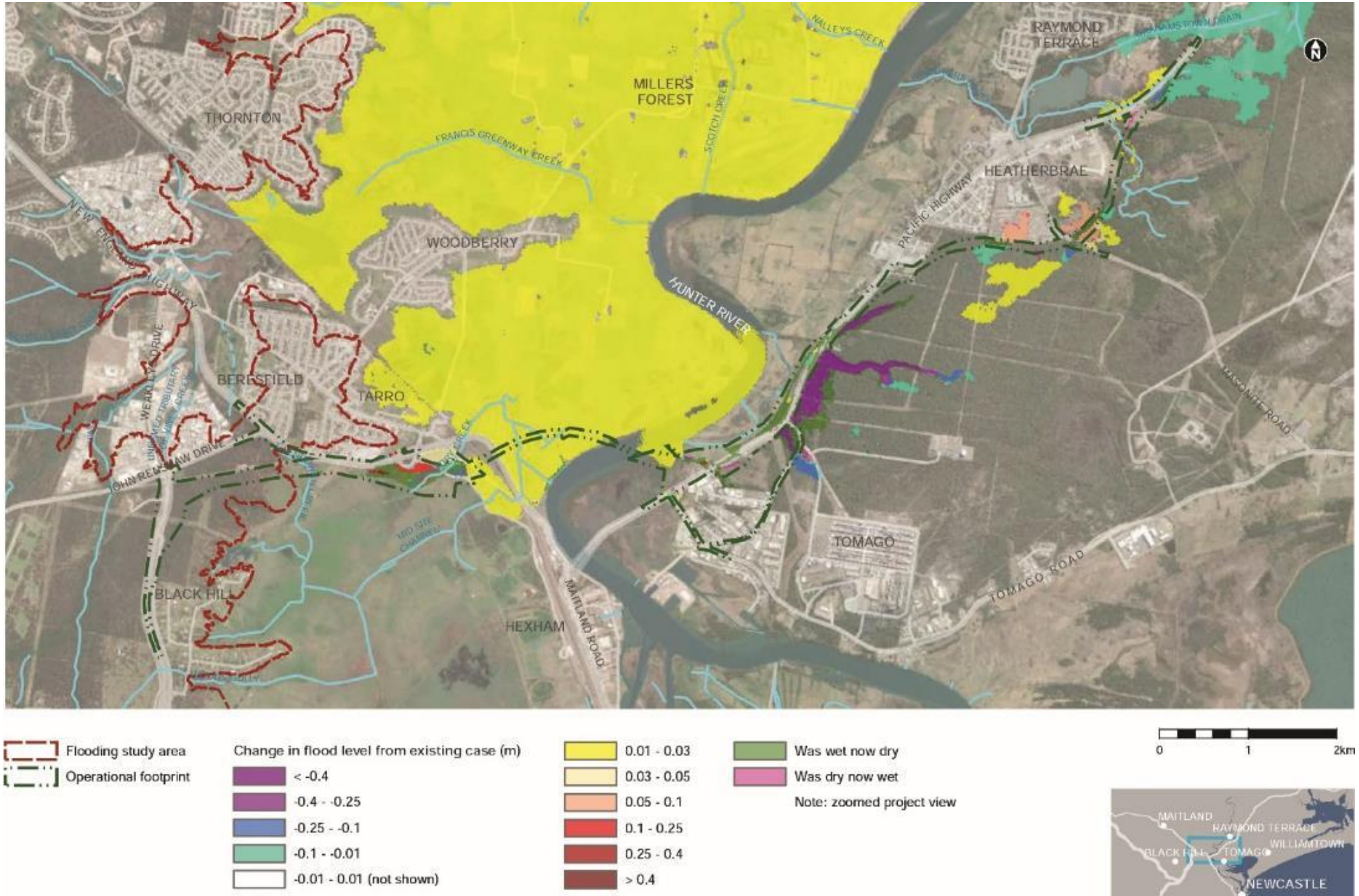


Figure 5-7 Change in flood level – operational phase versus existing case – April 2015 event (map 2 of 2)

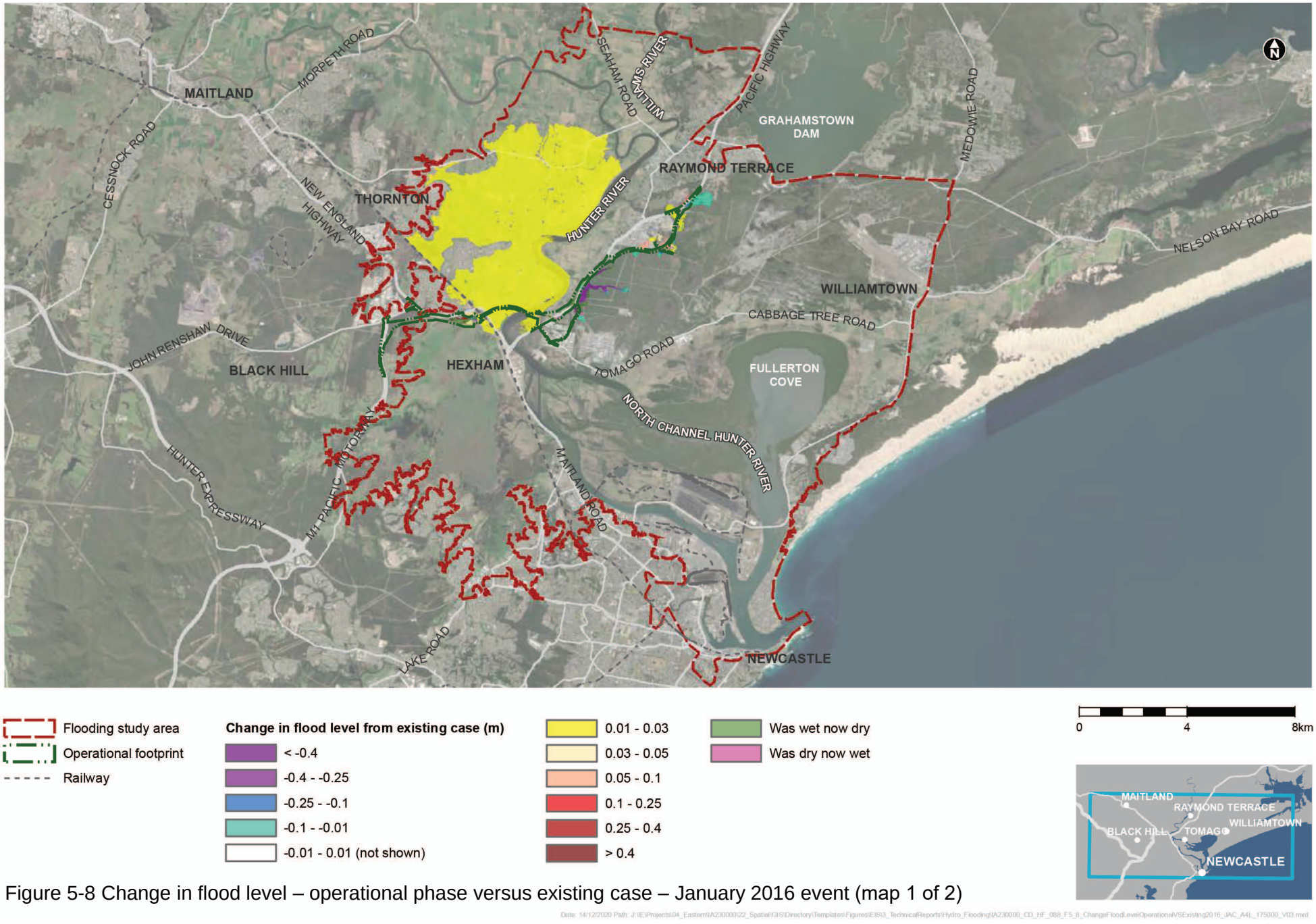


Figure 5-8 Change in flood level – operational phase versus existing case – January 2016 event (map 1 of 2)

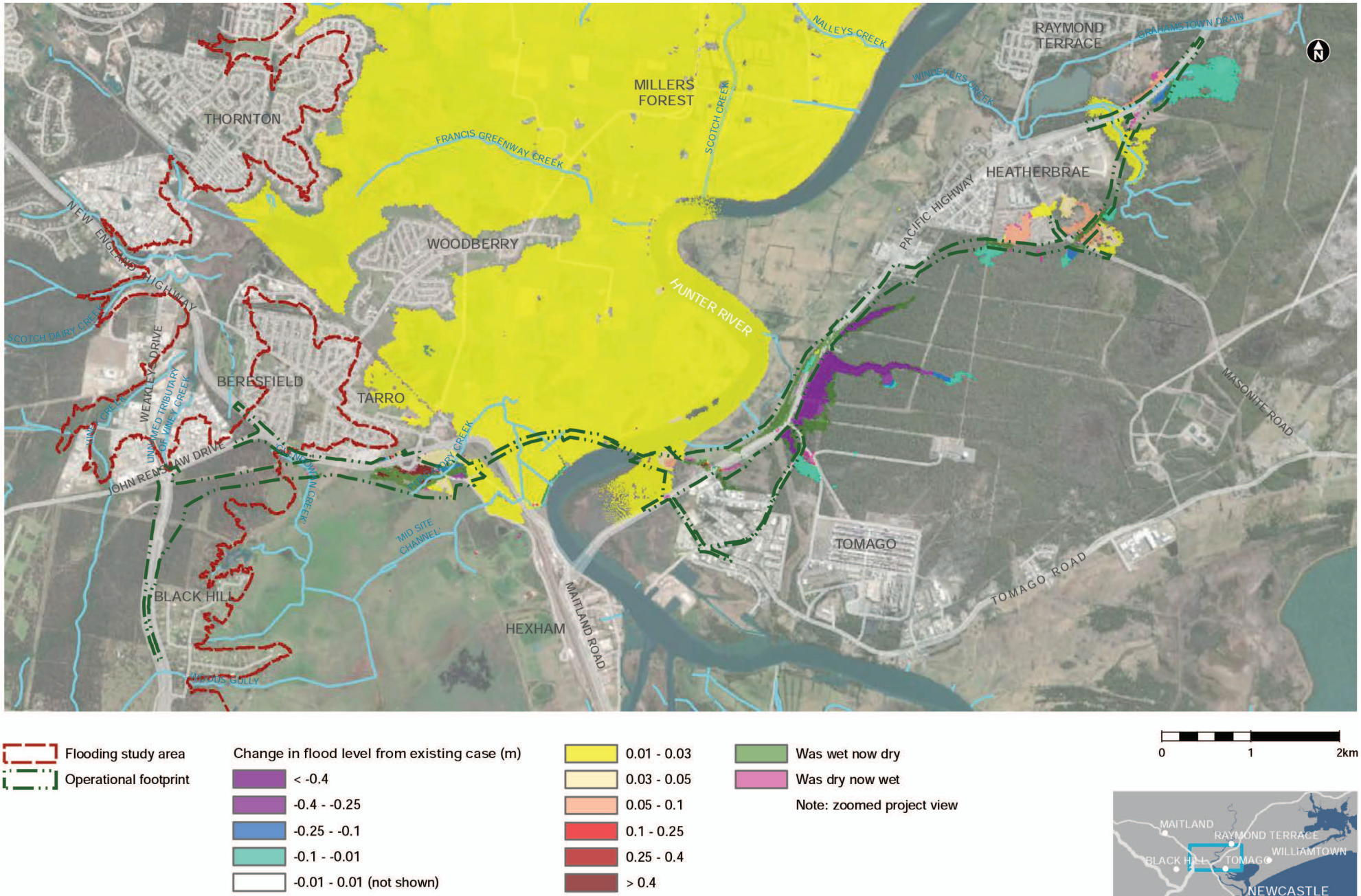


Figure 5-8 Change in flood level – operational phase versus existing case – January 2016 event (map 2 of 2)

Changes to design flood levels - operation

Impacts to flood levels during operational phase, including both increases and decreases in flood levels, are generally less than during construction for the 20% to 5% AEP events. Figures E-1 to E-6 in **Appendix E** show the change in flood levels for the 20%, 10%, 5%, 2% and 1% AEP events and probable maximum flood event, respectively, for the operational phase.

In the 20% AEP event, flood levels increase by up to 0.02 metres on the western bank of the Hunter River around Tarro and in Windeyers Creek in Raymond Terrace. Flood levels on rural land on the eastern bank of the river between the viaduct crossing and Raymond Terrace increase by about 0.05 metres. Flood levels in local catchments on the eastern (upstream) side of the project and between the viaduct and Heatherbrae decrease by over 0.4 metres as a result of increased transverse drainage capacity. Reductions in flood levels are also expected in localised areas around Masonite Road.

In the 10% and 5% AEP events, flood levels increase by up to 0.02 metres upstream of the project on both sides of the Hunter River, up to Raymond Terrace, including Windeyers Creek, and Millers Forest. There is an area of 0.03 metre increase on the western bank of the river, around Purgatory Creek. In the 5% AEP event, flood level increases are generally 0.02 to 0.03 metres in the northern part of Hexham Swamp, and 0.03 to 0.04 metres in the southern part of Hexham Swamp. There are increases of 0.05 metres affecting rural residential properties in Tarro, close to the western viaduct approach embankment. There are minor decreases in flood levels in the 5% AEP event downstream of the project. Flood levels in local catchments on the eastern side of the project and between the viaduct and Heatherbrae decrease by up to 0.8 metres as a result of increased transverse drainage capacity. There are localised increases in flood levels at the Tarro interchange exceeding 0.4 metres and a localised increase in a wetland area near the Williams River of 0.16 metres.

In the 2% and 1% AEP event, flood levels increase by up to 0.02 metres would also be experienced upstream of the project on both sides of the Hunter River, extending up the Williams and Hunter Rivers past Raymond Terrace, and also including Windeyers Creek and wetland areas around Masonite Road. There is an area of 0.03 metres increase on the western bank of the river, around Purgatory Creek and localised increases in flood levels at the Tarro interchange of 0.07 metres. Flood levels in local catchments on the eastern side of the project and between the viaduct and Heatherbrae change by up to +/- 0.1 metres as a result of changed transverse drainage capacity. There are minor decreases in flood levels in Hexham Swamp of over 0.01 metres in the 1% AEP event. Rural residential properties in Tarro, close to the western viaduct approach embankment, would experience an increase in 2% and 1% AEP flood levels of about 0.04 metres.

In the probable maximum flood event there are extensive flood level increases upstream of the project crossing of the Hunter River of 0.05 to 0.08 metres, which would extend up the Hunter River and Williams River upstream of the limit of mapping. There are increases exceeding 0.1 metres around the viaduct. There would be decreases in flood levels downstream of the project crossing of the Hunter River and in Hexham Swamp of 0.01 to 0.03 metres.

The afflux resulting from the project extends to the upstream boundary of the flood model, with afflux at the upstream boundary below the acceptable threshold of 0.05 metres (refer to the discussion on flood management objectives and criteria in **Section 3.6.3**). From this it can be inferred that the afflux beyond the model boundary would also be acceptable since the afflux reduces with distance upstream as the floodplain elevations increase up the valley.

Impacts of afflux on properties and buildings during operation are further discussed later in this section.

Changes to design flood velocities - operation

Broadly, there are no large areas with significant changes in velocities across the floodplain, with the majority of changes localised around the operational footprint. Figures E-7 to E-12 in **Appendix E** show the change in flow velocities for the 20%, 10%, 5%, 2% and 1% AEP events and probable maximum flood event for the operational phase.

In the 20% AEP event, changes in velocities are generally localised to areas around transverse drainage and downstream drainage channels, and where filled formations associated with the project, including permanent access roads, may partially impede existing flow patterns. Flow velocity changes are expected, mainly upstream of the operational footprint, with both increases and decreases of up to 0.3 metres per second being typical, and with isolated increases of 0.5 to one metre per second. There are increases in velocity of up to two metres per second within the operational footprint around the Tarro interchange and Tomago Road interchange.

In the 10% and 5% AEP events, flow velocity changes show similar trends to the 20% AEP event, with changes around the viaduct particularly on the western side of the river. Increases in velocity of up to 0.4 metres per second and decreases of up to 0.2 metres per second occur around the western side of the viaduct, due to the permanent access roads, and around the Tarro interchange.

In the 2% and 1% AEP events, in addition to impacts similar to the 10% and 5% AEP events, there are areas of increased velocity of 0.1 to 0.2 metres per second and decreased velocity of 0.1 metres per second in the far northern part of Hexham Swamp. There are also decreases of 0.2 metres per second around the New England Highway and railway near Purgatory Creek, in addition to decreases of 0.1 metres per second in local catchment waterways between Tomago and Heatherbrae. There are both localised increases and decreases of typically up to 0.3 metres per second around the Pacific Highway interchange at Raymond Terrace, with isolated increases and decreases of 0.6 metres per second.

In the probable maximum flood, there are numerous locations where flow velocities both increase and decrease, typically by up to 0.2 metres per second. The most prominent changes are located around the Tarro interchange, downstream of the western and eastern sides of the Hunter River and floodplain viaduct and around the Masonite Road interchange. Localised increases and decreases of one metre per second occur in these locations. Increases and decreases in velocities of up to 0.2 metres per second occur at the northern end of Hexham Swamp as a result of changed patterns of overflow into the swamp area. There are localised increases in velocities of over one metre per second within the operational footprint, mainly at interchange areas.

Changes to design flood hazard - operation

Changes to flood hazard are generally minor and localised. Figures E-13 to E-18 in **Appendix E** show the change in flood hazard for the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the operational phase. For the purposes of the assessment, H1 and H2 flood hazard are referred to a “low” hazard and H3 to H6 referred to as “high” hazard. The changes in hazard are expressed in terms of changes between a dry, low hazard and high hazard condition, or no change.

There are typically scattered increases in flood hazard as a result of the project, due to minor increases in flood depths rather than increases in flow velocity. Increases occur on the floodplain on either side of the Hunter River upstream of the project crossing in the 20% AEP event, on the fringes of Hexham Swamp and on Tarro sports fields in the 10% and 5% AEP events and in vegetated areas east of Heatherbrae and Raymond Terrace in up to the 1% AEP event. There are also increases in hazard around the fringes of the flood extent, outside of developed areas, in Thornton, Tarro, Woodberry, Heatherbrae and Raymond Terrace in up to the 1% AEP event. There are not large increases in extent of the high hazard areas, which would indicate a new floodway or flow path being formed as a result of the operational phase. Reductions in flood hazard in up to the 1% AEP event occur in local catchment areas between Tomago and Heatherbrae.

In the probable maximum flood, localised increases in flood hazard occur in developed areas of Thornton, Beresfield, Tarro, Woodberry, Heatherbrae and Raymond Terrace in addition to vegetated areas to the east of Raymond Terrace. These areas of increased hazard are due to increases in flood depths and are generally localised.

Overall, the change in flood hazard for the operational phase is localised and as such does not have adverse impacts on flood conveyance, floodways, flow direction and flood storage. In addition, the compatibility of the project with the flood hazard of the land and the hydraulic functions of flow conveyance, floodways and flood storage has been considered throughout the design process to minimise flood impacts. Firstly, an understanding of existing flood behaviour was developed including consideration of high hazard areas where substantial flow conveyance occurs. This was then followed by an iterative approach to identify the road alignment, and the required location and size of hydraulic structures. The design of each bridge and culvert structure would be further developed and refined as required during detailed design considering the flood hazard and flood conveyance.

Changes to design flood duration of inundation - operation

Figures E-19 to E-24 in **Appendix E** show the change in duration in inundation for the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the operational phase. Changes in duration of inundation would be minor.

The changes in the 20% AEP event are similar to those during construction, where the change in duration of inundation is typically within +/- five per cent from the existing case (up to 0.5 hour increase) in locations including in the Hunter River and Hexham Swamp. There are increases in the duration of inundation on the western bank of the Hunter River (in Purgatory Creek) and the eastern bank of the Hunter River upstream of the viaduct crossing of typically 10 to 20 per cent, with increases over 100 per cent on the fringes of the flooding extents (up to 10 hour increase). On the eastern bank of the Hunter River the increase in duration of inundation is attributed to the increase in flood levels of 0.05 metres over relatively shallow flood depths of 0.5 metres, due to increased transverse drainage capacity, discharging greater flow volumes into these areas (up to eight hour increase). In Purgatory Creek the increase in duration of inundation is attributed to interaction of flooding with proposed access roads and reduced drainage capacity posed by proposed culverts under the access roads, and potential reduction in floodplain storage.

In the 10% and 5% AEP events the change in duration in inundation is relatively uniform in distribution and typically within +/- five per cent of existing conditions (up to one hour increase). There are localised increases in durations of 10 to 20 per cent (six to 15 hour increase) along the fringes of the flooding extent and along embankment areas, generally upstream of the new viaduct crossing and in Hexham Swamp where increases in flood levels are expected. Downstream of the viaduct crossing there are localised decreases in durations of 10 to 20 per cent (up to 0.5 hour decrease) where reductions in flood levels are expected. There are reductions in duration of up to 50 per cent in the local catchment waterways between Tomago and Heatherbrae. There are also areas of reductions in Windeyers Creek upstream of the project.

In the 2% and 1% AEP events the changes in duration of inundation are similar to the 10% and 5% AEP events, with prominent differences in the local catchment waterways between Tomago and Heatherbrae, where both increases and decreases in flood duration of +/- 20 per cent occur. Typical increases in duration are up to one hour. There are localised areas occupying less than one per cent of the floodplain where increases in duration exceed one hour, with maximum increases up to 12 hours.

In the probable maximum flood event, the change in duration of inundation is again typically within +/- five per cent from the existing case across the majority of the floodplain, with increases over 40 per cent around the fringes of the floodplain, most notably around Raymond Terrace, Heatherbrae and Tomago. Typical increases in duration are up to 0.5 hours. There are localised areas occupying less than one per cent of the floodplain where increases in duration exceed one hour, with maximum increases up to eight hours.

Impacts to roads - operation

Main roads and other named roads were assessed for the total length of road affected by H2 flood hazard and higher during operation. The per cent change in total length when compared to the existing case is presented in **Table 5-11** for highways and major roads, and **Table 5-12** for other named roads.

Table 5-11 Change in length (per cent) of highways and major roads subject to H2 flood hazard, comparison of operational phase to existing case

Road	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Blue Gum Road	0	0	0	0	0	0
Cabbage Tree Road	0	0	0	0	0	0
Cormorant Road	0	0	0	0	0	-1
Hannell Street	0	0	0	0	0	0
Hunter Street	0	0	0	0	0	0
Industrial Drive	-	-	-	-	-	0
King Street	-	-	0	0	0	0
Lenaghans Drive	0	0	0	0	0	0
Maitland Road	0	4	-6	0	0	0
Nelson Bay Road	-	-	-	-	0	0
New England Highway	0	8	3	0	-19	1
Newcastle Road	0	0	0	0	0	0
Pacific Highway	91*	-3	-17	-27	-19	-2
Raymond Terrace Road	2	2	0	0	0	0
Sandgate Road	0	0	0	0	-1	0
Seaham Road	0	0	0	0	0	0
Teal Street	-	-	-	-	-	0
Thomas Street	0	0	0	0	0	4
Tillie Street	-	-	-	-	-	0
Tomago Road	-4	0	0	0	0	0
Tourle Street	0	0	0	0	0	0
Wilkinson Avenue	0	0	0	0	0	0
William Bailey Street	-	-	0	0	0	0

Note: "-" indicates that road is not affected by H2 flood hazard in existing and operational phase.

* An increase of 91 per cent from existing inundated length is experienced on the Pacific Highway in the 20% AEP event, where the total length affected increases from 51 metres to 97 metres.

Table 5-12 Change in length (per cent) of named roads subject to H2 flood hazard and higher in existing case, comparison of operational phase to existing case

Named roads	% change in total length affected by H2 and higher
20% AEP	0.0
10% AEP	0.0
5% AEP	0.0

Named roads	% change in total length affected by H2 and higher
2% AEP	0.0
1% AEP	0.0
PMF	0.0

Similar to the construction phase, for highways and major roads there is typically minor (less than five per cent) increase, nil increase or a decrease in the total length of each major road affected by H2 flood hazard or higher. An increase of 91 per cent is experienced on the Pacific Highway in the 20% AEP event, where the total length affected increases from 51 metres to 97 metres. This is considered to be a minor increase. A new 46 metre section of the Pacific Highway within the operational footprint is affected by H2 flood hazard at Tomago Road intersection, but not Tomago Road itself, due to a change in the modelled road levels Opportunities to adjust the design to minimise the flood impact to this localised section will be investigated at detailed design. Overall, there is a negligible to minor impact of the operational phase to flooding of major roads.

There are decreases of up to 27 per cent in the length of the Pacific Highway affected by H2 flood hazard. This is due to the old highway alignment being built up in elevation at the interchange with the project, in Tomago.

For the other named roads, it is observed that the change in total road length affected by H2 flood hazard is less than 0.01 per cent. Hence, there is negligible impact of the operational phase to flooding of minor roads.

Impacts to railway infrastructure - operation

Railways and railway facilities, including the Main North Rail Line, other rail lines and the Aurizon facility, were assessed for the total length of rail overtopped by floodwater during operation. There is a negligible impact of the operational phase on railways, with less than 0.1 per cent increase in affected length on the Main North Rail Line.

The Aurizon access road would be affected by less than a 0.01 metre change in flood level in the 20% and 10% AEP events, up to a 0.03 metre increase in flood level in the 5% AEP event and a 0.02 metre increase in flood level in the 1% AEP event, where the whole road is overtopped in the existing case in both events.

Impacts to major land uses - operation

The flood impacts to major land uses during operation are discussed in this section for the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events. The results are tabulated in the following tables in **Appendix B** and is based on lots from cadastral information as properties may consist of a number of lots:

- Table B-25 to Table B-27 in **Appendix B**: Number of residential, commercial and industrial lots, respectively affected by change in peak flood depth
- Table B-28 to Table B-30 in **Appendix B**: Number of residential, commercial and industrial lots, respectively affected by change in peak flood hazard
- Table B-31 in **Appendix B**: Area (hectares) on main rural land uses affected by different changes in peak flood hazard. The main rural land uses identified for the flooding study area include grazing, forestry and wetlands and national park areas
- Table B-32 to Table B-34 in **Appendix B**: Number of residential, commercial and industrial lots, respectively affected by change in peak duration of inundation
- Table B-35 in **Appendix B**: Change in area (hectares) on main rural land uses affected by different changes in peak flood duration of inundation.

The following observations are made:

- Broadly, the project achieves the flood management objectives and criteria discussed in **Section 3.6.3**, including for afflux, flood hazard and flood duration. The large majority of flood-affected residential, commercial and industrial properties in the existing case experience negligible change in flood depth (+/- 0.01 metres change), hazard and time of inundation (+/- three hours) during operation of the project
- The percentage of total residential, commercial and industrial properties[3] are affected by an increase in flood depths of over 0.01 metres in the following flood events:
  - In the 20% and 10% AEP events: residential (less than 0.5 per cent); commercial and industrial (nil)
  - In the 5% AEP event: residential (1.2 per cent); commercial (2.8 per cent); industrial (4.2 per cent)
  - In the 2% AEP event: residential (1.4 per cent); commercial (5.1 per cent); industrial (6.7 per cent)
  - In the 1% AEP event: residential (2.4 per cent); commercial (5.5 per cent); industrial (9.0 per cent)
  - In the probable maximum flood event: residential (20.6 per cent); commercial (8.4 per cent) industrial (22.4 per cent).
- The percentage of total residential, commercial and industrial lots[3] are affected by an increase in flood depths of over 0.05 metres, are summarised below:
  - Up to and including 1% AEP event: residential, commercial and industrial (less than 0.5 per cent in each category)
  - In the probable maximum flood event: residential (19.1 per cent); commercial (8.4 per cent); industrial (22.1 per cent).
- There are five residential lots affected by increase in 1% AEP flood depth of over 0.05 metres, four lots affected by increase in 1% AEP flood depth of over 0.1 metres and one lot with an increase over 0.3 metres
- There are 17 lots (residential and industrial) which are newly flooded during operation in the 1% AEP flood to depths between 0.05 metres and 0.3 metres
- There are up to eight residential lots with an increase to high flood hazard on some part of the property in the 1% AEP event. There are no commercial lots with an increase to high hazard in the 1% AEP event, and no industrial lots with an increase to high hazard in the 1% AEP event. There is one industrial lot with an increase to high hazard in the 2% AEP event
- There are up to two residential lots with a greater than a three hour increase in duration of inundation in the 20%, 10% and 5% AEP events. There are up to five residential lots with a greater than a three hour increase in duration of inundation in the 2% and 1% AEP events. There are no commercial and industrial lots with an increase in duration of inundation over three hours
- In the probable maximum flood event, three per cent of residential and commercial lots experience an increase in inundation duration greater than three hours
- The flood hazard on the main rural land uses including grazing, forestry and wetlands/national park areas does not change from existing for the large majority of these land use areas. On all main rural land uses, there would be an increase in flood hazard on up to two per cent of the land in all flood events assessed, while there would also be a decrease in flood hazard on up to one per cent of the land in all flood events assessed. On grazing land, the increase in flood hazard occurs on less than 0.5 per cent of land.

The tables indicate that some properties may be subject to high (>24 hours) increases in the peak duration of inundation on the property. These are generally localised effects, while the majority of the property would be subject to minimal increases in duration of inundation. The flood mapping in Figures E-19 to E-24 in **Appendix E** indicate that, broadly, there is minimal change in the duration of inundation on the overall

[3] Compared to 15,841 residential lots, 1,533 commercial lots and 1,315 industrial lots in the flooding study area.

floodplain. Higher increases would occur mainly on the fringes of flooding where shallow areas of flooding with short inundation times (depths of less than 0.5 metres and inundation times of up to one day) are sensitive to increases in flood levels and durations of inundation. The results indicate that some properties may be subject to high increases in flood depth, hazard and duration of inundation, in addition to change in flood extent. These estimates of localised impacts are due to small scale drainage features in comparison to the relatively coarse (20 metres) flood model resolution.

Note that flooding impacts which have been identified on individual lots does not necessarily translate to an impact to buildings or dwellings on those properties, as the buildings may be subject to nil change in flood depth, or are not flood affected. Refer to discussion below on impacts of afflux on properties and buildings.

Properties and buildings impacted by afflux – operation

Properties and buildings affected by afflux exceeding the adopted criteria in **Section 3.6.3** were identified from the change in flood level (i.e. afflux) mapping during operation, presented in **Appendix E**. Exceedance of the afflux criteria outside the operational footprint and across all flood events up to the 1% AEP event has been considered, and all land use zoned property types are included. The impacted lots are listed in Table B-36 in **Appendix B** and is based on lots from cadastral information as properties may consist of a number of lots. There are 10 lots identified as experiencing afflux exceeding the adopted criteria.

Impacted buildings are identified based on afflux at the building exceeding 50 millimetres in any of the flood events assessed during operation. The 50 millimetre threshold relates to buildings with above habitable floor flooding (100 millimetre threshold for no above habitable floor flooding), however, in the absence of floor level data the more conservative criterion has been adopted for the buildings count. The impacted buildings are listed in Table B-37 in **Appendix B**. There is one building identified as experiencing afflux exceeding the adopted criteria. Only buildings identified with habitable floors are included.

Impacts to sensitive receivers - operation

Agricultural and grazing activities - operation

Agricultural and grazing activities including movement and evacuation of stock during flood events are expected to experience minor impacts in the 20%, 10%, 5%, 2% and 1% AEP events as a result of the operational phase due to increases in flood depths of up to 0.02 - 0.04 metres. These activities may also be impacted by the die-off of pastures due to prolonged flooding. There may be impacts as a result of the operational phase in the 20% AEP event due to increases in duration of inundation of up to 40 per cent from the existing case. However, the areas affected are on the fringe of the flooding and would experience similar durations to surrounding areas of around 60 to 70 hours. There are no widespread increases in the duration of inundation in the 10% and 5% AEP event. The extent of the impacted area is relatively small compared to the overall floodplain in the 20% AEP event, while the area impacted in the 10% and 5% AEP events are more extensive.

The negligible change in duration of inundation for flood depths over 0.5 metres (typically less than one hour increase) means that the duration of isolation of stock flood refuges would not be substantially impacted. It is expected that the time to drain the floodplains for water depths under 0.5 metres would be similar (maximum five per cent increase in duration).

Overall, the impacts on agricultural and grazing activities due to the project are considered minor compared to the existing case flood effects.

Emergency service facilities and evacuation routes - operation

The highways and major roads (including the project) are expected to form the main emergency access and flood evacuation routes within the flooding study area. As indicated in the discussion on impacts to roads above in this section, there is typically minor (less than five per cent) increase, nil increase or a decrease in the total length of each major road affected by H2 flood hazard or higher during the operational

phase. The increases in inundated length occur at existing locations which are inundated in the existing case.

There is a new 46 metre section of the Pacific Highway at Tomago Road intersection which becomes cut-off in the 20% AEP event. This is considered a minor increase.

On minor roads, there is negligible change in the flood-affectation of these roads during operation of the project.

Flooding would have a negligible impact on emergency access and evacuation routes in up to the probable maximum flood during project operation. This is due to the low or nil change in the length of roads affected by H2 flood hazard, combined with broadly minor change in duration of inundation. The project would therefore provide some improvements of the trafficability of the Pacific Highway and New England Highway during operation, particularly in the 10% AEP event and below. The project itself would provide a new access route between Black Hill and Raymond Terrace with flood immunity up to the 5% AEP Hunter River flood event.

Identified emergency service facilities in the study area and potential flood impacts during operational phase are described in **Table 5-13**. Nil or negligible flood impact during operational phase is generally expected.

Table 5-13 Existing emergency service centres and operational phase flood impacts

Description	Potential flood impact
SES Lower Hunter, Metford	Located outside study area but situated at 22m AHD elevation and above the Hunter River PMF level. Direct flood impact to the centre due to the project is not expected
Raymond Terrace Police Station	On the fringe of the PMF extent and outside the 1% AEP extent. Direct flood impact to the police station due to the project is not expected in up to the 1% AEP event. Flood level increase of 0.07m in the probable maximum flood is considered a minor impact
Morpeth Police Station	Located outside flooding study area and within floodplain. Potentially impacted by flood level increase of about 0.05m in the probable maximum flood event during operational phase
Shortland Wastewater Treatment Works	Partly within PMF but not directly impacted by flood level increases from the project, which includes flood level increases of 0.04m in the 5% AEP event as it is above the 5% AEP flood.
Raymond Terrace Wastewater Treatment Works	Fully within PMF extent and partly within 1% AEP extent. Affected by flood level increase of 0.02m in the 1% AEP event, and indirectly affected by increases of 0.02m in the 5% AEP event.
Morpeth Wastewater Treatment Works	Located outside flooding study area and within floodplain. Potentially impacted by flood level increase of about 0.05m in the probable maximum flood event during operational phase

Hunter Valley Flood Mitigation Scheme

Project operation is expected to have similar impacts on the Hunter Valley Flood Mitigation Scheme to construction. Permanent embankments, access roads and other features of the project being constructed immediately next to or on levees, channels and drainage infrastructure related to the scheme may affect the structure and maintenance of the scheme, if no mitigation is in place. The project design would however ensure the existing scheme culverts and floodgates located in the flood levees would not be impeded by the project and there would be no impacts to the scheme's structural integrity, function or flow capacity from the construction of permanent access roads (including the floodgates).

The drainage channels which are a part of the scheme would also potentially be affected by increased storm flow rates discharged from the project. This is a result of some existing transverse drainage being upsized for the project, which may affect the drainage ability of the channels. This potential impact is most likely during frequent storm and flood events, as evident by the 20% AEP flood impact map Figure E-1 in **Appendix E** for the operational phase, which indicates increased flood levels on the eastern floodplain of the Hunter River upstream of the project. The drains that are a part of the scheme, in addition to other drains, which may require upgrade are shown on **Figure 5-6**. These have been identified based on enlarged drainage proposed as a part of the project (refer to assessment in **Section 5.3.7**). Transport would continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

Hunter Region Botanic Garden wetlands

Wetland areas in local catchments upstream of the project and within the Hunter Region Botanic Gardens may be affected by modified transverse drainage arrangements. The proposed culverts under the upgraded highway are currently designed to be 0.2 metres higher than the existing culverts under the current highway. This may translate to increased permanent water levels in the wetlands of 0.2 metres. However, this is not expected to have any material impact on the wetland community, refer further to the Biodiversity Assessment Report (Appendix I of the EIS).

As the proposed road drainage would discharge on the downstream side of the highway embankments, it is not expected that there would be impacts from increased road runoff to the wetlands.

Inundation depths in the wetlands during flood events is expected to be reduced as a result of the project by 0.5 to one metre in the 20% AEP event as a result of upgraded transverse culvert capacity, an improvement compared to existing.

Future development potential of affected land

Future residential growth areas identified around the project are shown on **Figure 5-9**. The majority of the residential growth areas lie outside of the probable maximum flood. Growth areas which are within the 1% AEP extent include:

- Wallsend – future residential growth area includes Maryland Creek floodplain. Not affected by increases in flood level as a result of the project in up to the 1% AEP event. Minor reduction in probable maximum flood level of 0.03 metres in this location
- North-west of Raymond Terrace adjacent to Newline Road. Small portion of the growth area would be affected by 0.02 metre increase in 1% AEP flood level and 0.07 metre increase in probable maximum flood level.

It is considered that there would be negligible impact on the development potential of the future residential growth areas.

It is also expected there would be negligible impact on the development potential for the large majority of other areas on the floodplain, given minor (typically 0.02 to 0.03 metre) increases in 1% AEP flood level and a negligible increase in duration of inundation. Further, access to these areas is not affected given negligible flooding impacts to roads and rail infrastructure.

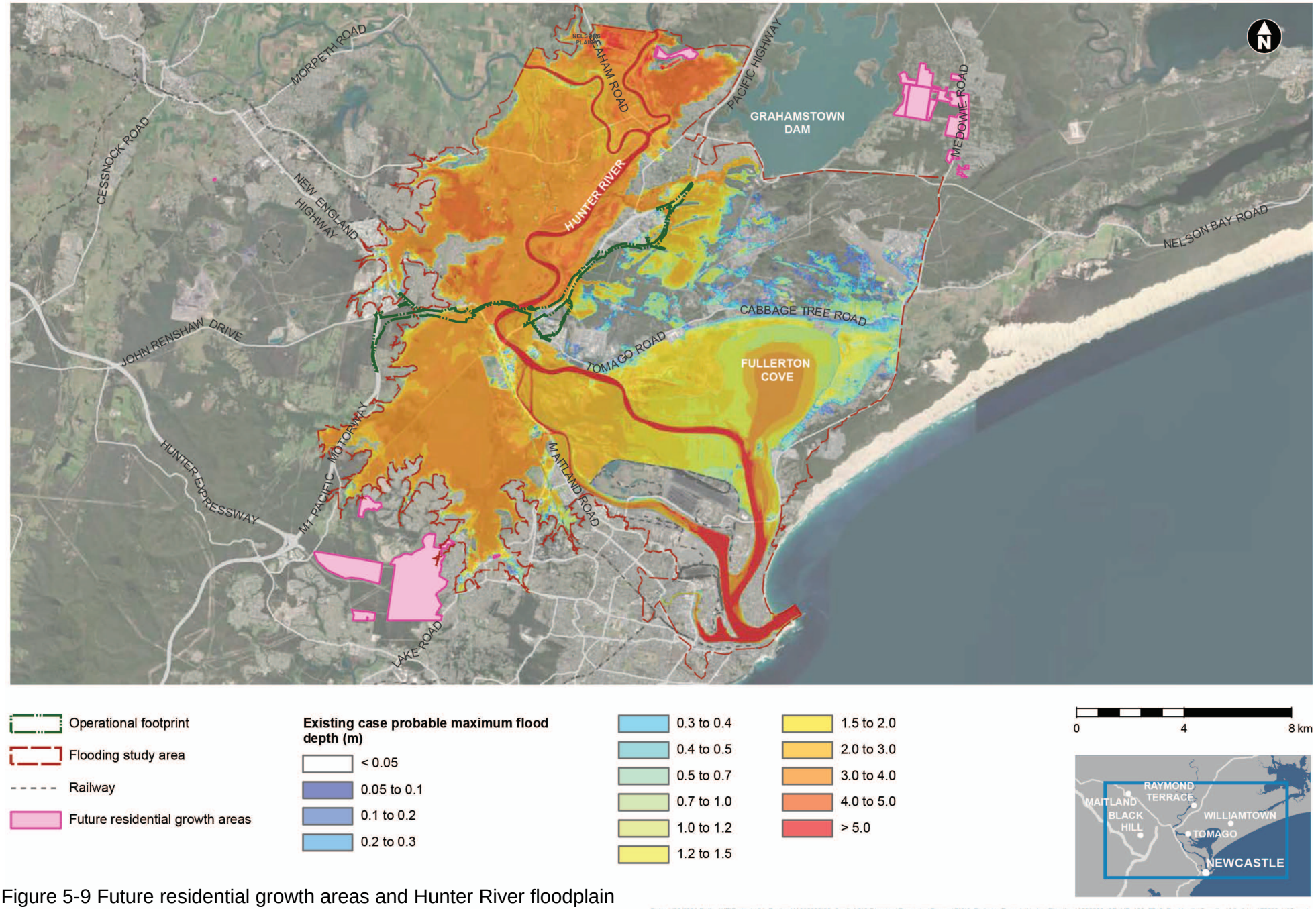


Figure 5-9 Future residential growth areas and Hunter River floodplain

Social and economic impacts - operation

Social impacts of flooding on the community relate to the intangible impacts such as the stress, anxiety, and ill-health that can be associated with the effects of flood inundation. These are often caused by the disruptions that flooding has to daily life, such as property damage, clean-up work, reduced access to supplies, restricted vehicular access, potential isolation, loss of electricity and telephones, odour associated with flood water, leeches/snakes, debris and rubbish, sewage spills, the risk of infection, ponding and slow drainage (time of inundation) after the flood event. The project would not cause any substantial broad scale social impacts as a result of changes to flood behaviour.

Economic impacts of flooding are those tangible financial impacts as a result of damage or loss caused by floodwaters to buildings, infrastructure, and agricultural activity, as well as costs associated with loss of wages, loss of production, and clean-up costs.

The project would cause negligible impacts associated with increased depth and duration of flooding to a number of residential properties that are already affected by flooding, as these increases are within the adopted tolerable limits for afflux and increased duration of inundation. Additionally, no residential dwellings were identified as being affected in the 1% AEP event by afflux exceeding the flood management objective of 0.05 metres or greater.

The impact of the project on flooding to roads and rail infrastructure is generally negligible with only minor changes to the length and duration of flooding affecting existing roads and railways (refer to subsections above which assess impacts to roads and impacts to railway infrastructure). As a result, the economic impacts of the project in relation to flood-induced existing road and rail infrastructure damage would also be negligible. Conversely, it may be noted that since the project is providing an upgraded major traffic route with increased flood immunity that there would be substantial economic benefits from the project.

Assessment of blockage of hydraulic structures - operation

The sensitivity of flooding to blockage of hydraulic structures related to the project was assessed for the 20%, 5% and 1% AEP events and the change in flood level from operational phase design flooding conditions is mapped on Figures F-1 to F-3 in **Appendix F** respectively. Blockage conditions were represented on transverse drainage structures with the blockage factors selected based on the guidance in ARR 2019 (Ball et al, 2019). Blockage factors of between 10 per cent and 100 per cent were applied in the sensitivity modelling depending on the culvert size. Zero blockage was applied in the design flood modelling.

Changes in flood behaviour are most prominent in the northern section of the project between Tomago and Raymond Terrace. The increase in flood levels in the 20% AEP event are 0.7 to two metres, 0.4 to two metres in the 5% AEP and up to 0.4 metres in the 1% AEP events, compared to the operational phase. This is due to full blockage condition of transverse culverts near Old Punt Road and Hunter Region Botanic Gardens and partial blockage at other culverts in the sensitivity run. Increases in flood levels of up to 0.4 metres also occur upstream of culverts at Old Punt Road and Masonite Road, and up to 0.05 metres Raymond Terrace interchange, in the 20% and 5% AEP events. Reductions in flood levels on the eastern Hunter River floodplain upstream of the project in the 20% AEP event as a result of reduced flows being discharged to the floodplain area. Culvert blockage would not result in overtopping of the main carriageway of the project, but overtopping would occur of the Hunter Region Botanical Gardens access road underpass and minor carriageways at Tomago interchange.

Reductions in flood levels occur in the 1% AEP event as a result of partial blockage of culverts in a number of locations in Tomago and Heatherbrae. The partial blockage of culverts reduces the backflow of Hunter River flooding to the areas upstream of the culverts.

At Tarro, there are increases in flood levels of 0.01 to 0.03 metres as a result of culvert blockage in the 5% and 1% AEP events, which affect adjacent residential properties. Black Hill is located on higher ground above the Hunter River floodplain and blockage of culverts was not analysed in the flood model. The areas upstream of the proposed culverts in Black Hill are forested or rural, and any flood level increases due to culvert blockage are expected to have negligible impact.

Appropriate management measures will be identified and assessed during detailed design to address adverse impacts on flooding due to debris blockage, refer further to **Chapter 8**.

Climate change assessment - operation

The Floodplain Development Manual (NSW State Government, 2005) requires that flooding studies consider the impacts of climate change on flood behaviour. Key elements of future climate change including sea level rise, increased storm rainfall intensity and resulting increased flood runoff, and their combined effects on flooding.

Previous guidance from the NSW Government recommended considering a 0.4 metre rise in sea level from current (1990) levels for the year 2050, and 0.9 metre rise for the year 2100 in assessing the impact of climate change on flooding. These projections are based on research by the Intergovernmental Panel on Climate Change (IPCC) and were refined for the Australian region.

Australian Rainfall and Runoff 2019 provides interim climate change factors for a range of climate change impact increase scenarios up to the year 2090. The IPCC in 2014 defined a range of scenarios of atmospheric greenhouse gas concentrations for the assessment of climate change impacts. Representative Concentration Pathways (RCP) 8.5 refers to the upper range projection of greenhouse gas concentrations in the atmosphere in those scenarios. For the upper range RCP 8.5 scenario, in the year 2050 and the year 2090 increases in rainfall depth and intensity of 9.0% and 19.7%, respectively, are predicted.

The impact of climate change on flooding at the project was assessed to determine the changes to flooding behaviour affecting the project and to the project's flood immunity. A number of combinations of increased catchment flooding (resulting from increased rainfall intensity due to climate change) and sea level rise were assessed. The 0.5% AEP (200 year ARI) and 0.2% AEP (500 year ARI) flood events were adopted as a proxy for increased rainfall intensity and river flood flows due to climate change on the current day 1% AEP flood event. The 0.5% AEP represents a 17 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event, and the 0.2% AEP represents a 45 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event. The percentage flow increases exceed the projected rainfall intensity increases for RCP 8.5.

Table 5-14 summarises the climate change scenarios assessed, the resultant change in flood levels at the project and locations where the project becomes overtopped by flooding in the climate change scenarios. The flood impacts are mapped in Figures G-1 to G-9 in **Appendix G**. The assessment is based in terms of the change in flood level in the climate change case from the current climate case, both with the project operational phase in place.

Sensitivity analysis of flood levels and project flood immunity to climate change has been carried out. Raising the proposed project road levels is not considered practical to achieve increased flood immunity in the climate change scenarios as raised road levels would exacerbate the potential flooding impacts resulting from the project. Raising of the proposed road levels would also result in increased project footprint, increased resources for construction and operation, and increased property and environmental impacts in many locations along the project alignment.

The project has a key design criterion of a 5% AEP Hunter River flood immunity in the existing climate, and it is noted that the main alignment of the project remains flood-free in the 5% AEP flood (existing climate) with a year 2100 sea level rise of 0.9 metres (i.e. climate change scenario 1). The comparisons of the 1% AEP with climate change scenarios (scenarios 2 to 9) to existing 1% AEP flood conditions are made only to

assess the sensitivity of flooding at the project, as a flood immunity level of 1% AEP for the project has not been adopted.

Table 5-14 Climate change scenarios and change in flooding at project

Scenario	Catchment flooding	Sea level rise	Change in flood level at the project due to climate change	Project overtopped?
1	Current day 5% AEP	0.9m sea level rise (year 2100)	Compared to current day 5% AEP event: • West of Main North Rail Line: increase of 0.6 to 0.7 metres. Hexham Swamp flooding influenced by sea level rise • East of Main North Rail Line to Heatherbrae: increase of 0.15 to 0.17 metres • Masonite Road to eastern end of project: increase of 0.12 metres.	Minor carriageway* only, Tomago interchange
2	Current day 1% AEP	0.4m sea level rise (year 2050)	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 0.06 metres • East of Main North Rail Line to Heatherbrae: increase of 0.03 to 0.05 metres • Heatherbrae to eastern end of project: increase of 0.03 to 0.04 metres.	• New England Highway, Tarro interchange • Main carriageway** and minor carriageways, Tomago interchange • Masonite Road • Main carriageway, Raymond Terrace interchange
3	Current day 1% AEP	0.9m sea level rise (year 2100)	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 0.17 metres • East of Main North Rail Line to Heatherbrae: increase of 0.1 to 0.13 metres • Heatherbrae to eastern end of project: increase of 0.09 to 0.13 metres.	• New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange
4	Current day 0.5% AEP	Nil sea level rise	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 0.45 metres • East of Main North Rail Line to Heatherbrae: increase of 0.45 metres • Heatherbrae to eastern end of project: increase of 0.46 to 0.48 metres.	• New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange

Scenario	Catchment flooding	Sea level rise	Change in flood level at the project due to climate change	Project overtopped?
5	Current day 0.5% AEP	0.4m sea level rise (year 2050)	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 0.48 metres • East of Main North Rail Line to Heatherbrae: increase of 0.45 to 0.48 metres • Heatherbrae to eastern end of project: increase of 0.48 to 0.58 metres.	• Main carriageway, New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange
6	Current day 0.5% AEP	0.9m sea level rise (year 2100)	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 0.58 metres • East of Main North Rail Line to Heatherbrae: increase of 0.5 to 0.54 metres • Heatherbrae to eastern end of project: increase of 0.55 to 0.65 metres.	• New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange
7	Current day 0.2% AEP	Nil sea level rise	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 1.04 to 1.09 metres • East of Main North Rail Line to Heatherbrae: increase of 0.97 to 1.05 metres • Heatherbrae to eastern end of project: increase of 1.08 to 1.2 metres.	• Main carriageway, New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange
8	Current day 0.2% AEP	0.4m sea level rise (year 2050)	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 1.07 to 1.1 metres • East of Main North Rail Line to Heatherbrae: increase of 1.02 to 1.07 metres • Heatherbrae to eastern end of project: increase of 1.09 to 1.22 metres.	• Main carriageway, New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange
9	Current day 0.2% AEP	0.9m sea level rise (year 2100)	Compared to current day 1% AEP event: • West of Main North Rail Line: increase of 1.15 metres • East of Main North Rail Line to Heatherbrae: increase of 1.1 to 1.12 metres • Heatherbrae to eastern end of project: increase of 1.14 to1.28 metres.	• Main carriageway, New England Highway and minor carriageways, Tarro interchange • Main and minor carriageways, Tomago interchange • Main carriageway and Masonite Road • Main carriageway, Raymond Terrace interchange

*Minor carriageway refers to adjustments to existing roads and new ramps identified in **Figure 1-2**.
Major carriageway refers to areas of the main alignment identified in **Figure 1-2.

5.3.9 Summary of operation impacts

Summary of surface water operation impacts

The project would have similar impacts to surface water hydrology during operation as those identified in construction, refer further to **Section 5.2.8**.

Summary of groundwater operation impacts

Ongoing interaction with groundwater during operation would occur due to the operation of permanent water quality basins below the water table and through the interruption to groundwater flow caused by soft soil consolidation. Potential impacts to groundwater quality are discussed in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

The soft soil consolidation is not anticipated to have any material impact and overall the project is not anticipated to have any detrimental effect on the local groundwater hydrology regime, including groundwater dependent ecosystems and other groundwater users during operation and this includes to the nearby Tomago Sandbeds Catchment Area drinking water supply.

Summary of flooding operation impacts

During operation, flood level increases of generally 0.02 to 0.04 metres in the 5% and 1% AEP event are expected to occur. A dwelling near the Tarro interchange experiences an increase of up to 0.06 metres, which exceeds the afflux design objective criterion during a 5% AEP flood event. The afflux criterion is exceeded for the 5% AEP event. Flood levels in vegetated local catchments on the eastern side of the project and between the viaduct and Heatherbrae change by up to +/- 0.1 metres as a result of changed transverse drainage capacity. Flood levels in the probable maximum flood generally increase by up to 0.08 metres across the Hunter River floodplain during operation.

Localised increases in flow velocities, flood hazard and duration of inundation are expected, with overall negligible to minor impacts. The absence of widespread increases in flood hazard indicate that there is negligible change to flood hydraulic characteristics, including floodways and flood storages.

Broadly, the project achieves the flood management objectives and criteria discussed in **Section 3.6.3**, including for afflux, flood hazard and flood duration. The large majority of existing flood-affected residential, commercial and industrial properties experience at most a negligible in flood depth (defined as 0.01 metres change), hazard and time of inundation (defined as a change of up to three hours) during operation of the project. There would be 17 lots (residential and industrial) that would be newly flooded in the 1% AEP flood event, with 10 lots and one habitable building identified as experiencing afflux exceeding the adopted criteria. Flood level increases of up to 0.02 metres reach Raymond Terrace and beyond the current flood model extent.

There are negligible impacts to existing roads and rail infrastructure. There are negligible to minor impacts to agricultural and grazing activities are expected, emergency services (including evacuation routes) and future development potential of affected lands.

Access roads for the project would be constructed immediately next to Hunter Valley Flood Mitigation infrastructure, namely existing flood levees on the western Hunter River Floodplain. These roads may affect the structure and maintenance of the levees, however there would be no impacts to the operation, function or structural integrity of the scheme (including the floodgates). Transport will continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

Summary of climate change impacts on operation flooding

The impact of climate change on flooding at the project was assessed to determine the changes to flooding behaviour affecting the project. A number of combinations of increased catchment flooding (resulting from increased rainfall intensity due to climate change) and sea level rise were assessed. The 0.5% AEP and 0.2% AEP flood events were adopted as a proxy for increased rainfall intensity and river flood flows due to climate change on the current day 1% AEP flood event. The 0.5% AEP represents a 17 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event, and the 0.2% AEP represents a 45 per cent increase in the Hunter River peak flow from the current day 1% AEP flood event. The sea level rise scenarios assessed included a 0.4 metre rise in sea level from current levels for the year 2050, and 0.9 metre rise for the year 2100 in assessing the impact of climate change on flooding. These projections are based on research by the Intergovernmental Panel on Climate Change (IPCC) and were refined for the Australian region. The assessment indicates:

- Increases in peak flood levels due to sea level rise (in conjunction with current day 5% and 1% AEP catchment flooding) are generally up to 0.17 metres, with exception of west of Main North Rail Line where increases of up to 0.7 metres are expected in the 5% AEP event due to sensitivity of flood conditions in Hexham Swamp
- Increases in peak flood levels with a 0.5% AEP catchment flood for all sea level rise scenarios are in the range of 0.45 to 0.65 metres
- Increases in peak flood levels with a 0.2% AEP catchment flood for all sea level rise scenarios are in the range of 0.97 to 1.28 metres.

Climate change results in a reduction in the flood immunity of the project. However, the main alignment of the project remains flood-free in the 5% AEP flood (existing climate) with a year 2100 sea level rise of 0.9 metres (i.e. climate change scenario 1), and hence would continue to meet the key design criterion of an existing climate 5% AEP Hunter River flood immunity.

Raising the proposed project road levels to address the climate change impact on project flood immunity is not considered practical, as raised road levels would exacerbate the potential flooding impacts resulting from the project. Raising of the proposed road levels would also result in increased project footprint, increased resources for construction and operation, and increased property and environmental impacts in many locations along the project alignment.

6. Cumulative impacts

Cumulative impacts may arise from the interaction of construction and operation activities of the project, and other approved or proposed projects in the area. When considered in isolation, specific project impacts may be considered minor. These minor impacts may, however, be more substantial, when the impact of multiple projects on the same receivers is considered.

This chapter provides an assessment of cumulative hydrology and flooding impacts based on the most current and publicly available information for major projects (near to the proposed project) that are in varying stages of delivery and planning. In many instances this is a high-level qualitative assessment.

Since potential surface water and groundwater hydrology impacts of the project are expected to be minor with the implementation of appropriate environmental management measures (refer further to **Chapter 8**), the project is expected to have a minor contribution to cumulative surface water and groundwater hydrology impacts. Potential cumulative impacts to surface water with respect to nearby projects is detailed in **Table 6-1**.

Potential impacts to groundwater during the construction and operational phases of the project have been assessed as likely to be minor to negligible. No material impacts to groundwater level and flow are anticipated to occur due to the project. The project's potential impacts to groundwater are localised and are not anticipated to interact cumulatively with the projects listed in **Table 6-1** and result in a material change to groundwater levels and flow. Recently completed projects including Hexham Train Support Facility and the Hexham Relief Roads project were included in the existing case, and the cumulative impacts of proposed projects are in addition to those completed projects. For flood modelling purposes, the Kinross Industrial and Weathertex developments have been assessed separately in this cumulative impact assessment.

Table 6-1 Assessment of potential cumulative impacts for relevant identified projects

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Black Hill Hunter Business Park (In planning)	Located south of John Renshaw Drive and west of the M1 Pacific Motorway. Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	Construction and operation of the Black Hill Hunter Business Park (part of the Emerging Black Hill Precinct) is likely to have some overlap with the construction of the project. During timeframes where construction activities are concurrent, there is a potential for increased surface water quantity impacts to Viney Creek which flows through the centre of the Black Hill Hunter Business Park development site, and the unnamed tributary of Viney Creek which is located on the north eastern corner of the proposed site. Due to the extent of clearing required for the construction of the Black Hill Hunter Business Park, there is potential for increased rates of stormwater discharge, volume and velocities. This may lead to downstream erosion and sedimentation and resultant loss of geomorphic stability in Viney Creek and the unnamed tributary to Viney Creek. The project is also likely to require construction discharges to these creeks. However, it is expected that construction activities and discharges associated with the development would be managed to avoid downstream impacts to sensitive receiving environment and erosion and sedimentation of banks and channels. During operation, it is expected that cumulative impacts to the flow regime and geomorphic stability of Viney Creek and the tributary of Viney Creek would be negligible. This is because the Black Hill Hunter Business Park development would ensure the landscape is stabilised and design would have incorporated water detention and bio-detention basins to adequately capture runoff. Additionally, the Black Hill Hunter Business Park development is expected to have a 'Green Buffer Zone' along the perimeter of the project which would assist to reduce sediment being transported to the unnamed tributary of Viney Creek and Viney Creek.

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Kinross Industrial Heatherbrae (approved)	Located within the project's construction footprint (AS16, AS18 and AS19) on Masonite Road, Heatherbrae. Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	The Kinross Industrial development is proposed on land identified for construction phase ancillary facilities near Masonite Road. If the Kinross Industrial development is developed before or during construction, this ancillary facility would be unavailable to the project for use. Should construction take place concurrently, there is potential for increased rates, volumes and velocities of construction runoff to be discharged into the nearby receiving waterway, Windeyers Creek. This may lead to downstream erosion and sedimentation and resultant loss of geomorphic stability. It is expected however, that construction activities associated with the Kinross Industrial development would be managed to minimise any potential impacts associated with the discharge of stormwater and construction discharges would be designed and implemented in accordance with standard practices and guidelines to ensure minimal surface water impacts (Landcom, 2004; DECC, 2008a; DECC, 2008b).Once operational, it is expected that cumulative impacts associated with construction of the two projects would be negligible as drainage structures and water quality control measures for runoff would be designed to ensure minimal downstream impacts and compliance with licenced discharges. The Kinross Industrial development would be on land which is affected by flooding in the existing case. Since the Kinross Industrial development would be on identified ancillary facilities, the cumulative impact in the construction and operational phase of the project is likely to be similar to the project construction phase flood impacts shown on Figure D-1 to D-3 in **Appendix D** around the Masonite Road interchange, of up to 0.04m increase in 5% AEP flood levels from existing case would occur.
Weathertex industrial development (approved)	Located within the project's construction footprint to the north of the project in Heatherbrae. Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	The timing for the Weathertex industrial development has not yet been announced, although some land has been cleared for the development to the north of the project. The industrial development is proposed on land identified for construction phase ancillary facilities and additionally overlaps with the Kinross Industrial development area. If the Weathertex industrial development is developed before or during construction this ancillary facility would be unavailable to the project for use. Should construction take place concurrently, due to its location within the Tomago Sandbeds Catchment Area, there is potential for earthworks and excavation to result in changes to rate, quantity and velocity of stormwater discharged. It is expected, however, that construction activities associated with the Weathertex industrial development would be managed to avoid impacts to the Tomago Sandbeds and construction discharges would be designed and implemented in accordance with standard practices and guidelines to ensure minimal surface water impacts (Landcom, 2004; DECC, 2008a; DECC, 2008b). Once operational, it is expected that cumulative impacts to the Tomago Sandbeds would be negligible as drainage structures and stormwater control measures for runoff would be designed to ensure minimal impacts and compliance with licenced discharges. The Weathertex development was modelled along with the operational phase of the project in the TUFLOW flood model. The cumulative flood impact is shown on Figure H-1 in **Appendix H** in terms of change in 1% AEP flood level from operational phase alone. Flood levels in the cumulative impact scenario are 0.01m higher than operational phase impact (refer Figure E-5 in **Appendix E**. Cumulative increase of 0.03m) around Masonite Road and Windeyers Creek. There is also an area of reduced flood impact of 0.02m to the south of Masonite Road, in addition to 0.03m flood level reduction during operation of the project (cumulative reduction of 0.05 m).

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Newcastle Power Station (in planning)	Located within the project's construction footprint at Tomago near Old Punt Road. Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	AGL propose to construct a 250 megawatt (MW) gas fired power station at Tomago, with gas pipelines and electricity transmission lines. The site for the proposed power station is located between the Pacific Highway and Old Punt Road, north of the Tomago industrial area (AGL, 2019). The power station would be located immediately adjacent to where the main carriageway is proposed to cross near the Tomago interchange. The site is currently undeveloped and forested. A substantial proportion of the area within the power station footprint would become impervious post construction, currently anticipated at around 30 per cent, resulting in an increase in stormwater runoff (flow rates and volumes) from the proposed power station site (AGL, 2019). Site runoff is expected to be discharged through the project's transverse culverts to the eastern floodplain of the Hunter River between Tomago and Heatherbrae. The power station site would be outside the 1% AEP flood extent and on the fringe of the probable maximum flood extent. There are expected to be negligible cumulative impacts on Hunter River flooding during operation of the project given the power station's location on the fringe of the probable maximum flood. Due to increased runoff volumes from the power station site there is expected to be a minor additional increase in flood levels on the eastern floodplain of the Hunter River between Tomago and Heatherbrae particularly in the 20% AEP event.
Hexham Straight (in planning)	Located about one kilometre south of the project at Hexham Potential to be consecutive (back to back) or concurrent (simultaneous) construction. Potential to be concurrent (simultaneous) operation.	This road project is currently in planning. Transport plan to upgrade the Hexham Straight (Maitland Road) between Sandgate and Hexham Bridge. The proposed scope of the Hexham Straight project involves the addition of an extra lane in both directions, removal of the existing bridges and construction of two new bridges at Ironbark Creek, adjustments to connecting roads as well as substantial utility relocation. During operation, it is expected that cumulative impacts to surface water hydrology of the Hunter River would be negligible. The combined volume of stormwater discharge from M12RT and Hexham Straight projects are negligible compared to the Hunter River flows. Hexham Straight passes through the Hunter River floodplain and is affected by the 5% AEP event. There is potential for cumulative flooding impacts during the operational phase, however, as the design of Hexham Straight is yet to be confirmed and effects on flooding modelled, the quantum of the cumulative flooding impacts is not known.
Lower Hunter Freight Corridor (in planning)	Investigation area includes Hexham.	The Transport Lower Hunter Freight Corridor (LHFC) website (TfNSW, 2018) indicates that in 2018 preliminary investigations were being carried out to assess options for a dedicated freight rail line between Fassifern and Hexham. No options were available on the website to review. An investigation areas figure between Fassifern and Hexham was available. As corridor options and environmental assessment are not available for the LHFC, the level of impact to downstream surface water hydrology and geomorphological environments in both receiving waterways and sensitive receptors and on flooding behaviour generated by this project is currently unknown. Consequently, cumulative impacts associated with the construction or operation of the project is unknown.
Hunter Gas Pipeline (approved)	Intersects the project at Tomago	This project would cross the main alignment at Tomago. Construction is planned between 2023 and 2028, with different construction times for each project consequently no cumulative impacts to surface water hydrology and groundwater are anticipated during construction. During operation, since the project is likely to consist of a buried pipeline, no cumulative surface water hydrology, groundwater hydrology impacts or flooding impacts are anticipated.

Overall, the project would have minor cumulative impacts to surface water hydrology and groundwater flow associated with both construction and operation. Where any minor impacts occur, they are likely to be either highly localised, temporary and/or readily assimilated into the existing waterway.

Potential cumulative flooding impacts have been identified for a number of proposed and approved developments, with the Weathertex and Kinross Industrial developments expected to result in cumulative flooding impacts of up to a 0.05 metre total increase in 1% AEP flood levels around those developments in the construction and operational phase of the project.

7. Site water balance

A detailed site water balance, incorporating surface water and groundwater components, has been compiled for the project construction phase. As the operational phase of the project is not anticipated to have any ongoing water demand or water take, an operational water balance is not presented. The water balance captures key sources of water that are available to the project during construction coupled with project water uses or demands. Due to logistical issues and the physical barrier of the Hunter River, the water balance has been split into sources and demands south of the Hunter River, and sources and demands north of the Hunter River.

Water quality constraints have also been considered in terms of indicative salinity of various water sources and typical water quality constraints based on end water use.

The project aims for sustainable use of water resources, and as such re-use of water would be incorporated where possible. However, as outlined in **Section 7.4**, issues around timing and water quality constraints mean that re-use of produced or captured water is not always possible.

7.1 Project water demands

Key project water demands are outlined as follows:

- Earthworks – conditioning of bulk fill materials and pavement foundations
- Dust suppression – ancillary facilities, access roads and work areas
- Concrete batching – for pavements and bridges
- Landscaping – irrigation for revegetation and landscaping
- Potable water – for use at ancillary facility offices, crib rooms and ablutions.

For each water demand there is an upper limit to the acceptable water quality (salinity) for project use. Adopted water quality criteria and salinity constraint for water uses adopted in the water balance are provided on **Table 7-1** and **Table 7-2**.

Table 7-1 Water quality classification

Classification	Salinity as total dissolved solids (mg/L)	Salinity as electrical conductivity (µS/cm)
Fresh	< 1000	< 1500
Slightly brackish	1000 to 5000	1500 to 7500
Brackish	5000 to 10000	7500 to 15000
Saline	> 10000	> 15000

Table 7-2 Water use salinity criteria – upper limit

Use	Criteria
Potable	Fresh
Concrete batching	Fresh
Irrigation	Slightly brackish
Dust suppression	Slightly brackish
Fill conditioning	Brackish

Due to health and quality assurance considerations all water required for potable supply and concrete batching would be imported or sourced from scheme water to ensure consistent quality.

Highly saline water would be reused in applications where there is minimal risk of harm to biodiversity, infrastructure, existing soils or entry into waterways (such as compaction of elevated formations, dust suppression etc) and where the salinity is commensurate with existing soil and groundwater conditions.

7.2 Project water sources

Key project water sources (intake locations) that are available for use have been incorporated as follows.

- Water quality basins
  - The water quality basins receive runoff from the construction footprint and are designed to still surface water runoff and allow time for suspended sediment to settle out to meet EPA discharge limits. The water quality basins need to be emptied within five days following a storm event to comply with EPL conditions. This requirement means that the water source is temporary and variable and would only be able to be used in an opportunistic manner for construction activities. It is also noted that key water demands, such as dust suppression and fill conditioning would be reduced during period of rain when the supply is available following storm events
  - Where the invert of the water quality basin is below the water table, there is potential for mixing of runoff water with groundwater. In cases such as this, the quality of the groundwater would influence the quality of the water held in the basin following a storm event.
- Temporary construction dewatering
  - Where excavations for construction proceed below the water table, temporary dewatering would be required. An assessment of dewatering requirements is provided in **Section 5.2.3**. Key activities that proceed below the water table and would require dewatering include water quality basins, excavation for bridge pier foundations, and the adjustment of Purgatory Creek.
- Soft soil consolidation wick drains
  - Vertical wick drains would be installed in soft soil areas at Tarro and Tomago to accelerate the rate of consolidation by allowing excess pore water pressure to dissipate via the wick drains. During this process water is extruded from the soil and would discharge at surface. Discharges from wick drains have been incorporated in the water balance. It is assumed that wick drain discharges would be diverted to local water quality basins with potential for use as a project water source.
- An assessment of local groundwater quality at each water basin and the potential mixed basin water quality (as salinity) is provided in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS) and is incorporated into the water balance
- An assessment of local groundwater quality (as salinity) at each dewatering location is incorporated into the water balance.

7.3 Project discharge locations

Project activities that require discharge of water include temporary construction dewatering (at water quality basin excavations, bridge pier foundation excavations, and the Purgatory Creek drainage channel adjustment) and water produced from soft soil consolidation wick drains. Water produced from temporary construction dewatering or wick drains would be directed where possible to local water quality basins, or to transportable sedimentation settling tanks. Details of construction water discharges and their management are provided in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS) and would be detailed in the Soil and Water Management Plan of the project Construction Environmental Management Plan (CEMP).

7.4 Water balance assumptions

Key assumptions made in compiling the project construction water balance are as follows:

- Timing of all water demands, dewatering, and wick drain discharges are based on the 80% Concept Design construction schedule
- Construction commences on 31 July 2024 and ends 27 May 2027. August 2024 is month one of construction. Construction extends over a 35 month period
- Water produced from temporary dewatering (typically of the order of two to 10 days duration per event) is averaged over the corresponding construction month(s)
- Water quality basins are not available as a water supply option until month 12 (July 2025) to reflect the timing of basin construction
- Water quality basins are required to be emptied within five days of a storm event. To allow for this in the construction water balance, it is assumed that only 25% of the runoff volume is available for use
- It is assumed that 100% of dewatering discharge is available for use (water quality dependent)
- Water use quality constraints (upper limit) as outlined in **Table 7-2** are applied
- All water for potable supply and concrete batching is imported.

7.5 Water balance scenarios

The base case water balance scenario is based on the supplied construction water demands (**Appendix I**) and median monthly rainfall. Water balance input variations for wet and dry scenarios are summarised on **Table 7-3**.

Table 7-3 Water balance scenarios

Scenario	Inputs			Demands				
	Basins	De-watering	Wick-drains	Potable	Concrete	Land-scaping	Dust suppression	Fill conditioning
Dry	15%ile rainfall	Base case	Base case	Base case	Base case	Base case plus 50%	Base case plus 50%	Base case plus 20%
Wet	85%ile rainfall	Base case	Base case	Base case	Base case	Base case less 50%	Base case less 50%	Base case less 20%

7.6 Water balance results

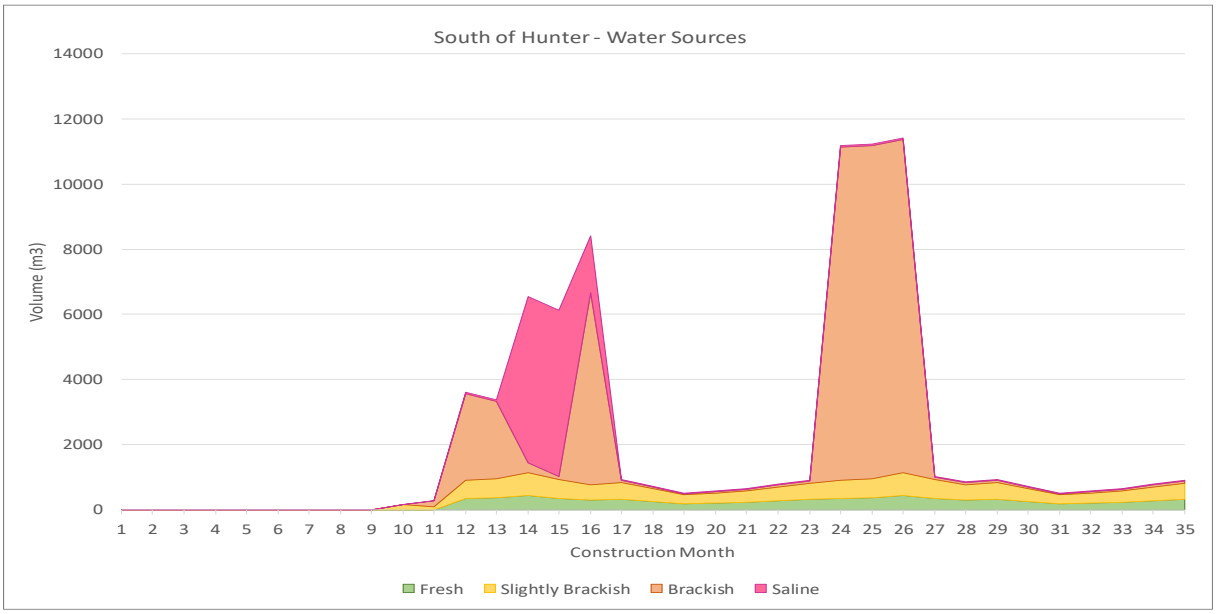
Water balance outputs are summarised on **Table 7-4** with base case scenario presented graphically on **Figure 7-1** and **Figure 7-2** for results south of the Hunter River and north of the Hunter River respectively. Full water balance outputs are provided in **Appendix I**.

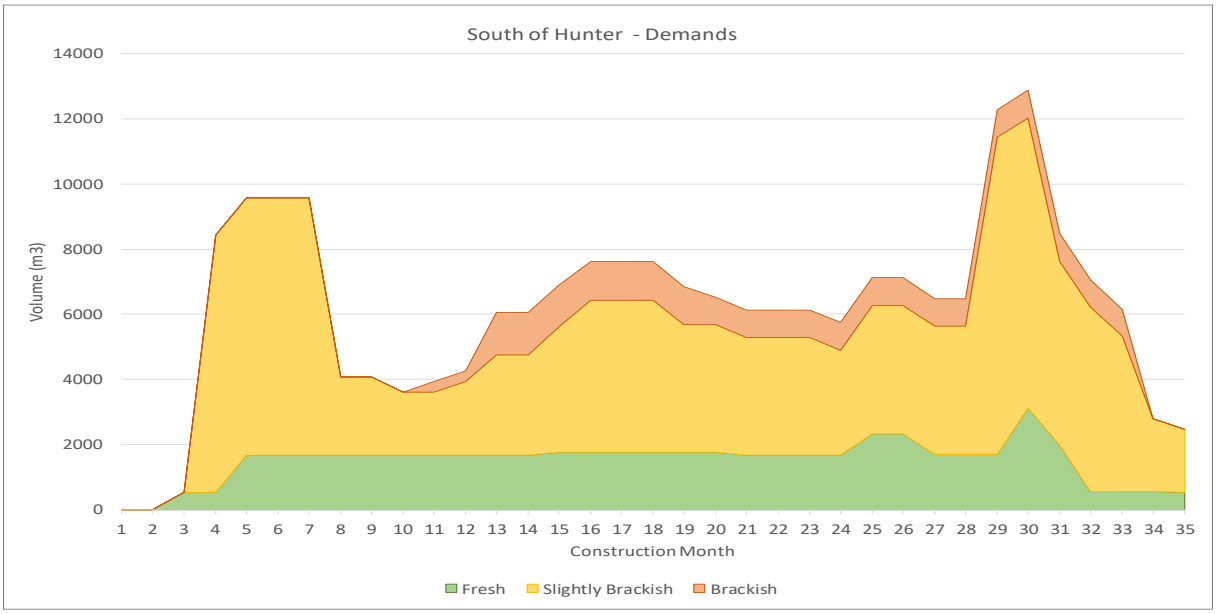
Key water balance outputs for the base case scenario are:

- The project would operate with a net deficit of water even without considering the limitations on water use and availability, with net demand exceeding net supply by approximately 7.3 ML/month or 254 ML over the construction phase
- With consideration for limitations on water re-use and availability, the project would need to import approximately 10.6 ML/month or 370 ML of potable water over the construction phase
- Given the limited opportunity for re-use, the majority of runoff water captured in the water quality basins would be discharged. Over the project construction phase, an average of 2.66 ML/month, and a total of approximately 93 ML are anticipated to be discharged
- The project is expected to produce a total volume of approximately 26 ML of saline water from temporary construction. Highly saline water would be reused in applications where there is minimal risk of harm to biodiversity, infrastructure, existing soils or entry into waterways (such as compaction of elevated formations, dust suppression etc) and where the salinity is commensurate with existing soil and groundwater conditions
- From **Figure 7-1**, the increase in water sources in months 11 to 17 is largely the result of the temporary construction dewatering. The large increase over months 24, 25, and 26 is due to soft sediment consolidation and wick drain discharge at Tarro
- From **Figure 7-2**, the increase in water sources in months 8 to 25 is due to both temporary construction dewatering and wick drain discharge at Tomago (months 8 to 16). Additional dewatering occurs over 25 to 28 for pier foundation excavation and construction
- The production of saline and brackish water through dewatering and wick drain extrusion occurs predominantly on the low lying floodplain areas
- The dry season water balance scenario results in a 29 per cent increase in makeup water demand and a 25 per cent reduction in discharge
- The wet season water balance results in a 30.5 per cent reduction in makeup water demand and 48% increase in discharge.

Table 7-4 Water balance summary

Water balance component	Base case volumes (ML)		Dry scenario volumes (ML)		Wet scenario volumes (ML)	
	Monthly average	Project total	Monthly average	Project total	Monthly average	Project total
South of Hunter summary						
Inputs - demand (net surplus / deficit)	-4.06	-142.03	-6.22	-217.61	-1.58	-55.27
Make up water required - potable and concrete	*1.48*	*51.80*	*1.48*	*51.80*	*1.48*	*51.80*
Make up water required - Landscaping, dust suppression, pavements	*3.96*	*138.53*	*5.70*	*199.62*	*2.14*	*74.95*
Make up water required - Fill conditioning	*0.43*	*15.14*	*0.53*	*18.45*	*0.33*	*11.68*
Total make up required (imported potable)	**5.87**	**205.47**	**7.71**	**269.87**	**3.96**	**138.43**
Discharge to environment (brackish upper limit)	**1.47**	**51.28**	**1.15**	**40.29**	**2.02**	**70.57**
Disposal (saline)	**0.36**	**12.60**	**0.35**	**12.13**	**0.38**	**13.47**
North of Hunter summary						
inputs - demand (net surplus / deficit)	-3.21	-112.19	-4.76	-166.77	-1.31	-45.97
Make up water required - potable and concrete	*1.42*	*49.84*	*1.42*	*49.84*	*1.42*	*49.84*
Make up water required - Landscaping, dust suppression, pavements	*1.91*	*66.99*	*2.73*	*95.57*	*1.11*	*38.85*
Make up water required - Fill conditioning	*1.38*	*48.23*	*1.77*	*61.99*	*0.87*	*30.39*
Total make up required (imported potable)	**4.72**	**165.06**	**5.93**	**207.41**	**3.40**	**119.09**
Discharge to environment (brackish upper limit)	**1.19**	**41.79**	**0.84**	**29.48**	**1.92**	**67.15**
Disposal (saline)	**0.39**	**13.59**	**0.39**	**13.59**	**0.39**	**13.59**
Project total						
Total make up required (imported potable)	**10.59**	**370.53**	**13.64**	**477.28**	**7.36**	**257.52**
Discharge to environment (brackish upper limit)	**2.66**	**93.08**	**1.99**	**69.77**	**3.94**	**137.73**
Disposal (saline)	**0.75**	**26.19**	**0.73**	**25.72**	**0.77**	**27.06**





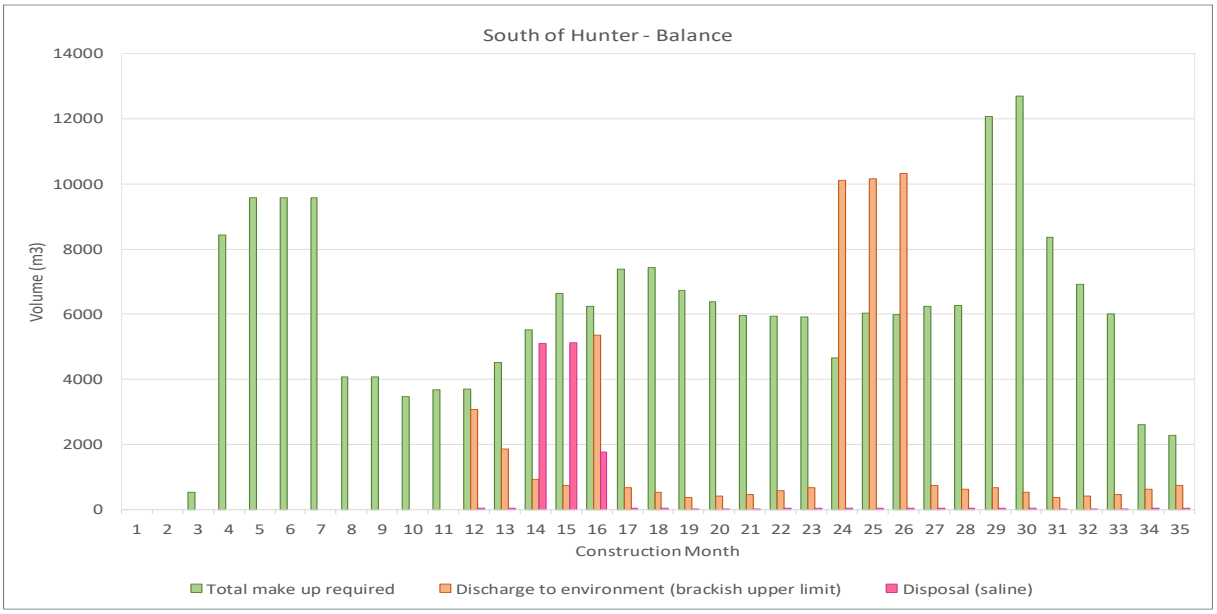
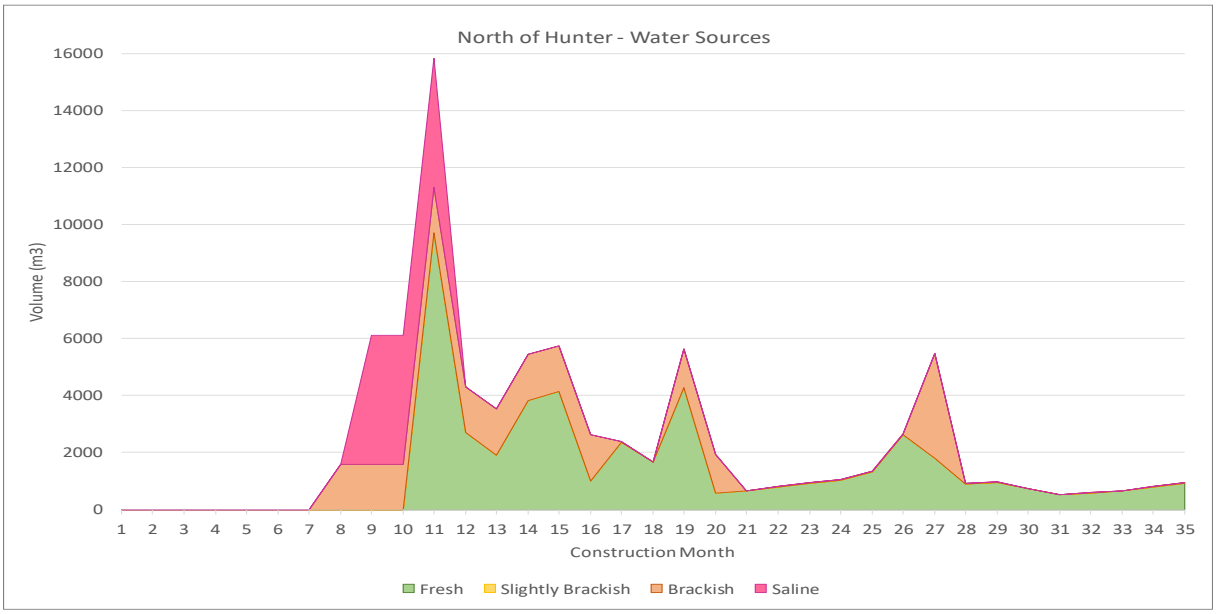
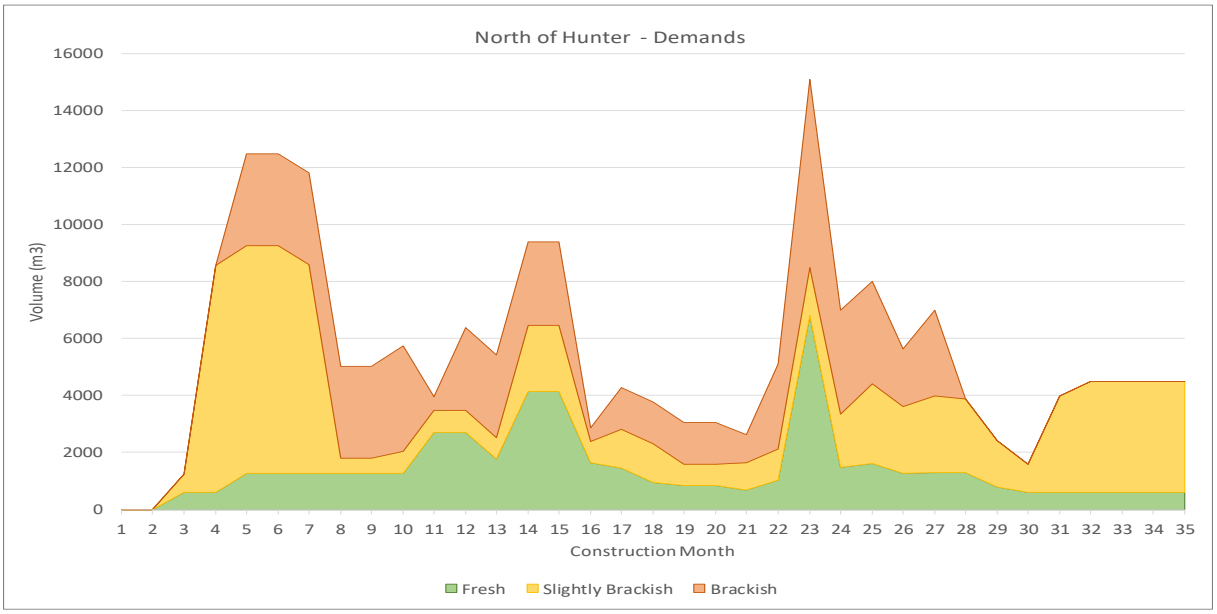


Figure 7-1 Construction water balance – south of Hunter River





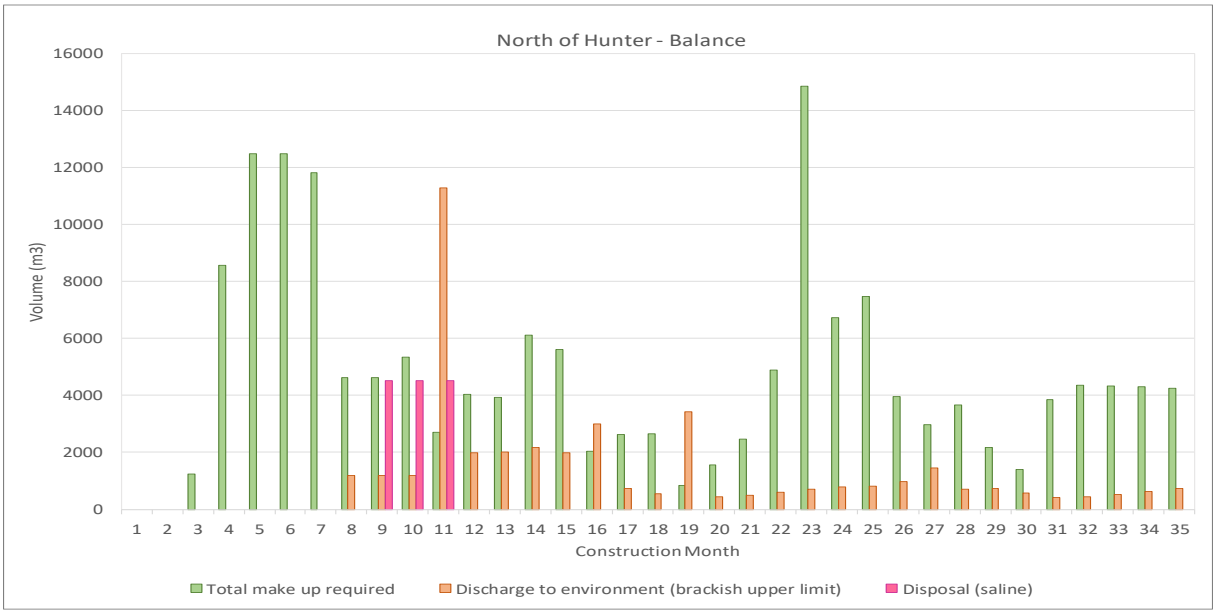


Figure 7-2 Construction water balance – north of Hunter River

8. Environmental management measures

The following management measures included in **Table 8-1** have been developed to specifically manage potential impacts which have been predicted as a result of the proposed works. These measures should be incorporated into relevant Environmental Management Plans (EMPs) during construction and operations.

Table 8-1 Environmental management measures

Impact	Reference	Management measure	Responsibility	Timing
Flooding impacts during construction	FH01	A Flood Management Plan (FMP) will be prepared for the project and will detail the processes for flood preparedness, materials management, weather monitoring, site management and flood incident management. The FMP will also address procedures and responsibilities for flood response (preparation of site upon receipt of flood warning, evacuation of site personnel) during and recovery following a flood event. The FMP will also include: • Consideration of temporary traffic arrangements to minimise impact on flood evacuation route traffic capacity. • Appropriate measures to manage potential flood impact associated with temporary ancillary facilities subject to flooding within 20% AEP flood level • Where feasible, the size of the ancillary facilities and the height and extent of temporary access tracks will be reduced to minimise flood impacts • Ancillary facilities will also be designed to provide for conveyance of flood flows in order to minimise flooding impacts to adjacent properties and environment	Transport / Contractor	Prior to construction
Potential changes to flood impacts resulting from detailed design	FH02	Any changes to the design described in this EIS would be further investigated during detailed design, including further flood investigations and hydrological and hydraulic modelling to ensure the flood immunity objectives and performance criteria for the project are met. The detailed design will consider refinement to temporary and permanent access roads to further reduce flood afflux with impacts to drainage capacity, where reasonable and feasible.	Transport/ Contractor	Detailed design
Flooding impacts on property	FH03	Consultation will be carried out with landowners impacted by flood affects from the project which exceed the flood management objectives (afflux, change in flood hazard, change in time of inundation) about reasonable and feasible management measures. Further modelling may be carried out at detailed design to assess impacts to property.	Transport / Contractor	Detailed design

Impact	Reference	Management measure	Responsibility	Timing
Impacts on existing drainage systems	FH04	Existing hydraulic capacity of drainage systems will be maintained during construction where practicable.	Contractor	Construction
	FH05	The requirement to provide further upgrades to existing drainage systems will be considered at detailed design where there is: • An increase of more than 20 per cent in the peak discharge rate during operation • An increase in drainage system capacity within the project footprint but where downstream infrastructure has not been upgraded.	Contractor	Detailed design
Impacts to flood mitigation schemes	FH06	The design of temporary and permanent works will ensure there is minimal impact to the function and flow capacity of the Hunter Valley Flood Mitigation Scheme or as otherwise agreed during consultation with operators of the scheme.	Transport / Contractor	Detailed design
Impacts to river banks immediately downstream of project discharge locations during construction	FH07	Monitoring of temporary construction phase stormwater discharge locations to minimise downstream geomorphological impacts from the project will be included in the Construction Soils and Water Management Plan.	Contractor	Construction
Impacts to river banks immediately downstream of project discharge locations during operation	FH08	The project design aims to ensure that stormwater discharge velocities are controlled at the project outlet to ensure minimal downstream impacts occur immediately downstream of the project. A geomorphological survey will be completed of the waterways downstream of the discharge points where there is greater than 20 per cent increase in stormwater discharge from the project. Waterways (channels and banks) immediately downstream of these project discharge locations will be monitored for a minimum period of twelve months or until establishment and stabilisation. Monitoring will look for evidence of initiation of erosion and scour and, if required, carry out appropriate remediation measures.	Transport	Operation
Impact to surface water and groundwater hydrology	FH09	Baseline monitoring of hydrological attributes would be carried out prior to the commencement of construction, with ongoing monitoring during construction and the initial stages of operation (refer to **Appendix K** and **Appendix L**) Should unforeseen impacts arise that are not already addressed by the environmental management measures outlined in this table, appropriate responses and management measures will be developed in consultation with the relevant authority.	Transport/ Contractor	Prior to construction/ construction/ operation

9. Conclusion

The existing road network has a low level of flood immunity. The Pacific Highway has a flood immunity of 20% AEP, with the road becoming flood-affected in several locations in Hexham and Tomago. During the 10% AEP event large sections are flooded particularly at Hexham and between Hexham Bridge and Tomago Road. Once operational the project would improve the trafficability of the road access between Black Hill and Raymond Terrace during flood events for all road users.

Minor and manageable impacts associated with surface water, groundwater and flooding are described in **Section 9.1.1**, **Section 9.1.2** and **Section 9.1.3**.

9.1.1 Surface water hydrology

Operational phase hydraulic modelling results indicate that the project may result in a moderate increase to the rate, volume and velocity of stormwater discharged downstream of the project. Although modelling was not completed for the construction phase of the project, potential changes to stormwater discharges are expected to follow the same trend of increased rates, volumes and velocity.

As a result of the quantified changes to stormwater discharge (moderate increase to the rate, volume and velocity of stormwater discharged), the project is likely to result in the following additional changes to existing receiving environment flow regimes during operation:

- A minor reduction in baseflow and moderate increase to quickflow contributions
- Minor to moderate increases to the rates of water level rise and fall
- Minor changes to the number, duration and magnitude of low flow events.

Changes to existing flow regimes identified above may result in impacts to local receiving waterway processes and health, immediately downstream of project discharge locations from storm events. Impacts include increased erosion and water turbidity, reduced bank stability and minor increases to the duration and depth of inundation for overbank events.

These impacts will be managed through the implementation of a construction phase erosion and control plan and during the operational phase by implementation of appropriate hydraulic design controls such as erosion and scour protection, and energy dissipation. Regular monitoring of key waterways immediately downstream of project discharge locations will be conducted for a minimum period of twelve months or until establishment and stabilisation to identify evidence of erosion and scour (if present) and initiate appropriate remediation measures, refer to **Appendix K**.

9.1.2 Groundwater

Potential impacts to groundwater levels and flow due to the project are negligible to minor and would be limited to the vicinity of the construction footprint. Changes to groundwater levels or flow are not anticipated to materially affect any GDEs (including high priority GDEs), baseflows, or existing groundwater users. Groundwater flows, water levels, or supply capacity of the Tomago Sandbeds Catchment Area drinking water supply will not be impacted by project construction or operation. Some long-term and very localised impediment to groundwater flow would occur as a result of soft soil consolidation, however this is not expected to have any material impacts on groundwater users or systems. A groundwater monitoring program is outlined in **Appendix L**.

9.1.3 Flooding

Flooding impacts during construction include flood level increases of generally 0.02 to 0.1 metres in the 5% AEP event. This increment exceeds the adopted flood management criteria. There are 19 lots and five habitable buildings , including one dwelling near the Tarro interchange, identified as experiencing afflux exceeding the adopted criteria during construction. Flood level increases of up to 0.02 metres reach Raymond Terrace and beyond the current flood model extent.

During operation, flood level increases of generally 0.02 to 0.04 metres in the 5% and 1% AEP event are expected to occur. A dwelling near the Tarro interchange experiences an increase of up to 0.06m, which exceeds the afflux design objective criterion during a 5% AEP flood event. Flood levels in vegetated local catchments on the eastern side of the project and between the viaduct and Heatherbrae change by up to +/- 0.1 metres as a result of changed transverse drainage capacity.

In the probable maximum flood event for the operational phase there are extensive flood level increases upstream of the project crossing of the Hunter River of 0.05 to 0.08 metres, which would extend up the Hunter River and Williams River upstream of the limit of mapping. There are increases exceeding 0.1 metres around the viaduct. The assessed flood impacts in events between the 10% AEP and probable maximum flood events reach Raymond Terrace and beyond the current flood model extent.

Predicted increases in peak flood levels during construction exceed the maximum tolerable limits in the adopted flood management objectives, noting that this would be for a short period of time during construction of the project. Increases in peak flood levels are generally within the maximum tolerable limits in the adopted flood management objectives. There is expected to be no or low impact to drainage capacity of adjusted watercourse channels.

Increases in flow velocities and flood hazard in the construction and operational phase are localised rather than widespread and indicate negligible impact to floodway, flood storage and flood conveyance. Increases in duration of flooding in the construction and operational phase are generally negligible to minor, typically +/- five per cent from existing durations.

Broadly, the project achieves the flood management objectives and criteria discussed in **Section 3.6.3**, including for afflux, flood hazard and flood duration. The large majority of flood-affected residential, commercial and industrial properties in the existing case experience negligible change in flood depth (+/- 0.01 metres change), hazard and time of inundation (+/- three hours) during operation of the project. Note that flooding impacts which have been identified on individual lots does not necessarily translate to an impact to buildings or dwellings on those lots, as the buildings may be subject to nil change in flood depth, or are not flood affected. There are 10 lots and one habitable building identified as experiencing afflux exceeding the adopted criteria during operation.

Negligible to minor impacts are expected to agricultural and grazing activities, emergency services (including evacuation routes), future development potential of affected lands, existing roads and rail infrastructure. Beneficial outcomes from the project include provision of a new flood emergency and evacuation access route (the project itself) between Black Hill and Raymond Terrace with a minimum 5% AEP flood immunity, which is a significant improvement from the current 20% AEP flood immunity in sections of the existing Pacific Highway.

Project construction phase activities need to ensure that modified traffic arrangements do not impact on flood evacuation routes. The project will impact on the Hunter Valley Flood Mitigation Scheme as a result of proposed access roads to be constructed immediately next to the existing flood levees on the western Hunter River floodplain which may affect the structure, functioning and maintenance of the levees, however there will be no impacts to the operation, function or structural integrity of the scheme (this includes the floodgates). Transport would continue to consult with the operators of the scheme during detailed design to minimise impacts on the scheme.

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Terms and acronyms

Term / Acronym	Description
AGMG	Australian Groundwater Modelling Guidelines
AHD	Australian Height Datum
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. The following relationships between AEP and ARI applies to this study (AR&R, 2016).

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	0.50
	1	**63.2**	1.58	1.00
Frequent	0.69	**50.00**	2	1.44
	0.5	39.35	2.54	2.00
	0.22	**20.00**	5	4.48
	0.2	18.13	5.52	5.00
	0.11	**10.00**	10.00	9.49
Infrequent	0.05	**5.00**	20	20.0
	0.02	**2.00**	50	50.0
	0.01	**1.00**	**100**	100
Rare	0.005	0.50	**200**	200
	0.002	0.20	**500**	500
	0.001	0.10	**1000**	1000
	0.0005	0.05	**2000**	2000
Extremely Rare	0.0002	0.02	5000	5000
			↓	
Extreme			PMP	

ASS	Acid sulfate soils
Bgl	below ground level
BoM	Bureau of Meteorology
CPT	cone penetrometer testing
DRN	MODFLOW Drain package

Term / Acronym	Description
EIS	environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979*
EVT	MODFLOW Evapotranspiration Package
GDE	groundwater dependent ecosystem
OEH	Office of Environment and Heritage
RIV	MODFLOW River Package
SEPP	State Environmental Planning Policy
TEC	threatened ecological community
Transport	Transport for New South Wales
USGS	United States Geological Survey
WAL	Water Access License
WM Act	The *Water Management Act 2000*
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Development	Is defined in Part 4 of the EP&A Act In fill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. E.g. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. E.g. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
Effective Warning Time	The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
Exceedances per Year (EY)	The number of times an event is likely to occur or be exceeded within any given year.
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 local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
Floodplain risk management options	The measures that might be possible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

Term / Acronym	Description
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designed flood" or the “flood standard” used in earlier studies.
Flood readiness	Readiness is an ability to react within the effective warning time.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m AHD	Metres Australian Height Datum (AHD)
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Overland flow path	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.

Term / Acronym	Description
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as a streamflow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
XP-RAFTS	XP-RAFTS is a hydrologic modelling computer program which is used to simulate catchment rainfall-runoff and is widely used across Australia.

Appendix A Groundwater quantity modelling

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M1 Pacific Motorway extension to Raymond Terrace

Groundwater modelling report

Transport for New South Wales | October 2020

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1. Introduction

1.1 Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the Environmental Planning and Assessment Act 1979 (EP&A Act) and Part 9, Division 1 of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

The project would connect the existing M1 Pacific Motorway at Black Hill and the A1 Pacific Highway at Raymond Terrace within the Newcastle City and Port Stephens local government areas.

This report is a technical appendix to the Hydrology and Flooding Working Paper prepared to support the environmental impact statement (EIS) for the project. This report documents the existing environment, groundwater monitoring results and details and results of a numerical groundwater model used to assess potential impacts to groundwater due to the project.

Whilst numerical groundwater model results are documented in this report, impact assessment is outside the scope of this report and is covered in the project's Hydrology and Flooding Working Paper (Appendix J of the EIS). Groundwater quality is also outside the scope of this report and is covered in the project's Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

1.2 Project description

The project would include the following key features:

- A 15 kilometre motorway comprised of a four lane divided road (two lanes in each direction)
- Motorway access from existing road network via four new interchanges at:
  - Black Hill: connection to the M1 Pacific Motorway
  - Tarro: connection and upgrade (six lanes) to the New England Highway between John Renshaw Drive and the existing Tarro interchange at Anderson Drive
  - Tomago: connection to the Pacific Highway and Old Punt Road
  - Raymond Terrace: connection to the Pacific Highway.
- A 2.6 kilometre viaduct over the Hunter River floodplain including new bridge crossings over the Hunter River, the Main North Rail Line and the New England Highway
- Bridge structures over local waterways at Tarro and Raymond Terrace, and an overpass for Masonite Road in Heatherbrae
- Connections and modifications to the adjoining local road network
- Traffic management facilities and features
- Roadside furniture including safety barriers, signage, fauna fencing and crossings and street lighting
- Adjustment of waterways, including at Purgatory Creek at Tarro and tributary of Viney Creek
- Environmental management measures including surface water quality control measures
- Adjustment, protection and/or relocation of existing utilities
- Walking and cycling considerations, allowing for existing and proposed cycleway route access
- Permanent and temporary property adjustments and property access refinements
- Construction activities, including establishment and use of temporary ancillary facilities, temporary access tracks, haul roads, batching plants, temporary wharves, soil treatment and environmental controls.

A detailed project description is provided in Chapter 5 of the EIS. The locality of the project is shown in **Figure 1-1**, while an overview of the project is shown in **Figure 1-2**.

Figure 1-1 Regional context of the project

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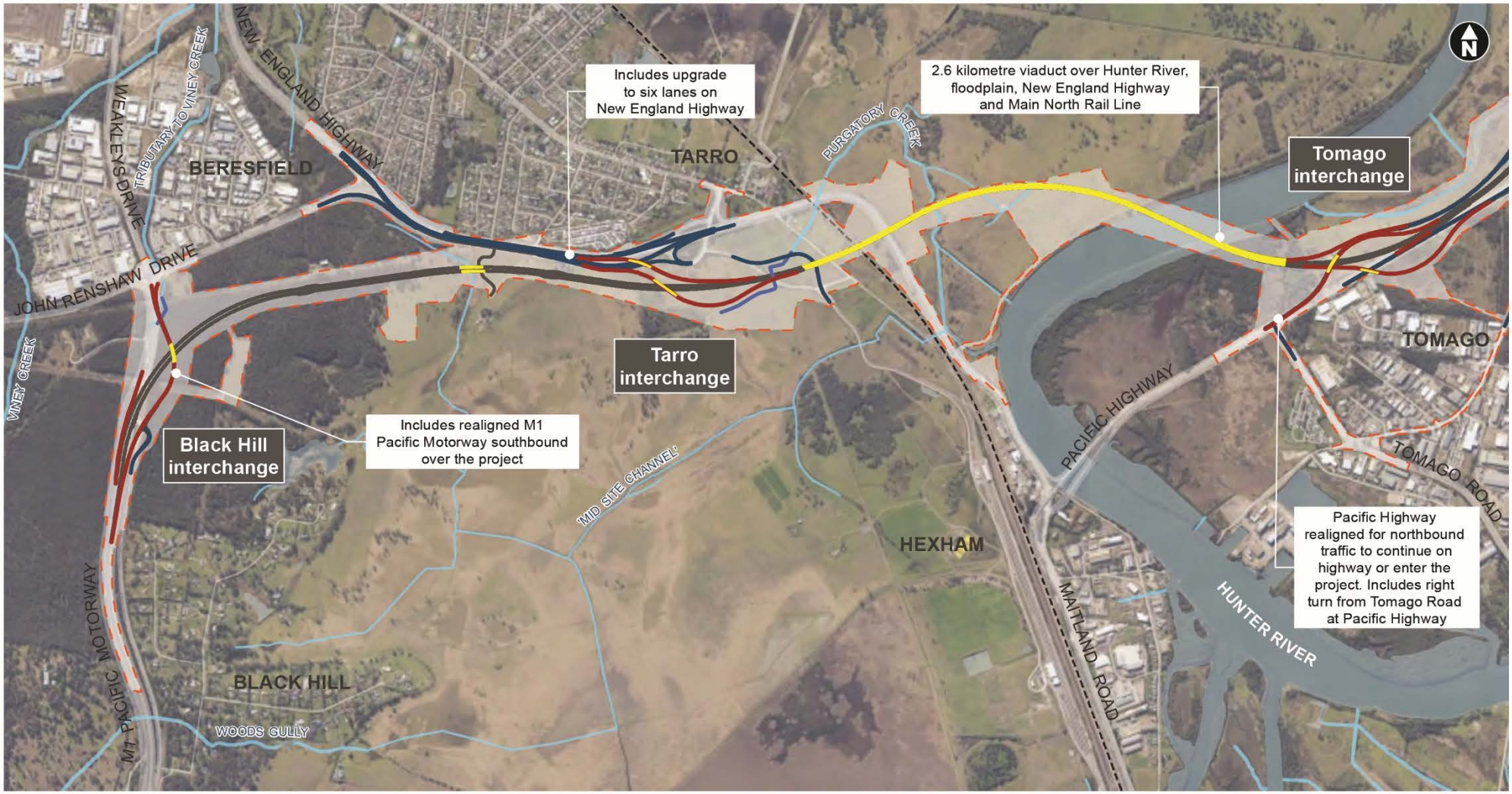

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Figure 1-2 Project key features (map 1 of 2)

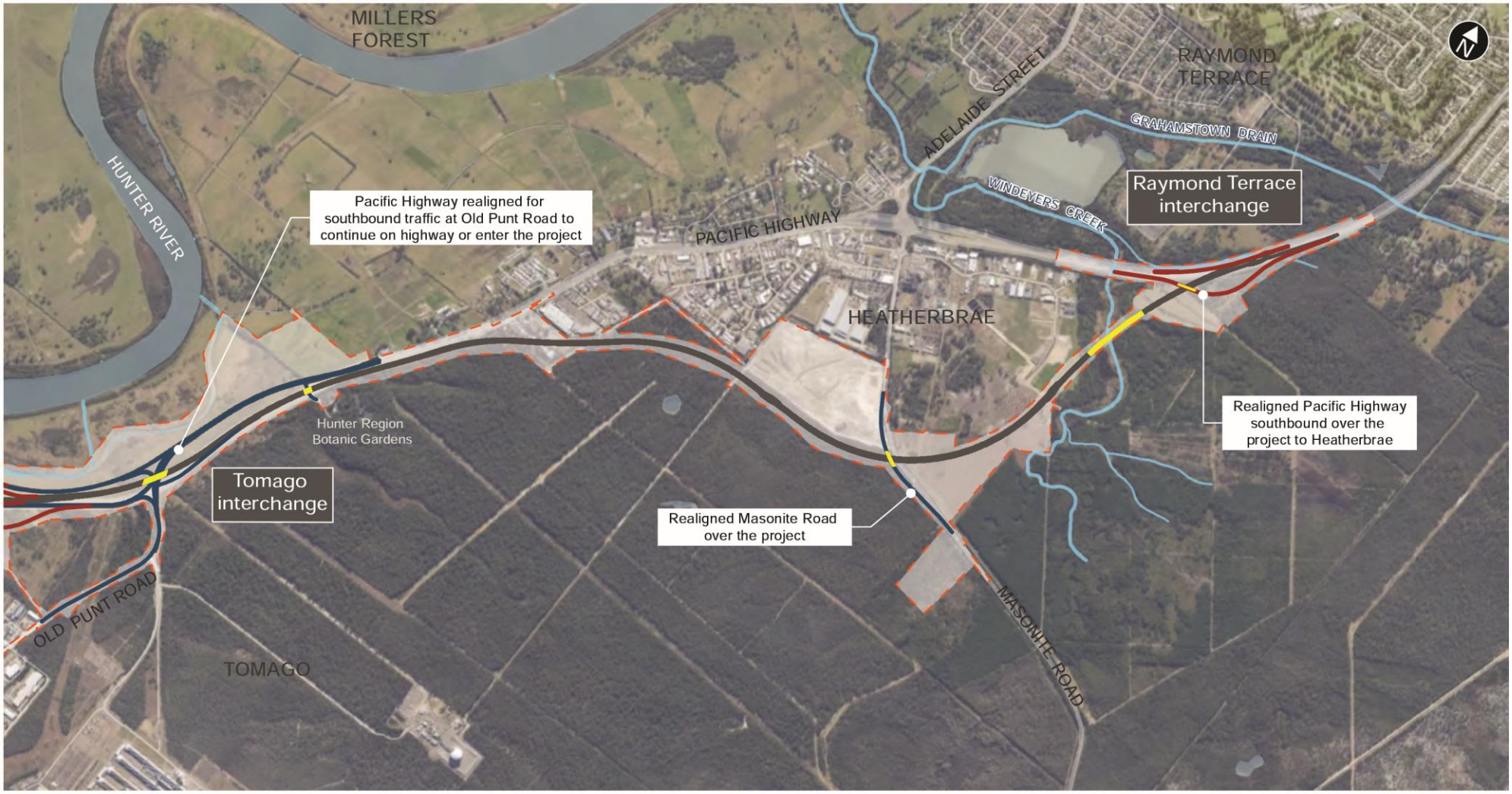

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Figure 1-2 Project key features (map 2 of 2)

1.3 Report structure

The report is structured as follows:

- Chapter 1 – introduces the project and report
- Chapter 2 – describes the methodology and approach
- Chapter 3 – describes the existing environment, including the physical characteristics of the groundwater systems in the vicinity of the project
- Chapter 4 – documents the approach and results of numerical groundwater modelling undertaken for the project for impact assessment purposes
- Chapter 5 – documents the approach and results of estimation of dissipation from consolidated soils.

As mentioned in **Section 1.1**, groundwater impact assessment and coverage of groundwater quality is outside the scope of this report and is covered in the project's Hydrology and Flooding Working Paper (Appendix J of the EIS) and Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS) respectively.

2. Methodology & approach

2.1 Study area

For the purpose of describing the existing environment, including the physical characteristics of the groundwater systems in the vicinity of the project, the same 'groundwater study area' (**Figure 2-1**) that was used in the groundwater impact assessment covered in the project's Hydrology and Flooding Working Paper (Appendix J of the EIS) was adopted.

The groundwater study area includes the construction footprint and a two kilometre buffer and was selected to encapsulate a large number of existing groundwater bores in the vicinity of the proposal, to increase the amount of bore data available for analysis.

It is noted that the groundwater model, which was developed for assessment purposes, extended beyond the groundwater study area boundary, to enable incorporation of appropriate model boundary conditions.

2.2 Methodology

2.2.1 Overview

Existing environmental conditions and values were evaluated through:

- Desktop assessment, and
- Field assessment (**Section 2.2.2**).

Groundwater systems in the vicinity of the project were modelled within a three dimensional numerical groundwater model. The methodology for the construction and implementation of the numerical groundwater model is described later in this report, in **Chapter 4**.

2.2.2 Field assessment

Field assessment undertaken for the project is covered comprehensively in **Section 3.9**, with an investigation summary provided below. Field assessment included:

- Pore pressure dissipation tests via cone penetrometer testing (CPT) (refer **Figure 2-2**)
- Establishment of a groundwater monitoring network, which included a total of 20 piezometers at 13 locations, comprising six single and seven paired (one deep and one shallow) installations (refer **Figure 2-2**)
- Groundwater monitoring at the project piezometers, which included:
  - Four groundwater quality sampling rounds, spanning between September 2016 and July 2017, including testing of field parameters (electrical conductivity, pH, temperature, redox and dissolved oxygen), collection of groundwater samples and subsequent laboratory analysis of a broad analytical suite
  - Five groundwater level sampling rounds, spanning between September 2016 and July 2017, including manual dip gauging of groundwater level and download of groundwater level data loggers (six-hourly data recording frequency), which were installed at 12 of the project's 20 piezometers.

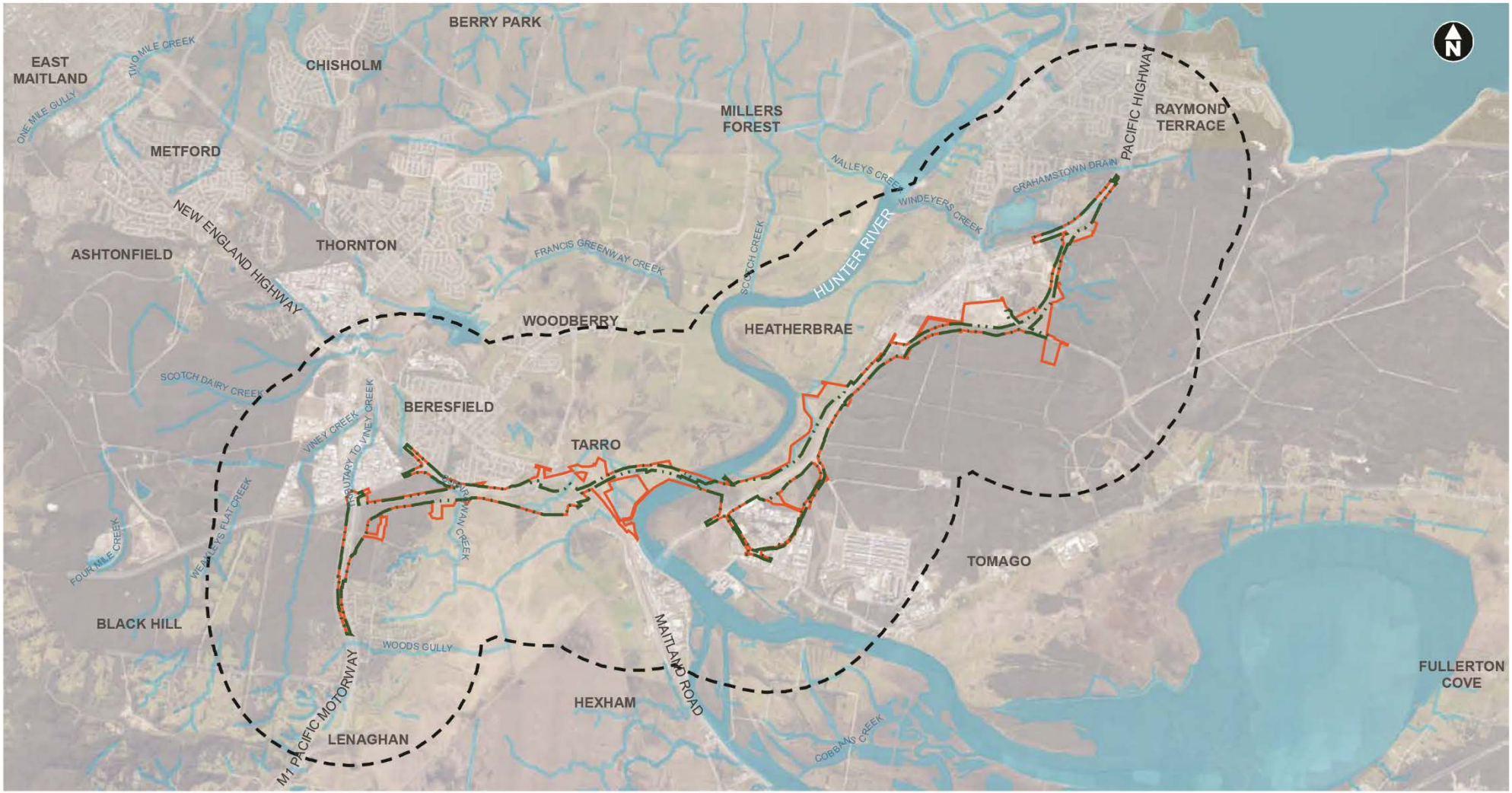

Figure 2-1 Study area – Groundwater assessment

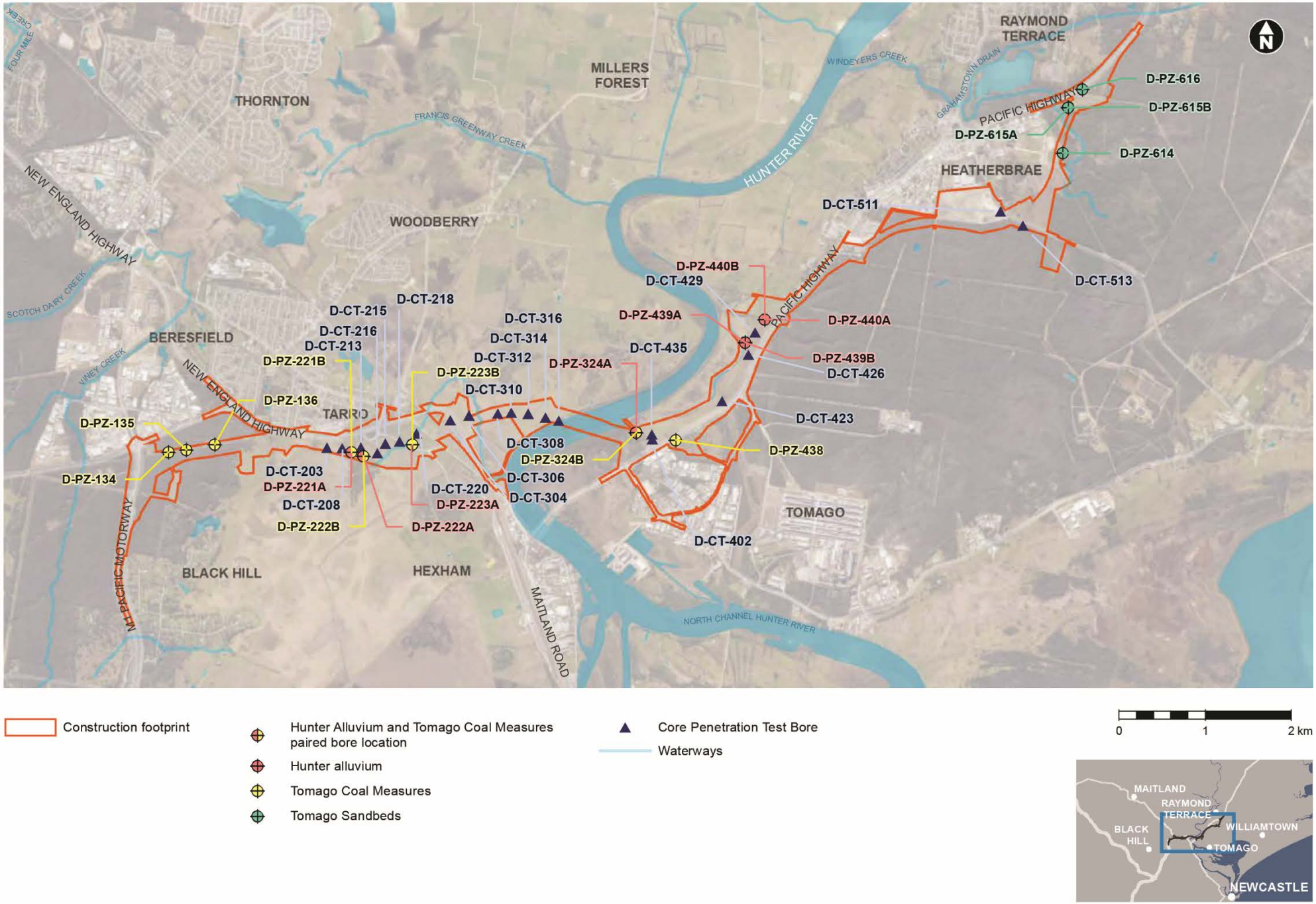

Figure 2-2 Groundwater investigations

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3. Existing environment

3.1 Climate

The project area lies within a temperate climate with average annual rainfall of the order of 1,040 to 1,118 millimetres (Bureau of Meteorology (BoM) Station Nos. 061031 (Raymond Terrace) and 061078 (Williamtown RAAF)). Summers are warm with average minimum and maximum temperatures of about 17 and 28 degrees Celsius, respectively. Winters are relatively mild with average minimum and maximum temperatures of six and 19 degrees Celsius.

3.1.1 Rainfall

BoM Station No. 61031 (Raymond Terrace) has a complete rainfall data record from 1895 to 1998, while from 1998 to present, most years have one or two data gaps for monthly rainfall. Monthly rainfall statistics are provided in **Table 3-1**. August and September are historically the driest months, with the most rain falling in March.

Table 3-1 Monthly rainfall statistics - Raymond Terrace (BoM station 61031)

Statistic	Rainfall (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	97	106	119	107	91	106	71	63	63	69	72	86	1,041
Lowest	6	0	2	2	1	3	0	0	0	1	1	2	536
5th %ile	15	12	21	12	14	14	6	6	5	10	8	15	680
10th %ile	18	20	29	24	19	21	12	10	11	19	18	20	718
Median	82	85	102	83	69	75	58	41	46	51	63	73	1,025
90th %ile	186	204	228	223	197	224	152	137	136	142	146	149	1,390
95th %ile	258	278	275	273	240	264	175	171	181	192	169	211	1,477
Highest	410	590	396	525	367	550	316	477	245	267	255	391	1,872

3.1.2 Evaporation

Monthly evaporation data for Williamtown RAAF Base (BoM Station 061078) is summarised in **Table 3-2**. Data for Williamtown is shown as opposed to Raymond Terrace because evaporation data was not available for Raymond Terrace. Average monthly evaporation exceeds average monthly rainfall for all months except May and June. The average annual rainfall deficit is about 711 millimetres.

Table 3-2 Monthly evaporation – Williamtown RAAF Base (BoM Station 61078)

Statistic	Evaporation (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average daily evaporation (mm)	6.9	6.2	5.0	3.8	2.7	2.5	2.6	3.6	4.7	5.6	6.3	7.2	4.8
Average monthly evaporation (mm)	214	174	155	114	84	75	81	112	141	174	189	223	1,752

3.2 Topography

Elevation and topography varies along the project's alignment with three distinct areas as follows (refer to **Figure 3-1**):

- Western portion – comprises gently sloping ground from about four metres Australian Height Datum (AHD) in the east to 22 metres AHD in the central northern portion (ridgeline orientated north to south)
- Central portion – comprises typically low lying flood plains at levels typically less than two metres AHD
- Eastern portion – comprises slightly undulating terrain with levels typically between two and eight metres AHD, with a localised elevated area (possibly fill area) adjacent to Masonite Road (western side) up to 20 metres AHD.

The site elevations generally suggest the absence of significant filling across the study area, however, due to the broad scale of the contours on **Figure 3-1**, indicators of site specific filling would not necessarily be evident. Localised filling associated with some industrial / commercial areas, existing roads and areas to the east of Masonite Road (and potential stockpile to the west) are, however, evident.

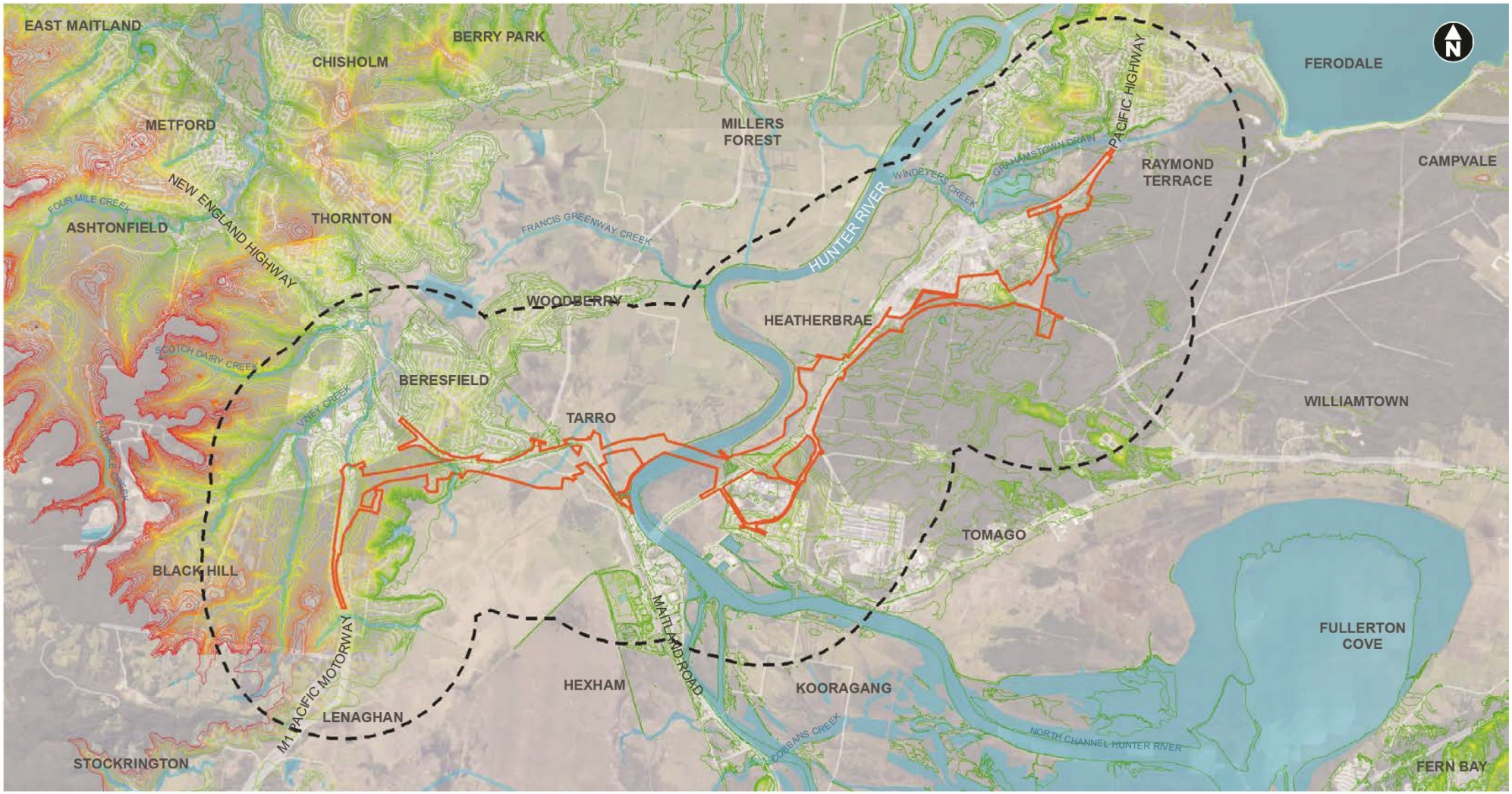

Figure 3-1 Topography of the project

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3.3 Hydrology and key water courses

Compressive discussion of water courses and wetlands is provided in the project's Hydrology and Flooding Working Paper (Appendix J of the EIS), with surface water quality specifically covered in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

3.4 Surrounding land use

Hunter River catchment

The project is located in the lower portion of the Hunter River catchment in NSW.

The lower reaches of the Hunter River form an open, wave-dominated barrier estuary which extends about 64 kilometres inland to its tidal limits at Oakhampton (OEH, 2017). The estuary supports a substantial fishery, particularly for School Prawn. Commercial fishing occurs from the ocean to Raymond Terrace (about 30 kilometres up river from the ocean) where prawns, several species of finfish and crustacean species are harvested.

The upper Hunter River catchment is predominantly an agricultural landscape on floodplains dispersed with smaller urban centres. The area surrounding the lower estuary is heavily urbanised with significant industrial, commercial and residential development and a major harbour port near the mouth of the estuary. The water quality of the Hunter River and other watercourses within the study area have been substantially affected by industrial development, coal mining, and agriculture. Land clearing has resulted in erosion and salinity issues within the Hunter River. The estuary and surrounding wetland systems of the lower Hunter River have also become degraded due to these activities, as well as from surrounding agricultural practices in the upper catchment and the installation of dykes and floodgates that have removed connectivity between wetlands and the main estuary channels (Taylor, et al, 2019).

Project vicinity

A range of land types and uses occur in the vicinity of the project, including woodland, agricultural grazing land, pockets of industrial and residential development and estuaries and wetlands.

The western area of the project includes existing portions of the M1 motorway and the New England Highway, areas of woodland and areas of agricultural grazing land. Pockets of industrial and residential development are located close to the project at Beresfield and Tarro respectively.

The central portion of the project traverses agricultural grazing land, wetland, the Hunter River and a pocket of industrial development at Tomago.

The north eastern portion of the project includes portions of the Pacific Highway and woodland, is close to industrial and commercial development at Heatherbrae and close to residential development at Raymond Terrace.

The Tomago Sandbeds Catchment area generally either underlies or is close to the central and northern portions of the project. Hunter Water Corporation groundwater bores used to extract groundwater for potable use are located within the Tomago Sandbeds.

Wastewater plants managed by Hunter Water discharge within the immediate catchment and influence the quality of water within the Hunter River. The wastewater treatment plant at Raymond Terrace discharges secondary treated water (at approximately 7.3 megalitres per day) to Windeyers Creek via Grahamstown Drain and then the Hunter River (Parsons Brinckerhoff, 2012).

3.5 Geology

Geology in the area of the project is shown on **Figure 3-2**, which has been sourced from the 1:100,000 scale regional geology map for Newcastle (Newcastle Coalfield Regional Geology, Sheet 9321, NSW Department of Mineral Resources).

The geology is characterised by the following components:

- The western end of the project near John Renshaw Drive at Black Hill is underlain by the Tomago Coal Measures of late Permian age. The lithology of the Tomago Coal Measures consists of shale, siltstone, fine sandstone, coal and minor tuffaceous claystone
- The Tomago Coal Measures also subcrop about two kilometres north of the Hexham Bridge
- The geology map suggests that the Mulbring Siltstone and the Muree Sandstone of the Maitland Group of middle to late Permian age are exposed near the northern end of the alignment. The lithologies of these units consist of siltstone, sandstone, conglomerate and minor clay
- Quaternary aged sediments are located elsewhere along the corridor. A brief summary of the quaternary aged alluvium is presented below:
  - The northern part and to the west of the alignment is dominated by a Pleistocene aged dune system which forms part of the Tomago Sand Beds. The sediments predominately comprise fine to medium grained sand. The Tomago Sandbeds are locally incised by Holocene aged alluvium, particularly around Windeyer's Creek near the northern parts of the site
  - Based on Roy & Boyd (1995), the Hexham area includes a deep paleo-valley where the Hunter River has incised a channel into the underlying Permian aged rocks. The channel has been filled with initially Pleistocene aged estuary deposits and channel sands which have since been overlain by Holocene aged swamp and flood deposits. The Holocene deposits are generally clay dominated soils which are normally or slightly over-consolidated.

The regional geology map indicates that the following geological structures pass through or close to the site:

- The Williams River Fault which consists of an emergent thrust fault and crosses the Hunter River in the vicinity of the proposed bridge crossing. The fault strikes approximately north-east and parts of the Hunter River and William River, north of the project site, follow the approximate alignment of the thrust fault
- Two 'normal' faults are shown traversing in a north-south orientation to the south of the corridor
- The Thornton Syncline is shown to cross the south-western part of the site. A second syncline is also shown north of the site and the axis of the syncline is oriented north-south.

The region is an area of low to moderate seismicity and lies within an intra-plate tectonic region. A significant earthquake occurred in December 1989 ('the Newcastle Earthquake') which registered approximately 5.6 on the Richter Scale, and was assessed to have a return period of about 500 years.

3.6 Soil

3.6.1 Soil landscapes

The Soil Landscapes of the Newcastle 1:100,000 Sheet indicates that the project traverses a number of soil landscapes, as shown in **Figure 3-3**. These include:

- Beresfield residual landscape (be) – western portion of the alignment between the Pacific Motorway and a gully along The New England Highway, and in the vicinity of Tomago
- Hamilton residual landscape (hm) – immediately east of the Beresfield landscape on the higher ground
- Millers Forest estuarine landscape (mf) – east of the Hamilton landscape within the lower lying land in Black Hill, Hexham and part Tomago (generally west of the Pacific Highway)
- Fullerton Cove estuarine landscape (fc) – along the Hunter River bank north of the Hexham Bridge
- Hexham Swamp landscape (hs) – between the Hunter River bank (fc) and Tomago Road, Tomago
- Tea Gardens Landscape Variant Aeolian landscape (tna) – north of Tomago to Windeyers Creek Heatherbrae
- Blind Harrys Swamp landscape (ba) – within the creek/swampy areas interesting the Pacific Highway near the Botanic Gardens
- Bobs Farm Beach Landscape (bfa) – within the Windeyers Creek alignment.

The majority of the study area is underlain by unconsolidated Quaternary aged sediments, which are dominated by Holocene soft soils.

3.6.2 Acid sulphate soils

As shown on **Figure 3-4**, based on Acid Sulfate Soil (ASS) risk mapping, ASS has the potential to be located in the construction footprint as described:

- Class One (Any works) – Within the Hunter River
- Class Two (Works below the ground surface) – On the southern side of the project between Black Hill and Hexham (between Tarro and Tomago), on the western side of the project in Heatherbrae and Raymond Terrace, and along Windeyers Creek and Grahamstown Drain
- Class Three (Works more than one metre below the natural ground surface) – In central Tomago, in central Black Hill and in Beresfield (adjoining the northern and western project extent)
- Class Four (Works more than two metres below the natural ground surface) – In Tarro at the western end of the Tarro interchange, in Tomago on the eastern side of the project, along Tomago Road, Old Punt Road, the existing Pacific Highway, Heatherbrae and Raymond Terrace
- Class Five (works within 500 metres of adjacent Class One, Two, Three or Four land that is below five metres AHD and by which the water table is likely to be lowered below one metre AHD on adjacent Class One, Two, Three or Four land) – At Black Hill and Beresfield.

ASS is covered comprehensively in the Soils and Contamination Working Paper (Appendix P of the EIS).

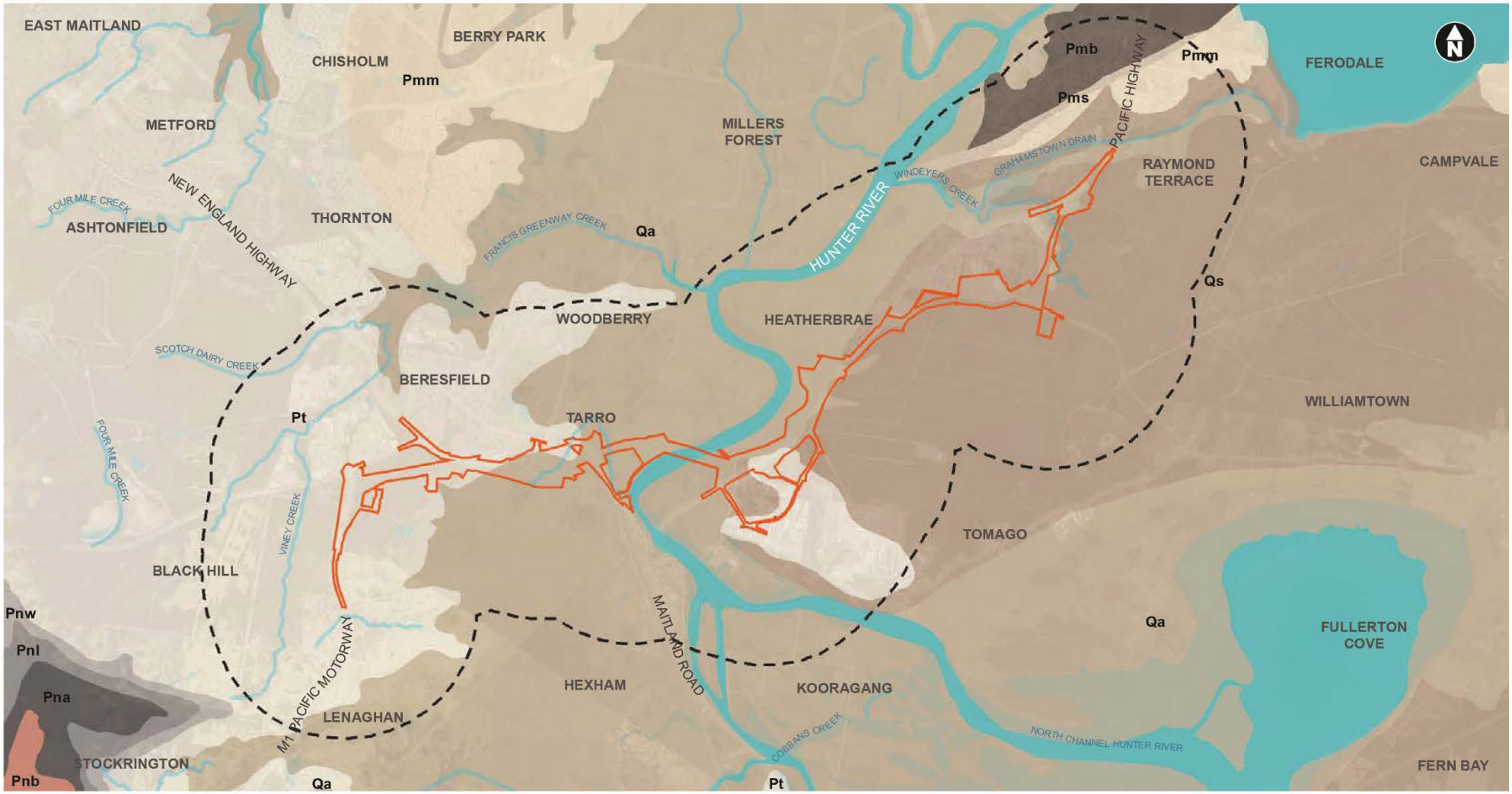

Figure 3-2 Regional geology (source: Newcastle Coalfield Regional Geology, 1:100,000 map sheet)

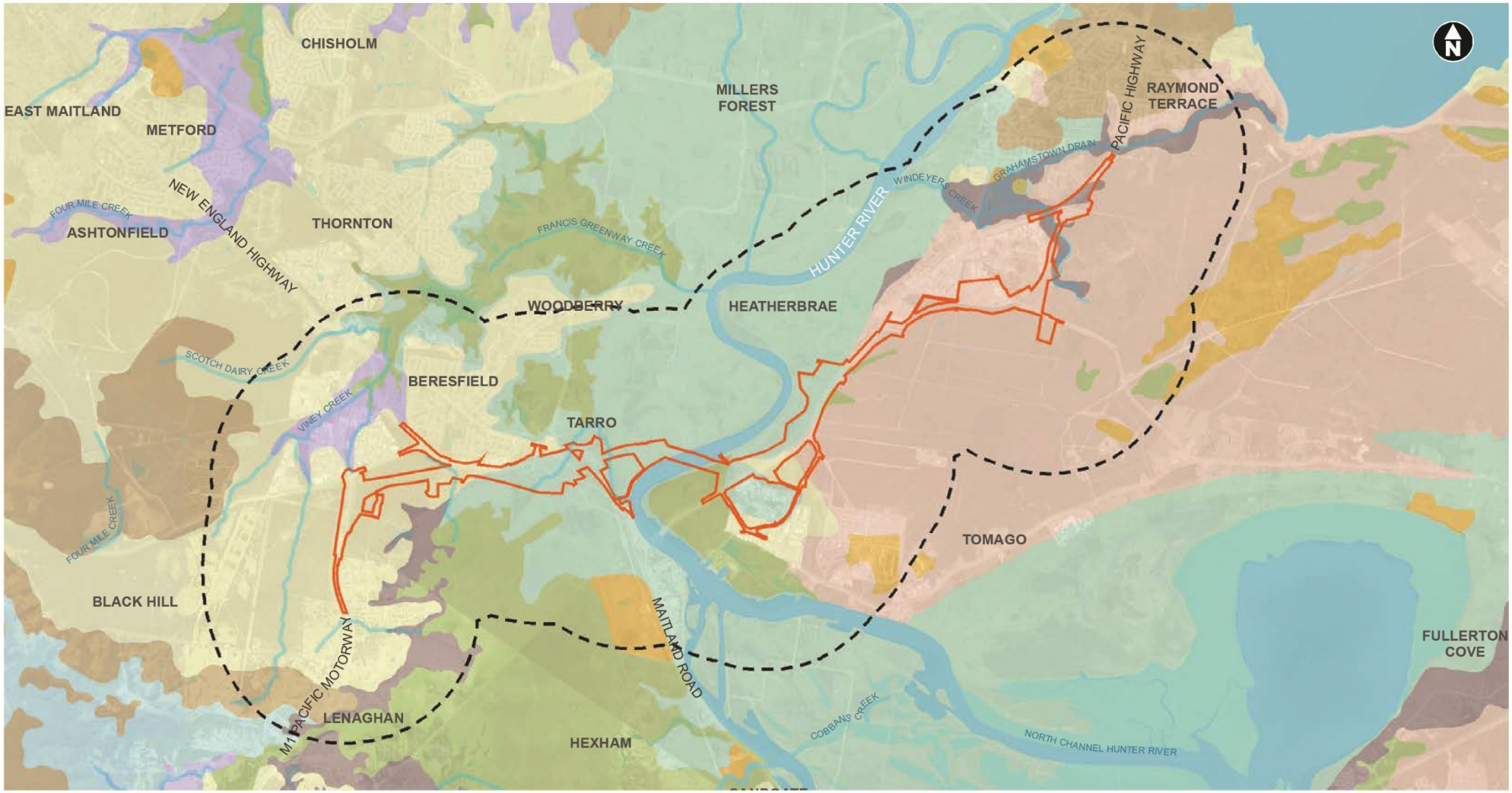

Figure 3-3 Soil landscapes (source: Newcastle 1:100,000 Soil Landscape Map)

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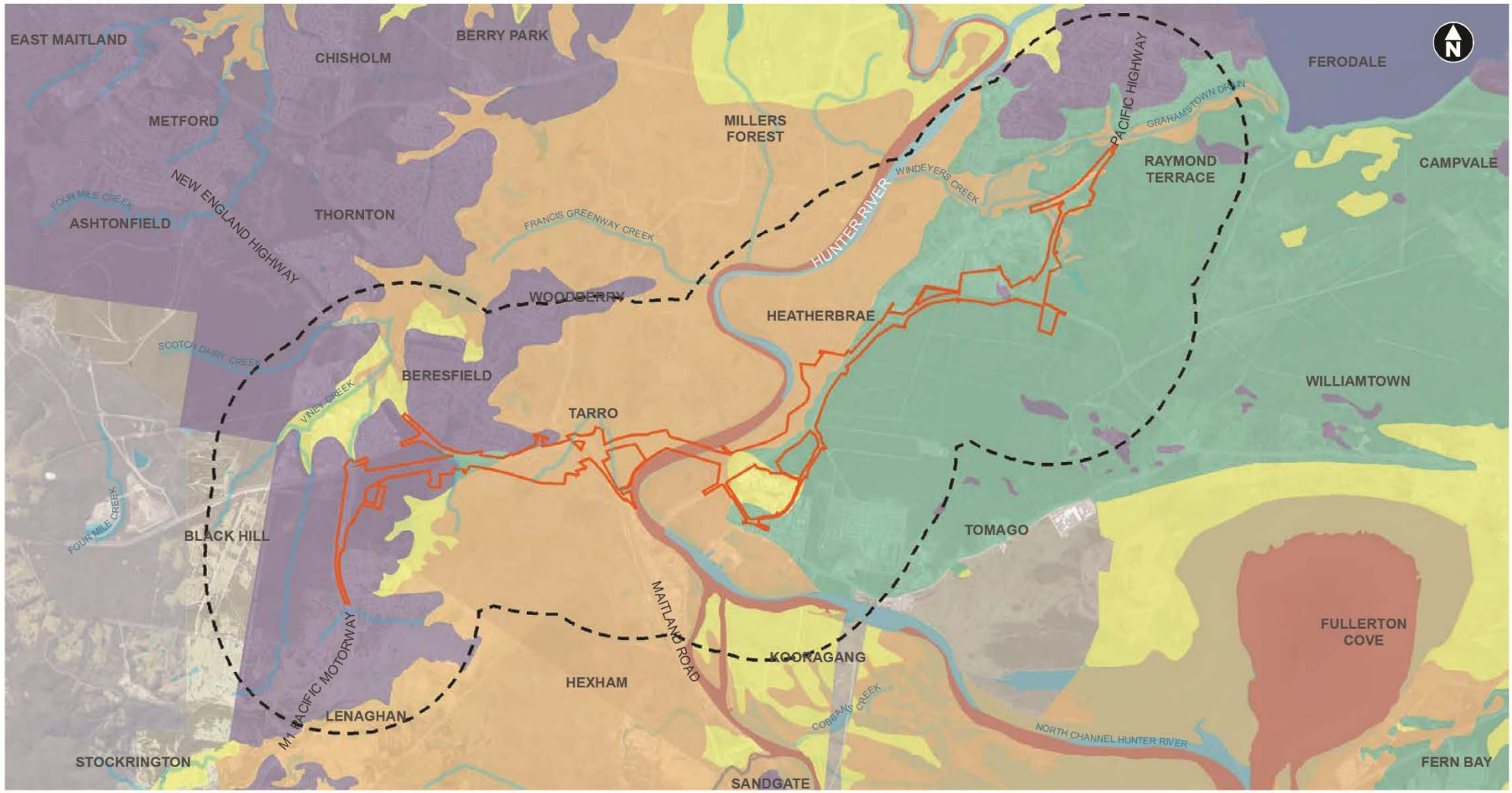

Figure 3-4 Acid sulfate soils (source: OEH 1:25,000 acid sulfate soil risk maps)

3.6.3 Salinity

Soil salinity is a complex issue relating to salt and water cycles both above and below the ground. Surface and groundwater can dissolve and mobilise salts and cause their accumulation in other areas. Development can cause changes to these water flows and result in salt to accumulate in different areas.

Areas of salinity potential are where soil, geology, topography and groundwater conditions predispose a site to salinity. These areas are most commonly drainage systems or low lying/flat grounds where there is a high potential for the ground to become waterlogged.

A review of salinity risk carried out as part of the Preliminary Site Investigation Contamination and Acid Sulphate Soil Assessment (Douglas Partners, 2015) identified several areas with dryland salinity characteristics (observations of saline indicator species to salt outbreaks), including in the vicinity of Purgatory Creek, between Hexham Bridge and Tomago Road, within creek alignments south of the Hunter River and along Windeyers Creek.

A review of the National Land and Water Resources Audit Dryland Salinity Data Source identified that majority of the construction footprint lies in an area rated as high hazard or risk of dryland salinity. High salinity risk areas are located within the construction footprint at Black Hill, Tarro, Hexham, Tomago, Heatherbrae and Raymond Terrace.

Salinity mapping is provided in the Soils and Contamination Working Paper (Appendix P of the EIS).

3.7 Ecology

A review of database records has identified 12 vegetation communities located near and within the project alignment, including.

- Alluvial Woodland
- Blackbutt-Apple-Bloodwood Forest
- Botanic Gardens (canopy only)
- Coastal Saltmarsh
- Freshwater Wetlands
- Lower Hunter Spotted Gum Ironbark Forest
- Mangrove Woodland
- Paperbark-Apple-Swamp Mahogany Forest
- Pine Plantation
- Planted vegetation
- Swamp Oak Floodplain Forest
- Swamp Sclerophyll Forest.

Six native vegetation communities listed as ‘threatened ecological communities’ (TEC) under the TSC Act have been identified in the vicinity of the project:

- Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions
- Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Lower Hunter Spotted Gum – Ironbark Forest in the Sydney Basin Bioregion
- River-flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions

- Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions.

The coastal saltmarsh TEC is also listed under the Commonwealth EPBC Act as a vulnerable ecological community.

A Mangrove-Estuarine Complex community (Grey Mangrove low closed forest) listed under the *Fisheries Management Act 1994* has also been identified in the vicinity of the project. The Mangrove-Estuarine Complex is equivalent to the Subtropical and Temperate Coastal Saltmarsh, which is listed as a vulnerable ecological community under the EPBC Act.

Details of groundwater dependent ecosystems are presented in **Section 3.8.2**.

3.8 Hydrogeology

3.8.1 Major groundwater systems

There are three main geological units along the project alignment as presented on the 1:100,000 scale regional geology map for Newcastle (Newcastle Coalfield Regional Geology, Sheet 9321, NSW Department of Mineral Resources). Geology in the vicinity of the project alignment is presented on **Figure 3-2**. From west to east, these geological units along the alignment include:

- Permian Tomago Coal Measures of the Singleton Supergroup (Sydney Basin)
- Quaternary alluvium associated with the Hunter River
- Quaternary Coastal Sands (Tomago Sandbeds).

These geological units are host to the three main groundwater systems that are present in the vicinity of the project's construction footprint:

- Hunter Alluvium
- Tomago Sandbeds
- Tomago Coal Measures.

Key characteristics of these three groundwater systems are summarised below.

Hunter alluvium

The indicative extent of Quaternary alluvial in the project area is shown as unit Qa in **Figure 3-2**. The alluvial deposits commonly comprise sequences of clays, silts, sands and gravels. The deposits are highly heterogeneous and within the floodplain area are likely to be typically of low permeability. More permeable and coarser, sand and gravel materials maybe found locally within discontinuous sheets of stringers, or at the base of the alluvial deposits or within palaeochannels (basal deposits). The deposits typically are fining upward sequences of sediments.

In a regional context, the Hunter River floodplain and its associated alluvial groundwater systems form a regional groundwater sink for the surrounding and underlying Permian and Triassic rocks of the Hunter Valley (Kellett et. al. 1987). Groundwater largely flows from the rocks of the Sydney Basin into the Quaternary Alluvium.

In the vicinity of the project, aquifer yields and water quality are likely to be highly variable due to the generally fine grained nature of the sediments and the salinity of the Hunter River in proximity to the coast.

Tomago Sandbeds

Coastal sands are typically unconsolidated sediments comprising estuarine deposits, palaeochannels, dunes or lowland coastal sands. These aquifers are typically unconfined with a high porosity and shallow depth to water table.

In the vicinity of the project area, the coastal sands aquifer consists of the Tomago Sandbeds (unit Qs in **Figure 3-2**). The Tomago Sandbeds are of Pleistocene age, consisting of fine to medium grained, well sorted, quartzose beach sand with discontinuous indurated sand layers (Woolley et. al. 1995).

The sandbeds comprise of extensive inner barrier sand ridge deposits extending from Tomago to Port Stephens (to the northeast) and about 5 to 15 kilometres inland from the present coastline. The Tomago Sandbeds are up to 30 metres thick and are underlain by the Medowie Clay Member. The Tomago Sandbeds are overlain (towards the coast) by the Tilligerry Mud Member and the Stockton Sand member (Woolley et. al. 1995). The Tomago Sandbeds are locally incised by Holocene age alluvium, particularly around Windeyer's Creek near the northern parts of the site and are truncated by the Hunter Alluvium around Tomago.

Since deposition, the inner barrier sand has been subjected to weathering processes and fluctuating water levels that have resulted in the varying colour and induration due to the mobilisation and deposition of iron (oxide and carbonate). This has resulted in the presence of yellow brown to black, indurated, iron cemented (by iron oxyhydroxide) layers. Where present, these cemented layers can be sufficiently continuous and of low permeability to reduce vertical hydraulic conductivity significantly.

The Tomago Sandbeds receive a relatively high percentage of recharge from rainfall runoff and infiltration. DPI Water (2016) have calculated an average infiltration rate of 25 per cent of average annual rainfall for the Tomago Sandbeds.

The Tomago Sandbeds are utilised for public drinking water supply by Hunter Water.

Tomago Coal Measures

Hardrock groundwater systems in the area of the project's construction footprint occur within the Permian Tomago Coal Measures, which outcrop in the western and central portions of the project (refer to **Figure 3-2**).

The coal measures are typically of relatively low permeability, particularly at depth, with the interbedded sandstones and siltstones generally of lower permeability than the coal seams. The permeability of the coal seams relative to the interburden and overburden is enhanced by the presence of cleating and joints within the coal and can produce permeabilities typically an order of magnitude greater than the surrounding formation.

An upper weathered layer can exist in the Permian bedrock, where permeability is enhanced by weathering and un-loading.

Groundwater flow within the deeper Permian formations is conceptualised to generally be controlled by bedding and fracture networks, with variable water quality. A shallow unconfined groundwater system can also exist in the weathering zone that is often in hydraulic connection with localised colluvial groundwater systems and local drainage systems.

3.8.2 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are considered to be ecosystems in which the species composition and natural ecological processes are wholly or partially determined by the availability of

groundwater (Serov *et al.*,2012). GDEs in the vicinity of the project are discussed in detail in the Biodiversity Assessment Report (Appendix I of the EIS) and summarised below.

Coastal management SEPP areas and wetlands

Coastal management SEPP and wetlands, including RAMSAR wetlands, are shown in **Figure 3-5**. The areas are generally considered to constitute groundwater dependent ecosystems (GDEs).

BoM mapping

The BoM's (2020a) Groundwater Dependent Ecosystem Atlas identifies a number of known and potential GDEs. These communities are shown on **Figure 3-6** and include:

- Known aquatic GDEs
  - Floodplain wetlands (Hexham Swamp, Hunter Wetlands National Park)
  - Hunter River.
- High potential terrestrial GDEs
  - Coastal Floodplain Wetlands on the floodplains of Hunter River (Tarro, Hexham and Tomago)
  - Mangrove Swamps on the margins of the Hunter River
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae).
- Moderate potential terrestrial GDEs
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae).

It is noted that a number of these potential and known GDEs coincide with the Coastal Wetlands (Coastal Management SEPP) and fall within the construction footprint.

High priority GDEs

High priority GDEs within the groundwater study area as mapped within Water Sharing Plans (WSPs) are summarised below:

- WSP for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government, 2009)
  - Hexham Swamp, located near western area of project, south of Tarro
  - Woodberry Swamp, located near western area of project in Woodberry, about 700 metres north of construction footprint.
- WSP for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government, 2016a)
  - Hexham Swamp and Woodberry Swamp
  - Wetland on boundary of groundwater study area, located about 1.8 kilometres north of the intersection of Masonnite Road and Cabbage Tree Road, Tomago.
- WSP for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government, 2016b)
  - Hexham Swamp and Woodberry Swamp
  - Wetland east of Tarro and south of Woodberry Swamp
  - Narrow (about 100 metres to 300 metres wide and up to 1.2 kilometres long) isolated pockets of 'North Coast Coastal Sands GDEs' adjacent to the western side of the Hunter River and relatively large pocket of 'North Coast Coastal Sands GDEs' adjacent to western side of Hunter River near Tomago, in the vicinity of where the project crosses the Hunter River.

- Two pockets of 'North Coast Coastal Sands GDEs' south west of Heatherbrae and at least 500 metres south west of the project's construction footprint. Each pocket is about 300 metres to 400 metres in diameter.

The above high priority GDEs generally coincide with areas of mapped SEPP 14 coastal wetland. However, not all of the mapped SEPP 14 coastal wetland areas in the vicinity of the project are designated as high priority GDE by the WSPs.

3.8.3 Groundwater users

Existing licensed groundwater bores

The BoM's Australian Groundwater Explorer (2020b) was reviewed in a geographic information system (GIS) to assess existing bores in the vicinity of the project. The analysis was restricted to within a 2 kilometre buffer to the project's construction footprint (i.e the groundwater assessment study area). Results are summarised as follows:

- 303 existing licensed bores were identified with the following purposes:
  - Monitoring – 144
  - Unknown – 134
  - Water supply – 16
  - Dewatering – six
  - Irrigation – three.
- There were five bores within the construction footprint. Their State bore numbers are:
  - GW079605 (unknown purpose)
  - GW200103 (monitoring purpose)
  - GW079447 (unknown purpose)
  - GW079591 (unknown purpose)
  - GW200102 (monitoring purpose).
- Average and maximum bore depth was about nine and 54 metres respectively.
- None of the bores had water level data.
- Within 500 metres of the operational footprint, there were 91 bores.

Supplementary to the BoM (2020b) bore data review, the 91 bores within 500 metres of the project's operational footprint were queried in a bore data base provided by WaterNSW. This was carried out because BoM bore data omits yield data and generally omits water level and salinity data unless a bore is a state groundwater monitoring bore. The following data was extracted:

- 69 bores had water level measurements, ranging from 0.48 metres to 9.89 metres below ground level (bgl), with an average value of 6.90 metres bgl
- Six bores had yield data, with yield ranging from 0.5 to 8.7 litres per second and an average of 3.3 litres per second.

It is noted that WaterNSW works summary reports for individual bores were not opened and reviewed. Instead, water levels and yield were extracted from a single collated file. This collated file contained, some, but not all, of the available water level and yield data. This is because the collated file extracted water level and yield data from one part of the works reports. However, there are multiple places for water level and yield data entries on the works reports.

BoM (2020b) bores within the groundwater study area are shown in **Figure 3-6**. Licensed bores within a 100 metre buffer to the project's construction footprint are shown in **Table 3-3**.

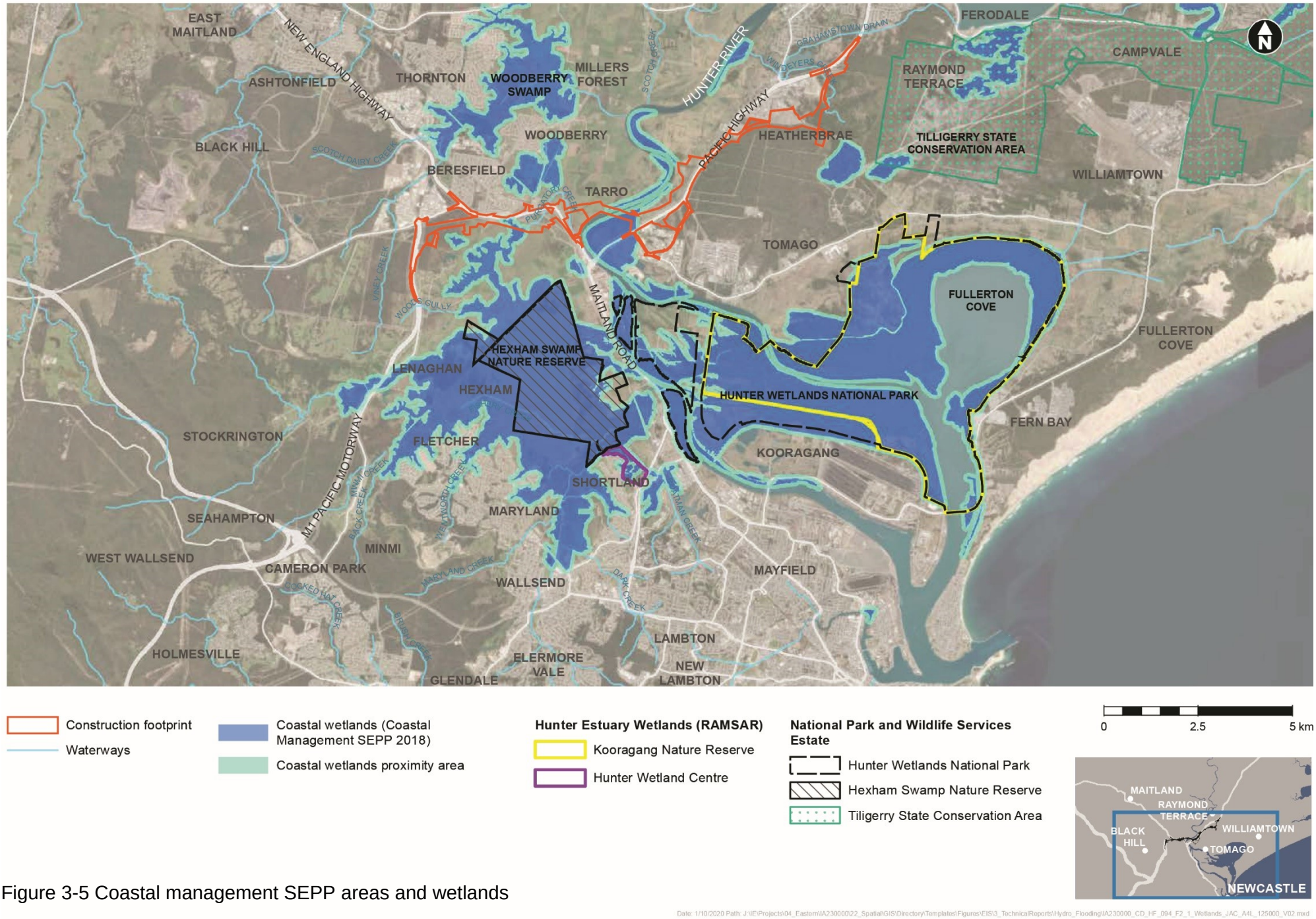

Figure 3-5 Coastal management SEPP areas and wetlands

Date: 1/10/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_094_F2_1_Wetlands_JAC_A4L_125000_V02.mxd

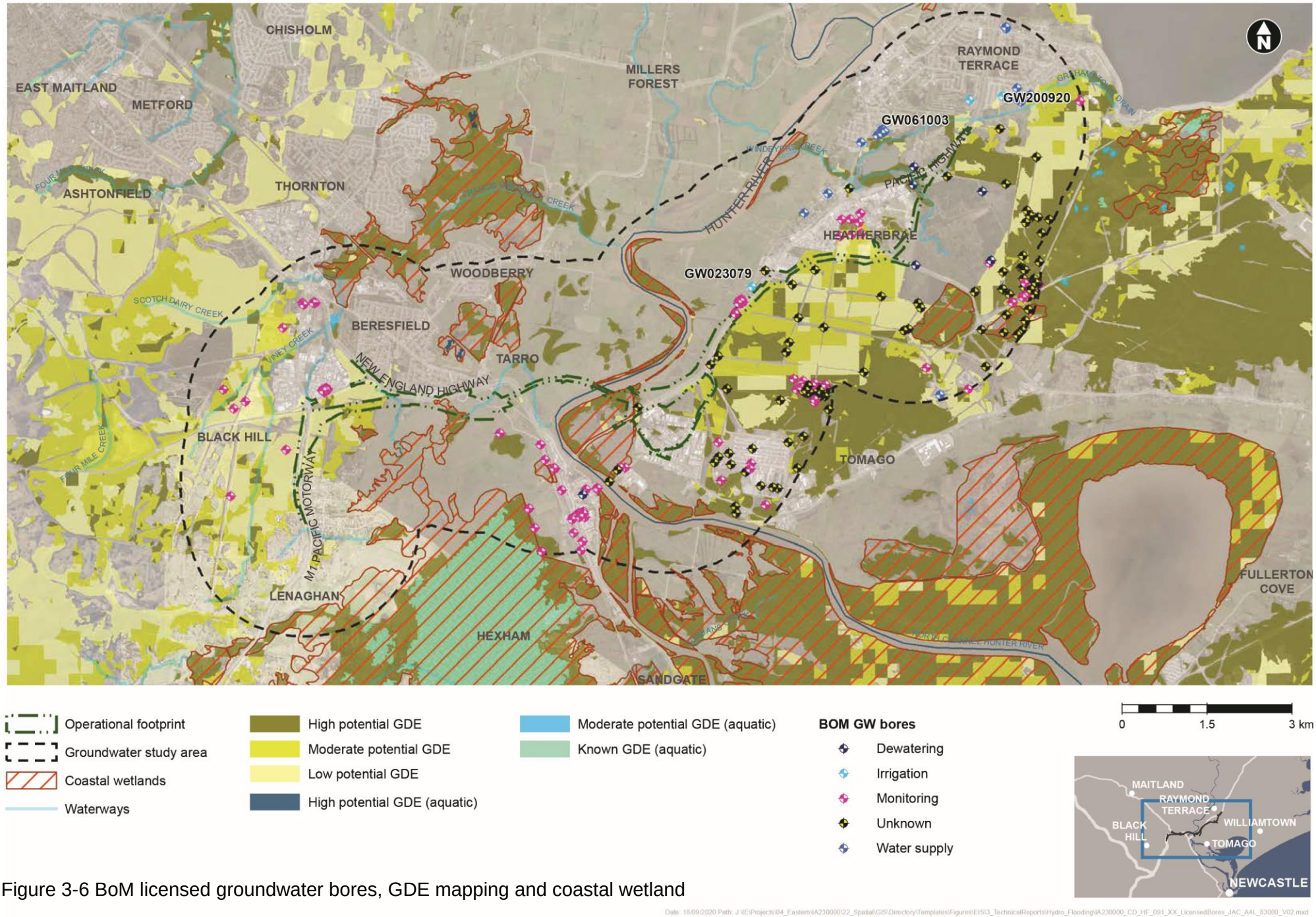

Figure 3-6 BoM licensed groundwater bores, GDE mapping and coastal wetland

Table 3-3 Summary of licensed groundwater bores within 100 metre buffer to project's construction footprint

ID	Purpose	Drilled date	Status	X mMGA56	Y mMGA56	Bore depth (m bgl)
GW201386	Monitoring	18/01/2010	FUNCTIONAL	379867	6370368	3.9
GW201381	Monitoring	18/01/2010	FUNCTIONAL	379891	6370325	3.5
GW201383	Monitoring	18/01/2010	FUNCTIONAL	379918	6370394	3.5
GW202728	Monitoring	25/11/2011	FUNCTIONAL	381650	6371505	8.75
GW203227	Monitoring	14/11/2014	FUNCTIONAL	379929	6370340	6.9
GW203232	Monitoring	12/11/2014	FUNCTIONAL	379902	6370330	3.2
GW079447	Unknown		UNKNOWN	383533	6372559	0
GW201384	Monitoring	18/01/2010	FUNCTIONAL	379918	6370378	3.9
GW202727	Monitoring	24/11/2011	FUNCTIONAL	381859	6371532	8.5
GW203234	Monitoring	12/11/2014	FUNCTIONAL	379908	6370350	2.7
GW203231	Monitoring	13/11/2014	REMOVED	379930	6370339	0.75
GW203225	Monitoring	13/11/2014	FUNCTIONAL	379940	6370340	6.8
GW203235	Monitoring	12/11/2014	FUNCTIONAL	379909	6370360	2.7
GW203226	Monitoring	13/11/2014	FUNCTIONAL	379929	6370350	7
GW203230	Monitoring	13/11/2014	FUNCTIONAL	379921	6370340	6.8
GW203233	Monitoring	12/11/2014	FUNCTIONAL	379907	6370340	2.9
GW203228	Monitoring	27/05/2015	FUNCTIONAL	379924	6370350	6.6
GW203229	Monitoring	13/11/2014	FUNCTIONAL	379923	6370350	6.8
GW202458	Dewatering	3/07/2012	IN USE	382941	6372415	6.8
GW201382	Monitoring	18/01/2010	FUNCTIONAL	379903	6370363	3.5
GW202726	Monitoring	24/11/2011	FUNCTIONAL	382027	6371556	8.5
GW201385	Monitoring	18/01/2010	FUNCTIONAL	379863	6370326	3.9
GW079412	Unknown		UNKNOWN	379499	6369390	0

ID	Purpose	Drilled date	Status	X mMGA56	Y mMGA56	Bore depth (m bgl)
GW200103	Monitoring	16/10/2003	UNKNOWN	379805	6370159	0
GW200102	Monitoring	16/10/2003	UNKNOWN	379806	6370136	0
GW202457	Dewatering	20/08/2012	IN USE	382980	6370995	4.8
GW079599	Unknown		UNKNOWN	380811	6370651	0
GW079591	Unknown		UNKNOWN	379370	6369241	0
GW023079	Irrigation	1/10/1965	UNKNOWN	380099	6370611	8.5
GW079605	Unknown		UNKNOWN	378090	6368487	0

Water Access License information

The *Water Management Act 2000* (WM Act) allows for the extraction of water from surface water and groundwater sources without an access licence to provide basic landholder rights, which include domestic and stock rights, as well as Native Title rights.

All water extraction that is not for basic landholder rights must be authorised by an access licence. Each access licence specifies a share component. The share components of specific purpose licences, such as town water supply, stock and domestic are expressed as megalitres per year. The share components of high security, general security and supplementary water access licences (WALs) are expressed as a number of unit shares. **Table 3-4** shows the categories of access licences allocated within the three water sources designated by DPIE Water under WSPs located within the project area. **Table 3-4** also shows the total share components registered for each water source in the 2019/2020 financial year period.

Table 3-4 Total share components for different water access licence categories within the water sources

Water source	WAL category	No of WALs	Total share component	Share component unit
Newcastle Water Source	Aquifer	2	91	ML/share
	Major Utility	1	100,000	ML/share
	Unregulated River	7	480	ML/share
Sydney Basin–North Coast Groundwater Source	Aquifer	167	66,857.5	ML/share
	Local utility water	9	1300	ML/percentage of share component
Tomago Groundwater Source	Aquifer	17	790	ML/share
	Major Utility (Urban Water)	1	25,300	ML/percentage of share component

Other groundwater extraction

In addition to the WALs summarised above, a number of groundwater works are registered as domestic bores and supply water for domestic and stock water under Basic Landholder Rights. As such the owners are not required to hold a WAL.

Tomago Sandbeds Catchment Area

The Tomago Sandbeds Catchment Area covers about 100 square kilometres and provides about 20 per cent of the Lower Hunter's drinking water. The sandbeds are located parallel to the coast between Newcastle and Port Stephens, starting at Tomago and extending northeast for about 25 kilometres to Lemon Tree Passage. About half of the project traverses or is adjacent to the western section of the Tomago Sandbeds.

The sandbeds are strategically important for both ongoing and backup drinking water supply. Ongoing supply from the sandbeds reduces the demand from surface water sources, such as Chichester Dam and Grahamstown Dam, and thereby allows greater overall yield from the total Lower Hunter water supply system.

The sandbeds consist of a layer of highly permeable fine grained sands underlain by low permeability clay and rock. The thickness of the sand layer reaches a maximum of 50 metres, but on average is approximately 20 metres thick. The aquifer is replenished directly by rainfall, with some water lost to evapotranspiration.

There is a network of more than 500 individual bores covering about 100 square kilometres from Lemon Tree Passage west to Tomago. After treatment at Grahamstown Water Treatment Plant, water from the western Tomago Sandbeds is piped to consumers in Newcastle and the lower Hunter regions.

Most land within the Tomago Sandbeds Catchment Area is protected, which minimises activities that could degrade water quality for this underground water source (Hunter Water, 2016).

An extensive system of underground bores and vacuum stations draw groundwater from the sandbeds to surface well heads and provides Hunter Water Corporation access to about 60,000 megalitres for the Lower Hunter water supply. The Hunter Water Corporation draws this water using existing infrastructure from a portion of Tomago Sandbeds (Hunter Water, 2014). Some of these bore well heads are located near the project (refer to **Figure 4-2**).

3.8.4 Surface water / groundwater interaction

Surface water and groundwater interaction is covered in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

3.9 Hydrogeological investigations

3.9.1 Previous investigations

Permian Coal Measures

Representative hydraulic properties of the Tomago Coal Measures and shallow weathered Permian lithologies are reported on by Dundon (2006). In a groundwater assessment for the Abel Coal Project, a number of shallow piezometers were installed and tested, with data presented for a total of 61 piezometers across the Donaldson, Abel, Tasman, and Bloomfield Collieries.

Permeability testing undertaken on the piezometers and on core samples comprised a combination of low yield constant rate pump-out tests, slug tests, and laboratory testing.

Indicative slug and constant rate pumping test permeability results for shallow lithologies (12 to 30 metres bgl) are typically in the range 0.02 to 0.4 metres per day, while laboratory permeability test results in the same depth range were generally two to three orders of magnitude lower, indicating that the majority of the permeability is likely to be secondary and resulting from discontinuities.

Shallow water levels, in proximity to the western end of the project, were in the range 5.7 to 14 metres AHD.

Tomago Sandbeds

Numerous investigations have been undertaken into the hydraulic properties of the Tomago Sandbeds as these have historically been assessed for public water supply and mineral sand mining. Based on evaluation of pump out test results undertaken as part of the Steering Committee review (Coffey and SKM, 1996), to review studies on the effect of heavy mineral mining on the hydrogeology of the Tomago Sandbeds, the transmissivity of the Tomago Sandbeds aquifer was reported ranging from 80 to 920 m2/day. The adopted horizontal hydraulic conductivity was reported as 10 to 15 metres per day (Coffey and SKM, 1996).

As part of a groundwater assessment for the Newcastle Gas Storage Facility Project, Coffey (2011) installed and tested three monitoring bores at the proposed site on the Tomago Sandbeds. Derived hydraulic conductivity values from slug testing ranged from 7.4 to 11.3 metres per day.

A groundwater mound exists within the Tomago Sandbeds and water level elevations generally range from around five metres AHD, one to two kilometres southeast of the project area, declining to around one metre AHD at the Hunter River floodplain.

Geotechnical investigations

Previous geotechnical investigations in the vicinity of the project were compiled by Douglas Partners (2015a). As part of the geotechnical investigations a number of sites were subject to cone penetrometer testing (CPT) and pore pressure dissipation testing using a piezocone.

A total of eight pore pressure dissipation tests were undertaken at five locations. The test locations are located within flood and swamp deposits west of the Hunter River (refer **Figure 2-2**), at depths of between one and 12 metres below ground level. The results indicate very low permeability as presented on **Table 3-5**.

Table 3-5 Previous permeability (pore pressure dissipation) testing

Location	Easting	Northing	Depth (m bgl)	Geotech-nical unit	K lower (cm/s)	K upper (cm/s)	K av (cm/s)	K av (m/d)
CPTU101	373919	6368250	1	2.2	1.00E-07	2.00E-07	1.50E-07	1.30E-04
CPTU102	374881	6368180	3	2.3	1.10E-06	1.50E-06	1.30E-06	1.12E-03
CPTU103	375326	6368132	3	2.2	1.00E-06	1.40E-06	1.20E-06	1.04E-03
CPTU104	375768	6368029	6	2.1	7.80E-06	1.09E-05	9.35E-06	8.08E-03
CPTU104	375768	6368029	9	2.2	1.00E-07	1.00E-07	1.00E-07	8.64E-05
CPTU104	375768	6368029	12	2.2	1.00E-07	1.00E-07	1.00E-07	8.64E-05
CPTU105	376342	6767853	5	2.2	2.00E-07	2.00E-07	2.00E-07	1.73E-04
CPTU105	376342	6767853	8	2.2	3.00E-07	4.00E-07	3.50E-07	3.02E-04

3.9.2 Current investigations

Recent investigations undertaken for the project include permeability testing, monitoring bore installation and water quality analysis as discussed in the sections below.

Geotechnical investigations

As part of the current geotechnical investigations a total of 27 locations were subject to cone penetration tests (CPT).

The cone penetration tests were undertaken using purpose-built CPT rigs capable of pushing through dense to very dense sand layers, often to cone resistance values in excess of 50 or 60 megapascals. In areas of difficult access, a track-mounted CPT rig was used with less thrust resulting in shallower depths of refusal.

A total of 21 pore pressure dissipation tests (**Figure 2-2**) were carried out at 8 locations in soft soil layers (Douglas Partners 2016). The testing comprised stopping penetration and recording the decay in pore pressure with time. The dissipation tests were run until the pore pressure reduced to at least 50 per cent of

the initial pore pressure, or two hours duration, whichever occurred first. The dissipation test results were processed and plotted which provides an estimate of t_{50} (the time for 50 per cent dissipation of excess pore pressure). Formation hydraulic conductivity values have been derived from the dissipation tests using the following formula (Parez and Fauriel, 1988) and are summarised in **Table 3-6**:

$K = [1/(251x\ t_{50})]^{1.25}$

Where k = hydraulic conductivity (cm/sec)

t_{50} = time in second for 50 per cent dissipation of excess pore pressure

Table 3-6 Current permeability (pore pressure dissipation) testing

Location	Easting	Northing	Depth (m bgl)	Geotechnical Unit	K (cm/s)	K (m/d)
D-CT-208	374661.5	6368520.1	1.08	2.1	2.10E-05	1.82E-02
D-CT-208	374661.5	6368520.1	1.6	2.2	1.96E-07	1.70E-04
D-CT-213	374875.8	6368521.4	1.28	2.2	5.52E-08	4.77E-05
D-CT-215	375161	6368570.2	1.16	2.2	8.79E-05	7.60E-02
D-CT-220	375525.4	6368689.6	1.64	2.2	9.97E-07	8.61E-04
D-CT-304	375920.9	6368845.5	2.04	2.2	2.32E-06	2.01E-03
D-CT-306	376136.4	6368894.8	2	2.2	5.42E-06	4.69E-03
D-CT-306	376136.4	6368894.8	3.3	2.2	8.70E-07	7.52E-04
D-CT-306	376136.4	6368894.8	3.56	2.2	6.21E-07	5.37E-04
D-CT-306	376136.4	6368894.8	4.98	2.2	4.11E-08	3.55E-05
D-CT-306	376136.4	6368894.8	7	2.2	1.03E-07	8.91E-05
D-CT-306	376136.4	6368894.8	10	2.2	2.01E-08	1.74E-05
D-CT-426	379382.7	6369605	3	2.2-3	3.39E-05	2.93E-02
D-CT-426	379382.7	6369605	4.5	2.2-3	8.79E-05	7.60E-02
D-CT-426	379382.7	6369605	6.7	2.2	2.55E-06	2.20E-03
D-CT-426	379382.7	6369605	7.51	2.2	8.98E-08	7.76E-05
D-CT-426	379382.7	6369605	8.11	2.2	6.91E-08	5.97E-05
D-CT-429	379462.9	6369865.1	2.93	2.2	1.38E-06	1.19E-03
D-CT-429	379462.9	6369865.1	4.71	2.2	7.00E-06	6.05E-03
D-CT-429	379462.9	6369865.1	6.51	2.2	1.08E-08	9.32E-06
D-CT-429	379462.9	6369865.1	8.51	2.2	8.53E-09	7.37E-06

The test locations are located within flood and swamp deposits west and east of the Hunter River (refer **Figure 2-2**), at depths of between 1.08 metres bgl and 10 metres bgl. The results indicate very low permeability as presented on **Table 3-6**.

Groundwater monitoring network

The project has a groundwater monitoring bore network (**Figure 2-2**) consisting of a total of 20 monitoring bores at 13 locations, comprising six single and seven paired (one deep and one shallow) installations. Paired sites are indicated by suffix A (shallow) and B (deep).

Groundwater monitoring bore details are summarised in **Table 3-7** and groundwater level sampling occurrences shown in **Table 3-8**.

The monitoring bores were constructed using environmental grade, machine-slotted, Class 18 PVC with threaded connectors. A filter pack, comprising washed and graded sand, was placed to at least 100 millimetres above the top of the PVC screen, and a bentonite seal (using granular bentonite or bentonite grout) was placed above the filter pack to seal the screened section in the target stratum. The wells were completed at the surface with a locked cover and monument. Following completion, the bores were developed by hand bailing and subject to falling and rising head slug testing.

Table 3-7 Monitoring bore summary

Location	Easting	Northing	Ground level (m AHD)	Total Depth (m bTOC) [2]	Screened Interval (m bgl)	Screened lithology [1]	Interpreted screened hydrogeological unit
D-PZ-134	372642	6368469	22.48	18.92	11.8 - 17.8	Sandstone (PT)	Tomago Coal Measures
D-PZ-135	372853	6368499	16.11	13.35	6.1 - 12.1	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-136	373183	6368558	21.22	18.60	12.0 - 18.0	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-221A	374772	6368470	0.65	5.02	1.5 - 4.5	Sandy clay / Clayey sand (QA)	Hunter alluvium
D-PZ-221B	374772	6368470	0.65	15.31	11.5 - 14.5	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-222A	374910	6368425	0.53	3.70	0.5 - 2.5	Clay (QA)	Hunter alluvium
D-PZ-222B	374910	6368425	0.53	13.84	9.5 - 12.5	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-223A	375480	6368559	0.83	6.10	2.0 - 5.0	Clay / Silty Clay (QA)	Hunter alluvium
D-PZ-223B	375480	6368559	0.83	13.80	7.0 - 13.0	Carbonaceous claystone/ sandstone (PT)	Tomago Coal Measures
D-PZ-324A	378085	6368698	1.58	3.55	1.0 -2.5	Clay / sand (QA)	Hunter alluvium
D-PZ-324B	378085	6368698	1.58	9.82	6.0 – 9.0	Sandstone (PT)	Tomago Coal Measures
D-PZ-438	378543	6368611	7.12	10.65	7.0 – 10.0	Sandstone (PT)	Tomago Coal Measures

Location	Easting	Northing	Ground level (m AHD)	Total Depth (m bTOC) [2]	Screened Interval (m bgl)	Screened lithology [1]	Interpreted screened hydrogeological unit
D-PZ-439A	379350	6369744	0.75	3.82	2.0 - 3.0	Clayey silt (QA)	Hunter alluvium
D-PZ-439B	379350	6369744	0.75	10.03	4.0 - 10.0	Clayey silt / silty clay (QA)	Hunter alluvium
D-PZ-440A	379577	6370011	1.25	4.05	0.5 - 3.0	Clay / clayey sand (QA/QS)	Hunter alluvium
D-PZ-440B	379577	6370011	1.25	8.51	5.0 - 8.0	Sand (QS)	Hunter alluvium
D-PZ-614	383045	6371950	6.17	6.23	3.5 - 5.0	Sand (QS)	Tomago Sandbeds
D-PZ-615A	383108	6372474	3.62	6.05	2.5 - 4.0	Sand (QS)	Tomago Sandbeds
D-PZ-615B	383108	6372474	3.62	8.0	5.0 - 8.0	Sand (QS)	Tomago Sandbeds
D-PZ-616	383271	6372687	2.14	9.03	7.0 - 10.0	Sand (QS)	Tomago Sandbeds

Notes: [1] PT= Permian Tomago Coal Measures; QA = Quaternary Alluvium; QS = Quaternary Sand. [2] mbTOC = metres below top of casing.

Table 3-8 Groundwater level sampling occurrences

Location	2016				2017						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
D-PZ-134	M		M		M		M				M
D-PZ-135	M		M		M		M				M
D-PZ-136	M		M		M		M				M
D-PZ-221A			M		M		M				M
D-PZ-221B			M		M		M				M
D-PZ-222A	M		M		M		M				M
D-PZ-222B	M		M		M		M				M
D-PZ-223A	M		M		M		M				M
D-PZ-223B	M		M		M		M				M
D-PZ-324A					M		M				M
D-PZ-324B					M		M				M
D-PZ-438	M		M		M		M				M
D-PZ-439A			M		M		M				M
D-PZ-439B			M		M		M				M
D-PZ-440A			M		M		M				M
D-PZ-440B			M		M		M				M
D-PZ-614			M		M		M				M
D-PZ-615A			M		M		M				M
D-PZ-615B			M		M		M				M
D-PZ-616			M		M						M

Note: Shaded cells indicate piezometer equipped with water level data logger recording at six-hourly frequency. (M) manual water level measurement.

3.9.3 Groundwater levels

Project groundwater monitoring bores

Minimum, average and maximum groundwater levels are summarised for all project piezometers in **Table 3-9** and hydrographs with daily rainfall are shown in **Figure 3-7**.

The following comments are made in relation to hydrograph trends and manual groundwater level measurements:

- Monitored groundwater elevations ranged from -1.28 metres AHD to 9.85 metres AHD. Water levels below 0 metres AHD are inferred to be due to evapotranspiration and/or interference drawdown from nearby pumping
- Relative to ground levels, monitored groundwater depth ranged from artesian (0.26 metres above ground level) to 14.4 metres below ground level. Artesian conditions were noted at times at D-PZ-221B (screened in Tomago Coal Measures) and D-PZ-221A, D-PZ-439B and D-PZ-440B (screened in Hunter alluvium)
- Groundwater levels were relatively higher (although also relatively deeper in terms of depth below ground level) at piezometers D-PZ-134, D-PZ-135 and D-PZ-136, which were screened within the Permian Tomago Coal Measures and have relatively higher ground elevations ranging from about 16 to 22.5 metres AHD
- With the exception of paired location D-PZ-324A and D-PZ-324B, all 6 remaining paired piezometer locations had upward vertical hydraulic gradients. That is, the relatively deep piezometers had higher hydraulic head than the shallow piezometers, indicating semi-confining groundwater conditions in these areas
- Groundwater level in D-PZ-134 (located within the Black Hill area, south of John Renshaw Drive), installed within the Permian Tomago Coal Measure, did not respond significantly to seasonal variation of rainfall
- Groundwater level responses are noted in all piezometers (installed within Quaternary Alluvium and underlying Permian bedrock or within the Quaternary Coastal Sand) close to the Hunter River (Tarro, Hexham, Viaduct and west of Tomago) during high rainfall
- The responses to rainfall within the alluvial groundwater systems as well as underlying bedrock groundwater systems indicates these systems are likely to have some degree of connection with each other
- The maximum seasonal influence, taken as the range in groundwater level during the monitoring period, was:
  - Permian Tomago Coal Measures – 2.44 metre range (D-PZ-135)
  - Hunter alluvium – 2.15 metre range (D-PZ-439B)
  - Tomago Sandbeds – 0.90 metre range (D-PZ-615B).
- The smaller range in groundwater level fluctuation within the Tomago Sandbeds is inferred to be due to elevated porosity and specific yield, rather than reduced recharge.

Table 3-9 Minimum, average and maximum groundwater levels for all project piezometers

Sample ID	Groundwater level summary (m AHD)			Groundwater level summary (m bgl)		
	Min	Average	Max	Min	Average	Max
D-PZ-134 [1]	5.69 [2]	9.37	9.75	16.79	13.11	12.73
D-PZ-135	7.41	9.24	9.85	8.70	6.87	6.26
D-PZ-136	6.82	6.98	7.14	14.40	14.24	14.08
D-PZ-221A [1]	-0.72	0.26	0.85	1.37	0.38	-0.21
D-PZ-221B [1]	-0.11	0.50	0.91	0.76	0.15	-0.26
D-PZ-222A	-1.04	-0.12	0.36	1.57	0.66	0.17
D-PZ-222B [1]	-0.05	0.15	0.33	0.58	0.39	0.20
D-PZ-223A [1]	-0.20	0.13	0.49	1.02	0.70	0.34
D-PZ-223B [1]	0.37	0.54	0.66	0.46	0.28	0.17
D-PZ-324A	0.00	0.54	1.09	1.58	1.04	0.49
D-PZ-324B	-0.23	0.33	0.83	1.81	1.25	0.75
D-PZ-438 [1]	4.33	5.07	6.57	2.78	2.04	0.54
D-PZ-439A	-1.28	-0.65	0.35	2.03	1.40	0.40
D-PZ-439B [1]	-1.25	-0.14	0.90	2.00	0.89	-0.15
D-PZ-440A [1]	0.42	0.56	1.00	0.82	0.68	0.25
D-PZ-440B [1]	0.45	0.93	1.34	0.79	0.31	-0.09
D-PZ-614 [1]	3.75	4.16	4.64	2.42	2.02	1.53
D-PZ-615A	1.16	1.38	1.66	2.46	2.25	1.96
D-PZ-615B [1]	1.17	1.58	2.07	2.46	2.04	1.55
D-PZ-616	-0.53	-0.30	-0.19	2.67	2.44	2.33

Notes: [1] Piezometer installed with groundwater level data logger. [2] Minimum level occurs due to sampling. Excluding impact from sampling, the minimum level is about 9.20 metres AHD.

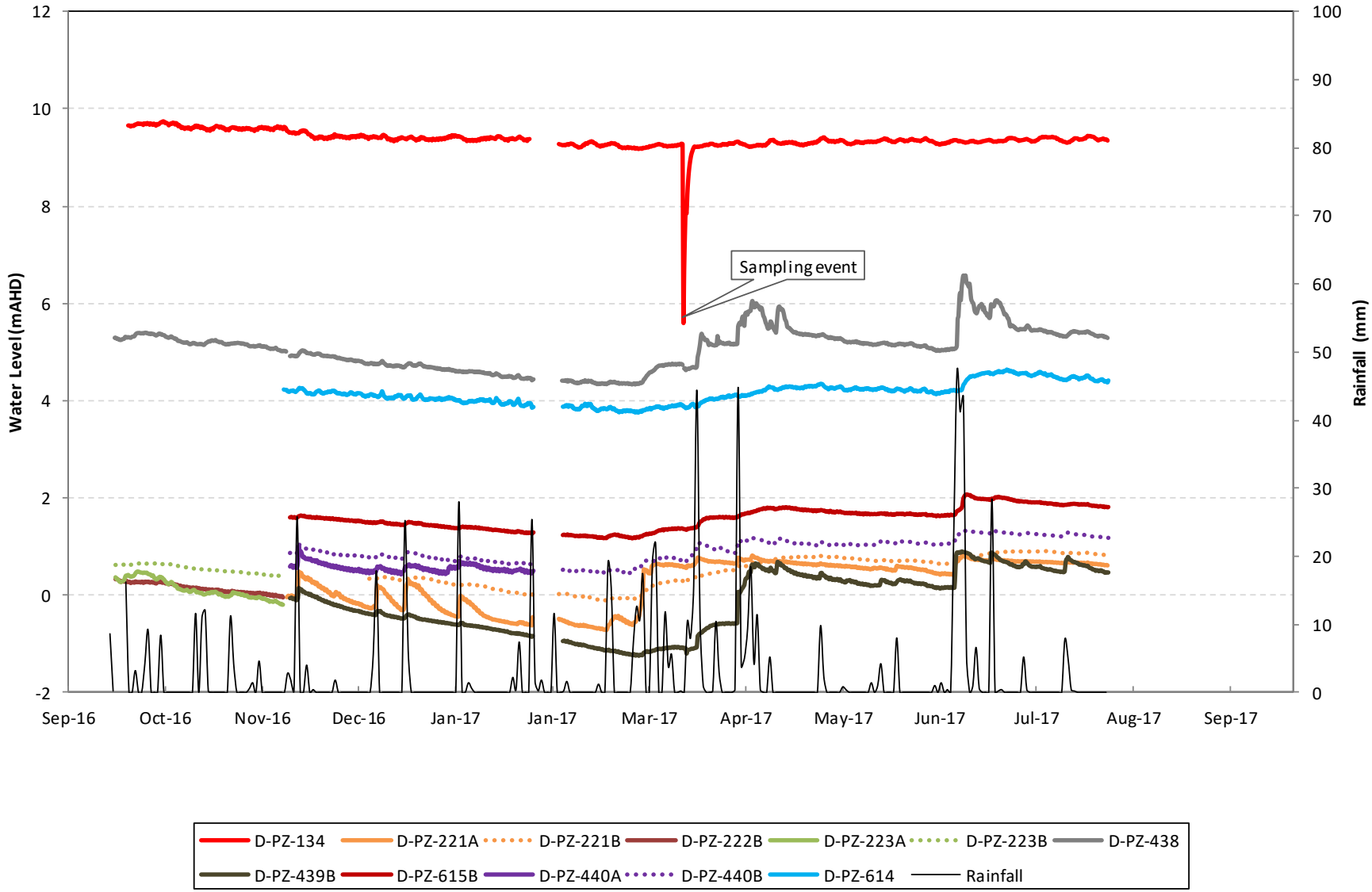

Figure 3-7 Project piezometer hydrographs and daily rainfall

Hunter Water bore groundwater levels

Detailed time series water level data is available for the Hunter Water bores. Hydrographs of selected bores in close proximity to the alignment are provided on **Figure 3-8** with the location of the bores shown on **Figure 3-9**. The hydrographs are presented along with the cumulative rainfall deviation (CRD). It is noted that these hydrographs are for the highly permeable Tomago Sandbeds. Groundwater levels within the Hunter Alluvium are likely to show reduced seasonal fluctuations and a more muted response to rainfall. Monitoring Bore 230 is located adjacent to the Hunter River floodplain and displays the lowest range of groundwater fluctuations for the bores presented, and also has the lowest average water level.

The majority of the bores display very similar responses, with exception of SK4939. SK4939 is located at a higher elevation within the sandbeds and is in an area of groundwater mounding.

The CRD is representative of the longer term climatic trends. Periods of above average rainfall are represented by increasing CRD, or an upward trending line, periods of bellow average rainfall by a downward trending line, and periods of predominantly average rainfall by a horizontal trend. Four dry periods of predominantly below average rainfall periods are apparent, these being: July 1979 to March 1987, October 1990 to March 1998, March 2000 to February 2007, and October 2016 to February 2020. These predominantly dry periods are interspersed with shorter more intense wet periods.

The hydrographs generally show a good correlation with the long-term CRD trends, as well as responding to the individual rainfall events. The hydrographs will also likely be influenced by extraction from the Hunter Water well fields.

Average water levels range from 1.29 metres AHD at monitoring bore 230 to 2.29 metres AHD at SK3519, and 4.18 metres AHD at SK4939.

Maximum water level fluctuations range from 1.70 metres (monitoring bore 230) to 3.51 metres (monitoring bore 40A). The average maximum water level fluctuation is 2.67 metres.

The 80 per cent water level range (between the 10th and 90th percentiles) ranges from 0.98 metres (monitoring bore 230) to 2.21 metres (monitoring bore 40A). The average 80 per cent water level fluctuation is 1.54 metres.

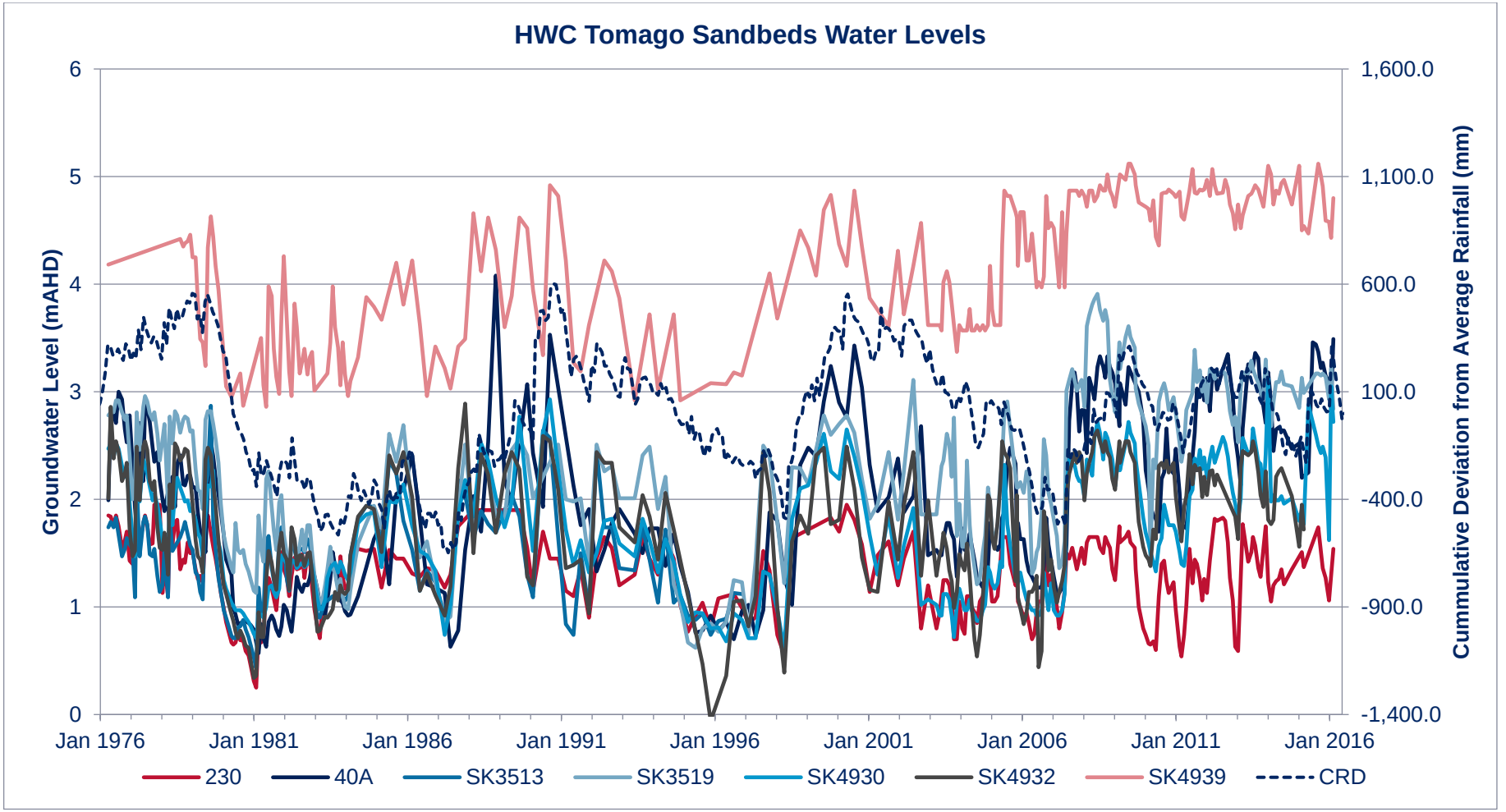

Figure 3-8 Hunter Water Corporation bore hydrographs

Composite groundwater level contours

Composite groundwater levels derived from available data are provided on **Figure 3-9**. The water levels represent a composite compiled from average water levels from time series data and spot levels as available (Dundon, 2006; Coffey, 2011; Douglas Partners, 2012; and Hunter Water). As such the water levels are indicative, but highlight key groundwater flow directions and trends. **Figure 3-9** illustrates the groundwater sink represented by the Hunter River and its alluvial floodplain. In the west groundwater flow is from the high-ground associated with the Permian Tomago Coal Measures outcrop eastward towards the Hunter River floodplain.

In the east, elevated groundwater levels are associated with the enhanced infiltration and recharge on the Tomago Sandbeds. Groundwater flow from the Tomago Sandbeds is to the northwest, west, and south towards the Hunter River and Fullerton Cove.

Groundwater levels beneath the Hunter floodplain are typically below two metres AHD. An exception to this occurs in the vicinity of Hexham, where a localised groundwater mound occurs, rising to approximately eight metres AHD. The mounding is associated with a historical coal tailings stockpile, that until recently included a tailings dam/sediment control pond at its crest. Review of historical imagery shows that the pond was backfilled and rehabilitated in late 2015.

Groundwater levels along the alignment range from 11 to 12 metres AHD in the west, declining to zero metres AHD in the vicinity of the Hunter River. East of the Hunter River groundwater elevations are typically below two metres AHD, rising to four metres AHD in the vicinity of Heatherbrae and declining to two metres AHD at Raymond Terrace.

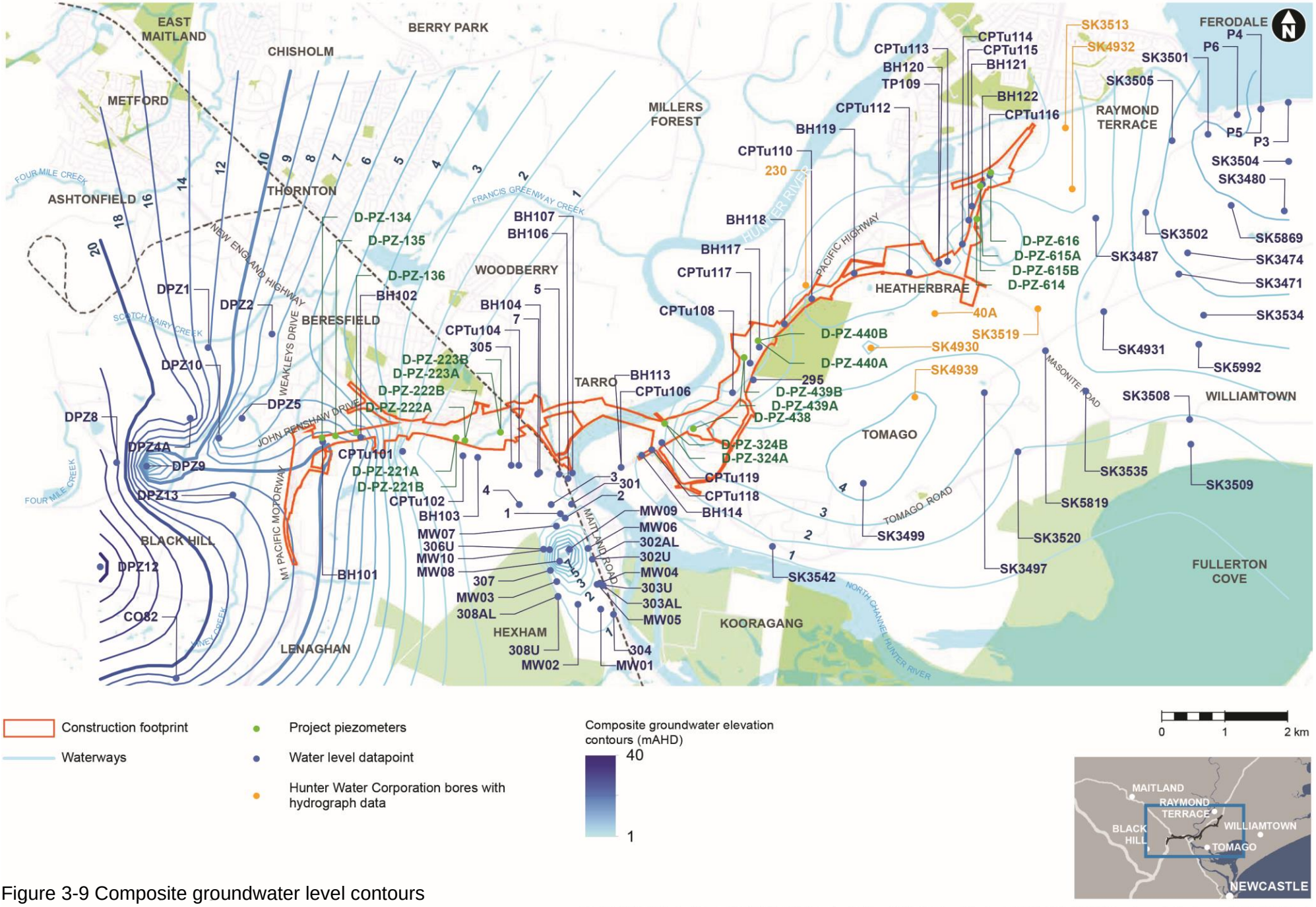

Figure 3-9 Composite groundwater level contours

3.9.4 Hydraulic conductivity – project monitoring bores

Hydraulic conductivity estimates from slug testing are summarised in **Table 3-10**.

The hydraulic conductivity values for D-PZ-223A and D-PZ-223B are considered to not be representative of the target hydrogeological units, a Clay/Silty Clay and a Carbonaceous Claystone/Sandstone, respectively. The conductivity values for the two bores are likely to be representative of a gravel lens within the clay (D-PZ-223A), and geological fault (D-PZ-223A).

Table 3-10 Hydraulic conductivity estimates from slug testing

Location	Ground level (m AHD)	Total Depth (m bTOC)	Screened Interval (m bgl)	Screened lithology [1]	Interpreted screened hydrogeological unit	Hydraulic conductivity (m/d)
D-PZ-134	22.48	18.92	11.8 - 17.8	Sandstone (PT)	Tomago Coal Measures	0.20
D-PZ-135	16.11	13.35	6.1 - 12.1	Sandstone / Siltstone (PT)	Tomago Coal Measures	0.09
D-PZ-136	21.22	18.60	12.0 - 18.0	Sandstone / Siltstone (PT)	Tomago Coal Measures	0.10
D-PZ-223A	0.83	6.10	2.0 - 5.0	Clay / Silty Clay (QA)	Hunter alluvium	16.9
D-PZ-223B	0.83	13.80	7.0 - 13.0	Carbonaceous claystone/ sandstone (PT)	Tomago Coal Measures	21.5
D-PZ-438	7.12	10.65	7.0 – 10.0	Sandstone (PT)	Tomago Coal Measures	0.06

Notes: [1] PT= Permian Tomago Coal Measures; QA = Quaternary Alluvium; QS = Quaternary Sand

3.9.5 Groundwater quality

Groundwater quality is covered in the project's Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

3.10 Conceptual hydrogeological model

3.10.1 Project description and potential for groundwater interaction

Key project features that have the potential to interact with groundwater are describes as follows:

- Cuttings – excavation below the water table requiring dewatering, potentially resulting in changes to the water table
- Construction of embankments / causeways over flat flood plains and soft soil areas, potentially resulting in compaction/consolidation of soils resulting in reduced hydraulic properties and displacement of groundwater. Centrally, beneath the embankments, excess water will be removed via wick-drains, while on the margins excess water will be squeezed laterally into the surrounding formation. Extracted or

exuded water will need to be licenced and accounted for. Potential changes to natural groundwater flow regimes will need to be assessed and managed

- Purgatory Creek adjustment and adjustment of a minor drainage line near the Botanic Gardens.

3.10.2 Key hydrostratigraphic units

Key hydrostratigraphic units can be directly correlated with the units of the geotechnical model and incorporate the major groundwater systems as described in **Section 3.8.1**. These units are summarised on **Table 3-11**, and include representative hydraulic parameters based on the results of the current investigation, previous investigations and past experience. The relationships and interaction of these hydrostratigraphic units are presented on **Figure 3-10**.

Table 3-11 Summary of hydrostratigraphic units

Geotechnical units		Geological origin	Description	Representative hydraulic parameters		
Main unit	Sub-unit			Horizontal hydraulic conductivity (m/d)	Specific yield (%)	Specific storage (m^{-1})
2	2.1	Holocene flood and swamp deposits	Hunter alluvium, flood plain deposits, variable permeability. - ***Low permeability aquifer***	$1x10^{-2}$ to 2	5 to 10	$1x10^{-3}$ to $1x10^{-2}$
	2.2					
	2.3		Tilligerry Creek estuarine deposits. - ***Aquitard***	$1x10^{-4}$ to $1x10^{-2}$	1 to 5	$1x10^{-3}$ to $1x10^{-2}$
3	3.1	Pleistocene channel sand deposits	Basal sand and Hunter river palaeochannel deposits. - ***Aquifer***	1 to 5	10 to 15	$1x10^{-4}$ to $1x10^{-3}$
	3.2	Pleistocene barrier sands	Tomago Sandbeds - ***High permeability aquifer***	5 to 30	20 to 30	$1x10^{-4}$ to $1x10^{-3}$
4	4.0	Pleistocene Estuary deposits (mud)	Medowie Clay Member - ***Aquitard***	$1x10^{-4}$ to $1x10^{-3}$	1 to 5	$1x10^{-3}$ to $1x10^{-2}$
5	5.1	Permian aged residual soils	Weathered Tomago Coal measures - ***Low to moderate permeability aquifer***	$1x10^{-2}$ to 10	5 to 15	$1x10^{-3}$ to $1x10^{-2}$
	5.2	Permian aged extremely weathered bedrock				

Geotechnical units		Geological origin	Description	Representative hydraulic parameters		
Main unit	Sub-unit			Horizontal hydraulic conductivity (m/d)	Specific yield (%)	Specific storage (m^{-1})
6	6.0	Permian Aged Tomago Coal Measures	Competent Tomago Coal Measures. Permeability dependent of coal seams and fractures - ***Low permeability aquifer to aquitard***	$1x10^{-5}$ to 1	0.1 to 10	$1x10^{-6}$ to $1x10^{-5}$

3.10.3 Groundwater levels and flow

Groundwater flow is typically from areas of high relief to areas of low relief, with the Hunter River acting as a groundwater sink in the vicinity of the project.

Groundwater levels are elevated to the west, where the Tomago Coal Measures outcrop. From the high ground in the west, groundwater flow is in a general eastward direction towards the Hunter River. In areas where the Tomago Coal Measures are overlain by the Hunter River alluvium, there is likely to be an upwards vertical hydraulic gradient from the coal measures to the alluvium.

To the northeast of the project area, groundwater heads are typically maintained by the Grahamstown Dam at an elevation of approximately 10 metres AHD. While extensive work and grouting has been undertaken to minimise seepage from the dam, the seepage will not have been entirely eliminated.

To the south east of the project area, elevated groundwater levels are associated with the Tomago Sandbeds, where very high infiltration and recharge rates result in a groundwater mound within the formation. Vertical percolation is limited by the underlying Medowie Clay Member (where present). From the western portion of the Tomago sand beds groundwater flow is generally radial and towards the Hunter River and Fullerton Cove. As the sand beds are also continuous at depth towards the coast, there will also be a component of groundwater throughflow to the southwest. Recharge within the Tomago Sandbeds is such that, locally, the unit is often completely saturated with the water table expressing at the ground surface.

Within the Hunter River floodplain groundwater levels are typically very shallow. This is due to the relatively low elevation with respect to the Hunter River, and poor drainage. An extensive network of drains has been excavated on the floodplain to lower the water table and create arable farmlands.

3.10.4 Recharge and discharge mechanisms

Rainfall infiltration is anticipated to the dominant source of groundwater recharge, with some localised infiltration of surface water runoff in areas of elevated topography and deeper depth to water table. The Hunter River itself is a gaining stream and a groundwater sink in the vicinity of the project.

Groundwater discharge is typically via direct outflow to surface water from the Tomago Sandbeds, Hunter River Alluvium and the Tomago Coal Measures, some inter-unit flow is also likely (for example, from the Tomago Coal Measures to Hunter River alluvium).

Given the shallow depth to groundwater and abundant vegetation, evapotranspiration will also comprise a component of groundwater loss from the system.

Throughflow and discharge to the coast, particularly in the Tomago Sandbeds will also occur.

3.10.5 Groundwater Dependent Ecosystems

There are numerous GDEs in the project area due to the generally shallow water table, as discussed in **Section 3.8.2**. Potential groundwater impacts from the project are anticipated to be relatively small and localised and are not expected to significantly impact on any GDEs.

3.10.6 Other groundwater users

Groundwater use in close proximity to the project is very limited (refer **Figure 3-6**). Given the limited and localised potential impacts of the project on groundwater, no detrimental impacts on other groundwater users are anticipated.

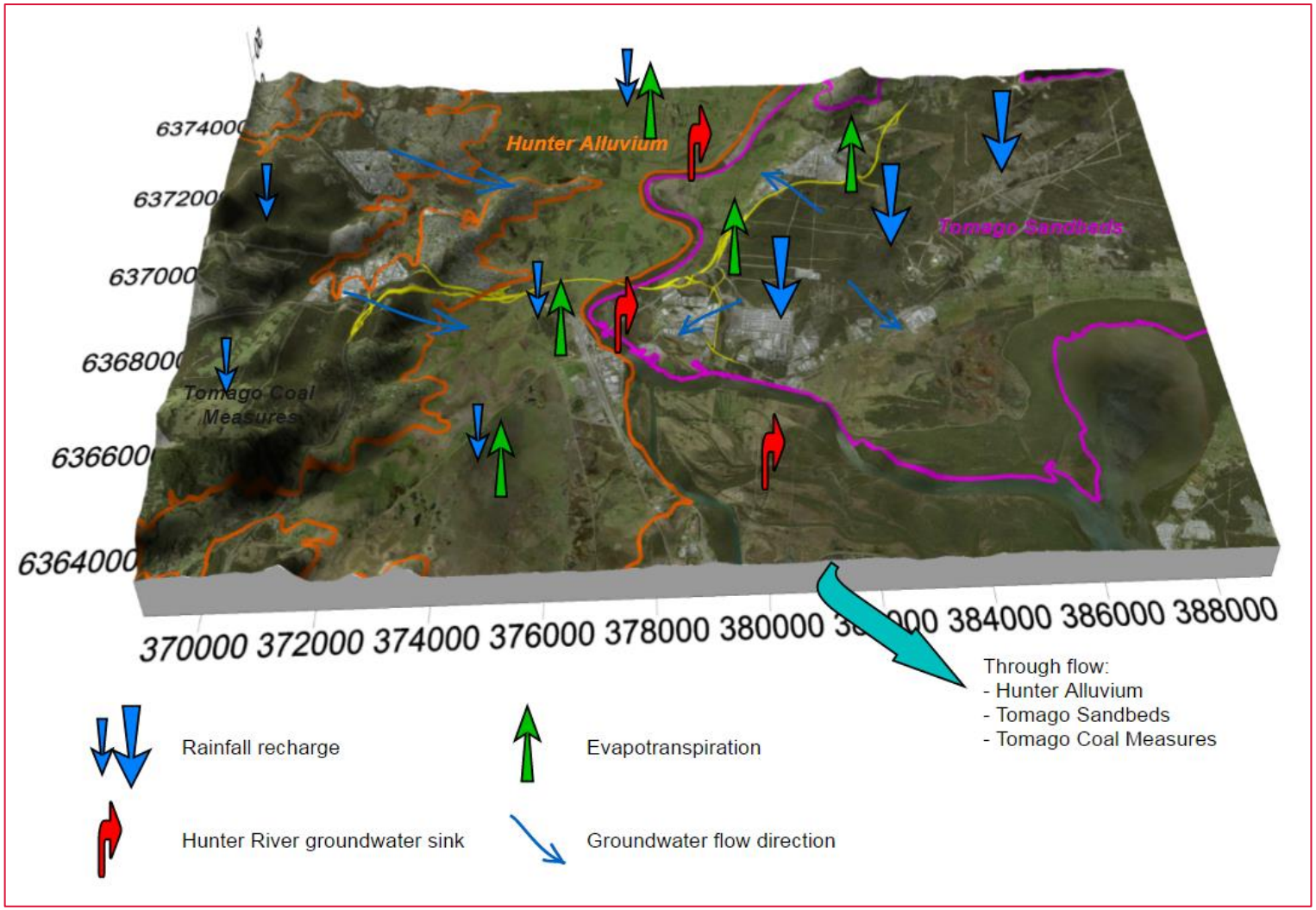

Figure 3-10 Conceptual hydrogeological model

4. Numerical Groundwater Modelling

4.1 Model purpose and objectives

The purpose of the groundwater modelling is to assess potential impacts associated with the project. The project involves ground treatment of embankments to overcome identified constraints with respect to soft soil conditions. As noted in **Section 3.6.2**, these soft soils have potential acid sulfate soil properties.

There are two minor creek / drainage line adjustments, one adjacent to the western embankment, referred to as Purgatory Creek, and the other, a tributary of Viney Creek, north of the Blackhill interchange.

In addition, the proposed cutting at Black Hill may lead to groundwater seepage.

Objectives of the groundwater model were to:

- Match historical groundwater levels
- Predict change in groundwater level due to the project
- Predict change in groundwater contribution to proximate surface watercourse and wetlands due to the project.

Target model confidence level classification, in accordance with Australian Groundwater Modelling Guidelines (AGMG) (Barnett et. al., 2012) is Class 2.

As per the requirements specified by DPI Water, a third party reviewer has been appointed to review the model.

4.2 Model Construction

The model was prepared in United States Geological Survey (USGS) MODFLOW code. MODFLOW is an industry standard saturated groundwater flow model code.

The version of MODFLOW used in this assessment was MODFLOW-NWT, Version 1.09. MODFLOW-NWT is a refinement prepared by the USGS to their MODFLOW-2005 code that implemented, primarily, a more robust approach treatment of inactivation and re-activation of model cells that had become desaturated.

The groundwater model was developed and implemented within the Groundwater Vistas Graphical User Interface, V7.24 Build 243.

4.2.1 Model domain

The model domain is centred on the project area and is shown on **Figure 4-1**.

The numerical model used in this assessment was based on a Hunter Water model (Hancock and Barnett, 2012) of the Tomago Sandbeds Drinking Water Supply. Accordingly, the rotation of the model (approximately 18°) and northern and southern extent were kept consistent with the Hunter Water model.

The model extends to the west to Black Hill and Maryland, above the Hexham wetlands. The model extends to the east to approximately Grahamstown Reservoir and Williamtown. The original Hunter Water model (Hancock and Barnett, 2012) extends to the east to Lemon Tree Passage; however, this model was able to be reduced due to modelled groundwater contours being perpendicular at that location.

The southern extent of the model includes Fullerton Cove and Kooragang Island. The northern extent of the model includes Beresfield. The Hunter River bisects the middle of the model domain.

4.2.2 Model geometry

The original Hunter Water model (Hancock and Barnett, 2012) had a uniform grid of 100 x 100 metres (103 rows and 365 columns).

The geometric dimensions of the modified model are as follows:

- 372026.27 XOffset, 6360729.68 YOffset,18.4081328 rotation (degrees)
- delX (cell width) was 25 to 100m; delY (cell height) was 25 to 100 metres
- 175 rows and 415 columns
- Four layers.

The model grid was refined in the vicinity of the project, with the minimum cell size being 25 x 25 metres.

There are four layers in the numerical model of the project compared to two layers in the Hunter Water model (Hancock and Barnett, 2012). **Table 4-1** summarises a summary of the hydrogeological units assigned to the model layers.

Table 4-1 Model geometry

Layer	Black Hill (western area)	Hunter River (central area)	Tomago Sandbeds (eastern area)
1	Residual	Clays and Sands (including Soft Soils)	Sands and Silts – adopted from Hunter Water model (Hancock and Barnett, 2012) without changes
2	N/A, set to minimal thickness (0.01 m)	Clays and Sands (including Soft Soils)	Sands – adopted from Hunter Water model (Hancock and Barnett, 2012) without changes
3	N/A, set to minimal thickness (0.01 m)	Sands and Gravels	N/A, set to minimal thickness (0.01 m)
4	Bedrock	Bedrock	Bedrock

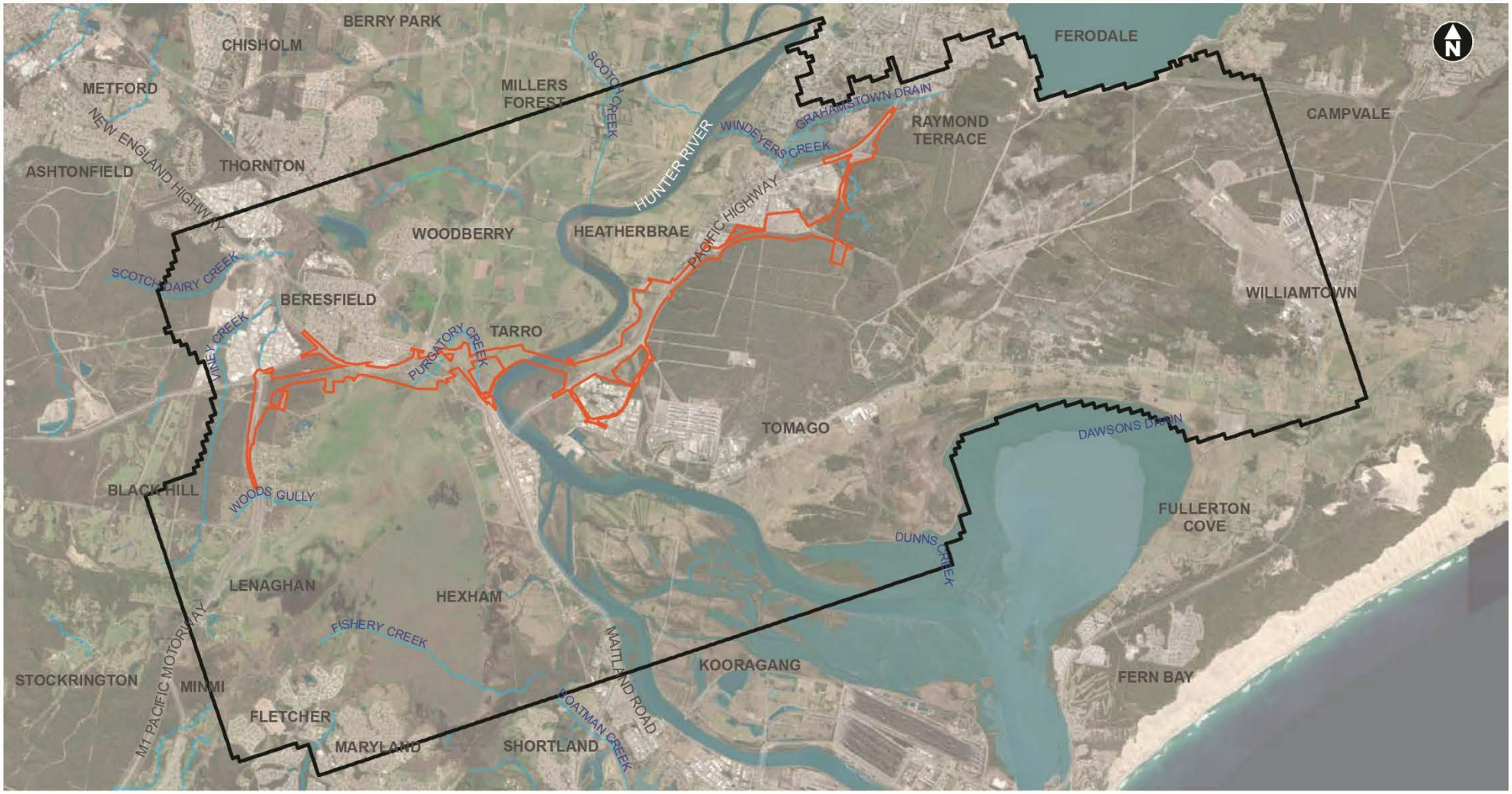

Figure 4-1 Model domain

4.2.3 Properties/Parameters

Hydraulic parameters were applied in the model using zones. The zonation used in the original Hunter Water model (Hancock and Barnett, 2012) was extended to encompass the refined model domain. The zonation and parameter values assigned to zones in the Hunter Water model (Hancock and Barnett, 2012) were preserved, except in the vicinity of the project where additional data was available.

Boundary conditions

Inflows

Inflows to the model included:

- Recharge
- Injection wells (within the Tomago Sandbeds).

Rainfall recharge

Recharge to the model was based on the following SILO processed climate stations:

- 61078 (Willamtown RAAF)
- 61031 (Raymond Terrace (Kinross))
- 61223 (Maryville)
- 61064 (Raymond Terrace Post Office)
- 61046 (Morpeth Post Office)
- 61034 (East Maitland Bowling Club)
- 61011 (Cockle Creek (Pasminco Metals)).

The distribution of rainfall stations applied to various recharge zones was based on a Voronoi analysis. The zonation for rainfall recharge was retained from the Hunter Water model (Hancock and Barnett, 2012) and extended as required for the refined model domain.

Rainfall recharge was assigned as a percentage of rainfall. The percentage of rainfall assigned as recharge was varied across model zones representing different hydrogeological units. The percentage of rainfall assigned as rainfall to each zone were initially set during the initial model calibration in 2016. Recharge rates ranged between 1 per cent and 35 per cent of rainfall, with an average of average of 14 per cent of rainfall. Rainfall was applied in the model to the highest active model layer.

It is noted that the original Hunter Water model (Hancock and Barnett, 2012) uses an external recharge model within EXCEL. That model includes consideration of the unsaturated zone as well as evapotranspiration. The external recharge model was not adopted in the numerical model for the Project due to adequate calibration being achieved via the standard MODFLOW approach, including application of the evapotranspiration package discussed further below.

Injection wells

Within the Tomago Sandbeds, there are some wells that inject water back into the aquifer. The location of these wells is presented in **Figure 4-2** below. Data pertaining to historical rates of injection, and withdrawal were based on the original Hunter Water model (Hancock and Barnett, 2012). This data was available monthly.

Outflows

Outflows from the model included:

- Evapotranspiration
- Pumping wells (within the Tomago Sandbeds)
- River
- Constant head (adjacent Fullerton Cove)
- Drains (ephemeral watercourses).

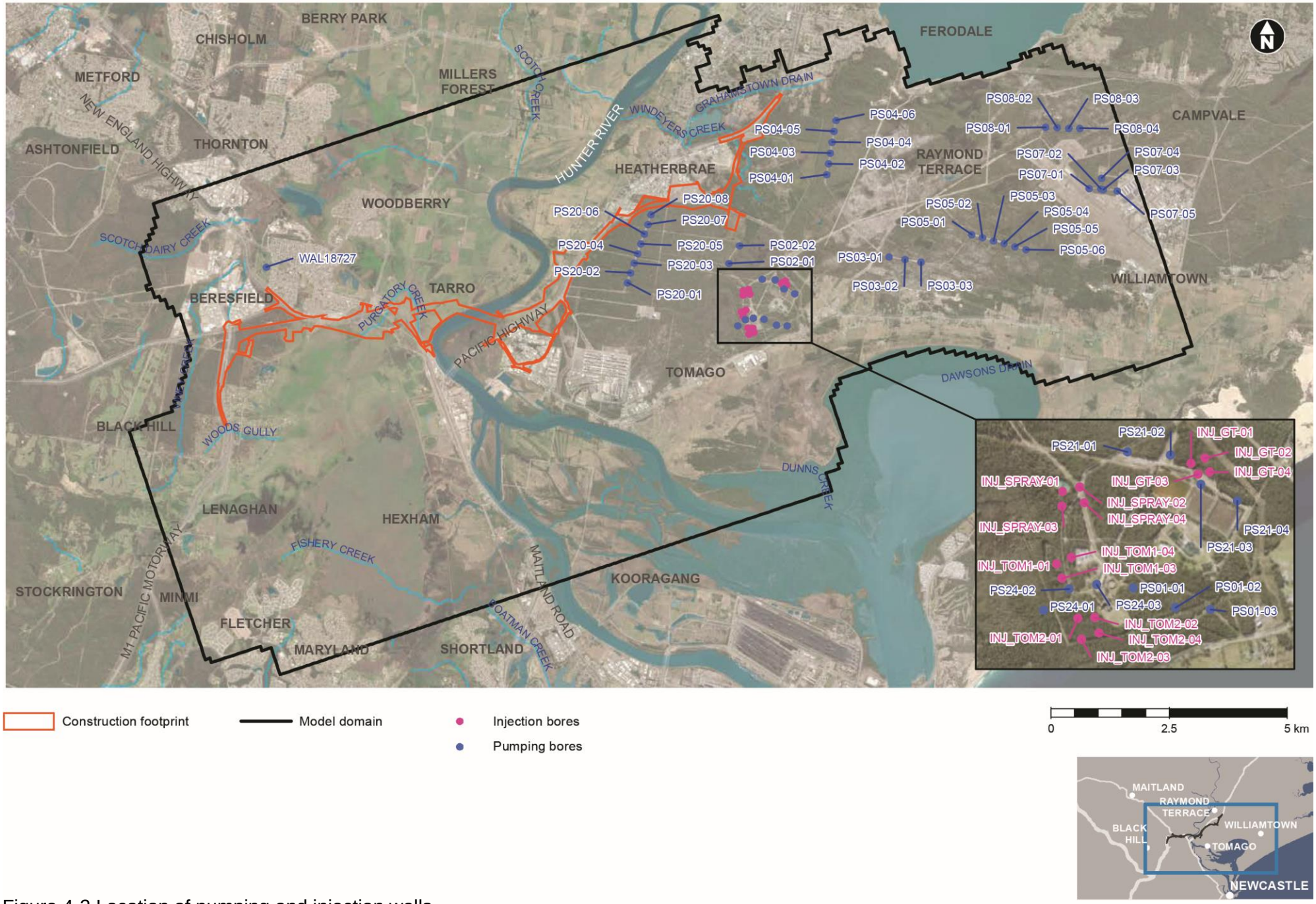

Figure 4-2 Location of pumping and injection wells

Date: 18/09/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_089_F4_2_PumpingInjectionWells_JAC_A4L_100000_V01.mxd

Evapotranspiration

Evapotranspiration was simulated in the model using the MODFLOW Evapotranspiration (EVT) Package. Inputs required for the EVT package are the maximum evapotranspiration rate and an extinction depth (i.e. maximum depth from which evaporation can occur).

Maximum evapotranspiration rates were based on the Penman-Monteith Method evapotranspiration (FAO56) dataset from SILO processed climate stations. Evapotranspiration data from the same climate stations used for rainfall analysis were used for this modelling assessment. Maximum evapotranspiration rates assigned during the initial calibration of the model in 2016 ranged between 50 per cent and 100 per cent of the evapotranspiration rates from the FAO dataset. The extinction depth ranged between 0.5 and 1.0 metres.

Evapotranspiration was applied in the model to the highest active layer. It is noted, however, that because the evapotranspiration surface was set to the elevation of the top of Layer One, evapotranspiration is disabled once modelled groundwater level falls below the extinction depth, regardless of the layer in which the modelled groundwater table surface is located.

Pumping wells

Within the Tomago Sandbeds, there are several pumping station ‘borelines’. The data pertaining to these was obtained from the original Hunter Water model (Hancock and Barnett, 2012). This data was available monthly. The location of the wells within the refined model domain is presented in **Figure 4-2** above.

The groundwater abstraction bore for water access licence WAL 18727, which was not included in the 2016 groundwater modelling, has been included in the updated groundwater model. The allocation for WAL 18727 is 91ML/yr. An average pumping rate of approximately 250 m^3/day (i.e. 91 ML/yr divided by 365) has been assigned to the model, for the purposes of this assessment.

River

The Hunter River was simulated in the model using the MODFLOW River (RIV) Package. RIV boundaries can be used to simulate both groundwater discharge to streams and leakage from streams to groundwater, depending on the relative difference between groundwater level and stream stage (stream water depth). For RIV boundaries, groundwater discharges to the stream when groundwater levels in areas adjacent to the stream are higher than the stream stage and leakage occurs from the stream when stream stage is higher than surrounding groundwater levels. The head elevation of the river boundary condition was set at zero metres AHD. The base of the river was variably set at between -four and -six metres AHD.

The conductance of the RIV cells was calculated in Groundwater Vistas, based on an assumed hydraulic conductivity of streambed of 0.00864 metres per day and bed thickness of two metres.

Constant head

A constant head boundary was set at Fullerton Cove. The elevation of the boundary was zero metres AHD.

The location of the constant head boundary was such that it operated as an outflow.

Drains

The MODFLOW Drain (DRN) package was used to represent ephemeral watercourses, wetlands and agricultural drains that are used on farming land to lower the groundwater level. DRN boundaries can only be used to simulate discharge of groundwater to streams when groundwater levels are higher than stream stage.

The 1:25,000 scale hydrographic GIS layer was used as the basis of delineating surface watercourses and wetlands. Agricultural drains were included wherever relevant, based on aerial photography.

The stage of DRN cells representing ephemeral watercourses were set, in general, at one metre below the top elevation of Layer One in the model. The stage and/or layer geometry was adjusted where necessary to accommodate the drain within Layer One of the model. The width of ephemeral watercourse was measured based on aerial photography and the streambed hydraulic conductivity was assumed to be 0.00864 metres per day, with a streambed thickness ranging between 0.1 and 0.4 metres, average of 0.2 metres.

The stage of DRN cells representing wetlands (SEPP14) and drainage depressions was set at 0.2 metres AHD. The streambed hydraulic conductivity was assumed to be 0.00864 metres per day and the streambed thickness was 0.3 metres.

The stage of DRN cells representing agricultural drains were set, in general, at zero to 0.5 metres below the top elevation of Layer One.

4.3 Model calibration

4.3.1 Overview

The model was calibrated for transient conditions. Calibration was conducted by iterative manual step-wise adjustment of hydraulic conductivity, storage parameters, recharge rates and evapotranspiration to achieve an acceptable match between simulated and observed heads (groundwater levels).

Two modelling periods were considered, the calibration period from January 2005 to November 2015 and the validation period from September 2016 to July 2017. Model calibration was initially carried out in 2016 using the groundwater level monitoring data available at that time**.** This calibrated model from 2016 is referred to as the “2016 Calibrated Model”. Subsequent to the initial model calibration, project specific piezometers were installed in 2016. Groundwater levels were measured in the project specific piezometers from September 2016 to July 2017 (**Section 3.9.3**).

A validation check of the 2016 Calibration Model was carried out to assess the accuracy of the model in simulating groundwater levels observed at project specific piezometers for the period from September 2016 to July 2017 (validation period). The validation check indicated that the accuracy and predictive capability of the 2016 Calibrated Model in the validation period (September 2016 to July 2017) was not within acceptable limits. The results of the validation check showed fairly poor performance with respect to replicating water levels and trends observed along the proposed road alignment for the validation period.

Results of the validation check indicated that the 2016 model required recalibration. During the recalibration, revisions to the model input parameters were made and the calibration and validation check procedures were repeated until an acceptable match was obtained between observed and simulated groundwater levels across the model for both the calibration period (January 2005 to November 2015) and the validation period (September 2016 to July 2017).

Calibration was conducted by iterative manual step-wise adjustment of model input parameters to achieve an acceptable match between simulated and observed heads (groundwater levels). Calibration was achieved by visually comparing simulated and observed hydrographs, as well as by assessing the statistical calibration measures.

4.3.2 Model setup

Calibration model set up

Transient calibration of the model was carried out for the period from January 2005 to November 2015 using monthly stress periods. As described in the preceding overview section, the model was initially calibrated in 2016 and the re-calibrated in 2020 following the validation check.

The calibration model has 131 stress periods with four time-steps per stress period. Variable zonal recharge and evapotranspiration rates were applied to each stress period. The initial time-varying recharge rates applied during the calibration in 2016 were based on values applied to the Hunter Water model (Hancock and Barnett, 2012).

Figure 4-3 shows the location of calibration targets used to calibrate the model. The calibration dataset comprised 100 targets. Of these, 52 were within the Tomago Sandbeds Drinking Water Supply and most of those targets are long-term records of monthly groundwater level. Groundwater monitoring data from January 2005 to November 2015 was used in the calibration. In total, there were 4285 observations in the calibration dataset.

Validation check model set up

A validation check of the 2016 Calibrated Model was carried out to assess the accuracy of the model in simulating groundwater levels observed at project specific piezometers for the period from September 2016 to July 2017 (validation period). The validation check model simulation time from January 2016 to July 2017 (19 months) includes the groundwater level monitoring period for project specific bores (September 2016 to July 2017).

Time-varying rainfall recharge and evapotranspiration was based on rainfall and evapotranspiration datasets from SILO processed climate stations described in **Section 4.2.3**. Recharge was applied as a percentage of rainfall based on percentages applied to the 2016 Calibrated Model. The maximum evapotranspiration rates applied to the MODFLOW Evapotranspiration (EVT) boundaries were varying percentages of FAO56 evapotranspiration rates based on percentages applied to the 2016 Calibrated Model.

Groundwater level monitoring data from project specific bores shown in **Figure 4-3** was used in the model validation check.

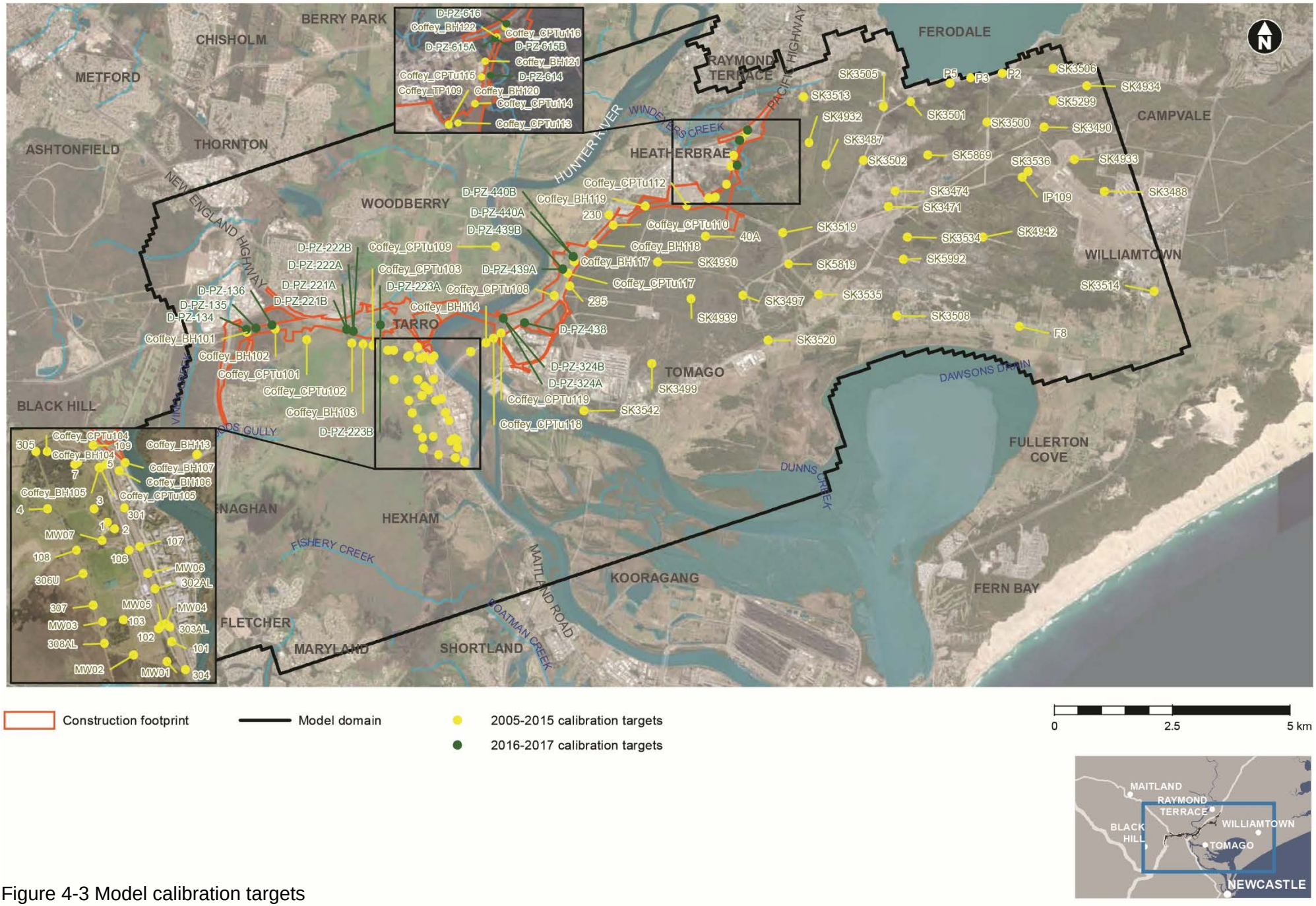

Figure 4-3 Model calibration targets

4.3.3 Calibrated model parameters

This section summarises the final calibrated parameter values assigned to re-calibrated model in 2020.

Calibrated Hydraulic conductivity values

Table 4-2 summarises the calibrated values for hydraulic conductivity. **Figure 4-4** to **Figure 4-7** show the distribution of hydraulic conductivity model zones assigned to the model. The distribution of horizontal hydraulic conductivity and vertical hydraulic conductivity zones are the same.

Table 4-2 Hydraulic conductivity values assigned to calibrated model

Zone #	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)
1	7	7
2	40	4
3	17	1.7
4	0.001	0.001
5	0.01	0.01
6	0.025	0.01
7	10	1
8	10	1
9	5	0.5
10	25	2.5
11	10	1
12	20	2
13	3	0.3
14	8	0.8
15	8	0.8
20	10	2
21	0.1	0.1
22	0.1	0.1
23	0.025	0.01
30	5	2
31	1	1
32	0.1	0.1
33	0.025	0.01
40	10	5
41	1	1
42	0.1	0.1
43	0.025	0.01
50	0.025	0.01
51	0.07	0.05
52	0.035	0.0035

Figure 4-4 Model zones of hydraulic conductivity in Layer One

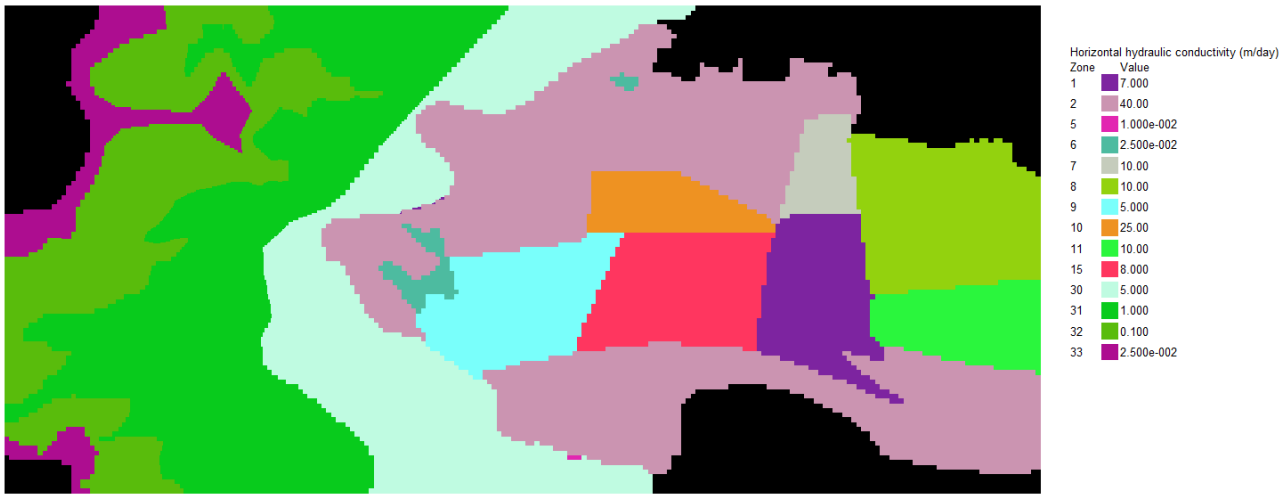

Figure 4-5 Model zones of hydraulic conductivity in Layer Two

Figure 4-6 Model zones of hydraulic conductivity in Layer Three

Figure 4-7 Model zones of hydraulic conductivity in Layer Four

Calibrated storage parameter values

Table 4-3 summarises the calibrated values for storage (specific yield and specific storage). **Figure 4-8** to **Figure 4-11** show the distribution of model zones of specific storage adopted in the model. The distribution of specific storage and specific yield zones are the same.

Table 4-3 Calibrated parameter values (storage)

Zone #	Specific storage (m^{-1})	Specific yield (%)
1	1.00E-05	0.20
2	1.00E-05	0.20
3	5.00E-06	0.25
4	5.00E-06	0.25
5	1.00E-5	0.05
6	5.00E-06	0.05
7	1.00E-05	0.20
8	1.00E-05	0.25
9	1.00E-05	0.20
10	1.00E-05	0.25
11	1.00E-05	0.12
12	5.00E-06	0.15
13	1.00E-05	0.25
14	5.00E-06	0.20
15	1.00E-05	0.25
16	1.00E-05	0.20
17	5.00E-06	0.20
20	5.00E-05	0.20
21	5.00E-06	0.05
22	5.00E-06	0.05

Zone #	Specific storage (m^{-1})	Specific yield (%)
23	5.00E-06	0.05
30	1.00E-05	0.25
31	1.00E-05	0.15
32	1.00E-06	0.10
33	5.00E-06	0.05
40	1.00E-5	0.20
41	1.00E-06	0.05
42	1.00E-06	0.10
43	5.00E-06	0.05
50	5.00E-06	0.05

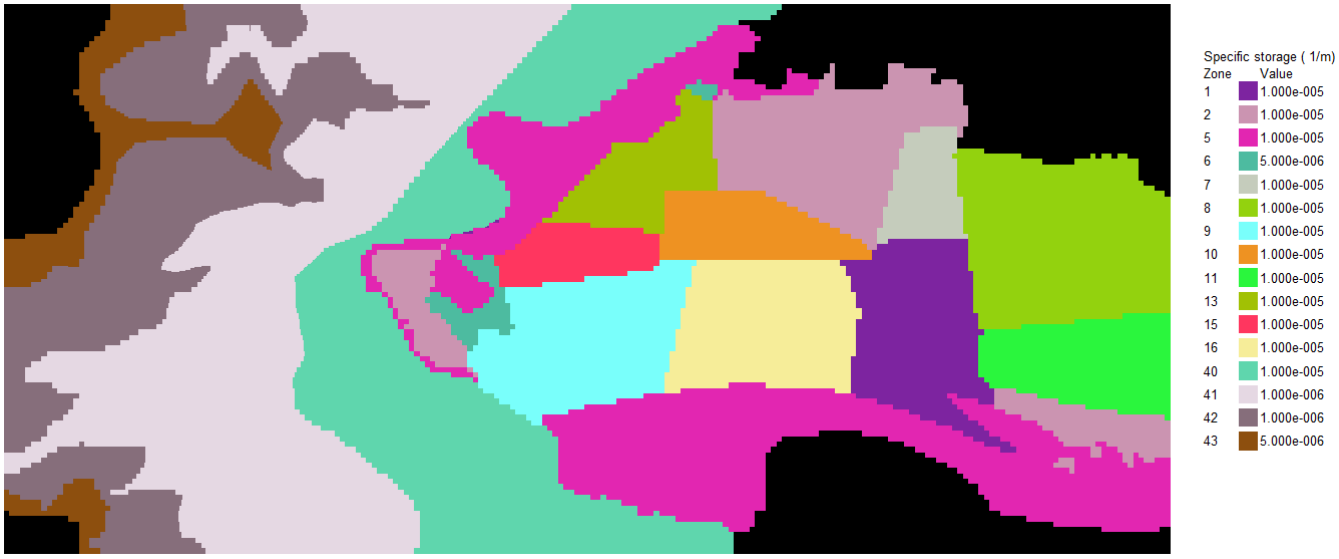

Figure 4-8 Model zones of storage in Layer One

Figure 4-9 Model zones of storage in Layer Two

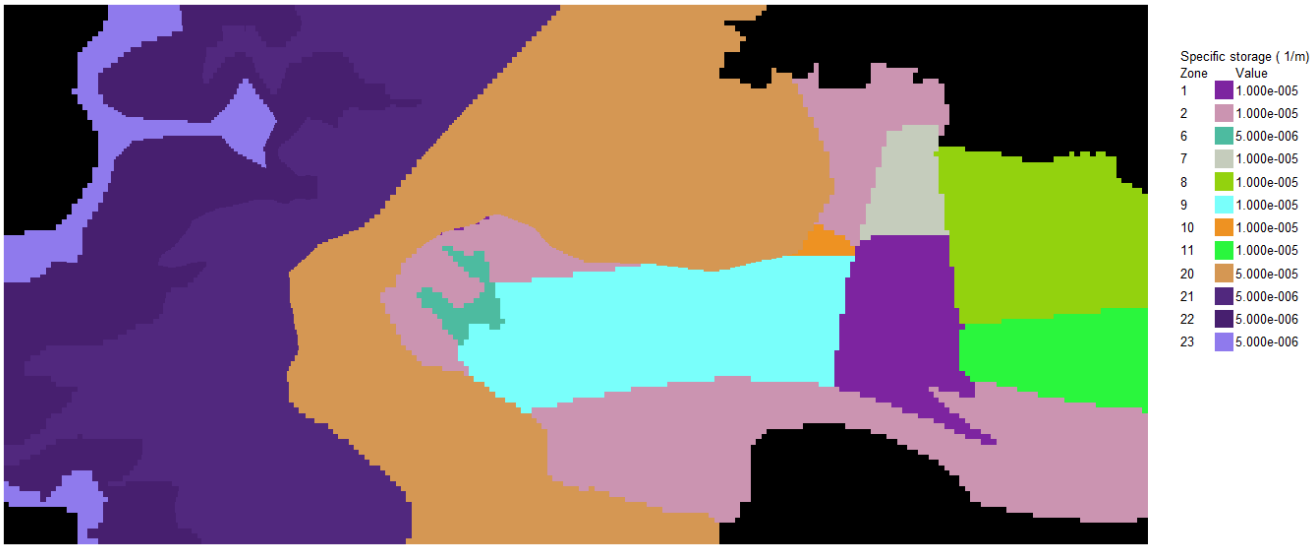

Figure 4-10 Model zones of storage in Layer Three

Figure 4-11 Model zones of storage in Layer Four

Calibrated recharge values

Figure 4-12 shows the zones for rainfall recharge assigned to the calibrated model. The legend in **Figure 4-12** also shows the calibrated model recharge rate (as a percentage of rainfall) for each zone.

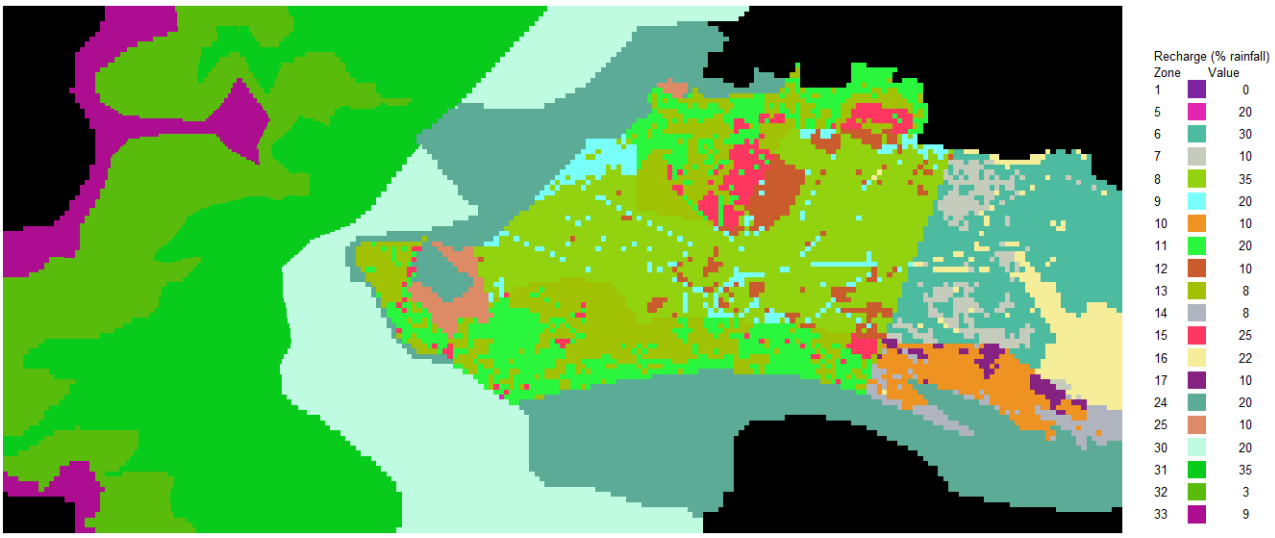

Figure 4-12 Recharge zones and recharge rates (per cent rainfall)

Calibrated evapotranspiration parameter values

Table 4-4 summarises the calibrated model evapotranspiration parameter values assigned to model zones shown in **Figure 4-13**. The maximum evapotranspiration rates applied to the calibrated model ranged from 50% to 100% of the daily FAO 56 evapotranspiration measured for the nearest climatic station (**Section 4.2.3).**

Table 4-4 Calibrated evapotranspiration parameter values

Zone #	Maximum evaporation (% of measured FAO56 ET for nearest climate station)	Extinction depth (m)
1	80%	1
5	80%	1
6	80%	1
7	90%	1
8	90%	1
9	90%	0.8
10	90%	0.8
11	60%	0.5
12	90%	1
13	90%	0.7
14	80%	0.75
15	90%	0.7
16	60%	0.5
17	100%	1
24	80%	0.7
25	50%	0.5
30	80%	0.7

Zone #	Maximum evaporation (% of measured FAO56 ET for nearest climate station)	Extinction depth (m)
31	80%	0.7
32	70%	0.7
33	60%	0.5

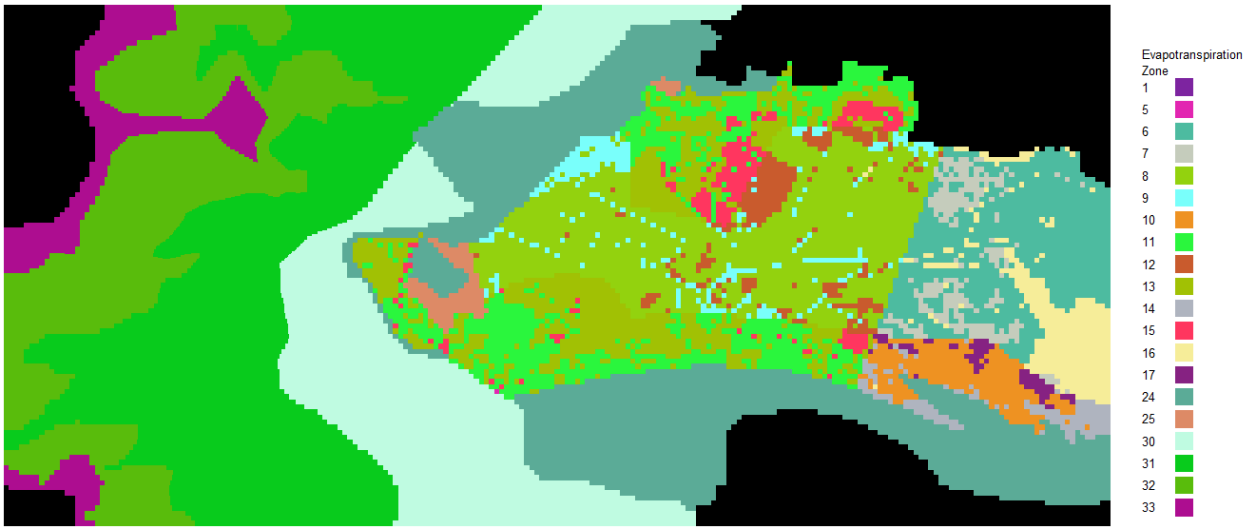

Figure 4-13 Model zones for evapotranspiration

Calibration assessment

Calibration was conducted by iterative manual step-wise adjustment of model input parameters to achieve an acceptable match between simulated and observed heads (groundwater levels). Calibration was achieved by qualitatively assessing the match between modelled and observed heads as well as assessing statistical calibration measures.

Calibration bi-variate plot

Figure 4-14 is a bi-variate for the re-calibration carried out in 2020 using groundwater level monitoring data from 2005 to 2015. The plot shows the match between simulated groundwater levels (heads) in the calibrated model and observed heads. Qualitatively assessing the match between modelled and observed heads (**Figure 4-14**), the degree of calibration can be assessed according to how close the plotted points are to the diagonal line from the origin (i.e. along the line y=x that represents perfect calibration). **Figure 4-14** shows a reasonably good match between simulated groundwater levels (heads) in the calibrated model and observed heads.

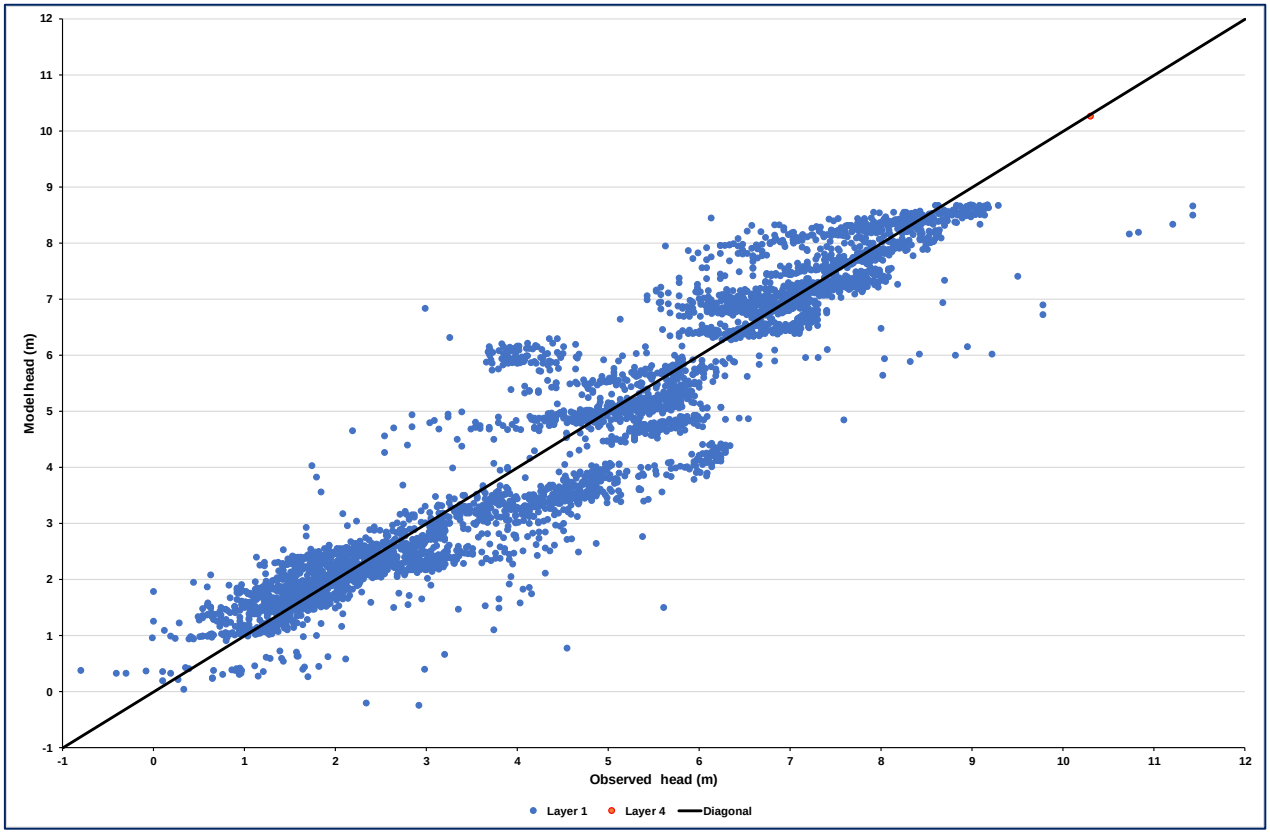

Figure 4-14 Bi-Variate Plot of Observed Versus Modelled Groundwater Levels

Calibration statistics

Table 4-5 summarises a summary of the calibration statistics for the re-calibration carried out 2020 using groundwater level monitoring data from 2005 to 2015. The scaled root mean square (scaled RMS) is one of the statistics often used to quantitatively assess the goodness-of-fit between simulated groundwater levels and actual observed groundwater levels. A scaled RMS error less than ten per cent usually indicates a reasonably high degree of calibration (Barnett et. al., 2012). The scaled RMS error of approximately six per cent obtained in the calibrated steady state model (**Table 4-5**) shows that the model is reasonably well calibrated to measured heads.

Table 4-5 Calibration statistics summary

Calibration statistic	Value
Residual Mean	0.07
Residual Standard Deviation	0.73
Absolute Residual Mean	0.52
Residual Sum of Squares	2,280
RMS Error	0.73
Minimum Residual	-3.85
Maximum Residual	4.11
Range of Observations	12.23
Scaled Residual Standard Deviation	0.059
Scaled Absolute Mean	0.043
Scaled RMS	0.060
Number of Observations	4,285

Calibration hydrographs

Calibration hydrographs in Appendix A and Appendix B present observed and simulated groundwater levels for groundwater monitoring locations.

- Appendix A summarises calibration hydrographs for the re-calibrated model simulating 2005 t0 2015 groundwater conditions
- Appendix B summarises hydrographs for the model simulating January 2016 to July 2017 groundwater conditions. Calibration targets for this model are from project specific bores.

The calibration hydrographs presented in Appendix A and B show a reasonably good match in groundwater level trends over time between observed and simulated groundwater levels.

Calibrated model mass balance

Model mass balance is another important indicator of model performance. The cumulative mass balance error for the calibration model was -0.14 per cent. A mass balance error of less than one per cent is considered appropriate. The mass balance at various times over the simulation period is presented in **Figure 4-15**.

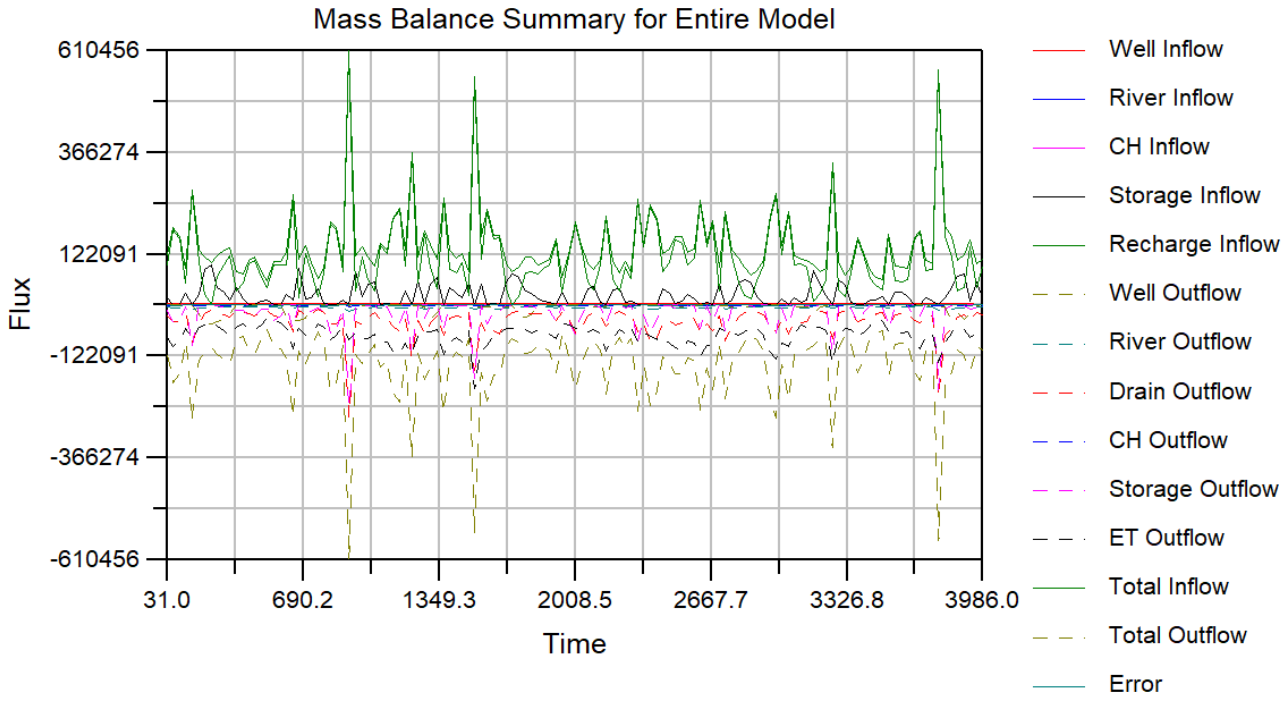

Figure 4-15 Calibration model – model mass balance

4.4 Model prediction

4.4.1 Prediction Model setup

Predictive model time settings (temporal discretization)

The simulation time for the prediction model was 12 years. The simulation period includes the two-year project construction phase and 10-year operation period. The model has 25 stress periods, with the first 24 stress periods each of one month and the final stress period with a length of 3,660 days (approximately 10 years). Each stress period has four timesteps. The stress period settings applied to the model is summarised in **Table 4-6**.

Table 4-6 Predictive model stress period settings

Stress period	Period length (days)	Number of time steps	Time step multiplier
1	30.5	4	1.2
2	30.5	4	1.2
3	30.5	4	1.2
4	30.5	4	1.2
5	30.5	4	1.2
6	30.5	4	1.2
7	30.5	4	1.2
8	30.5	4	1.2
9	30.5	4	1.2
10	30.5	4	1.2
11	30.5	4	1.2
12	30.5	4	1.2
13	30.5	4	1.2
14	30.5	4	1.2
15	30.5	4	1.2
16	30.5	4	1.2
17	30.5	4	1.2
18	30.5	4	1.2
19	30.5	4	1.2
20	30.5	4	1.2
21	30.5	4	1.2
22	30.5	4	1.2
23	30.5	4	1.2
24	30.5	4	1.2
25	3660	4	1.2

Prediction model boundary conditions

For the predictive modelling, the daily conditions assigned to model boundaries not directly related to the project (rainfall recharge, evapotranspiration, river and drain stage, well abstraction and injection rates wells) were the averages (mean values) from the calibrated models (i.e. daily mean boundary conditions applied to the calibration model and validation check model over the combined simulation period from 2005 to July 2020).

Construction and operational water quality basins

MODFLOW Drain (DRN) boundaries were used to simulate dewatering required to maintain dry working conditions in the following proposed basins:

- Temporary basins to be used for drainage purposes during the road construction phase
- Permanent basins to be used during the operational phase as settling basins for water quality control.

Table 4-7 lists the basins requiring dewatering due to the modelled existing groundwater table occurring above the proposed basin invert elevation. **Figure 4-16** shows the basin locations. The stage (elevation) of the DRN boundary cells was set at the basin invert levels provided in **Table 4-7**.

Table 4-7 Information on construction and operational water quality basins

Basin	Approximate chainage (m)	Basin type	Groundwater table elevation (mAHD)	Basin invert level (mAHD)
B 01000 L	1000	Temp & Perm.	11.08	9.25
B 00950 L	1100	Temp. Only	10.88	9.25
B 01120 L	1200	Temp & Perm.	9.73	9.1
B 02460 L	2450	Temp & Perm.	4.00	3.25
B 03350 L	3420	Temp. Only	1.72	0.5
B M 03340	3320	Temp & Perm.	0.75	-1.05
B 03480 R	3420	Temp. Only	0.16	-1.6
B 03750 L	3750	Temp & Perm.	0.70	-1.25
B 03800 M	3850	Temp & Perm.	-0.13	-0.45
B 04300 L	4300	Temp. Only	-0.07	-1.35
B 05700 L	5650	Perm. Only	0.04	-1.31
B 06100 L	6100	Perm. Only	0.12	-0.7
B 07150 L	7200	Temp & Perm.	1.53	0.25
B 07300 R	7400	Temp & Perm.	3.38	3.15
B 07450b R OP Rd	1150	Temp. Only	9.57	9.25
B 07500 L	7650	Temp & Perm.	0.33	-0.25
B 07800 R	8000	Temp & Perm.	4.29	3.75
B 07900 R OP Rd	750	Temp. Only	2.47	1.05
B 08000 L	8150	Temp & Perm.	0.55	-0.45
B 08150 L	8250	Temp & Perm.	0.61	-0.43
B 08360 R	8400	Temp. Only	1.48	0.25
B M 08980	9100	Temp & Perm.	0.47	-0.8
B 09160 M	9200	Temp & Perm.	0.77	-0.5

Basin	Approximate chainage (m)	Basin type	Groundwater table elevation (mAHD)	Basin invert level (mAHD)
B 09120 M	9100	Temp & Perm.	1.35	-0.25
B 09360 L	9480	Temp & Perm.	0.52	-0.8
B 09440 L	9550	Temp & Perm.	1.53	0.15
B 11500 R	11600	Temp. Only	1.90	0.95
B 11550 L	11700	Temp. Only	1.94	1.2
B 11950 R	12050	Temp. Only	1.99	1.65
B 12460 R	12500	Temp & Perm.	1.91	0.9
B 12650 R	12800	Temp & Perm.	1.78	0.6
B 13450 L	13500	Temp & Perm.	2.59	2.25
B 13900 L	14050	Temp & Perm.	1.41	0.98
B 13850 L	14100	Temp & Perm.	1.40	1.34
B 14160 M	14200	Temp & Perm.	1.43	1.1
B 14400 M	14500	Temp & Perm.	1.48	0.05

The DRN boundaries were used to simulate basin dewatering during the construction phase of the basins only. Information provided by Transport for NSW indicates that the maximum dewatering period during construction of any the basins is 10 days. For the purposes of this assessment, dewatering for all the basins were simulated during model Stress Period One only (i.e. DRN boundary cells for simulating basin dewatering will only be active in model Stress Period One). Given that the length of Stress Period One (approximately one month) is greater than the maximum period over which dewatering period would occur (10 days), the model will provide conservative predictions for both cumulative dewatering volumes and the associated groundwater drawdown.

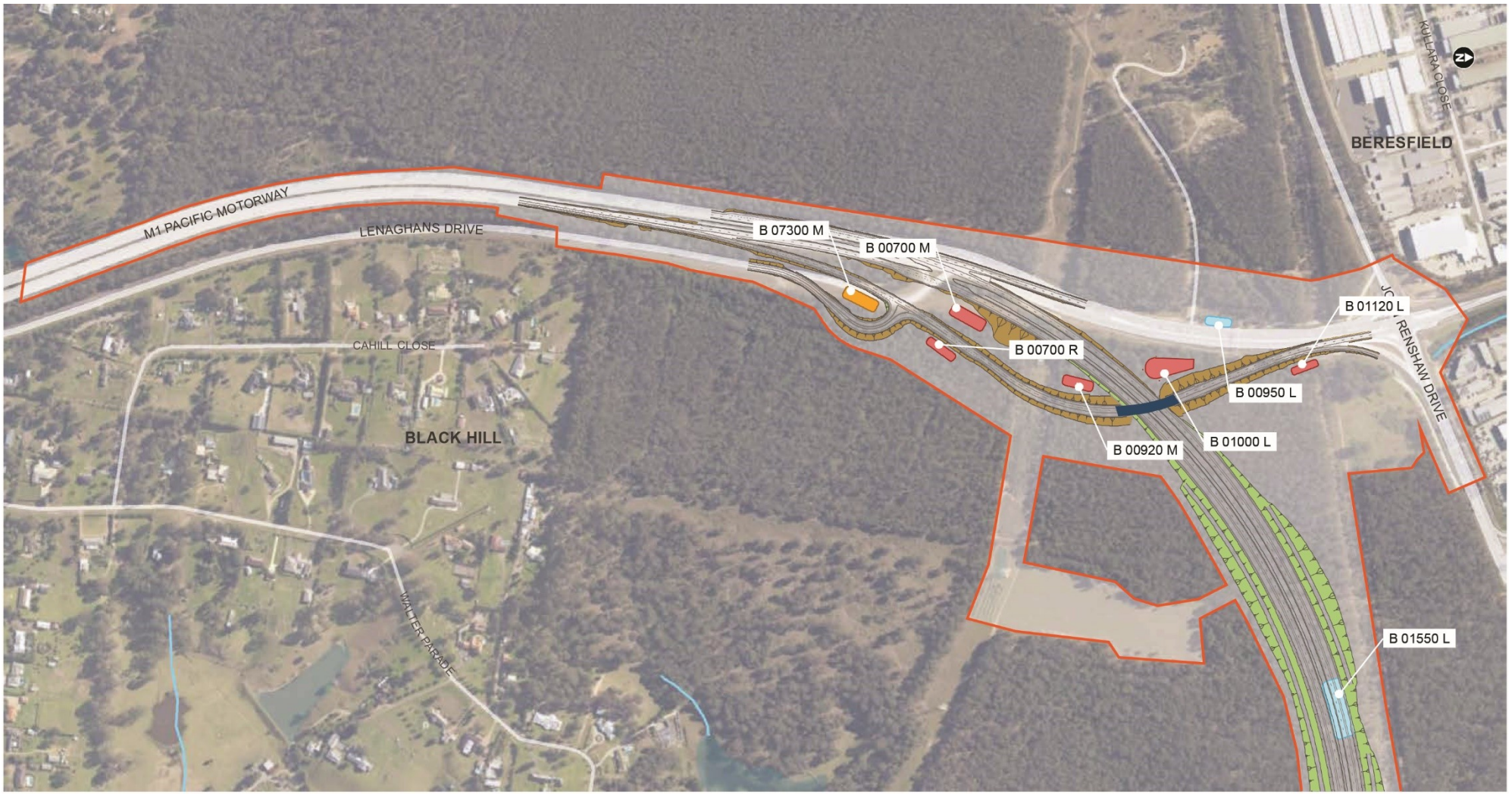

Figure 4-16 Basins requiring dewatering based on model results (map 1 of 8)

Page 1 of 8

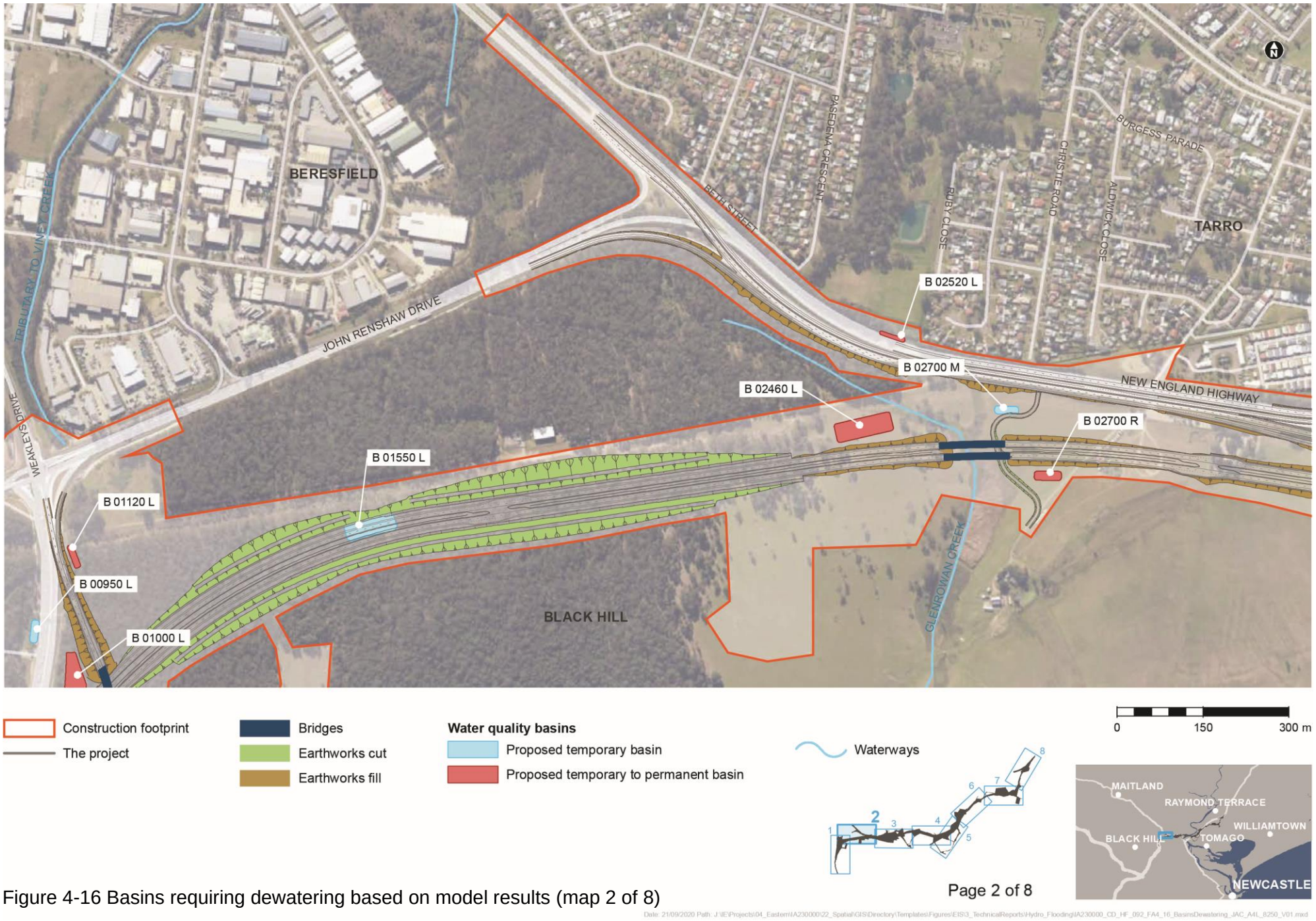

Figure 4-16 Basins requiring dewatering based on model results (map 2 of 8)

Page 2 of 8

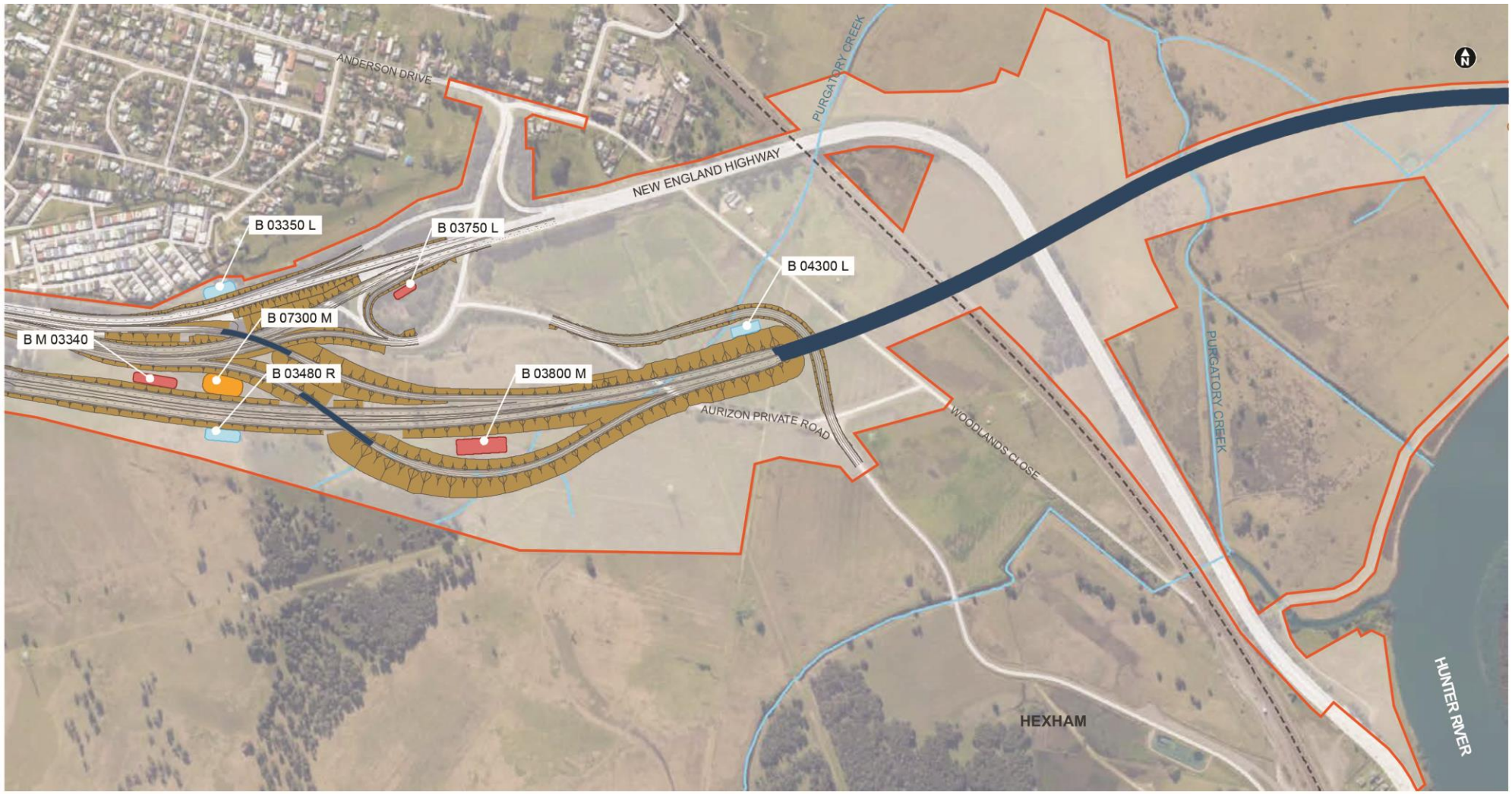

Figure 4-16 Basins requiring dewatering based on model results (map 3 of 8)

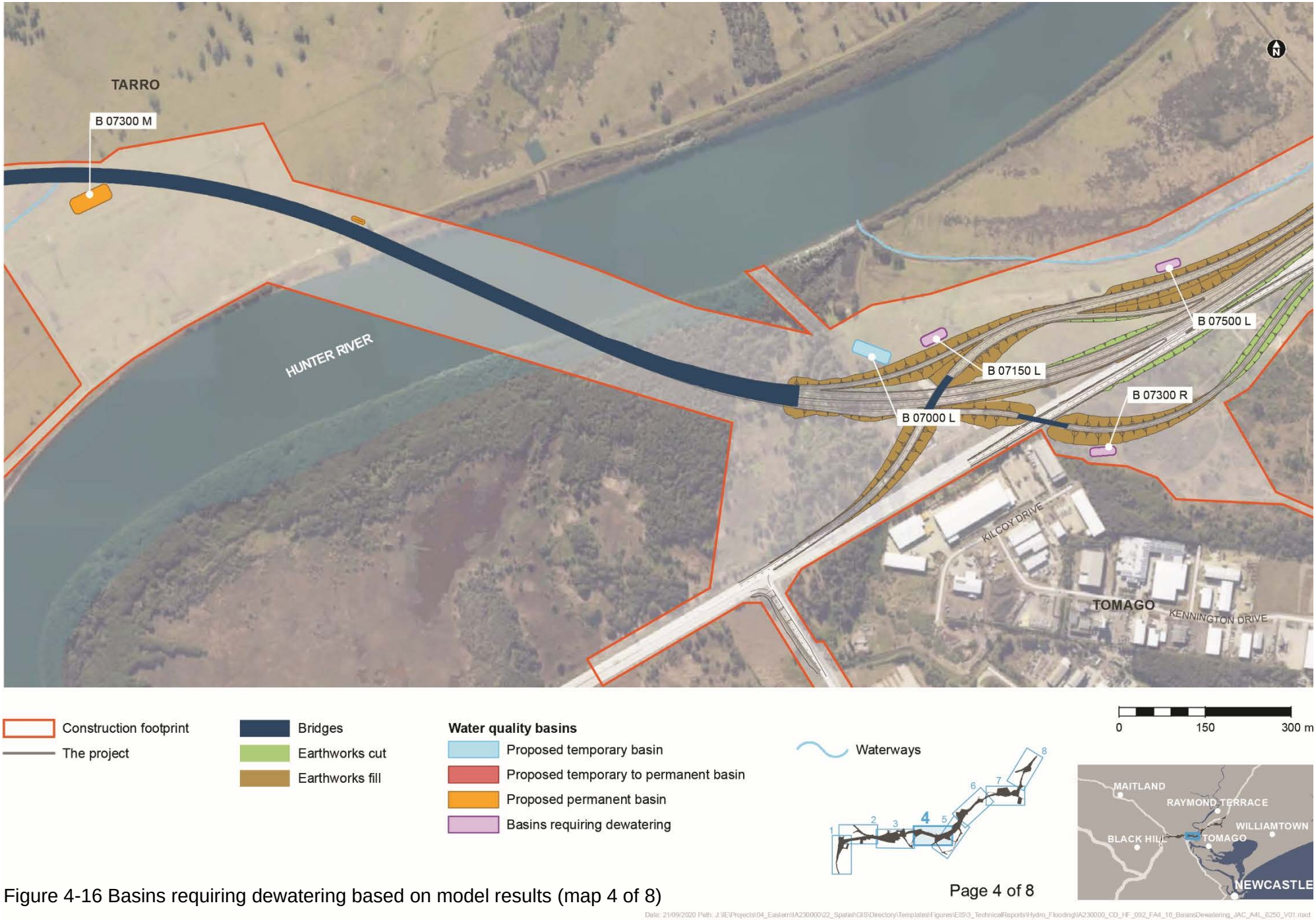

Figure 4-16 Basins requiring dewatering based on model results (map 4 of 8)

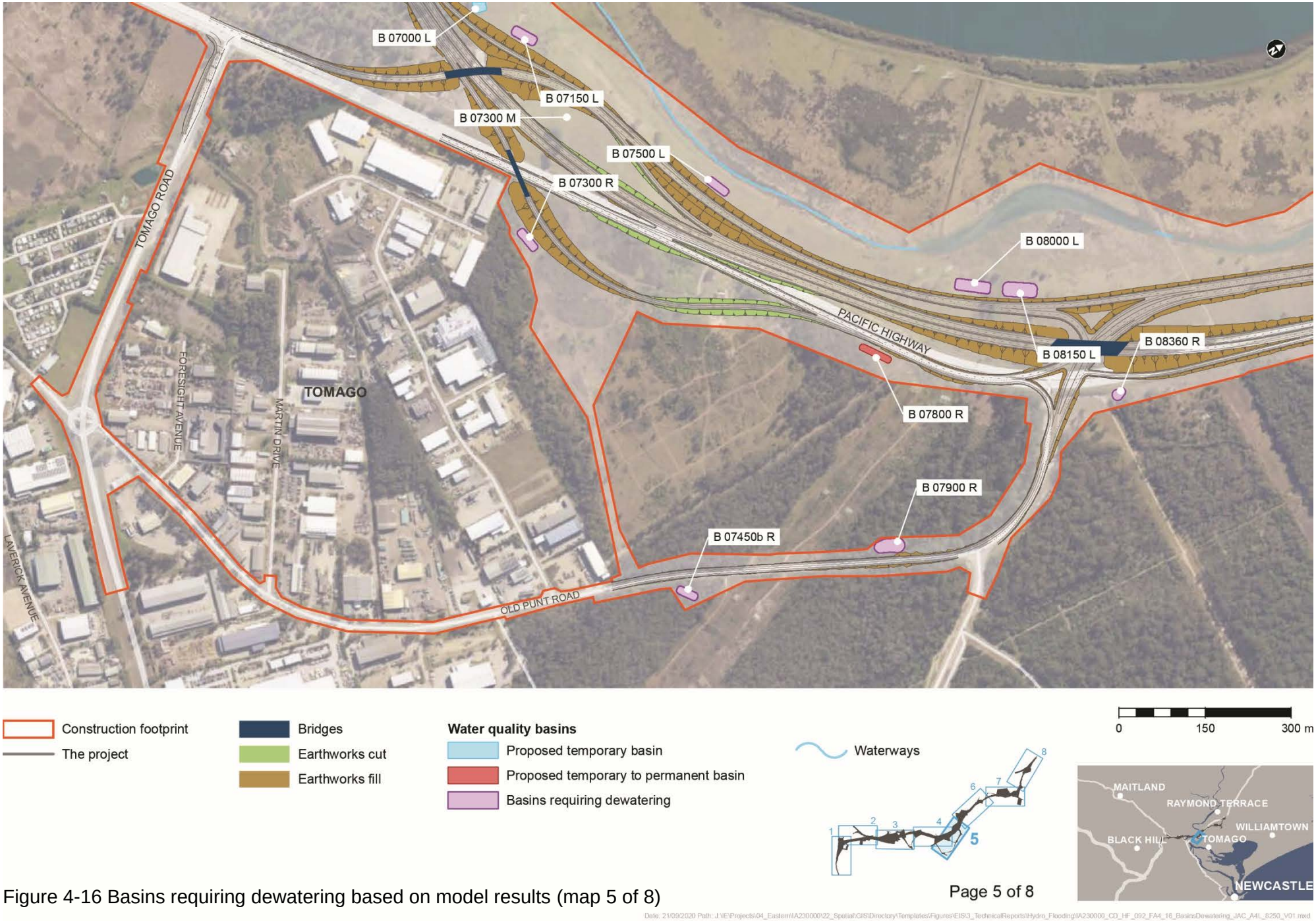

Figure 4-16 Basins requiring dewatering based on model results (map 5 of 8)

Page 5 of 8

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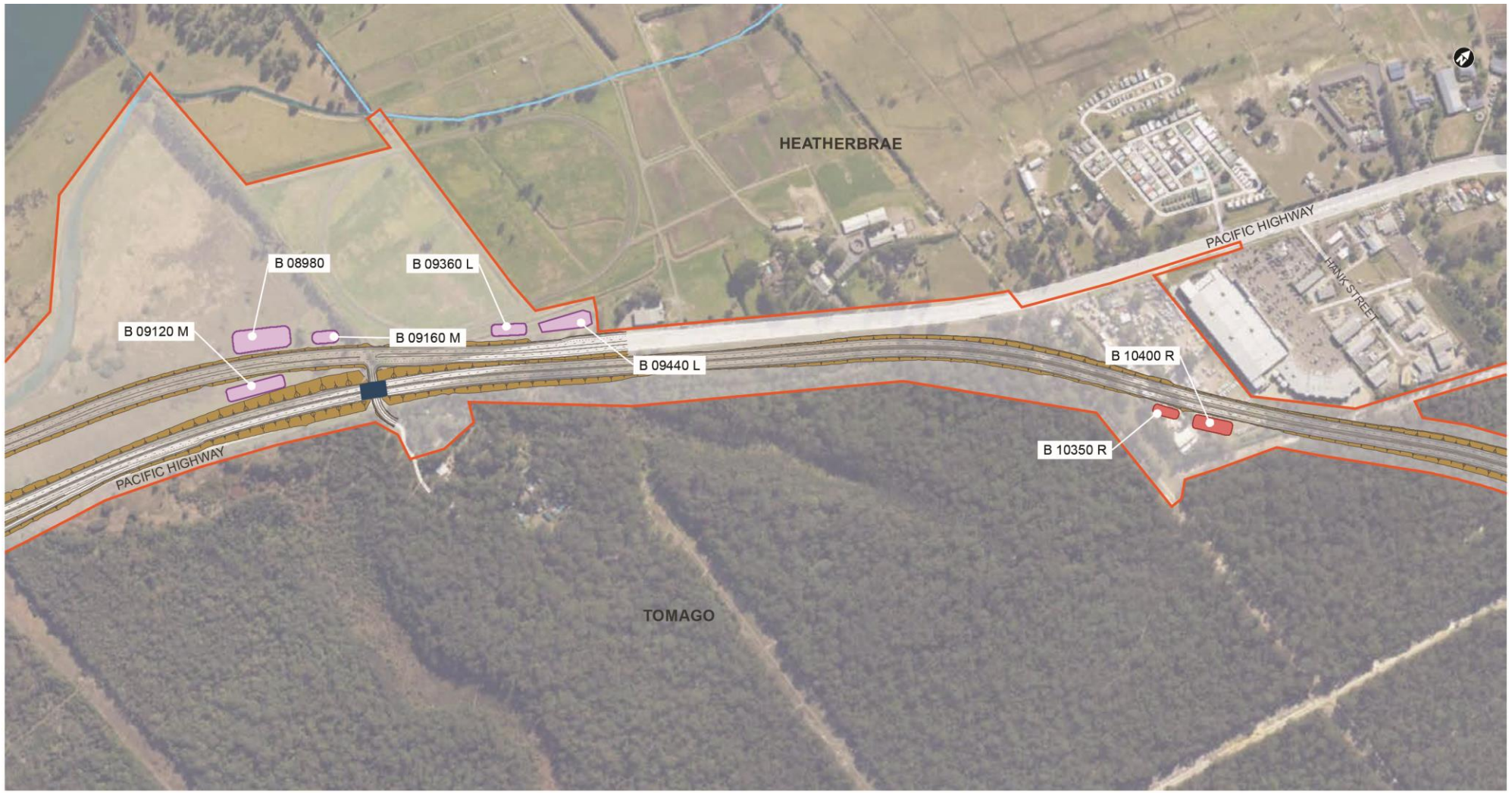

Figure 4-16 Basins requiring dewatering based on model results (map 6 of 8)

Figure 4-16 Basins requiring dewatering based on model results (map 7 of 8)

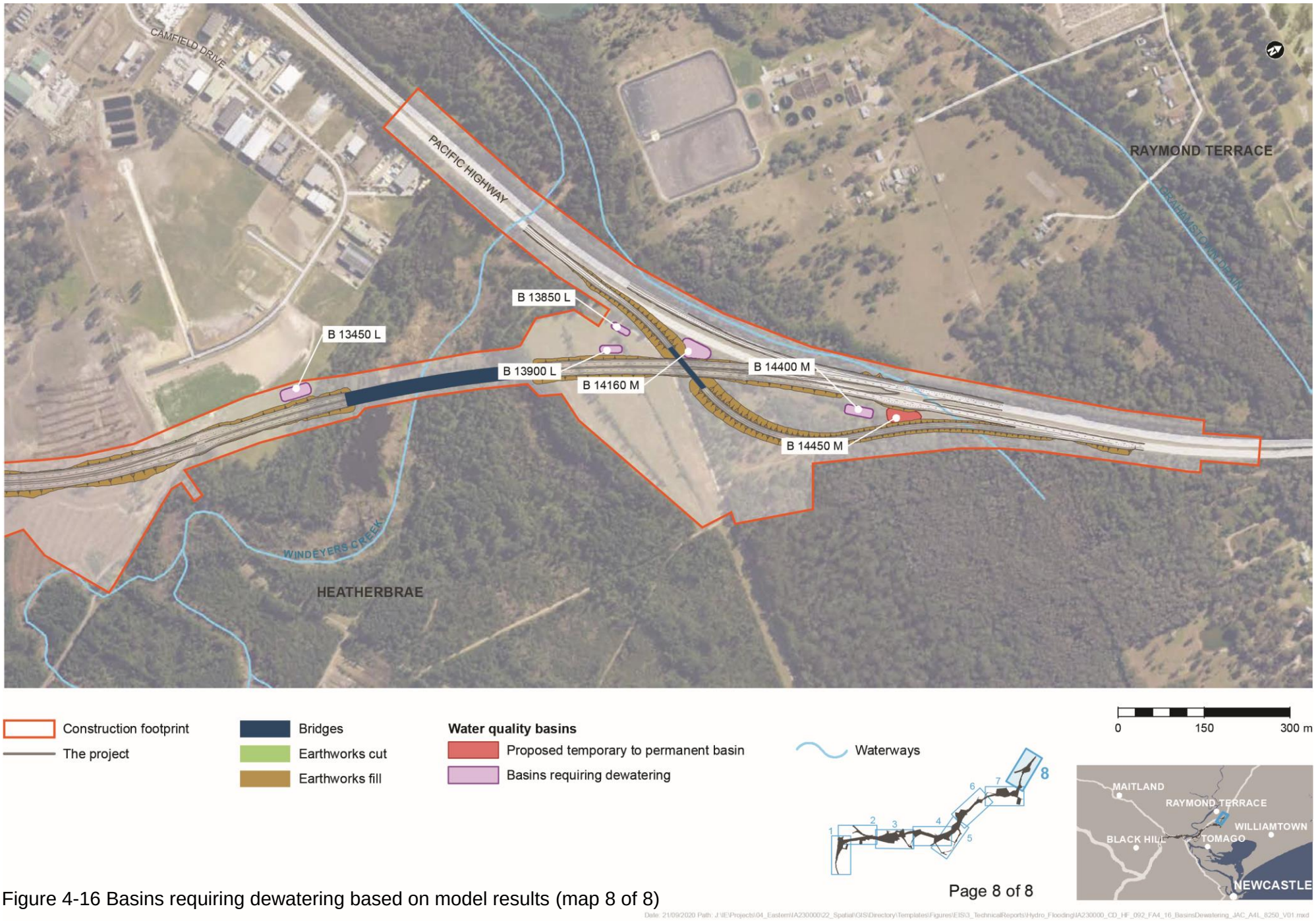

Figure 4-16 Basins requiring dewatering based on model results (map 8 of 8)

Purgatory Creek Adjustment

The project works include the minor adjustment of Purgatory Creek. The creek was represented by DRN boundary conditions. The location of Purgatory Creek was changed in the model by modifying the relevant cells.

The DRN boundaries were used at the Purgatory Creek adjustment to simulate the following:

- Dewatering during the excavation of the adjusted creek channel. Information provided by Transport for NSW indicates that dewatering will be required over a 10-day period during excavation for the creek adjustment. For the purposes of this assessment, dewatering for the Purgatory Creek adjustment construction was simulated during model Stress Period One only. The elevation of the DRN boundary condition was set at the elevation of the bottom of the adjusted creek. Information provided by Transport for NSW indicates that the adjusted creek bottom elevation ranges from -0.63 metres AHD to -0.79 metres AHD
- Baseflow discharge to Purgatory Creek, including the creek adjustment, during the simulated 12-year operational period. The stage elevation for the creek adjustment was set at 0.2 metres AHD, which is average creek stage in the existing segment of Purgatory Creek to be adjusted.

Prediction model hydraulic properties

Hydraulic properties assigned to the predictive models were similar to properties assigned to the calibrated model, except for the hydraulic conductivity assigned to soft sediment areas located underneath embankments. There is a potential for the soft sediments to undergo consolidation due to construction and operation of the proposed road.

To simulate the potential effect of consolidation, the hydraulic conductivity underneath embankments that corresponded to the location of soft sediments was reduced in the Project Case predictive model. The horizontal and vertical hydraulic conductivity values assigned to soft soil areas along the project alignment were reduced by one order of magnitude from values applied to the calibrated model.

The hydraulic conductivity was reduced in model Layer One only. The thickness of soft sediments in the area around the Purgatory Creek adjustment (approximately two metres) is generally similar to the thickness of model Layer One. Therefore, the model is likely to provide a more realistic simulation of the groundwater level changes due permeability reduction associated with soft sediment consolidation.

However, the thickness of soft sediments near the Hunter Region Botanical Gardens is generally significantly less than the thickness of model Layer One in the area (model Layer One thickness is up to 15 metres thick). Therefore, the model is likely to provide conservative predictions of the groundwater level changes due permeability reduction associated with soft sediment consolidation.

4.4.2 Prediction model results

Predictive modelling was formulated to quantify groundwater behaviour in relative terms by preparing a Project Case and a Null Case for prediction simulations. Using this approach, groundwater predictions for drawdown, mounding and flows were obtained by subtracting the Project case model results from the Null case model results.

Predicted groundwater drawdown at basins

Figure 4-17 shows the predicted groundwater table drawdown at the basins approximately one month after the beginning of construction. As previously discussed, the model predictions presented in **Figure 4-17** provide a conservative estimate of the maximum drawdown that could occur due to dewatering at the

basins for the purposes of maintaining dry working conditions during basin construction. Maximum drawdown of 2.4 m bgl occurs at the southern end of the project.

Predicted groundwater drawdown at Purgatory Creek adjustment

Figure 4-17 shows the predicted groundwater table drawdown at the Purgatory Creek adjustment at the end of simulated excavation period (after approximately one month). The model predictions presented in **Figure 4-17** are conservative given that the model assumes the dewatering will occur over approximately one month, but in reality the excavation will occur over approximately 10 days. The maximum predicted drawdown at the Purgatory Creek adjustment during construction dewatering is approximately 0.8 metres (**Figure 4-17**).

Figure 4-18 shows that predicted groundwater table drawdown in the area surrounding the Purgatory Creek adjustment after approximately 12 years of operation is negligible to minor. Positive values in **Figure 4-18** indicate drawdown and negative values indicate groundwater mounding. The predicted negligible to minor drawdown indicates that in the long-term, dynamic equilibrium will be established between the groundwater system and the surface water within the creek.

Predicted groundwater mounding at soft sediment areas

Figure 4-18 shows maximum predicted mounding of approximately 0.3 metres after 12-years at the soft sediment areas located adjacent to the Purgatory Creek adjustment. Positive values in **Figure 4-18** indicate drawdown and negative values indicate groundwater mounding. The model predicts that the groundwater table will not rise to the intersect the ground surface.

Figure 4-19 shows maximum predicted mounding of approximately 0.8 metres after 12-years at the soft sediment areas close the Hunter Region Botanic Gardens. The model predicts that the groundwater table will not rise to the intersect the ground surface.

The mounding predictions presented in **Figure 4-19** are considered conservative given that the thickness of soft sediments near the Hunter Region Botanical Gardens is generally significantly less than the thickness of model Layer One in the area (model Layer One thickness is up to 15 metres thick).

The model predicts negligible mounding during the construction period due to soft sediment consolidation beneath embankments.

Construction footprint
Operational footprint
Waterways

Terrestrial GDE
High potential GDE - from regional studies
Low potential GDE - from regional studies
Moderate potential GDE - from regional studies

Groundwater bores
Monitoring
Drawdown contours (m)

0 200 400m

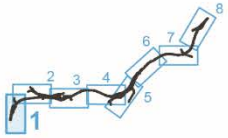

Figure 4-17 Predicted drawdown after one month of construction (map 1 of 8)

Page 1 of 8

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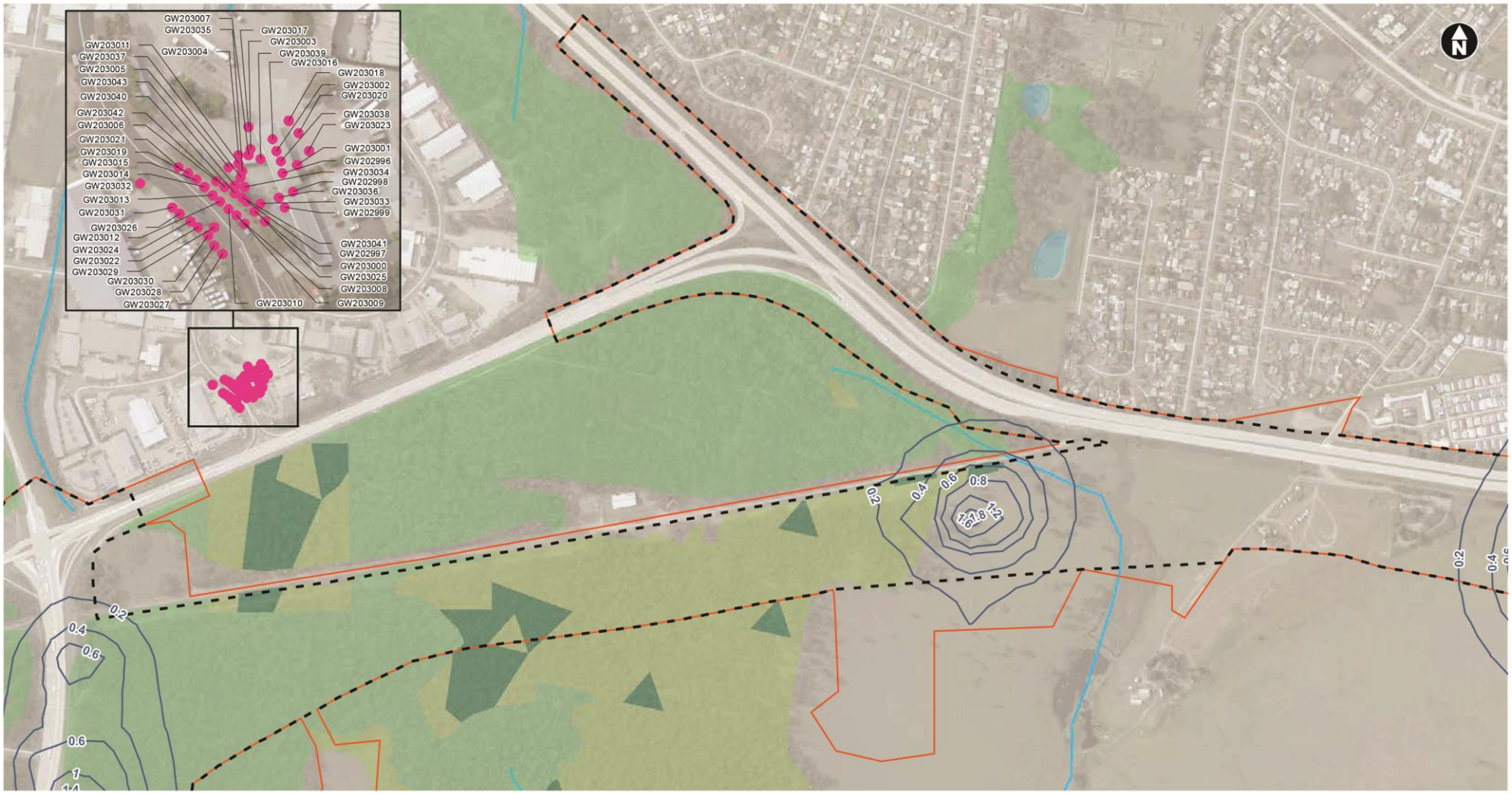

Figure 4-17 Predicted drawdown after one month of construction (map 2 of 8)

Page 2 of 8

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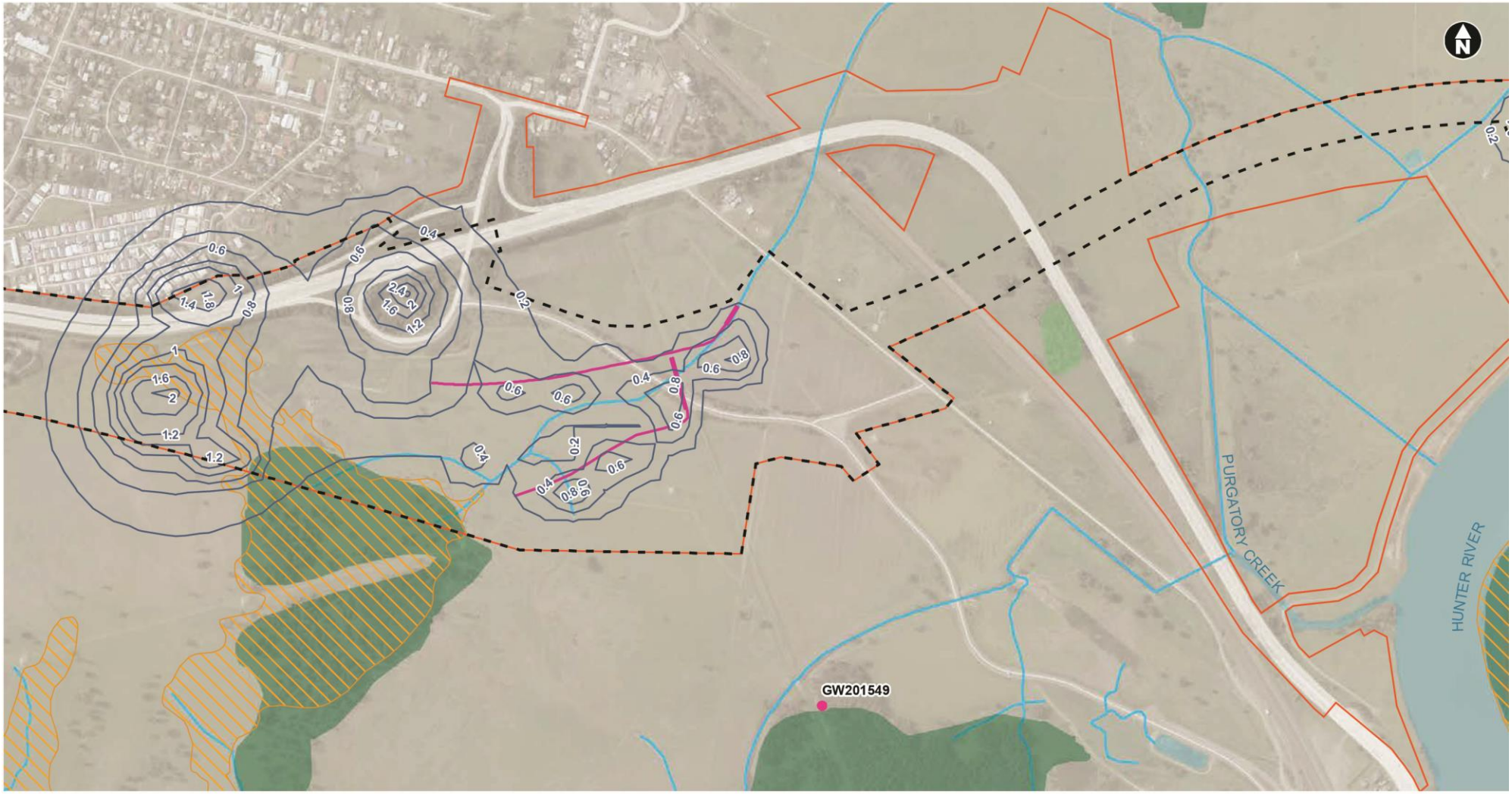
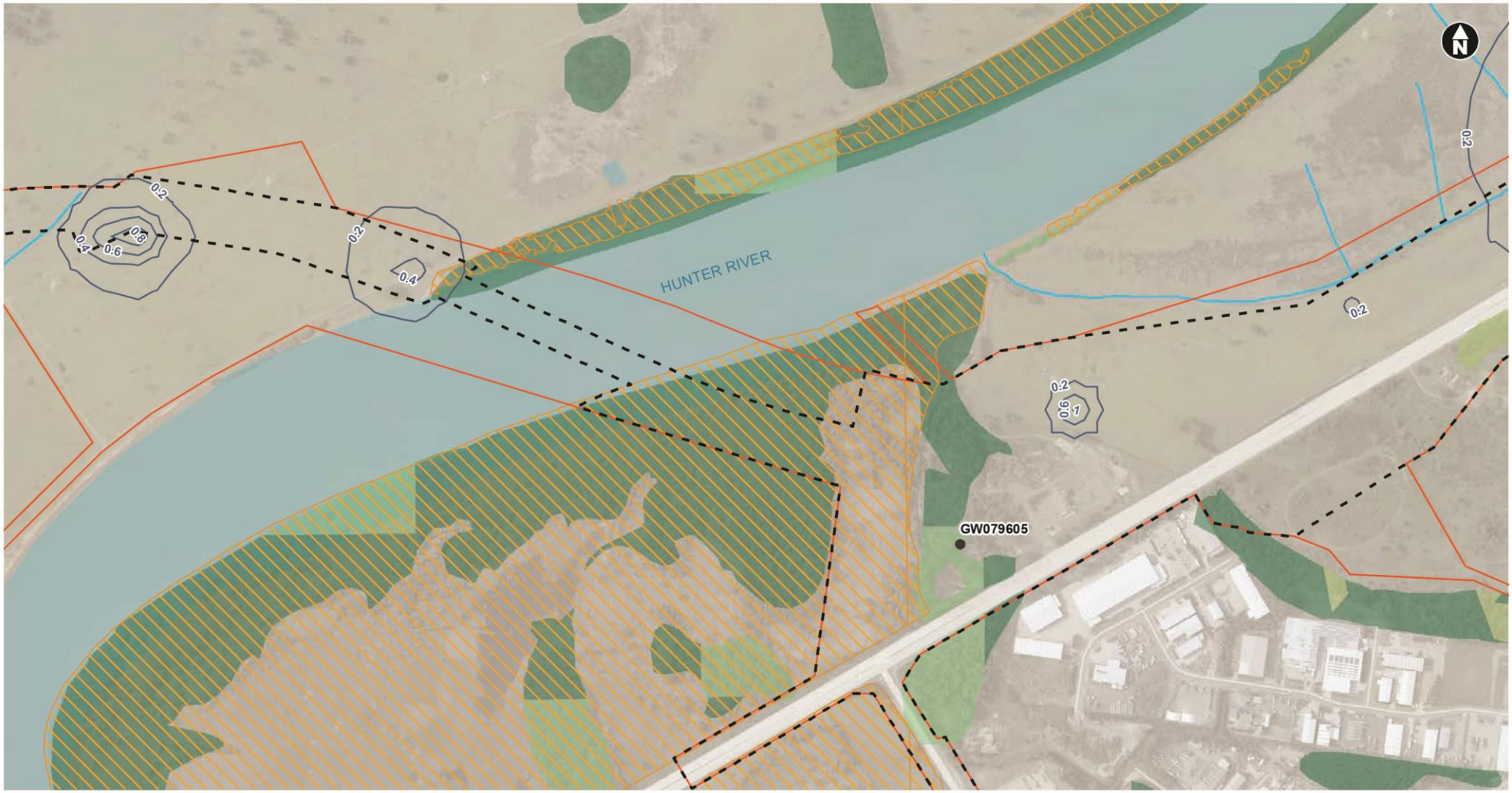


Figure 4-17 Predicted drawdown after one month of construction (map 3 of 8)

Page 3 of 8



Construction footprint
Operational footprint
Waterways

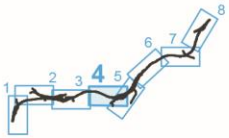
Terrestrial GDE
High potential GDE - from regional studies
Low potential GDE - from regional studies
Moderate potential GDE - from regional studies

Coastal wetlands (Coastal Management SEPP)

Groundwater bores
Unknown

Drawdown contours (m)

0 200 400m



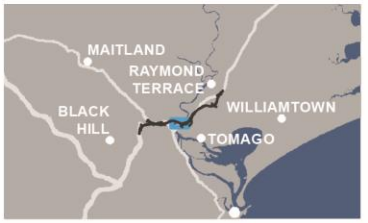


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Figure 4-17 Predicted drawdown after one month of construction (map 4 of 8)

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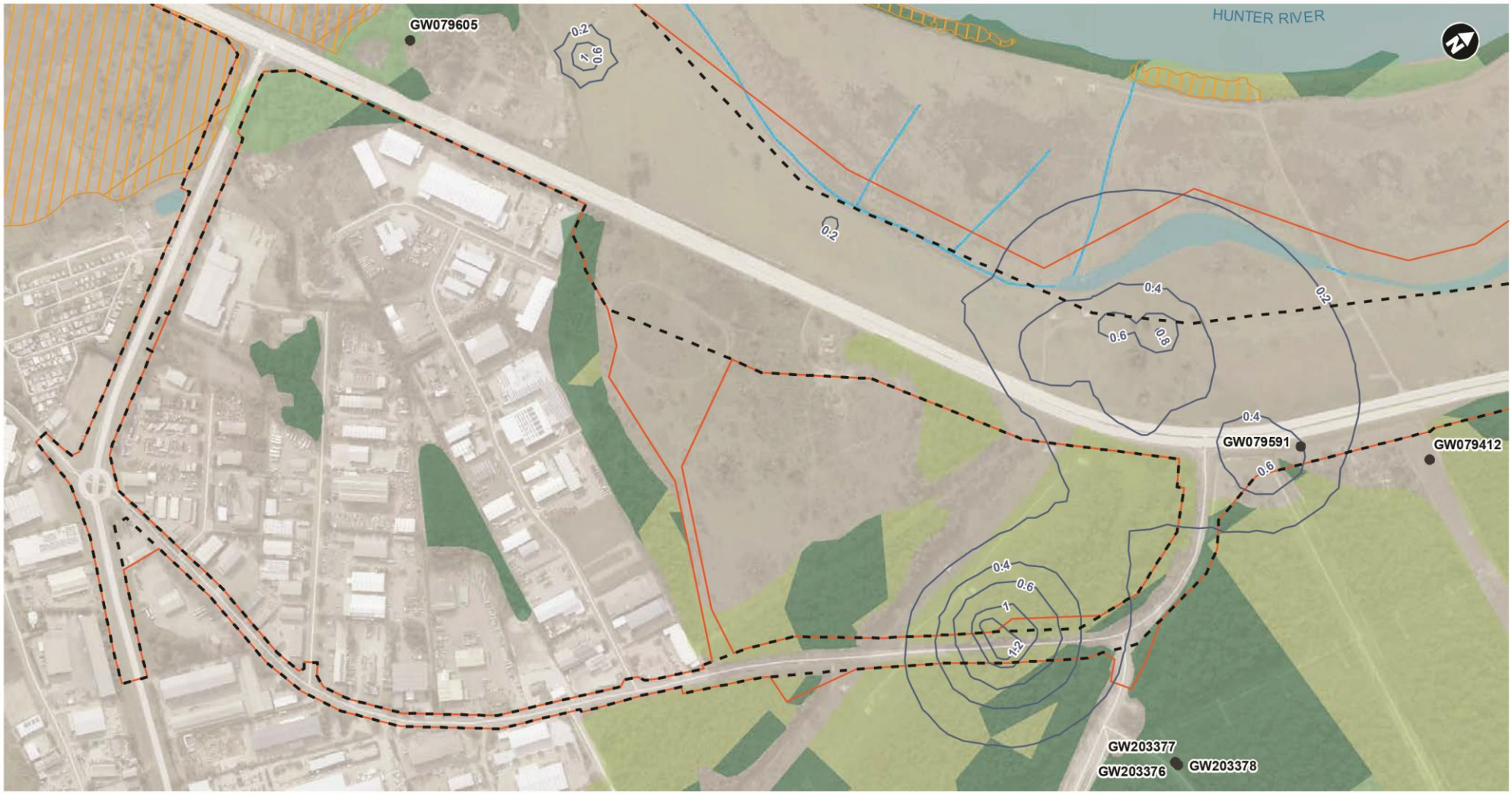

Figure 4-17 Predicted drawdown after one month of construction (map 5 of 8)

Page 5 of 8

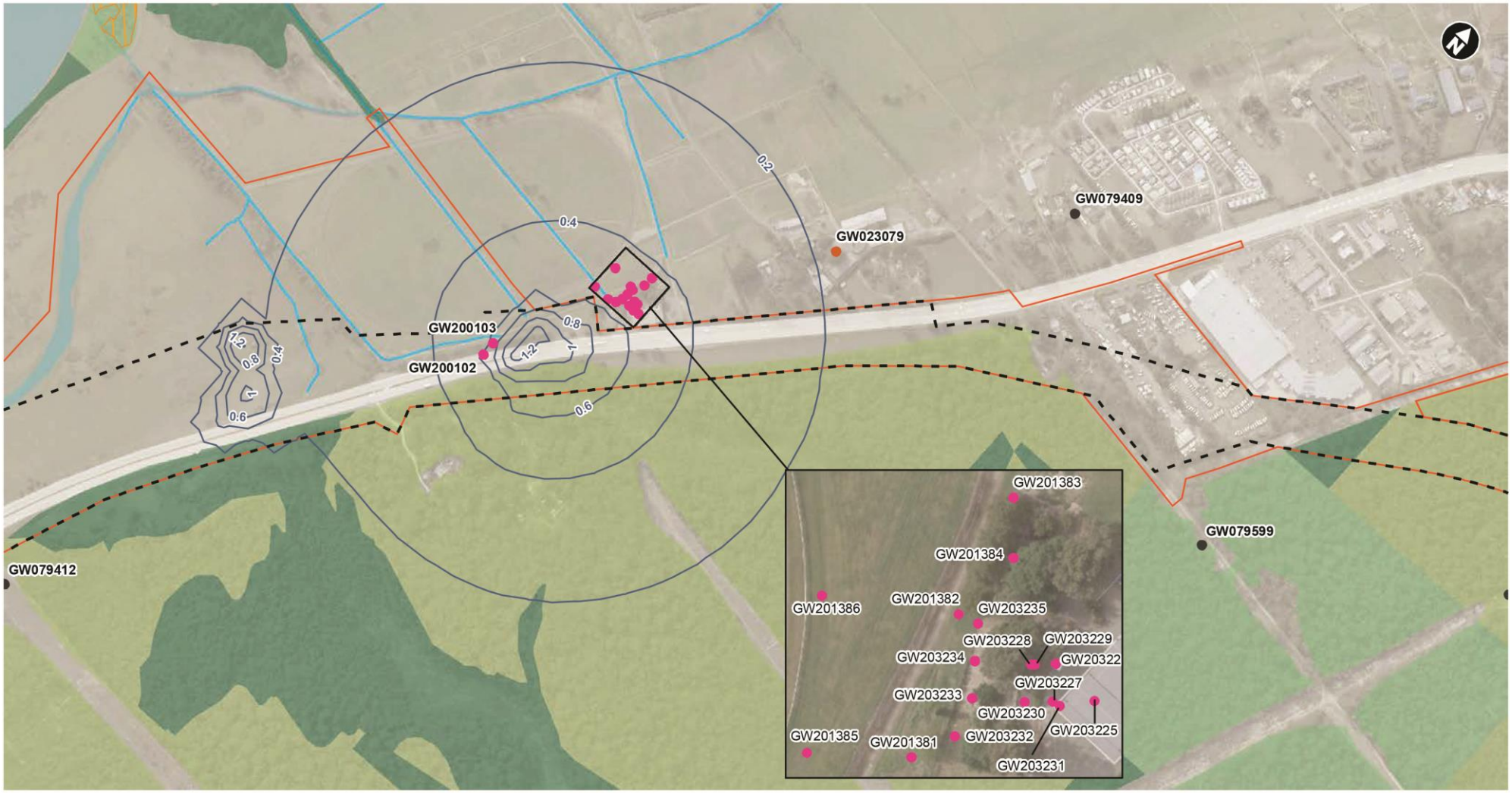

Figure 4-17 Predicted drawdown after one month of construction (map 6 of 8)

Page 6 of 8

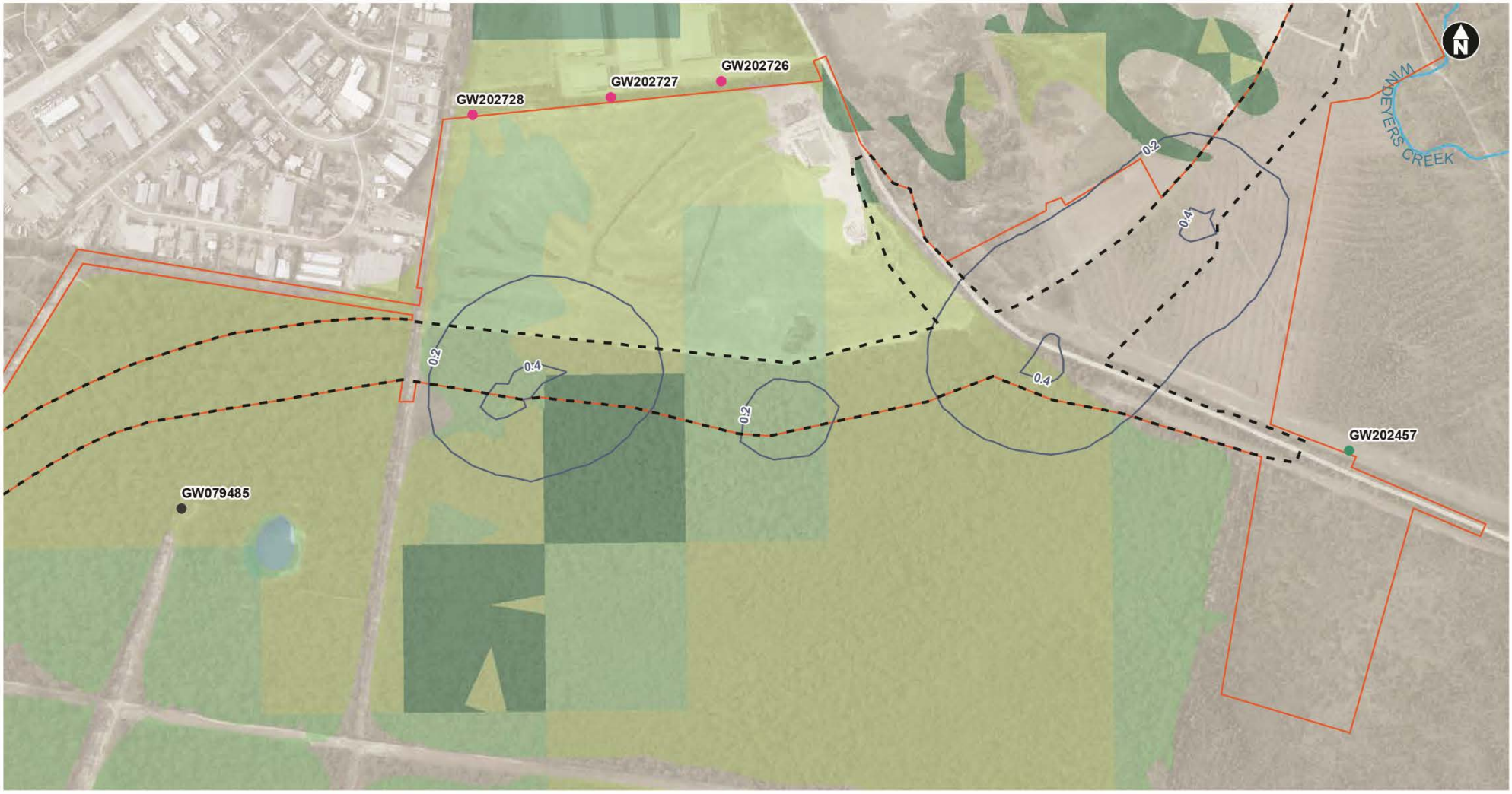

Figure 4-17 Predicted drawdown after one month of construction (map 7 of 8)

Page 7 of 8

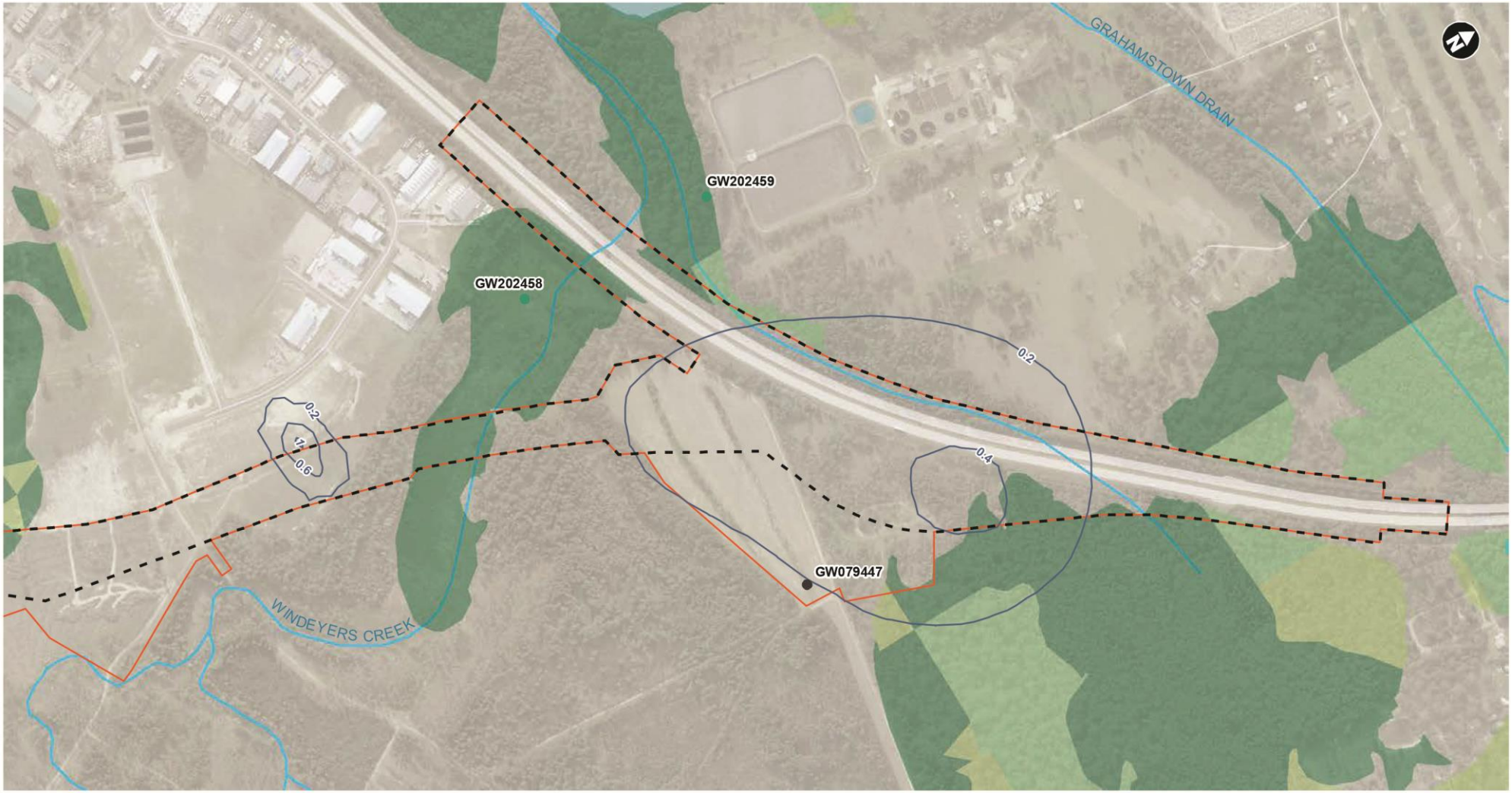

Figure 4-17 Predicted drawdown after one month of construction (map 8 of 8)

Page 8 of 8

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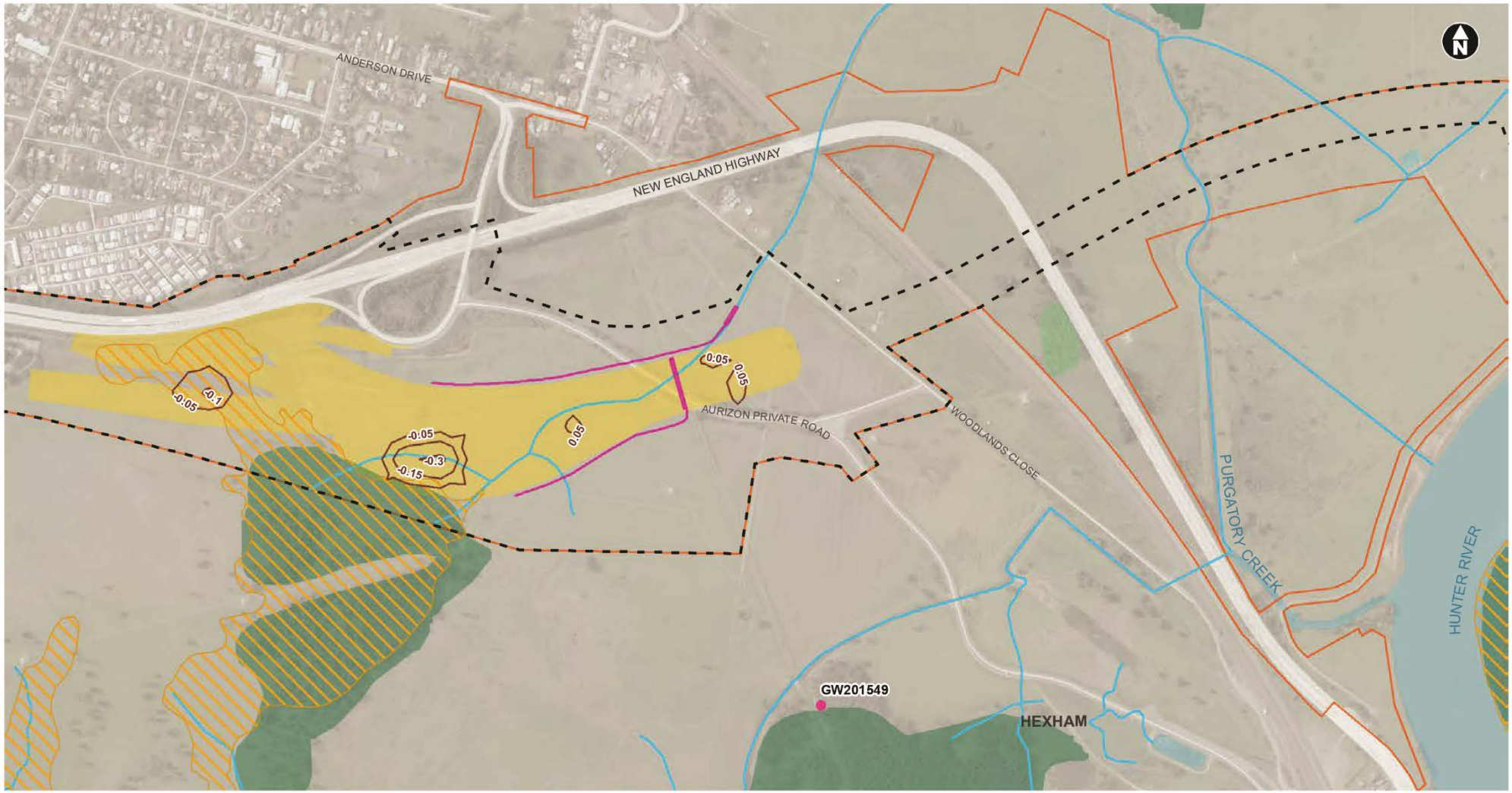

Figure 4-18 Drawdown after twelve years of operation, north of Hunter River

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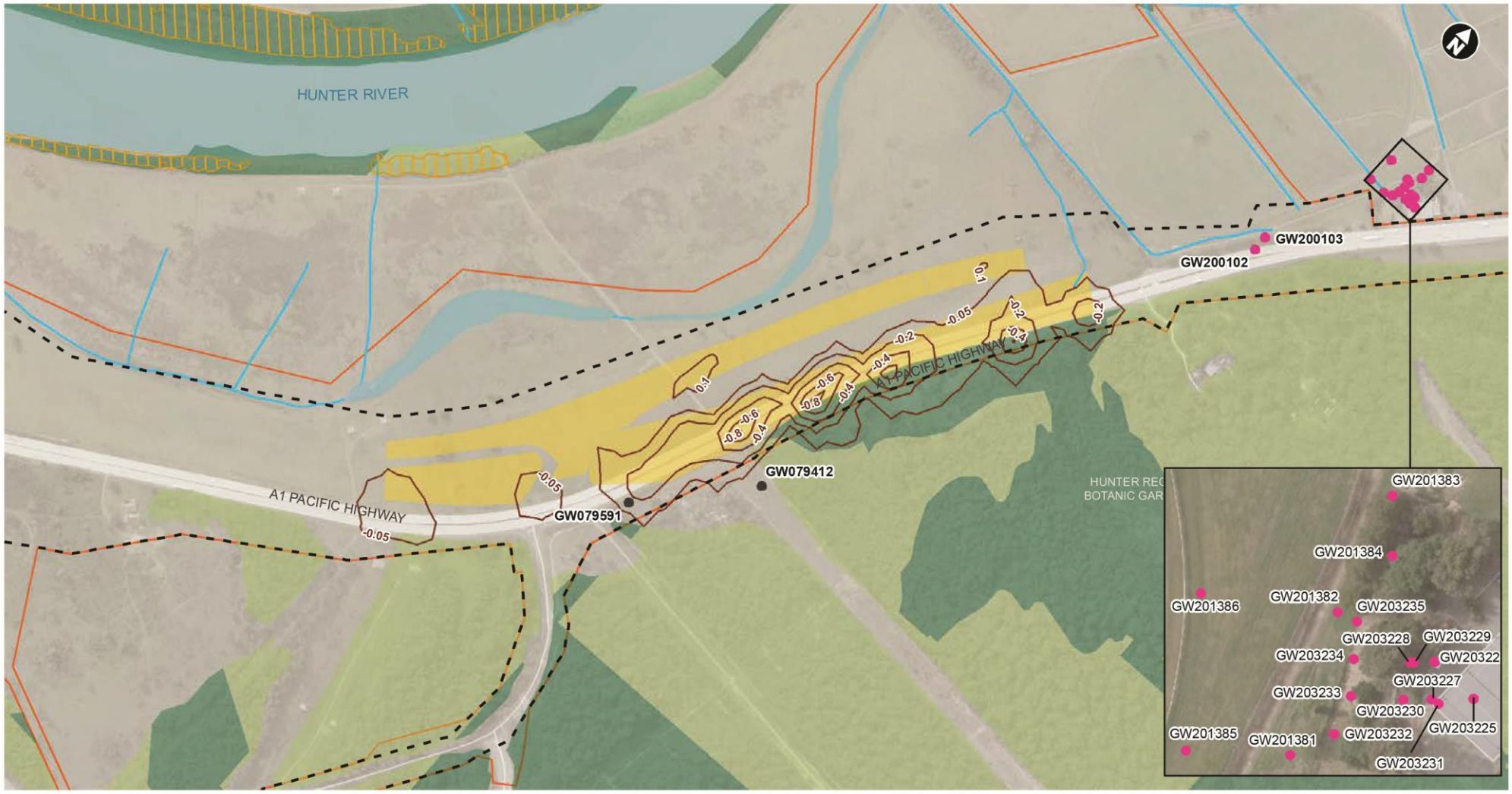

Figure 4-19 Drawdown after twelve years of operation, south of Hunter River

Predicted groundwater drawdown at cut areas of the proposed road.

Figure 4-20 shows the modelled existing groundwater table elevations and proposed bottom (minimum) excavation elevations for road cut area at Black Hill. There is likely to be negligible groundwater drawdown at road cut areas shown in **Figure 4-20** because the proposed bottom excavation elevations are all above the existing groundwater table elevation surface. This is also the case for cuttings at Tomago and Heatherbrae.

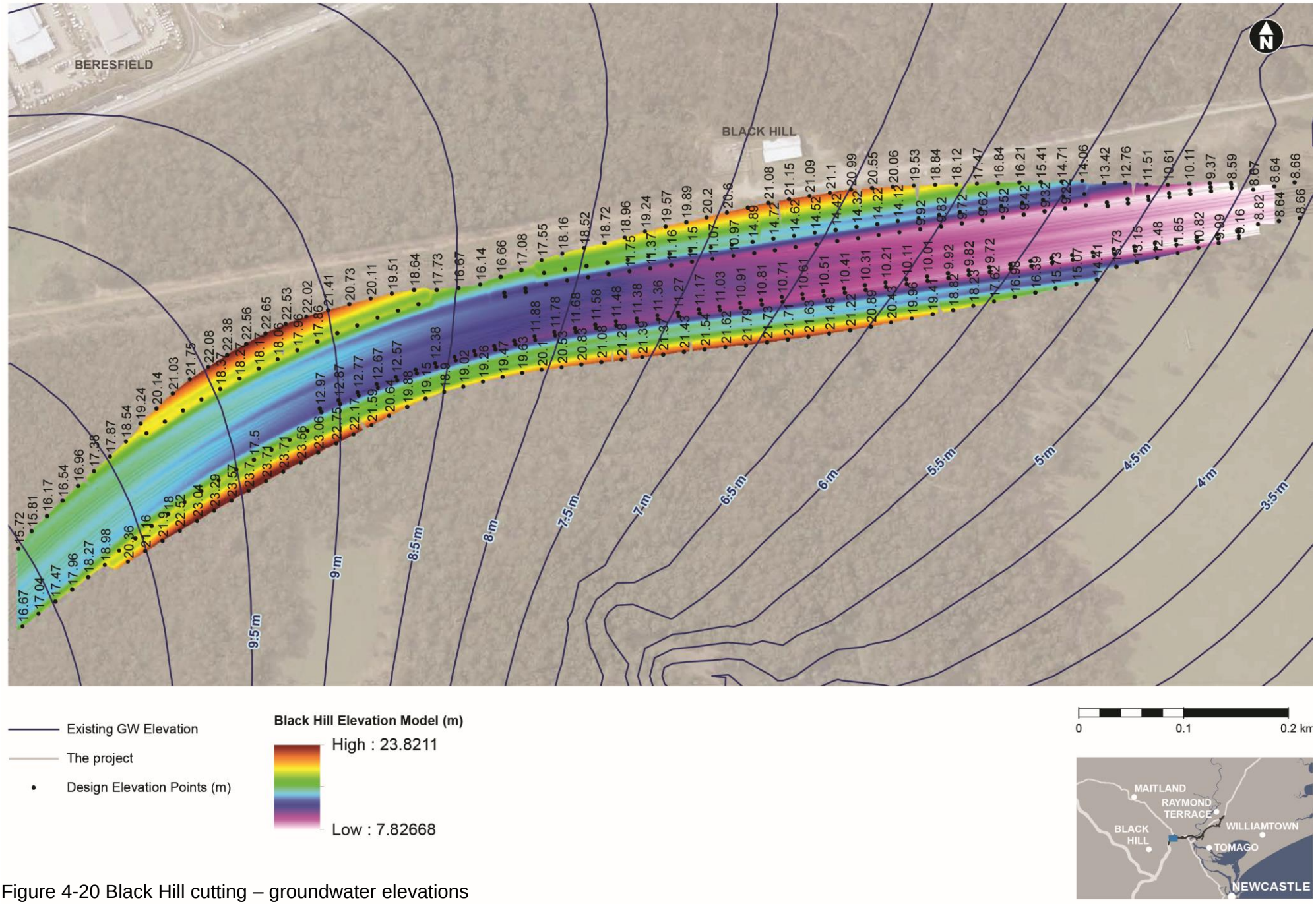

Figure 4-20 Black Hill cutting – groundwater elevations

Predicted dewatering rates at basins

Table 4-8 summarises the predicted daily dewatering rates required to maintain dry working conditions during the construction period of the basins. The predicted dewatering rates range from one cubic metre per day to 1950 cubic metres per day with an average dewatering rate of 238 cubic metres per day. The lower dewatering rates are associated with basins located in the basement rock outcrop areas to the west, in the Black Hill area. The maximum dewatering rates are associated with basins located in the Tomago Sands outcrop areas.

Table 4-8 Predicted basin dewatering rates during construction

Basin	Dewatering rate (m3/day)
B M 03340	47
B 03480 R	10
B 03800 M	4
B 04300 L	5
B 05700 L	142
B 06100 L	289
B 07150 L	1
B 07500 L	5
B 08000 L	145
B 08150 L	187
B M 08980	10
B 09160 M	4
B 01000 L	33
B 00950 L	2
B 01120 L	21
B 02460 L	46
B 03350 L	33
B 03750 L	56
B 07300 R	10
B 07450b R OP Rd	50
B 07900 R OP Rd	15
B 08360 R	189
B 09120 M	907
B 09360 L	3
B 09440 L	1950
B 11500 R	573
B 11550 L	416
B 11950 R	208
B 12460 R	635
B 12650 R	774
B 13450 L	7

Basin	Dewatering rate (m3/day)
B 13900 L	355
B 13850 L	26
B 14160 M	233
B 14400 M	941

4.4.3 Uncertainty analysis

The purpose of this uncertainty analysis was to investigate the sensitivity of model predictions to varying parameter values assigned to the model. The following parameters were assessed:

- Rainfall recharge
- Hydraulic conductivity
- Storage.

Uncertainty analysis - methodology

The uncertainty analysis was carried out as follows:

- Rainfall recharge uncertainty analysis: Recharge values from the high and low end of the range of plausible values for the hydrogeological units, were assigned to the “High Recharge” and “Low Recharge” scenarios respectively. Modelled groundwater drawdown/mounding for the Base Case model (prediction model with calibrated model parameters) was compared to model outputs for the high and low recharge scenarios. Recharge rates assigned to the High Recharge Scenario were 200 per cent of the recharge rates assigned to the Base Case model (i.e. recharge rates were doubled). Recharge rates assigned to the Low Recharge Scenario were 50 per cent of the recharge rates assigned to the Base Case model
- Hydraulic conductivity uncertainty analysis: Hydraulic conductivity values from the high and low end of the range of plausible values for the hydrogeological units, were assigned to the “High hydraulic conductivity” and “Low hydraulic” scenarios respectively. Modelled groundwater drawdown/mounding for the Base Case model was compared to model outputs for the high and low hydraulic conductivity scenarios. Horizontal hydraulic conductivity (K_h) and vertical hydraulic conductivity (K_v) values assigned to the high hydraulic conductivity scenario (High K Scenario) were one order of magnitude higher than values assigned to the base case model. K_h and K_v values assigned to the low hydraulic conductivity scenario (Low K Scenario) were one order of magnitude lower than values assigned to the base case model
- Storage parameter uncertainty analysis: Storage parameter values from the high and low end of the range of plausible values for the hydrogeological units, were assigned to the “High Storage” and “Low Storage” parameter scenarios respectively. Modelled groundwater drawdown/mounding for the Base Case model was compared to model outputs for the high and low storage parameter scenarios. Specific storage values assigned to the Low Storage scenario were all one order of magnitude lower than values assigned to the base case model. Specific storage values assigned to the High Storage scenario were one order of magnitude higher than Base case model values, up to a maximum value of 1.3×10^{-5} m^{-1}. Rau (2018) considers a specific storage of 1.3×10^{-5} m^{-1} to be the physically plausible upper limit for unconsolidated materials. The specific yield values assigned to the “High Storage” scenario was 200 per cent of the values assigned to the base case model. Specific yield values assigned to the “Low Storage” scenario was 50 per cent of the values assigned to the base case model.

Uncertainty analysis - results

The reporting of the uncertainty analysis focuses on the area of the most significant change to the groundwater system predicted from the groundwater modelling, in the Tomago area adjacent to the Hunter River. Predicted groundwater table elevations along the cross-section line shown in **Figure 4-21** are presented in this section.

Figure 4-22 shows the predicted groundwater table elevations for the Base case model, High Recharge scenario and Low Recharge scenario. **Figure 4-22** also shows the predicted groundwater table under the existing pre-construction conditions. The predicted mounding for the High Recharge scenario beneath the ridge is approximately 0.5 metres higher than the predicted mounding for the Base case Scenario. However, the model predicts that the groundwater table will not rise to intercept the ground surface for the high recharge scenario. **Figure 4-22** shows that the predicted groundwater table elevation beneath the ridge for the Low Recharge scenario is approximately 0.6 metres lower than the groundwater table elevation predicted from the Base Case model.

Figure 4-23 shows the predicted groundwater table elevations for the Base Case model, High hydraulic conductivity scenario and Low hydraulic conductivity scenario. **Figure 4-23** also shows the predicted groundwater table under the existing pre-construction conditions. The predicted groundwater table elevation beneath the ridge for the High hydraulic conductivity scenario is approximately 1.2 metres lower than the predicted mounding for the Base case Scenario. **Figure 4-23** indicates that the predicted mounding beneath the ridge for the Low hydraulic conductivity scenario is approximately 0.6 metres higher than the predicted mounding for the Base case Scenario. However, the model predicts that the groundwater table for the Low hydraulic conductivity scenario will not rise to intercept the ground surface.

The results of the storage parameter uncertainty analysis show negligible differences between the predicted groundwater table elevations for the Base Case model, High storage parameter scenario and the low storage parameter scenario.

Figure 4-21 Uncertainty analysis cross section location

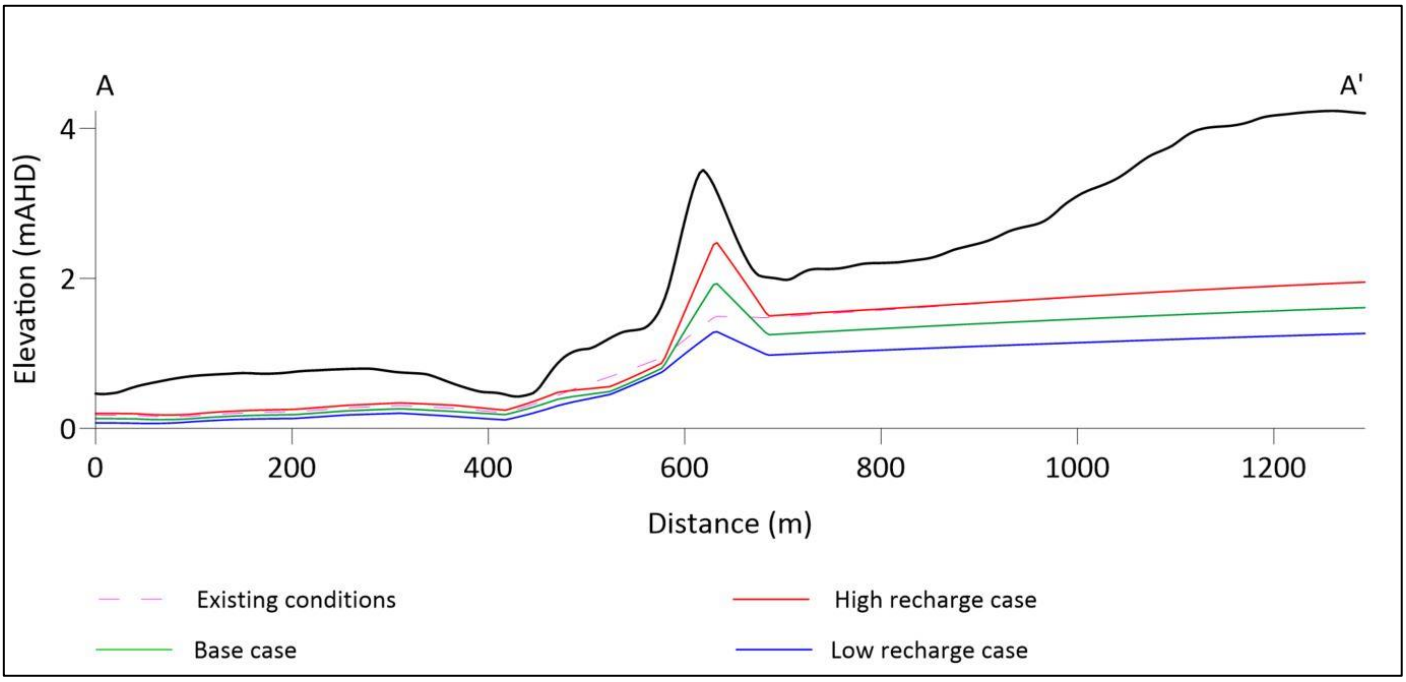

Figure 4-22 Recharge uncertainty analysis results– Predicted water-table elevations

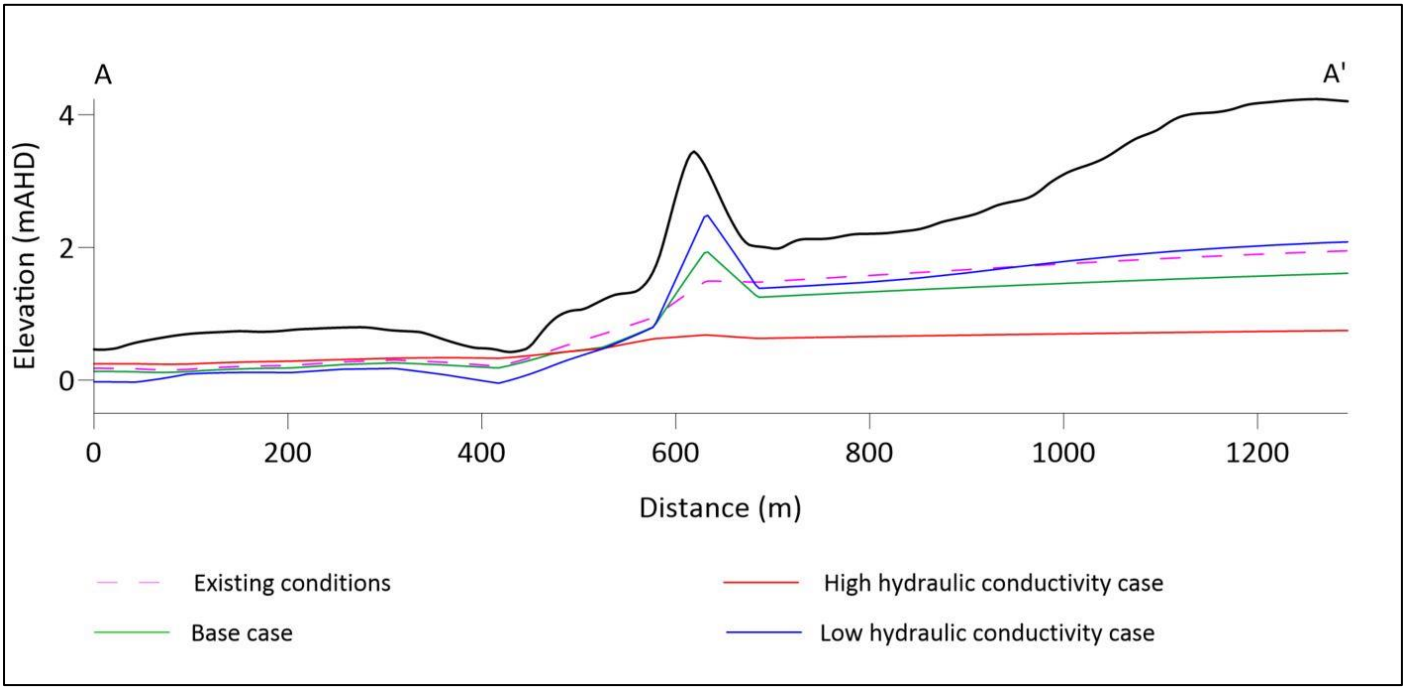

Figure 4-23 Hydraulic conductivity uncertainty analysis results– Predicted water-table elevations

5. Dissipation from consolidated soils

Displacement of water during consolidation was estimated outside of the model. The calculation assumed that 25 per cent consolidation of soft soil depth would, in effect, replace groundwater with solid phase. This calculation implicitly assumes that groundwater is displaced and not air and groundwater, and therefore should be conservative. By way of example, if depth of soft soil at a particular location was 2 metres, with a 25 per cent consolidation assumption, then 0.5 metres of water would be displaced.

The areal extent of embankments overlying soft soils was estimated from GIS and calculated using a regular grid with respect to depth of soft soil.

For the Newcastle Water Source, the calculated displacement of groundwater for a 25 per cent consolidation, was 38.8 megalitres. If consolidation was 20 per cent, then the displacement of groundwater would be 31.1 megalitres.

For the Tomago Groundwater Source, the calculated displacement of groundwater for a 25 per cent consolidation, was 249.9 megalitres. If consolidation was 20 per cent, then the displacement of groundwater would be 199.9 megalitres.

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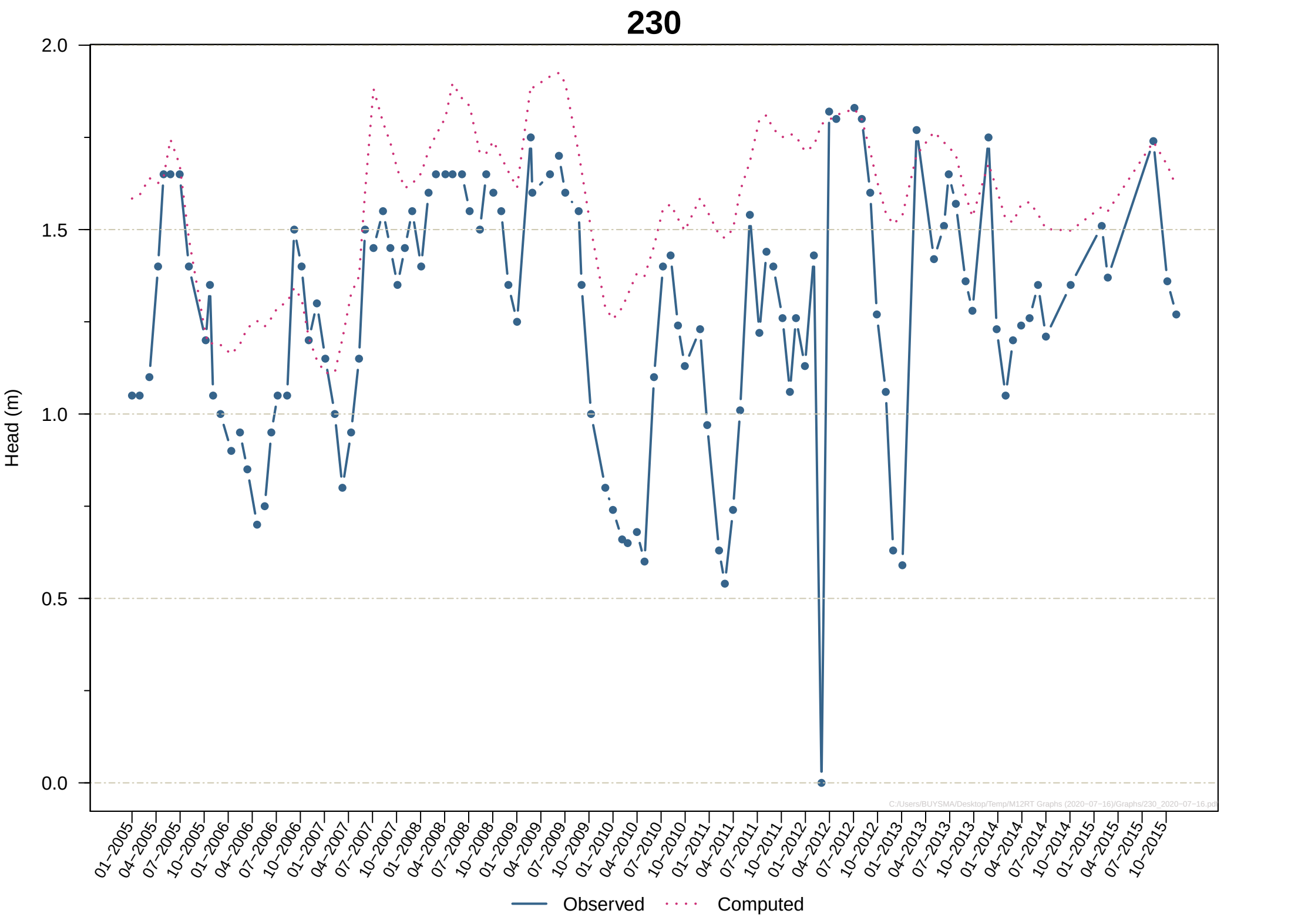
Terms and acronyms

Term / Acronym	Description
AGMG	Australian Groundwater Modelling Guidelines
AHD	Australian Height Datum
ASS	Acid sulfate soil
bgl	Below ground level
BoM	Bureau of Meteorology
CPT	Cone penetrometer testing
DRN	MODFLOW Drain package
EIS	Environmental Impact Statement
EP&A Act	Environmental Planning and Assessment Act 1979
EVT	MODFLOW Evapotranspiration Package
GDE	Groundwater Dependent Ecosystem
OEH	Office of Environemnt and Heritage
RIV	MODFLOW River Package
SEPP	State Environmental Planing Policy
TEC	Threatened Ecological Community
Transport	Transport for New South Wales
USGS	United States Geological Survey
WAL	Water Access License
WM Act	The *Water Management Act 2000*

Appendix A Calibration hydrographs


230
2.0
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Head (m)
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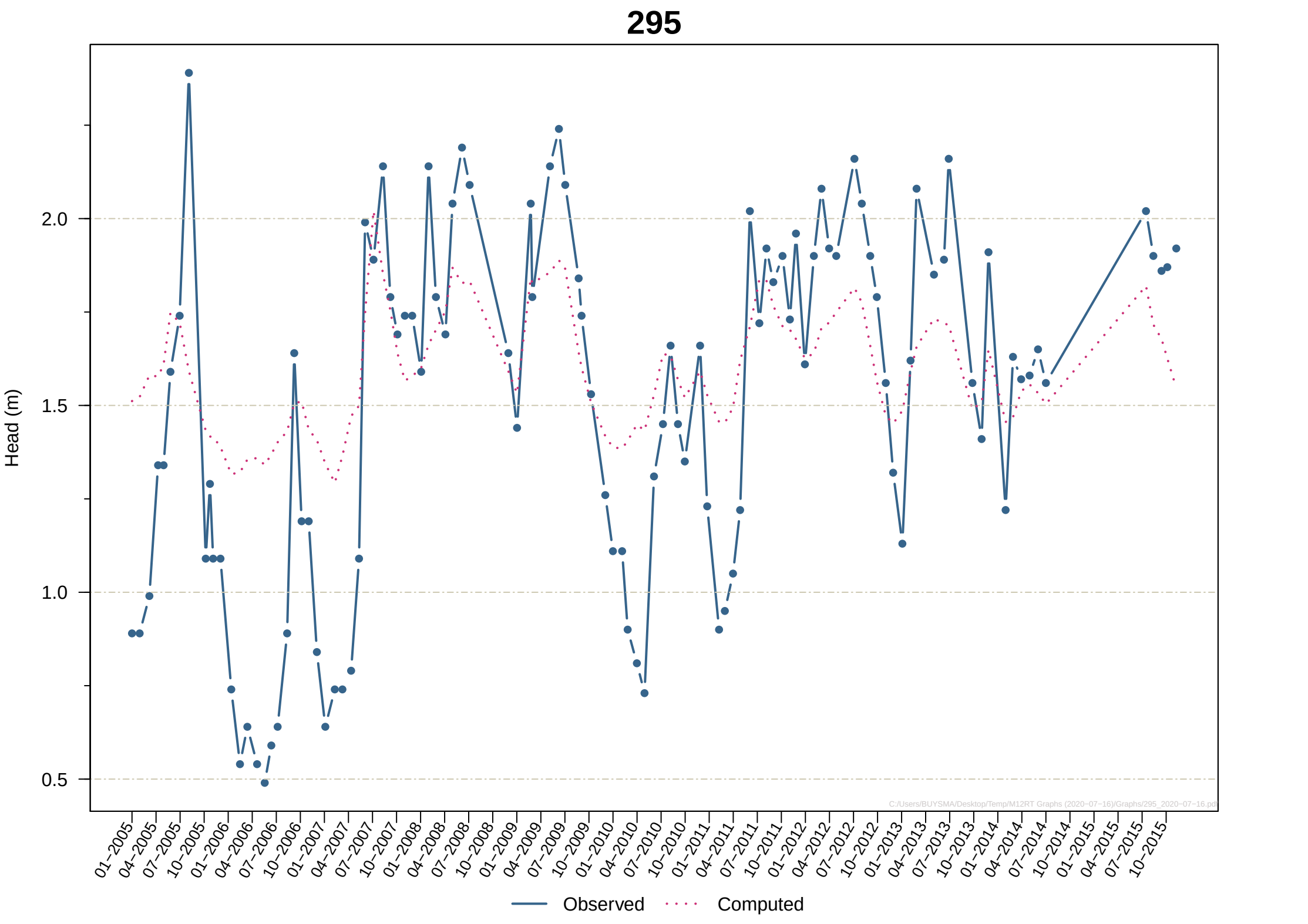
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Computed
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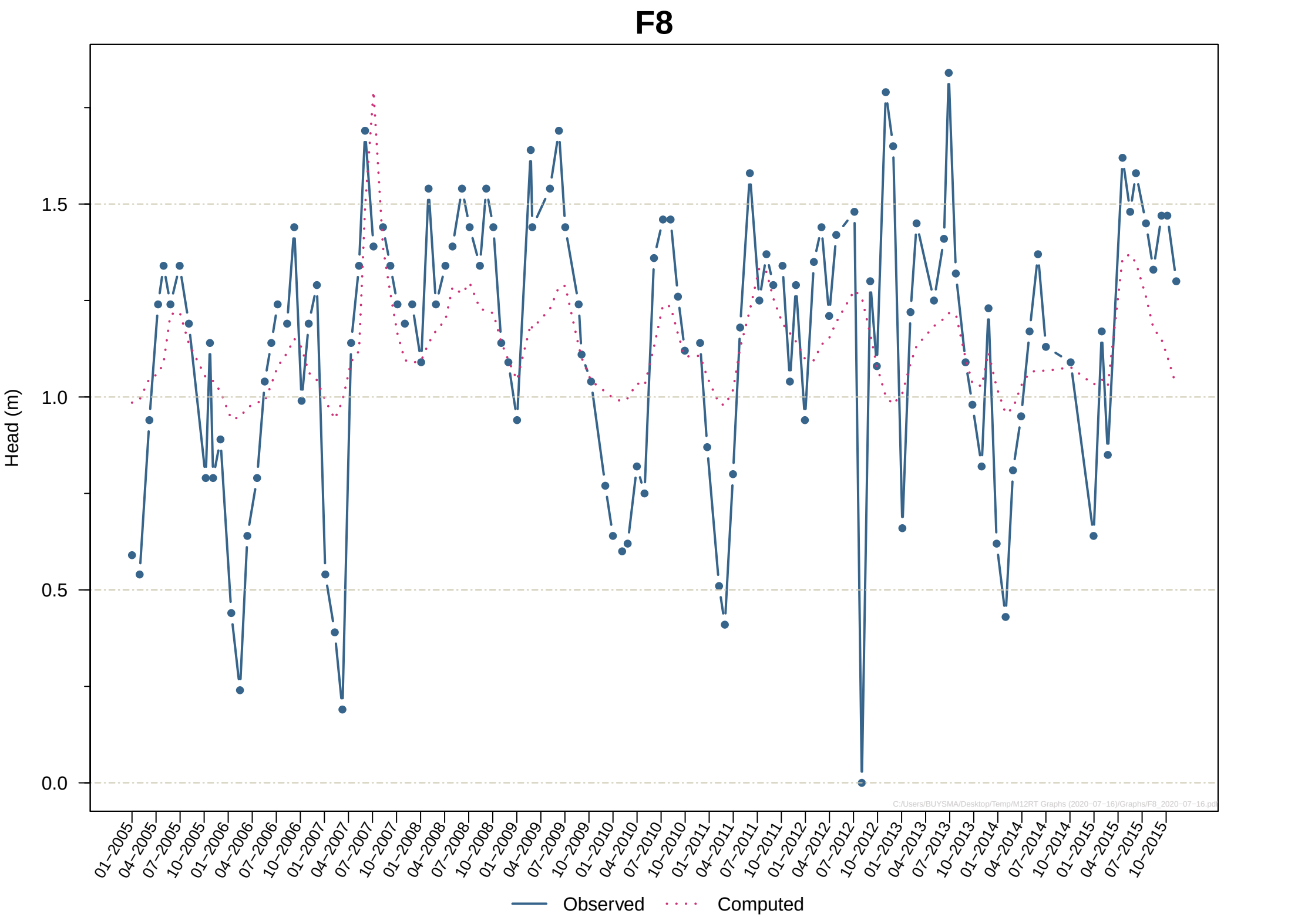
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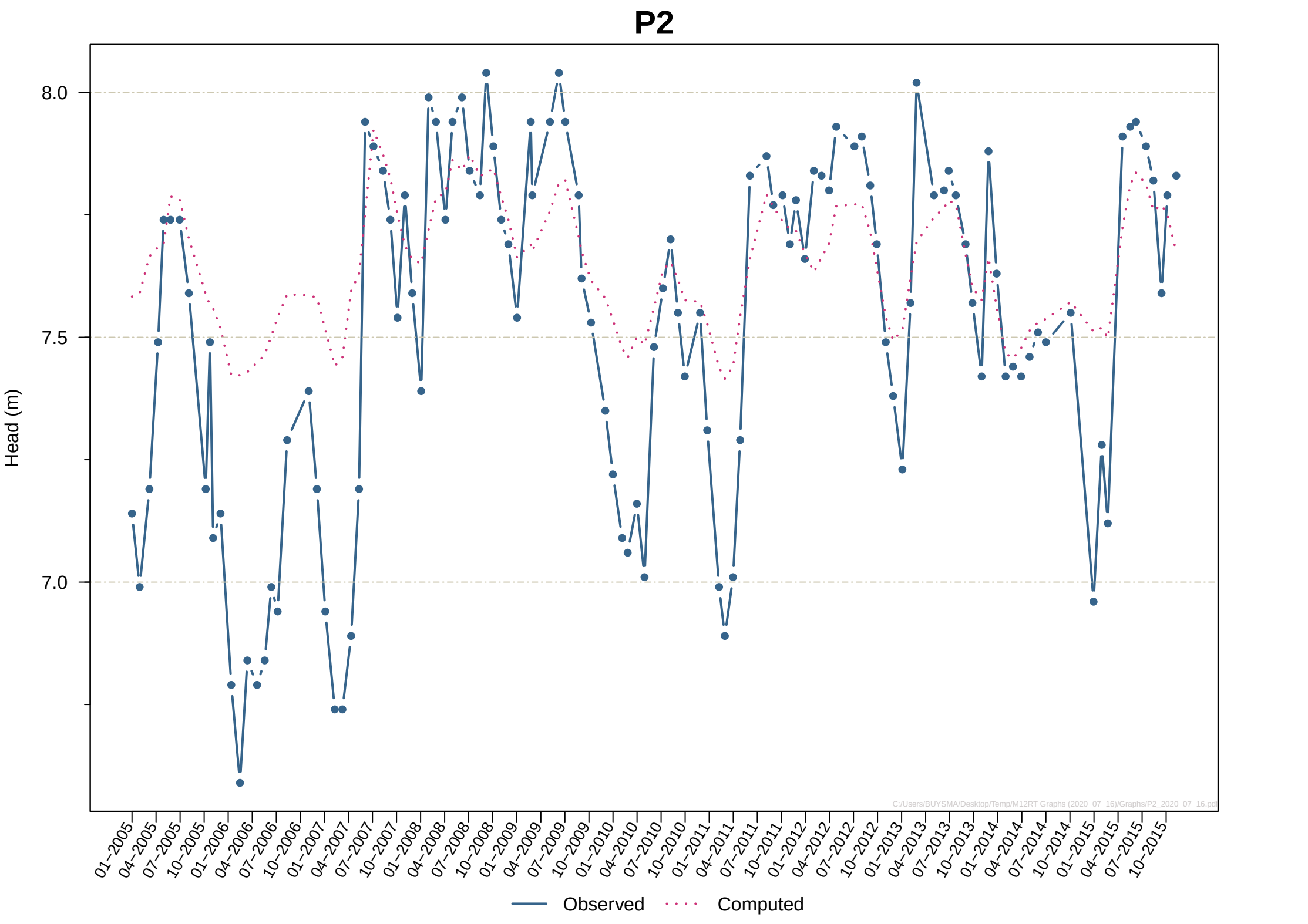
P2
8.0
7.5
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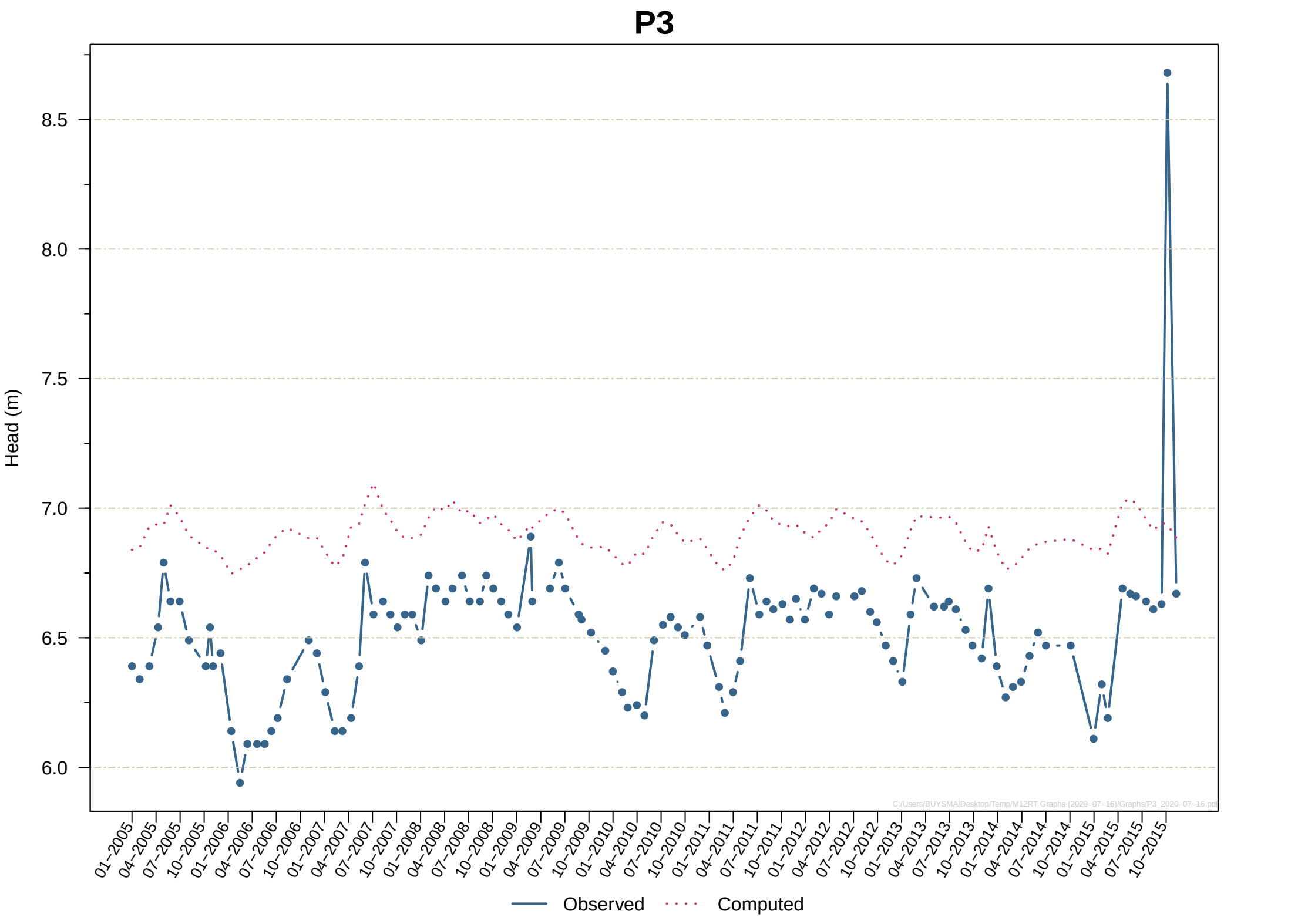
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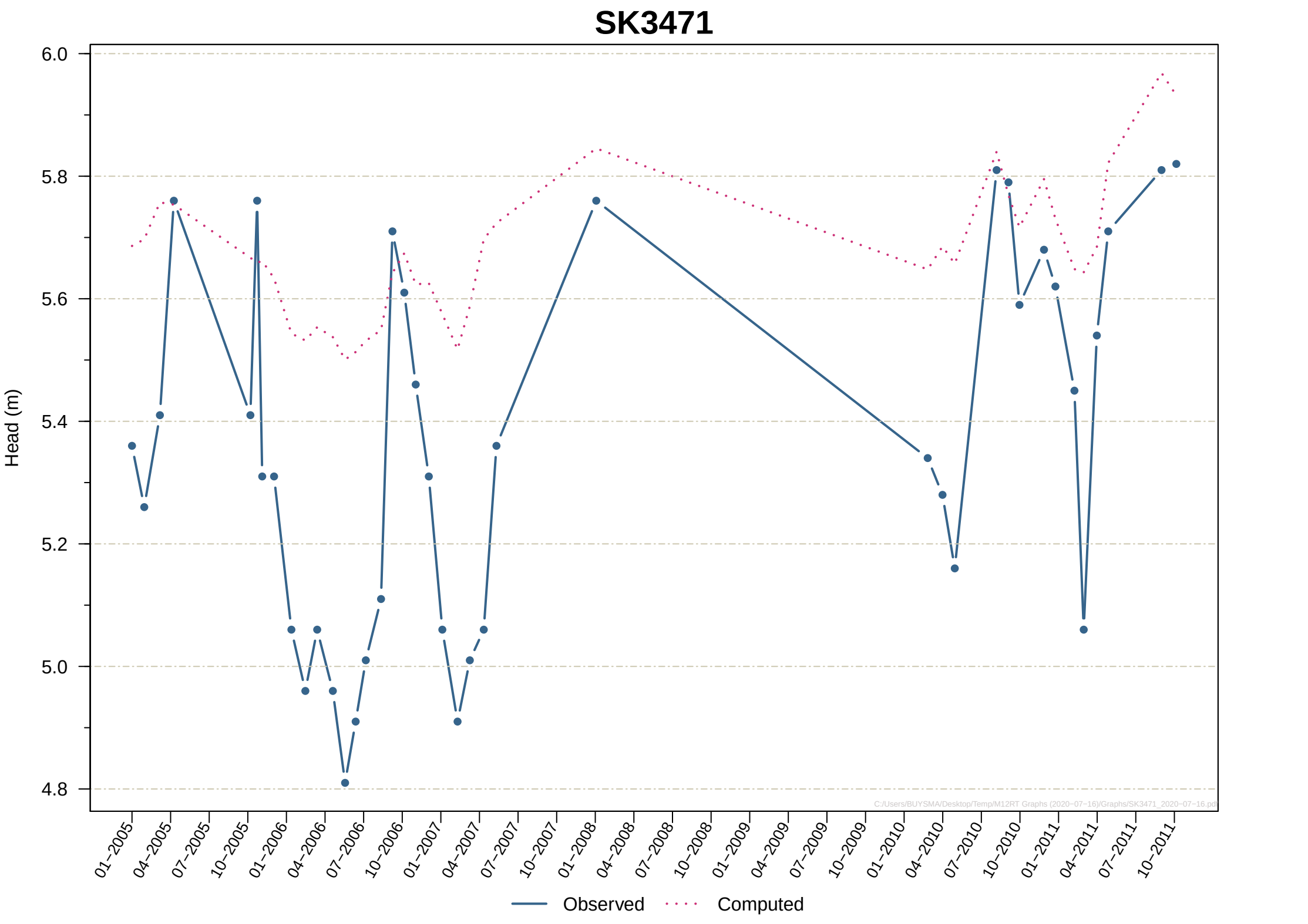
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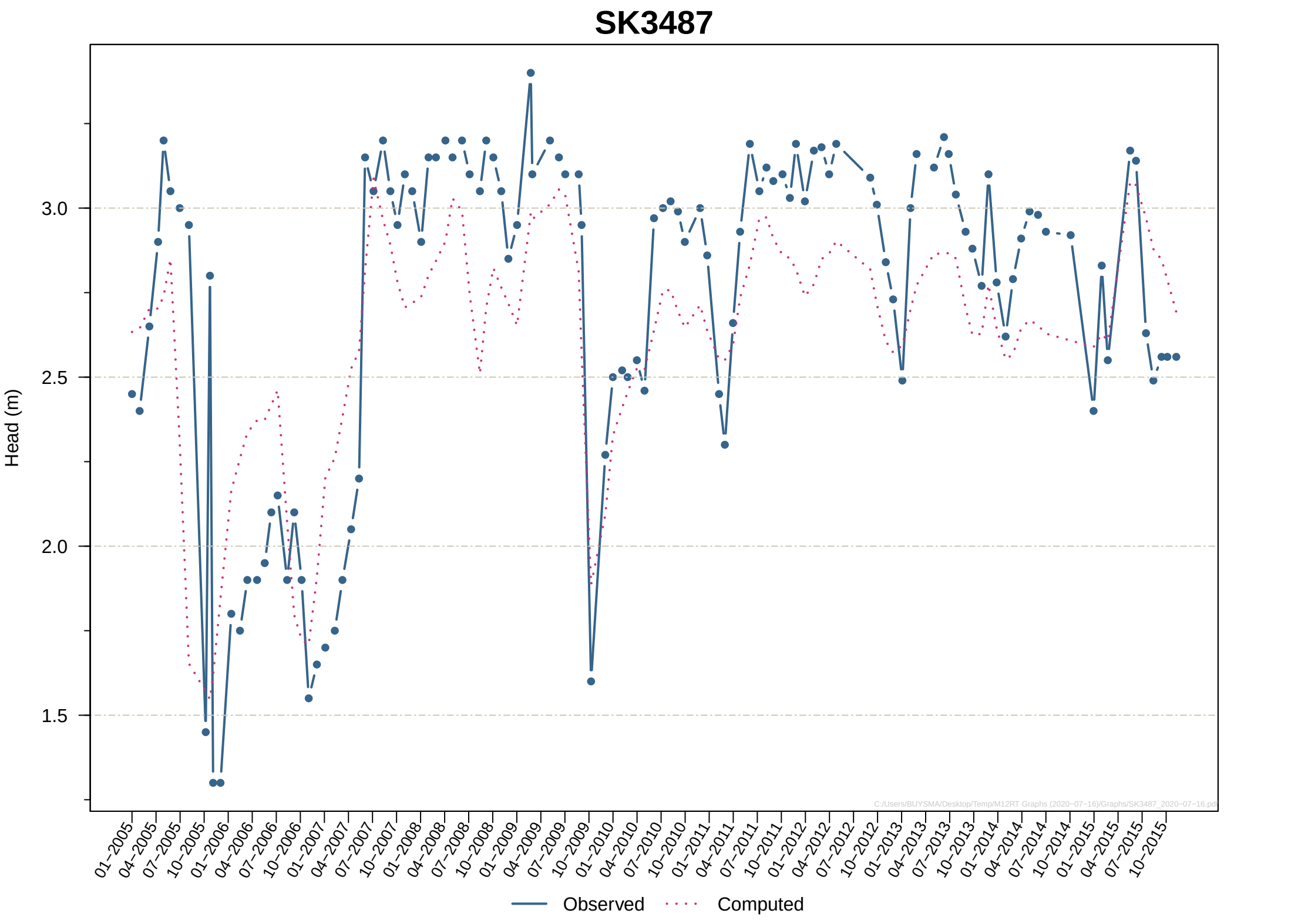
Observed
Computed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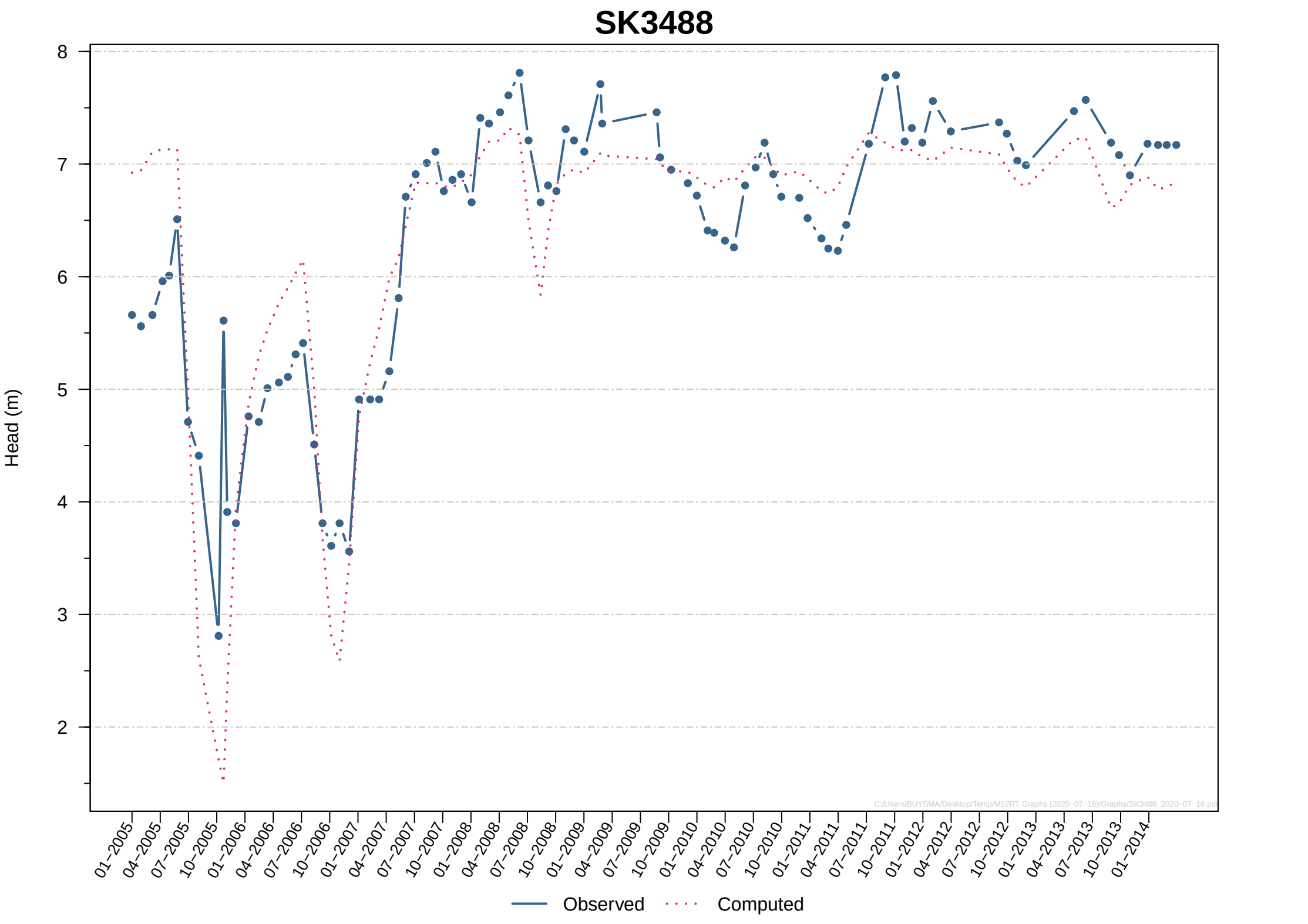
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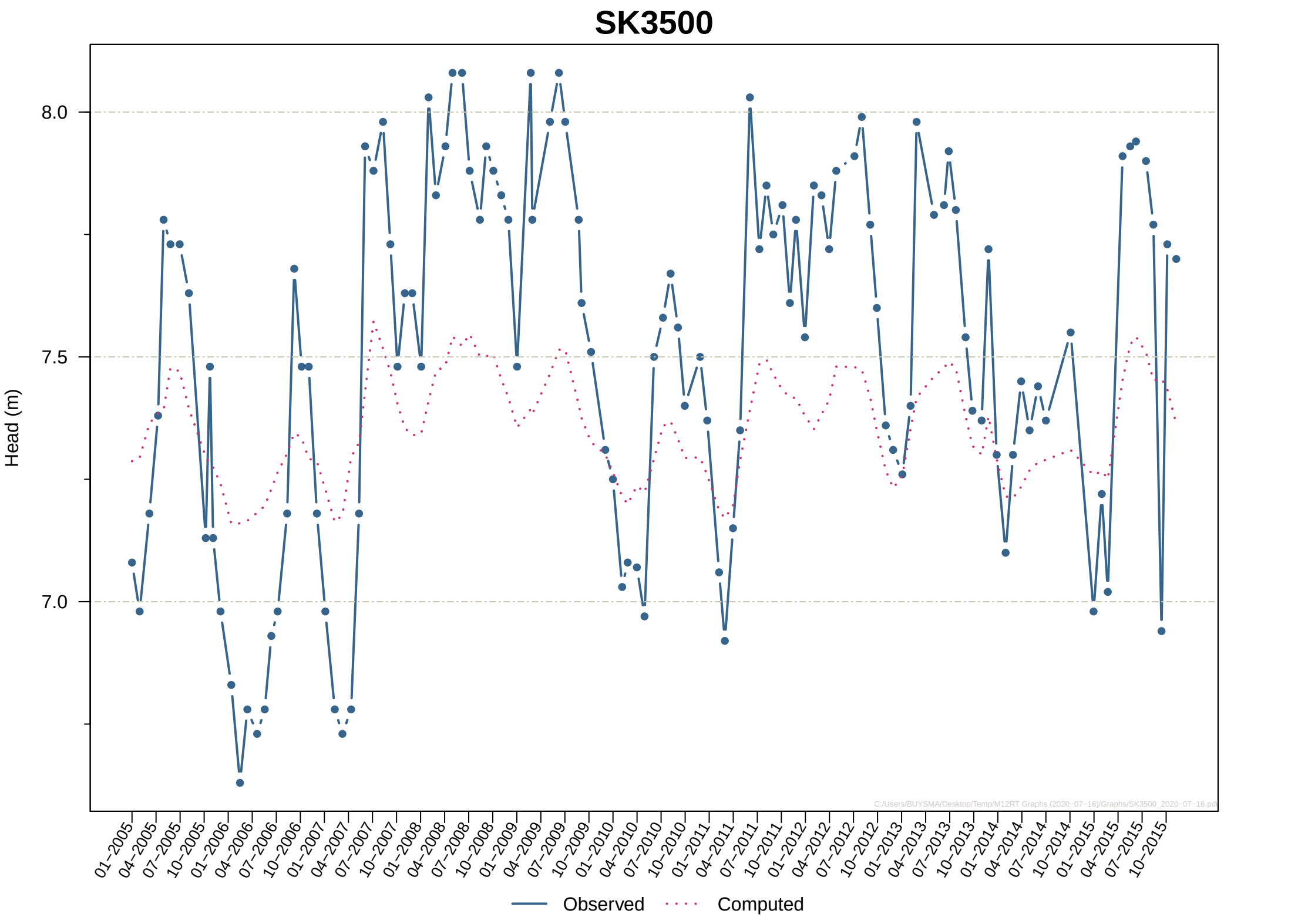
Computed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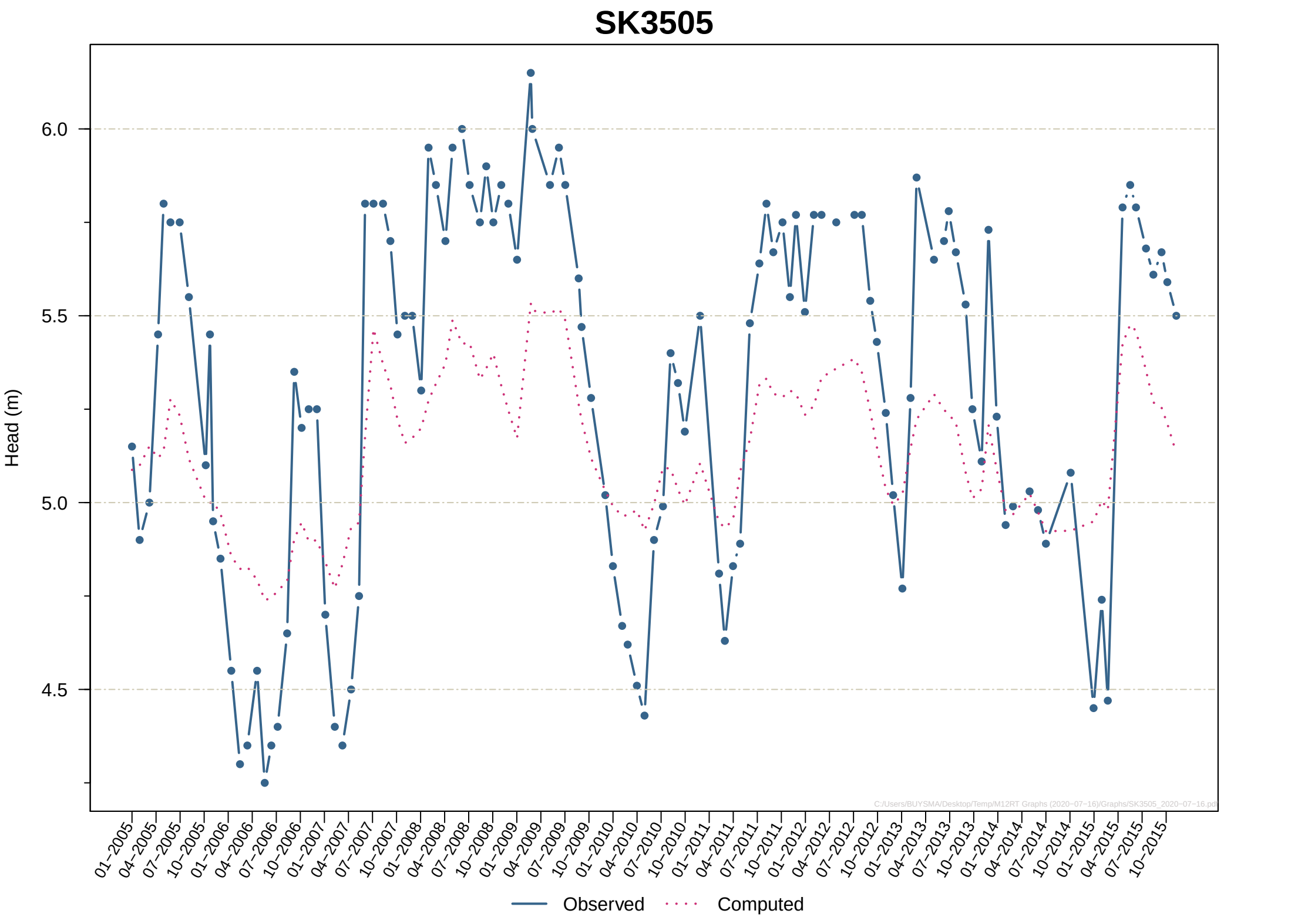
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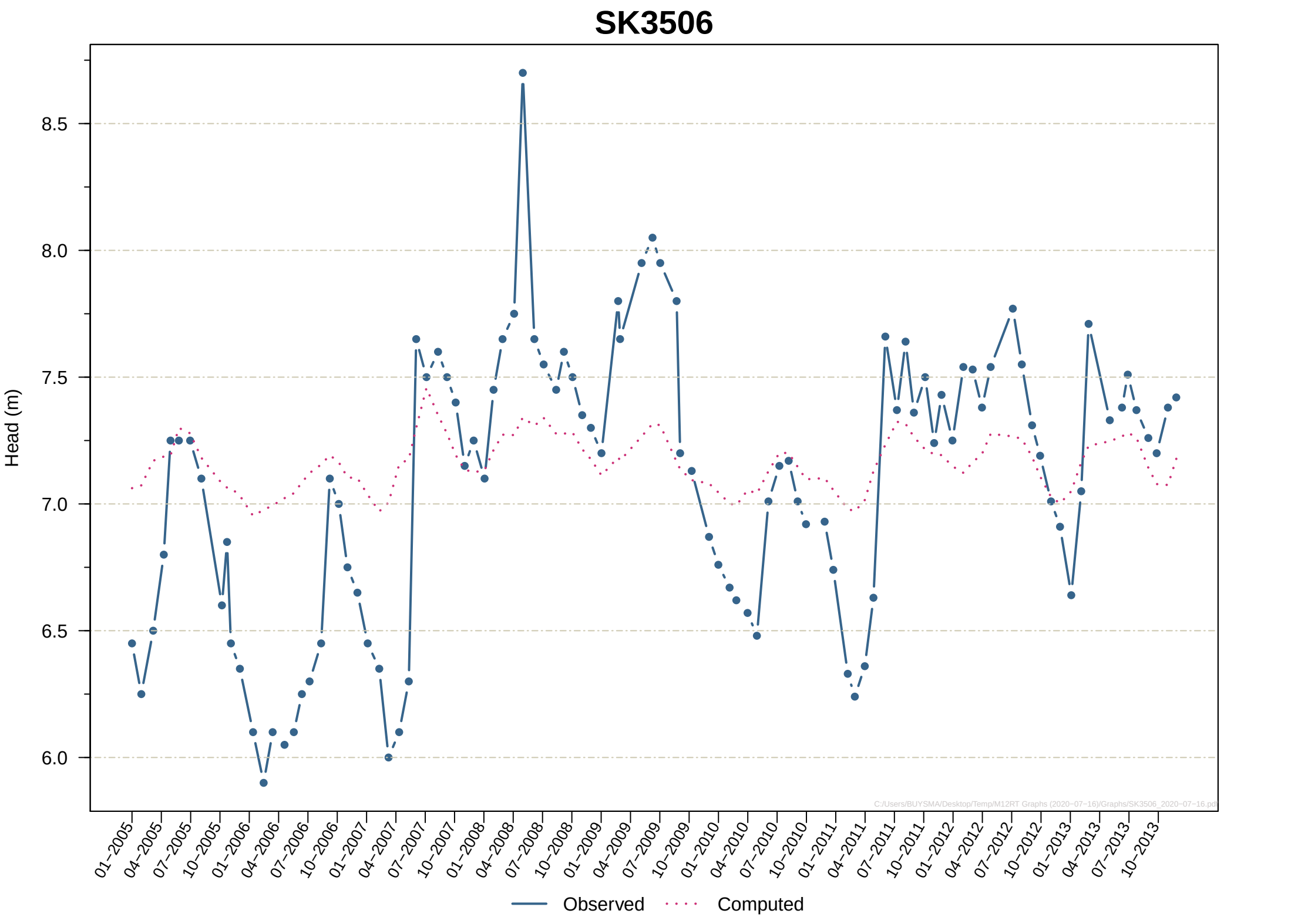
Computed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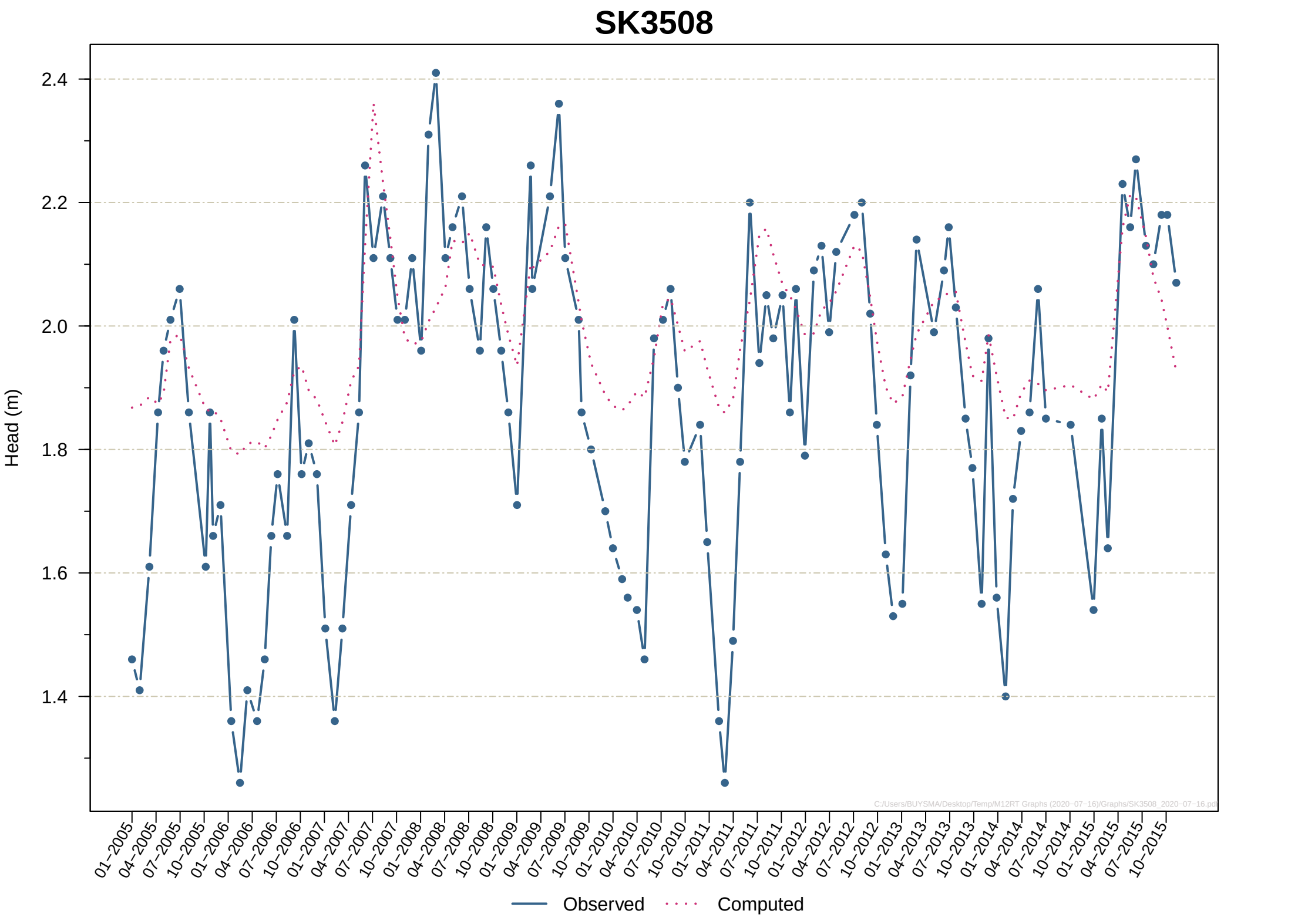
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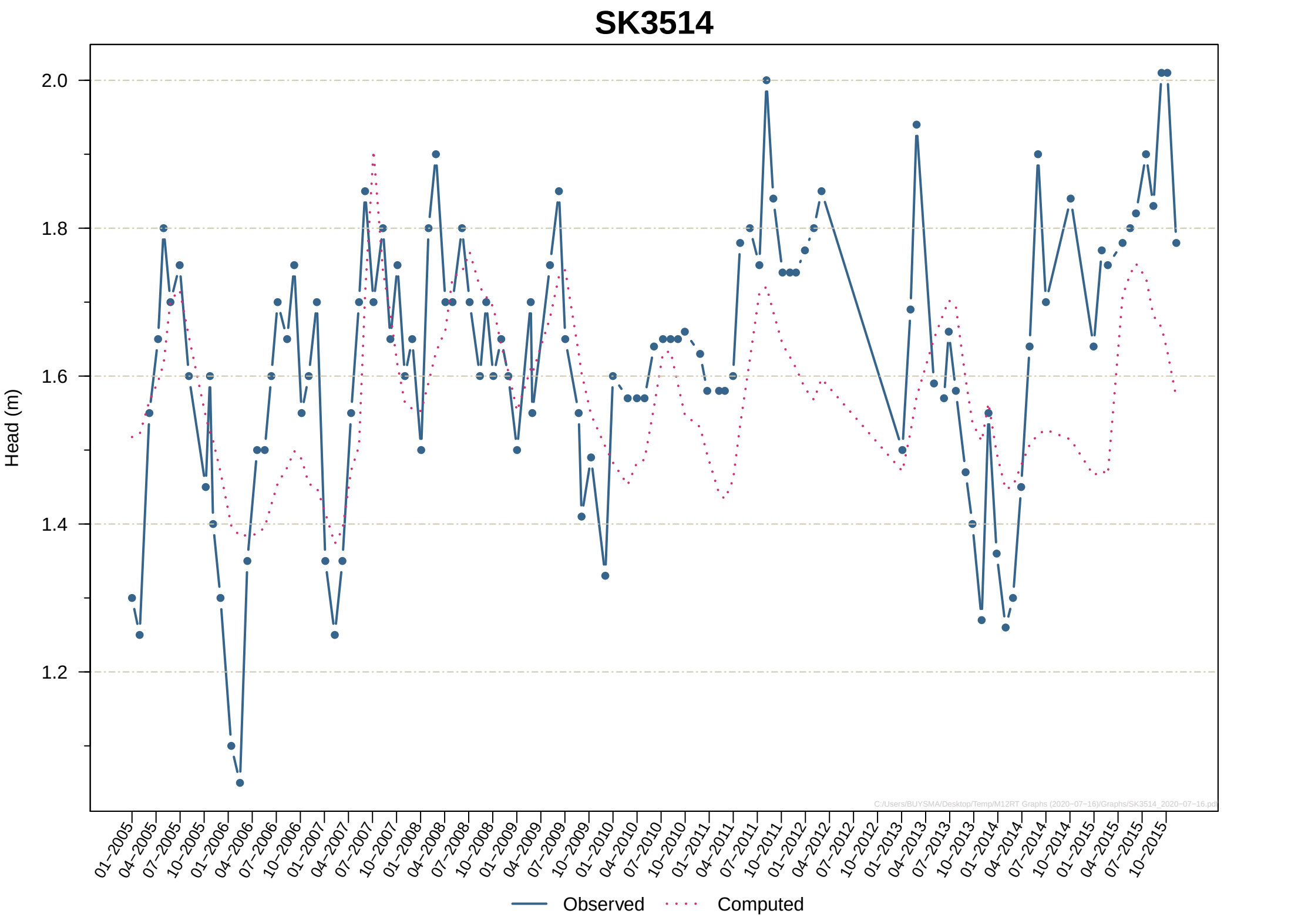
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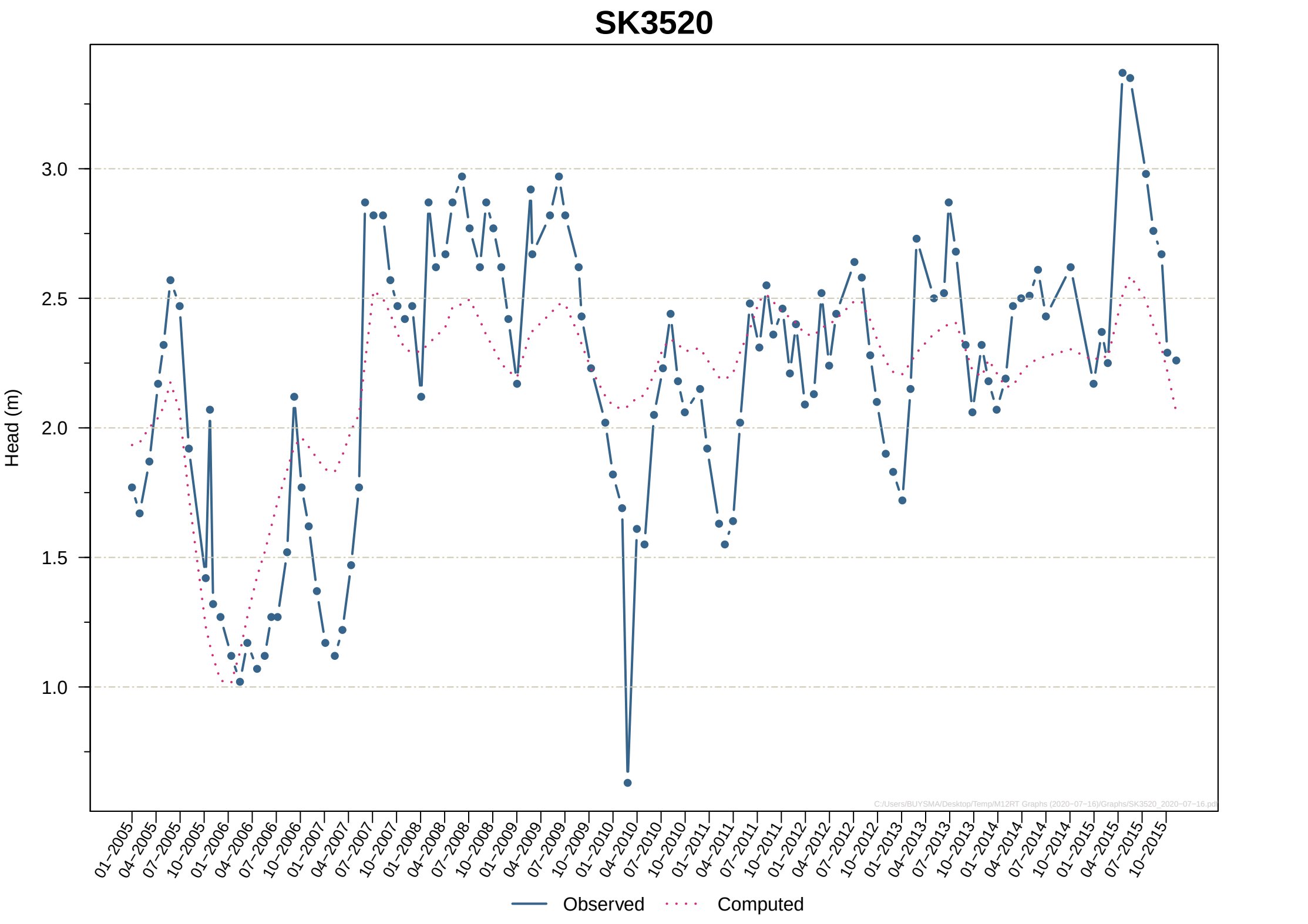
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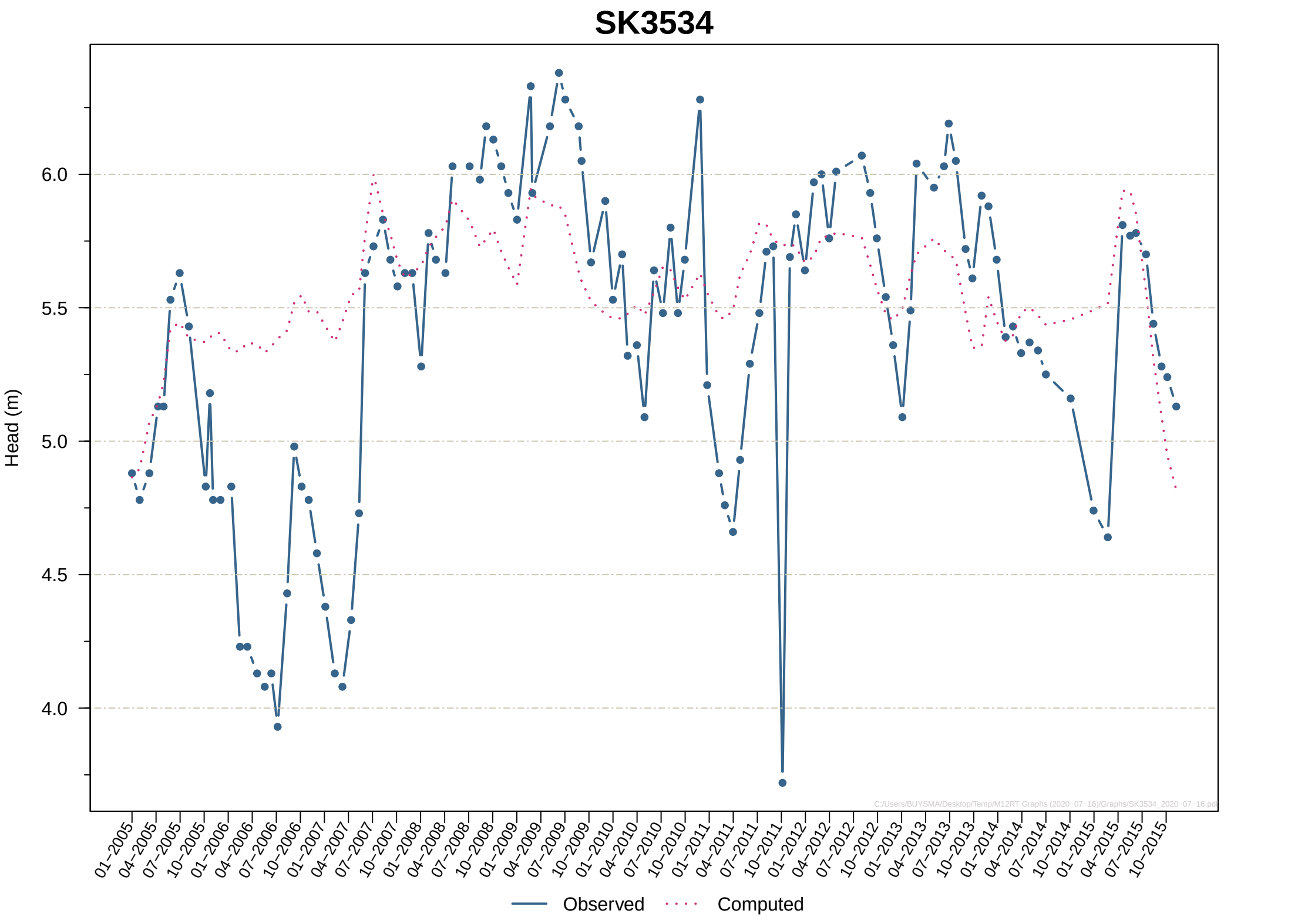
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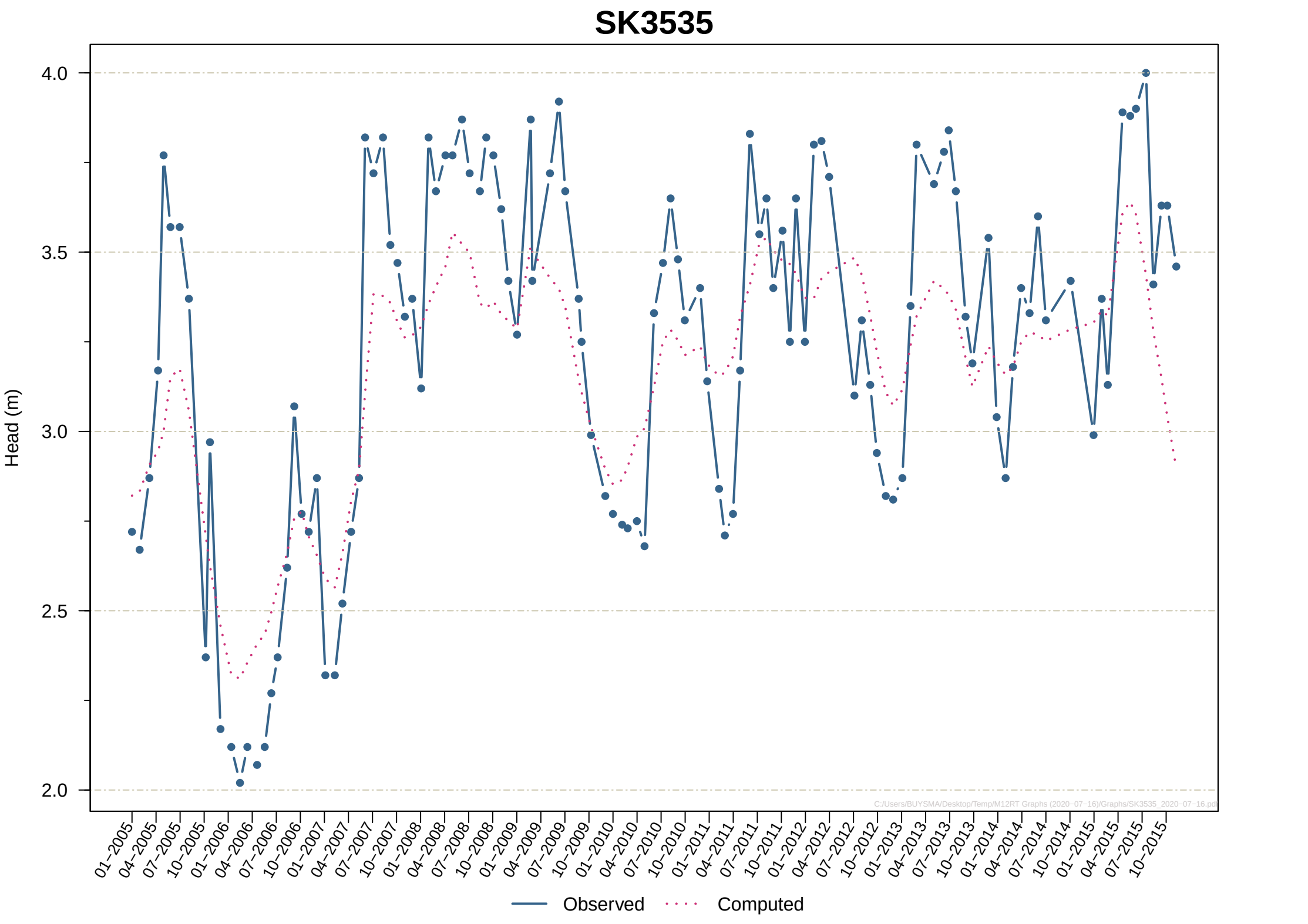
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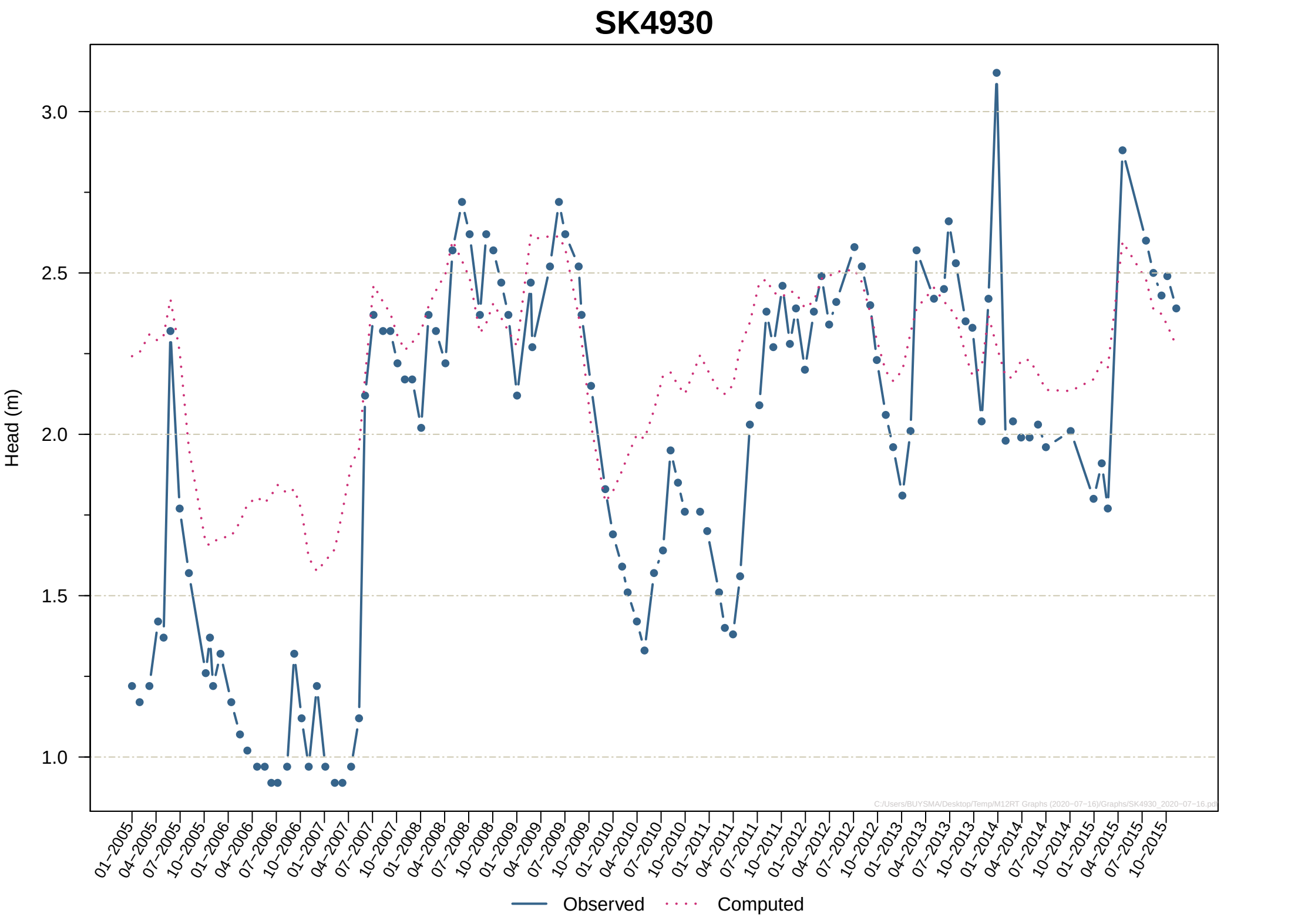
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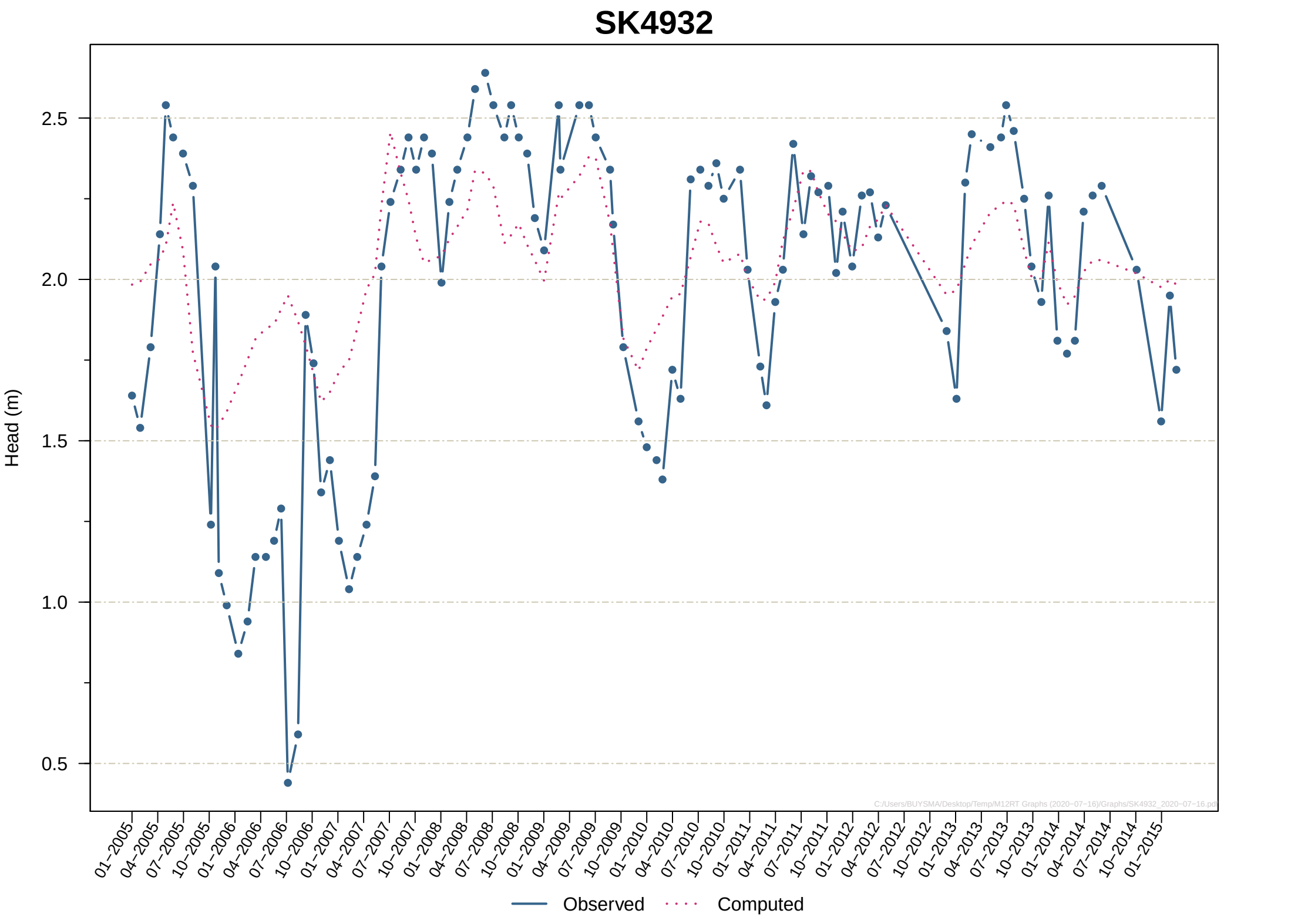
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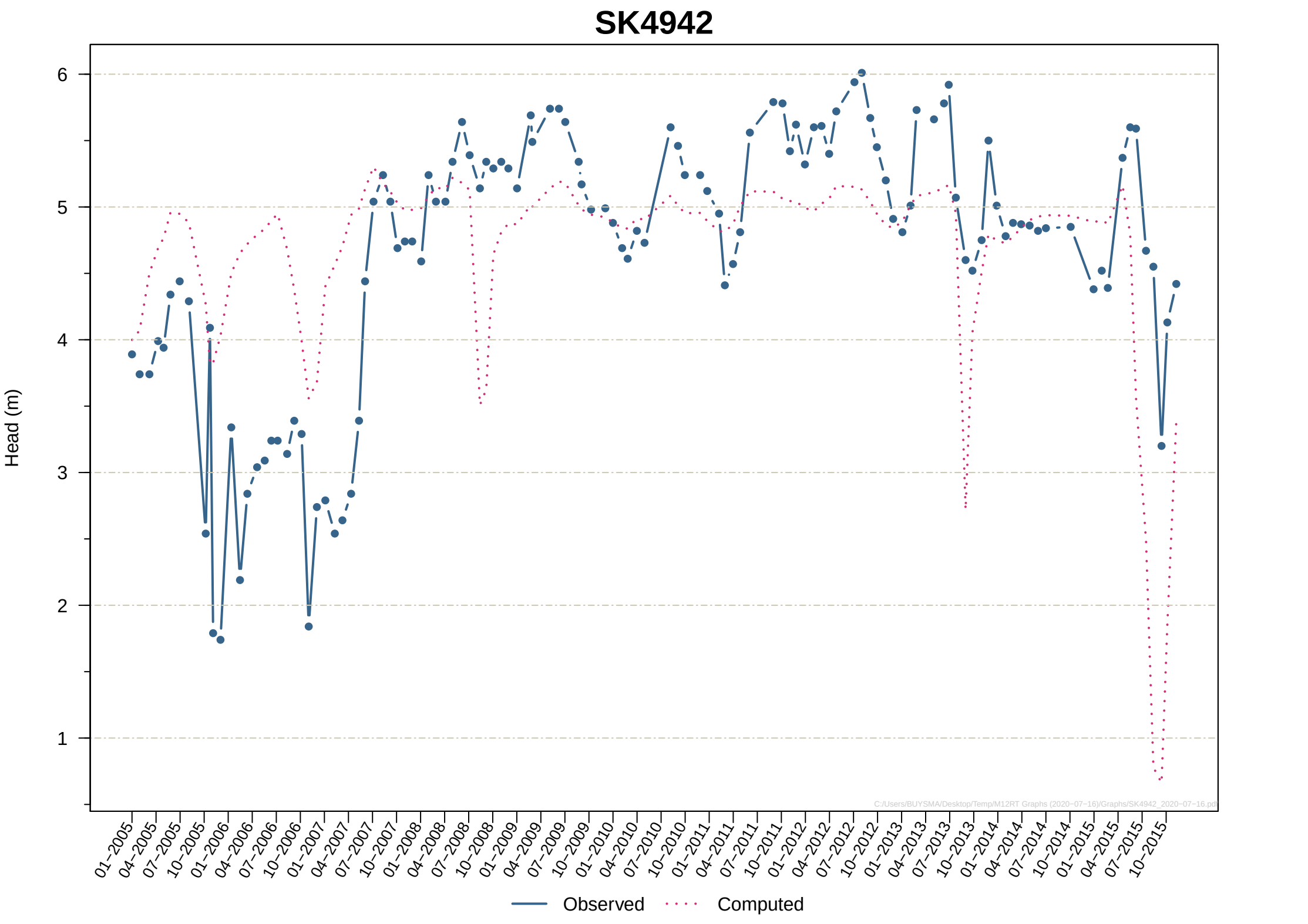
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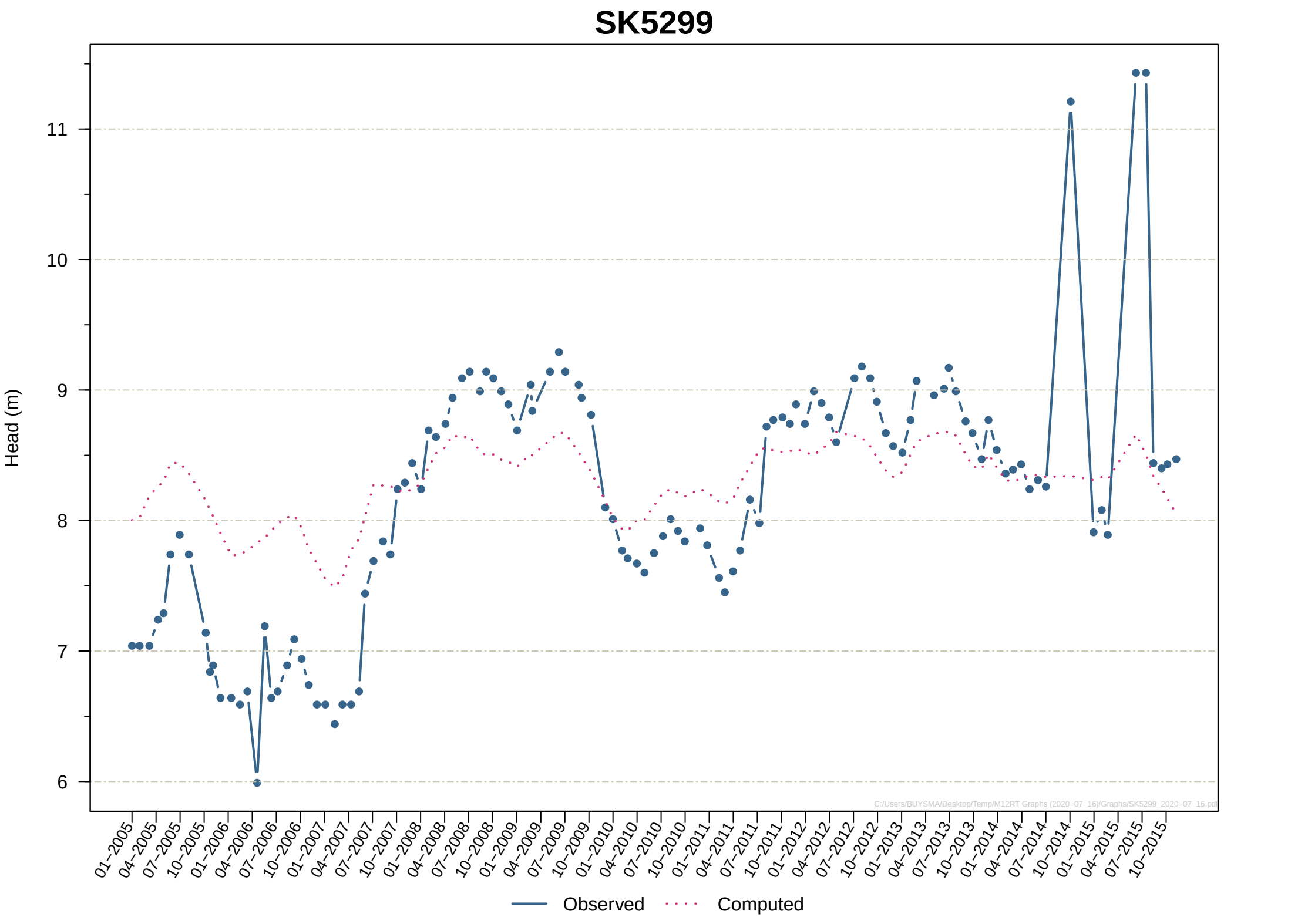
Observed
Computed


SK5299
Head (m)
11
10
9
8
7
6
01–2005
04–2005
07–2005
10–2005
01–2006
04–2006
07–2006
10–2006
01–2007
04–2007
07–2007
10–2007
01–2008
04–2008
07–2008
10–2008
01–2009
04–2009
07–2009
10–2009
01–2010
04–2010
07–2010
10–2010
01–2011
04–2011
07–2011
10–2011
01–2012
04–2012
07–2012
10–2012
01–2013
04–2013
07–2013
10–2013
01–2014
04–2014
07–2014
10–2014
01–2015
04–2015
07–2015
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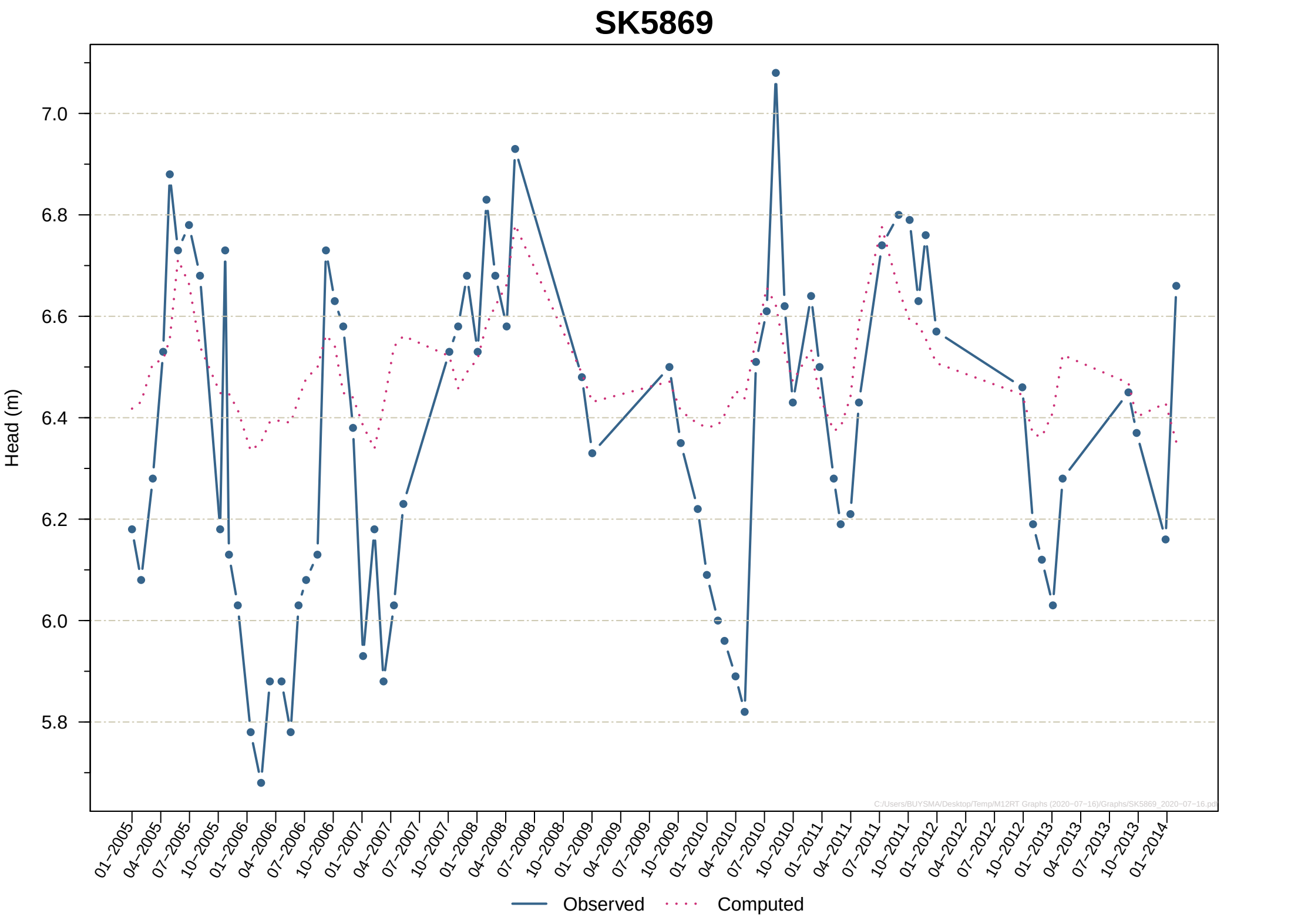
Observed
Computed


SK5869
Head (m)
7.0
6.8
6.6
6.4
6.2
6.0
5.8
01−2005
04−2005
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10−2005
01−2006
04−2006
07−2006
10−2006
01−2007
04−2007
07−2007
10−2007
01−2008
04−2008
07−2008
10−2008
01−2009
04−2009
07−2009
10−2009
01−2010
04−2010
07−2010
10−2010
01−2011
04−2011
07−2011
10−2011
01−2012
04−2012
07−2012
10−2012
01−2013
04−2013
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10−2013
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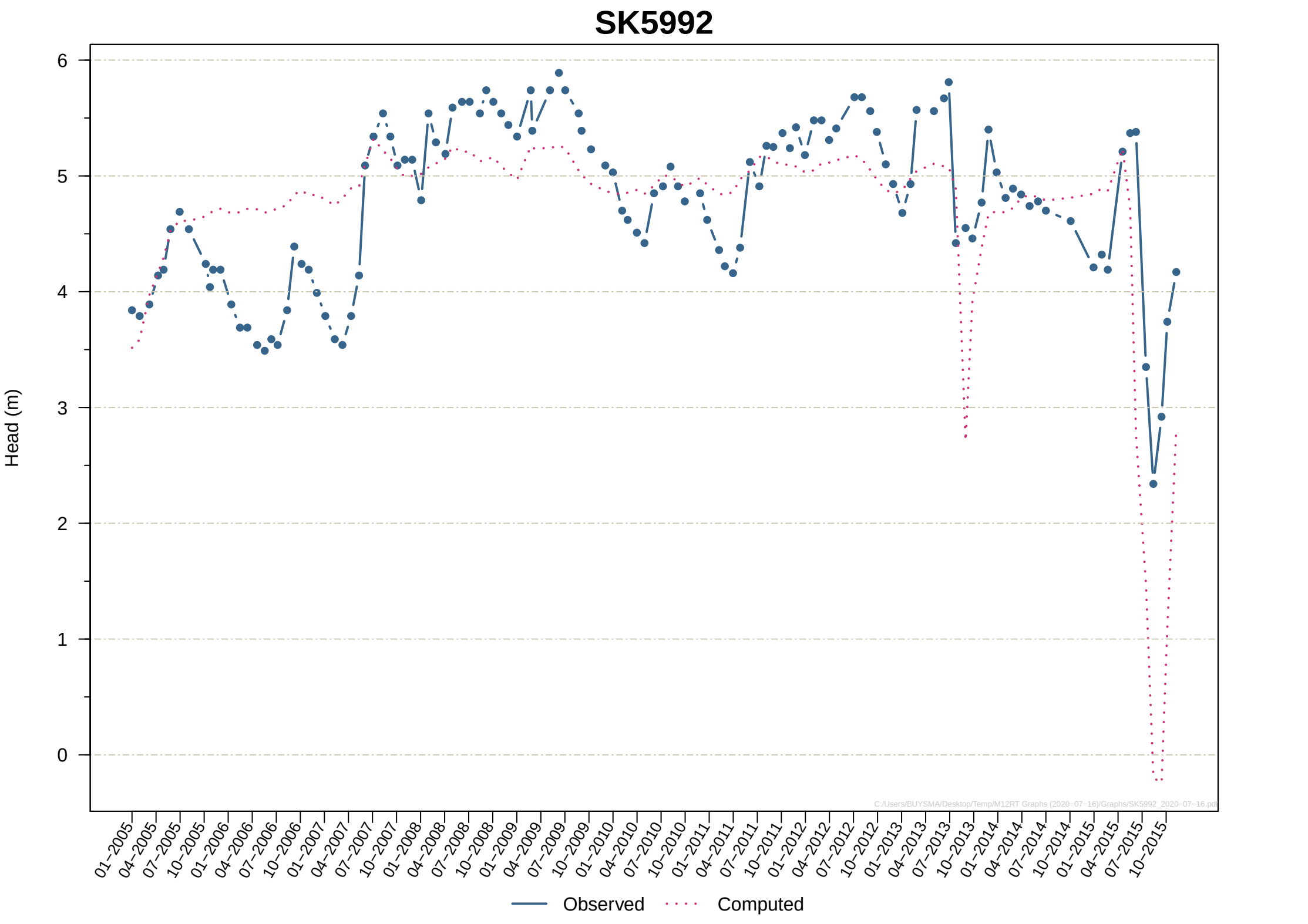
Observed
Computed


SK5992
Head (m)
6
5
4
3
2
1
0
01−2005
04−2005
07−2005
10−2005
01−2006
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07−2006
10−2006
01−2007
04−2007
07−2007
10−2007
01−2008
04−2008
07−2008
10−2008
01−2009
04−2009
07−2009
10−2009
01−2010
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07−2012
10−2012
01−2013
04−2013
07−2013
10−2013
01−2014
04−2014
07−2014
10−2014
01−2015
04−2015
07−2015
10−2015
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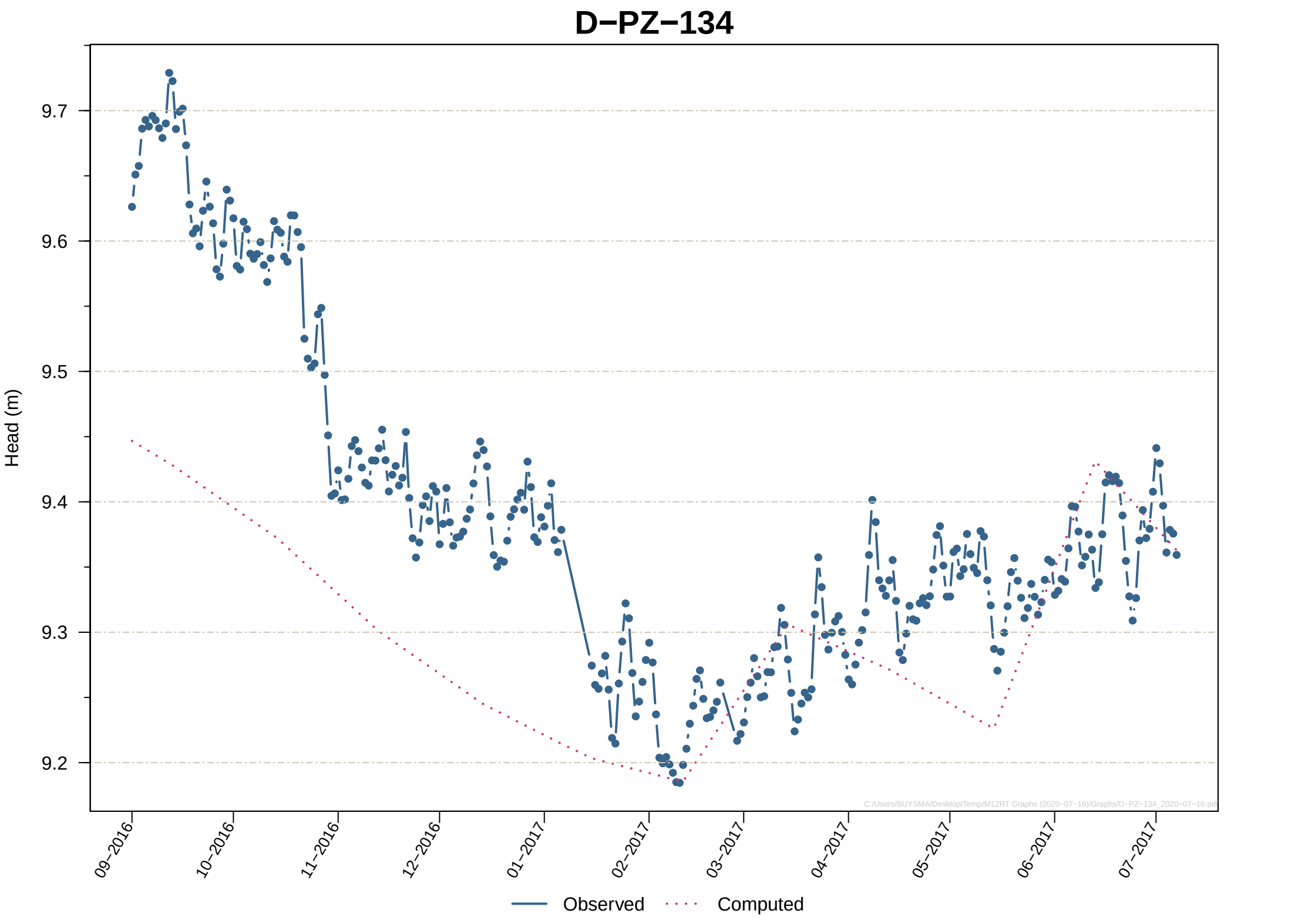
Observed
Computed

Appendix B Simulation hydrographs


D−PZ−134
Head (m)
9.7
9.6
9.5
9.4
9.3
9.2
09−2016
10−2016
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
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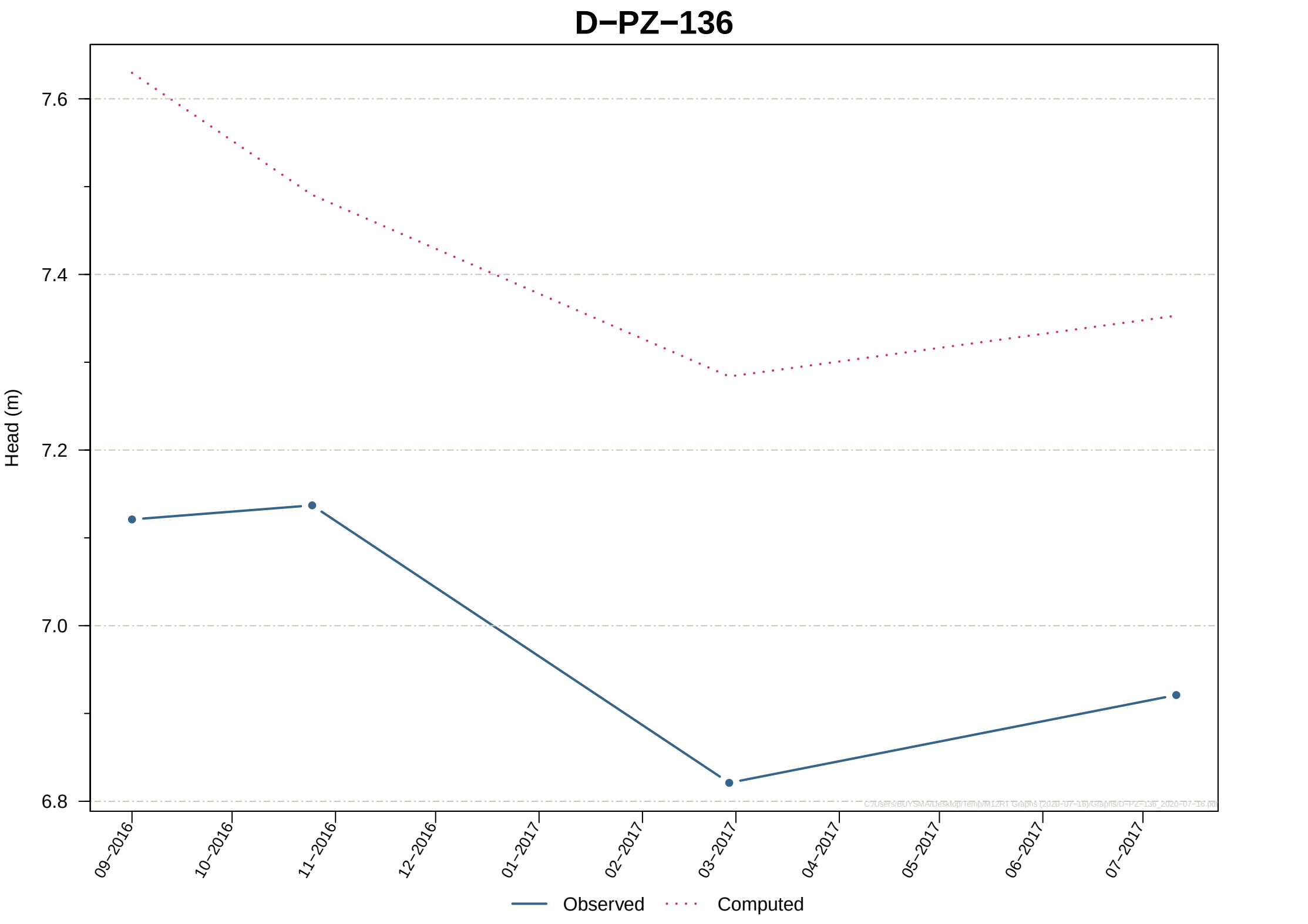
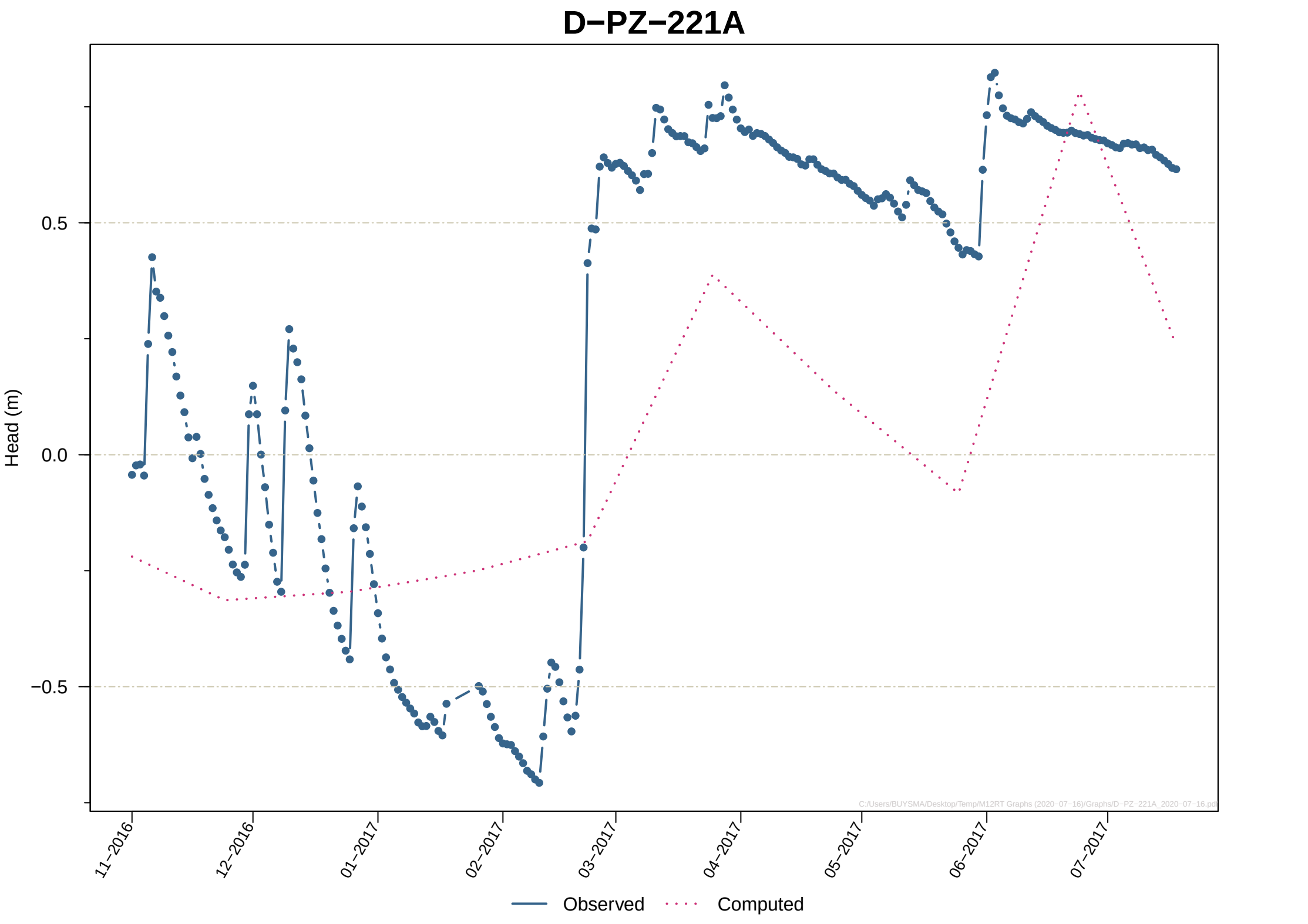

D−PZ−136
Head (m)
7.6
7.4
7.2
7.0
6.8
09−2016
10−2016
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed


D−PZ−221A
Head (m)
0.5
0.0
−0.5
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
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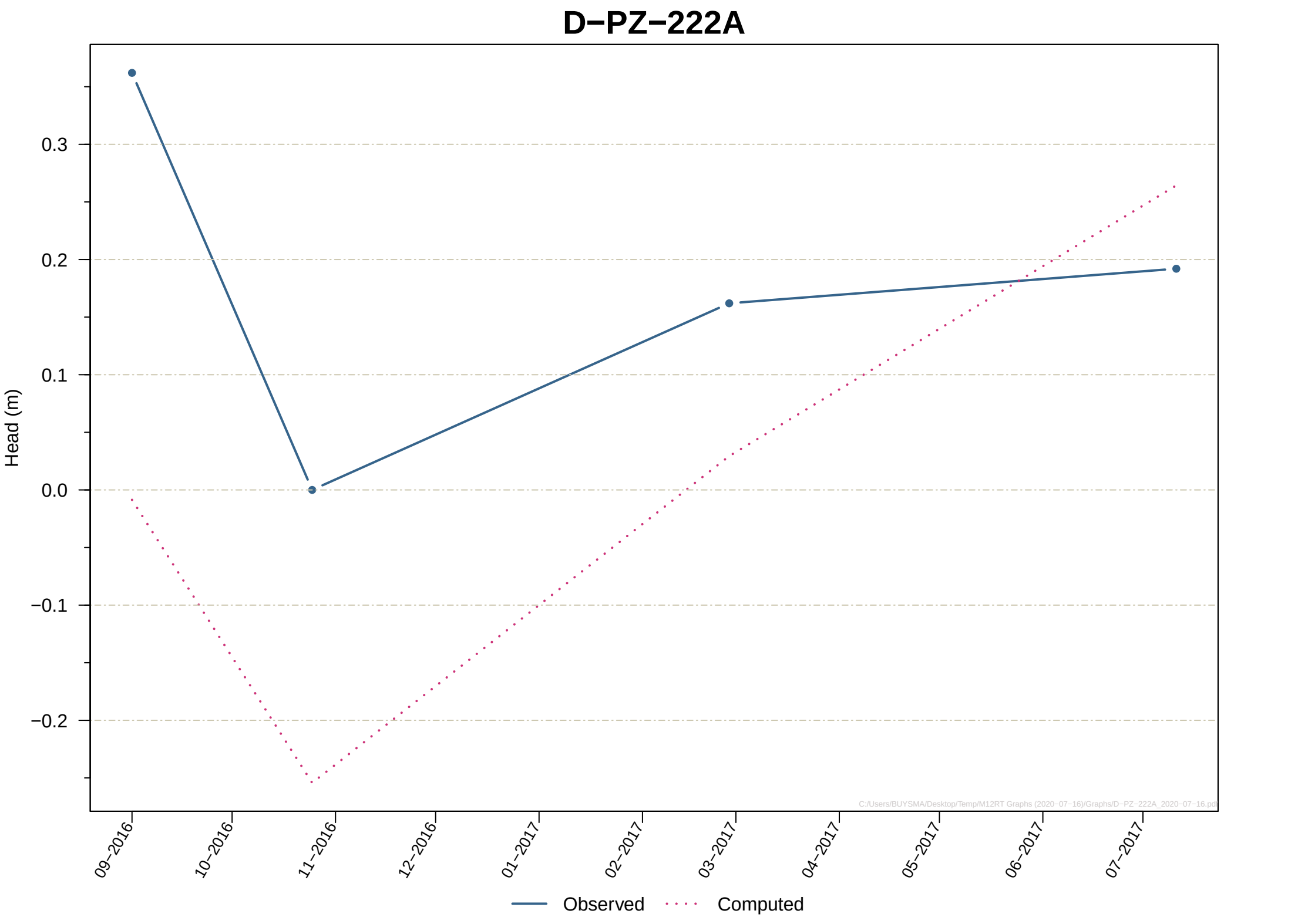
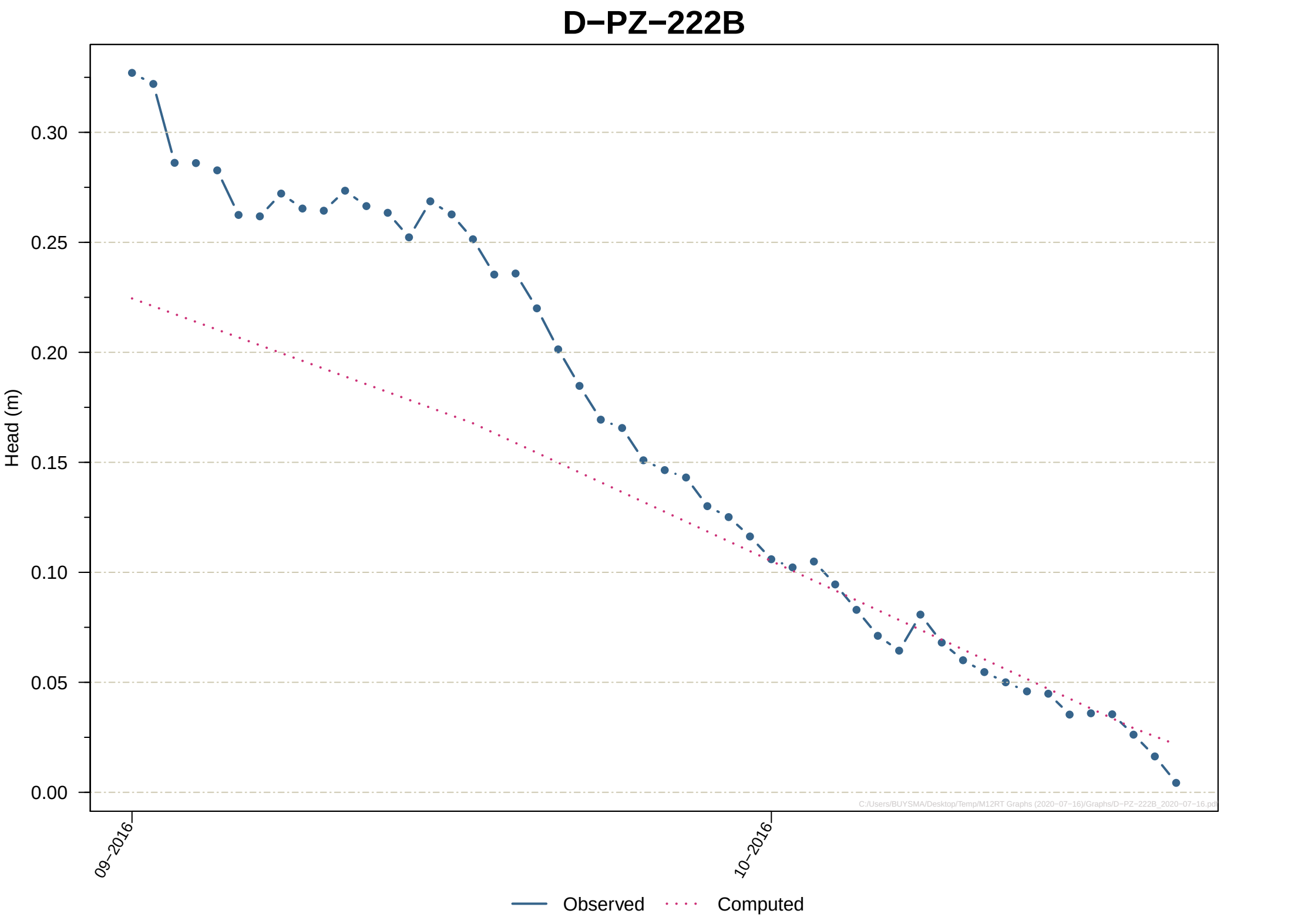

D−PZ−222A
Head (m)
0.3
0.2
0.1
0.0
−0.1
−0.2
09−2016
10−2016
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
C:/Users/BUYSMA/Desktop/Temp/M12RT Graphs (2020−07−16)/Graphs/D−PZ−222A_2020−07−16.pdf


D−PZ−222B
Head (m)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
09−2016
10−2016
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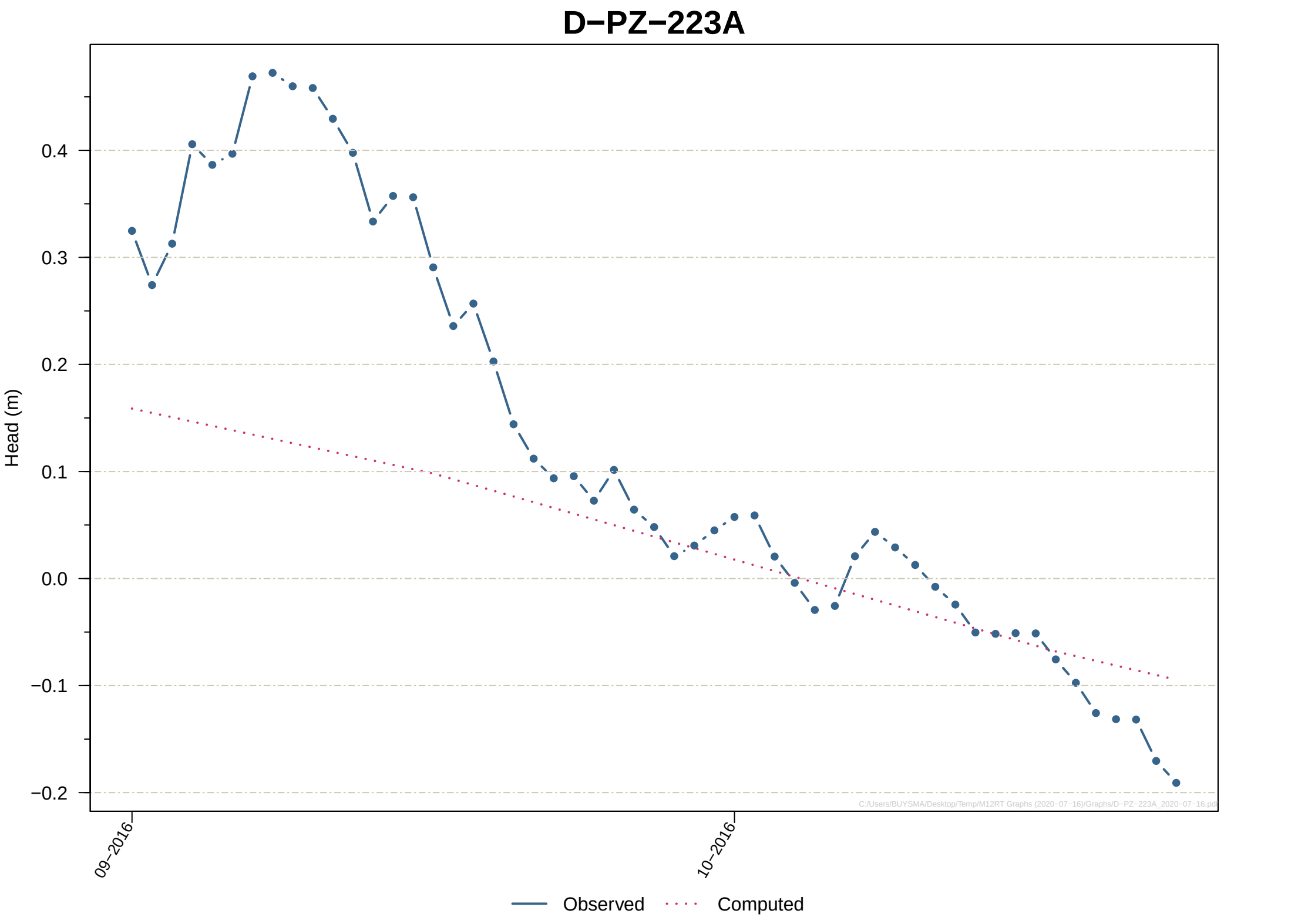
Observed
Computed


D−PZ−223A
Head (m)
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
09−2016
10−2016
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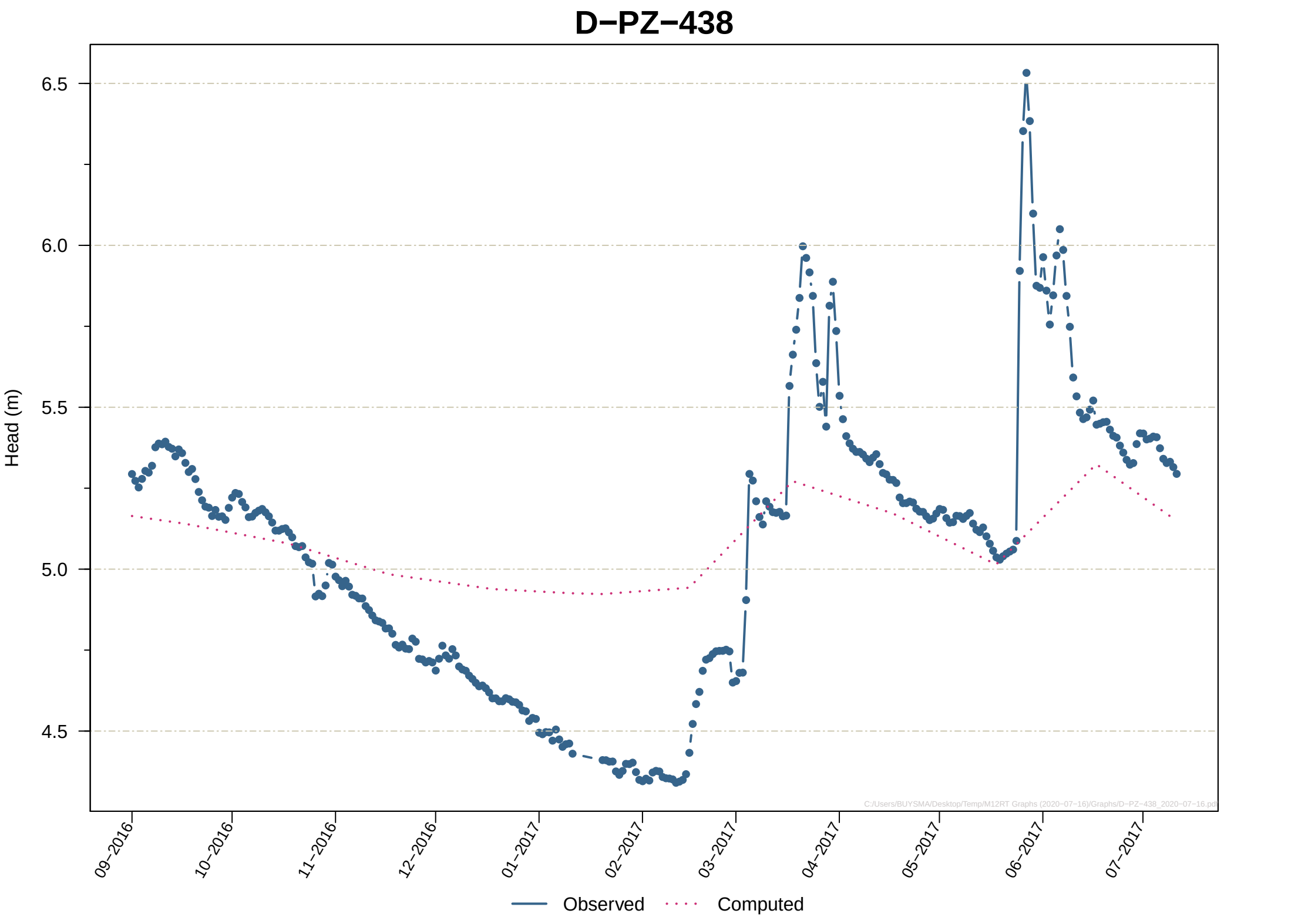
Observed
Computed


D−PZ−438
Head (m)
6.5
6.0
5.5
5.0
4.5
09−2016
10−2016
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
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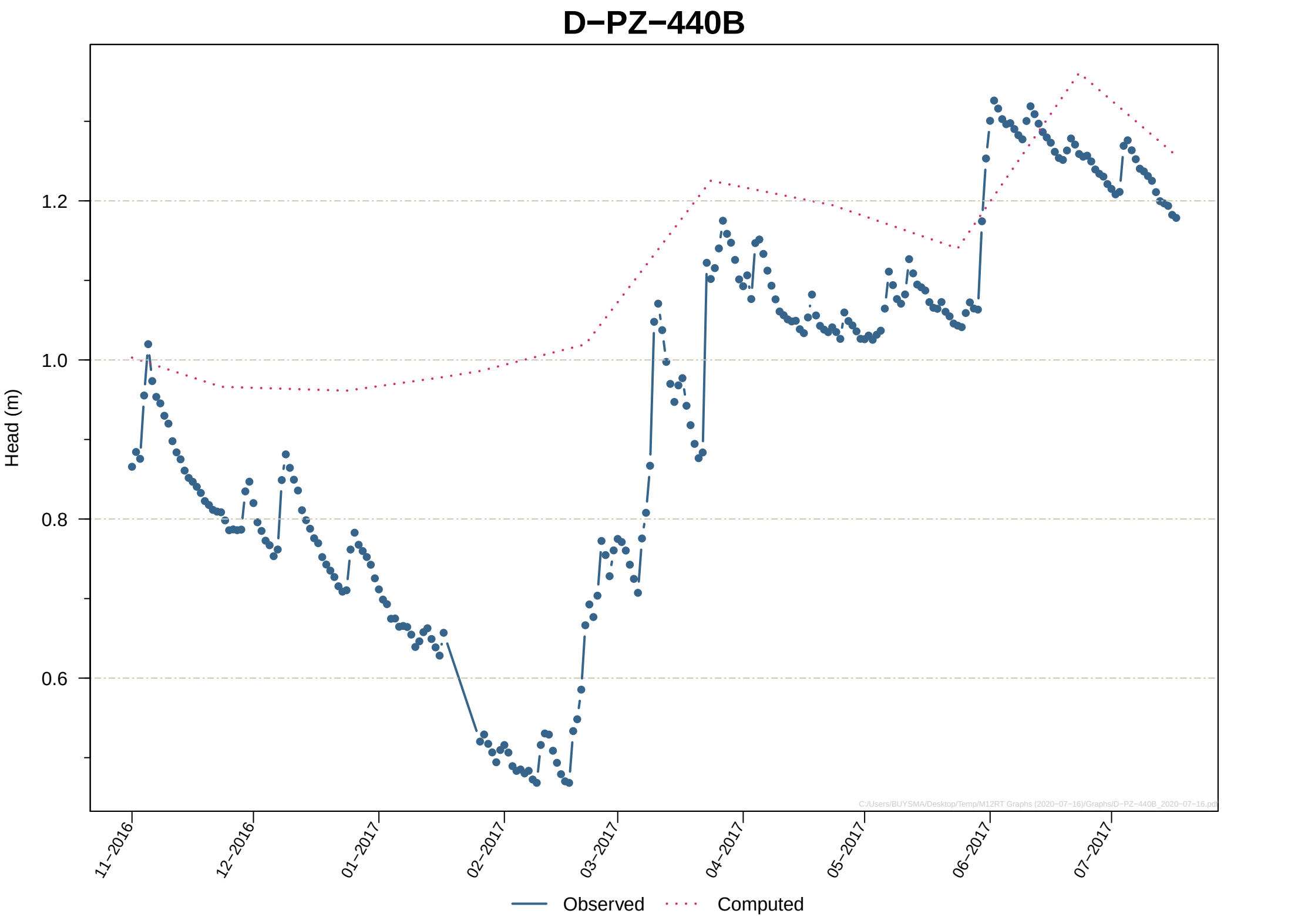
D−PZ−440B
Head (m)
1.2
1.0
0.8
0.6
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
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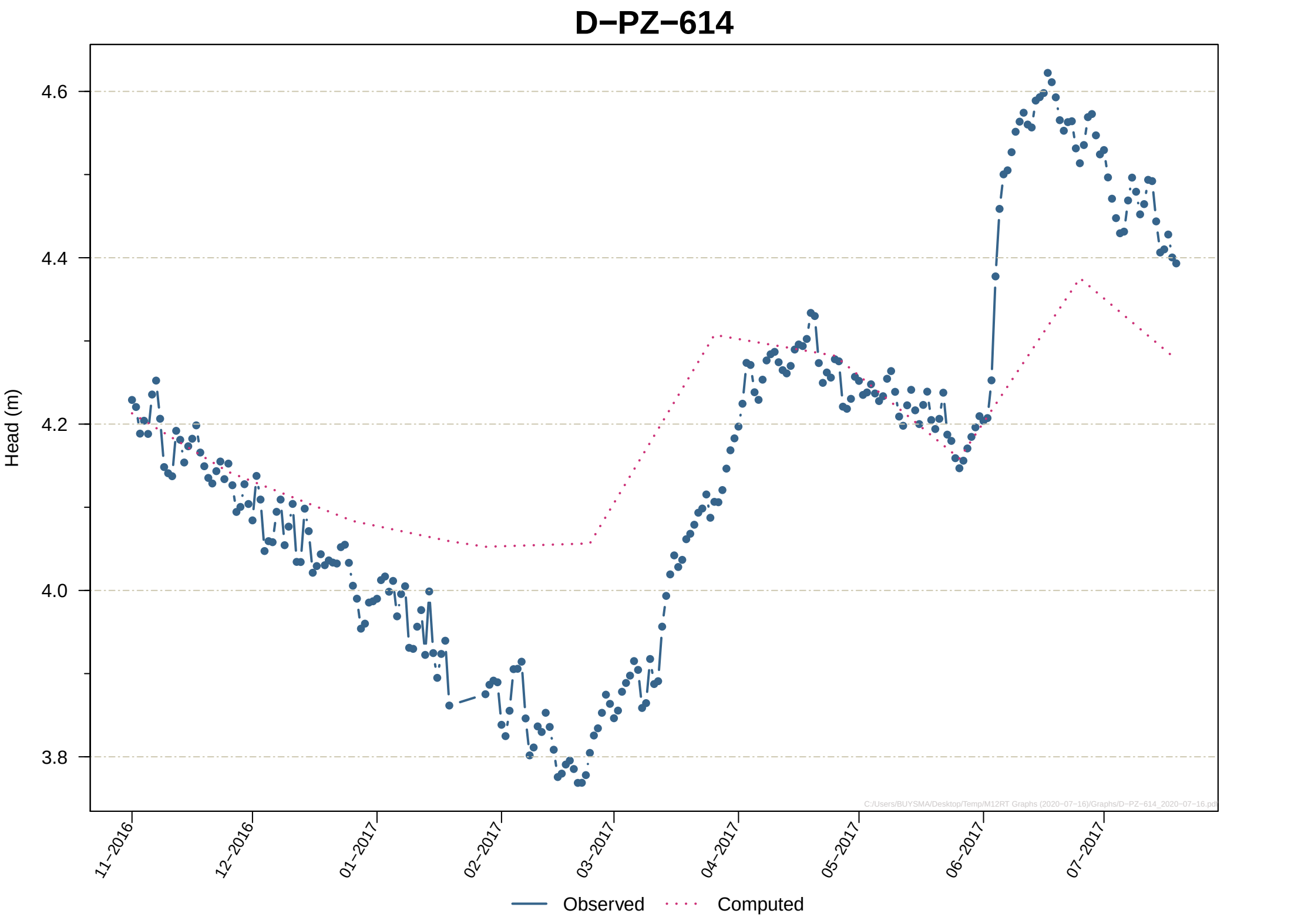
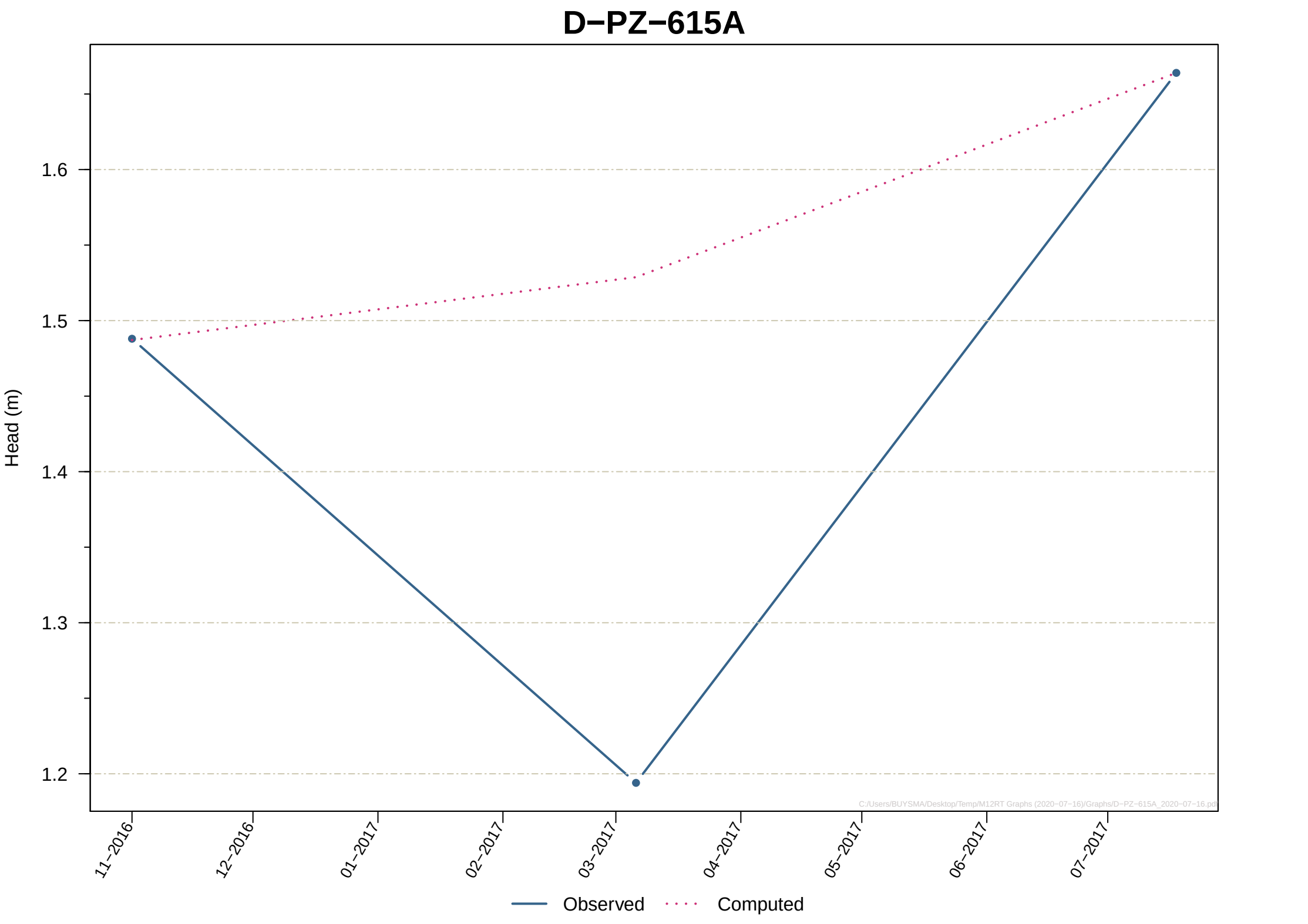

D−PZ−614
Head (m)
4.6
4.4
4.2
4.0
3.8
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
C:/Users/BUYSMA/Desktop/Temp/M12RT Graphs (2020−07−16)/Graphs/D−PZ−614_2020−07−16.pdf


D−PZ−615A
Head (m)
1.6
1.5
1.4
1.3
1.2
11−2016
12−2016
01−2017
02−2017
03−2017
04−2017
05−2017
06−2017
07−2017
Observed
Computed
C:/Users/BUYSMA/Desktop/Temp/M12RT Graphs (2020−07−16)/Graphs/D−PZ−615A_2020−07−16.pdf

Appendix B summary Flood modelling and impact assessment

Description

Detailed flood modelling was completed to inform the concept design and the environmental impact assessment. The modelling was carried out in a TUFLOW two-dimensional flood hydraulic model of the Lower Hunter River, that extends 5 kilometres upstream on the Hunter River and 4 kilometres upstream on the Williams River from Raymond Terrace, and extends down to the outlet to the Tasman Sea to the east of city of Newcastle. The model also extends to cover the Hunter River floodplain west to Thornton and Beresfield, Hexham Swamp in the west and the Fullerton Cove overflow onto the Tilligerry Creek floodplain at Williamtown and Salt Ash, and to the Tilligerry Creek outlet to Port Stephens, in the northeast. In summary, the flood modelling assessment included:

- Collection and review of existing flood studies and flood models from local Councils, information on historic flooding including recorded rainfall and water level data and other data contained in existing flood studies
- Review of XP-RAFTS hydrology and hydraulic TUFLOW (BMT, 2018) flood model developed for the Williamtown – Salt Ash Floodplain Risk Management Study and Plan (BMT WBM, 2017)
- Update and refinement of XP-RAFTS hydrology models for Purgatory Creek and Tomago area
- Simulation of runoff hydrographs for the flood events of April 2015 and January 2016 and design flood events including the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events on the basis of ARR 2019 (Ball et al, 2019)
- Conversion of the 20 metre grid TUFLOW Classic hydraulic model (BMT WBM, 2017) to a 20 metre grid TUFLOW HPC hydraulic model to reduce model run time
- Update and refinement of the TUFLOW model in key locations based on additional topographic survey and site reconnaissance
- Verification of the updated TUFLOW model for the flood events of April 2015 and January 2016
- Modelling of the April 2015 and January 2016 flood events for existing case, and assessment of operational phase to demonstrate impacts of the project on historic flood events
- Modelling assessment of a range of design flood events including the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the existing case utilising an envelope of flooding mechanisms dominated by a combination of rainfall runoff generated over the local catchments, Hunter River inflow and tide levels
- Validation of the results was undertaken with comparison to design flood levels presented in previous studies (DHI, 2008; BMT WBM, 2012; and BMT WBM, 2017)
- Modelling assessment of a range of design flood events including the 20%, 10% and 5%AEP flood events for the construction phase
- Modelling assessment of a range of design flood events including the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the operational phase
- Analysis of the sensitivity of flooding to blockage condition of hydraulic structures and to climate change scenarios (rainfall and flood flow increase, and sea level rise)
- Assessment of cumulative flooding impacts due to the project and other approved projects.
- Independent verification reviews of the flood modelling have been undertaken by third parties external to the project design and environmental assessment.

Refer to Figure B-1 for the TUFLOW model configuration for existing conditions, Figure B-2 for the TUFLOW model for construction phase and Figure B-3 for the operational phase.

Figure B-1 TUFLOW model configuration – Existing case (map 1 of 2)

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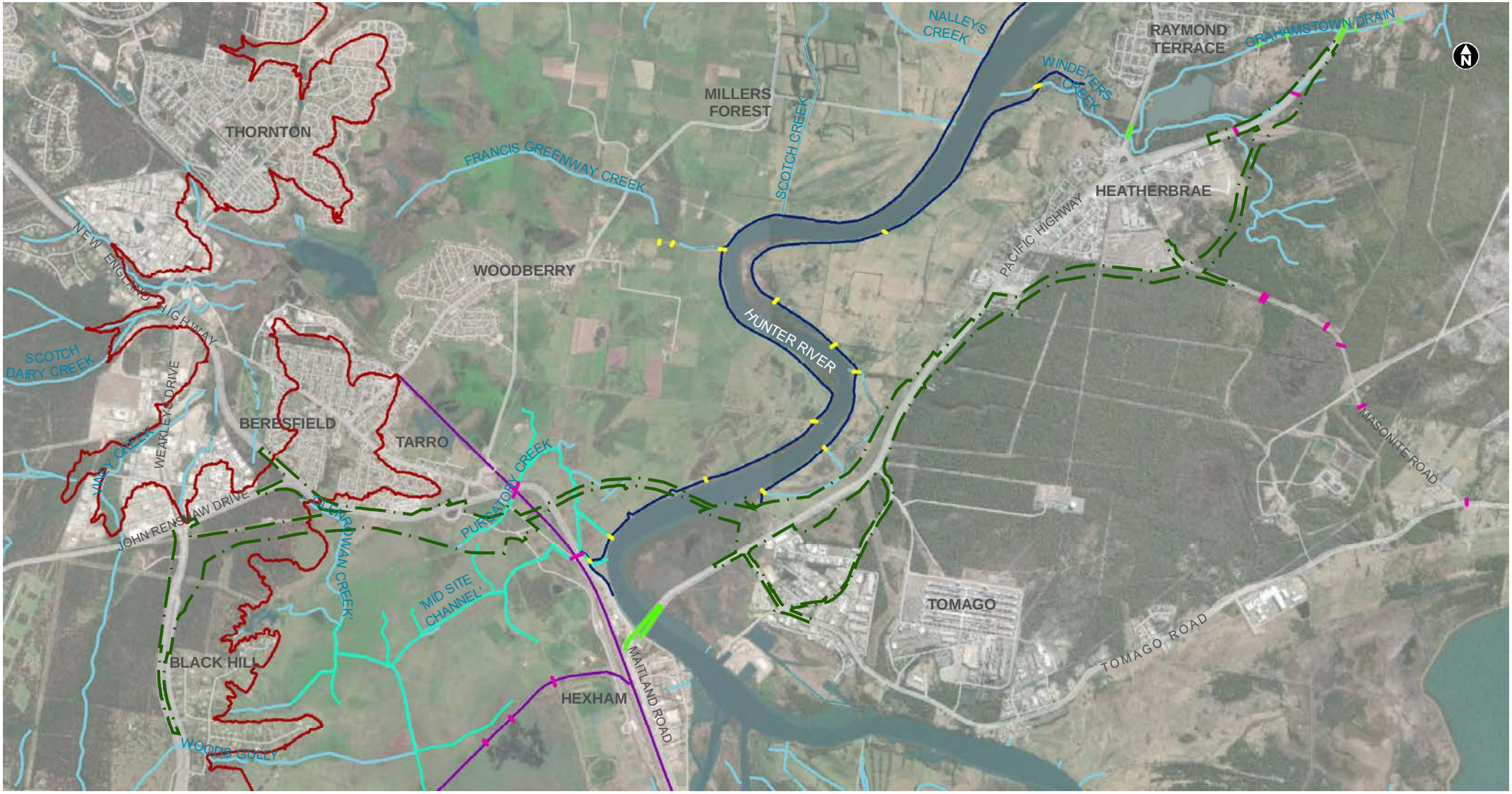

Figure B-1 TUFLOW model configuration – Existing case (map 2 of 2)

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Figure B-2 TUFLOW model configuration – Construction phase (map 1 of 2)

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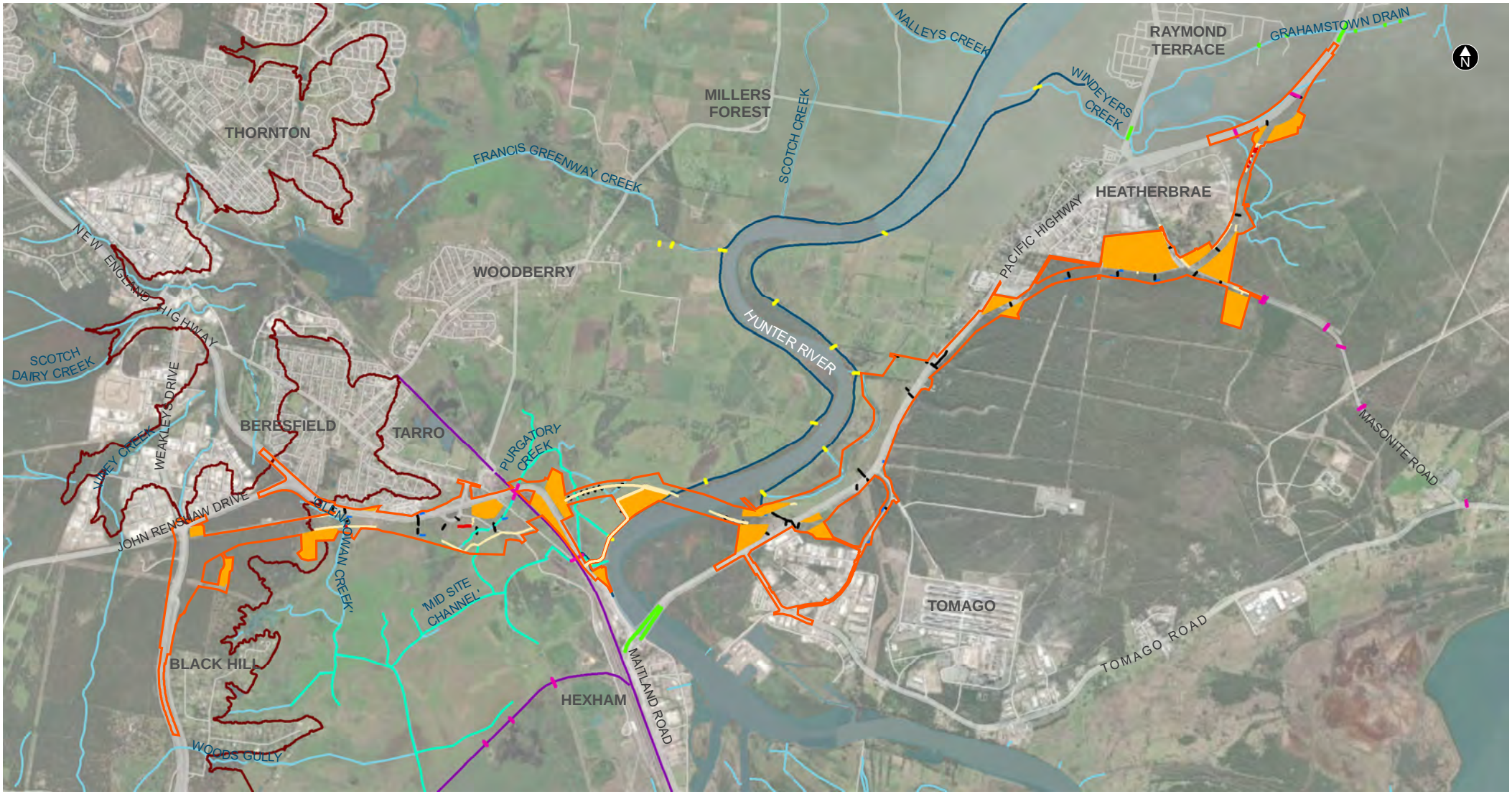


TUFLOW model extent
Construction footprint
Ancillary sites
Construction phase water quality basin

Construction phase access track culvert
Construction phase access track
Floodgates
Culverts
Permanent design culverts

Waterway crossing
Railway embankment breakline
Hexham Swamp channel breakline
Levee breakline

0 1 2km

Figure B-2 TUFLOW model configuration – Construction phase (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_100_B2_TUFLOWmodelConstruction_JAC_A4L_175000_V02.mxd

Figure B-3 TUFLOW model configuration – Operational phase (map 1 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_101_B3_TUFLOWmodelOperational_JAC_A4L_175000_V02.mxd

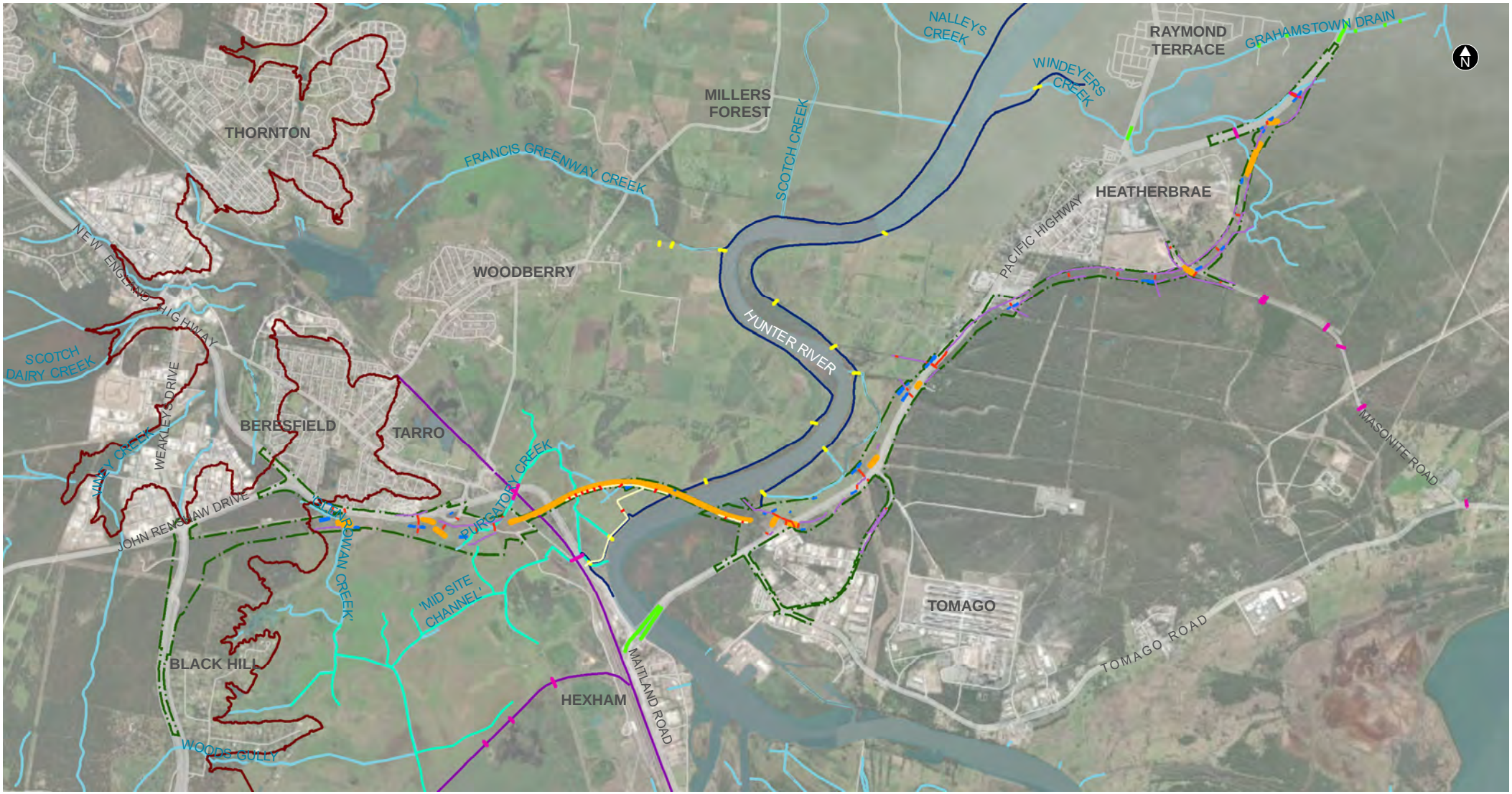


Figure B-3 TUFLOW model configuration – Operational phase (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_101_B3_TUFLOWmodelOperational_JAC_A4L_175000_V02.mxd

Property and land use flooding analysis method

Analysis of flooding of lots for residential, commercial and industrial land uses was conducted based on the following considerations:

- Maximum flood depths and flood hazard occurring on each lot was assigned to each individual property in the property database within the flooding study area. Lots with flood depths less than 0.05 metres were excluded
- Maximum duration of inundation occurring on each lot was assigned to each individual lot in the property database within the flooding study area. Areas with depths less than 0.5 metres were excluded to remove the effects of fine-scale drainage conditions which may not be represented by the coarser 20 metre flood model grid resolution of the regional flood model
- The area (in hectares) of major rural land uses were calculated by sampling the flood mapping data for the flood hazard and duration of inundation
- The lot and land use flood affectation details were assessed for the 20%, 10%, 5%, 2% and 1% AEP and probable maximum flood events for the existing and operational phases, and for the 20%, 10% and 5% AEP events for the construction phase
- Impacts to lots were assessed based on the differences between the construction or operational phases from the existing case, including:
  - Number of residential, commercial and industrial lots, respectively, affected by change in peak flood depth
  - Number of residential, commercial and industrial lots, respectively affected by change in peak flood hazard
  - Area (hectares) on main rural land uses affected by different changes in peak flood hazard. The main rural land uses identified for the flooding study area include grazing, forestry and wetlands and national park areas
  - Number of residential, commercial and industrial lots, respectively affected by change in peak duration of inundation
  - Change in area (hectares) on main rural land uses affected by different changes in peak flood duration of inundation.
- Lots and buildings affected by afflux exceeding the adopted criteria in **Section 3.6.3** were identified from the change in flood level (i.e. afflux) mapping for construction, presented in **Appendix D**. Exceedance of the afflux criteria outside the construction or operation boundary, as appropriate for construction or operation phase assessment, and across all flood events assessed has been considered, and all land use zoned lots types are included
- Impacted buildings are identified based on afflux at the building exceeding 50mm in any of the flood events assessed for construction and operation phases. The 50mm threshold relates to buildings with above habitable floor flooding (100mm threshold for no above habitable floor flooding), however, in the absence of floor level data the more conservative criterion has been adopted for the buildings count. Only buildings identified with habitable floors are included
- Residential lots included those zoned R1 – General Residential, R2 – Low Density Residential, R3 – Medium Density Residential, R4 – High Density Residential, and R5 – Large Lot Residential
- Commercial lots included those zoned B1 - Neighbourhood Centre, B2 - Local Centre, B3 – Commercial Core, and B4 - Mixed Use
- Industrial lots include those zoned IN1 - General Industrial, IN2 - Light Industrial, and IN3 – Heavy Industrial
- The rural land uses were identified from NSW Office of Environment and Heritage land use type spatial data
- The analysis is based on lots from cadastral information as properties may consist of a number of lots.

Property and land use flooding analysis – Existing case

Table B-1 Number of residential lots affected by different peak depths – existing case

Depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0.05–0.1	57	56	58	53	77	150
0.1–0.2	95	83	90	94	104	282
0.2–0.3	69	72	74	79	105	265
0.3–0.5	89	95	100	127	150	543
0.5–0.7	98	106	107	108	118	458
0.7–1.0	69	100	105	131	140	657
1.0–1.2	18	32	50	59	64	571
1.2–1.5	25	25	44	52	86	926
1.5–2.0	20	18	30	63	137	998
2.0–3.0	12	25	28	93	115	1052
>3	4	8	12	31	90	1083
Total	556	620	696	889	1185	6983

Table B-2 Number of commercial lots affected by different peak depths – existing case

Depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0.05–0.1	10	7	8	5	8	13
0.1–0.2	7	11	9	10	10	39
0.2–0.3	12	10	9	9	8	42
0.3–0.5	36	21	22	19	17	117
0.5–0.7	19	32	31	24	16	126
0.7–1.0	31	28	48	37	35	225
1.0–1.2	12	21	28	16	19	83
1.2–1.5	27	22	34	34	30	91
1.5–2.0	5	11	33	51	38	56
2.0–3.0	13	12	14	41	56	56
>3	5	6	5	6	24	200
Total	177	181	241	252	261	1048

Table B-3 Number of industrial lots affected by different peak depths – existing case

Depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0.05–0.1	4	11	11	1	3	3
0.1–0.2	13	18	16	11	10	18
0.2–0.3	17	23	19	12	12	8
0.3–0.5	25	33	36	24	21	19
0.5–0.7	18	21	42	21	22	17
0.7–1.0	20	16	31	33	20	74

Depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
1.0–1.2	5	15	25	26	17	90
1.2–1.5	3	2	38	48	22	218
1.5–2.0	4	7	16	56	45	186
2.0–3.0	2	2	8	46	132	99
>3	2	2	2	4	24	370
Total	113	150	244	282	328	1101

Table B-4 Number of residential lots affected by different flood hazard – existing case

Hazard		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
H1	Low	159	155	154	135	149	391
H2		123	116	125	139	167	779
H3	High	187	231	249	293	324	1669
H4		53	68	110	164	298	2068
H5		33	47	54	148	221	1528
H6		1	3	4	10	26	548

Table B-5 Number of commercial lots affected by different flood hazard – existing case

Hazard		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
H1	Low	22	18	21	14	16	70
H2		29	20	27	25	21	146
H3	High	57	63	76	56	41	419
H4		34	41	78	81	75	131
H5		26	31	29	68	98	157
H6		9	8	10	8	10	125

Table B-6 Number of industrial lots affected by different flood hazard – existing case

Hazard		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
H1	Low	24	42	36	18	12	16
H2		31	34	44	19	25	17
H3	High	40	54	91	88	57	184
H4		9	11	62	99	74	407
H5		9	8	9	53	154	207
H6		0	1	2	5	6	270

Table B-7 Area of land (hectares) on rural lots affected by different flood hazard – existing case

Hazard		Grazing						Forestry						Wetland/ National Park					
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
H1	Low	1341.5	559.5	407.4	148.9	108.9	14.7	98.0	93.4	65.3	20.4	4.2	0.1	614.7	302.7	229.5	141.7	136.8	120.5
H2		829.4	478.7	316.9	128.4	104.5	26.4	55.5	69.0	75.5	31.6	9.2	0.5	1055.3	496.0	335.4	120.0	107.1	136.2
H3	High	1375.6	1939.4	1266.3	699.3	336.3	67.8	25.1	27.5	88.7	125.7	45.2	1.7	2095.7	2714.0	1888.4	516.1	252.5	283.4
H4		449.0	2318.0	2267.4	858.4	639.1	98.4	0.0	11.2	18.1	111.7	156.8	6.3	105.5	362.0	1231.1	894.0	567.0	187.5
H5		112.4	935.8	2226.4	4910.7	4922.9	502.7	0.0	0.0	0.0	17.4	118.4	31.9	14.2	169.1	426.6	2566.9	3053.0	308.6
H6		0.7	1.9	5.5	95.9	887.6	6782.0	0.0	0.0	0.0	0.0	0.0	322.3	0.0	1.1	2.8	9.1	230.5	4006.4

Table B-8 Number of residential lots affected by different durations of inundation above 0.5 metres depth – existing case

Duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0–3	59	71	77	72	64	125
3–6	13	11	8	12	15	138
6–12	18	26	26	32	44	224
12–18	7	14	21	34	75	337
18–24	20	18	25	34	84	305
24–36	25	37	52	94	151	505
36–48	14	32	47	61	95	404
48–72	32	43	75	156	207	1091
72–96	118	131	131	155	165	1278
>96	9	7	7	6	6	1801

Table B-9 Number of commercial lots affected by different durations of inundation above 0.5 metres depth – existing case

Duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0–3	9	11	17	23	30	143
3–6	3	3	2	4	1	98
6–12	5	7	6	3	2	58
12–18	0	2	8	6	7	43
18–24	4	5	6	9	7	27
24–36	10	13	12	19	25	44
36–48	7	9	18	13	12	21
48–72	9	13	58	67	66	73
72–96	81	77	73	73	75	93
>96	5	5	5	5	5	296

Table B-10 Number of industrial lots affected by different durations of inundation above 0.5 metres depth – existing case

Duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0–3	1	5	3	3	0	4
3–6	1	0	1	6	1	7
6–12	12	4	5	5	8	39
12–18	3	7	21	5	5	36
18–24	4	5	5	13	5	33
24–36	2	7	15	33	27	79
36–48	1	5	13	30	35	56
48–72	9	7	74	119	163	179
72–96	33	36	37	37	49	157
>96	7	6	6	6	6	482

Table B-11 Area of land (hectares) on rural lots affected by different durations of inundation above 0.5 metres depth – existing case

Duration of inundation (hours)	Grazing						Forestry						Wetland/National Park					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
0–3	43.3	22.3	18.5	10.3	12.3	0.9	0.5	0.4	0.8	0.9	0.1	0.0	181.3	64.0	36.7	28.4	10.0	12.4
3–6	40.3	41.4	24.8	17.4	17.9	1.2	1.3	1.7	2.5	3.0	0.4	0.0	169.4	186.1	58.1	36.5	18.5	19.7
6–12	63.7	72.8	46.3	45.1	27.1	3.6	2.9	3.2	11.2	13.5	3.6	0.1	103.3	156.8	74.2	31.4	33.3	35.2
12–18	73.2	95.6	63.1	59.5	43.8	4.3	3.1	3.3	15.6	19.8	9.9	0.1	65.4	90.8	82.9	35.1	48.7	20.5
18–24	84.5	138.3	95.9	91.0	60.9	4.0	2.2	3.0	18.2	28.0	19.1	0.1	59.3	88.6	115.9	48.4	47.3	16.0
24–36	265.5	456.2	303.4	285.3	191.2	8.6	4.3	5.4	26.9	68.2	48.2	0.2	205.9	161.0	288.9	145.8	94.7	32.8
36–48	275.4	609.8	629.0	315.0	335.5	12.8	6.5	4.6	9.6	60.1	73.6	0.2	364.9	283.3	309.1	254.1	128.5	48.4
48–72	714.2	2772.6	3304.7	3037.4	2068.6	63.6	4.2	12.4	12.5	41.3	136.0	1.9	695.7	1371.9	1157.3	1392.1	1330.9	123.5
72–96	397.6	992.4	1278.1	2696.1	4023.4	112.3	3.8	8.5	14.1	20.7	29.7	9.2	393.2	853.8	1433.6	2019.9	2397.8	164.5
>96	0.0	0.0	0.0	0.0	0.0	31.8	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	31.9

Property and land use flooding analysis and impacts – Construction phase

Table B-12 Number of residential lots affected by change in peak flood depth – construction case

Change in peak flood depth (m)	20% AEP	10% AEP	5% AEP
Was wet now dry	0	0	0
< -0.01	5	2	3
-0.01–0.01	520	533	465
0.01–0.05	30	59	130
0.05–0.1	0	26	97
0.1–0.2	0	0	0
0.2–0.3	0	0	0
> 0.3	2	2	2
Was dry now wet	8	7	7

Table B-13 Number of commercial lots affected by different change in peak flood depth – construction case

Change in peak flood depth (m)	20% AEP	10% AEP	5% AEP
Was wet now dry	0	0	0
< -0.01	0	0	0
-0.01–0.01	176	178	172
0.01–0.05	1	3	69
0.05–0.1	0	0	0
0.1–0.2	0	0	0
0.2–0.3	0	0	0
>0.3	0	0	0
Was dry now wet	0	0	0

Table B-14 Number of industrial lots affected by different change in peak flood depth – construction case

Change in peak flood depth (m)	20% AEP	10% AEP	5% AEP
Was wet now dry	2	3	5
< -0.01	0	5	64
-0.01–0.01	109	140	85
0.01–0.05	1	1	81
0.05–0.1	0	0	7
0.1–0.2	1	1	1
0.2–0.3	0	0	2
>0.3	0	0	0
Was dry now wet	0	0	0

Table B-15 Number of residential lots affected by different changes in flood hazard condition – construction case

Change in flood hazard	20% AEP	10% AEP	5% AEP
Was dry, now high	1	1	1
Was low, now high	3	5	15
Was dry, now low	7	9	6
No change	551	615	680
Was low, now dry	0	0	0
Was high, now low	3	2	2
Was high, now dry	0	0	0

Table B-16 Number of commercial lots affected by different changes in flood hazard condition – construction case

Change in flood hazard	20% AEP	10% AEP	5% AEP
Was dry, now high	0	0	0
Was low, now high	0	0	0
Was dry, now low	0	0	0
No change	177	181	240
Was low, now dry	0	0	0
Was high, now low	0	0	1
Was high, now dry	0	0	0

Table B-17 Number of industrial lots affected by different changes in flood hazard condition – construction case

Change in flood hazard	20% AEP	10% AEP	5% AEP
Was dry, now high	0	0	0
Was low, now high	0	0	2
Was dry, now low	0	0	0
No change	111	146	237
Was low, now dry	2	3	5
Was high, now low	0	1	1
Was high, now dry	0	0	0

Table B-18 Area (hectares) on main rural land uses affected by different changes in flood hazard condition – construction case

Change in flood hazard	Grazing			Forestry			Wetland/ National Park		
	20% AEP	10% AEP	5% AEP	20% AEP	10% AEP	5% AEP	20% AEP	10% AEP	5% AEP
Was dry, now high	0.6	0.4	0.5	0.0	0.1	0.0	0.0	0.0	0.2
Was low, now high	34.8	38.1	35.3	2.3	3.5	9.5	1.4	6.9	5.9
Was dry, now low	23.8	9.2	14.3	3.4	4.4	4.7	1.3	0.5	3.0
No change	7714.1	7711.9	7703.0	349.0	346.3	335.8	5504.9	5495.4	5492.6
Was low, now dry	37.7	13.8	15.1	8.0	8.0	6.8	2.0	1.7	1.0
Was high, now low	1.1	20.8	23.1	0.4	0.3	2.8	1.6	5.1	6.2
Was high, now dry	0.9	18.8	21.6	0.8	1.3	4.3	1.2	2.8	3.6

Table B-19 Number of residential lots affected by change in peak durations of inundation above 0.5 metres depth – construction case

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP
<-96	0	0	0
-96 – -72	0	0	0
-72 – -48	0	0	0
-48 – -36	0	0	0
-36 – -24	0	0	1
-24 – -18	0	0	0
-18 – -12	0	0	0
-12 – -6	0	0	1
-6 – -3	0	0	0
-3–0	40	52	62
0–3	274	329	395
3–6	1	6	7
6–12	0	3	1
12–18	0	0	1
18–24	0	0	0
24–36	0	0	0
36–48	0	0	0
48–72	0	0	0
72–96	0	0	1
>96	0	0	0

Table B-20 Number of commercial lots affected by change in peak durations of inundation above 0.5 metres depth – construction case

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP
<-96	0	0	0
-96 – -72	0	0	0
-72 – -48	0	0	0
-48 – -36	0	0	0
-36 – -24	0	0	0
-24 – -18	0	0	0
-18 – -12	0	0	0
-12 – -6	0	0	0
-6 – -3	0	0	1
-3 – 0	13	31	29
0–3	120	114	174
3–6	0	0	1
6–12	0	0	0

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP
12–18	0	0	0
18–24	0	0	0
24–36	0	0	0
36–48	0	0	0
48–72	0	0	0
72–96	0	0	0
>96	0	0	0

Table B-21 Number of industrial lots affected by change in peak durations of inundation above 0.5 metres depth – construction case

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP
<-96	0	0	0
-96 – -72	0	0	0
-72 – -48	0	0	0
-48 – -36	0	0	1
-36 – -24	0	0	0
-24 – -18	0	0	0
-18 – -12	0	0	0
-12 – -6	0	0	2
-6 – -3	0	0	10
-3–0	17	26	36
0–3	56	55	127
3–6	0	0	0
6–12	0	0	1
12–18	0	0	0
18–24	0	0	0
24–36	0	0	0
36–48	0	0	0
48–72	0	0	1
72–96	0	0	0
>96	0	0	0

Table B-22 Change in the area of land (hectares) on rural lots affected by different durations of inundation above 0.5 metres depth – construction case

Duration of inundation (hours)	Grazing			Forestry			Wetland/ National Park		
	20% AEP	10% AEP	5% AEP	20% AEP	10% AEP	5% AEP	20% AEP	10% AEP	5% AEP
<-96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-96 – -72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-72 – -48	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0
-48 – -36	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0
-36 – -24	0.0	0.8	2.1	0.0	0.0	0.1	0.0	0.0	0.5
-24 – -18	0.2	0.4	1.7	0.0	0.1	0.0	0.0	0.0	0.8
-18 – -12	0.4	0.3	1.2	0.0	0.2	0.1	0.1	0.1	1.0
-12 – -6	1.7	2.4	2.9	0.1	0.2	0.2	0.3	1.4	2.1
-6 – -3	4.7	4.6	7.6	0.2	0.3	0.9	1.2	2.4	3.3
-3–0	726.2	765.3	937.1	11.0	8.7	10.5	1472.9	2262.3	2433.1
0–3	1063.9	4378.9	4708.0	15.4	30.4	94.3	755.6	980.0	1096.5
3–6	59.2	18.7	54.3	1.0	1.0	1.5	3.9	7.7	9.3
6–12	86.9	7.7	17.8	0.1	0.3	0.8	1.3	1.1	6.0
12–18	11.7	1.7	3.0	0.0	0.0	0.4	0.3	0.0	0.5
18–24	0.5	0.5	0.9	0.0	0.1	0.3	0.1	0.0	0.1
24–36	0.2	0.5	1.0	0.0	0.0	0.2	0.0	0.1	0.1
36–48	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.1	0.0
48–72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72–96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B-23 Lots with afflux criteria exceeded – construction case

Lot Number	Plan Number	Plan Label	Zoning	Zoning Code	AEP events where afflux exceeded
32	1014864	DP1014864	General Industrial	IN1	5%
1200	1174968	DP1174968	General Industrial	IN1	20% 10%
100	849413	DP849413	Low Density Residential	R2	20% 10% 5%
1	1181217	DP1181217	Low Density Residential	R2	20% 10% 5%
100	1044020	DP1044020	Environmental Conservation	E2	20% 10% 5%
1015	1193555	DP1193555	Infrastructure	SP2	20% 10% 5%
1014	1193539	DP1193539	Infrastructure	SP2	10%

Lot Number	Plan Number	Plan Label	Zoning	Zoning Code	AEP events where afflux exceeded
6	842856	DP842856	Low Density Residential	R2	20% 10% 5%
1	225218	DP225218	Infrastructure	SP2	20% 5%
906	1256183	DP1256183	Infrastructure	SP2	20% 10% 5%
102	1038663	DP1038663	Infrastructure	SP2	20% 10% 5%
12	863342	DP863342	Primary Production	RU1	20%
191	997845	DP997845	Primary Production	RU1	20%
14	232594	DP232594	Primary Production	RU1	20%
13	232594	DP232594	Primary Production	RU1	20%
1	1073784	DP1073784	Primary Production	RU1	20%
2	1074258	DP1074258	Primary Production	RU1	20%
19	4297	DP4297	Primary Production	RU1	20%
2	1098770	DP1098770	Infrastructure	SP2	5%

Table B-24 Buildings with afflux criteria exceeded – construction case

Lot Number	Plan Number	Plan Label	Zoning	Zoning Code
12	1189457	DP1189457	Primary Production	RU1
100	1044020	DP1044020	Environmental Conservation	E2
270	605404	DP605404	Environmental Conservation	E2
1	199286	DP199286	Environmental Management	E3
12	740160	DP740160	General Residential	R1

Property and land use flooding analysis and impacts – Operation phase

Table B-25 Number of residential lots affected by change in peak flood depth – operational case

Change in peak flood depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was wet now dry	0	0	0	0	0	4
< - -0.01	2	2	3	4	36	1478
-0.01–0.01	549	574	510	663	769	2317
0.01–0.05	4	42	182	194	379	215
0.05–0.1	1	3	2	29	1	2972
0.1–0.2	1	0	0	1	3	17
0.2–0.3	0	0	0	1	0	11
> 0.3	0	0	0	0	1	25
Was dry now wet	7	6	6	7	14	43

Table B-26 Number of commercial lots affected by different change in peak flood depth – operational case

Change in peak flood depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was wet now dry	0	0	0	0	0	0
< -0.01	0	0	0	0	0	169
-0.01–0.01	177	181	200	178	180	756
0.01–0.05	0	0	41	74	81	1
0.05–0.1	0	0	0	0	0	122
0.1–0.2	0	0	0	0	0	0
0.2–0.3	0	0	0	0	0	0
>0.3	0	0	0	0	0	0
Was dry now wet	0	0	0	0	0	0

Table B-27 Number of industrial lots affected by different change in peak flood depth – operational case

Change in peak flood depth (m)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was wet now dry	2	3	4	4	5	0
< -0.01	0	1	11	0	10	272
-0.01–0.01	111	146	174	190	195	541
0.01–0.05	0	0	55	88	118	15
0.05–0.1	0	0	0	0	0	261
0.1–0.2	0	0	0	0	0	16
0.2–0.3	0	0	0	0	0	0
>0.3	0	0	0	0	0	0
Was dry now wet	0	0	0	0	3	1

Table B-28 Number of residential lots affected by different changes in flood hazard condition – operational case

Change in flood hazard	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was dry, now high	0	0	0	1	1	0
Was low, now high	0	2	8	7	7	108
Was dry, now low	7	6	6	6	13	43
No change	555	617	687	883	1179	6889
Was low, now dry	0	0	0	0	0	4
Was high, now low	2	2	2	2	3	38
Was high, now dry	0	0	0	0	0	0

Table B-29 Number of commercial lots affected by different changes in flood hazard condition – operational case

Change in flood hazard	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was dry, now high	0	0	0	0	0	0
Was low, now high	0	0	0	0	0	0
Was dry, now low	0	0	0	0	0	0
No change	177	181	240	252	261	1048
Was low, now dry	0	0	0	0	0	0
Was high, now low	0	0	1	0	0	0
Was high, now dry	0	0	0	0	0	0

Table B-30 Number of industrial lots affected by different changes in flood hazard condition – operational case

Change in flood hazard	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was dry, now high	0	0	0	0	0	0
Was low, now high	0	0	0	1	0	1
Was dry, now low	0	0	0	0	3	1
No change	111	147	239	277	323	1104
Was low, now dry	2	3	4	1	2	0
Was high, now low	0	0	1	0	0	0
Was high, now dry	0	0	0	3	3	0

Table B-31 Area (hectares) on main rural land uses affected by different changes in flood hazard condition – operational case

Change in flood hazard	Grazing						Forestry						Wetland/ National Park					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
Was dry, now high	0.4	0.1	0.2	0.2	0.3	0.6	0.1	0.6	0.6	0.2	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Was low, now high	29.8	20.4	14.7	2.6	1.9	4.6	1.1	2.3	4.1	1.9	0.8	0.4	1.2	2.9	2.5	0.7	1.0	32.0
Was dry, now low	17.9	4.4	6.6	2.3	2.4	4.8	0.8	0.9	2.0	1.3	0.6	0.1	0.9	0.1	1.4	0.4	1.2	17.5
No change	7737.0	7758.0	7754.7	7782.2	7785.8	7791.8	358.9	356.6	354.5	356.8	358.3	363.4	5507.3	5507.4	5504.6	5511.2	5509.5	5462.2
Was low, now dry	25.7	12.7	11.3	4.0	3.5	1.7	2.5	2.3	0.7	0.7	0.4	0.0	0.3	0.4	0.4	0.0	0.3	0.0
Was high, now low	1.6	2.7	4.4	2.1	2.1	2.2	0.3	0.7	0.1	0.2	0.4	0.1	2.7	1.6	3.4	0.0	0.4	0.5
Was high, now dry	0.7	14.8	21.2	19.6	17.1	7.4	0.3	0.5	1.9	2.7	3.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0

Table B-32 Number of residential lots affected by change in peak duration of inundation above 0.5 metres depth – operational case

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
<-96	0	0	0	0	0	0
-96 – -72	0	0	0	0	0	0
-72 – -48	0	0	0	1	0	0
-48 – -36	0	0	0	1	0	0
-36 – -24	0	0	1	0	0	0
-24 – -18	0	0	0	0	0	0
-18 – -12	0	0	0	0	0	0
-12 – -6	0	0	0	0	1	0
-6 – -3	0	1	1	1	0	0
-3–0	54	40	54	38	180	54
0–3	260	347	413	611	722	260
3–6	1	2	0	2	1	1
6–12	0	0	0	1	1	0
12–18	0	0	0	1	1	0
18–24	0	0	0	0	0	0
24–36	0	0	0	1	1	0
36–48	0	0	0	0	0	0
48–72	0	0	0	0	0	0
72–96	0	0	0	0	0	0
>96	0	0	0	0	0	0

Table B-33 Number of commercial lots affected by change in peak durations of inundation above 0.5 metres depth – operational case

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
<-96	0	0	0	0	0	0
-96 – -72	0	0	0	0	0	0
-72 – -48	0	0	0	0	0	0
-48 – -36	0	0	0	0	0	0
-36 – -24	0	0	0	0	0	0
-24 – -18	0	0	0	0	0	0
-18 – -12	0	0	0	0	0	0
-12 – -6	0	0	0	0	0	0
-6 – -3	0	0	0	0	0	4
-3–0	12	32	21	36	29	782
0–3	121	113	184	186	201	108

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
3–6	0	0	0	0	0	0
6–12	0	0	0	0	0	2
12–18	0	0	0	0	0	0
18–24	0	0	0	0	0	0
24–36	0	0	0	0	0	0
36–48	0	0	0	0	0	0
48–72	0	0	0	0	0	0
72–96	0	0	0	0	0	0
>96	0	0	0	0	0	0

Table B-34 Number of industrial lots affected by change in peak durations of inundation above 0.5 metres depth – operational case

Change in duration of inundation (hours)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
<-96	0	0	0	0	0	0
-96 – -72	0	0	0	0	0	0
-72 – -48	0	0	0	0	0	0
-48 – -36	0	0	0	0	0	0
-36 – -24	0	0	0	0	0	0
-24 – -18	0	0	0	0	0	1
-18 – -12	0	0	0	0	0	1
-12 – -6	0	0	0	0	0	0
-6 – -3	0	0	0	0	0	4
-3–0	16	25	38	90	98	680
0–3	57	57	142	164	198	343
3–6	0	0	0	0	0	24
6–12	0	0	0	0	0	16
12–18	0	0	0	0	0	4
18–24	0	0	0	0	0	0
24–36	0	0	0	0	0	0
36–48	0	0	0	0	0	0
48–72	0	0	0	0	0	0
72–96	0	0	0	0	0	0
>96	0	0	0	0	0	0

Table B-35 Change in the area of land (hectares) on rural lots affected by different durations of inundation above 0.5 metres depth – operational case

Change in duration of inundation	Grazing						Forestry						Wetland/ National Park					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	PMF
<-96	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-96 – -72	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
-72 – -48	0.0	0.2	0.0	0.9	1.4	2.8	0.1	0.1	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
-48 – -36	0.0	0.7	0.3	1.2	2.3	2.9	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.1
-36 – -24	0.0	0.8	2.1	1.5	2.7	4.3	0.0	0.0	0.1	0.1	0.1	1.7	0.0	0.0	0.5	0.0	0.0	0.2
-24 – -18	0.2	0.4	1.7	1.4	1.3	2.6	0.0	0.1	0.0	0.1	0.2	0.9	0.0	0.0	0.8	0.0	0.0	0.4
-18 – -12	0.4	0.3	1.2	2.8	2.0	4.1	0.0	0.2	0.1	0.1	0.3	1.1	0.1	0.1	1.0	0.1	0.0	1.0
-12 – -6	1.7	2.4	2.9	4.6	5.8	9.0	0.1	0.2	0.2	0.2	0.5	1.6	0.3	1.4	2.1	0.5	0.5	3.1
-6 – -3	4.7	4.6	7.6	6.8	6.9	11.7	0.2	0.3	0.9	0.4	0.4	1.4	1.2	2.4	3.3	0.7	1.4	3.3
-3–0	726.2	765.3	937.1	1454.4	1601.3	5912.2	11.0	8.7	10.5	10.9	16.4	182.0	1472.9	2262.3	2433.1	2777.7	2790.2	3824.3
0–3	1063.9	4378.9	4708.0	5036.8	5112.6	1453.0	15.4	30.4	94.3	236.3	293.9	167.1	755.6	980.0	1096.5	1212.1	1316.6	813.0
3–6	59.2	18.7	54.3	14.8	13.6	17.6	1.0	1.0	1.5	1.4	1.9	2.4	3.9	7.7	9.3	0.3	0.3	76.9
6–12	86.9	7.7	17.8	6.7	9.1	9.4	0.1	0.3	0.8	1.3	1.6	1.2	1.3	1.1	6.0	0.0	0.2	47.0
12–18	11.7	1.7	3.0	2.3	2.1	3.2	0.0	0.0	0.4	0.8	0.7	0.3	0.3	0.0	0.5	0.1	0.0	20.5
18–24	0.5	0.5	0.9	0.9	0.3	0.7	0.0	0.1	0.3	0.4	0.4	0.0	0.1	0.0	0.1	0.1	0.0	5.1
24–36	0.2	0.5	1.0	0.4	0.4	0.3	0.0	0.0	0.2	0.3	0.5	0.0	0.0	0.1	0.1	0.0	0.0	0.3
36–48	0.0	0.1	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0
48–72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72–96	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

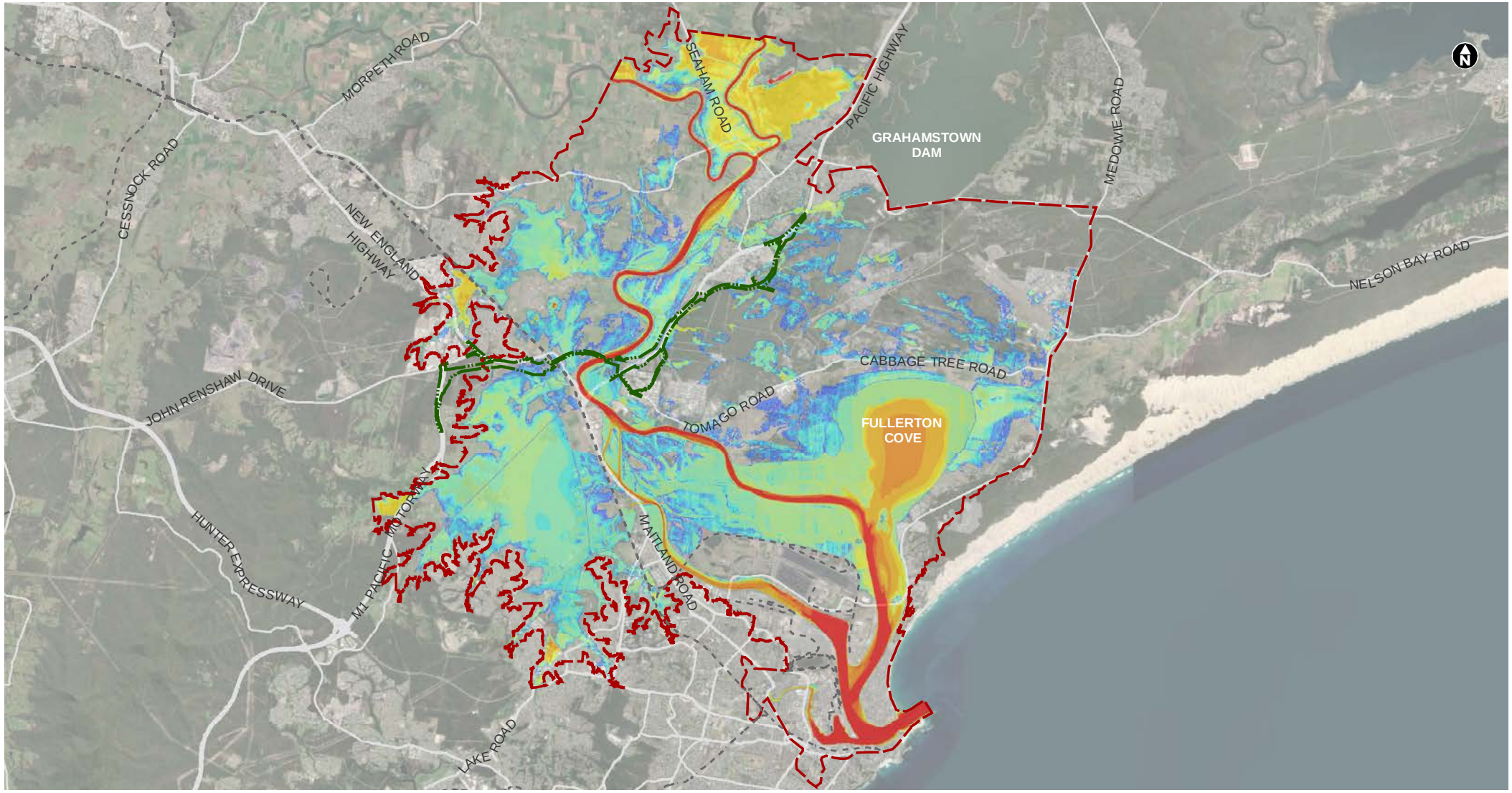
Table B-36 Lots with afflux criteria exceeded – operational case

Lot Number	Plan Number	Plan Label	Zoning	Zoning Code	AEP events where afflux exceeded
100	849413	DP849413	Low Density Residential	R2	20%, 10%, 5%
10	1150648	DP1150648	Infrastructure	SP2	10%
1015	1193555	DP1193555	Infrastructure	SP2	10%
1014	1193539	DP1193539	Infrastructure	SP2	10%
6	842856	DP842856	Low Density Residential	R2	20%, 10%, 5%
5	225218	DP225218	Infrastructure	SP2	10%
1	225218	DP225218	Infrastructure	SP2	10%
1	128309	DP128309	Infrastructure	SP2	20%
905	1256183	DP1256183	Infrastructure	SP2	20%, 10%, 5%, 2%
2	1098770	DP1098770	Infrastructure	SP2	5%

Table B-37 Buildings with afflux criteria exceeded – operational case

Lot Number	Plan Number	Plan Label	Zoning	Zoning Code
100	1044020	DP1044020	Environmental Conservation	E2

Appendix C Existing case flood mapping



Flooding study area

Operational footprint

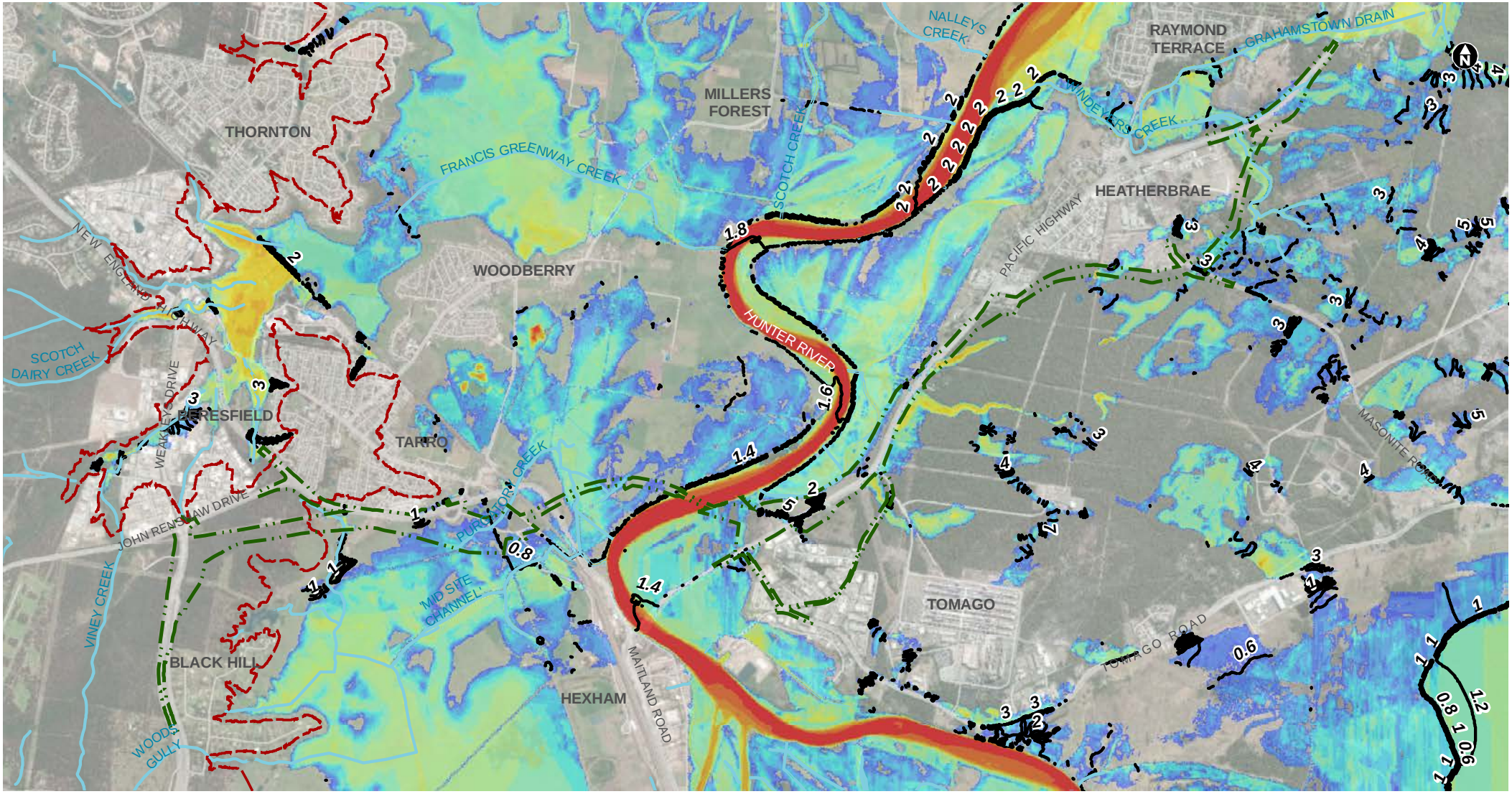
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 4 8km

Figure C-1 Flood level and depth - Existing - 20% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_001_C1_Flood_level_depth_Existing_20_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Flood level contour (0.2m AHD interval)

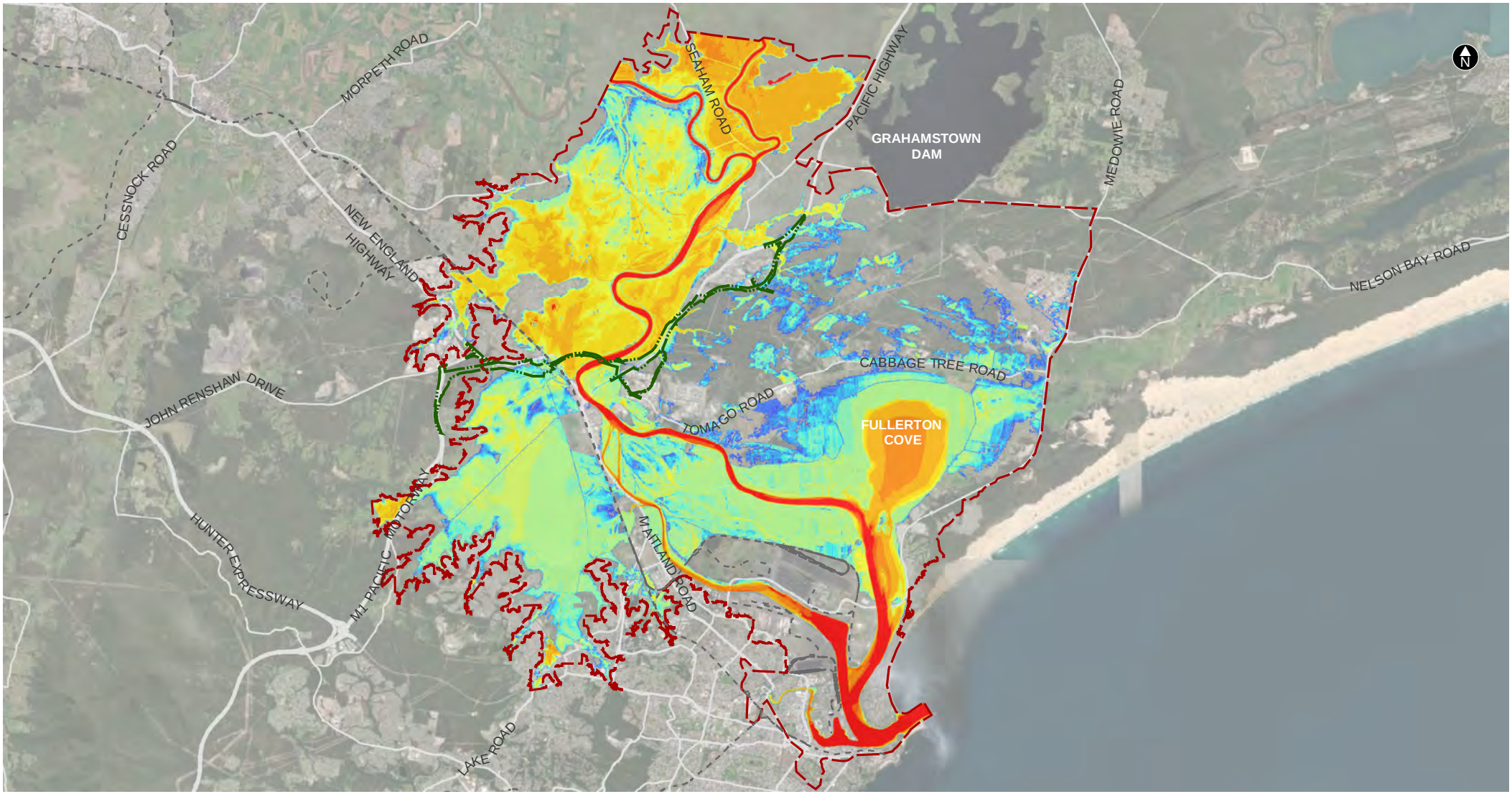
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 1 2km

Figure C-1 Flood level and depth - Existing - 20% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_001_C1_Flood_level_depth_Existing_20_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

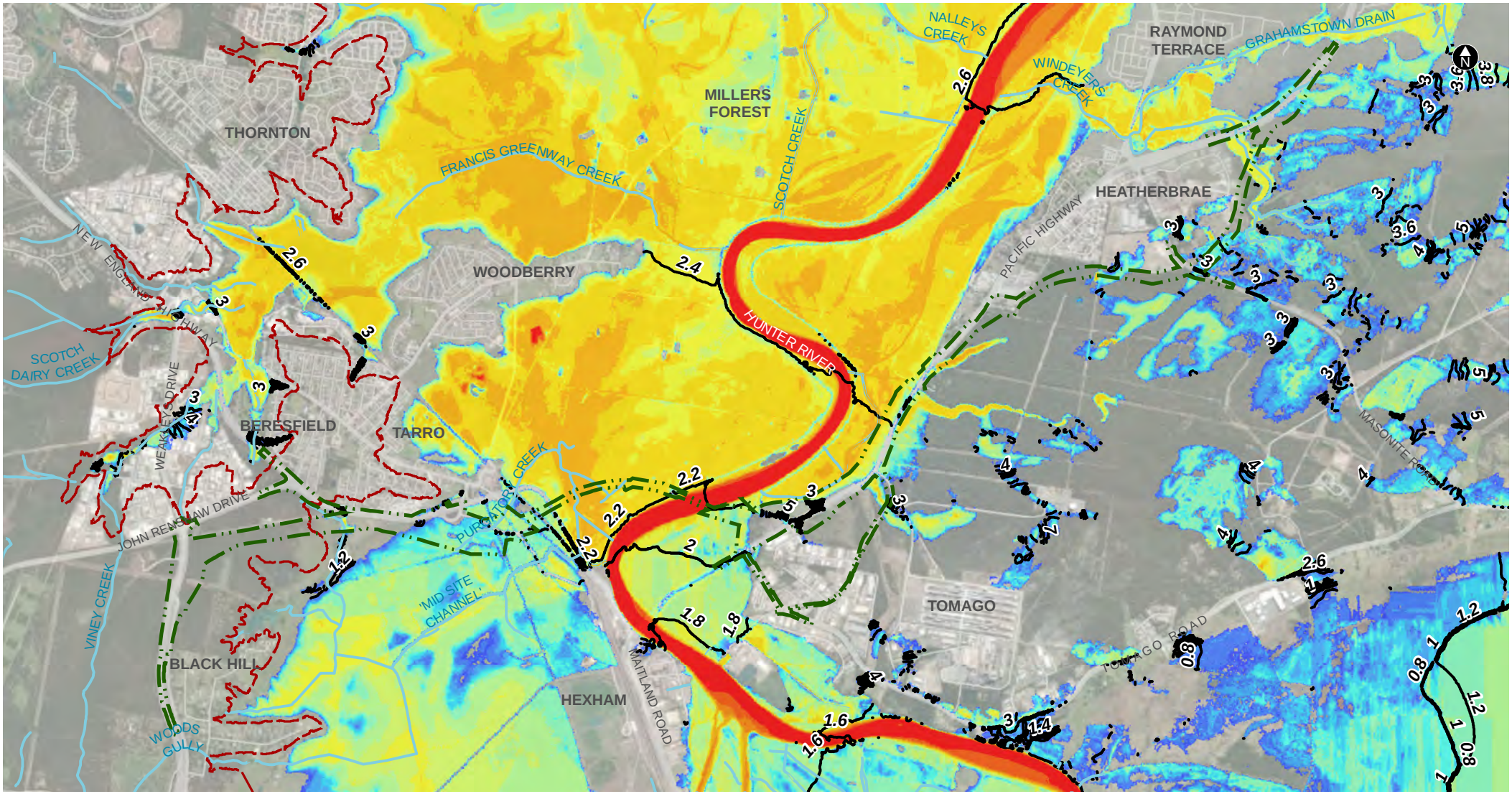
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 4 8km

Figure C-2 Flood level and depth - Existing - 10% AEP (map 1 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_002_C2_Flood_level_depth_Existing_10_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Flood level contour (0.2m AHD interval)

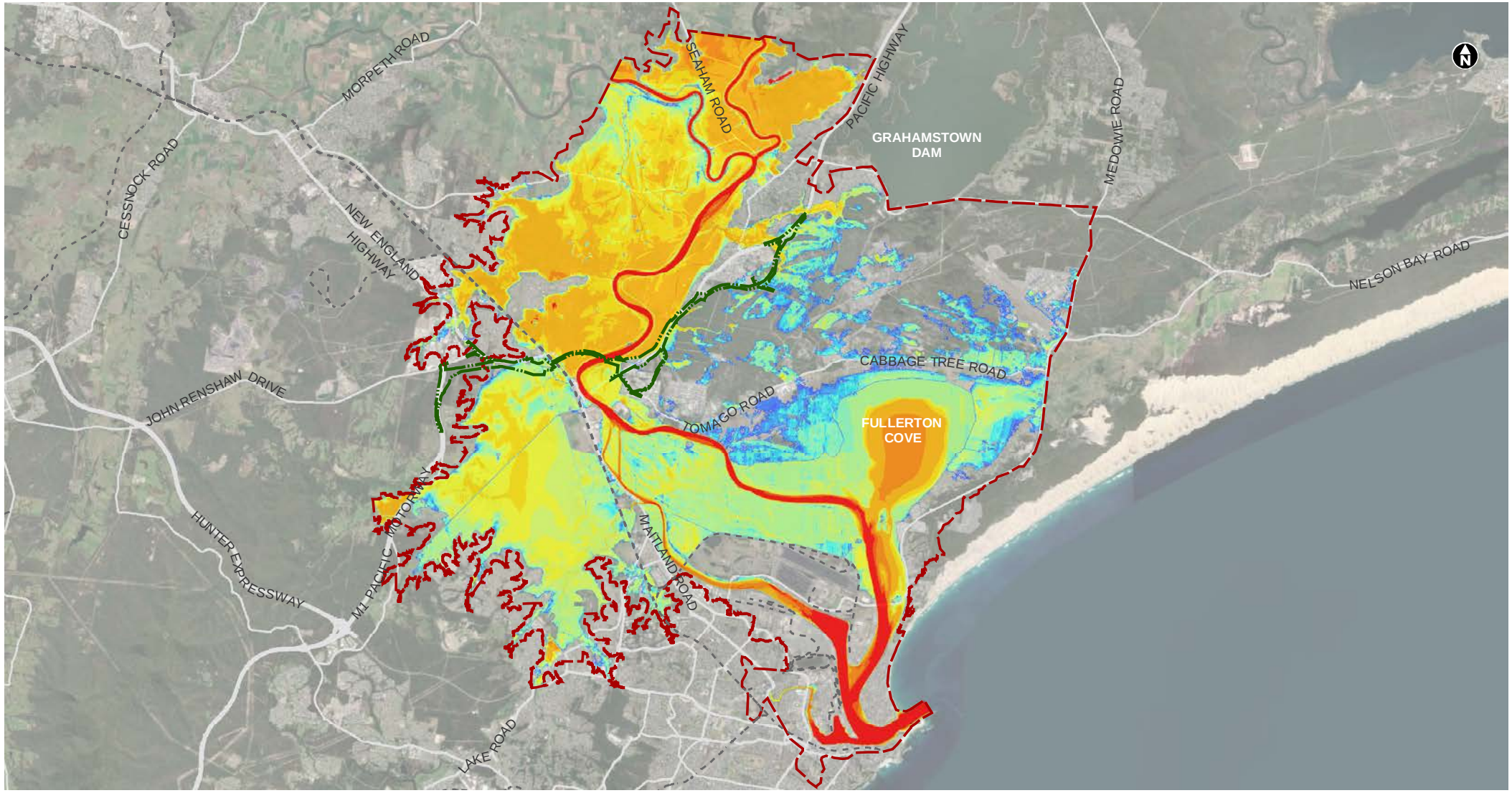
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 1 2km

Figure C-2 Flood level and depth - Existing - 10% AEP (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\A230000_CD_HF_002_C2_Flood_level_depth_Existing_10_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

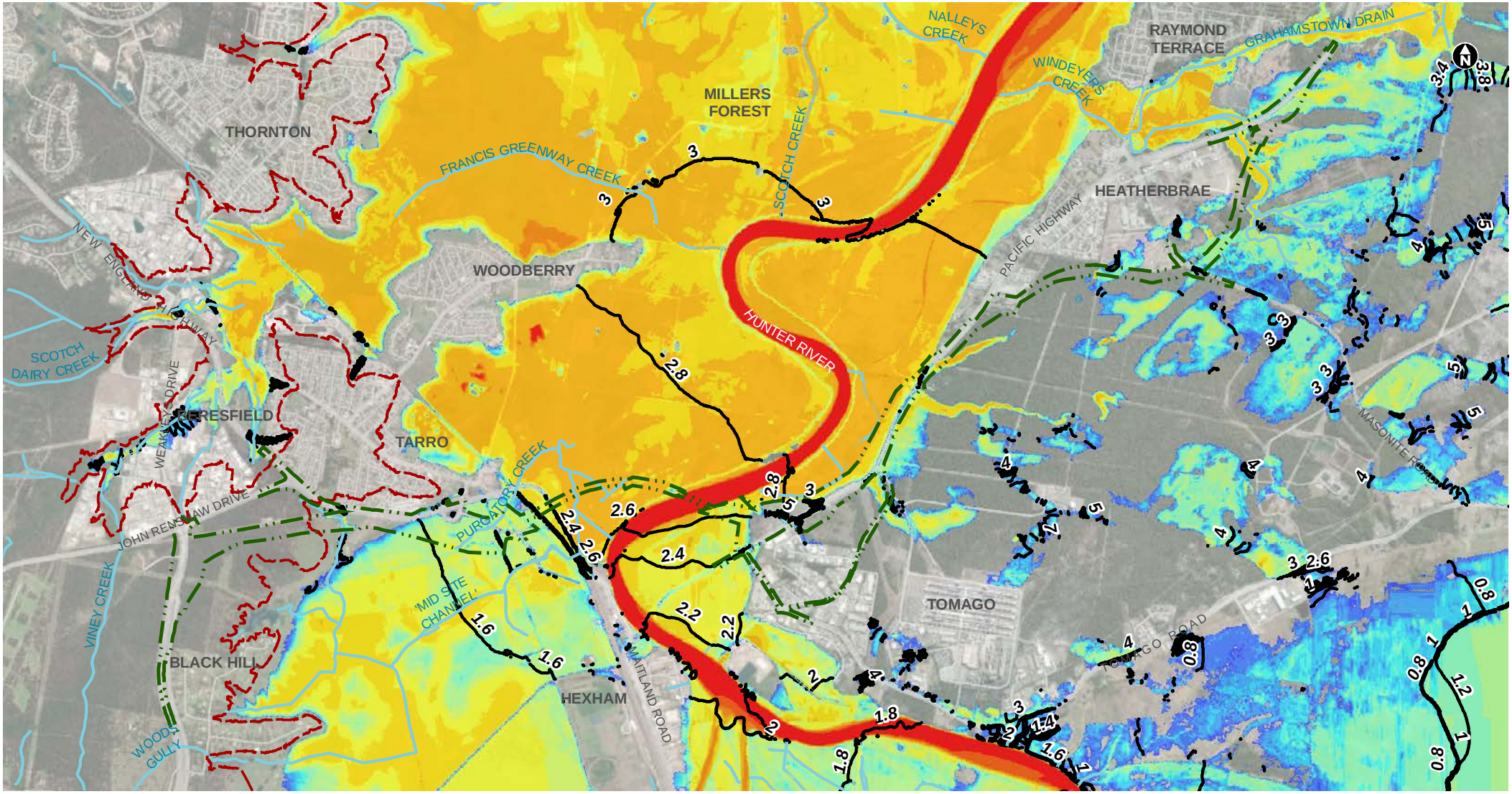
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 4 8km

Figure C-3 Flood level and depth - Existing - 5% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_003_C3_Flood_level_depth_Existing_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood level contour (0.2m AHD

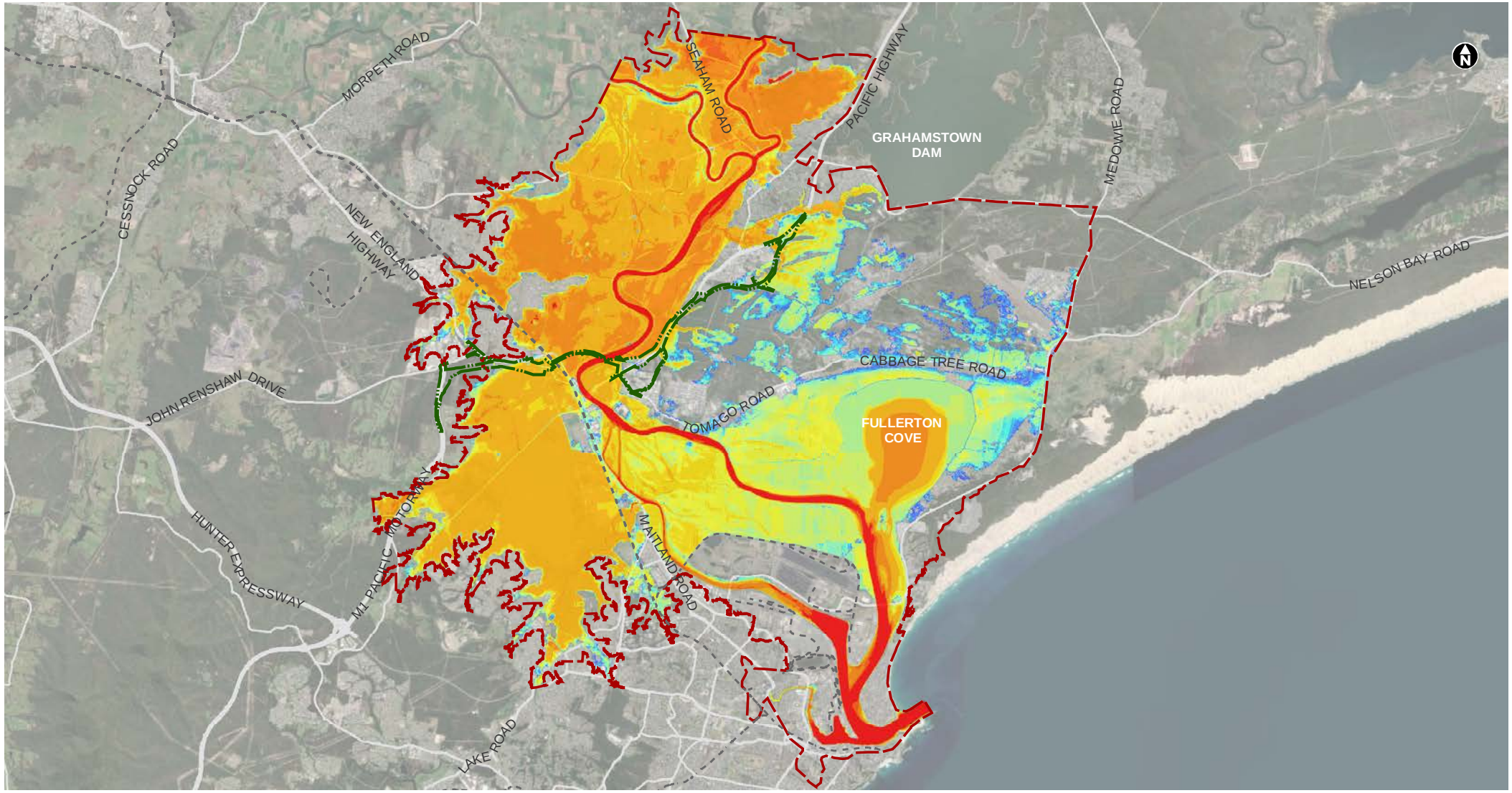
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 1 2km

Figure C-3 Flood level and depth - Existing - 5% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_003_C3_Flood_level_depth_Existing_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

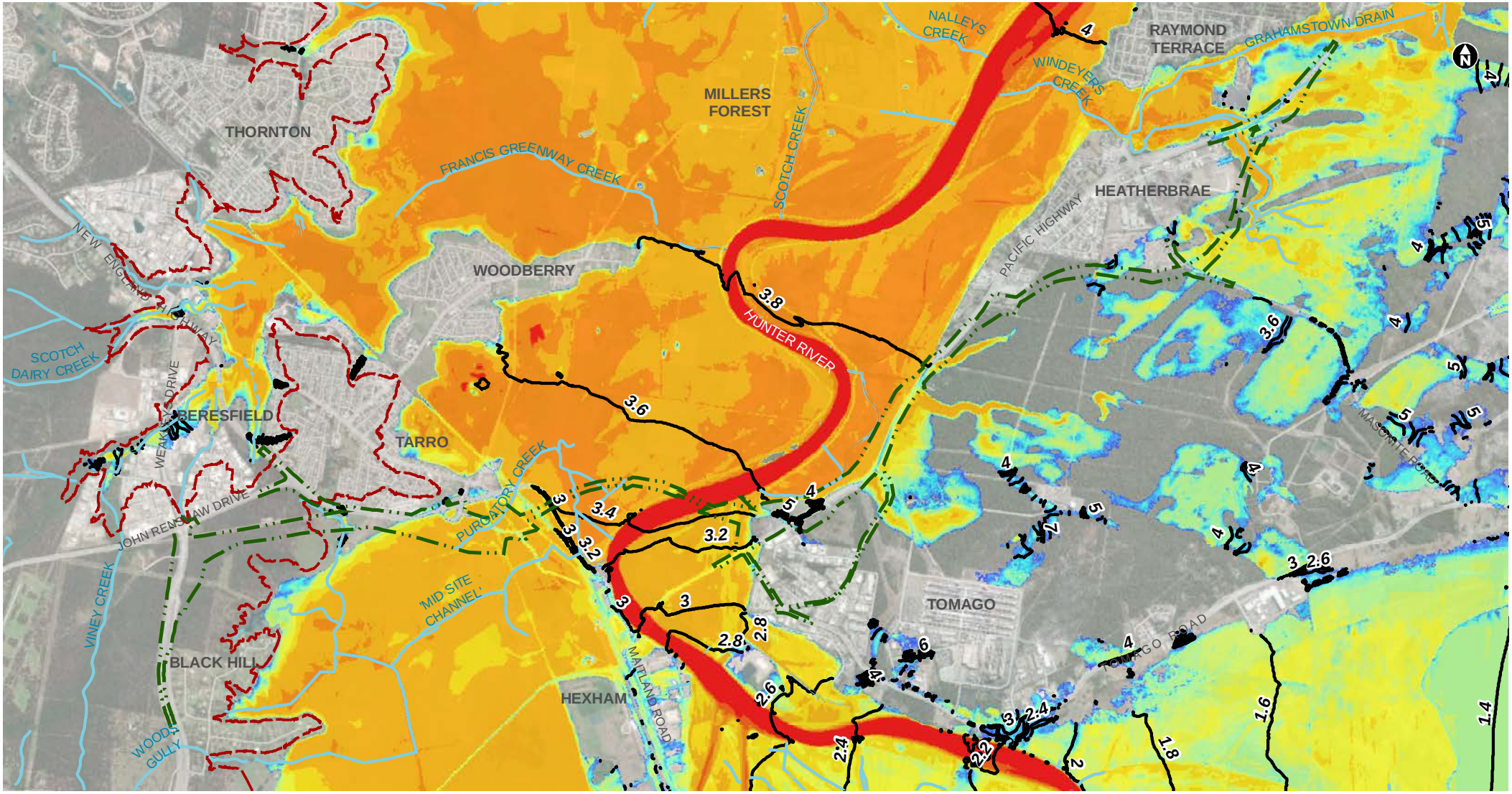
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 4 8km

Figure C-4 Flood level and depth - Existing - 2% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_004_C4_Flood_level_depth_Existing_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood level contour (0.2m AHD

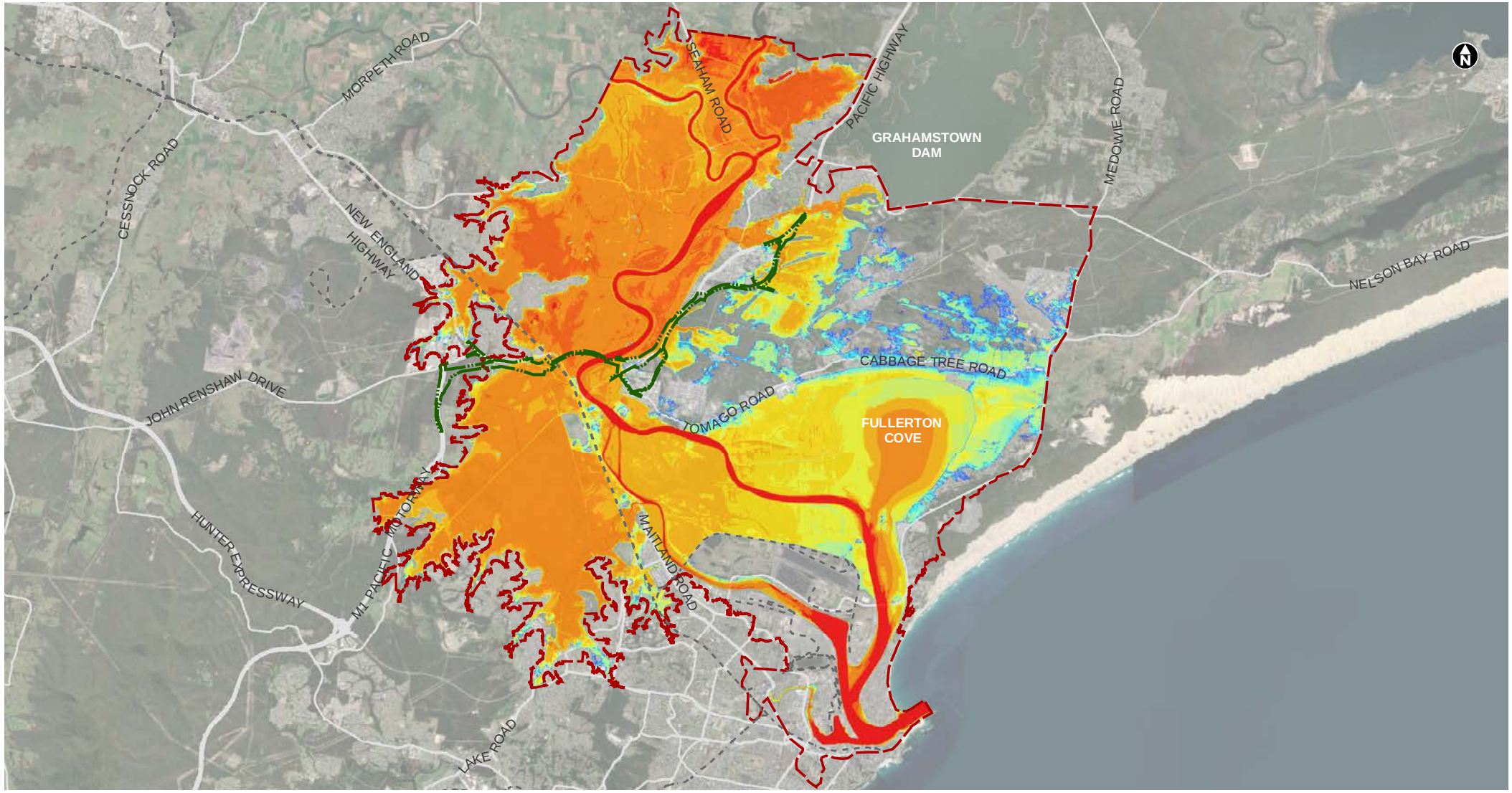
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 1 2km

Figure C-4 Flood level and depth - Existing - 2% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_004_C4_Flood_level_depth_Existing_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

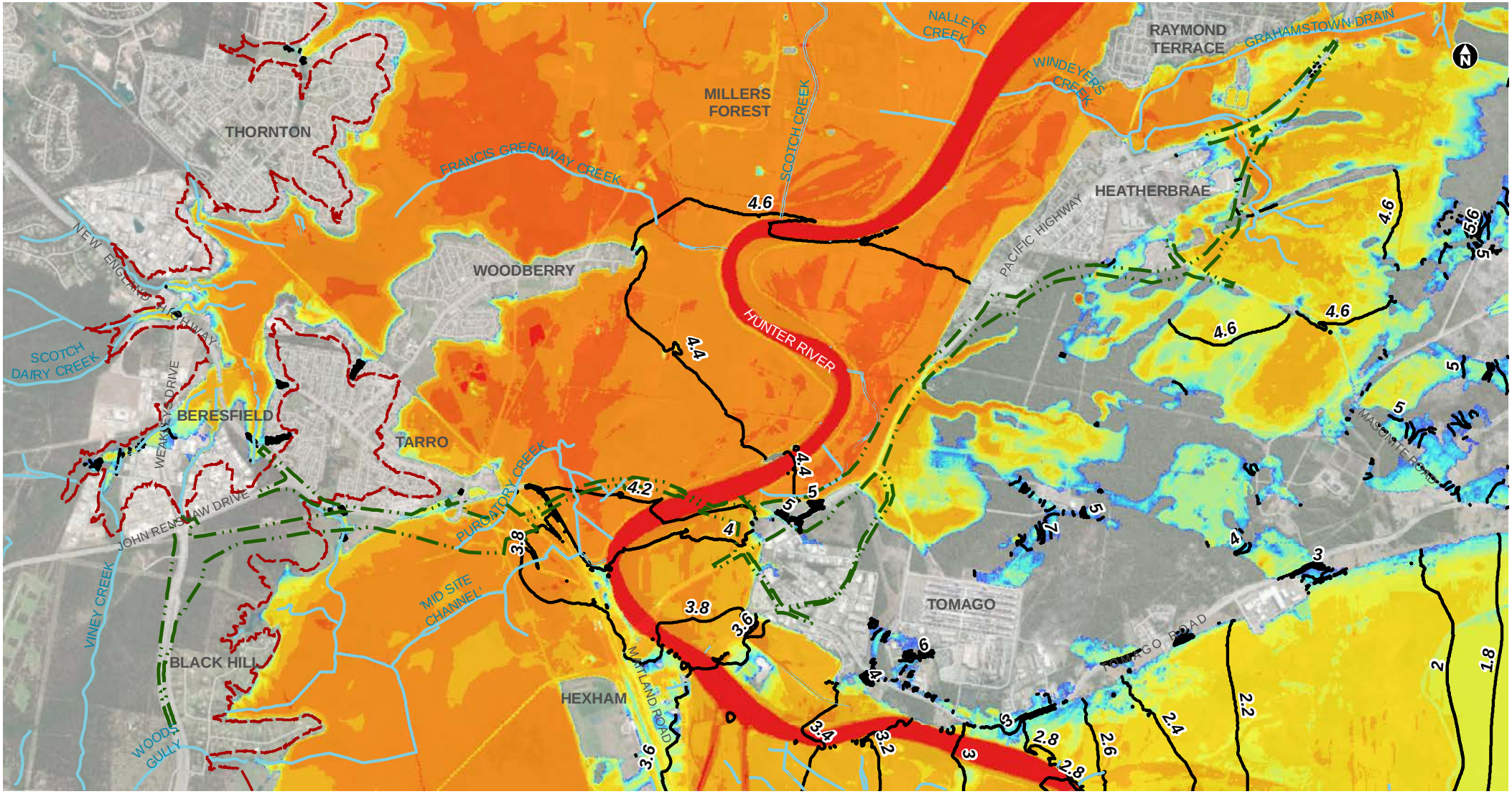
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 4 8km

Figure C-5 Flood level and depth - Existing - 1% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_005_C5_Flood_level_depth_Existing_1_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood level contour (0.2m AHD

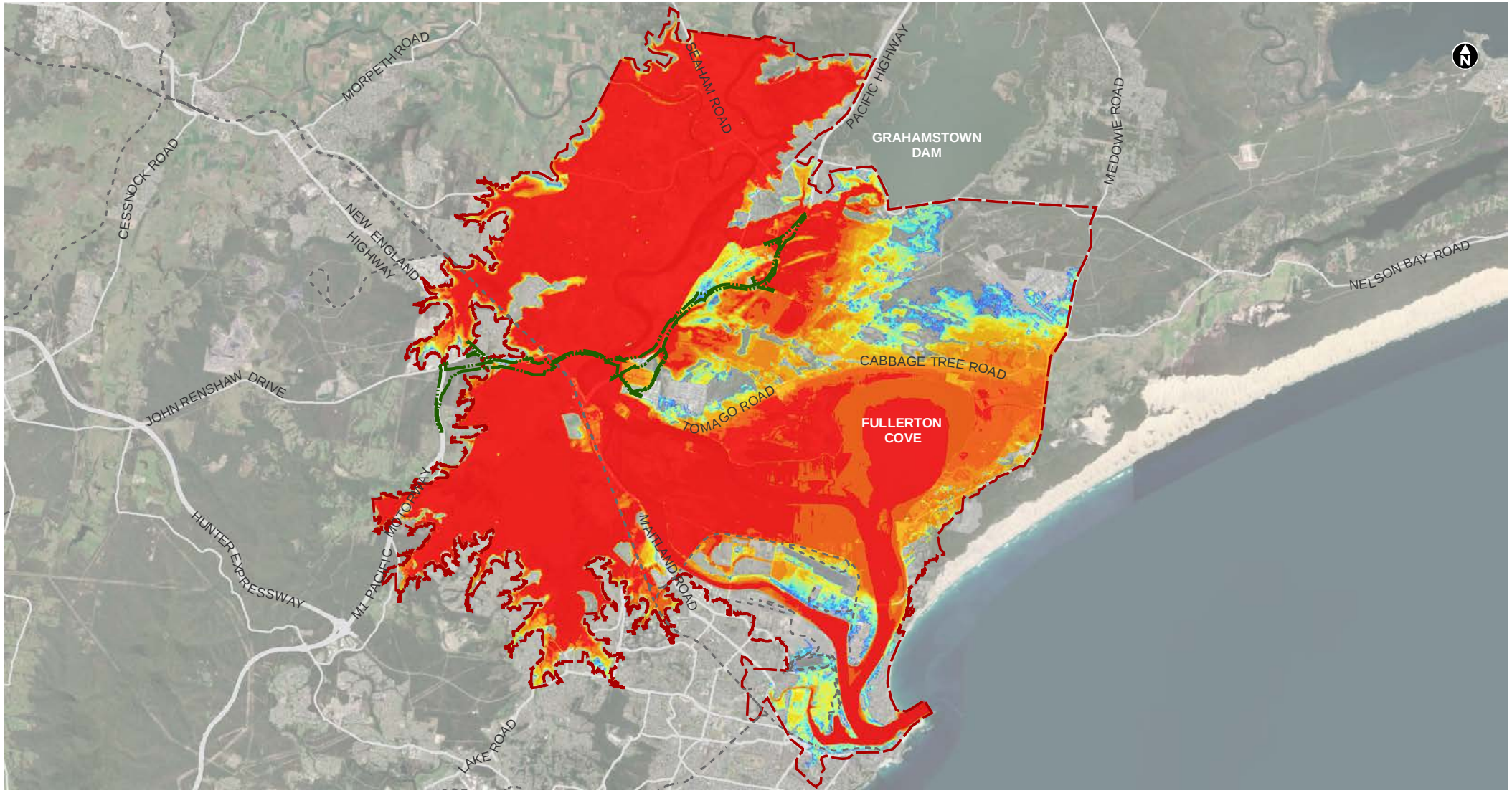
Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 1 2km

Figure C-5 Flood level and depth - Existing - 1% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_005_C5_Flood_level_depth_Existing_1_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood depth (m)

< 0.05	0.4 to 0.5	2.0 to 3.0
0.05 to 0.1	0.5 to 0.7	3.0 to 4.0
0.1 to 0.2	0.7 to 1.0	4.0 to 5.0
0.2 to 0.3	1.0 to 1.2	> 5.0
0.3 to 0.4	1.2 to 1.5	
	1.5 to 2.0	

0 4 8km

Figure C-6 Flood level and depth - Existing - Probable maximum flood (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_006_C6_Flood_level_depth_Existing_ProbMax_JAC_A4L_175000_V01.mxd

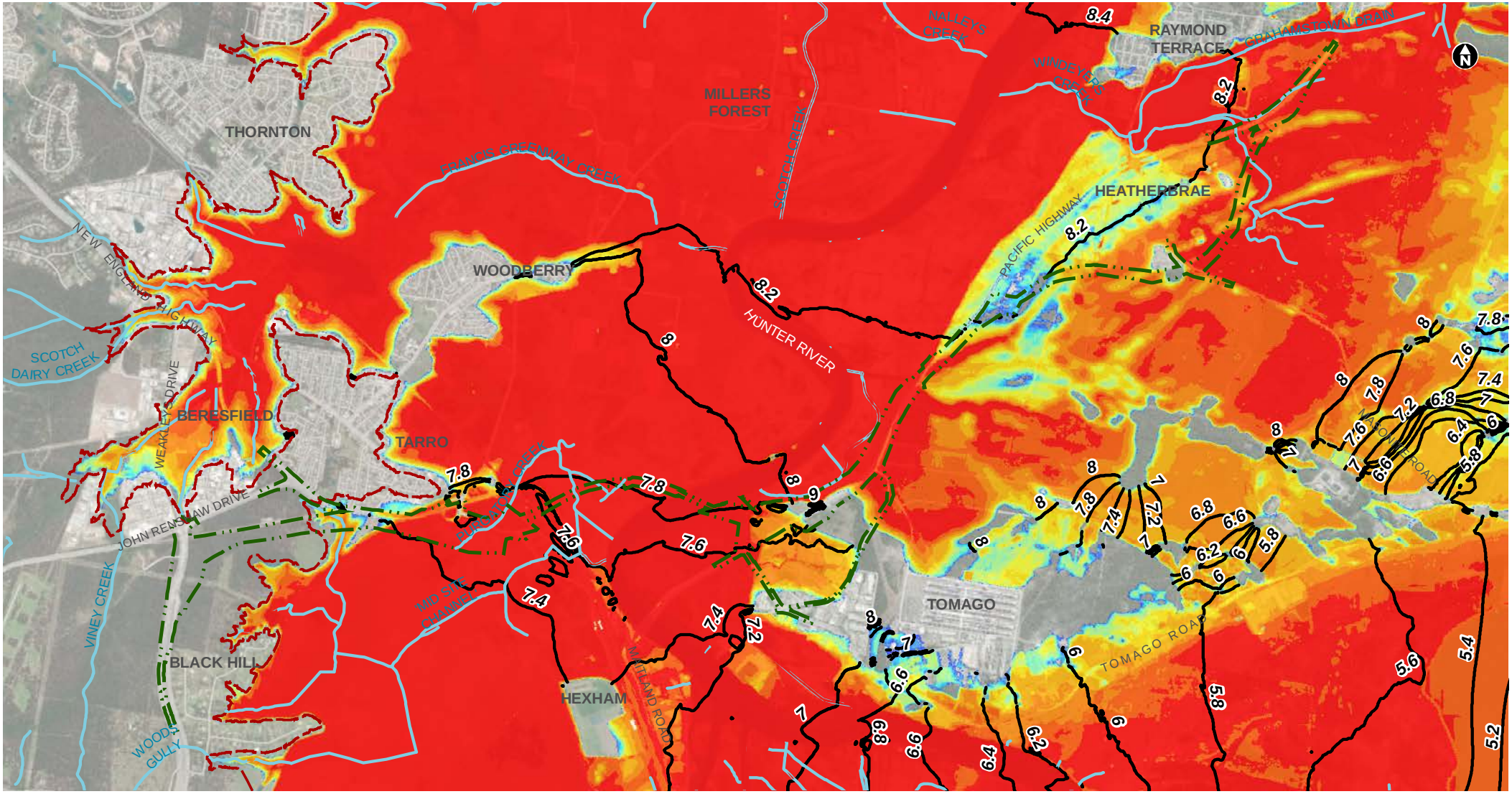
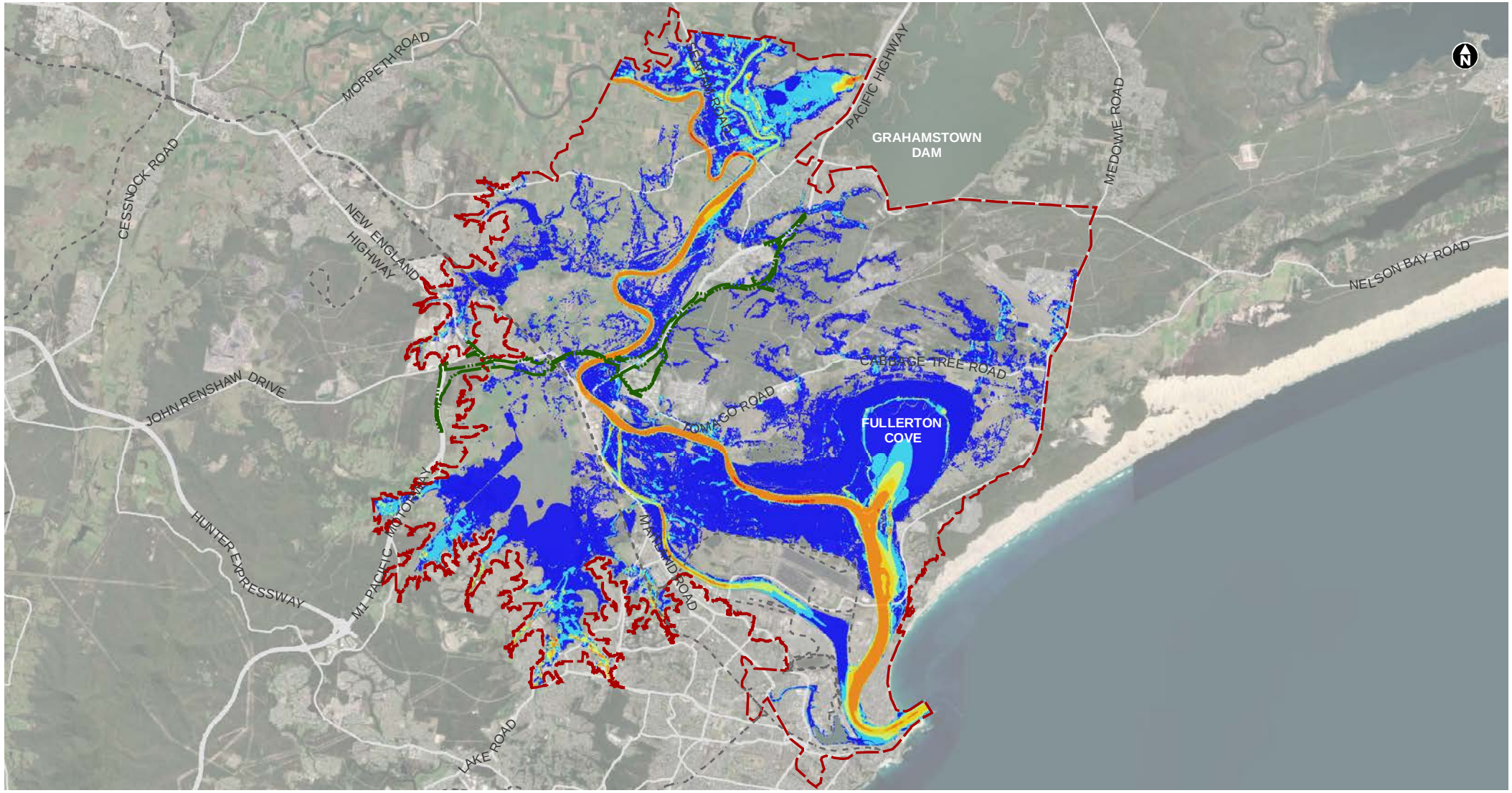


Figure C-6 Flood level and depth - Existing - Probable maximum flood (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_006_C6_Flood_level_depth_Existing_ProbMax_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flow velocity (m/s)

< 0.05	0.75 to 1.0
0.05 to 0.25	1.0 to 2.0
0.25 to 0.5	2.0 to 3.0
0.5 to 0.75	> 3.0

0 4 8km

Figure C-7 Flow velocity - Existing - 20% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_007_C7_Flow_Velocity_Existing_20_AEP_JAC_A4L_175000_V01.mxd

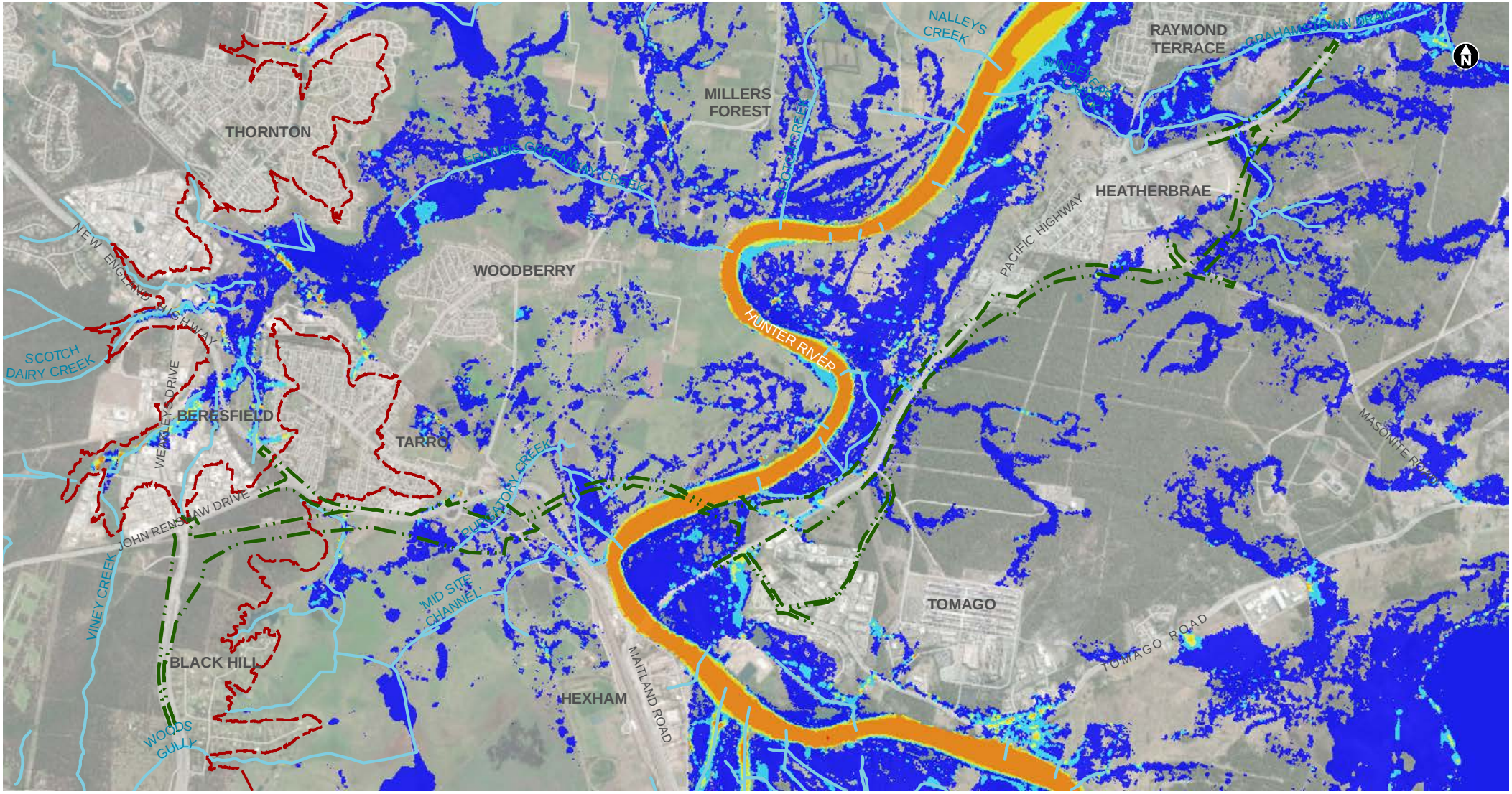
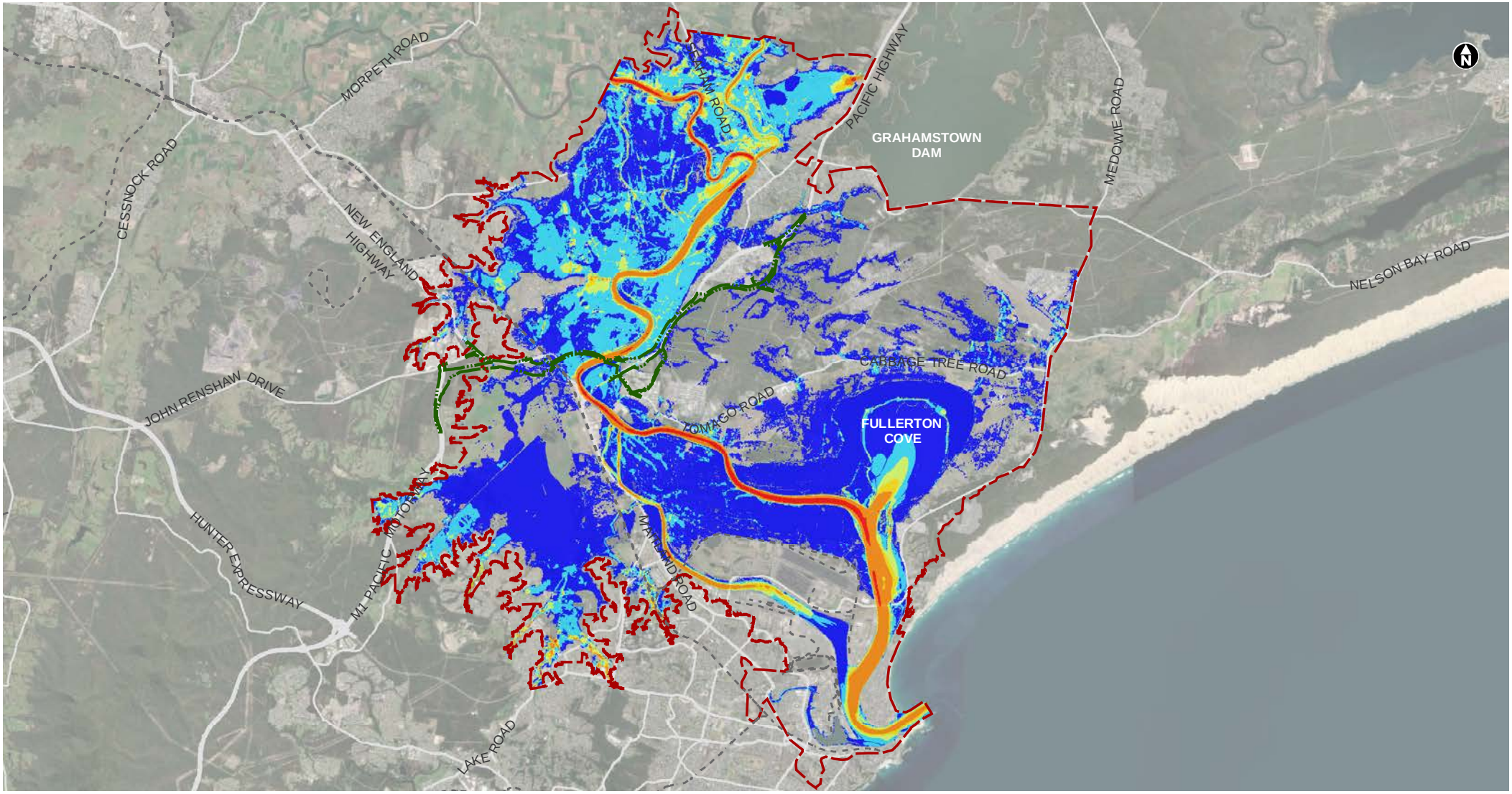


Figure C-7 Flow velocity - Existing - 20% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_007_C7_Flow_Velocity_Existing_20_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flow velocity (m/s)

< 0.05	0.75 to 1.0
0.05 to 0.25	1.0 to 2.0
0.25 to 0.5	2.0 to 3.0
0.5 to 0.75	> 3.0

0 4 8km

Figure C-8 Flow velocity - Existing - 10% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_008_C8_Flow_Velocity_Existing_10_AEP_JAC_A4L_175000_V01.mxd

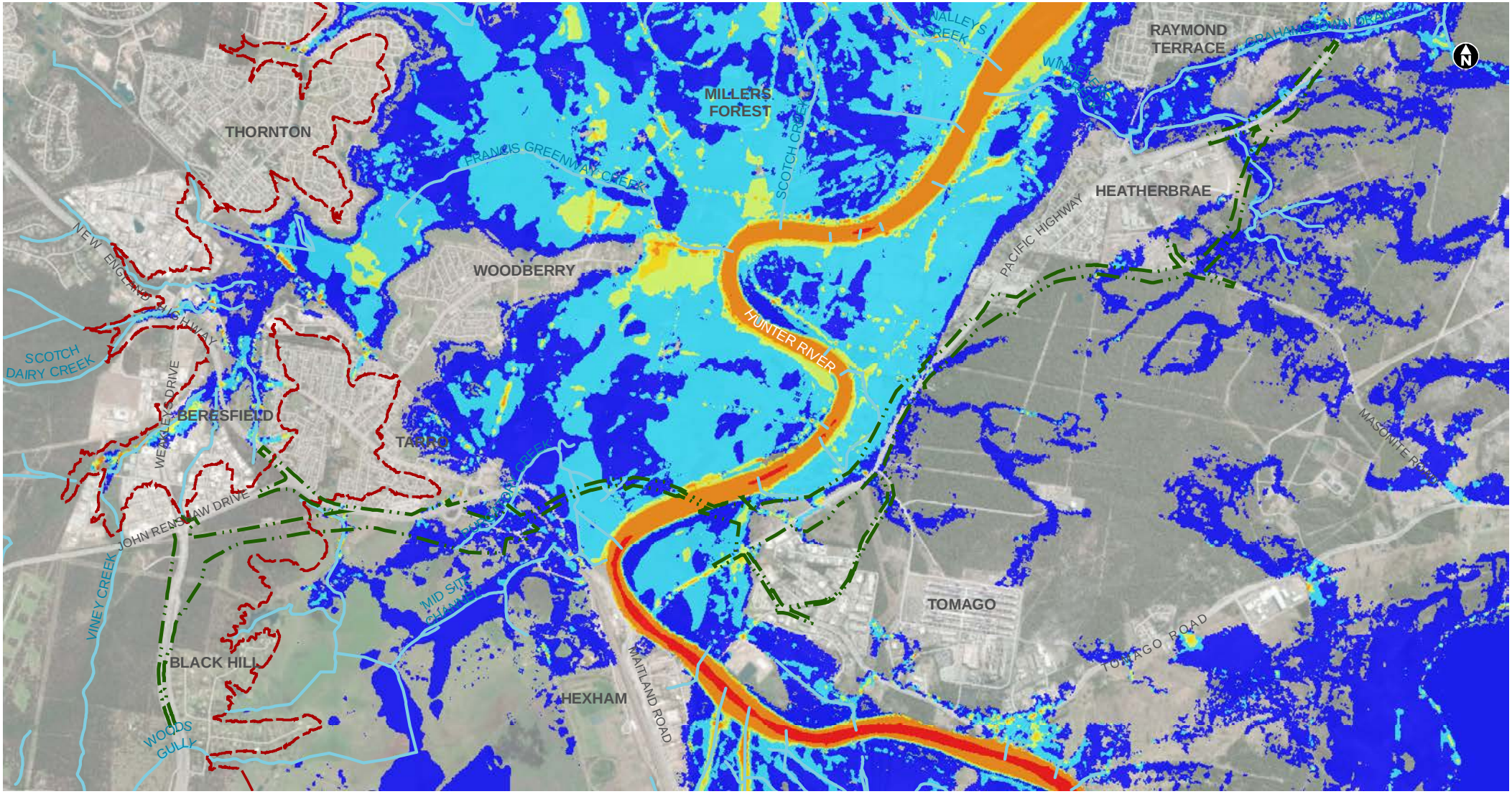
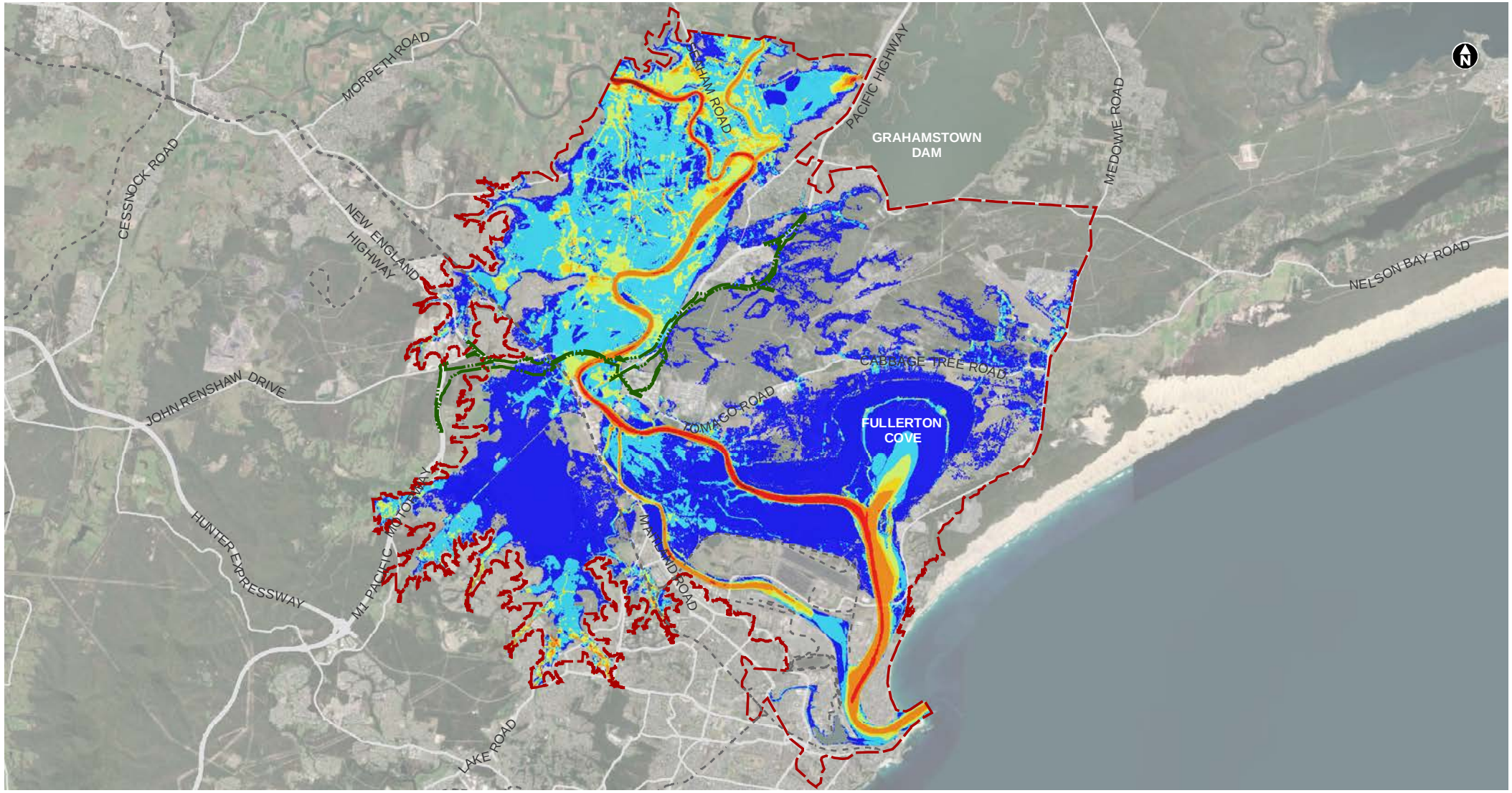


Figure C-8 Flow velocity - Existing - 10% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_008_C8_Flow_Velocity_Existing_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

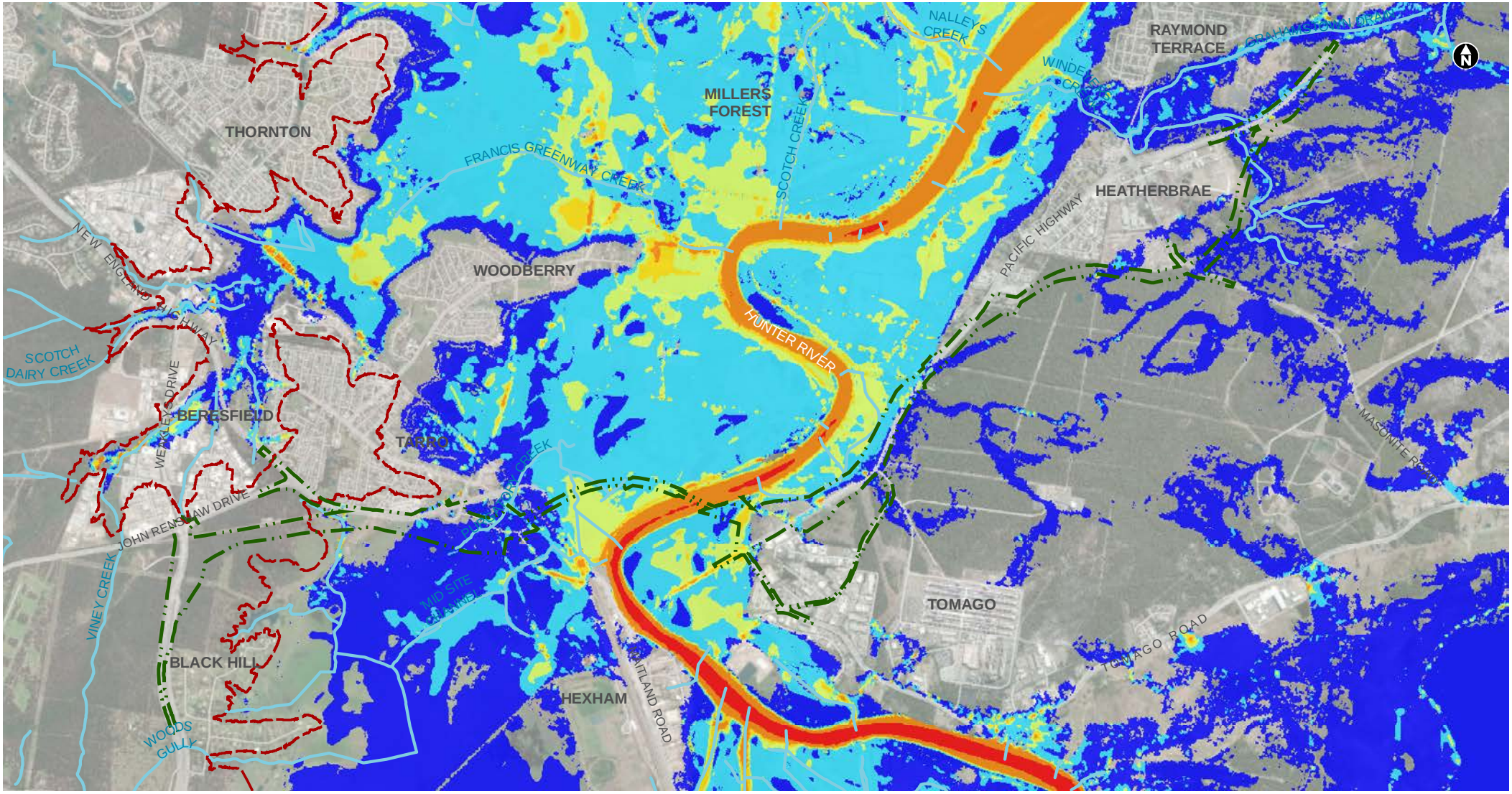
Flow velocity (m/s)

- < 0.05
- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

0 4 8km

Figure C-9 Flow velocity - Existing - 5% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_009_C9_Flow_Velocity_Existing_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flow velocity (m/s)

< 0.05

0.05 to 0.25

0.25 to 0.5

0.5 to 0.75

0.75 to 1.0

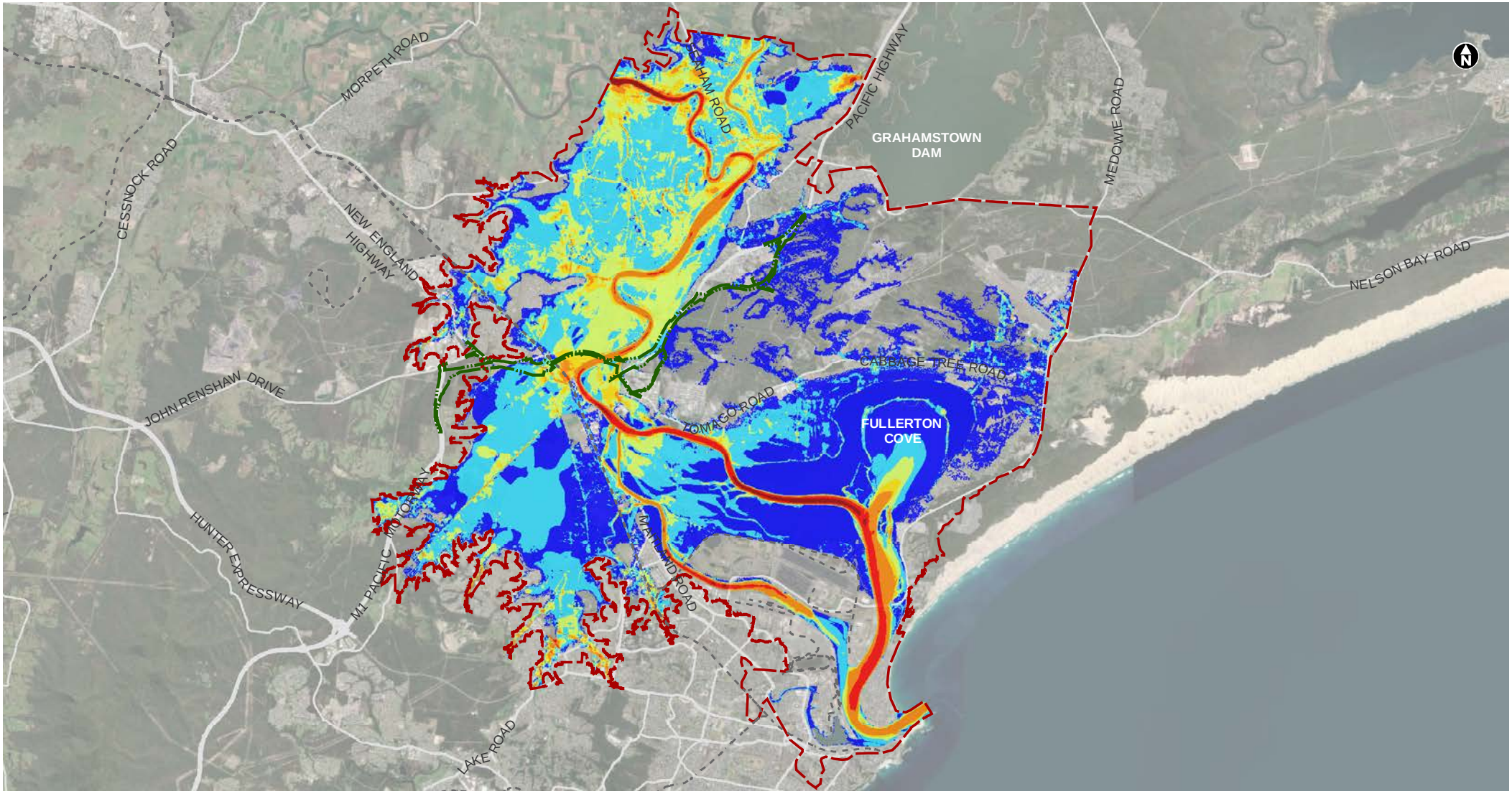
1.0 to 2.0

2.0 to 3.0

0 1 2km

Figure C-9 Flow velocity - Existing - 5% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_009_C9_Flow_Velocity_Existing_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

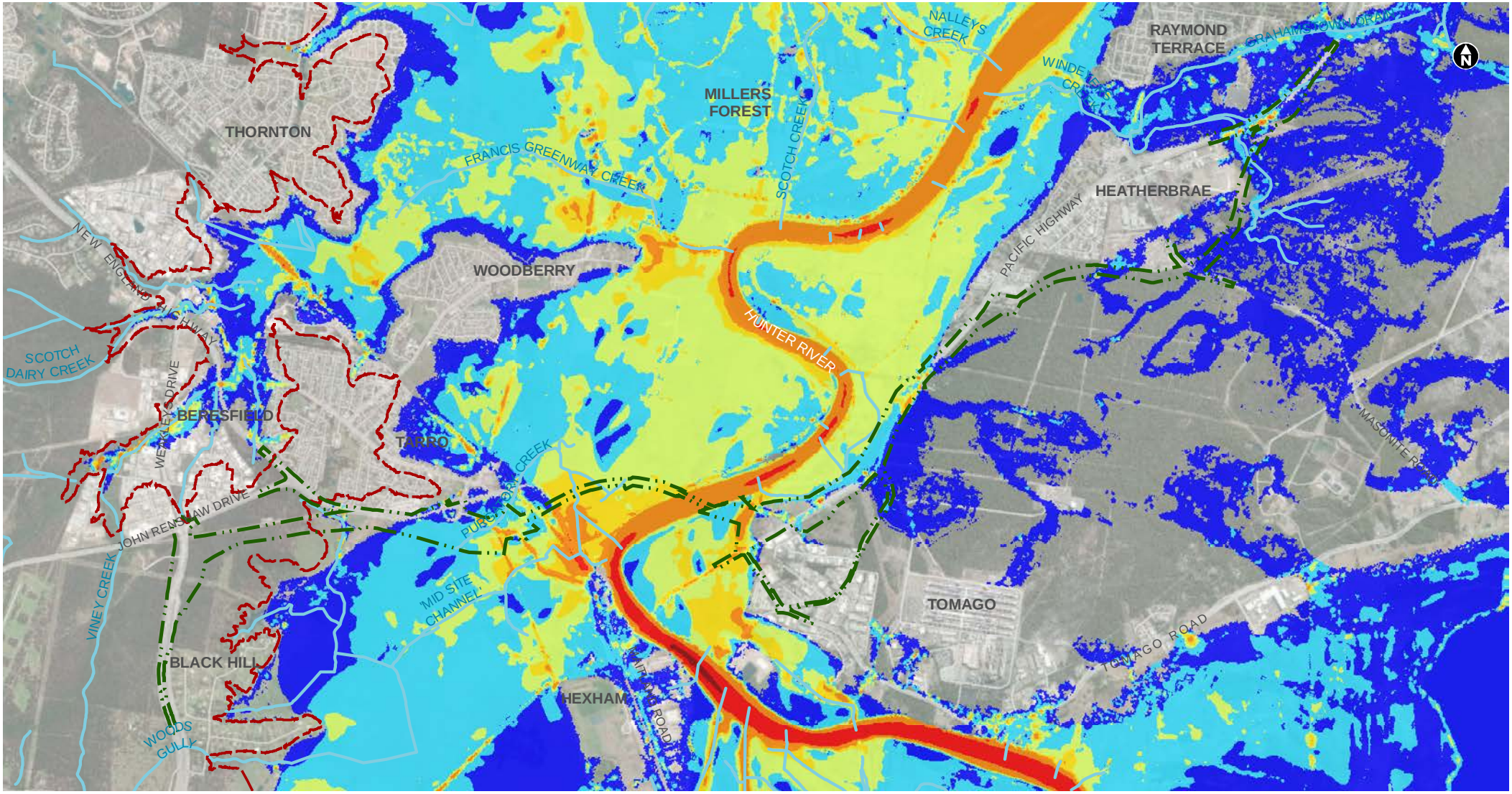
Flow velocity (m/s)

- < 0.05
- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

0 4 8km

Figure C-10 Flow velocity - Existing - 2% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_010_C10_Flow_Velocity_Existing_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

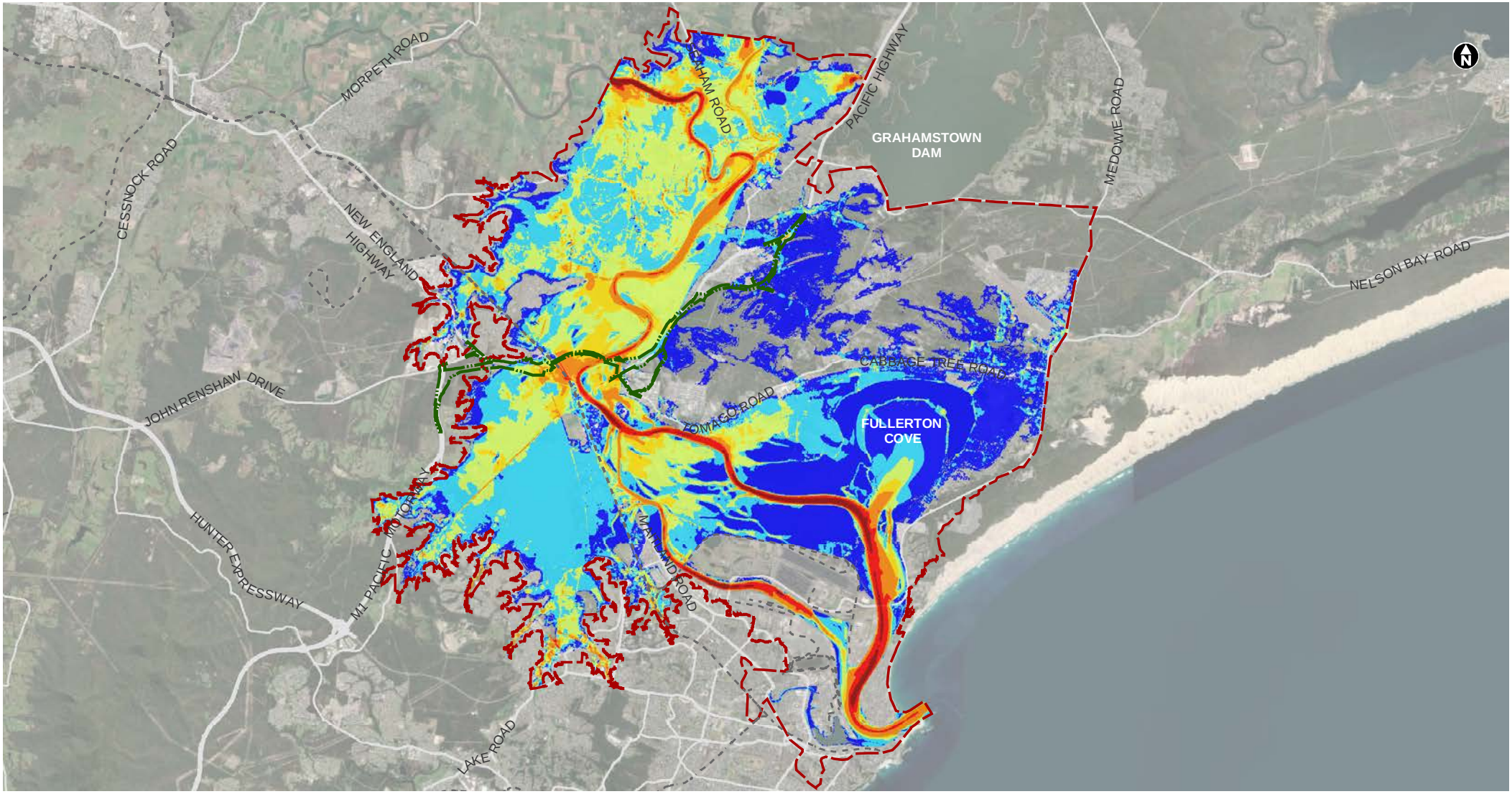
Flow velocity (m/s)

- < 0.05
- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

0 1 2km

Figure C-10 Flow velocity - Existing - 2% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_010_C10_Flow_Velocity_Existing_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

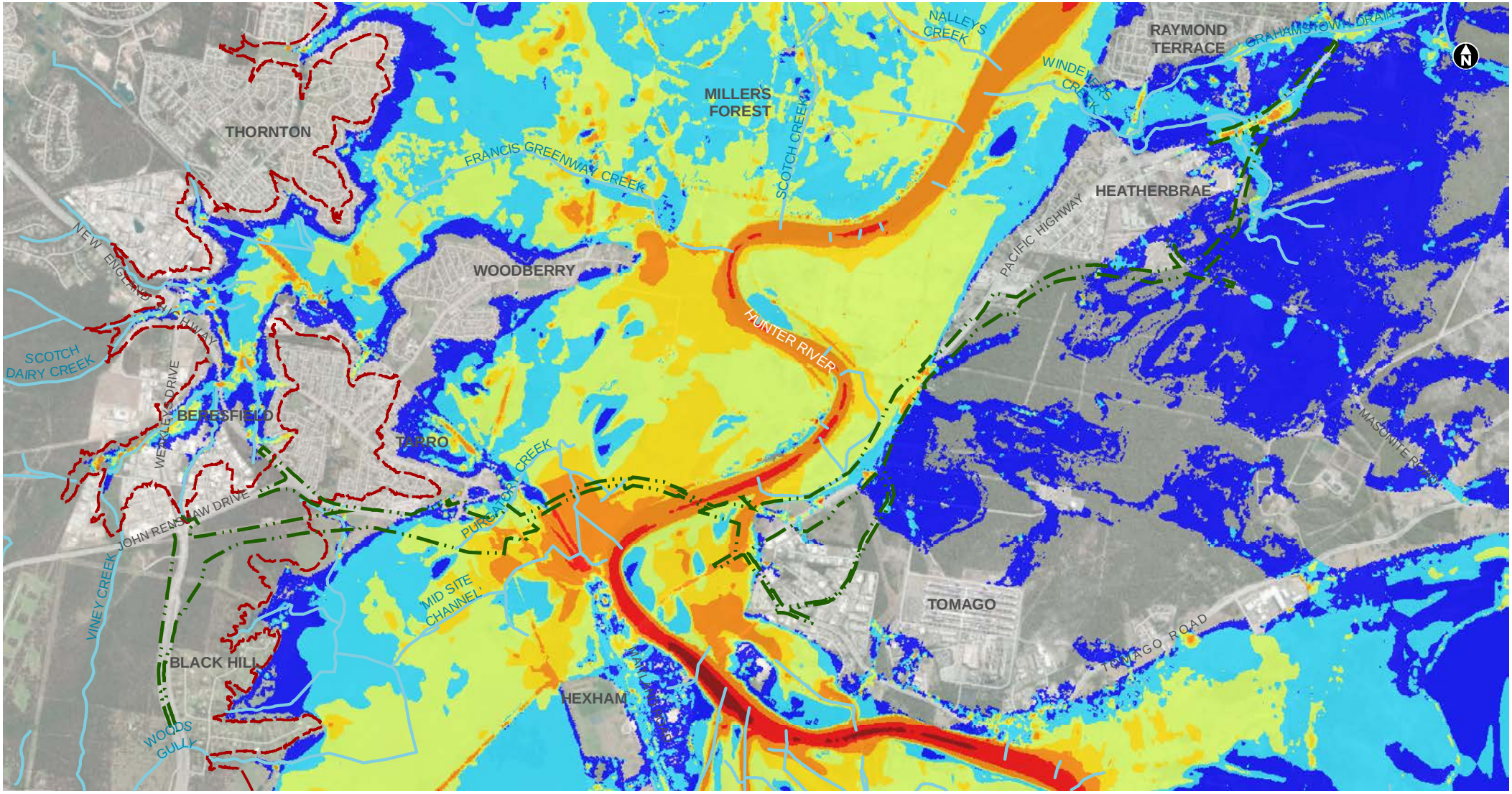
Flow velocity (m/s)

- < 0.05
- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

0 4 8km

Figure C-11 Flow velocity - Existing - 1% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_011_C11_Flow_Velocity_Existing_1_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

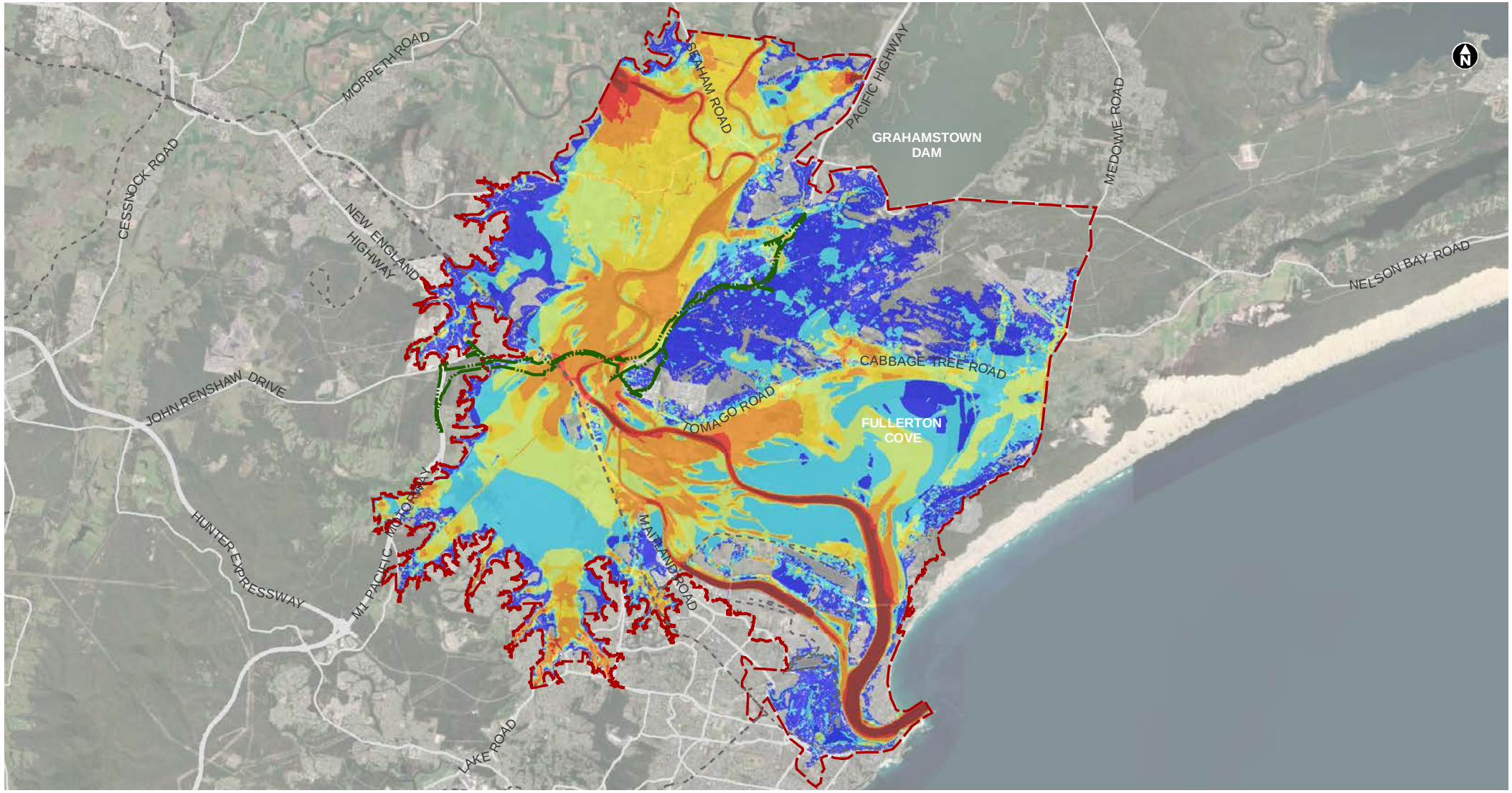
Flow velocity (m/s)

- < 0.05
- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

0 1 2km

Figure C-11 Flow velocity - Existing - 1% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_011_C11_Flow_Velocity_Existing_1_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flow velocity (m/s)

- < 0.05
- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

0 4 8km

Figure C-12 Flow velocity - Existing - Probable maximum flood (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_012_C12_Flow_Velocity_Existing_ProbMax_AEP_JAC_A4L_175000_V01.mxd

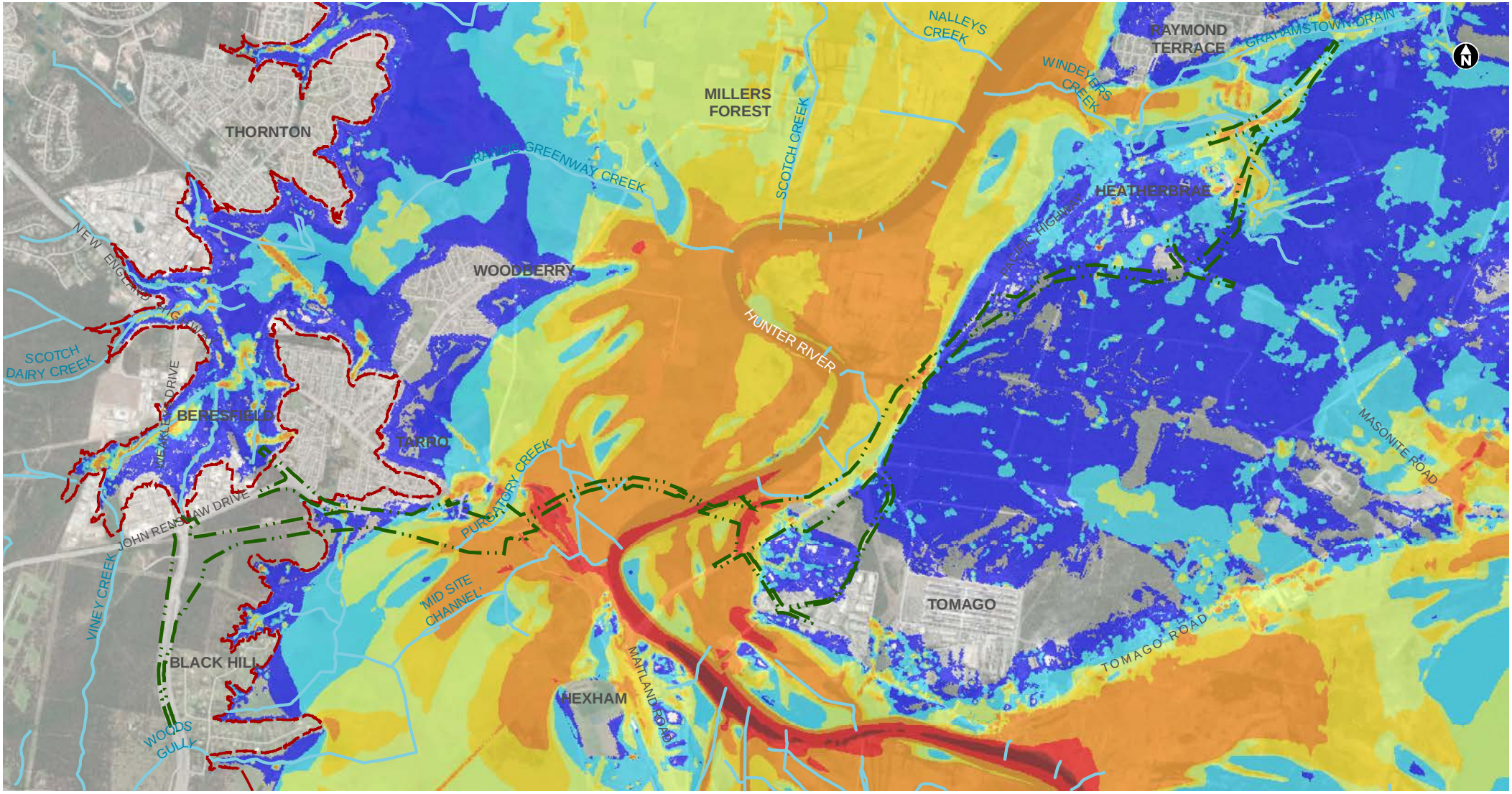
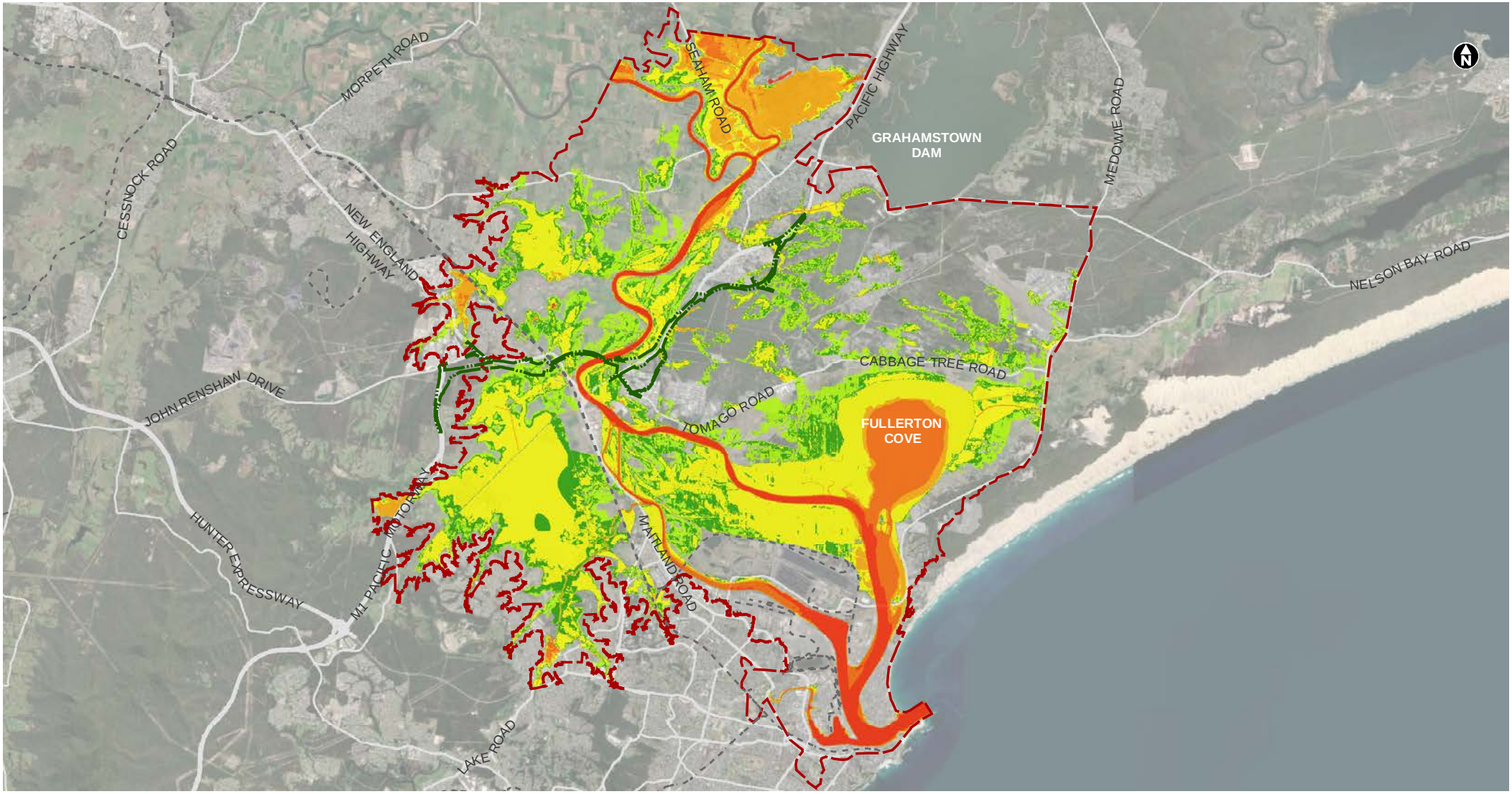


Figure C-12 Flow velocity - Existing - Probable maximum flood (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_012_C12_Flow_Velocity_Existing_ProbMax_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood hazard

H1 - No restrictions

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

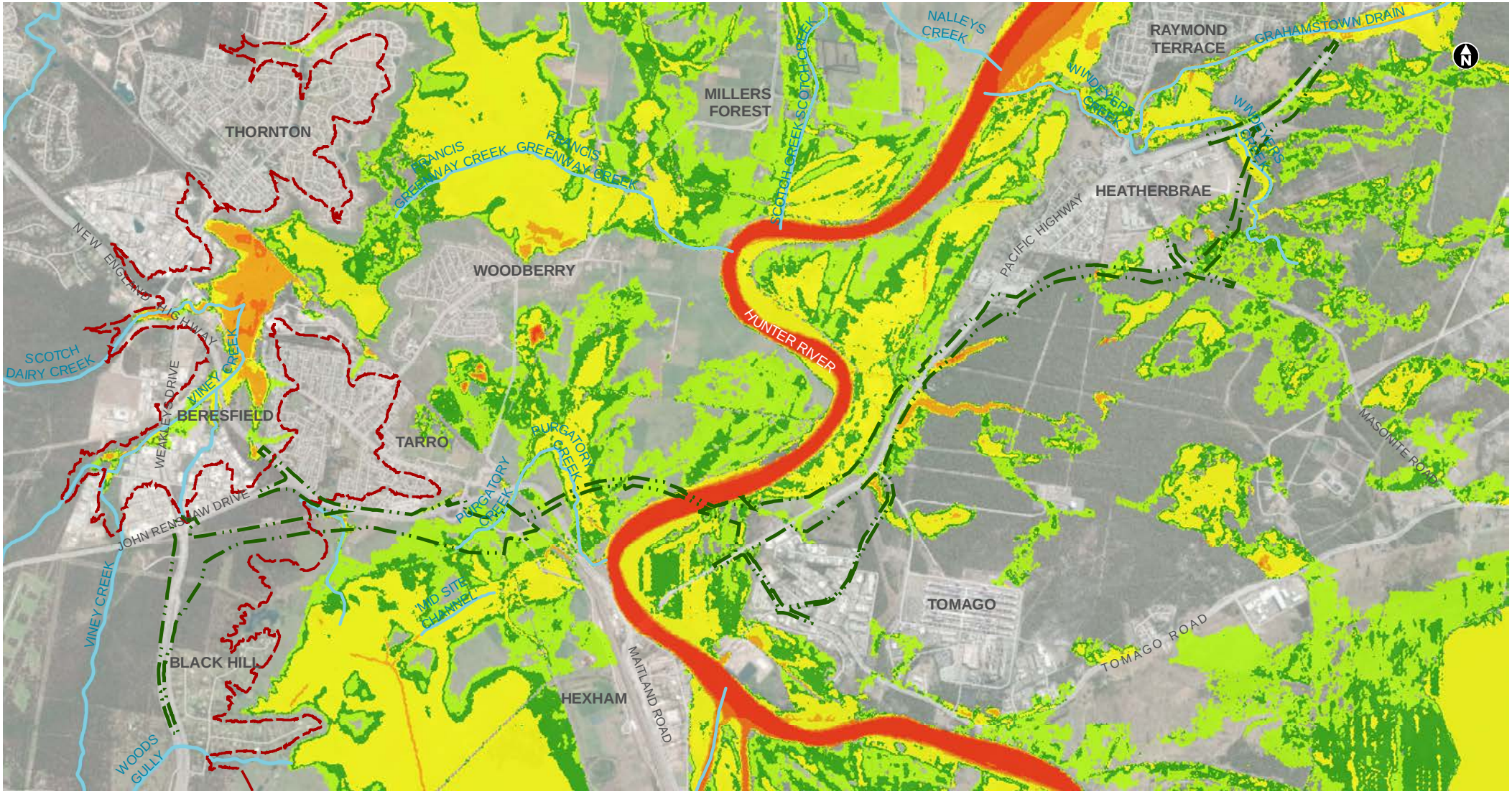
H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction

H6 - Not suitable for people, vehicles or buildings

0 4 8km

Figure C-13 Flood hazard - Existing - 20% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_013_C13_Flood_hazard_Existing_20_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood hazard

H1 - No restrictions

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

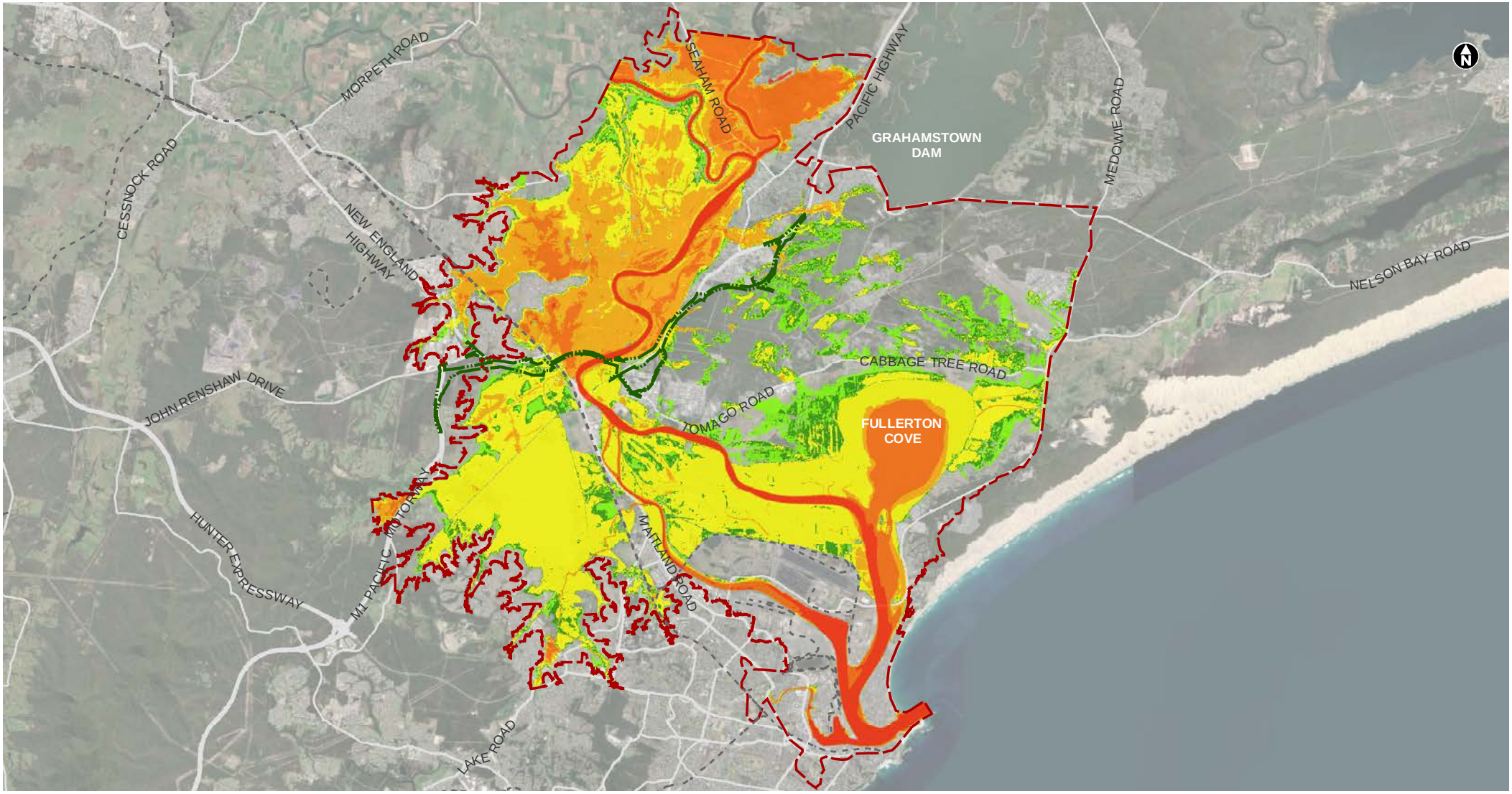
H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction

H6 - Not suitable for people, vehicles or buildings

0 1 2km

Figure C-13 Flood hazard - Existing - 20% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_013_C13_Flood_hazard_Existing_20_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 4 8km

Figure C-14 Flood hazard - Existing - 10% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_014_C14_Flood_hazard_Existing_10_AEP_JAC_A4L_175000_V01.mxd

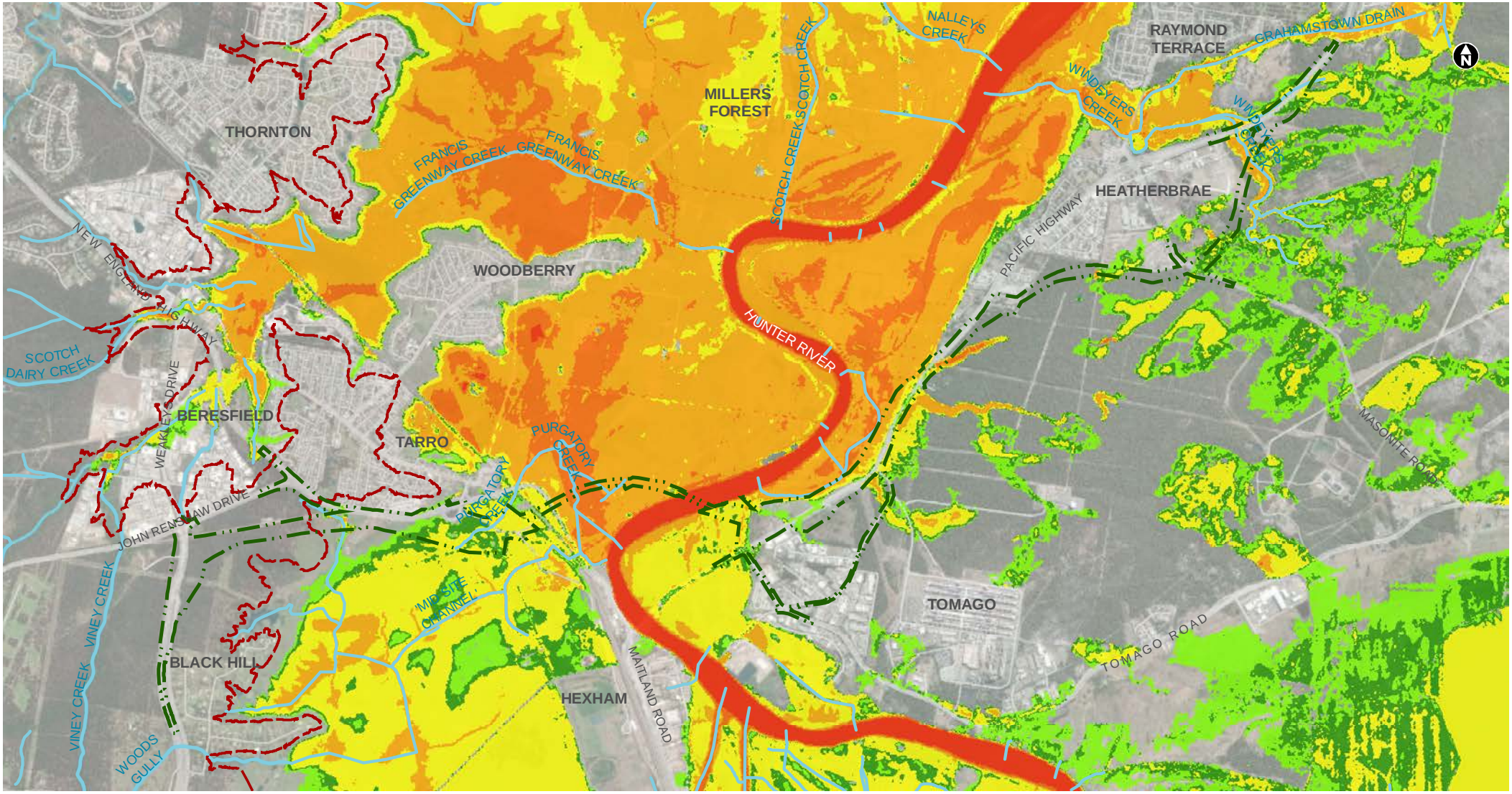
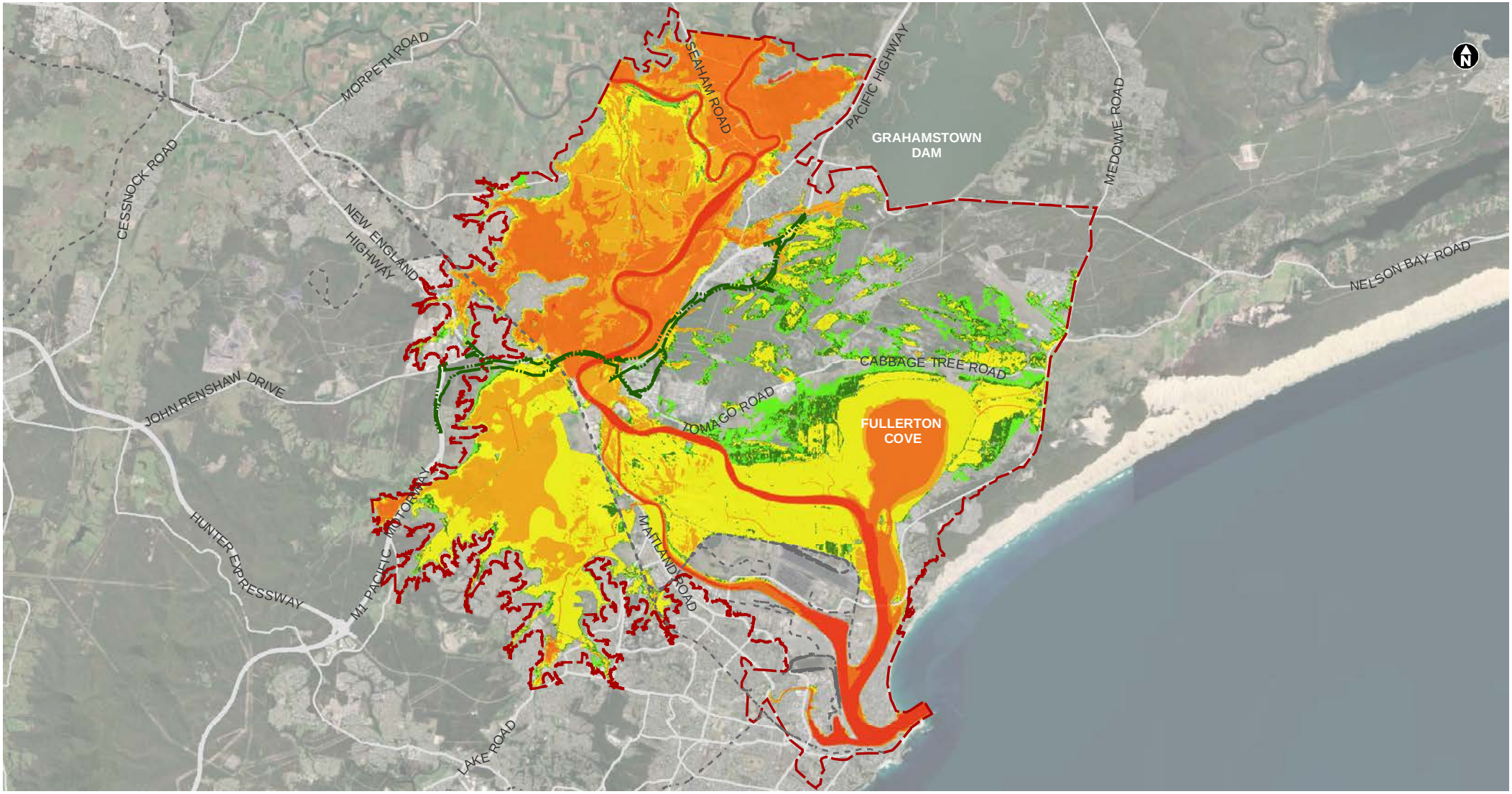


Figure C-14 Flood hazard - Existing - 10% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_014_C14_Flood_hazard_Existing_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood hazard

H1 - No restrictions

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

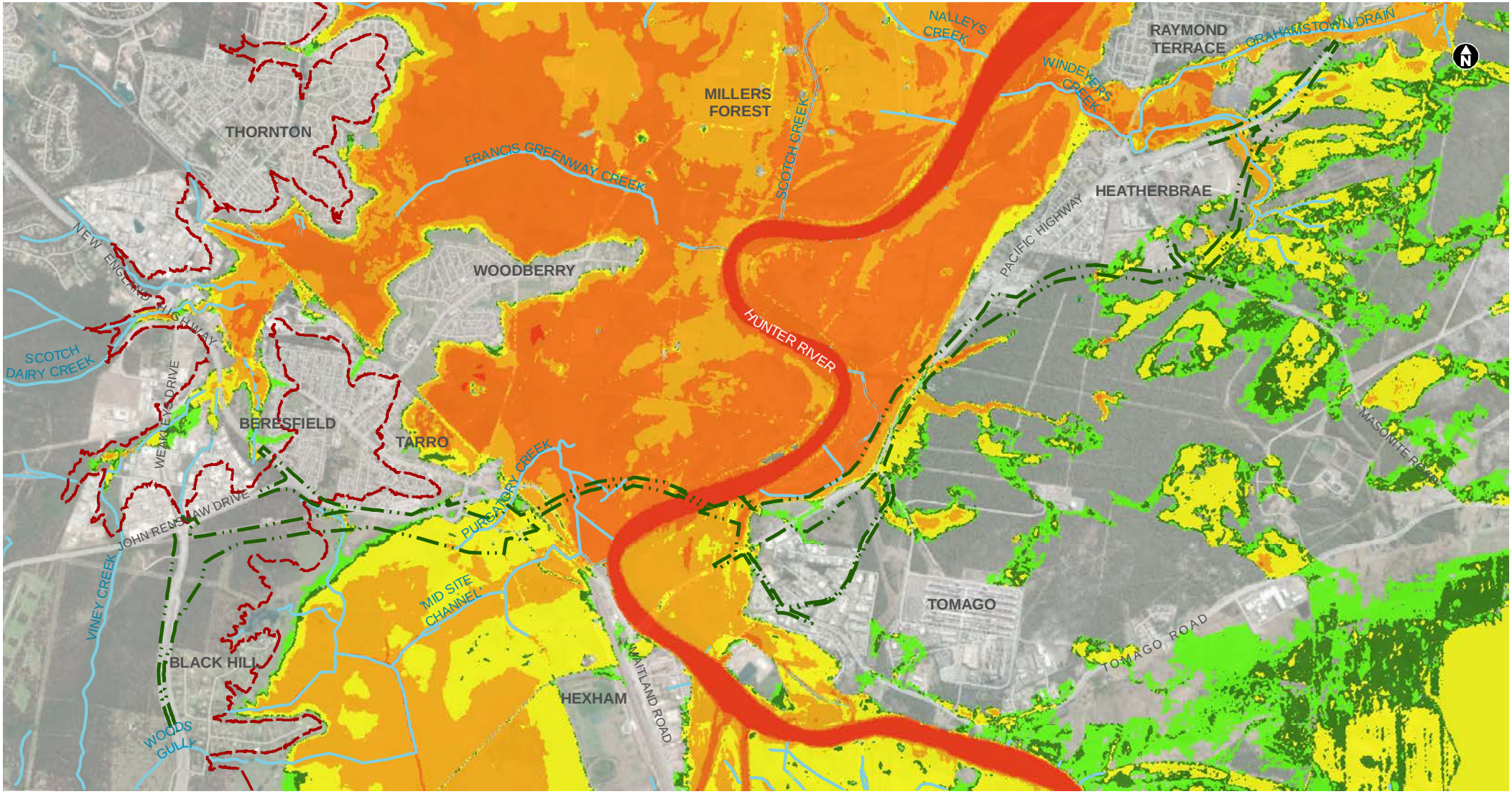
H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction

H6 - Not suitable for people, vehicles or buildings

0 4 8km

Figure C-15 Flood hazard - Existing - 5% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_015_C15_Flood_hazard_Existing_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood hazard

H1 - No restrictions

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

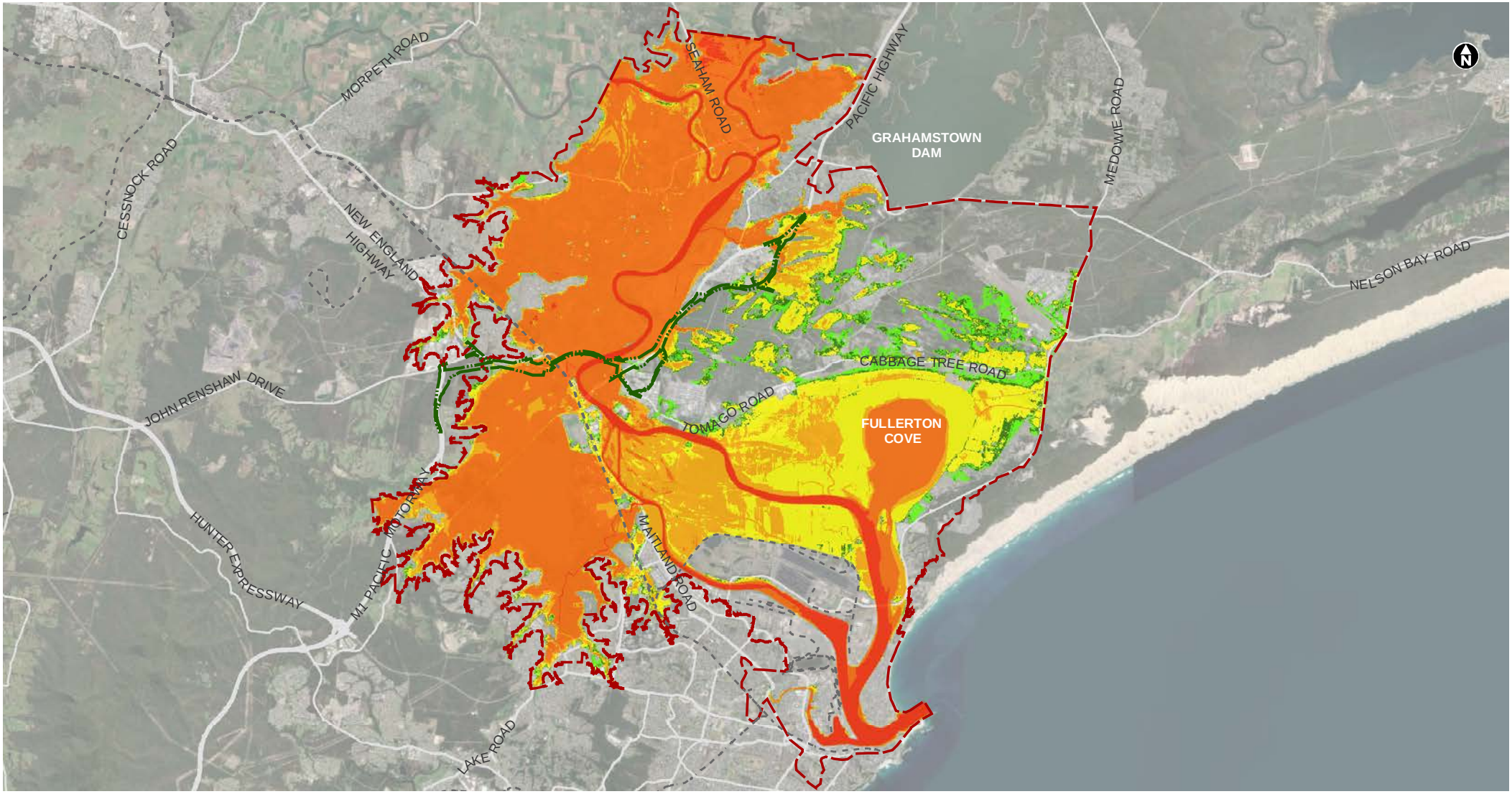
H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction

H6 - Not suitable for people, vehicles or buildings

0 1 2km

Figure C-15 Flood hazard - Existing - 5% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_015_C15_Flood_hazard_Existing_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

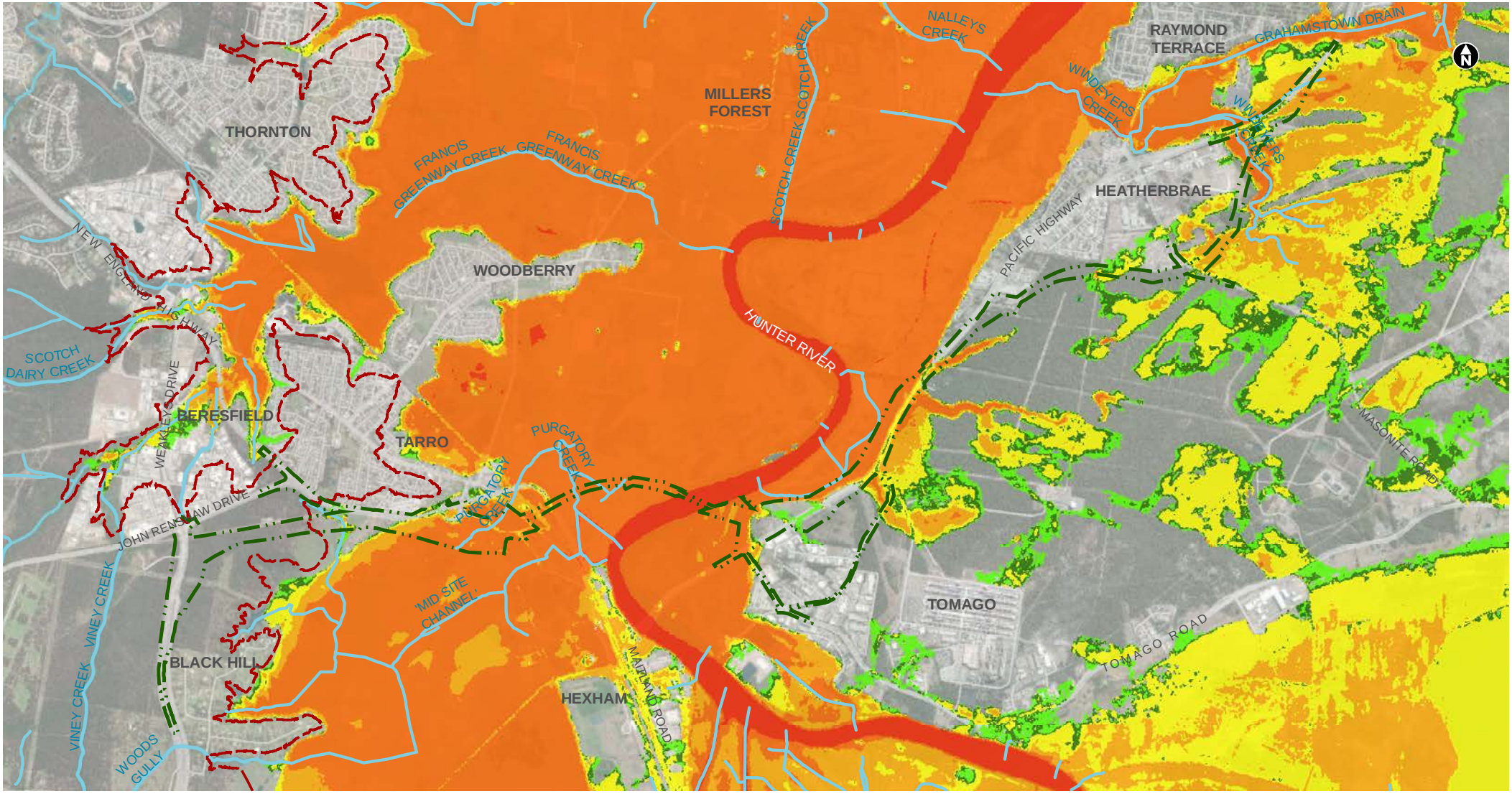
Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 4 8km

Figure C-16 Flood hazard - Existing - 2% AEP (map 1 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_016_C16_Flood_hazard_Existing_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

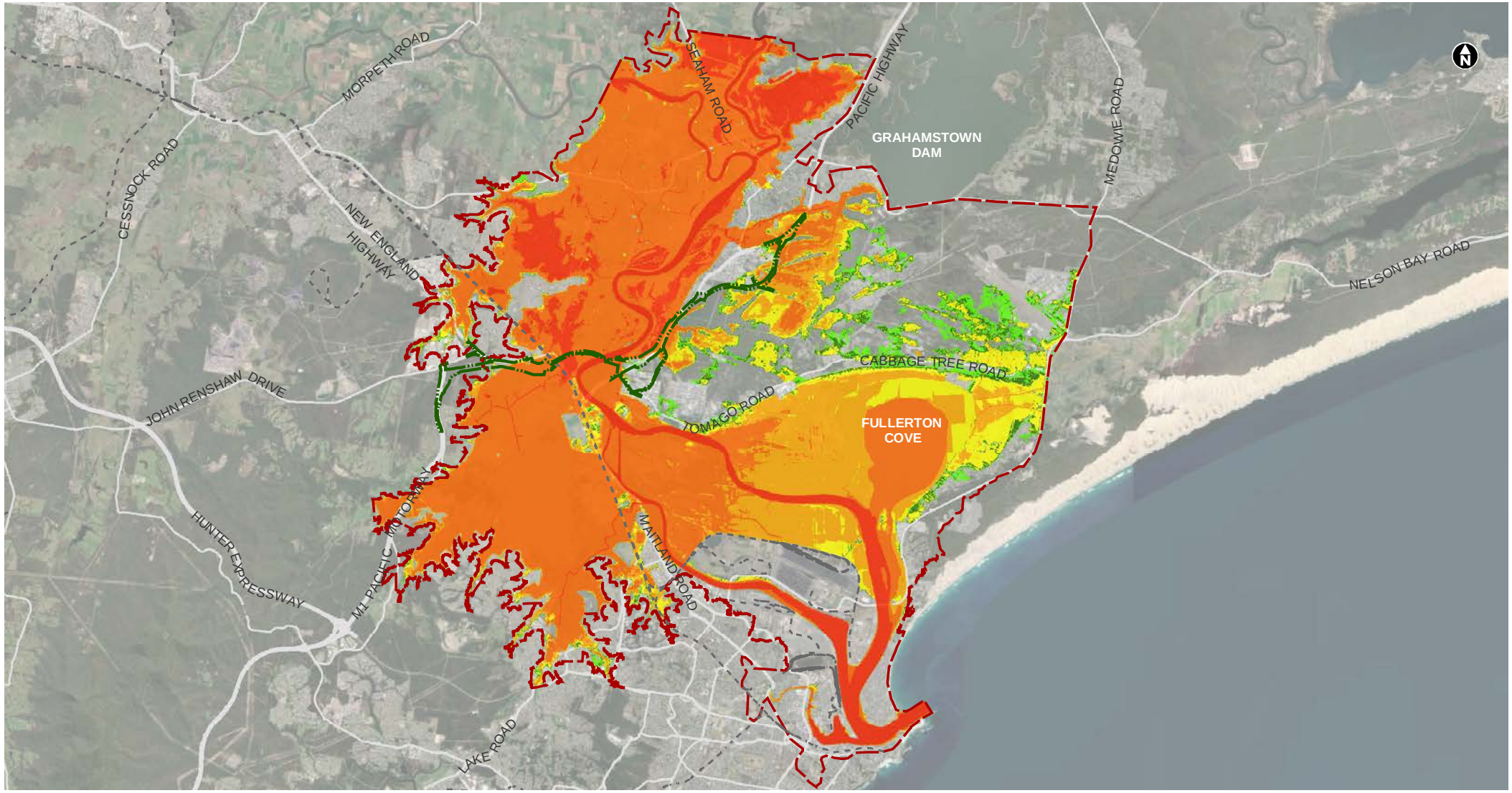
Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 1 2km

Figure C-16 Flood hazard - Existing - 2% AEP (map 2 of 2)

Date: 1/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_016_C16_Flood_hazard_Existing_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

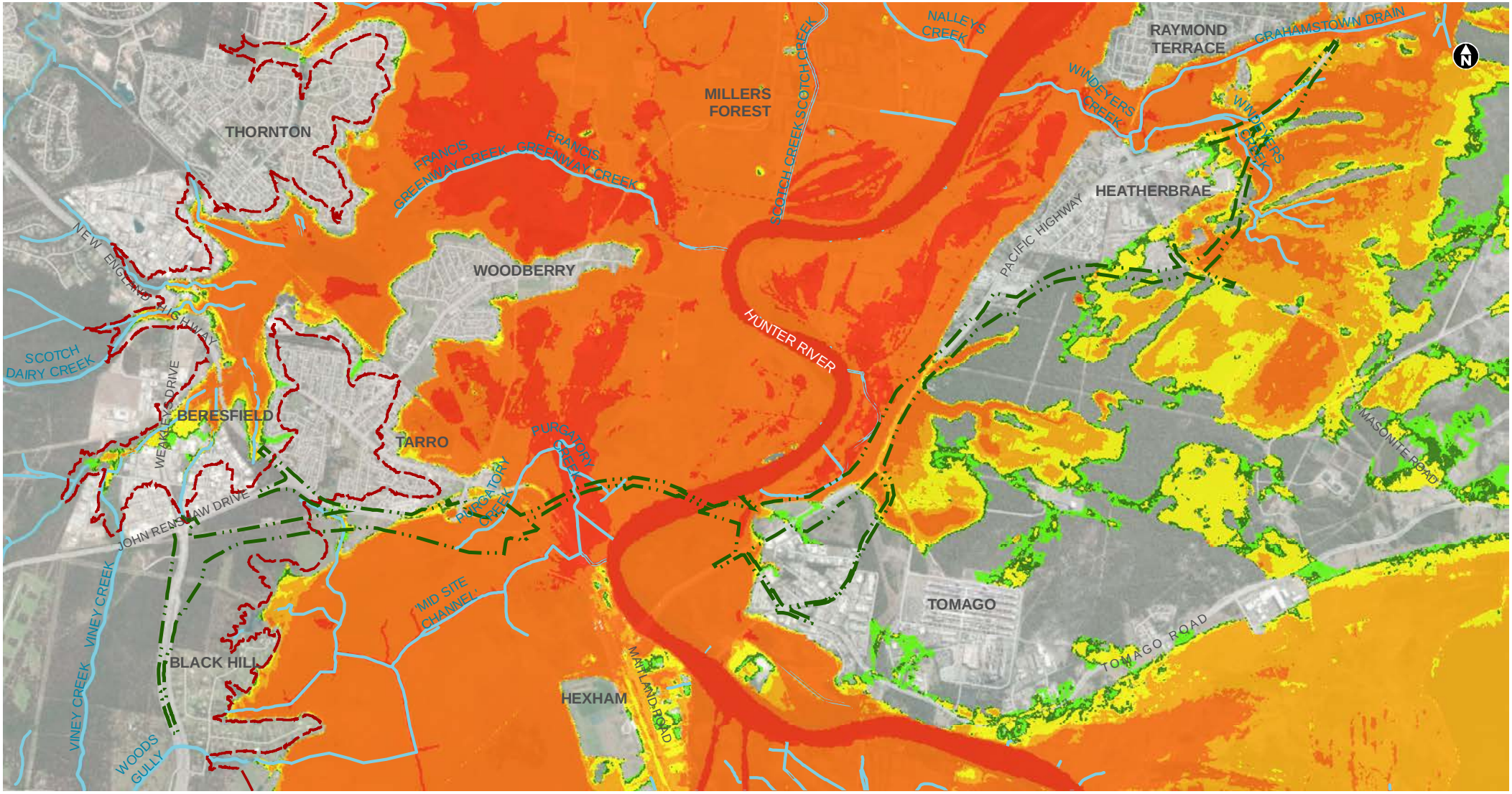
Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 4 8km

Figure C-17 Flood hazard - Existing - 1% AEP (map 1 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_017_C17_Flood_hazard_Existing_1_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

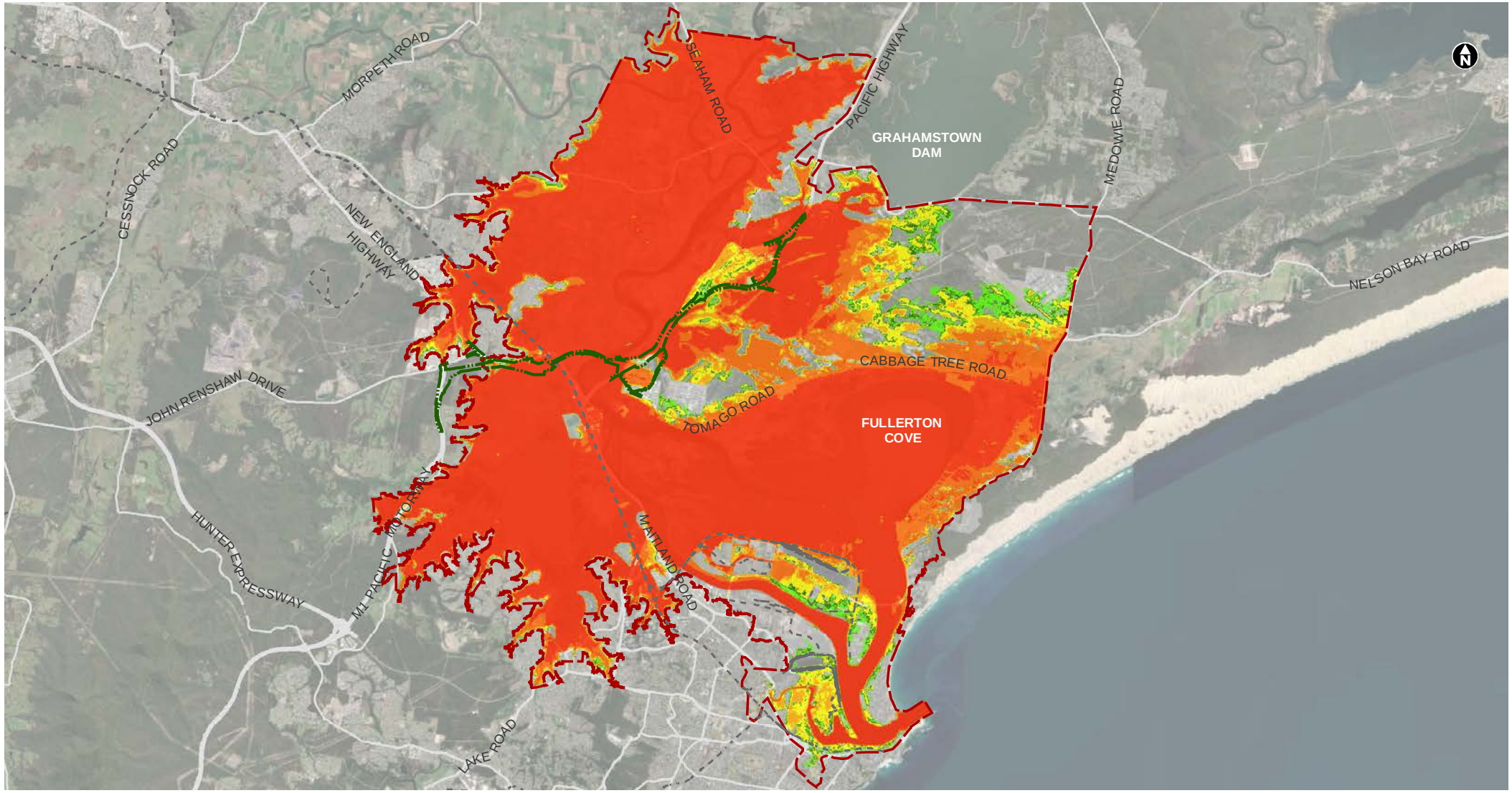
Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 1 2km

Figure C-17 Flood hazard - Existing - 1% AEP (map 2 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_017_C17_Flood_hazard_Existing_1_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

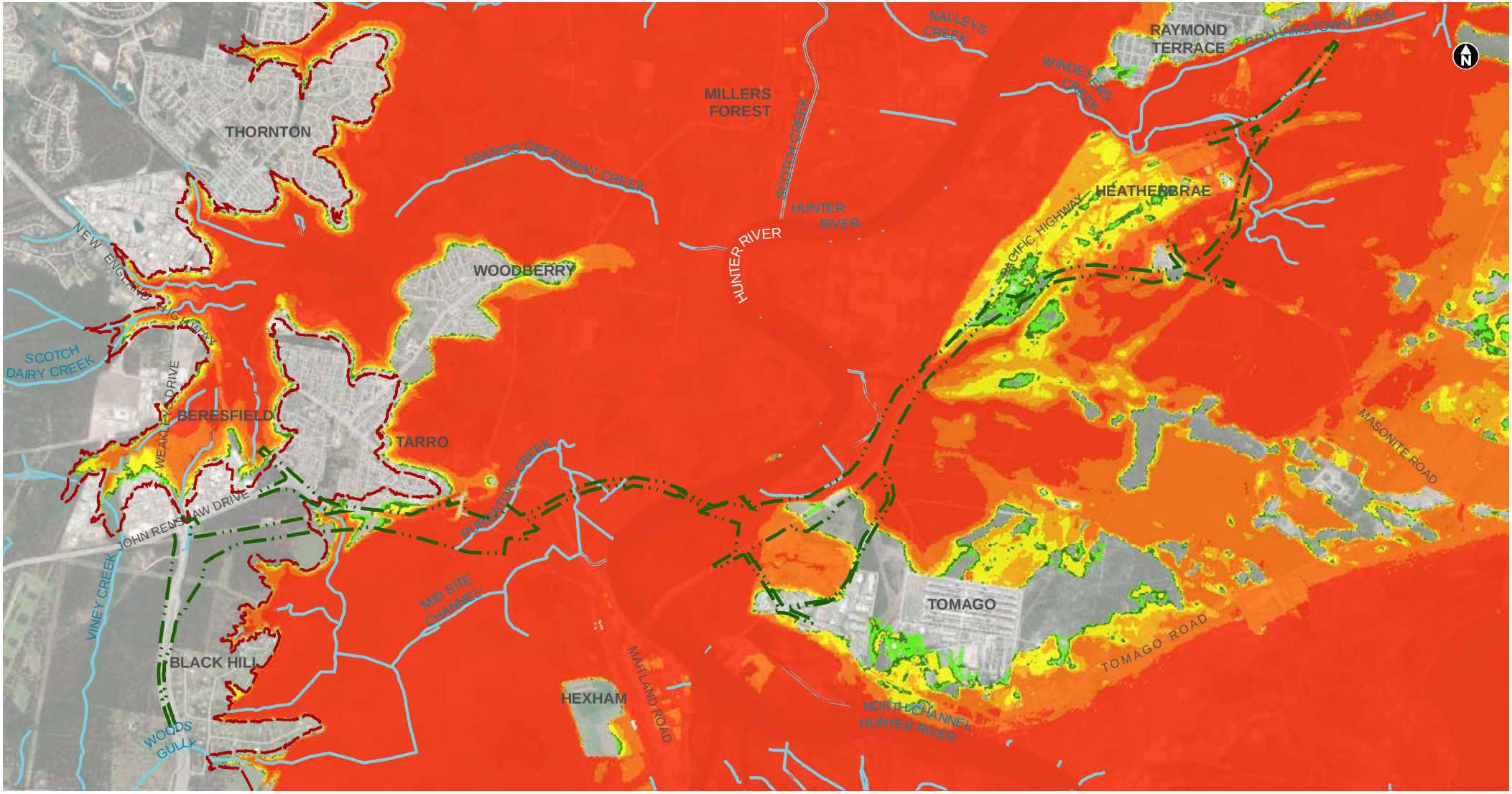
Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 4 8km

Figure C-18 Flood hazard - Existing - Probable maximum flood (map 1 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_018_C18_Flood_hazard_Existing_ProbMax_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Flood hazard

- H1 - No restrictions
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 1 2km

Figure C-18 Flood hazard - Existing - Probable maximum flood (map 2 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_018_C18_Flood_hazard_Existing_ProbMax_AEP_JAC_A4L_175000_V01.mxd

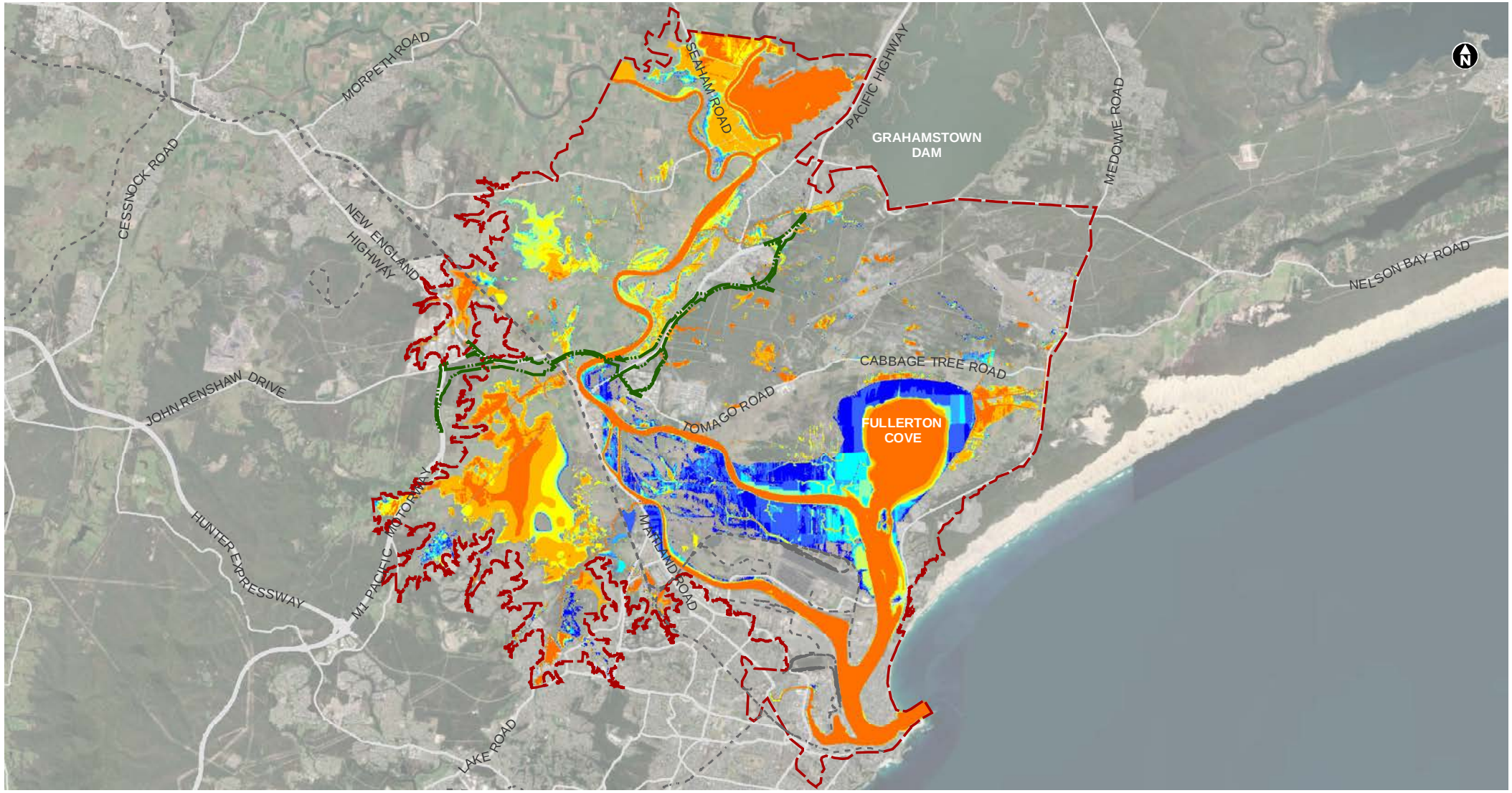


Figure C-19 Duration of inundation above 0.5m depth - Existing - 20% AEP (map 1 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_019_C19_Inundation_Duration_20_AEP_JAC_A4L_175000_V01.mxd

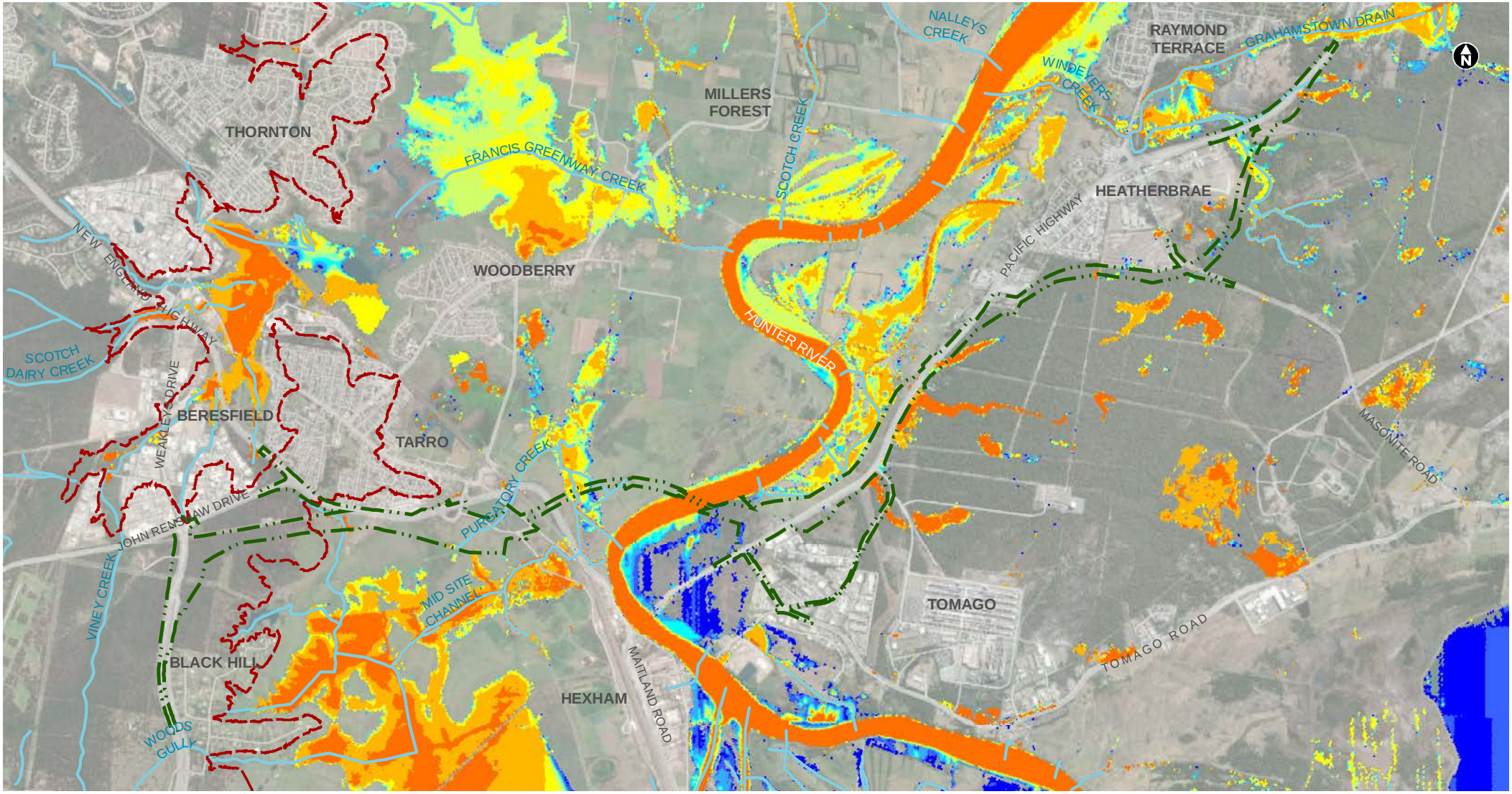


Figure C-19 Duration of inundation above 0.5m depth - Existing - 20% AEP (map 2 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_019_C19_Inundation_Duration_20_AEP_JAC_A4L_175000_V01.mxd

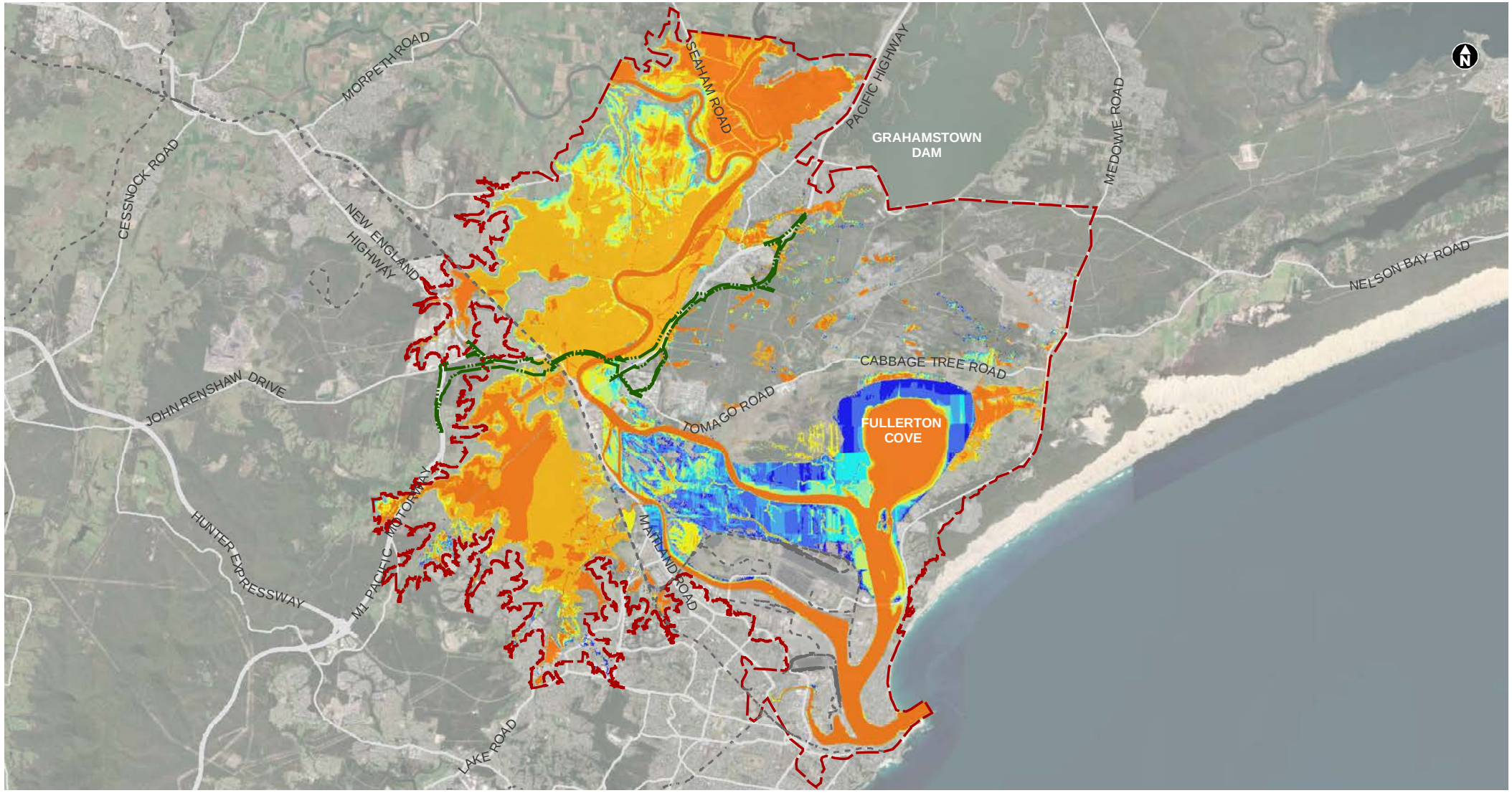
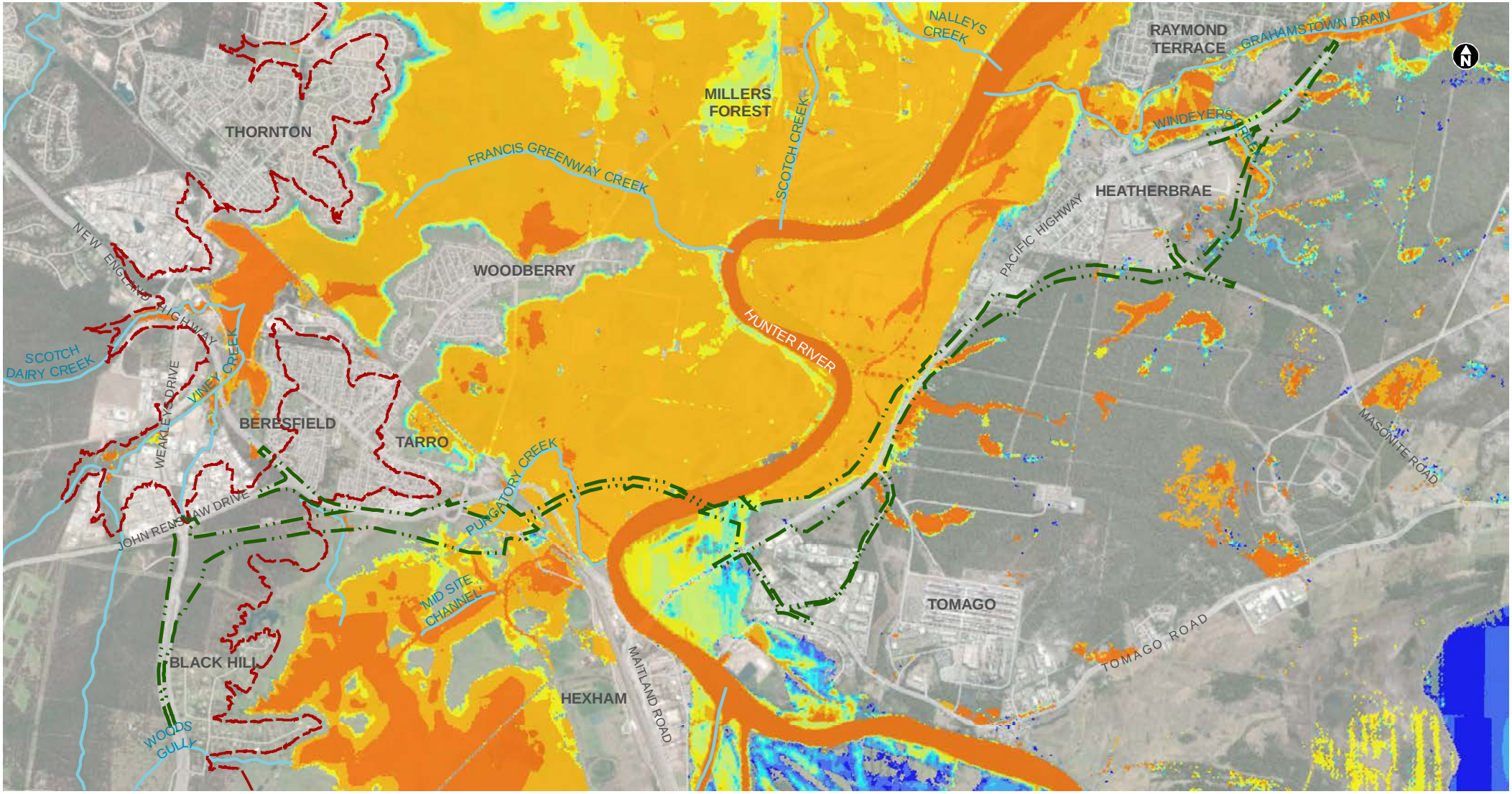


Figure C-20 Duration of inundation above 0.5m depth - Existing - 10% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_020_C20_Inundation_Duration_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Duration of inundation (hours)

0 - 3

3 - 6

6 - 12

12 - 18

18 - 24

24 - 36

36 - 48

48 - 72

72 - 96

>96

0 1 2km

Figure C-20 Duration of inundation above 0.5m depth - Existing - 10% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_020_C20_Inundation_Duration_10_AEP_JAC_A4L_175000_V01.mxd

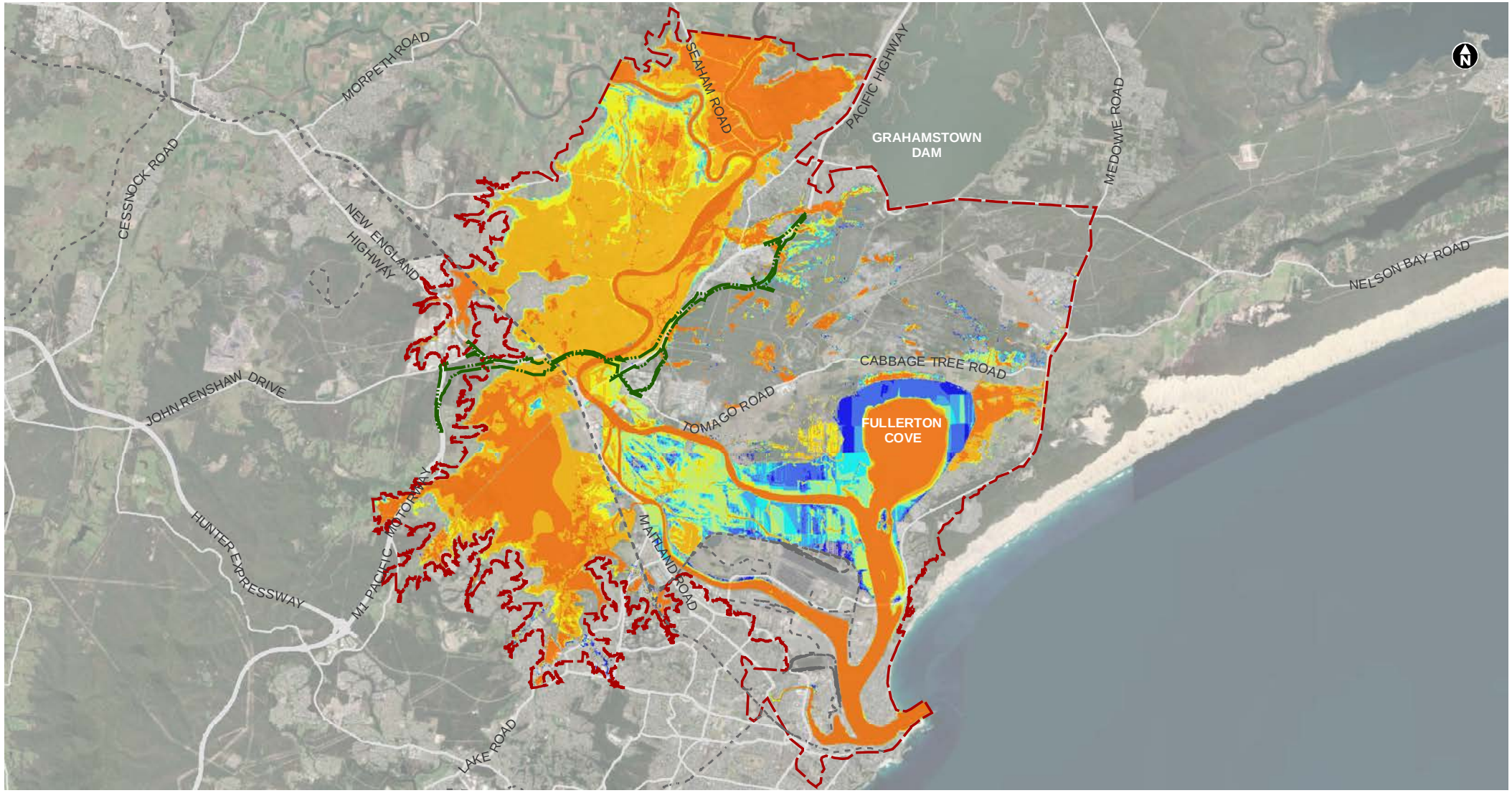
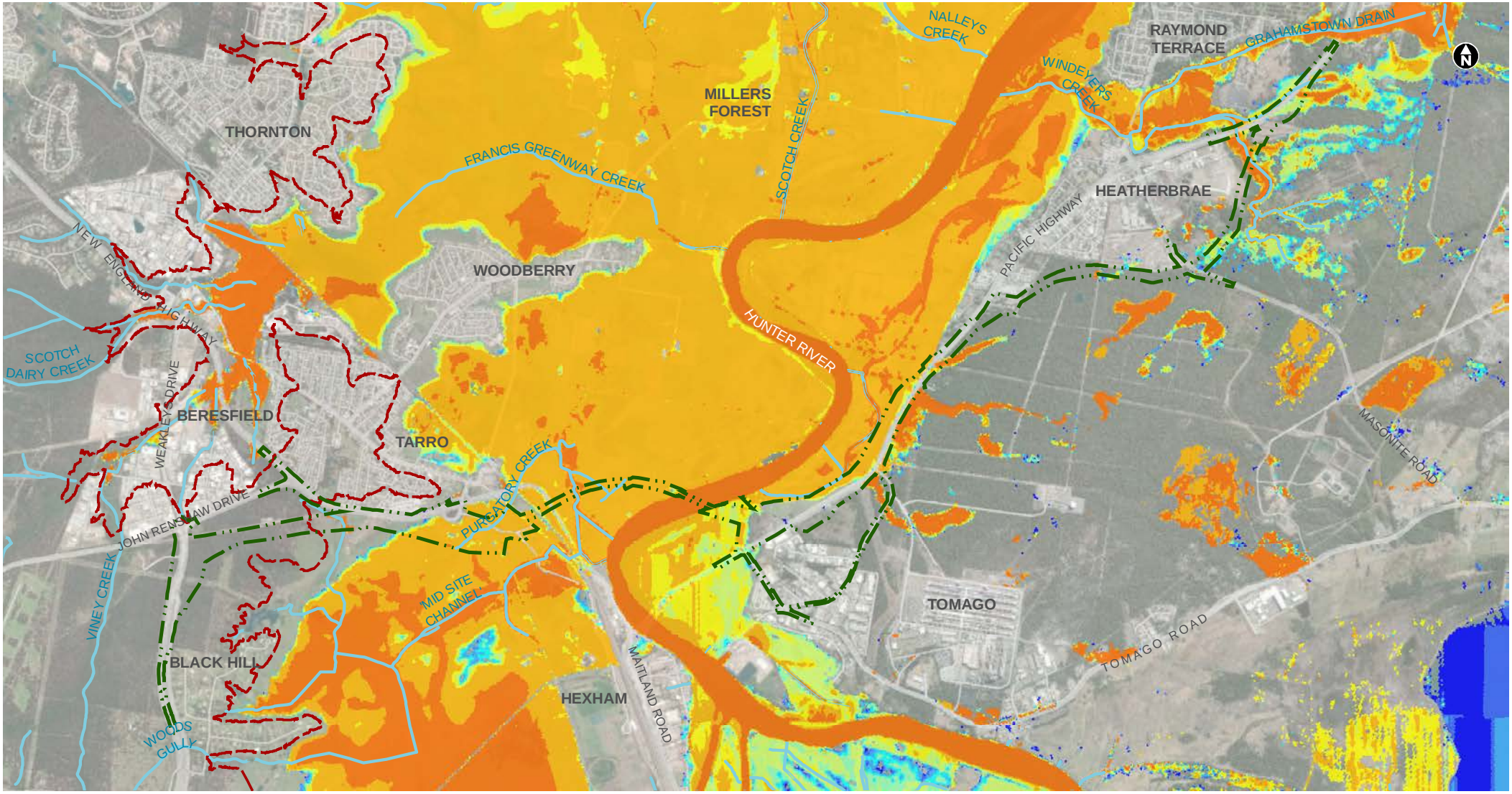


Figure C-21 Duration of inundation above 0.5m depth - Existing - 5% AEP (map 1 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_022_C22_Inundation_Duration_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Duration of inundation (hours)

0 - 3

3 - 6

6 - 12

12 - 18

18 - 24

24 - 36

36 - 48

48 - 72

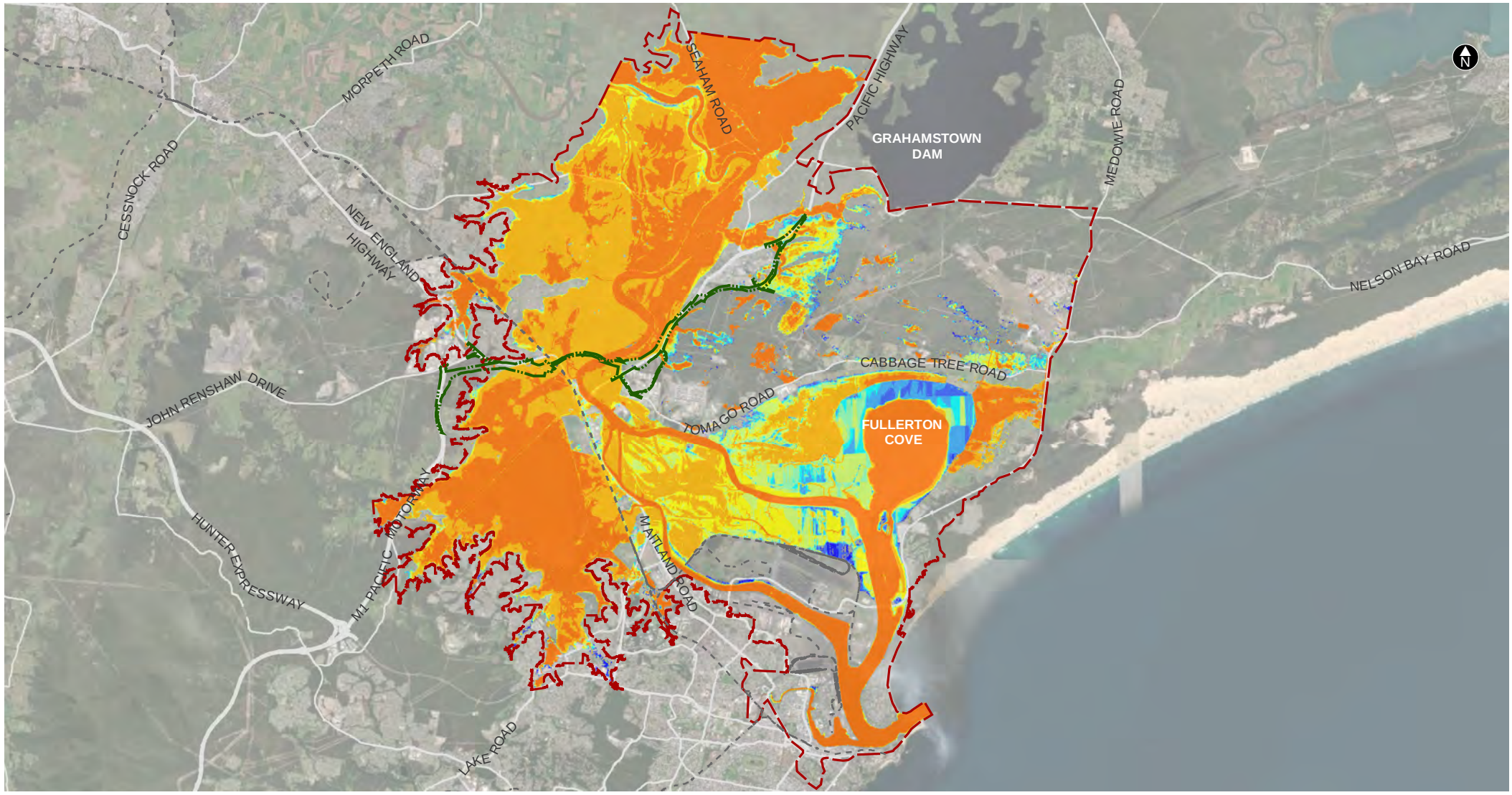
72 - 96

>96

0 1 2km

Figure C-21 Duration of inundation above 0.5m depth - Existing - 5% AEP (map 2 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_022_C22_Inundation_Duration_2_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

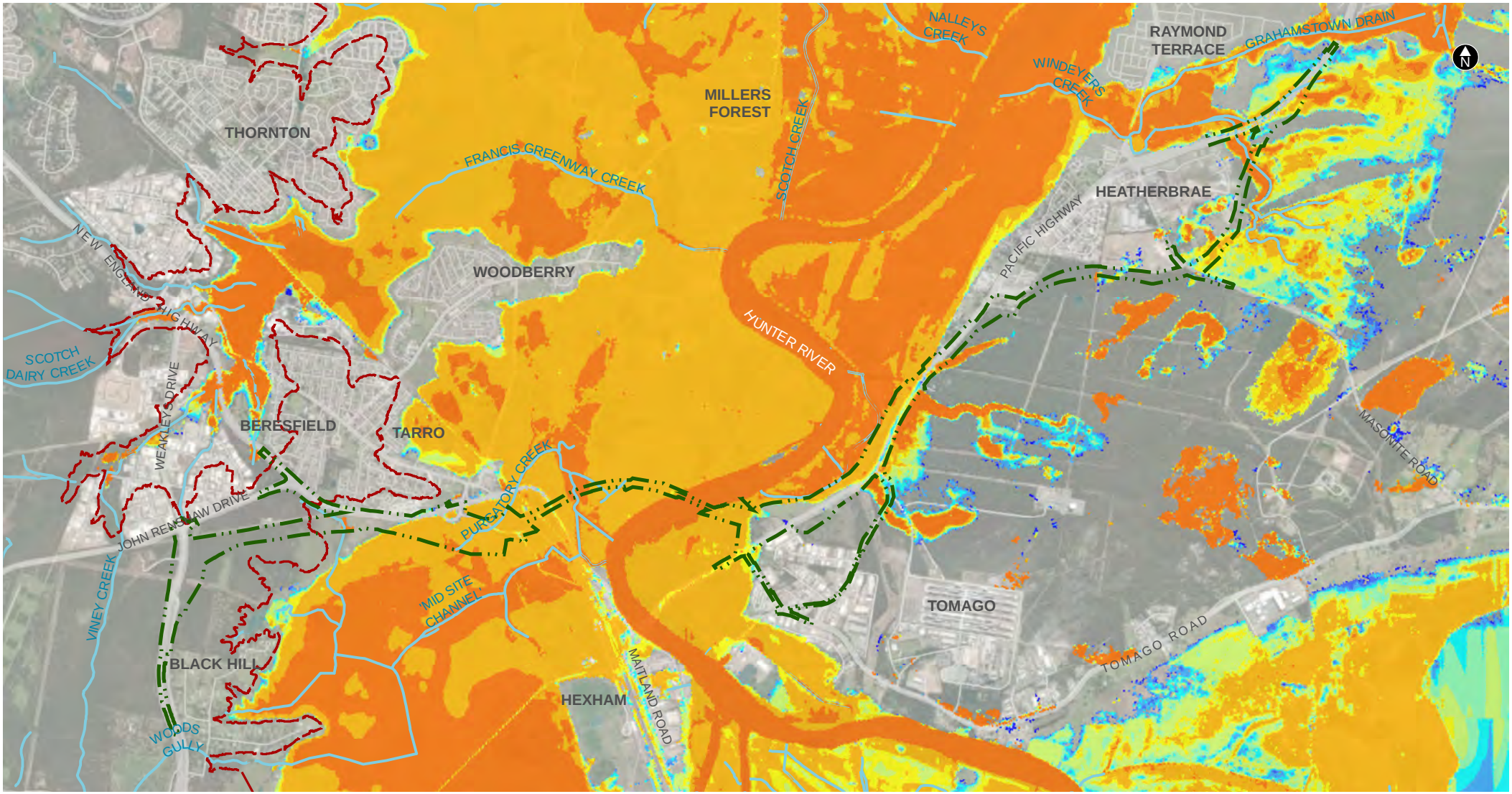
Duration of inundation (hours)

0 - 3	12 - 18	48 - 72
3 - 6	18 - 24	72 - 96
6 - 12	24 - 36	>96
	36 - 48	

0 4 8km

Figure C-22 Duration of inundation above 0.5m depth - Existing - 2% AEP (map 1 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_022_C22_Inundation_Duration_2_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Duration of inundation (hours)

0 - 3

3 - 6

6 - 12

12 - 18

18 - 24

24 - 36

36 - 48

48 - 72

72 - 96

>96

0 1 2km

Figure C-22 Duration of inundation above 0.5m depth - Existing - 2% AEP (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_022_C22_Inundation_Duration_2_AEP_JAC_A4L_175000_V02.mxd

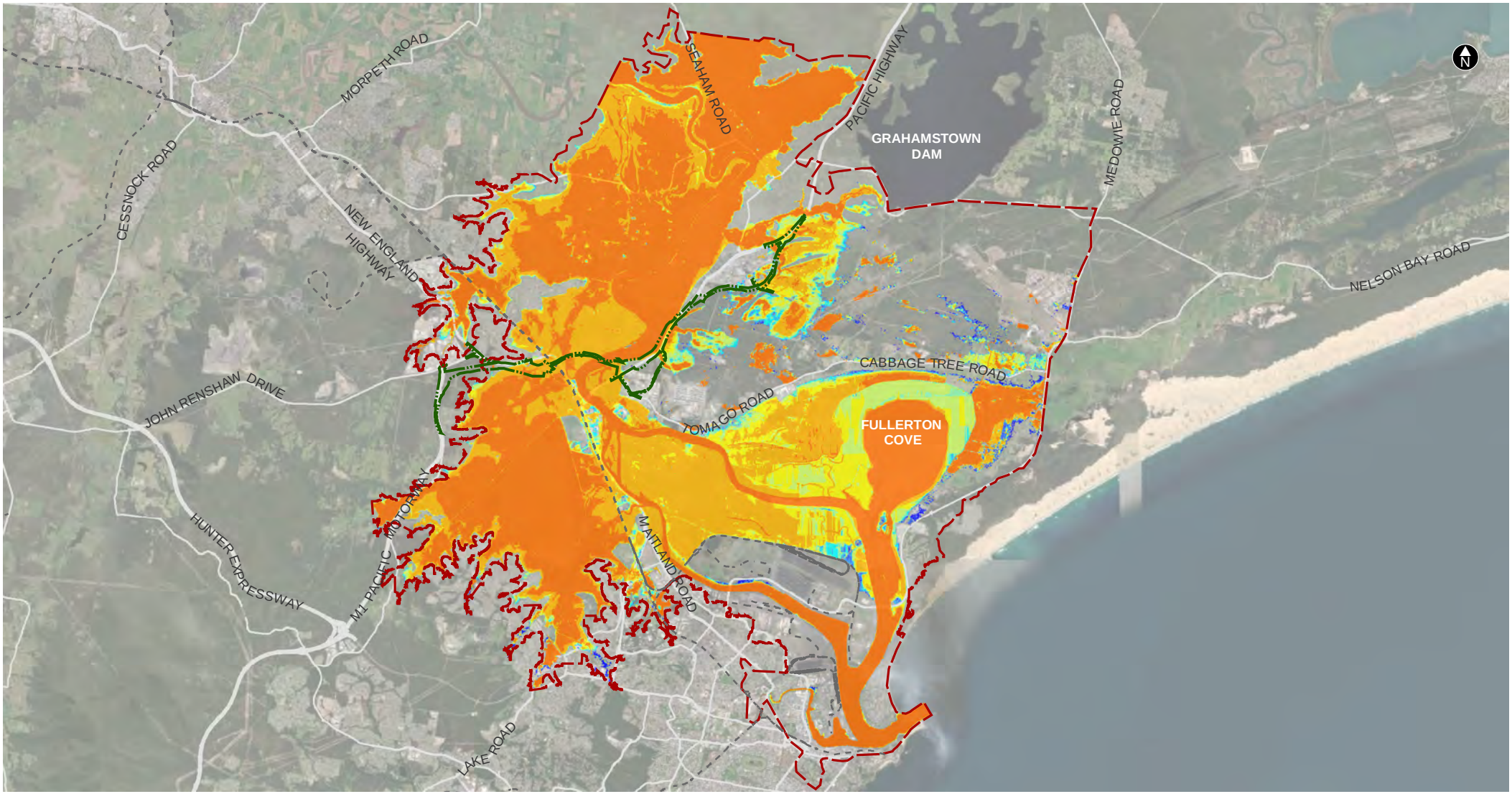
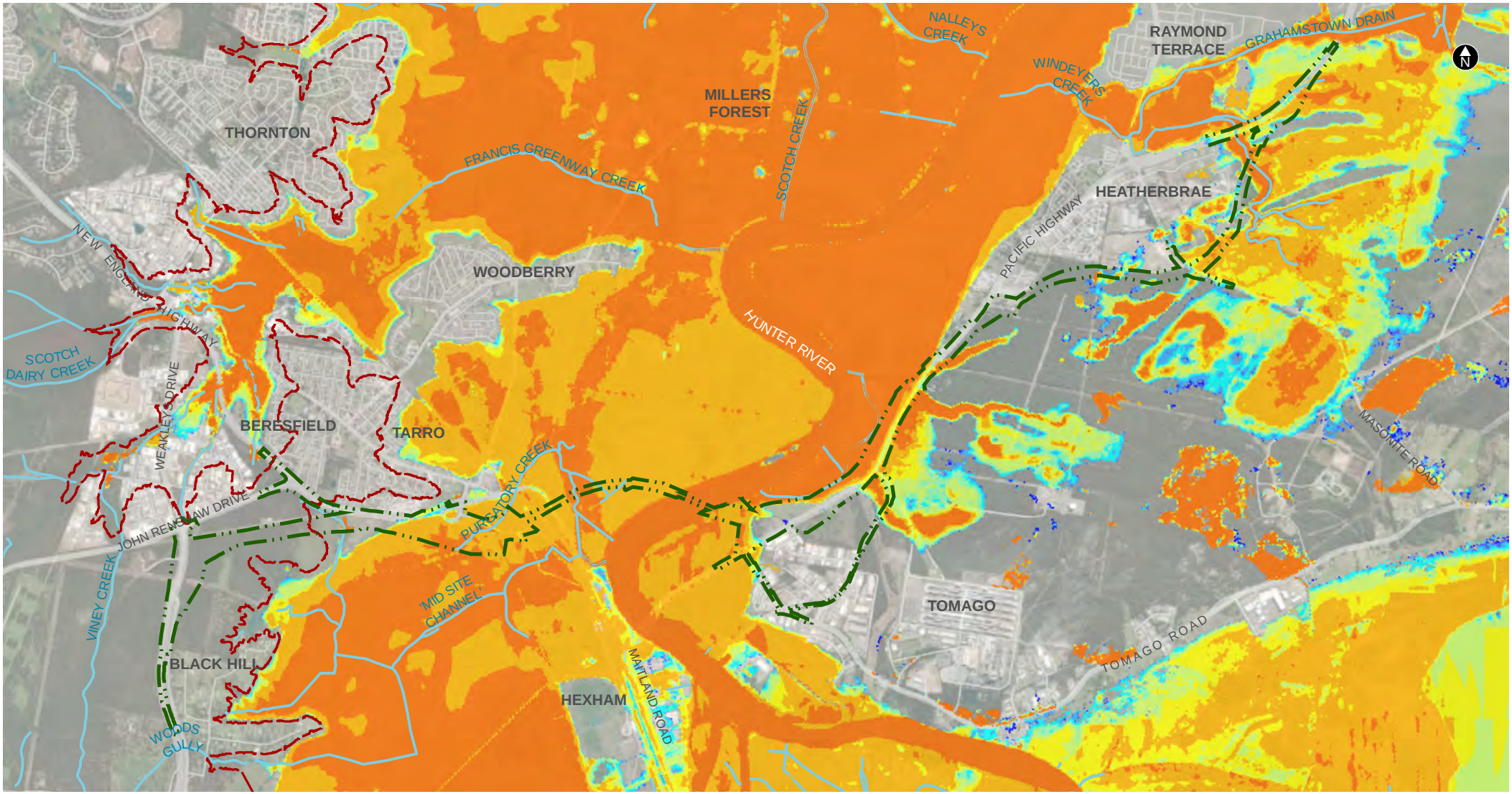


Figure C-23 Duration of inundation above 0.5m depth - Existing - 1% AEP (map 1 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_023_C23_Inundation_Duration_1_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Duration of inundation (hours)

0 - 3

3 - 6

6 - 12

12 - 18

18 - 24

24 - 36

36 - 48

48 - 72

72 - 96

>96

0 1 2km

Figure C-23 Duration of inundation above 0.5m depth - Existing - 1% AEP (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_023_C23_Inundation_Duration_1_AEP_JAC_A4L_175000_V02.mxd

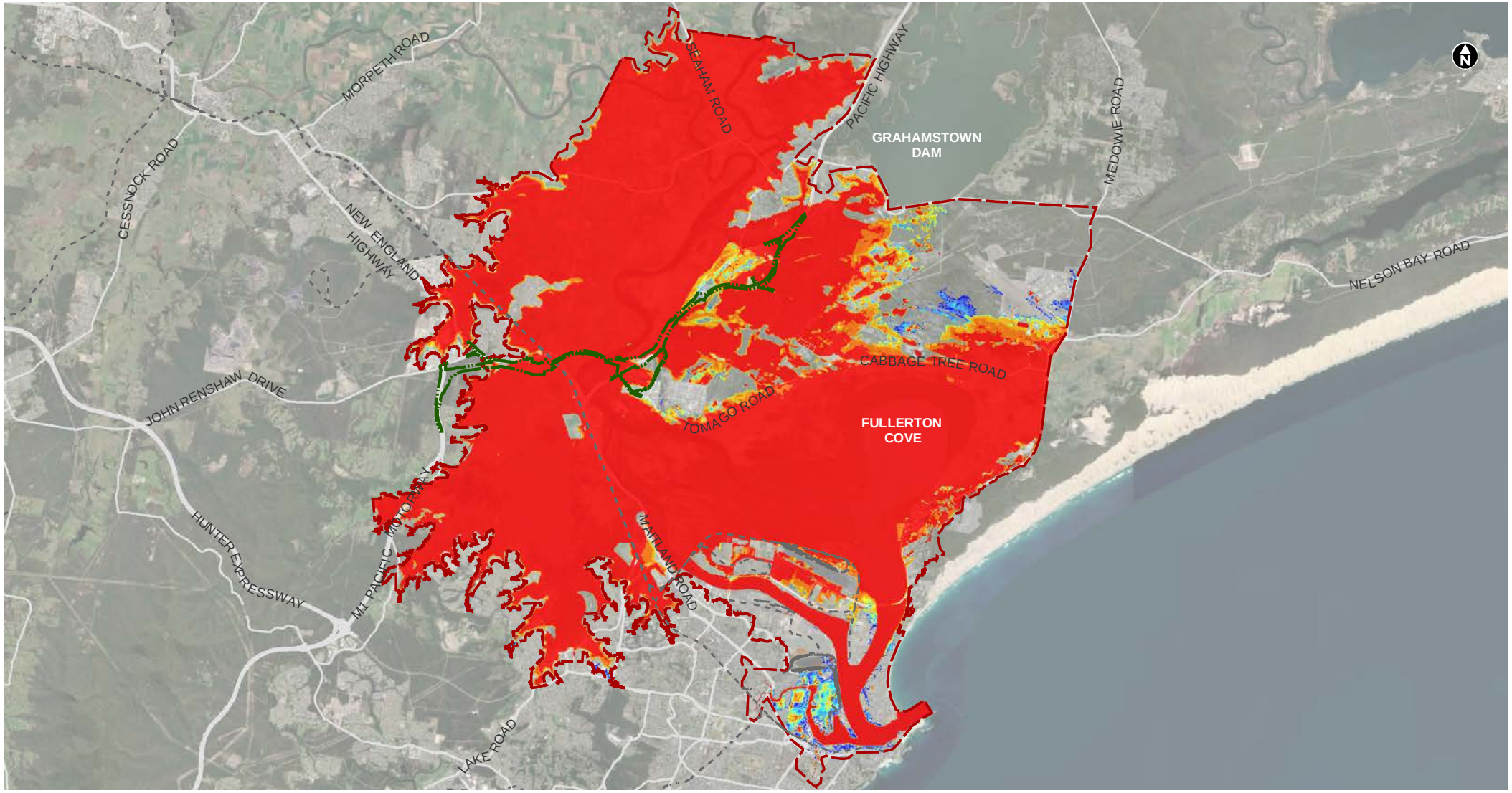


Figure C-24 Duration of inundation above 0.5m depth - Existing - Probable maximum flood (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_024_C24_Inundation_Duration_ProbMax_AEP_JAC_A4L_175000_V01.mxd

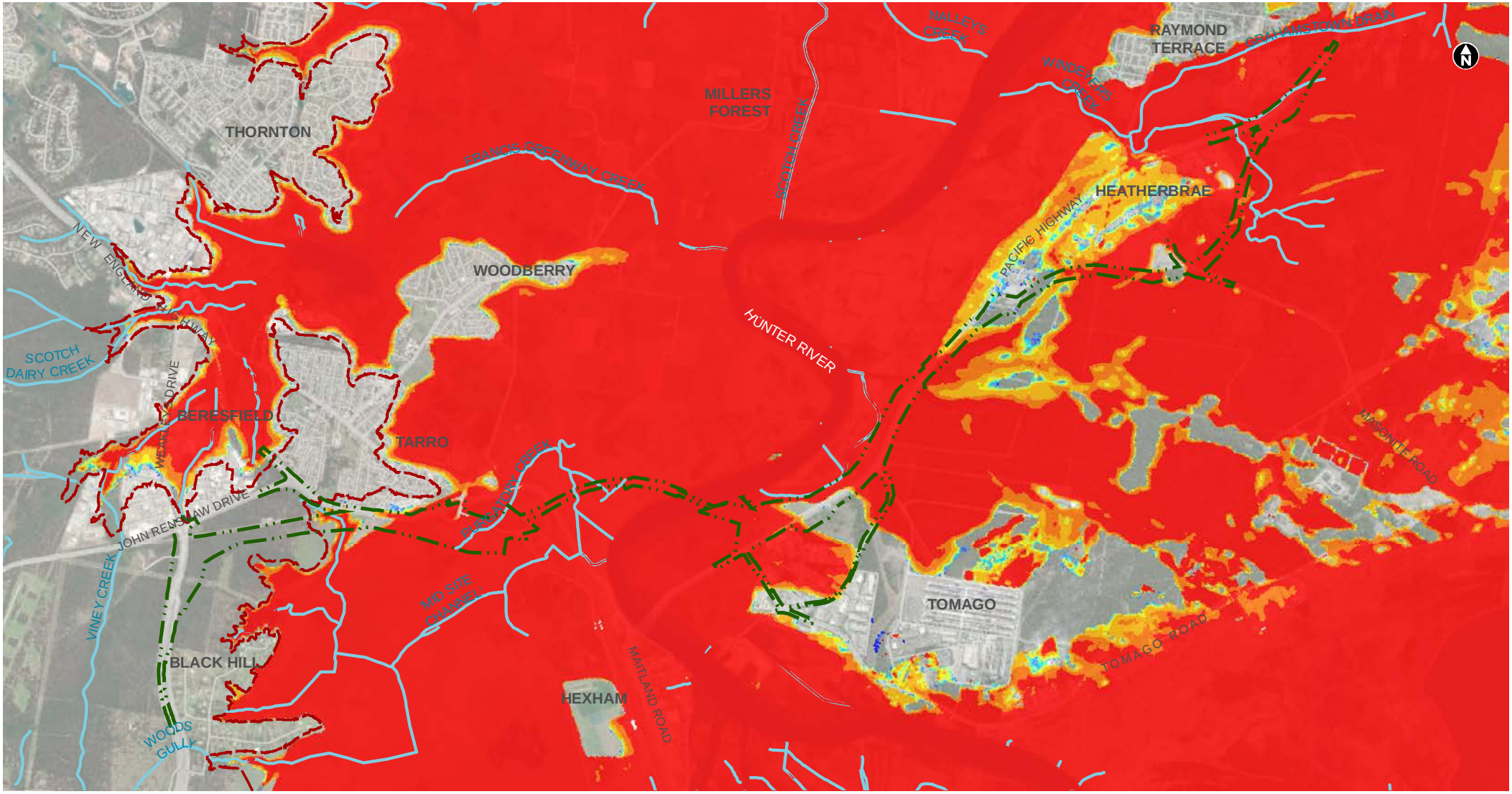
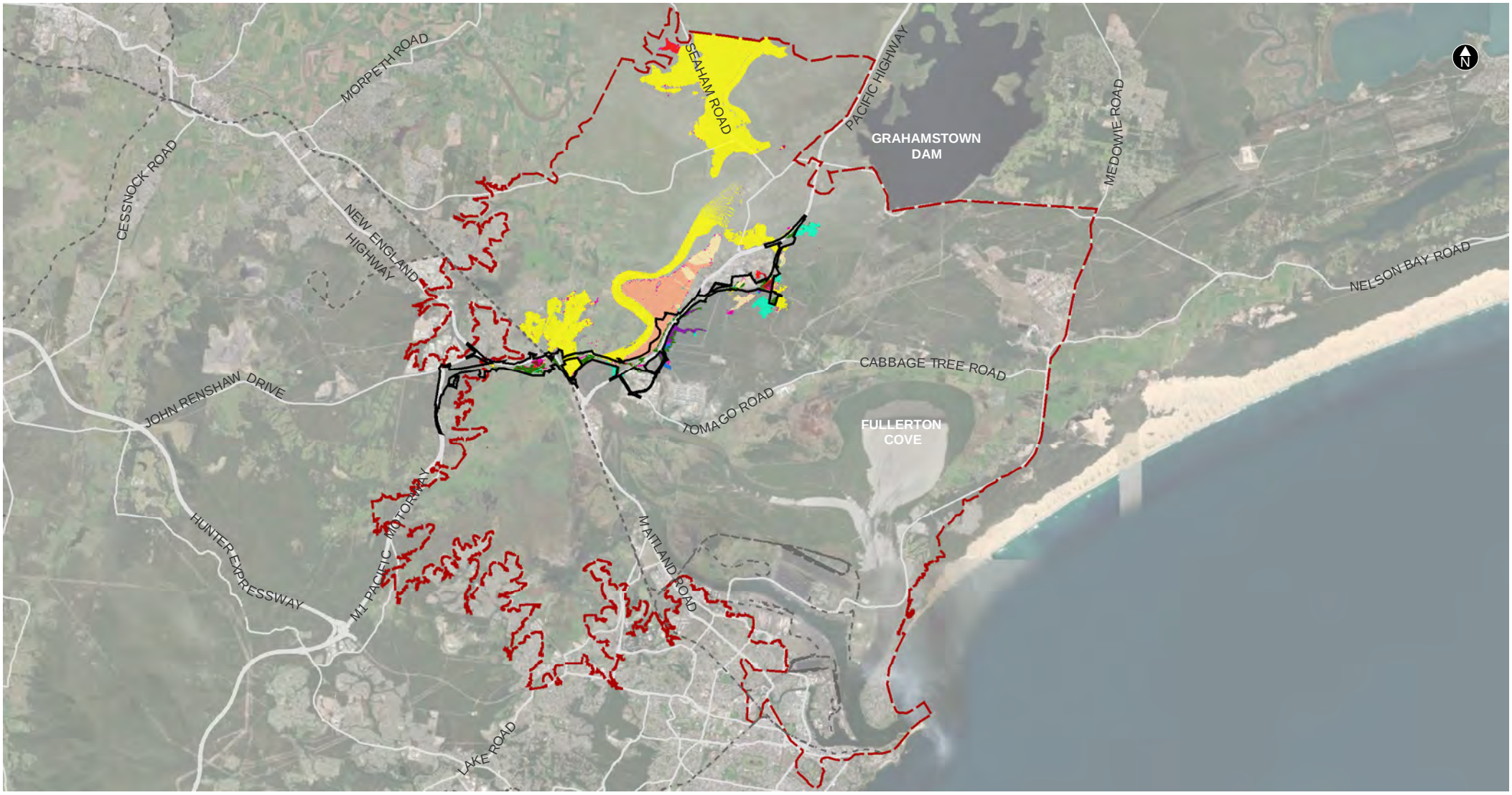


Figure C-24 Duration of inundation above 0.5m depth - Existing - Probable maximum flood (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_024_C24_Inundation_Duration_ProbMax_AEP_JAC_A4L_175000_V01.mxd

Appendix D Flood impact maps – Construction



Flooding study area

Construction footprint

Railway

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4

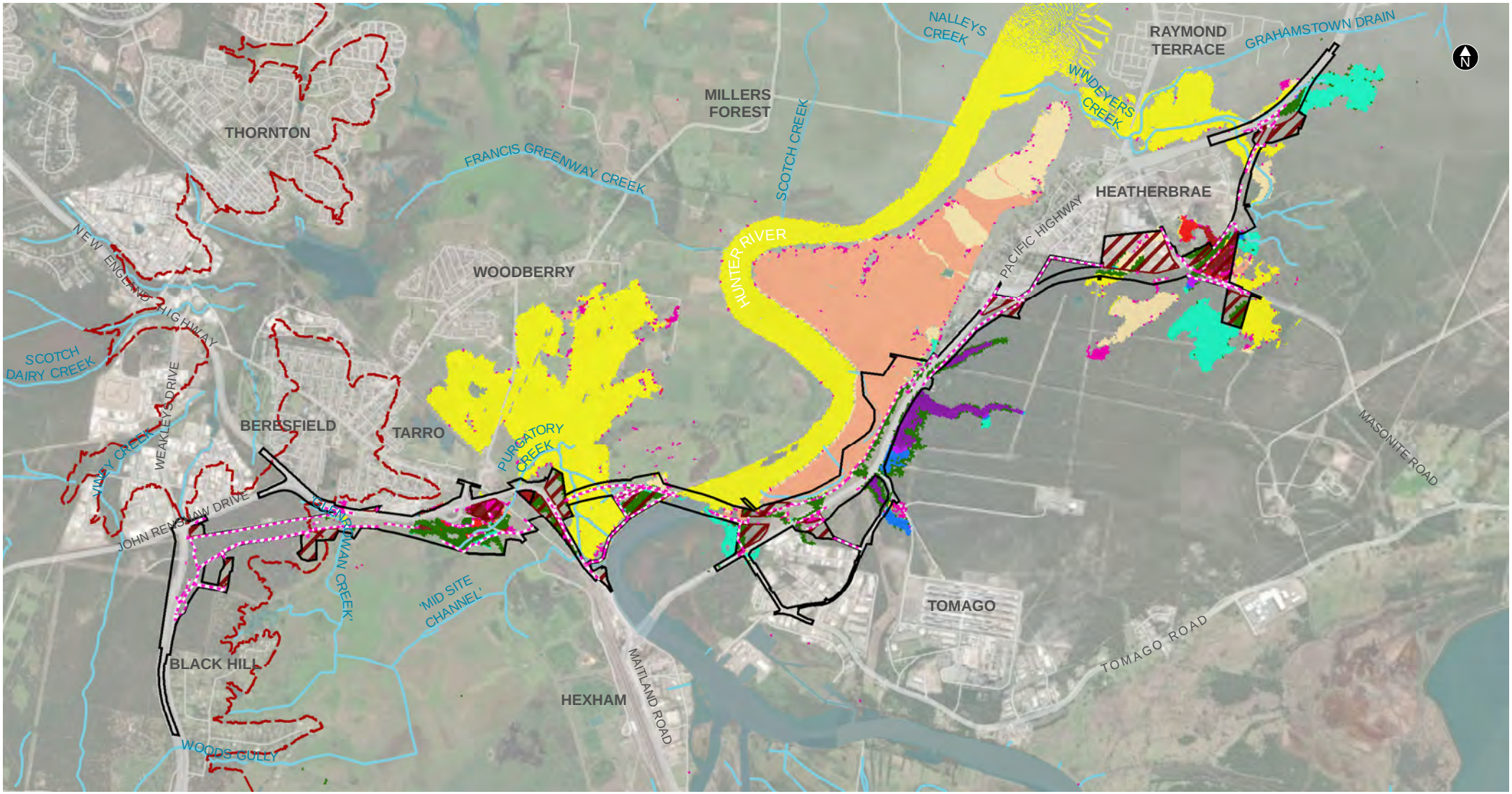
Change - Wet and Dry

- Was Wet Now Dry
- Was Dry Now Wet

0 4 8km

Figure D-1 Change in flood level - Construction phase - 20% AEP (map 1 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_025_D1_Change_in_Flood_Level_Construction_20_AEP_JAC_A4L_175000_V02.mxd



Flooding study area

Construction footprint

Ancillary facility

Access and haulage roads

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4

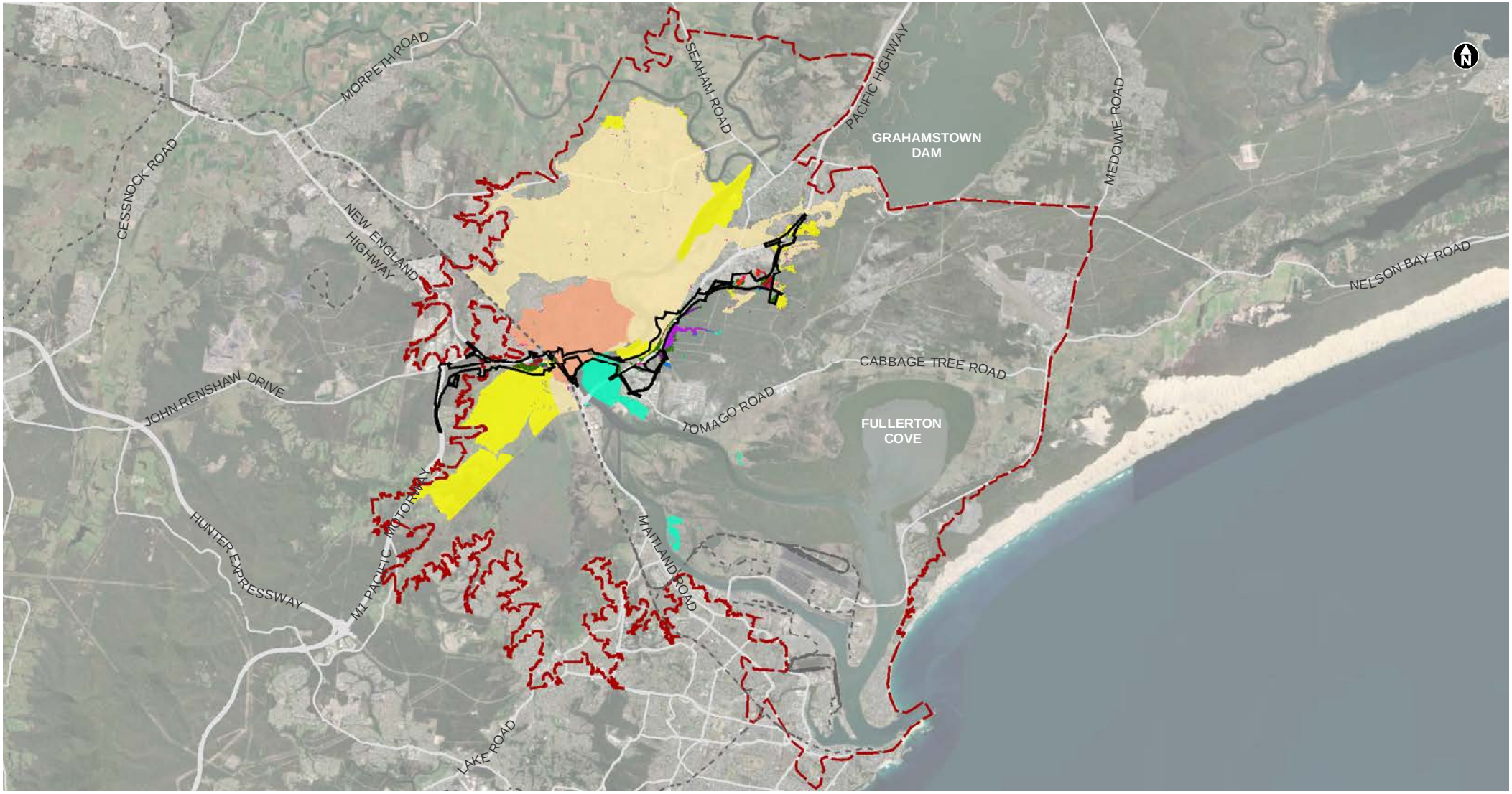
Change - Wet and Dry

- Was Wet Now Dry
- Was Dry Now Wet

0 1 2km

Figure D-1 Change in flood level - Construction phase - 20% AEP (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_025_D1_Change_in_Flood_Level_Construction_20_AEP_JAC_A4L_175000_V02.mxd



Flooding study area
Construction footprint
Railway

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4

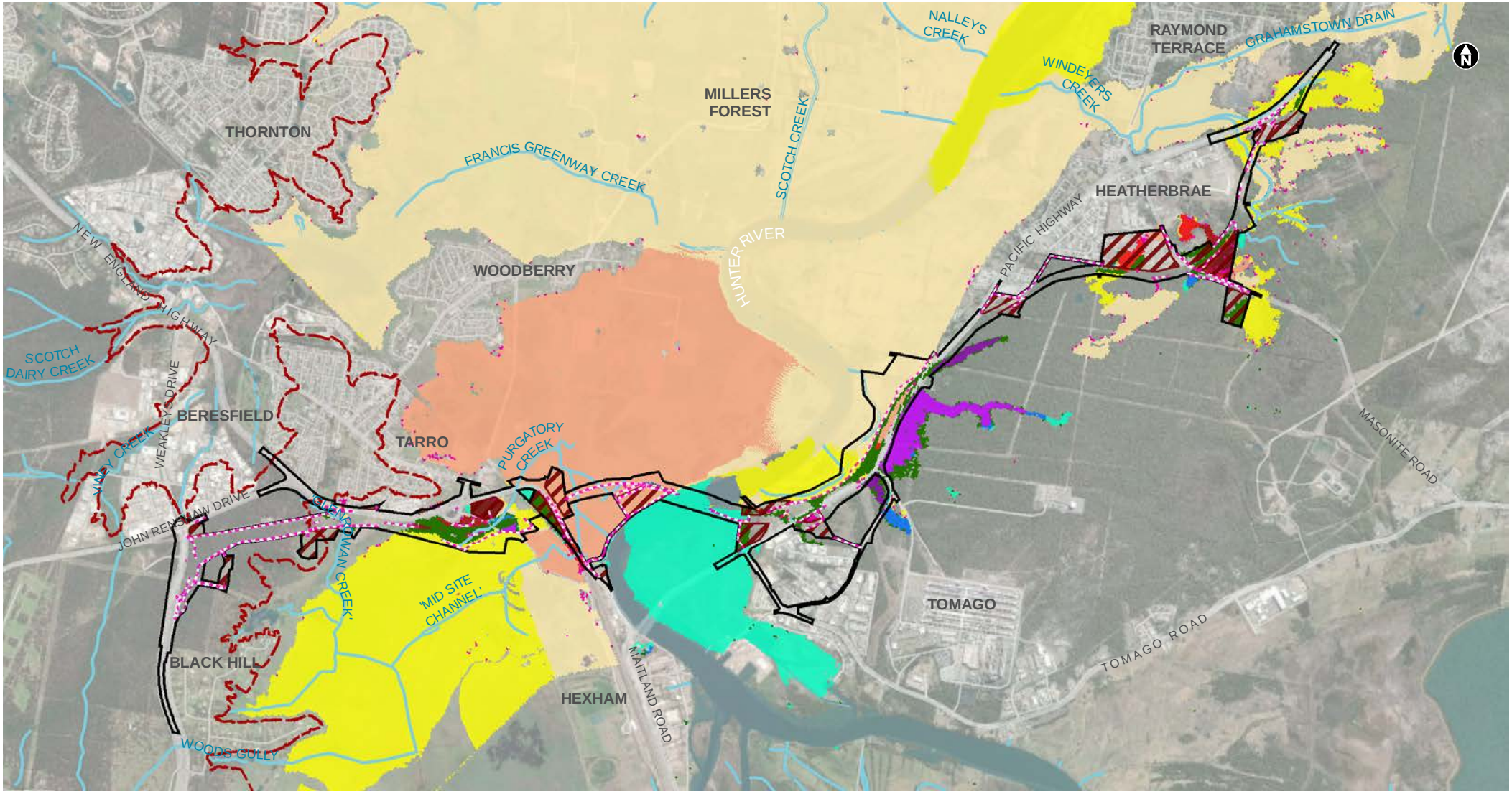
Change - Wet and Dry

- Was Wet Now Dry
- Was Dry Now Wet

0 4 8km

Figure D-2 Change in flood level - Construction phase - 10% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_026_D2_Change_in_Flood_Level_Construction_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

Change in flood level from existing case (m)

< -0.4
-0.4 - -0.25
-0.25 - -0.1
-0.1 - -0.01
-0.01 - 0.01 (not shown)
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.4
> 0.4

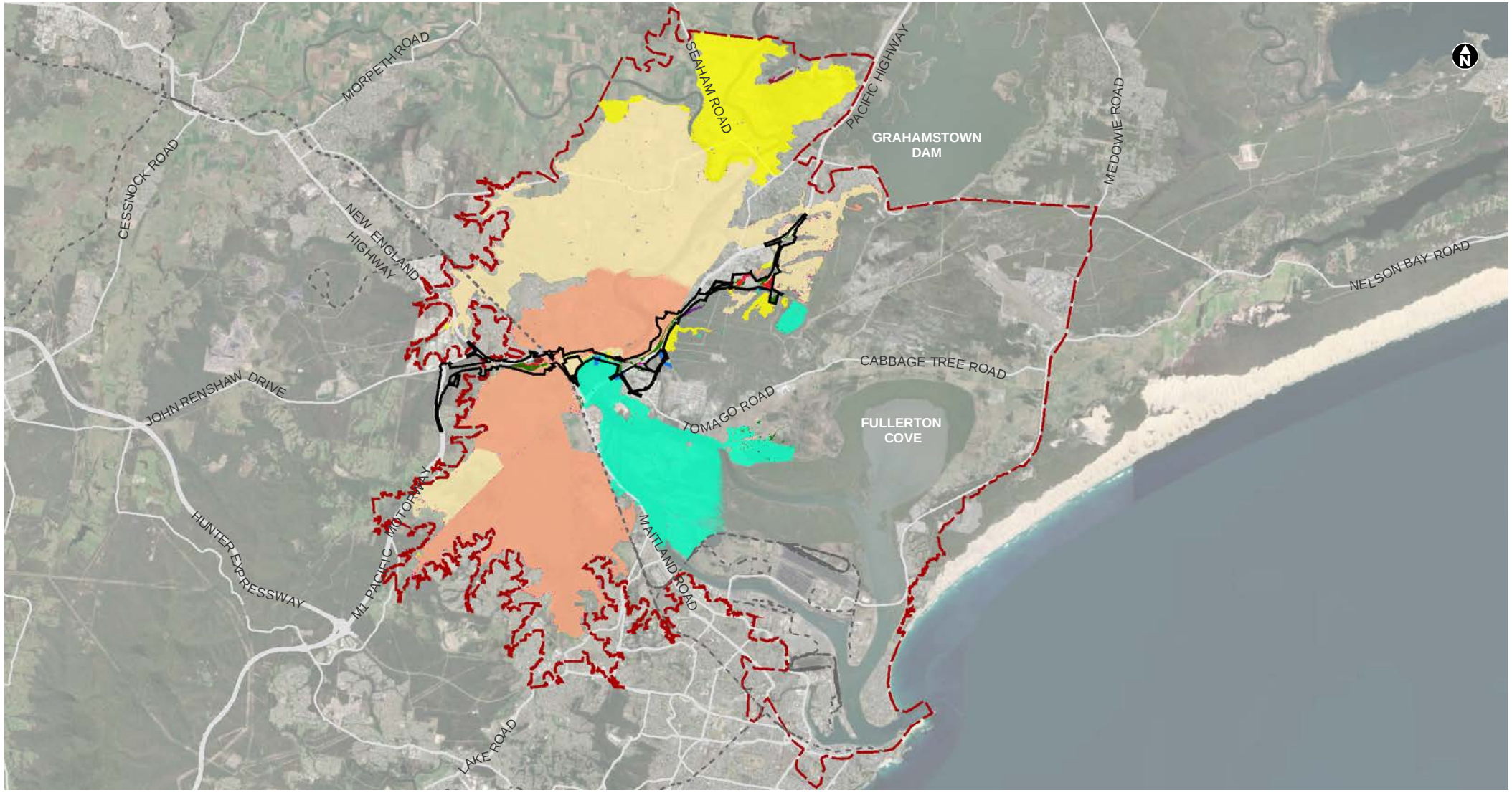
Change - Wet and Dry

Was Wet Now Dry
Was Dry Now Wet

0 1 2km

Figure D-2 Change in flood level - Construction phase - 10% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_026_D2_Change_in_Flood_Level_Construction_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Railway

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4

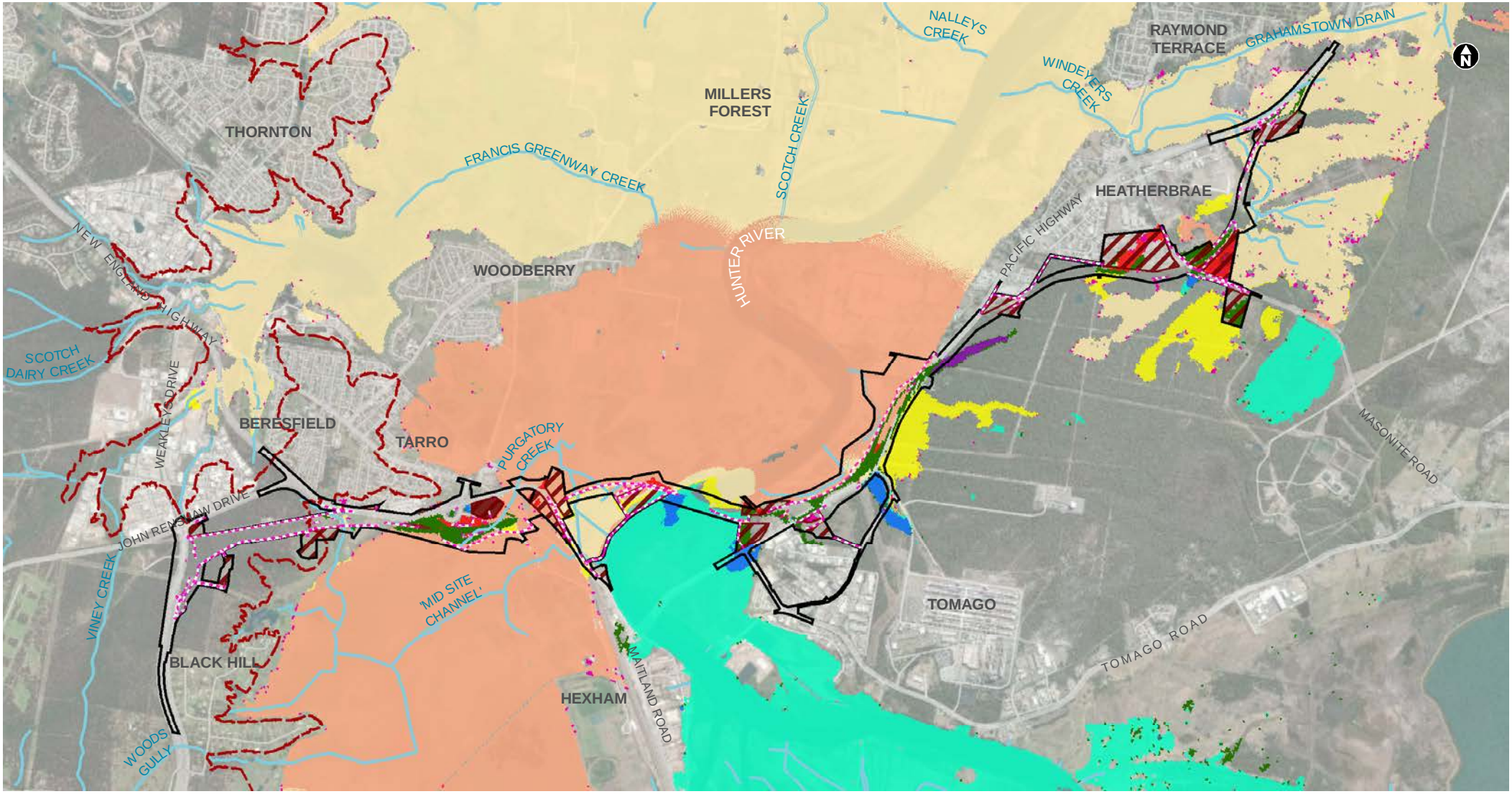
Change - Wet and Dry

- Was Wet Now Dry
- Was Dry Now Wet

0 4 8km

Figure D-3 Change in flood level - Construction phase - 5% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_027_D3_Change_in_Flood_Level_Construction_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

Change in flood level from existing case (m)

< -0.4
-0.4 - -0.25
-0.25 - -0.1
-0.1 - -0.01
-0.01 - 0.01 (not shown)
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.4
> 0.4

Change - Wet and Dry

Was Wet Now Dry
Was Dry Now Wet

0 1 2km

Figure D-3 Change in flood level - Construction phase - 5% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_027_D3_Change_in_Flood_Level_Construction_5_AEP_JAC_A4L_175000_V01.mxd

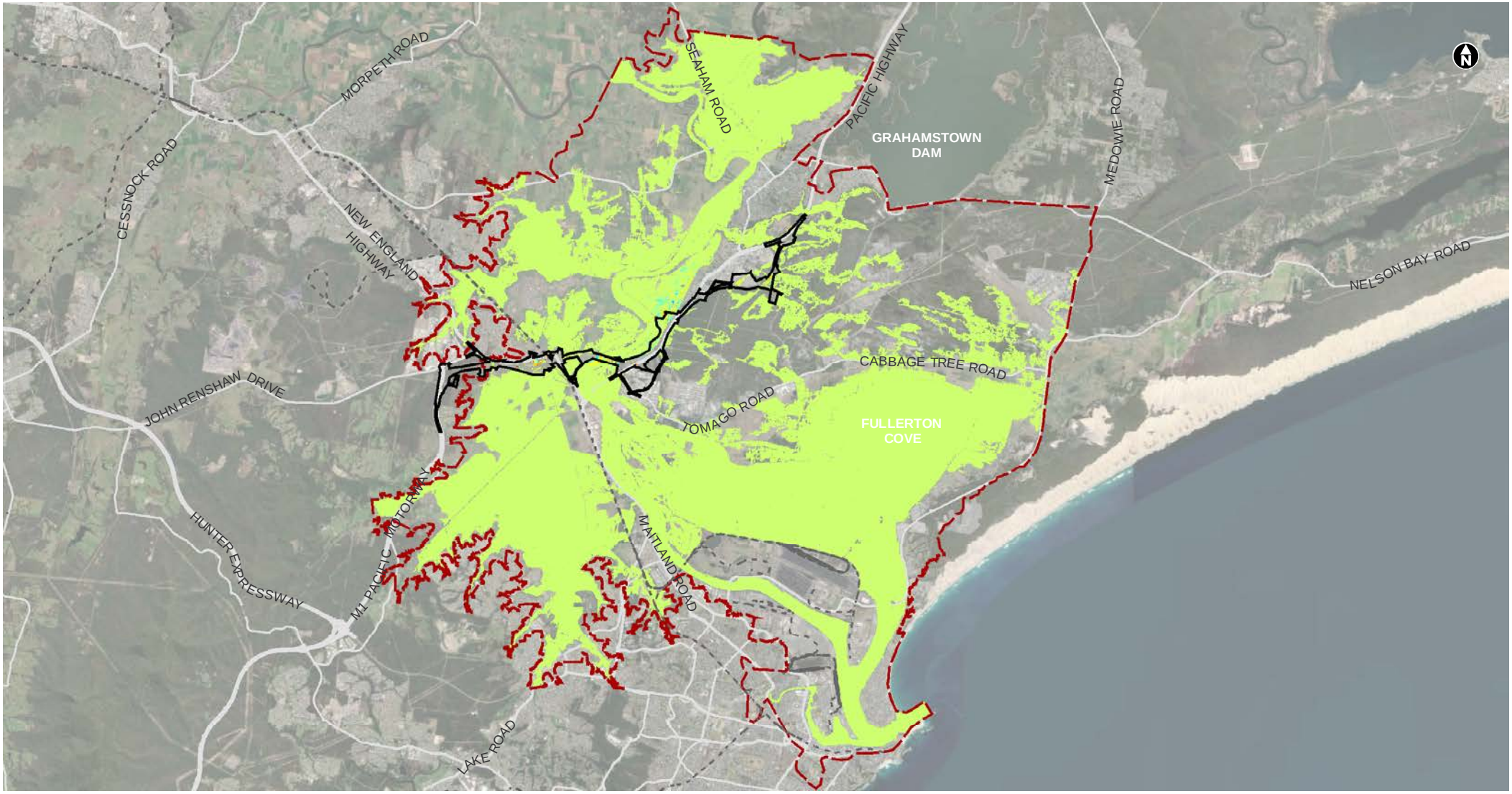
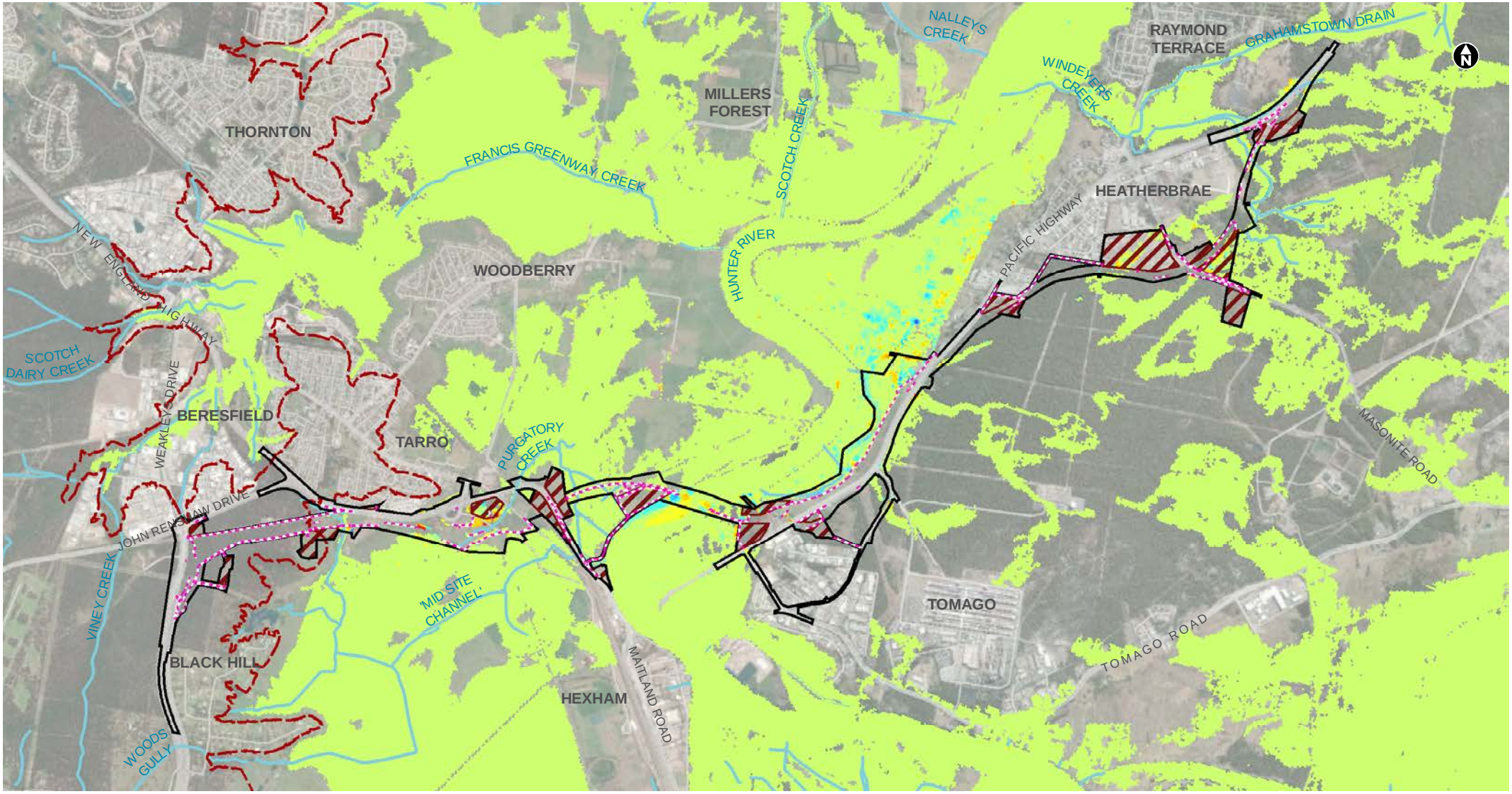


Figure D-4 Change in flow velocity - Construction phase - 20% AEP (map 1 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_028_D4_Change_in_FlowVelocity_Construction_20_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

Change in velocity from existing case (m/s)

< -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
>1

0 1 2km

Figure D-4 Change in flow velocity - Construction phase - 20% AEP (map 2 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_028_D4_Change_in_FlowVelocity_Construction_20_AEP_JAC_A4L_175000_V01.mxd

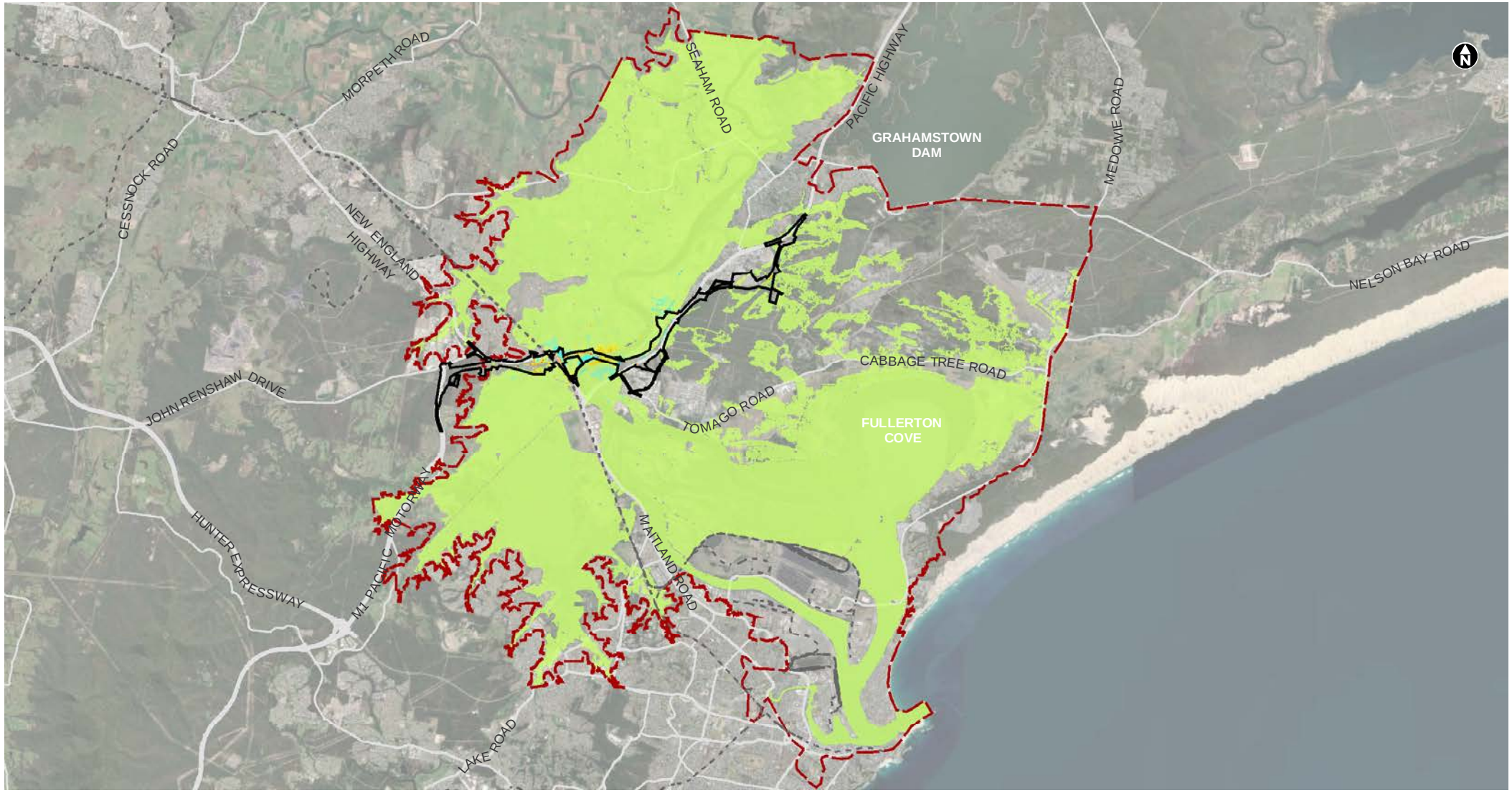
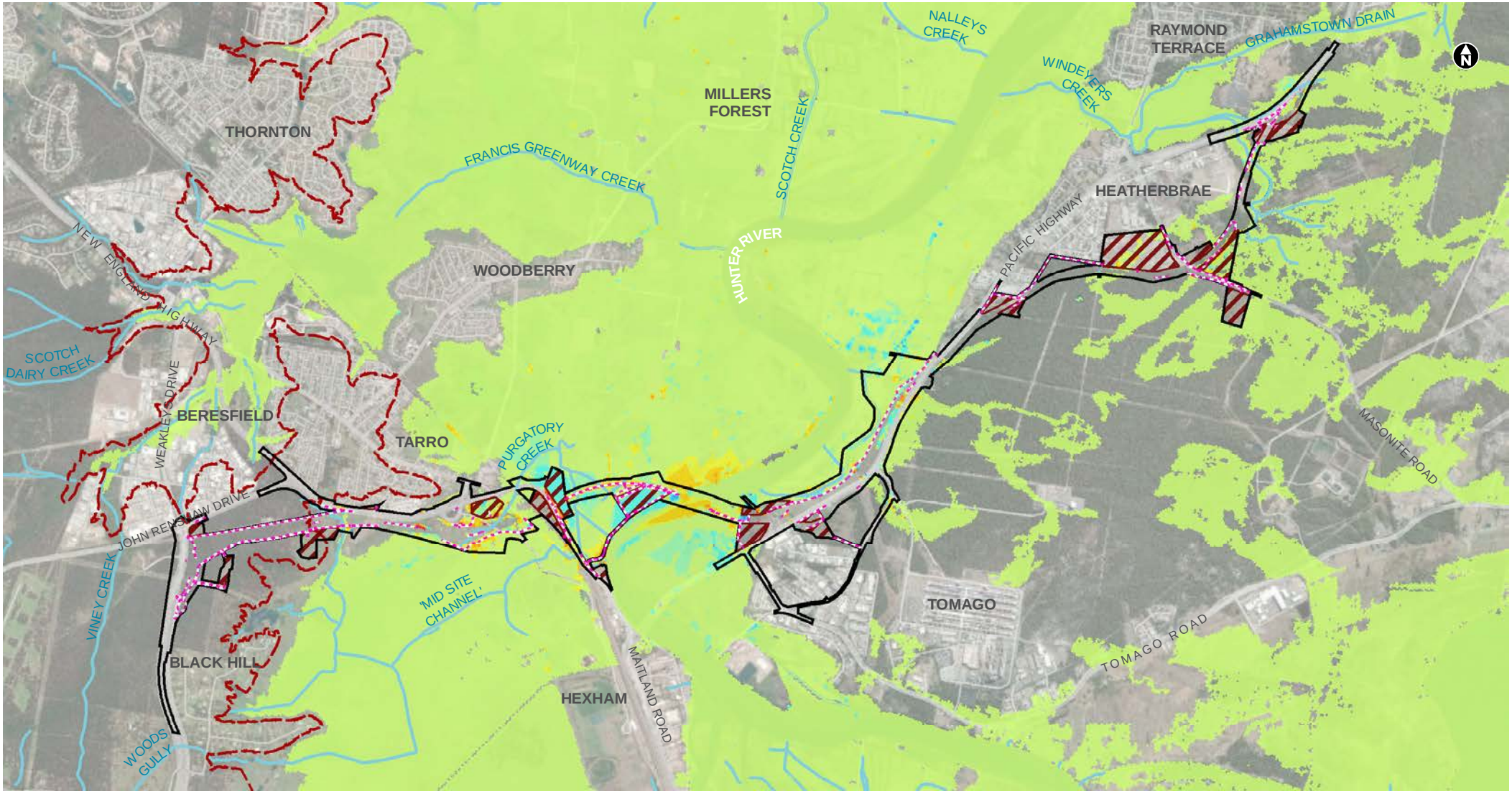


Figure D-5 Change in flow velocity - Construction phase - 10% AEP (map 1 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_029_D5_Change_in_FlowVelocity_Construction_10_AEP_JAC_A4L_175000_V01.mxd



Construction footprint
Limit of mapping
Ancillary facility
Access and haulage roads

Change in velocity from existing case (m/s)

< -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
>1

0 1 2km

Figure D-5 Change in flow velocity - Construction phase - 10% AEP (map 2 of 2)

Date: 11/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_029_D5_Change_in_FlowVelocity_Construction_10_AEP_JAC_A4L_175000_V01.mxd

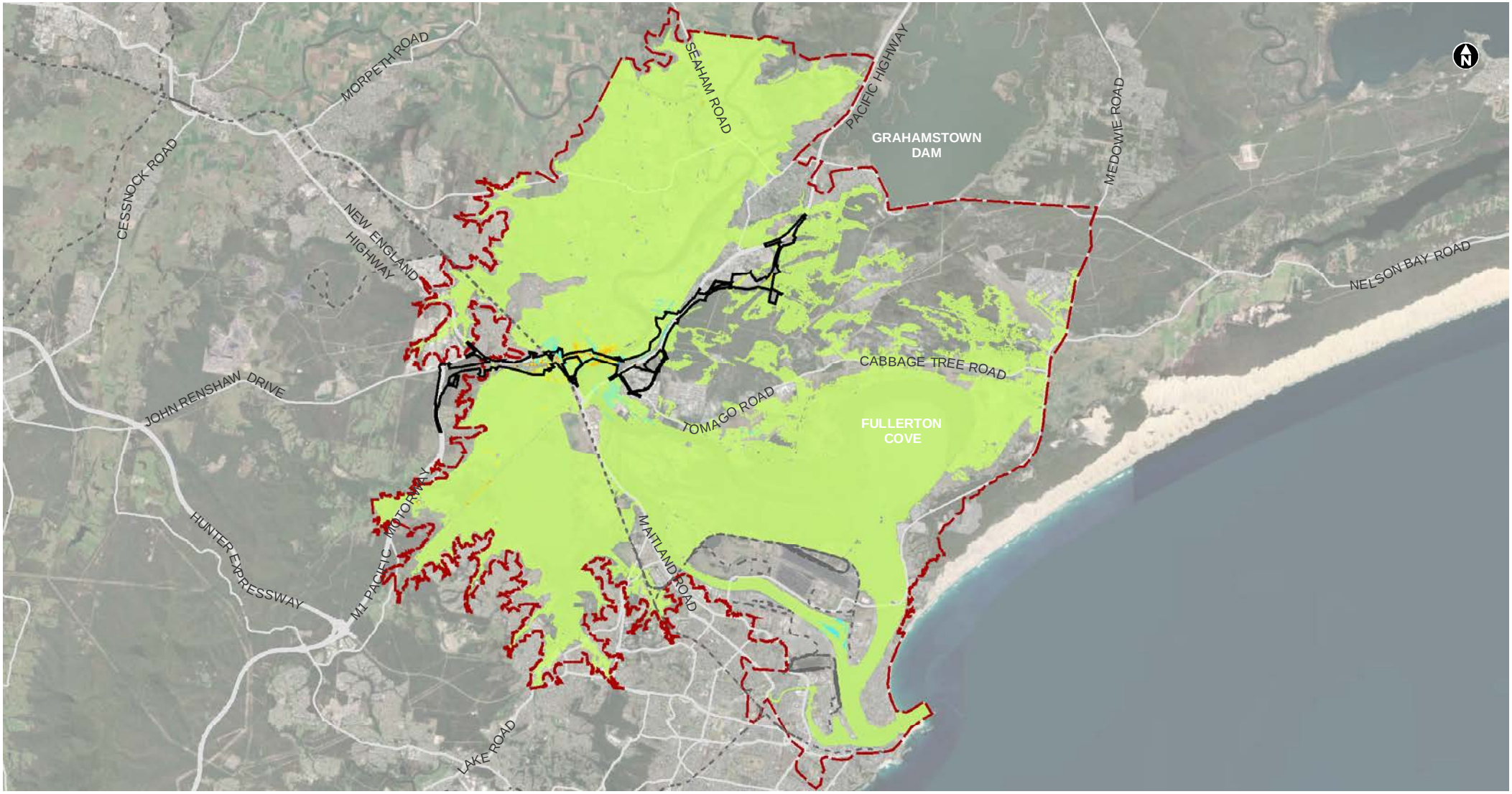
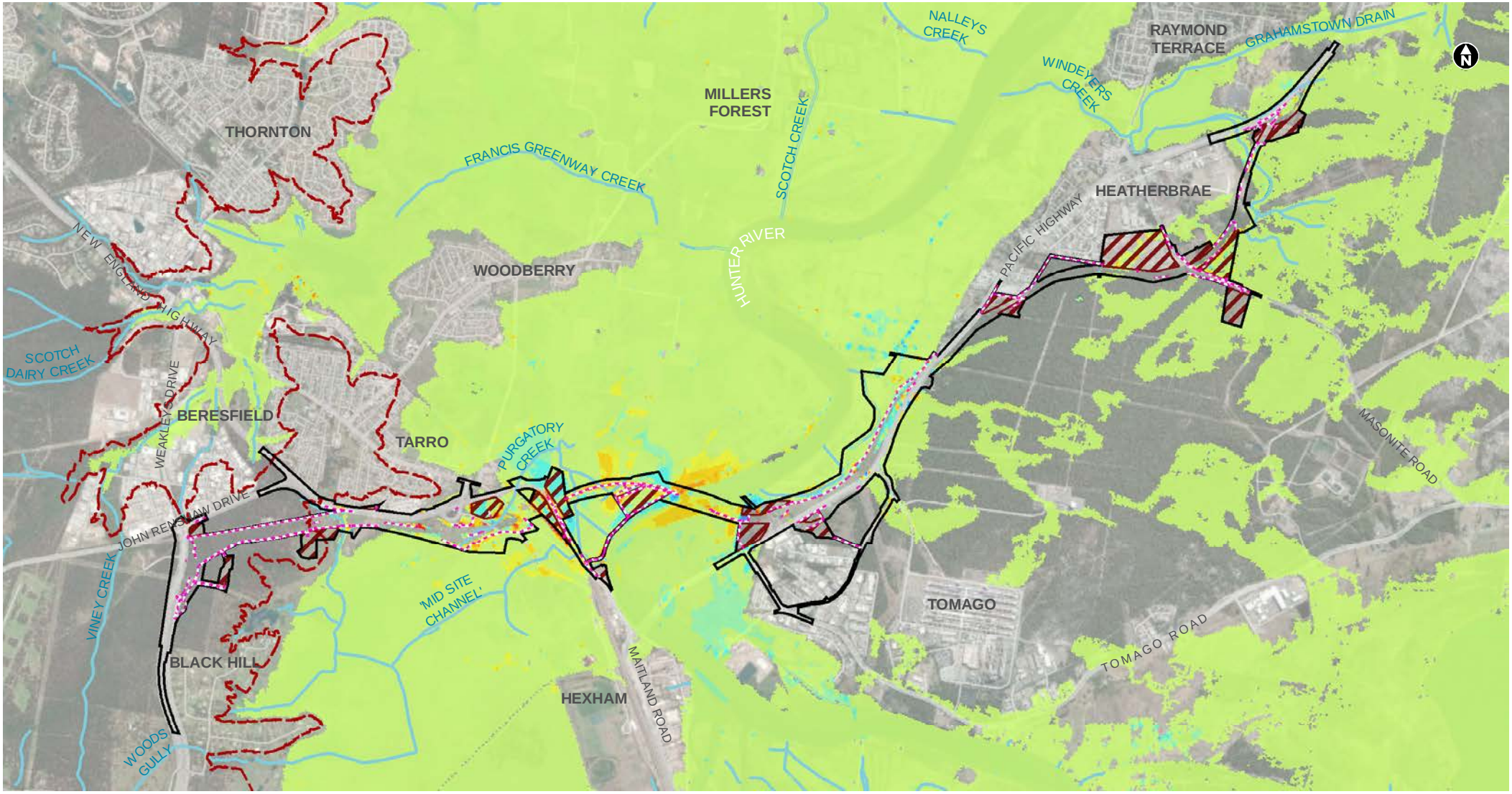


Figure D-6 Change in flow velocity - Construction phase - 5% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_030_D6_Change_in_FlowVelocity_Construction_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

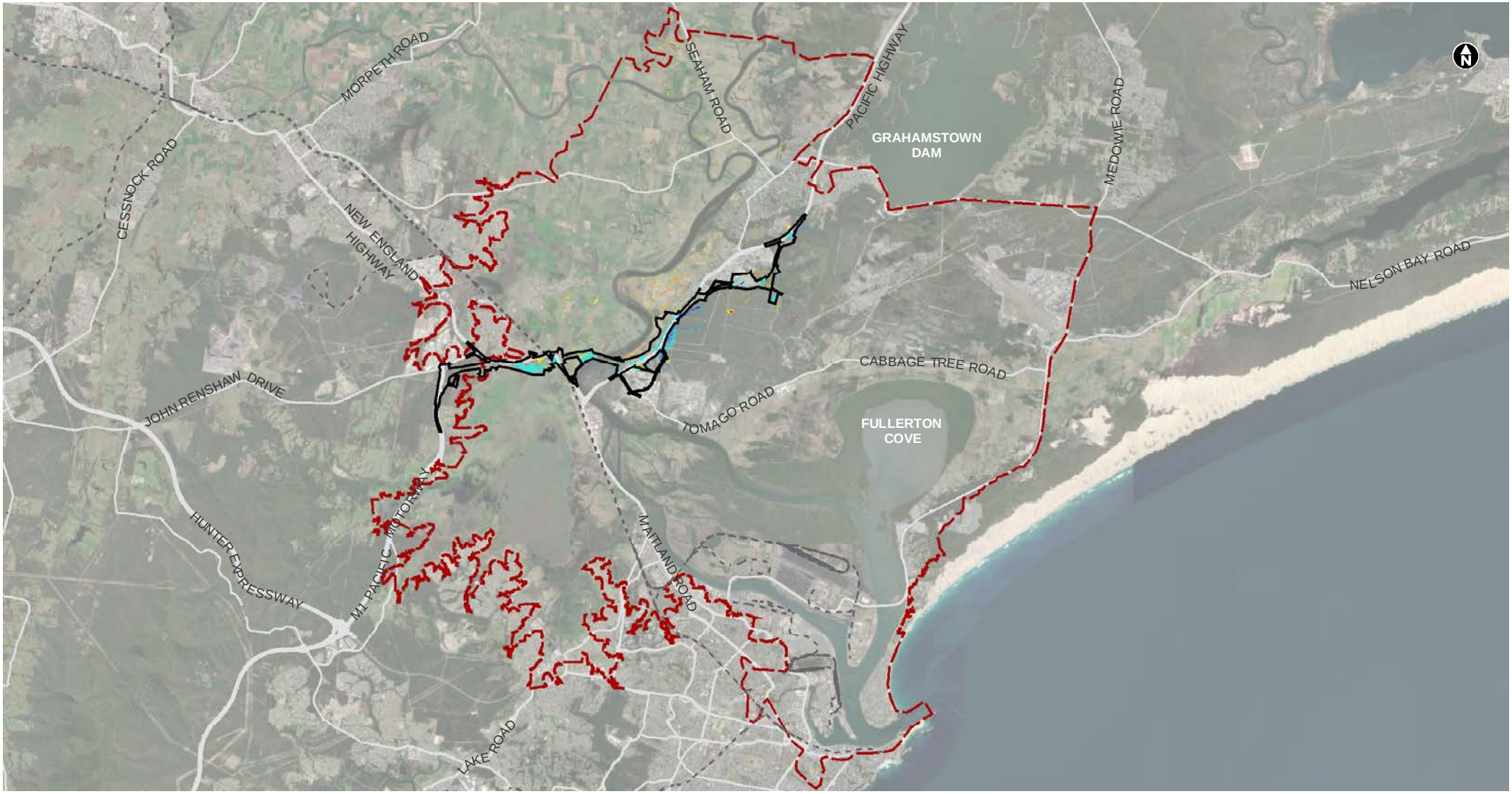
Change in velocity from existing case (m/s)

< -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
>1

0 1 2km

Figure D-6 Change in flow velocity - Construction phase - 5% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_030_D6_Change_in_FlowVelocity_Construction_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Railway

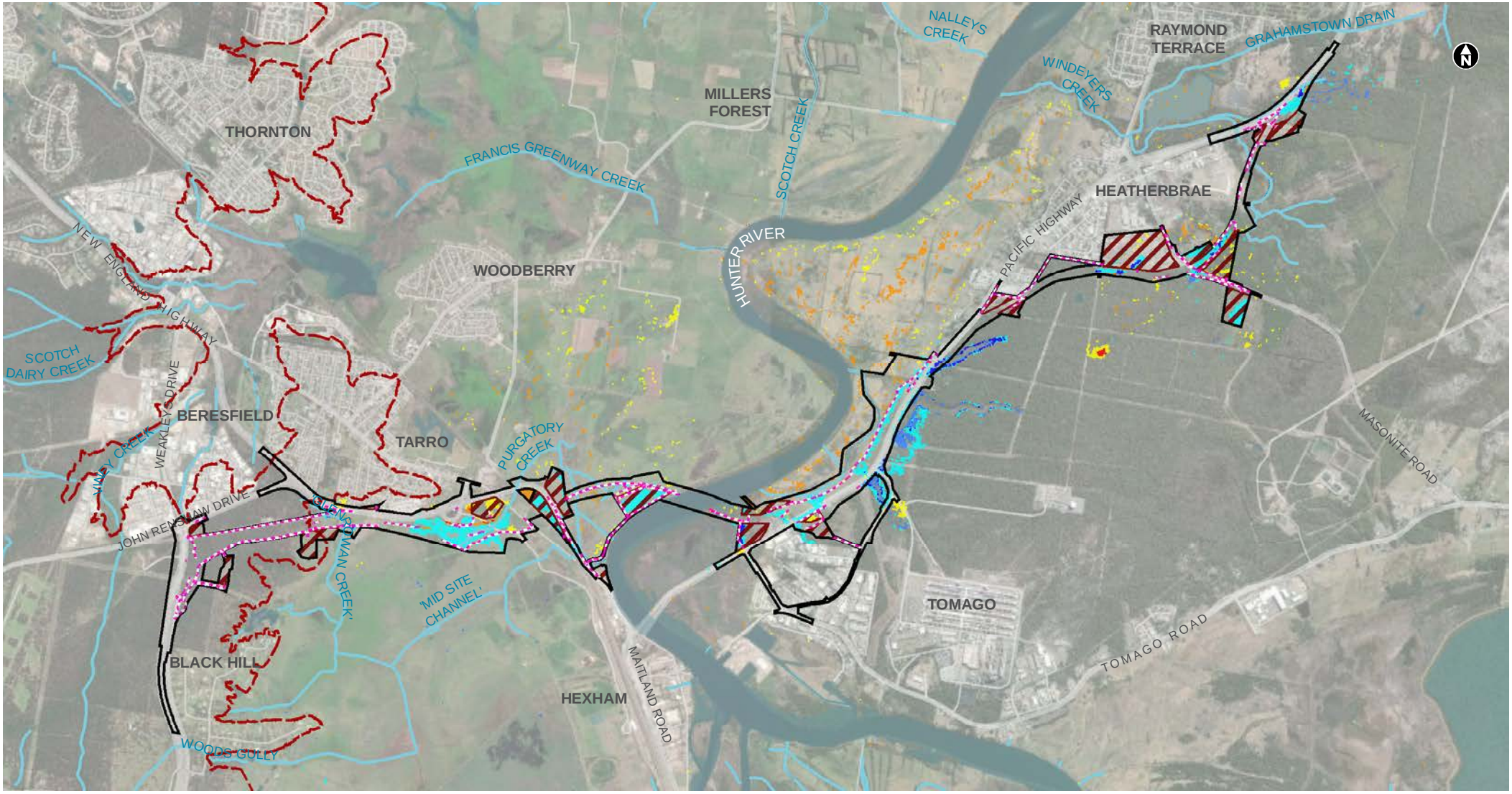
Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

0 4 8km

Figure D-7 Change in flood hazard - Construction phase - 20% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_031_D7_Change_in_Floodhazard_Construction_20_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

Figure D-7 Change in flood hazard - Construction phase - 20% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_031_D7_Change_in_Floodhazard_Construction_20_AEP_JAC_A4L_175000_V01.mxd

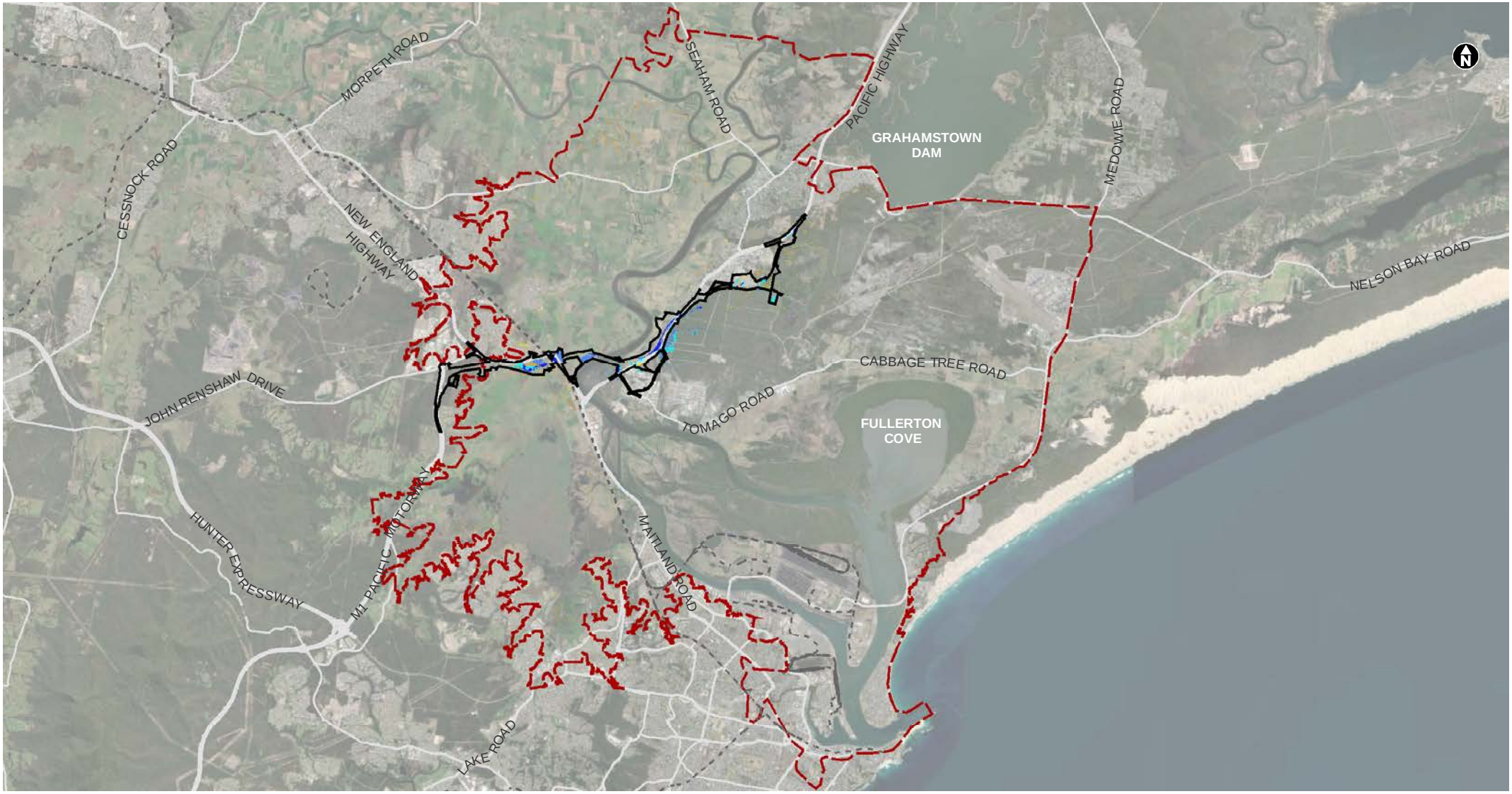
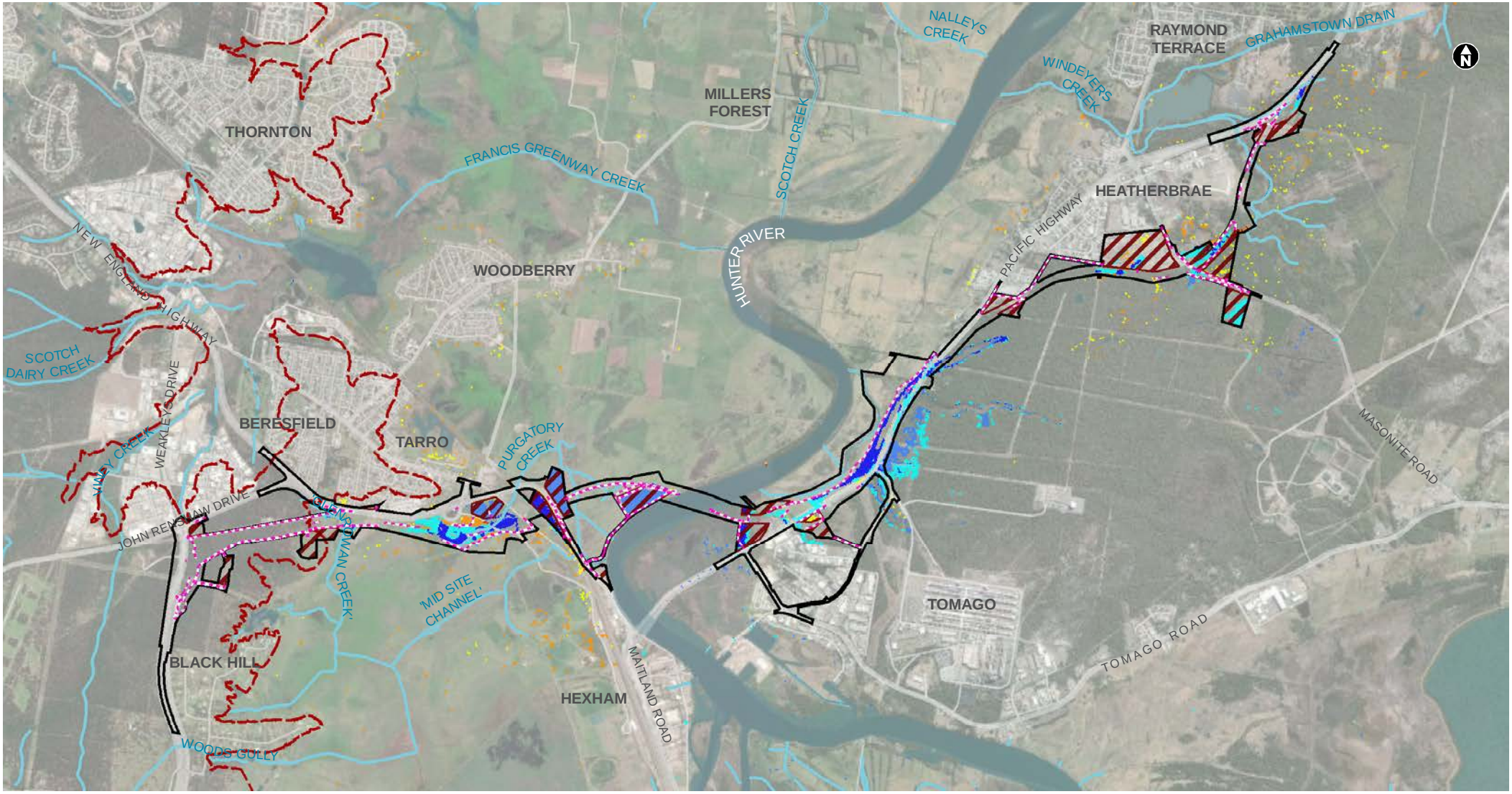


Figure D-8 Change in flood hazard - Construction phase - 10% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_032_D8_Change_in_Floodhazard_Construction_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

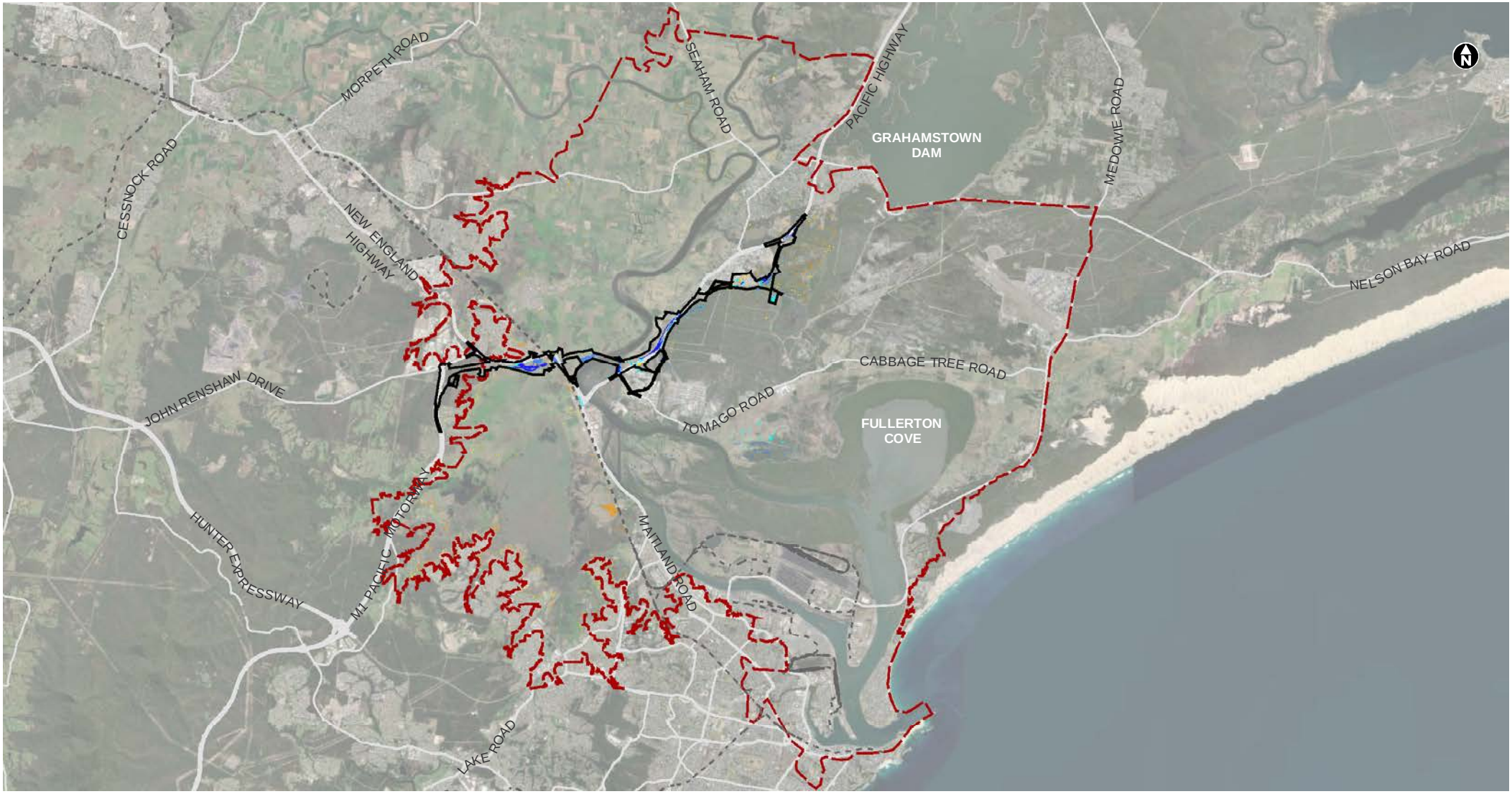
Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

0 1 2km

Figure D-8 Change in flood hazard - Construction phase - 10% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_032_D8_Change_in_Floodhazard_Construction_10_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Railway

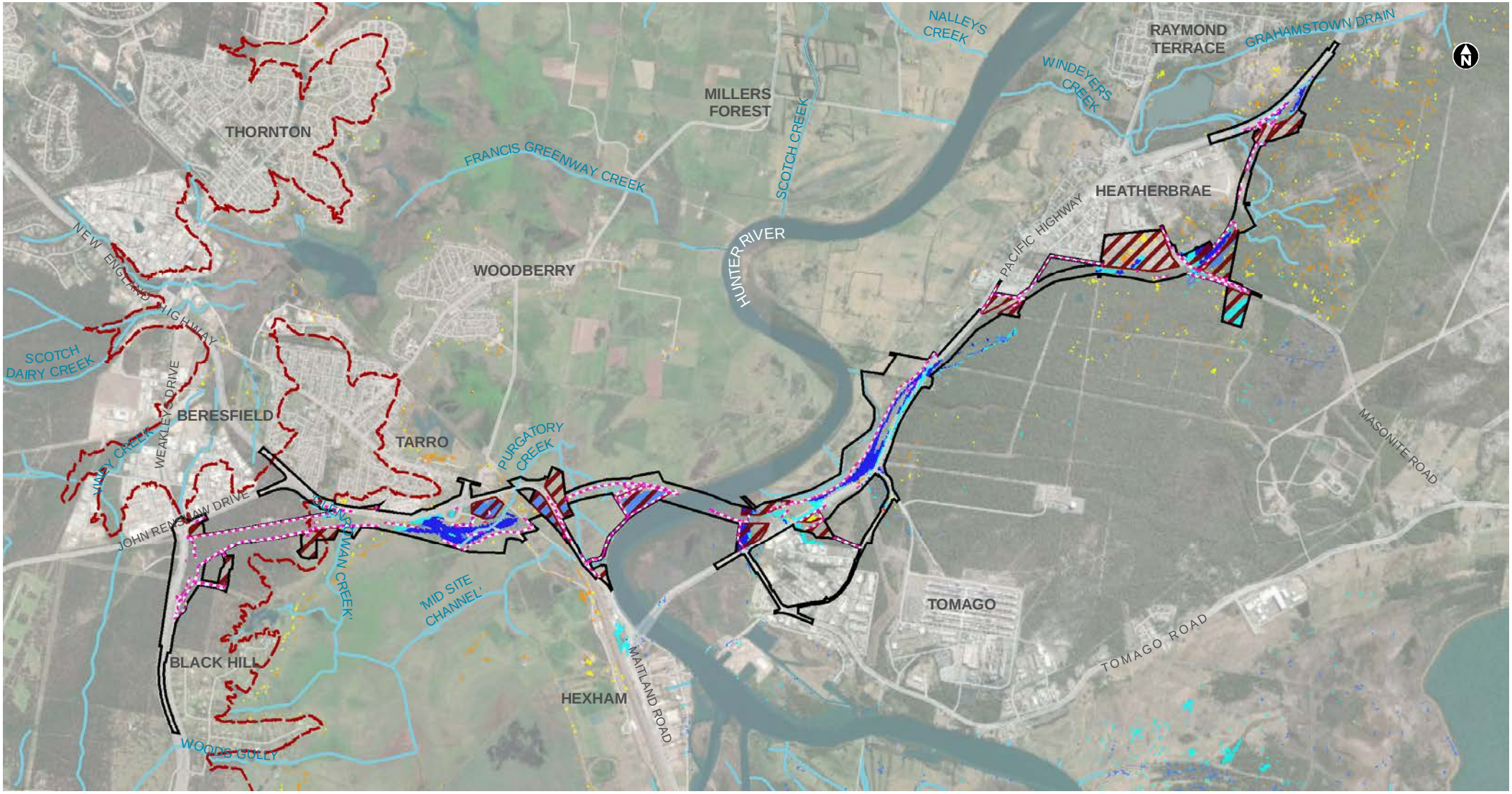
Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

0 4 8km

Figure D-9 Change in flood hazard - Construction phase - 5% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_033_D9_Change_in_Floodhazard_Construction_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area
Construction footprint
Ancillary facility
Access and haulage roads

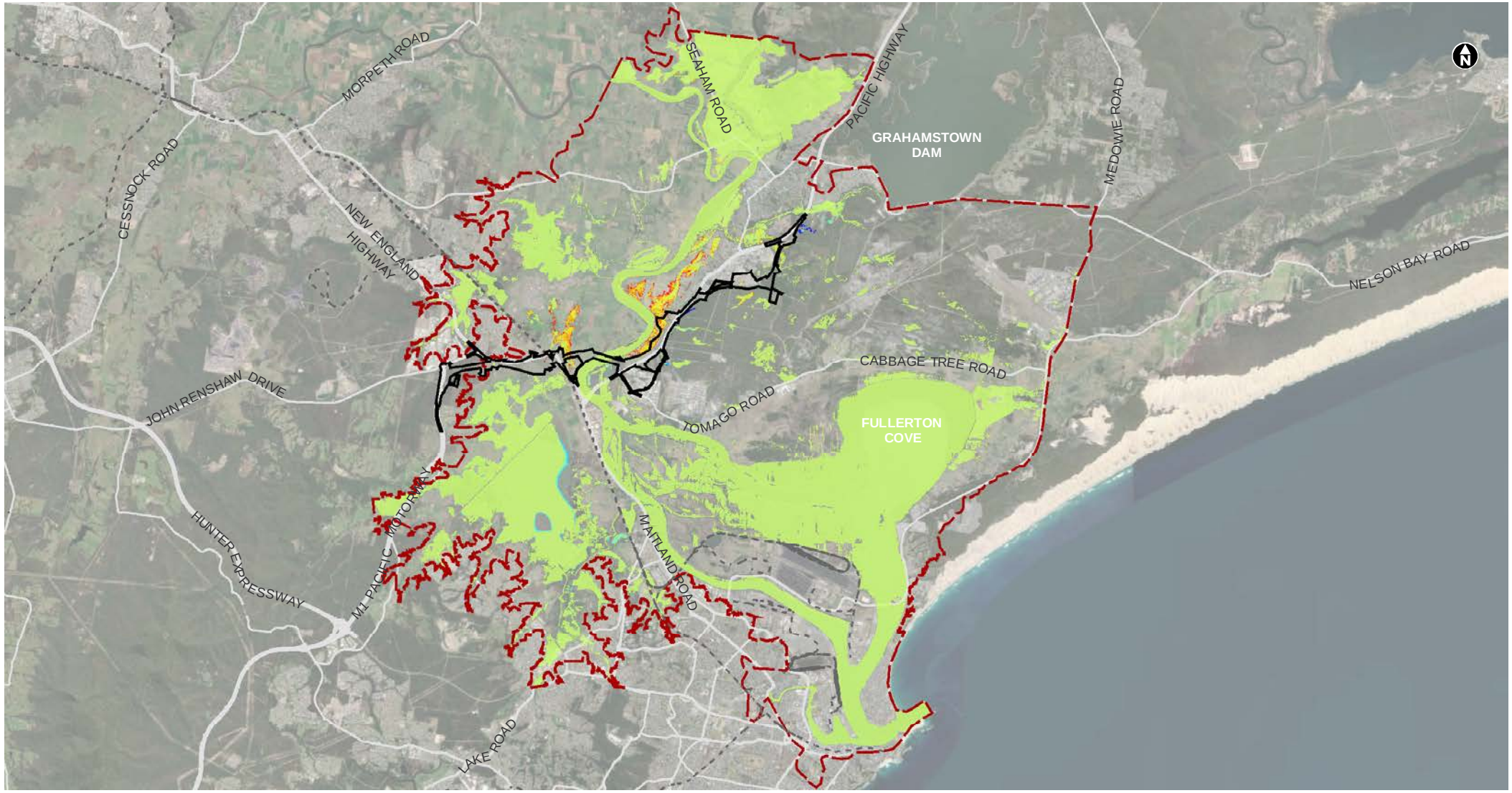
Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

0 1 2km

Figure D-9 Change in flood hazard - Construction phase - 5% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_033_D9_Change_in_Floodhazard_Construction_5_AEP_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Railway

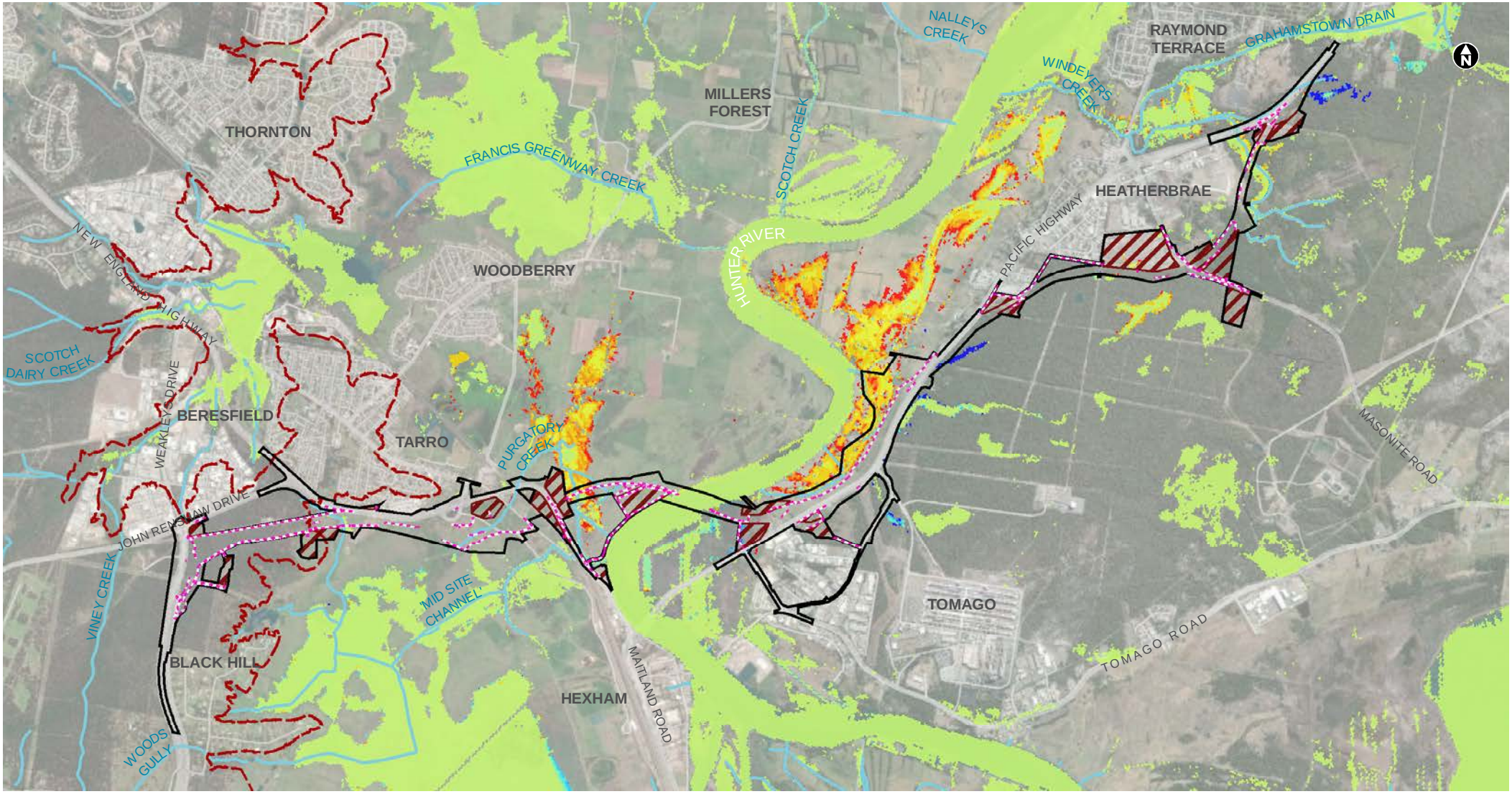
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 4 8km

Figure D-10 Change in duration of inundation - Construction phase - 20% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_034_D10_ChangeInundatonDuration20Construction_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Ancillary facility

Access and haulage roads

Change in duration of inundation from existing case (per cent)

< -50

-50 - -30

-30 - -20

-20 - -10

-10 - -5

-5 - 5

5 - 10

10 - 20

20 - 30

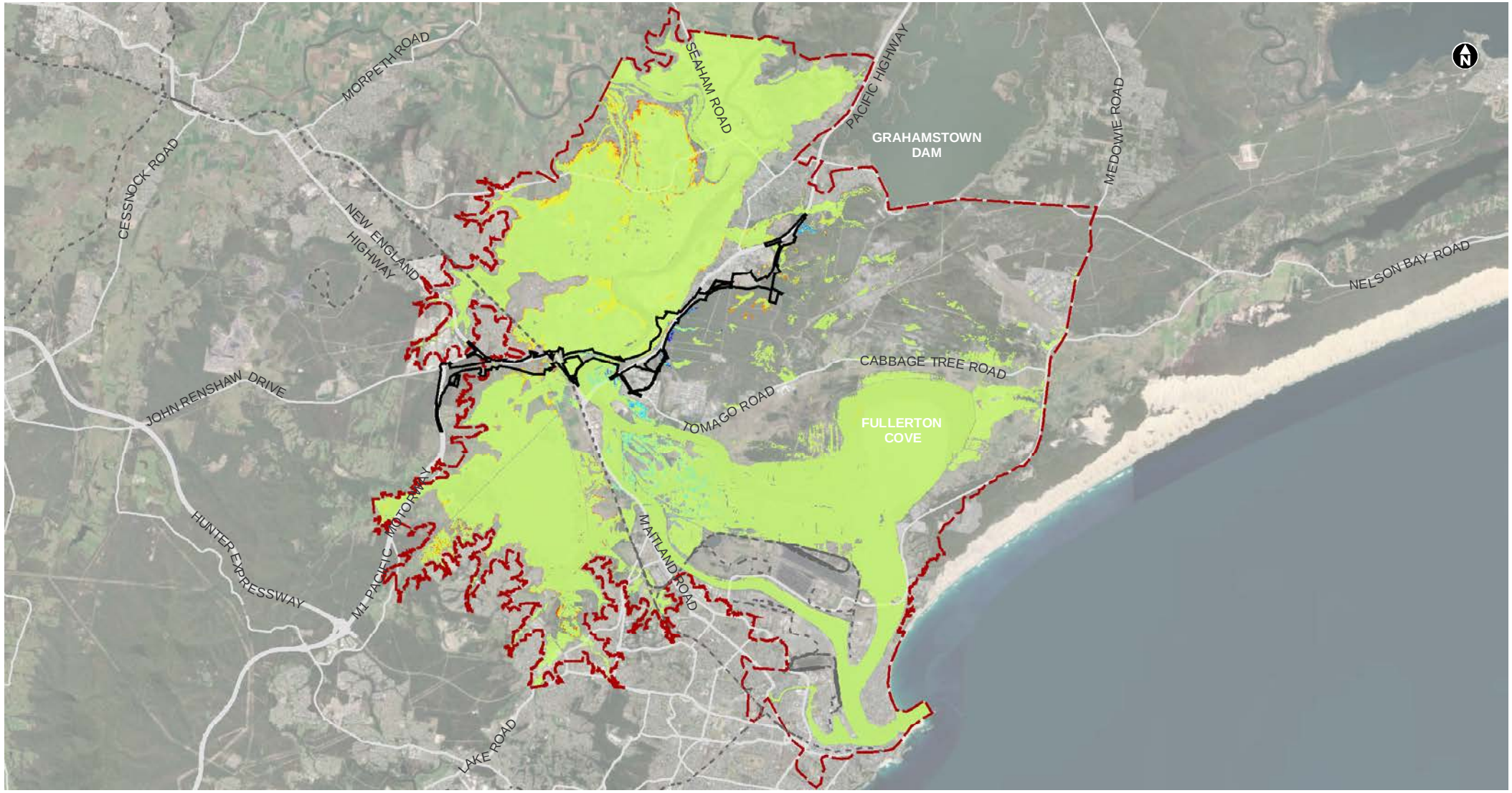
30 - 50

> 50

0 1 2km

Figure D-10 Change in duration of inundation - Construction phase - 20% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_034_D10_ChangeInundatonDuration20Construction_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Railway

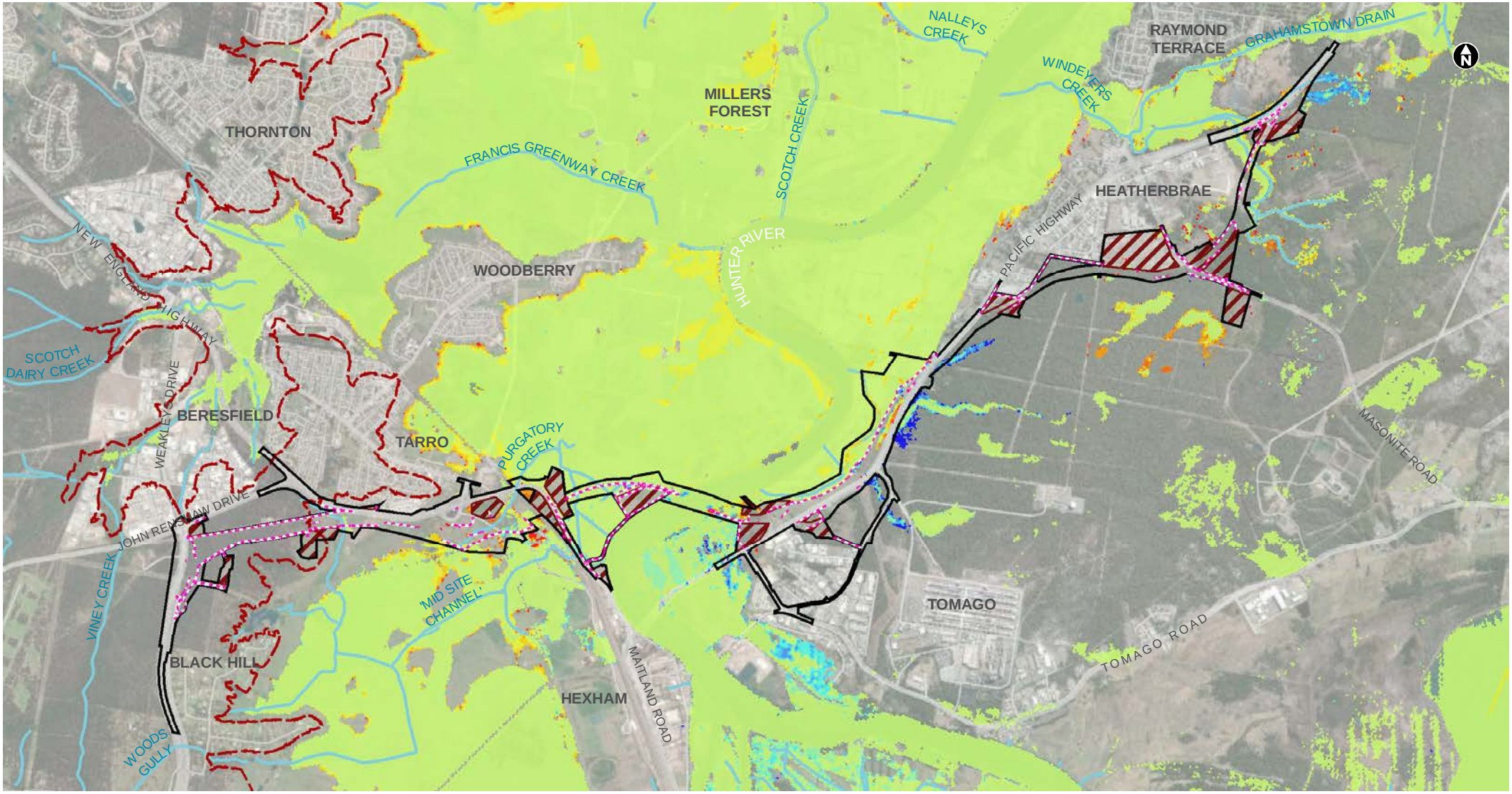
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 4 8km

Figure D-11 Change in duration of inundation - Construction phase - 10% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_035_D11_ChangeInundatonDuration10Construction_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Ancillary facility

Access and haulage roads

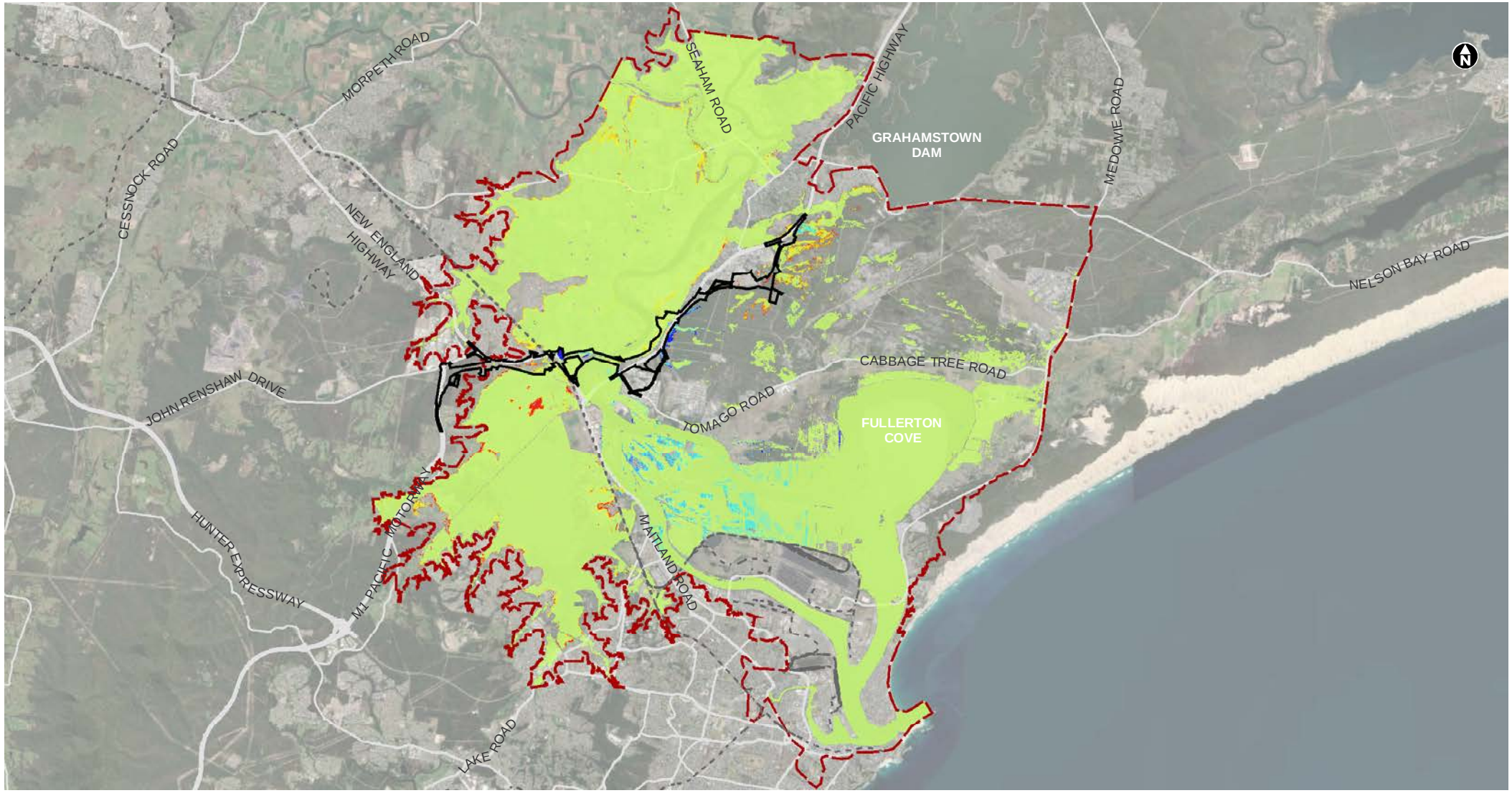
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure D-11 Change in duration of inundation - Construction phase - 10% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_035_D11_ChangeInundatonDuration10Construction_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Railway

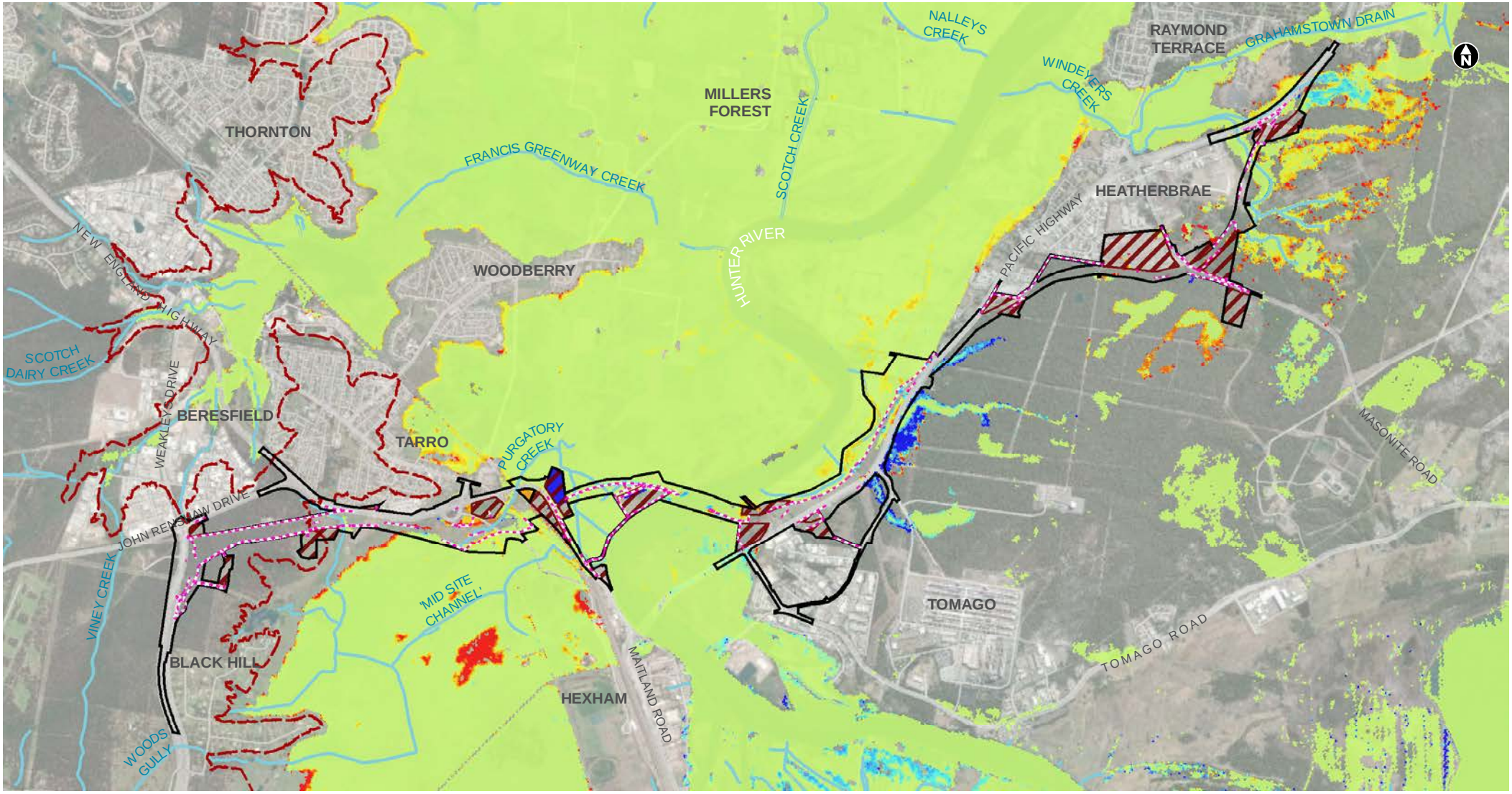
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 4 8km

Figure D-12 Change in duration of inundation - Construction phase - 5% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_036_D12_ChangeInundatonDuration5Construction_JAC_A4L_175000_V01.mxd



Flooding study area

Construction footprint

Ancillary facility

Access and haulage roads

Change in duration of inundation from existing case (per cent)

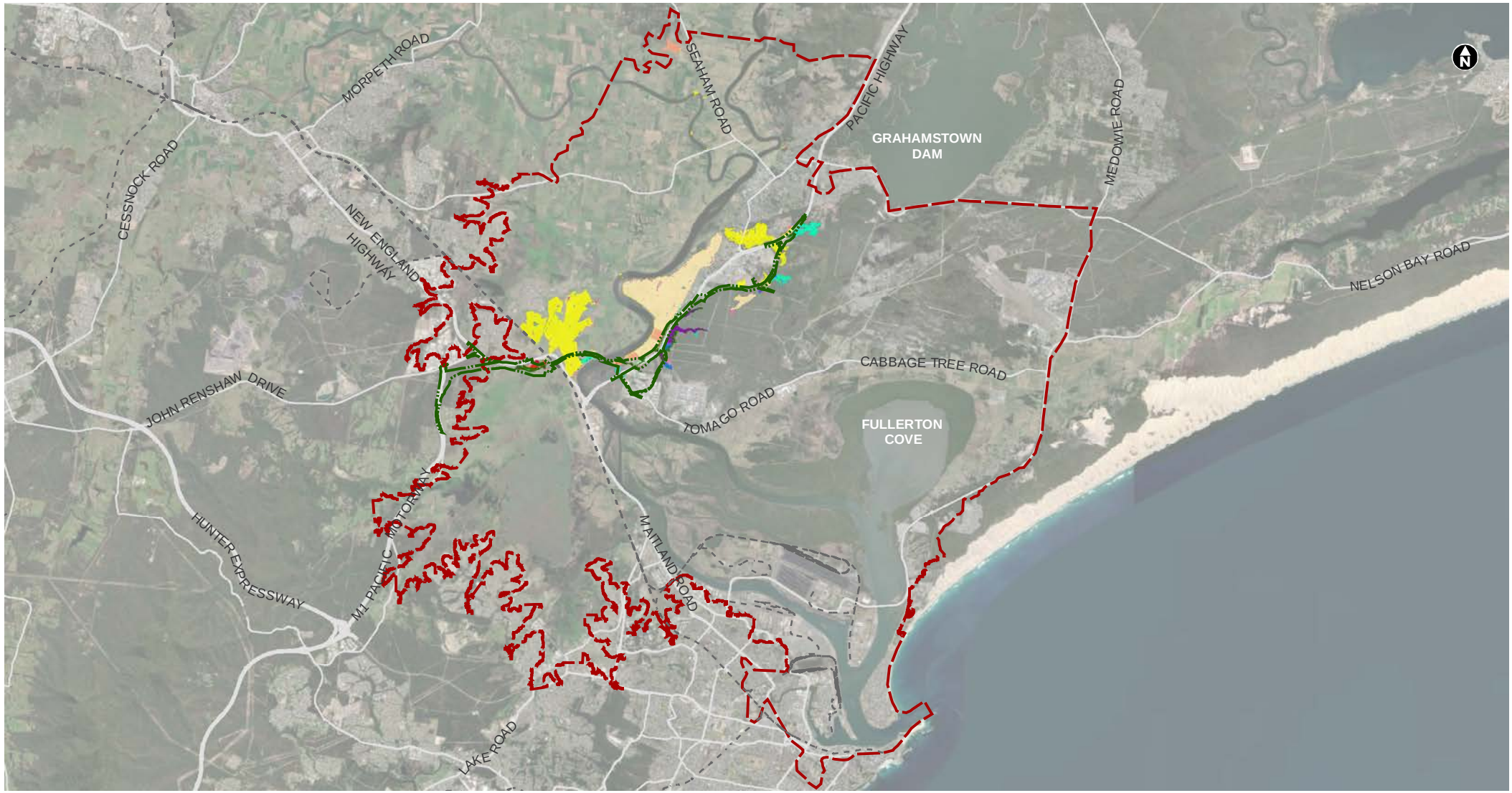
- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure D-12 Change in duration of inundation - Construction phase - 5% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_036_D12_ChangeInundatonDuration5Construction_JAC_A4L_175000_V01.mxd

Appendix E Flood impact maps – Operation



Flooding study area

Operational footprint

Railway

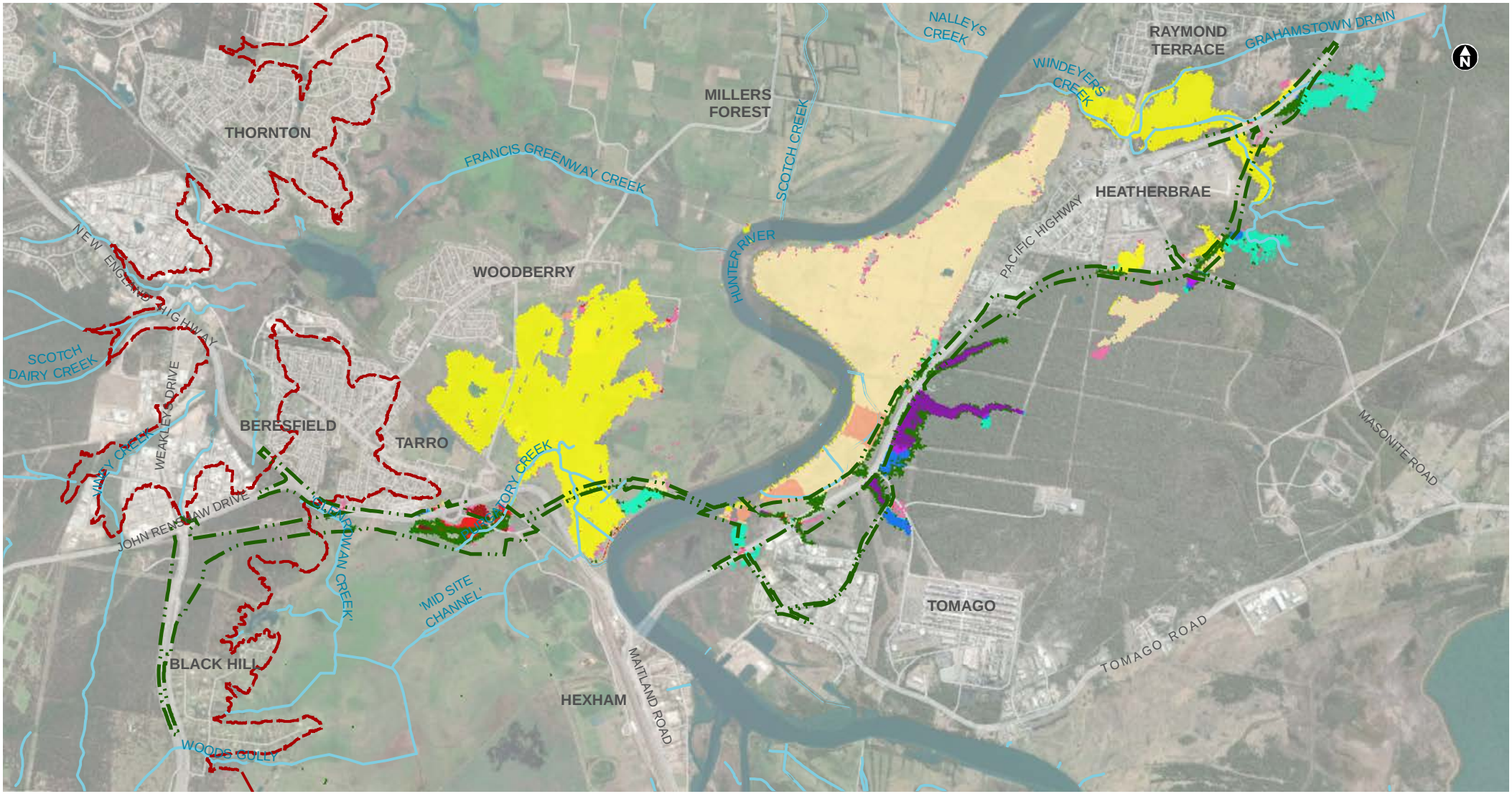
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 4 8km

Figure E-1 Change in flood level - Operational phase - 20% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_037_E1_ChangeFloodLevel20Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure E-1 Change in flood level - Operational phase - 20% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_037_E1_ChangeFloodLevel20Operational_JAC_A4L_175000_V02.mxd

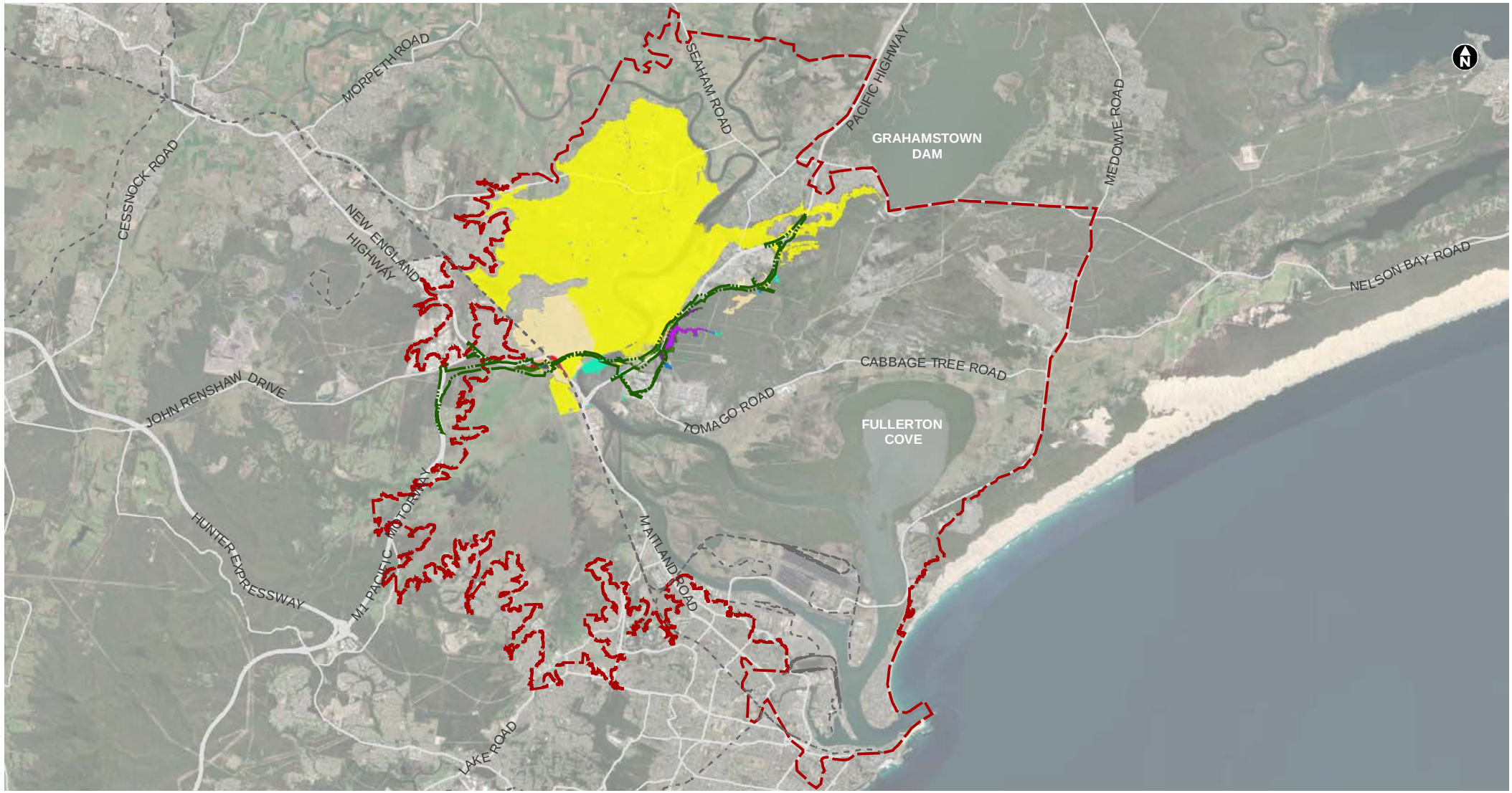
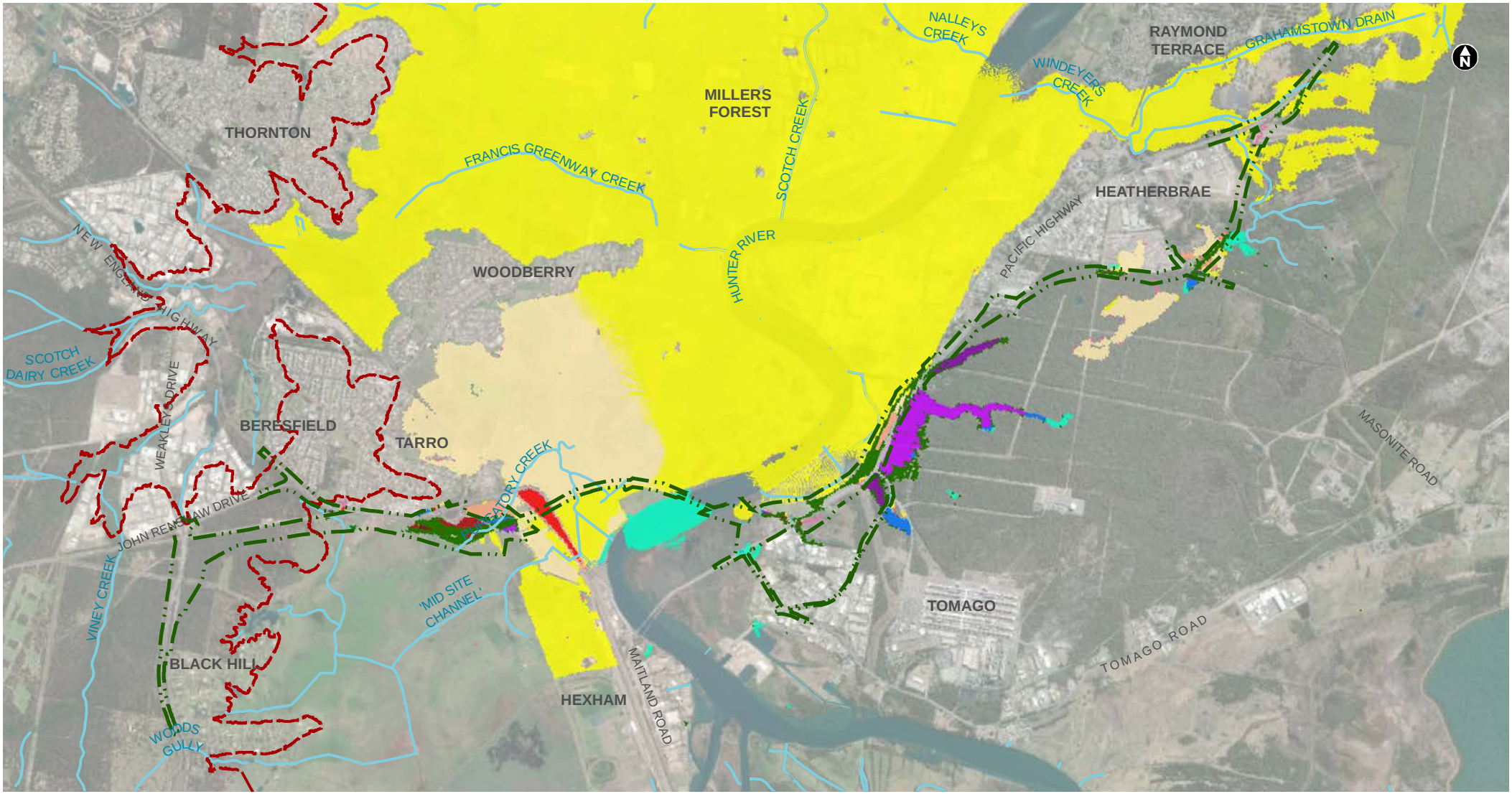


Figure E-2 Change in flood level - Operational phase - 10% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_038_E2_ChangeFloodLevel10Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

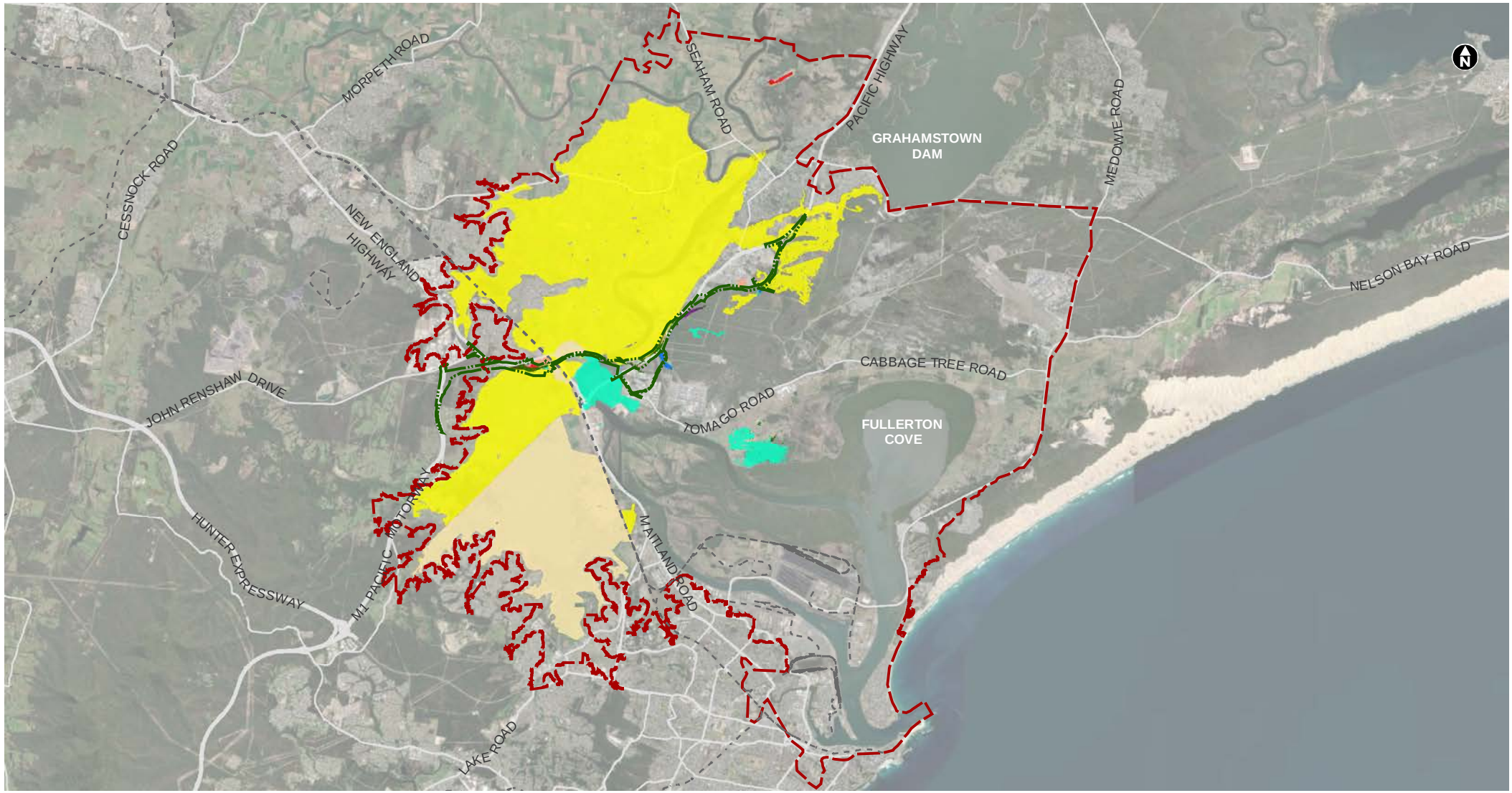
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure E-2 Change in flood level - Operational phase - 10% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_038_E2_ChangeFloodLevel10Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

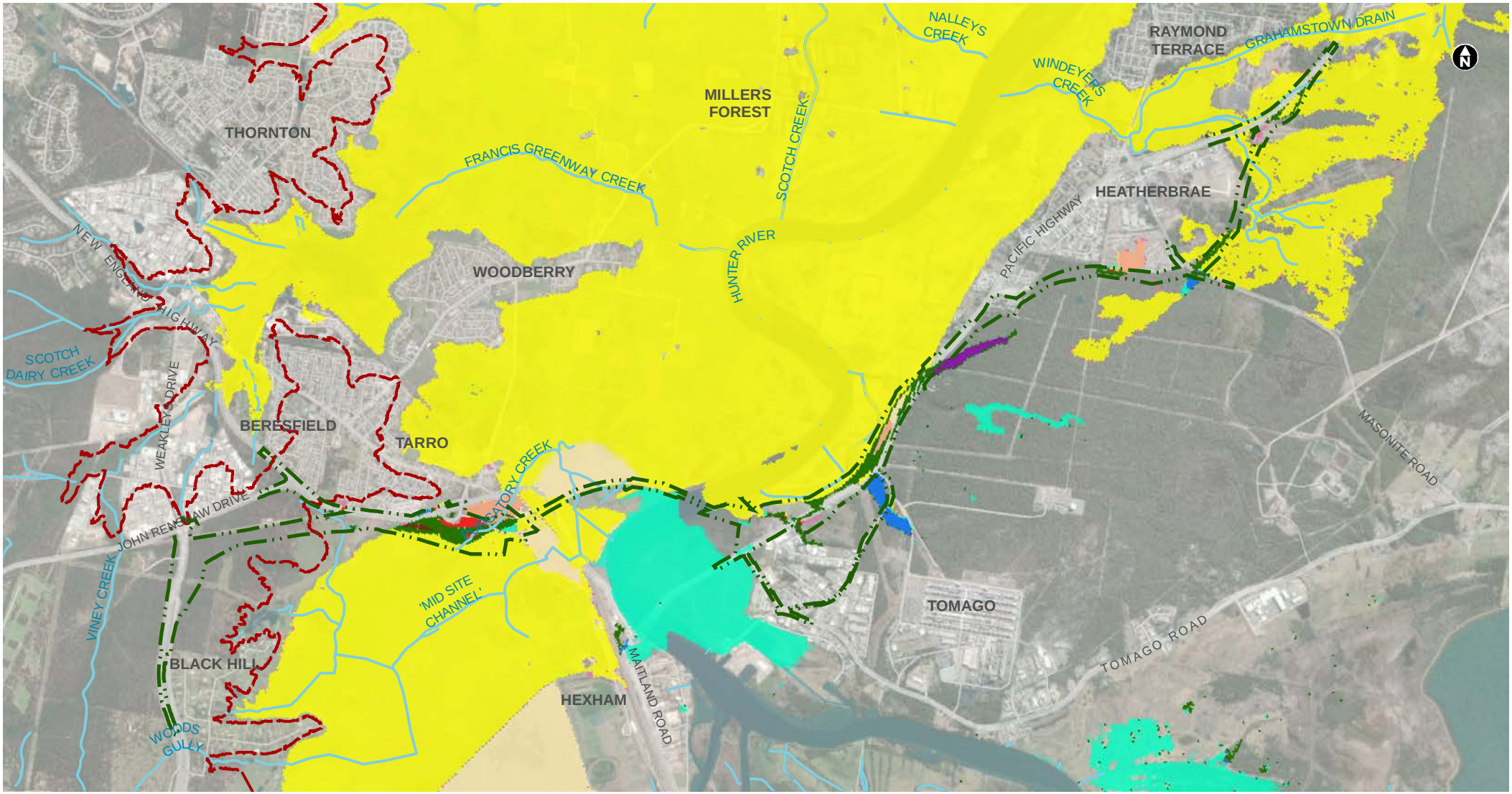
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 4 8km

Figure E-3 Change in flood level - Operational phase - 5% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_039_E3_ChangeFloodLevel5Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

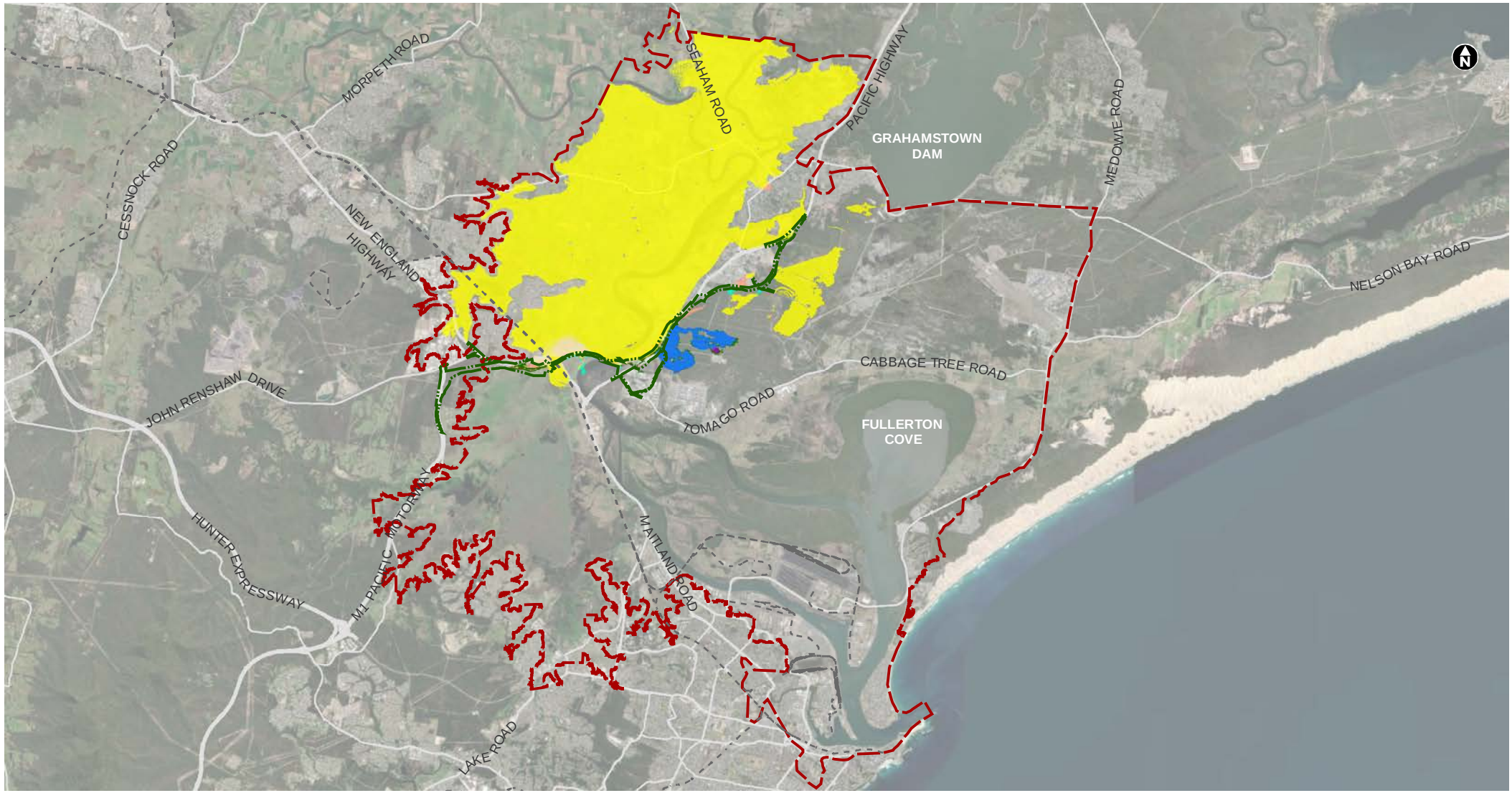
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure E-3 Change in flood level - Operational phase - 5% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_039_E3_ChangeFloodLevel5Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

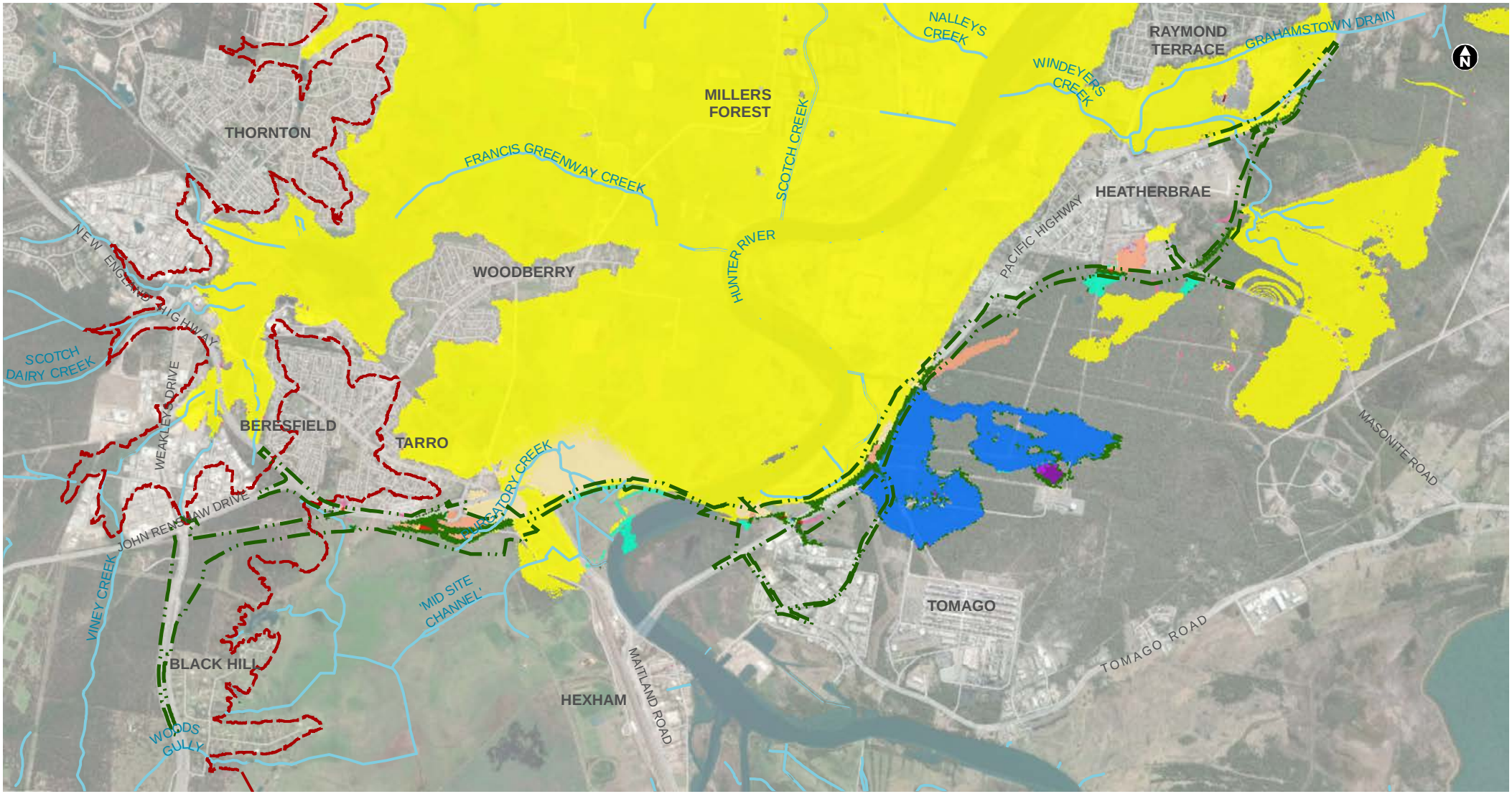
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 4 8km

Figure E-4 Change in flood level - Operational phase - 2% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_040_E4_ChangeFloodLevel2Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

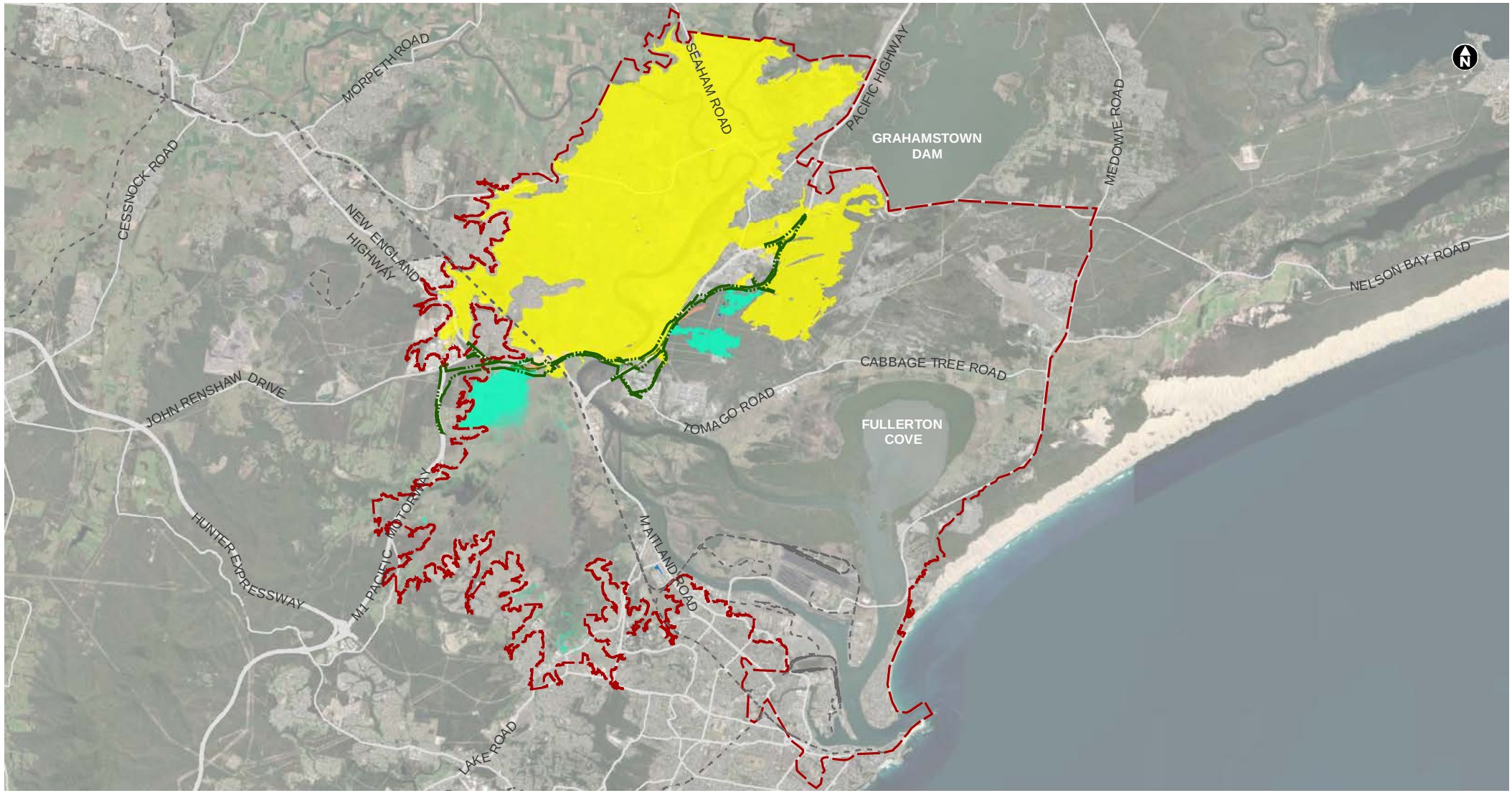
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure E-4 Change in flood level - Operational phase - 2% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_040_E4_ChangeFloodLevel2Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

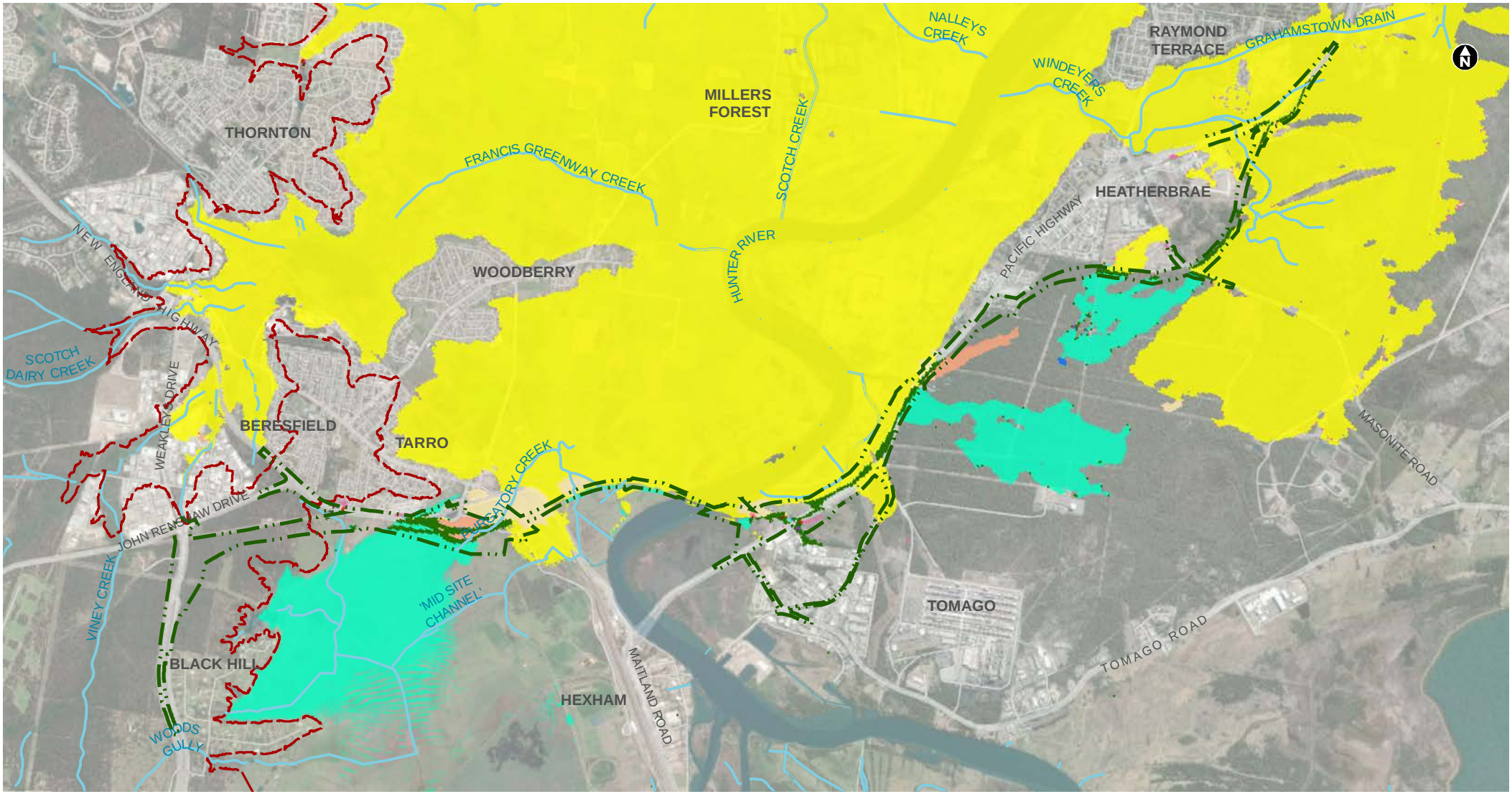
Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 4 8km

Figure E-5 Change in flood level - Operational phase - 1% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_041_E5_ChangeFloodLevel1Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure E-5 Change in flood level - Operational phase - 1% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_041_E5_ChangeFloodLevel1Operational_JAC_A4L_175000_V02.mxd

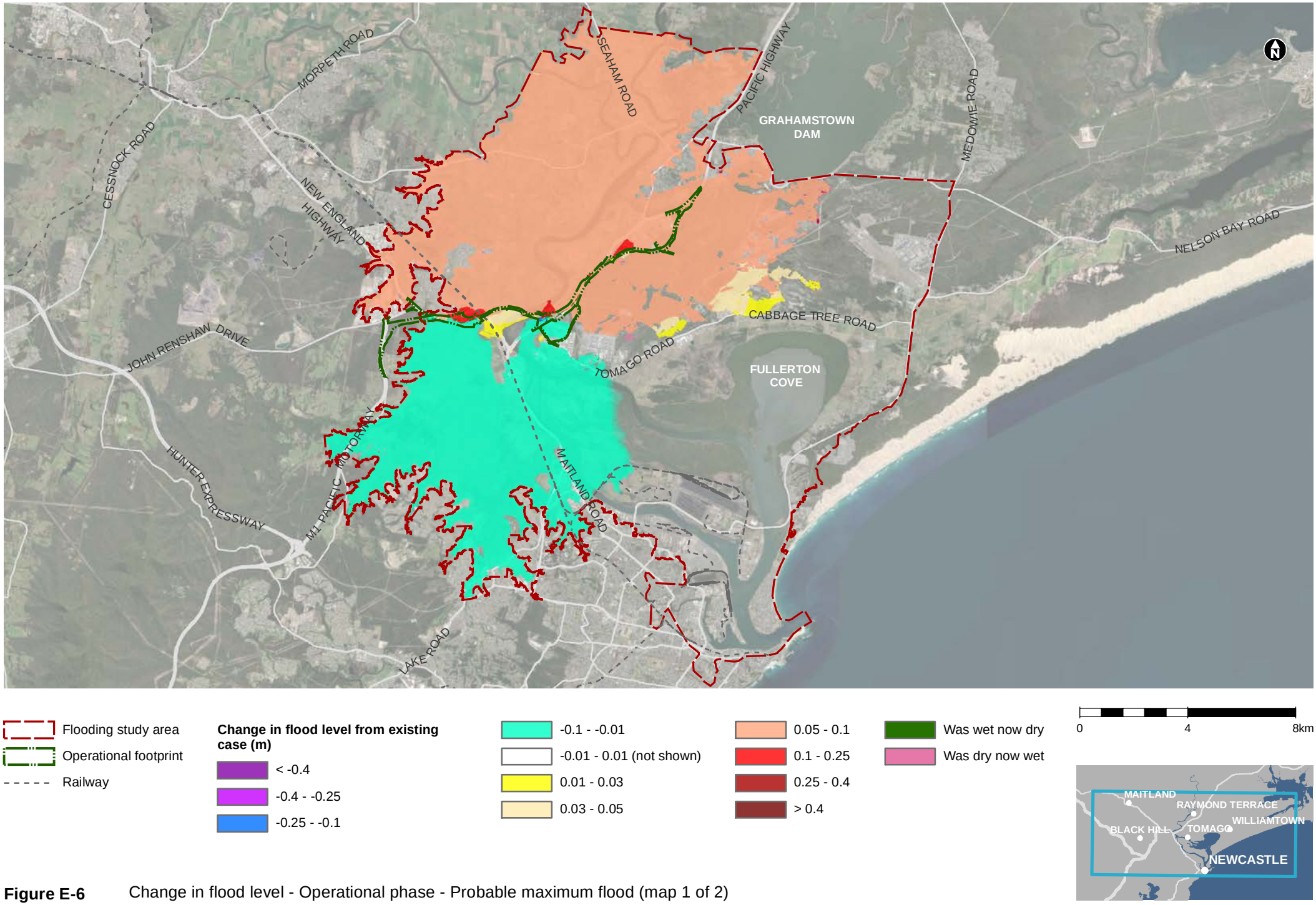
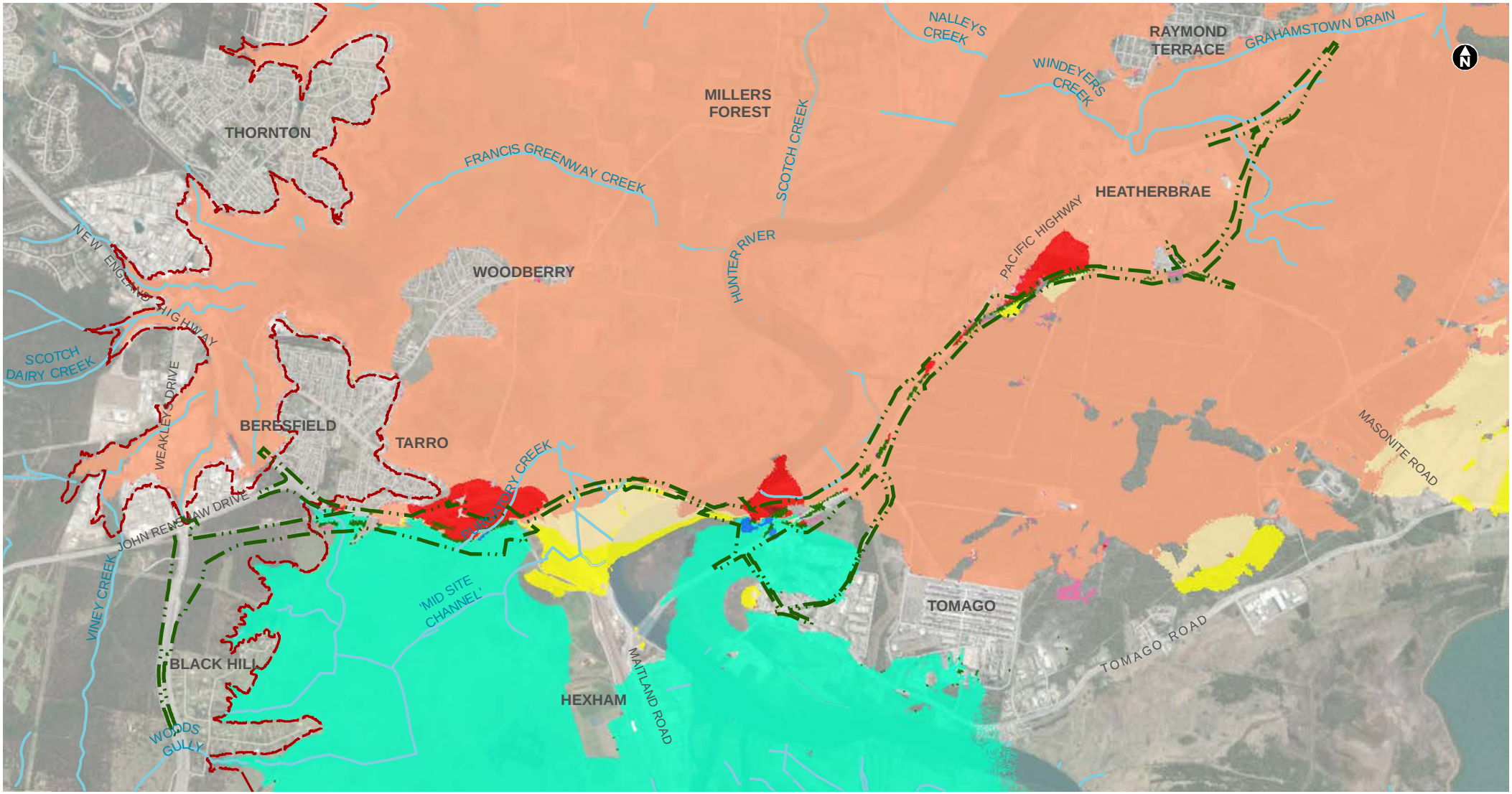


Figure E-6 Change in flood level - Operational phase - Probable maximum flood (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_042_E6_ChangeFloodLevelMaxOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in flood level from existing case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure E-6 Change in flood level - Operational phase - Probable maximum flood (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_042_E6_ChangeFloodLevelMaxOperational_JAC_A4L_175000_V02.mxd

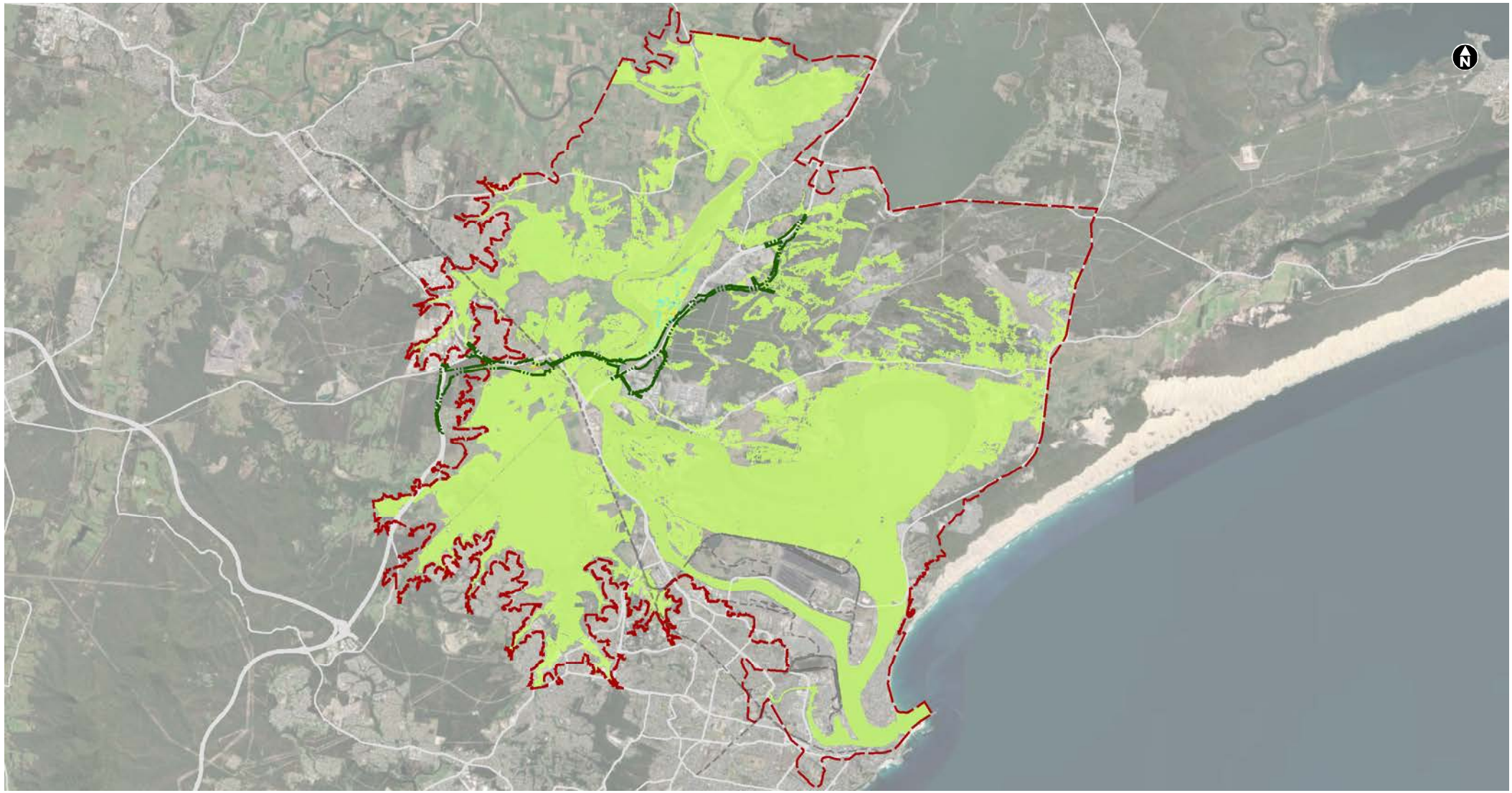


Figure E-7 Change in flow velocity - Operational phase - 20% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_043_E7_ChangeFlowVelocity20_Operational_JAC_A4L_175000_V02.mxd

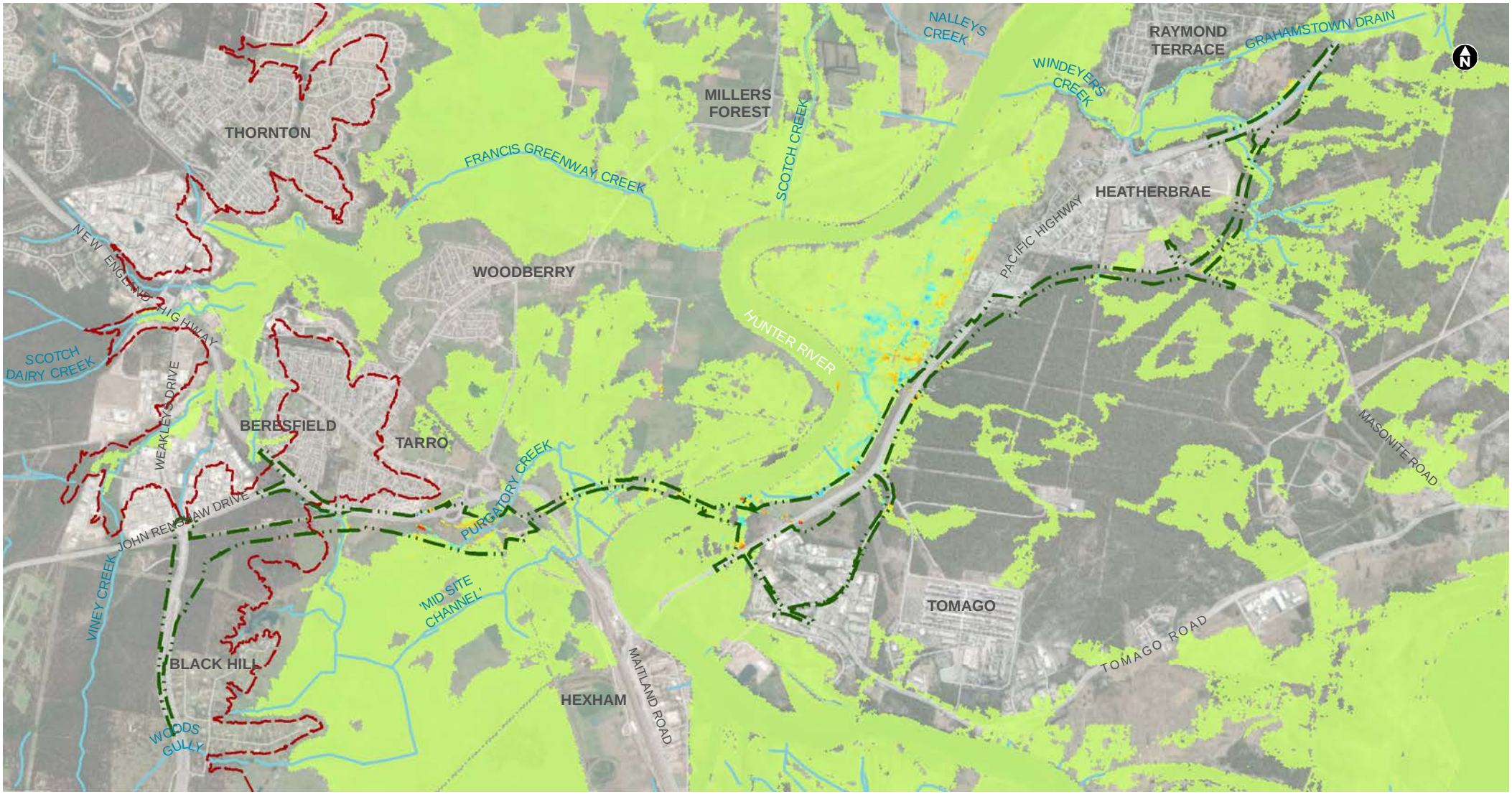


Figure E-7 Change in flow velocity - Operational phase - 20% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_043_E7_ChangeFlowVelocity20_Operational_JAC_A4L_175000_V02.mxd

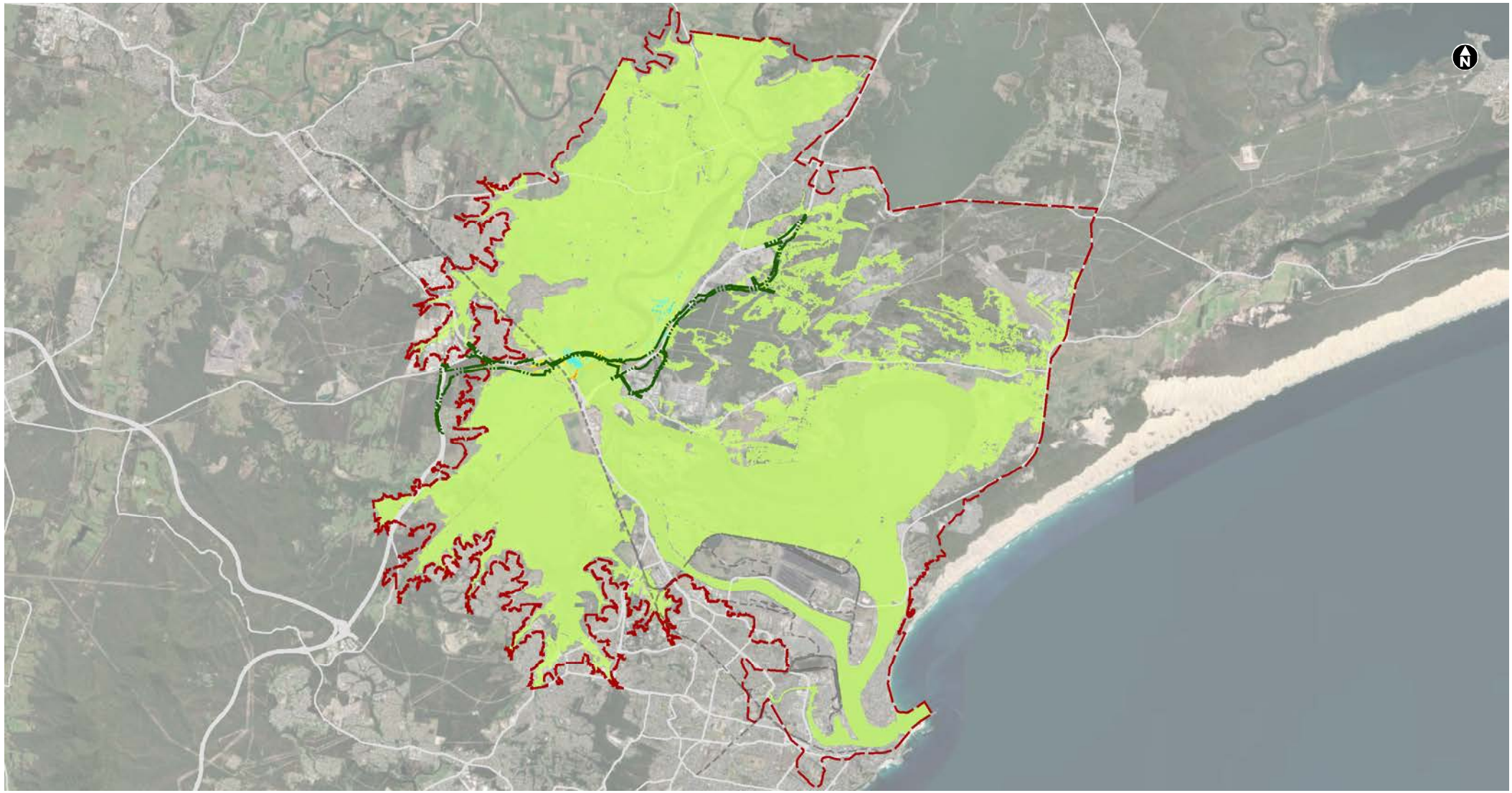
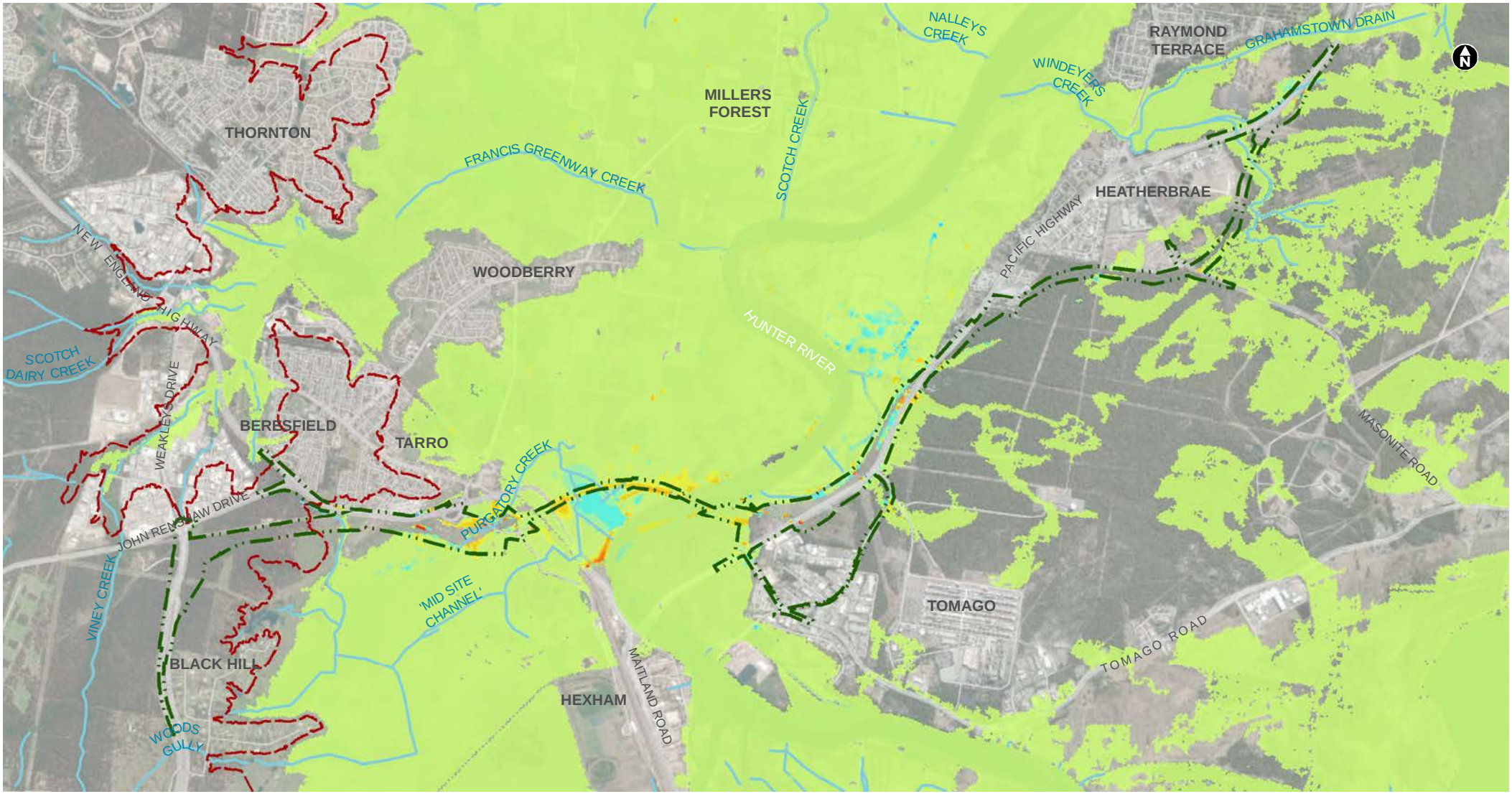


Figure E-8 Change in flow velocity - Operational phase - 10% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_044_E8_ChangeFlowVelocity10_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in velocity from existing case (m/s)

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- >1

0 1 2km

Figure E-8 Change in flow velocity - Operational phase - 10% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_044_E8_ChangeFlowVelocity10_Operational_JAC_A4L_175000_V02.mxd

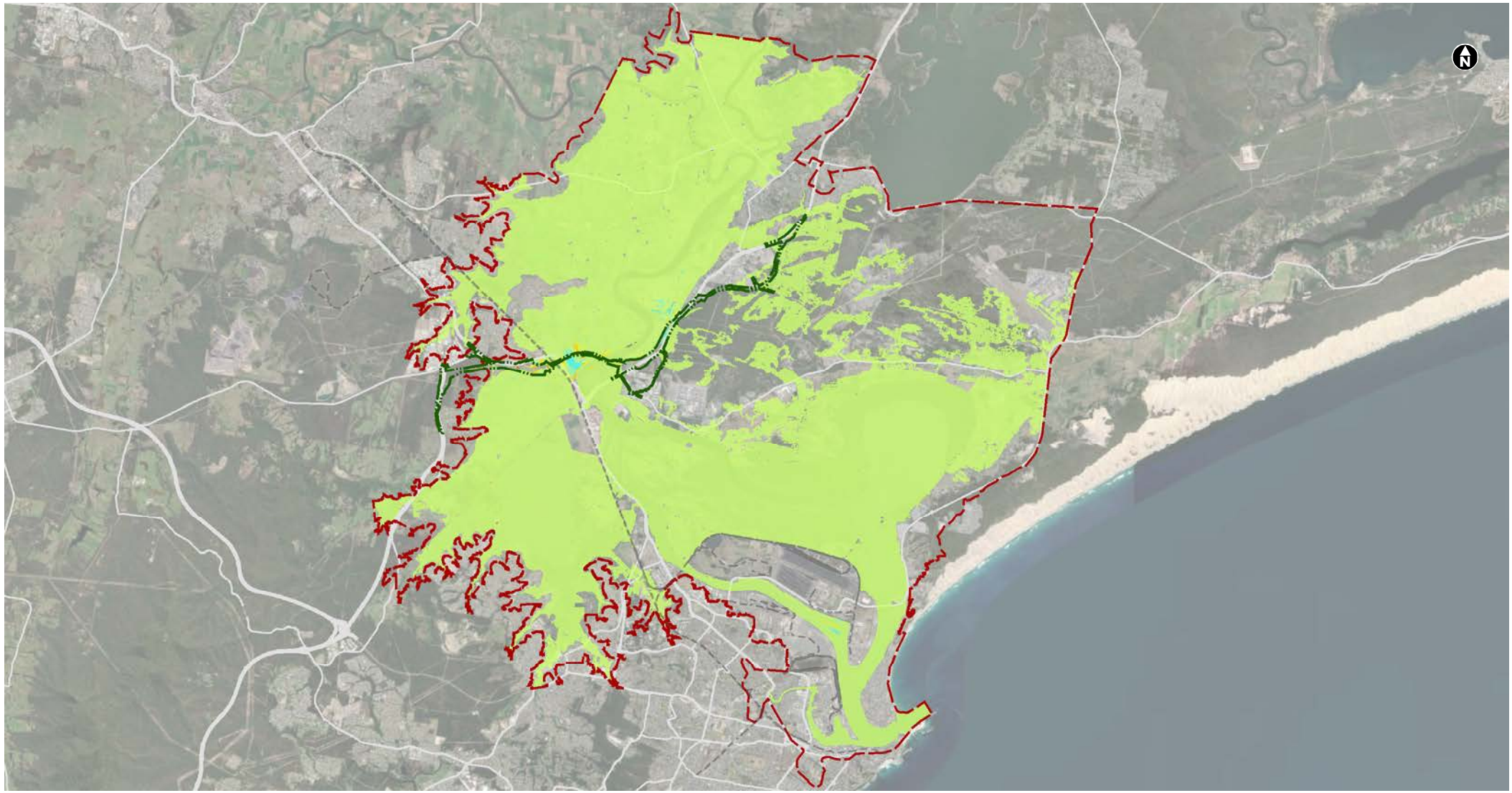


Figure E-9 Change in flow velocity - Operational phase - 5% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_045_E9_ChangeFlowVelocity5_Operational_JAC_A4L_175000_V02.mxd

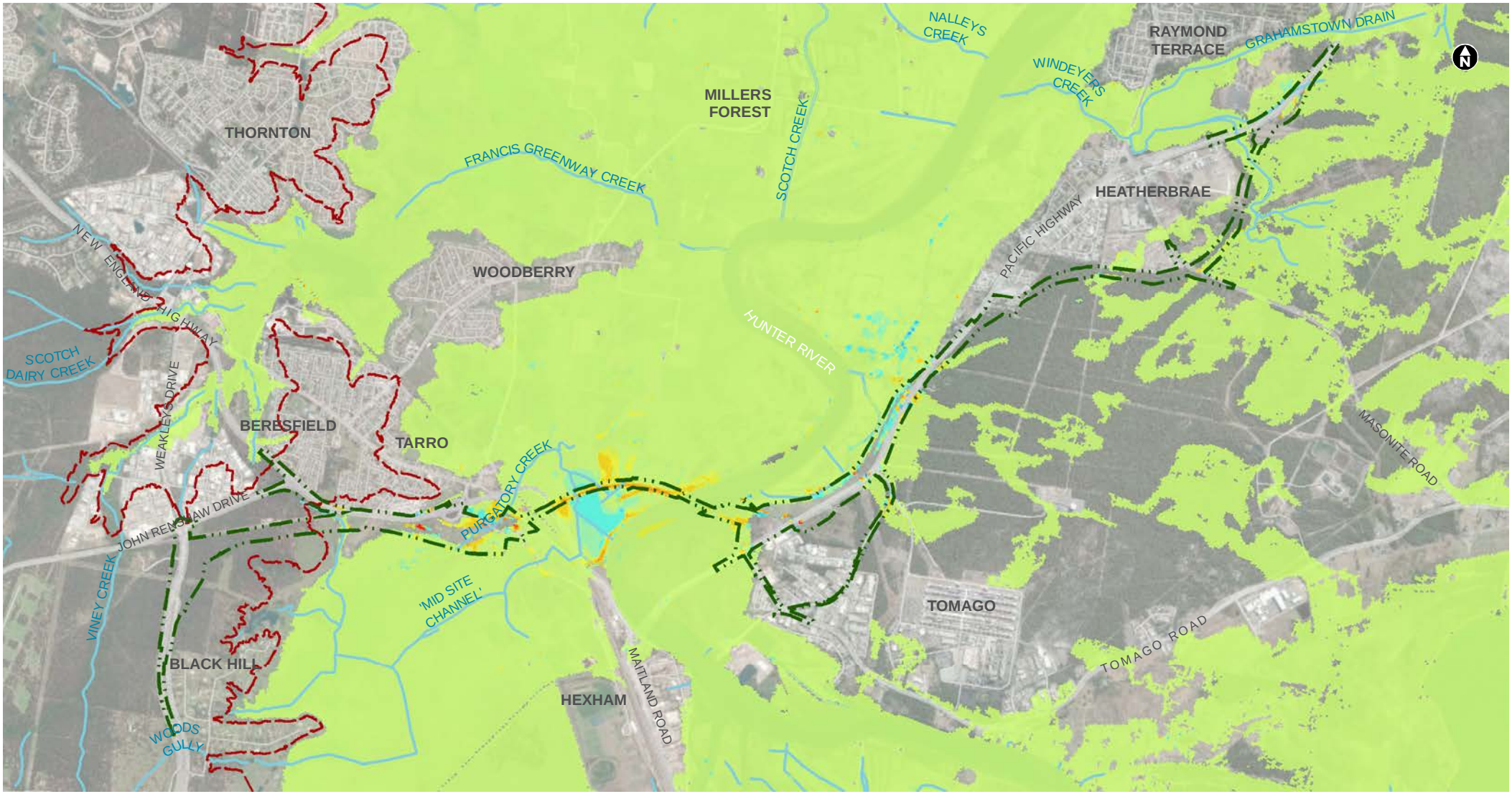


Figure E-9 Change in flow velocity - Operational phase - 5% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_045_E9_ChangeFlowVelocity5_Operational_JAC_A4L_175000_V02.mxd

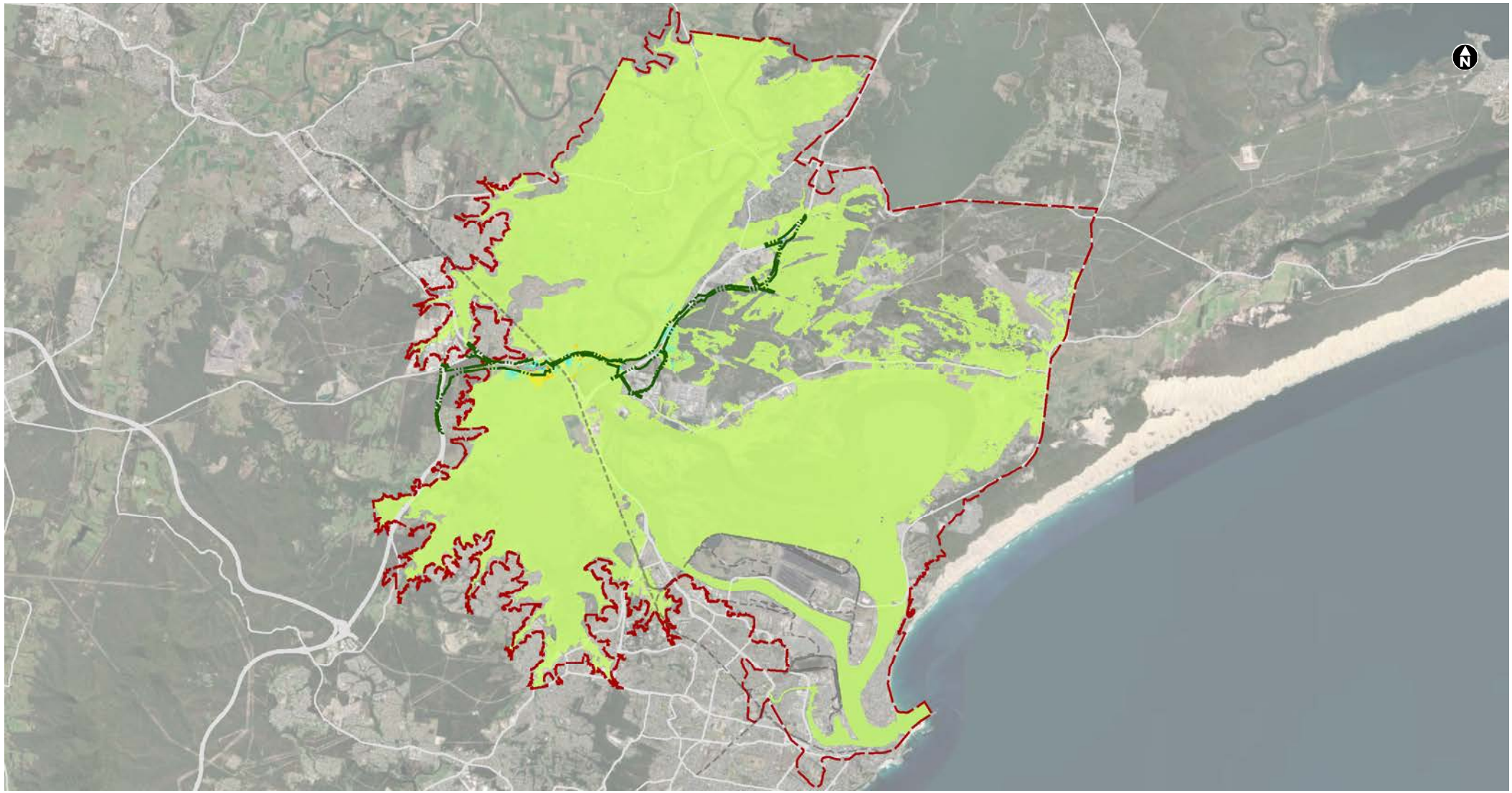
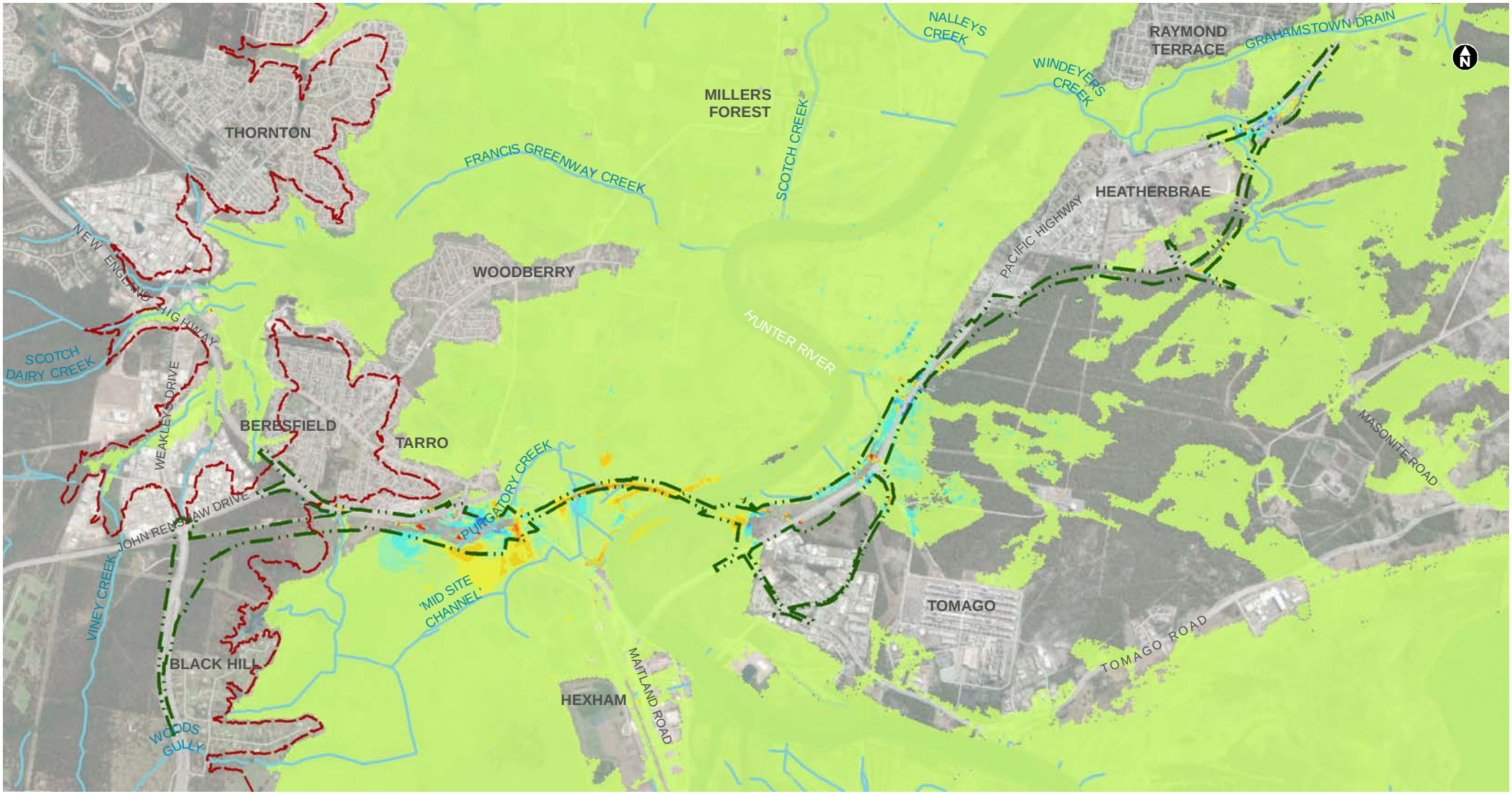


Figure E-10 Change in flow velocity - Operational phase - 2% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_046_E10_ChangeFlowVelocity2_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in velocity from existing case (m/s)

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- >1

0 1 2km

Figure E-10 Change in flow velocity - Operational phase - 2% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_046_E10_ChangeFlowVelocity2_Operational_JAC_A4L_175000_V02.mxd

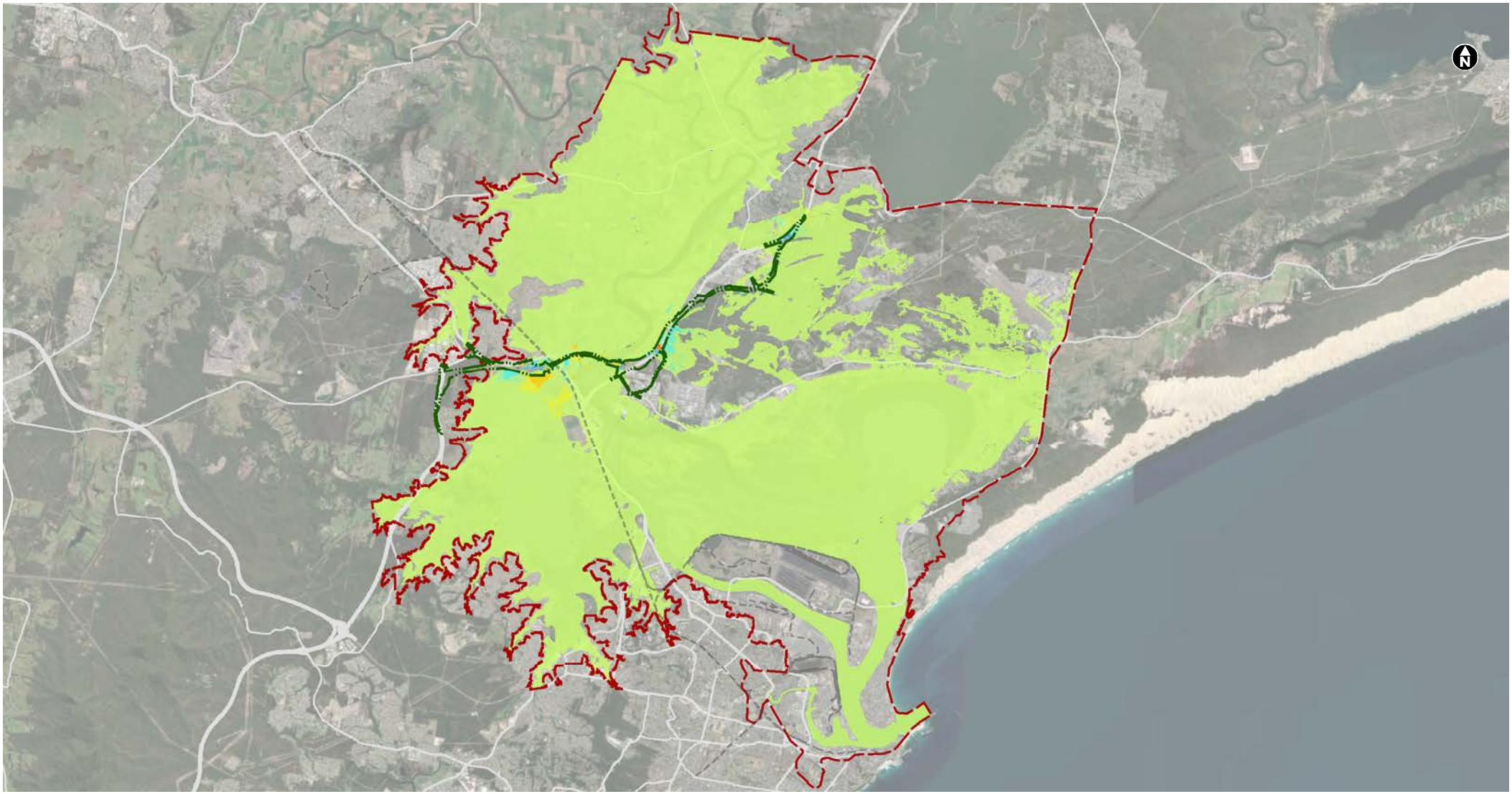


Figure E-11 Change in flow velocity - Operational phase - 1% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_047_E11_ChangeFlowVelocity1_Operational_JAC_A4L_175000_V02.mxd

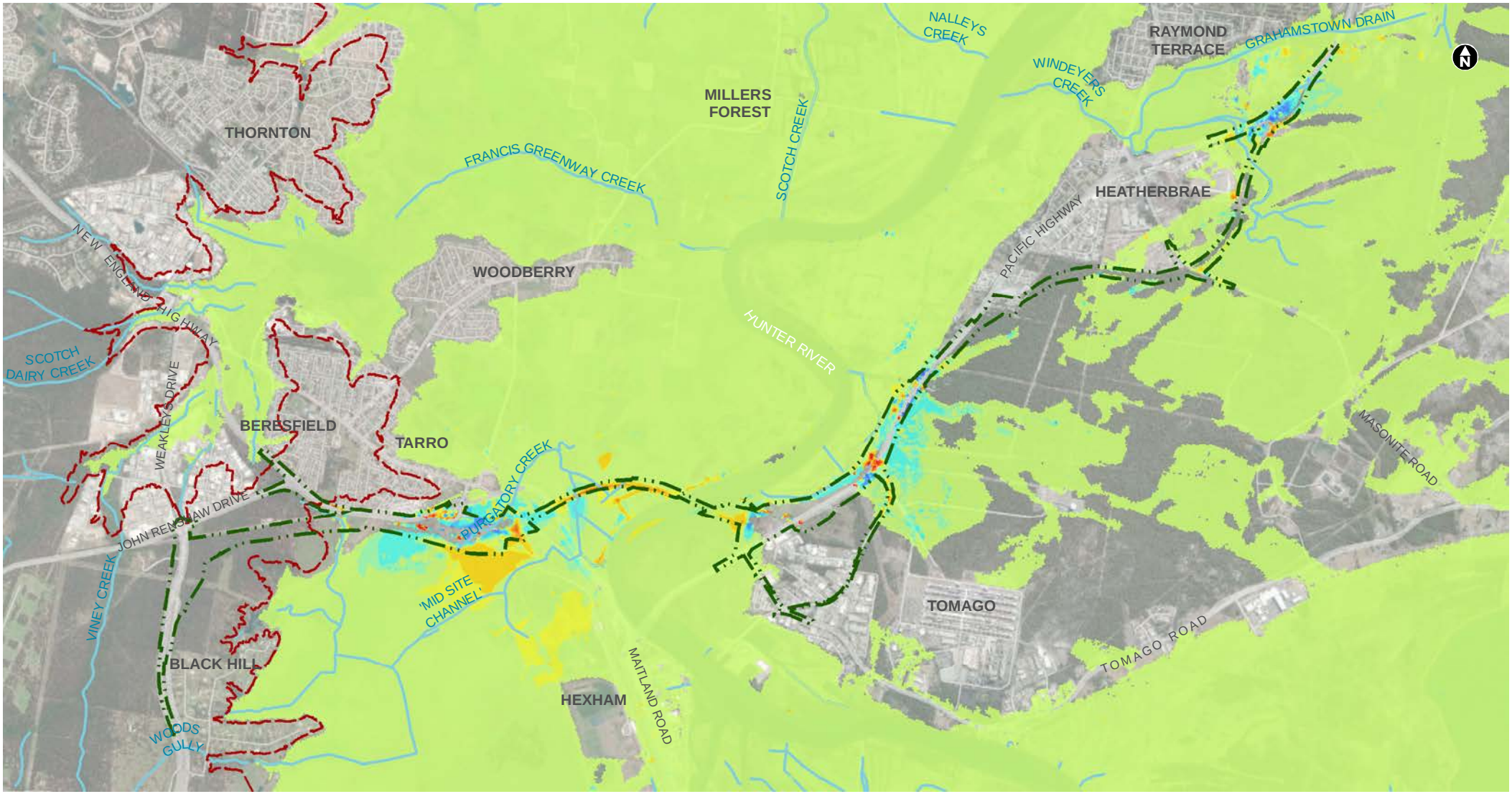


Figure E-11 Change in flow velocity - Operational phase - 1% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_047_E11_ChangeFlowVelocity1_Operational_JAC_A4L_175000_V02.mxd

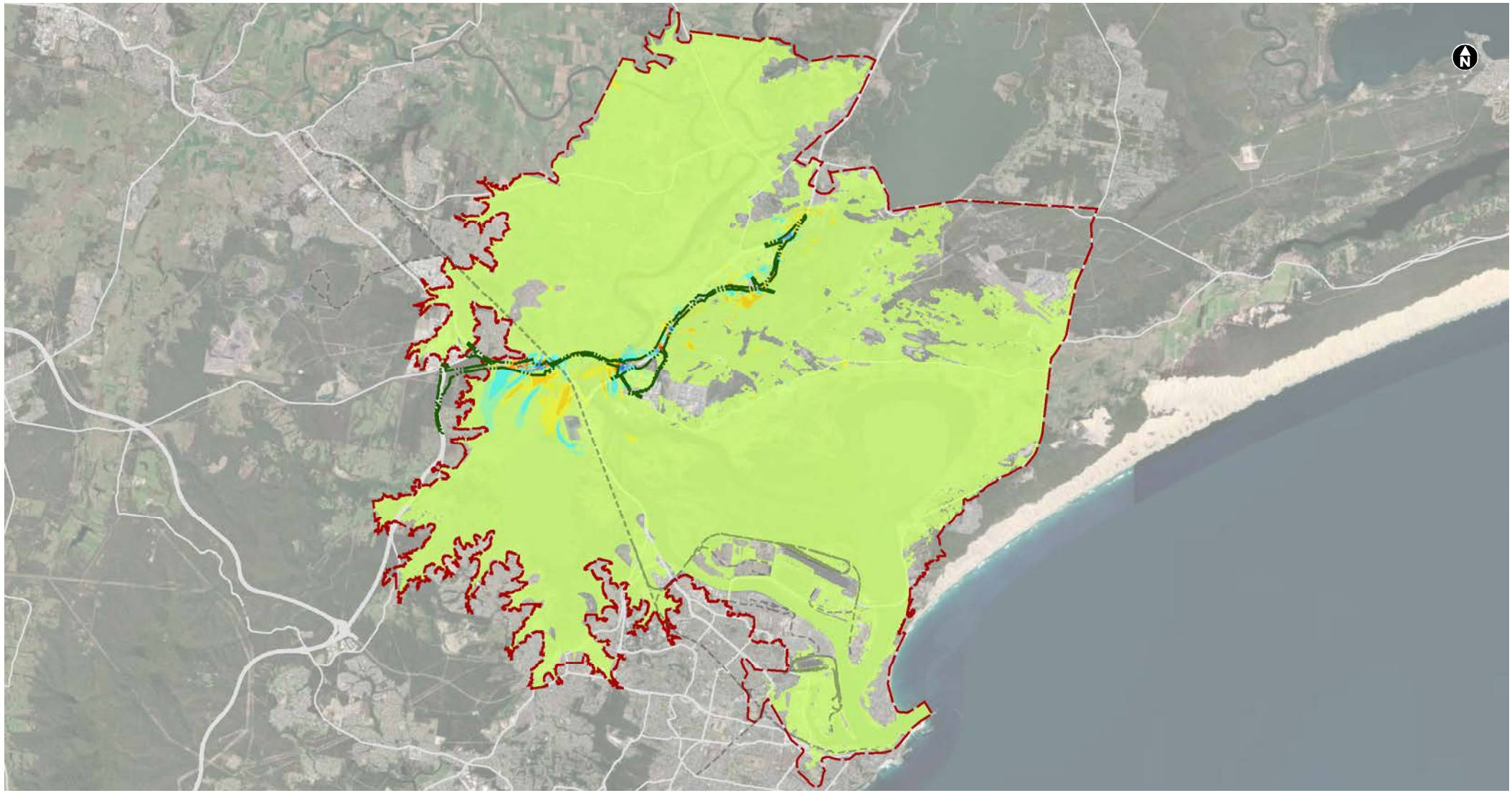
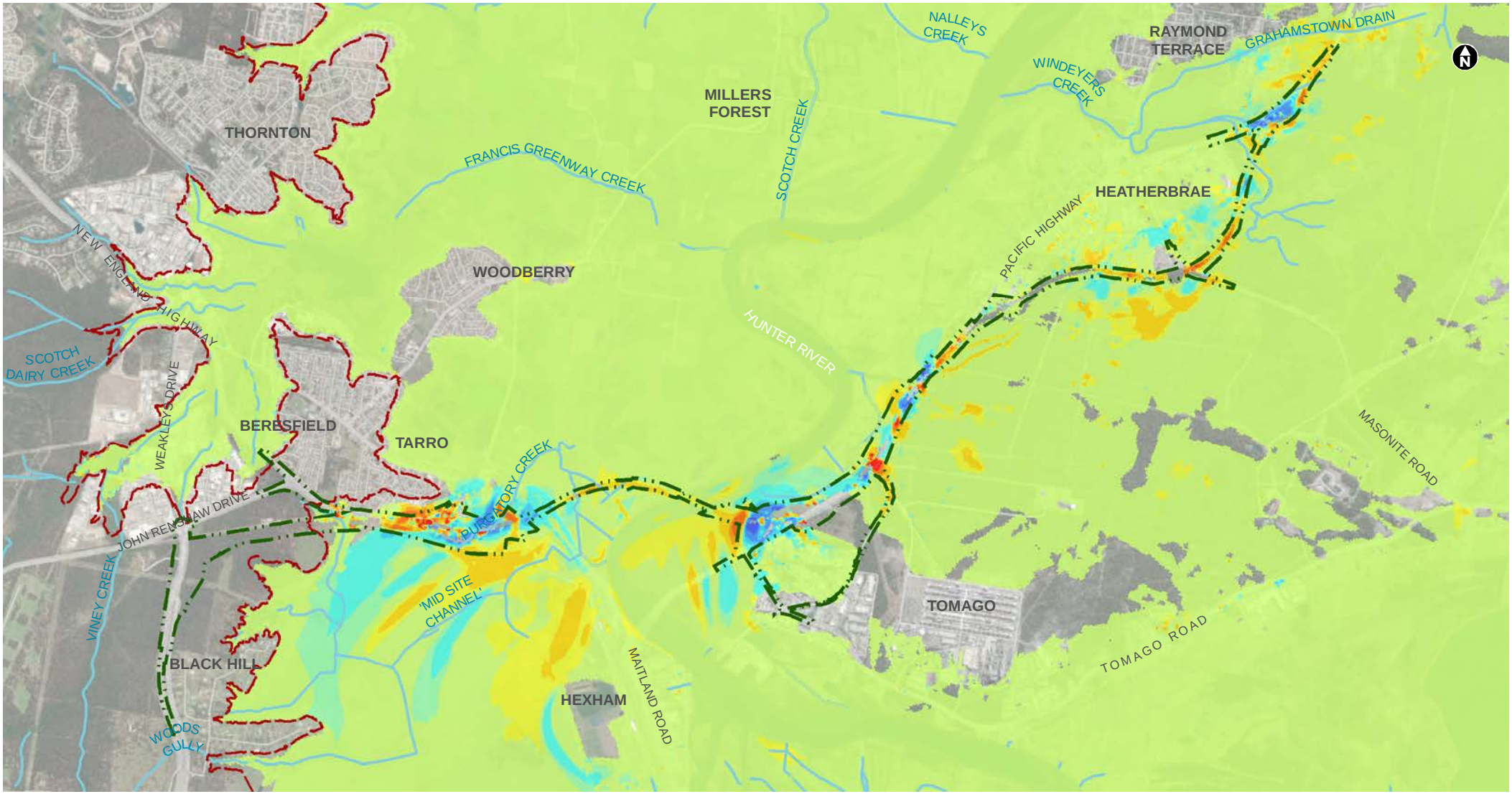


Figure E-12 Change in flow velocity- Operational phase - Probable maximum flood (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_048_E12_ChangeFlowVelocityProbMax_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

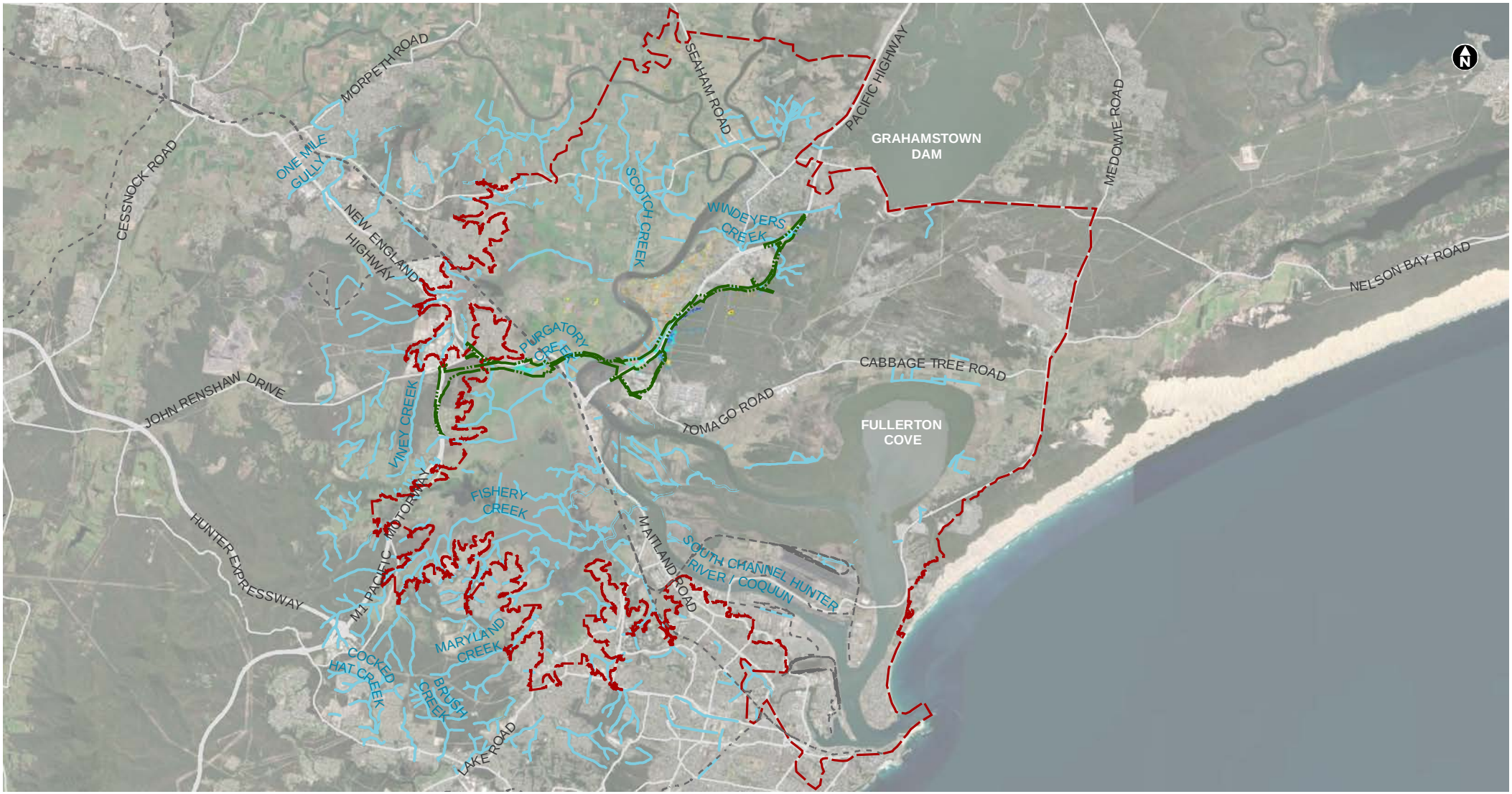
Change in velocity from existing case (m/s)

- < -1
- -1 - -0.5
- -0.5 - -0.3
- -0.3 - -0.1
- -0.1 - -0.05
- -0.05 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- >1

0 1 2km

Figure E-12 Change in flow velocity- Operational phase - Probable maximum flood (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_048_E12_ChangeFlowVelocityProbMax_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

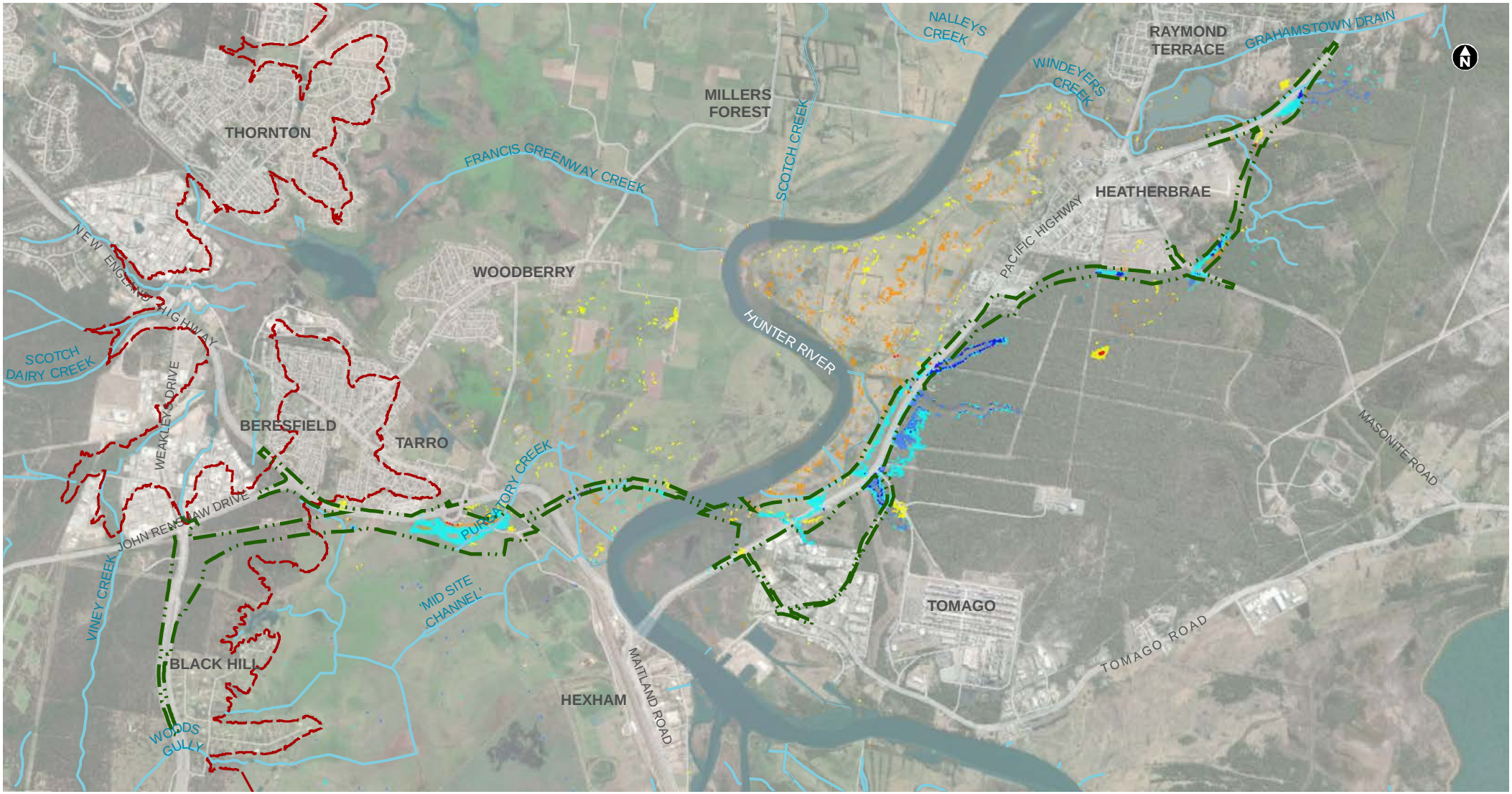
Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 4 8km

Figure E-13 Change in flood hazard - Operational phase - 20% AEP (map 1 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_049_E13_ChangeFloodHazard_20_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

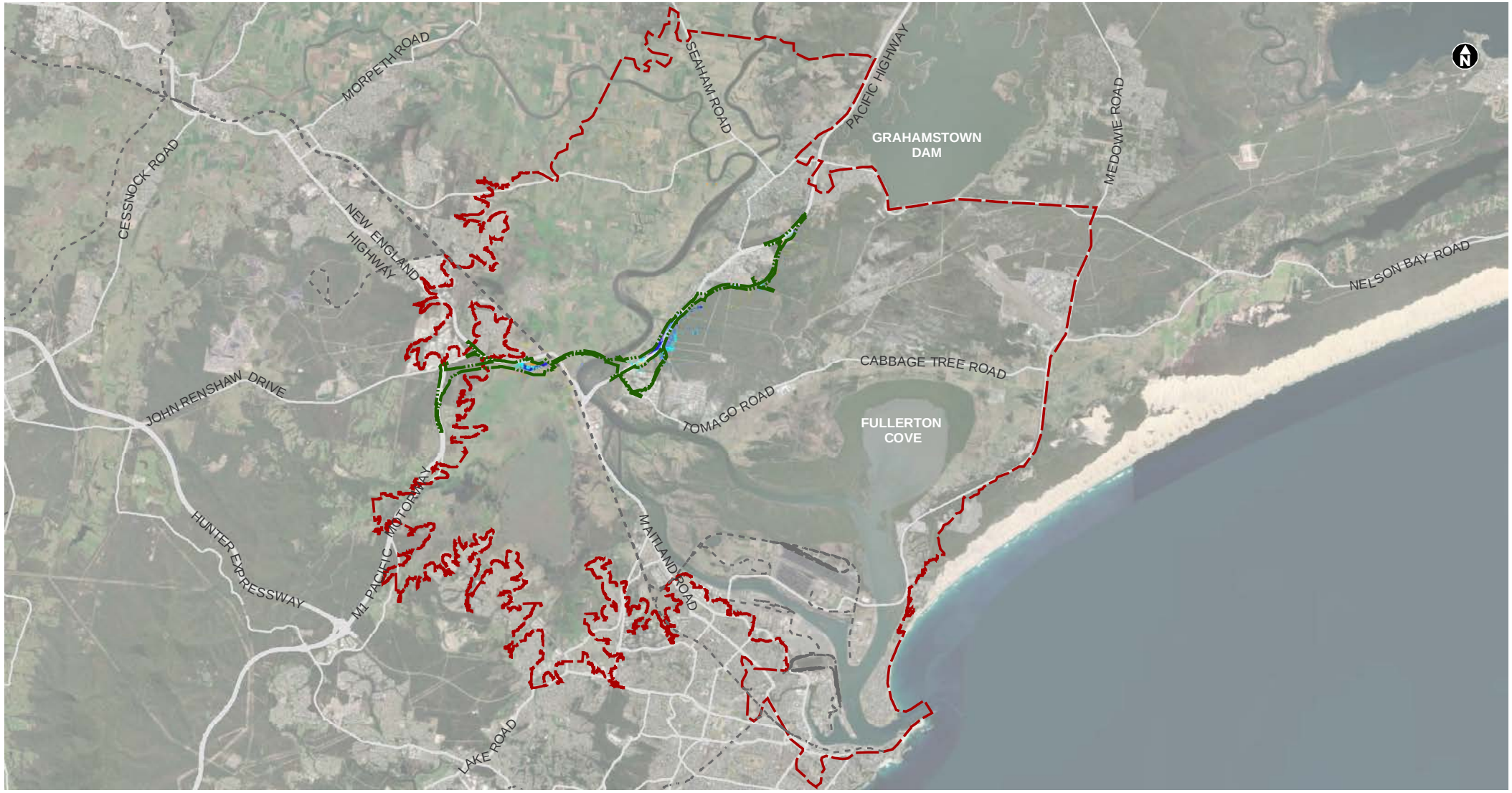
Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 1 2km

Figure E-13 Change in flood hazard - Operational phase - 20% AEP (map 2 of 2)

Date: 14/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_049_E13_ChangeFloodHazard_20_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Change in hazard from existing case

Was high, now dry

Was high, now low

Was low, now dry

Unchanged (not shown)

Was dry, now low

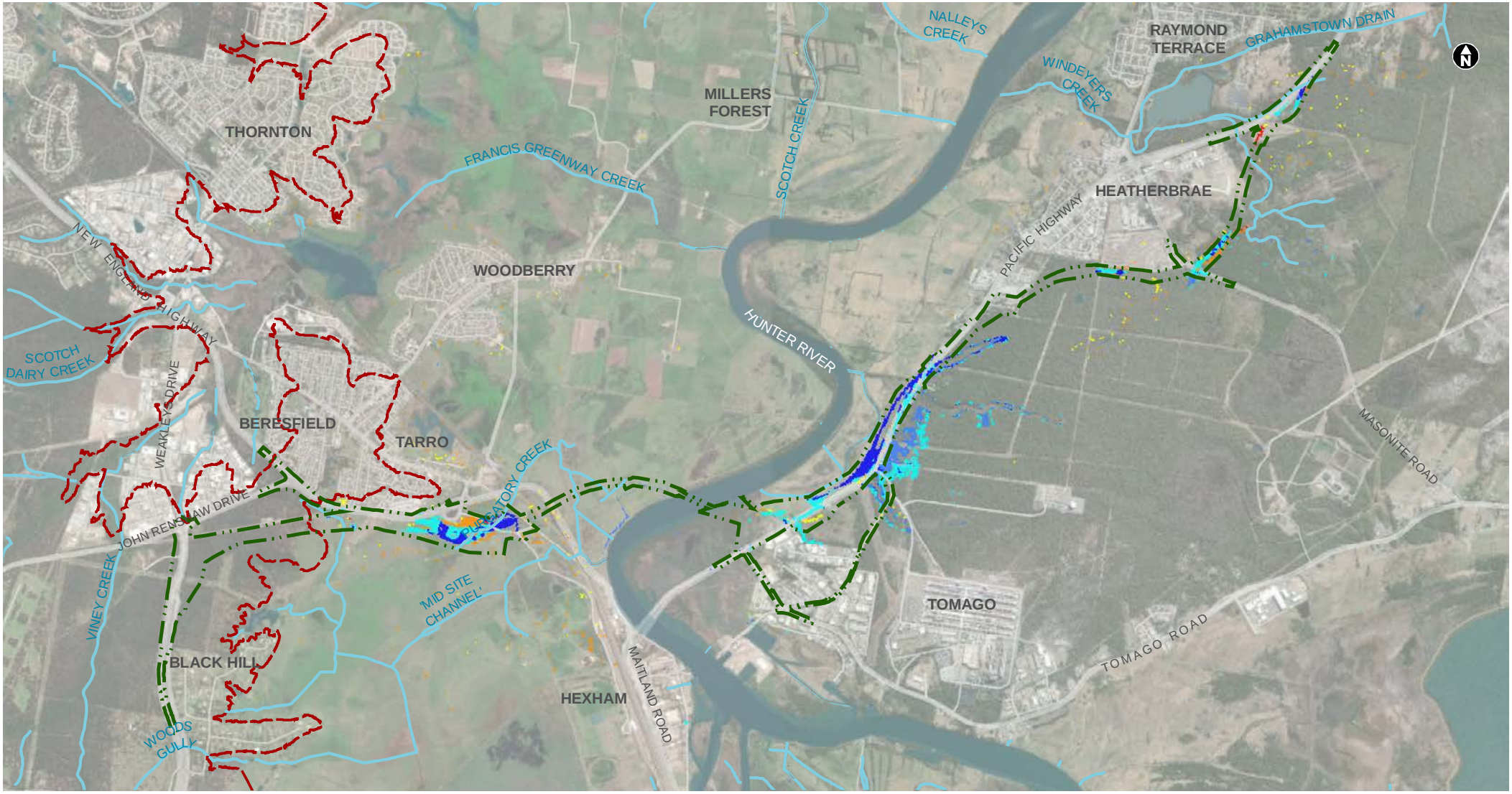
Was low, now high

Was dry, now high

0 4 8km

Figure E-14 Change in flood hazard - Operational phase - 10% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_050_E14_ChangeFloodHazard_10_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

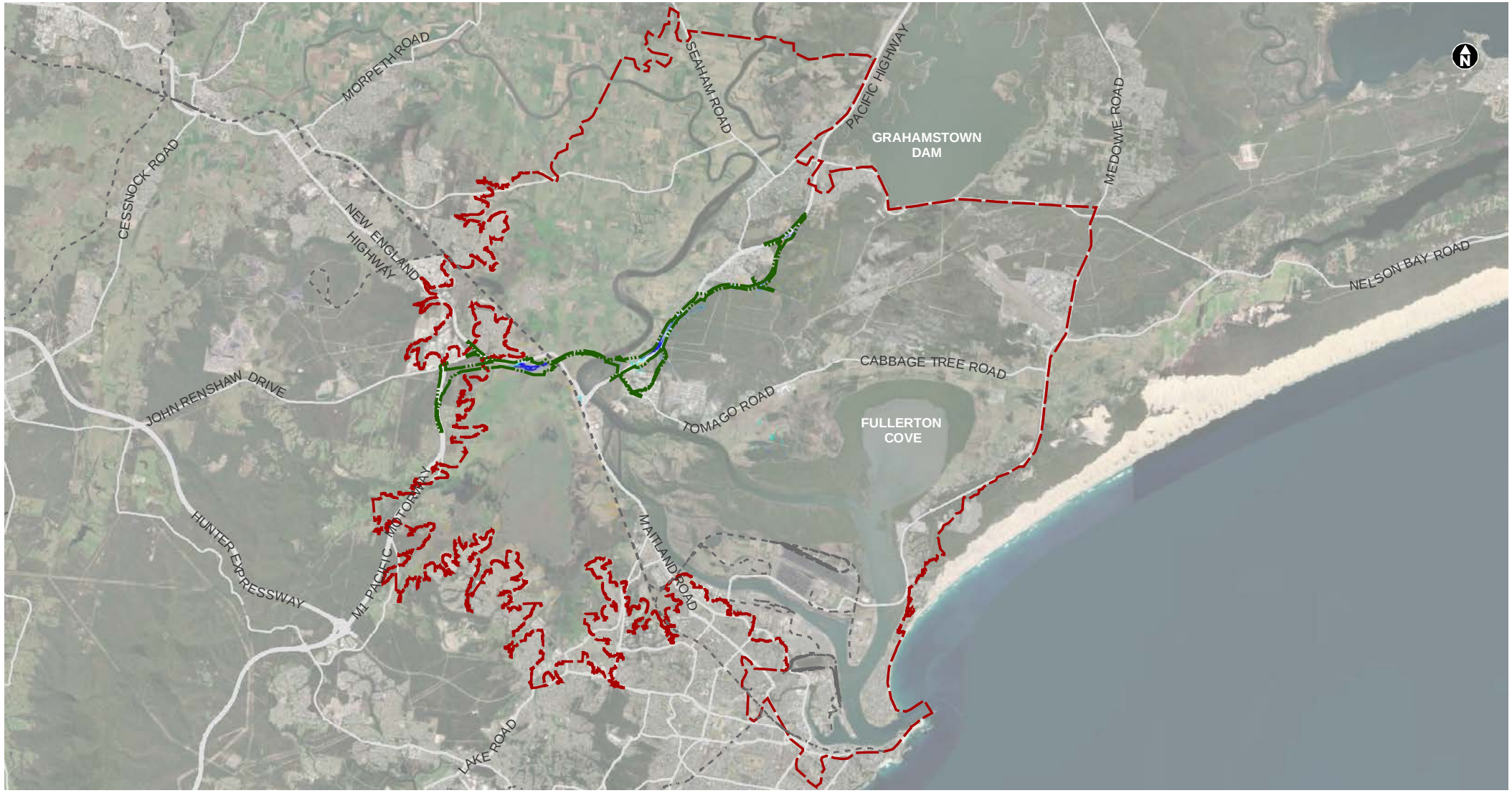
Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 1 2km

Figure E-14 Change in flood hazard - Operational phase - 10% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_050_E14_ChangeFloodHazard_10_Operational_JAC_A4L_175000_V02.mxd



Flooding study area
Operational footprint
Railway

Change in hazard from existing case

Was high, now dry
Was high, now low
Was low, now dry
Unchanged (not shown)
Was dry, now low
Was low, now high
Was dry, now high

0 4 8km

Figure E-15 Change in flood hazard - Operational phase - 5% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_051_E15_ChangeFloodHazard_5_Operational_JAC_A4L_175000_V02.mxd

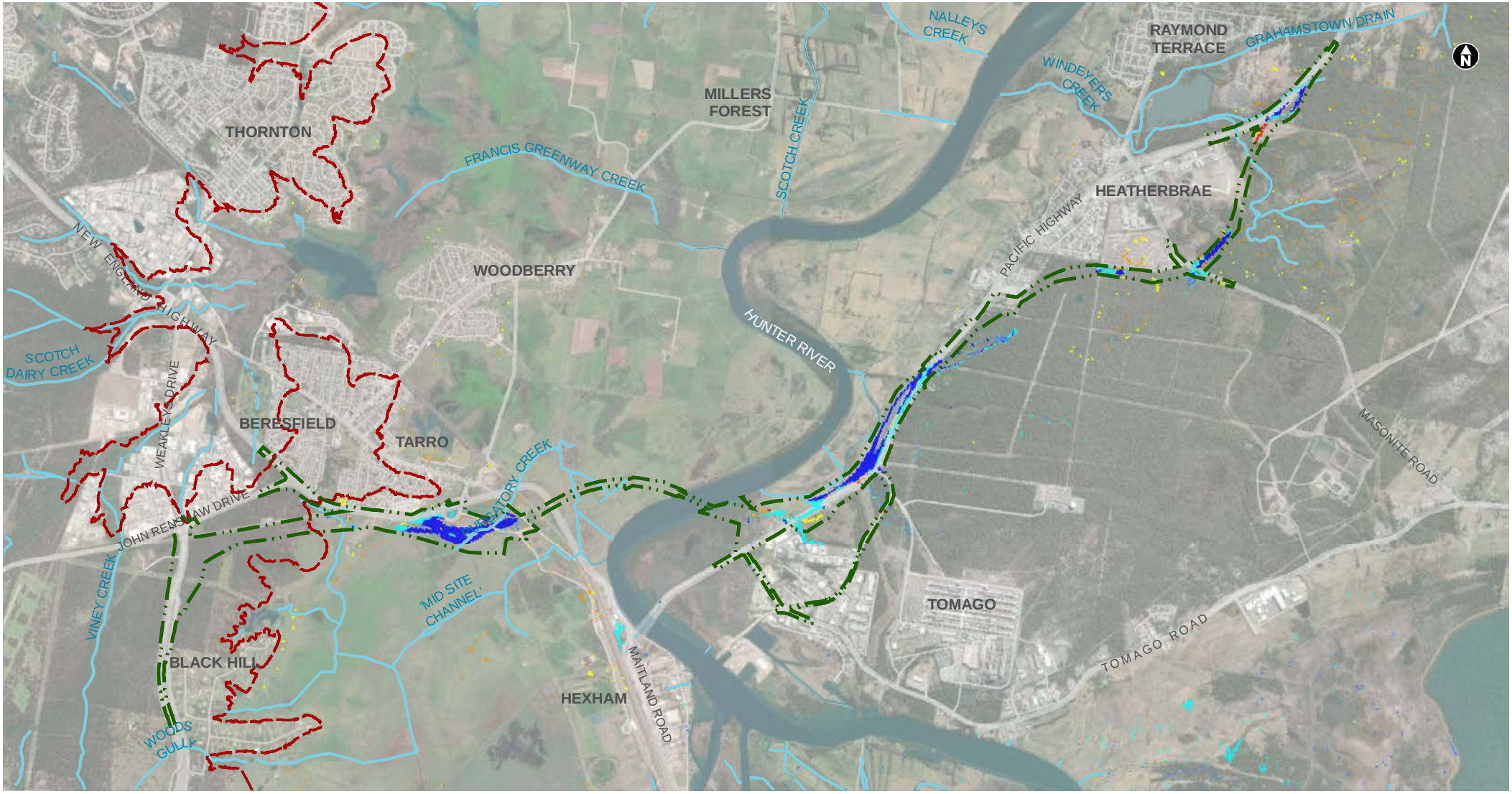
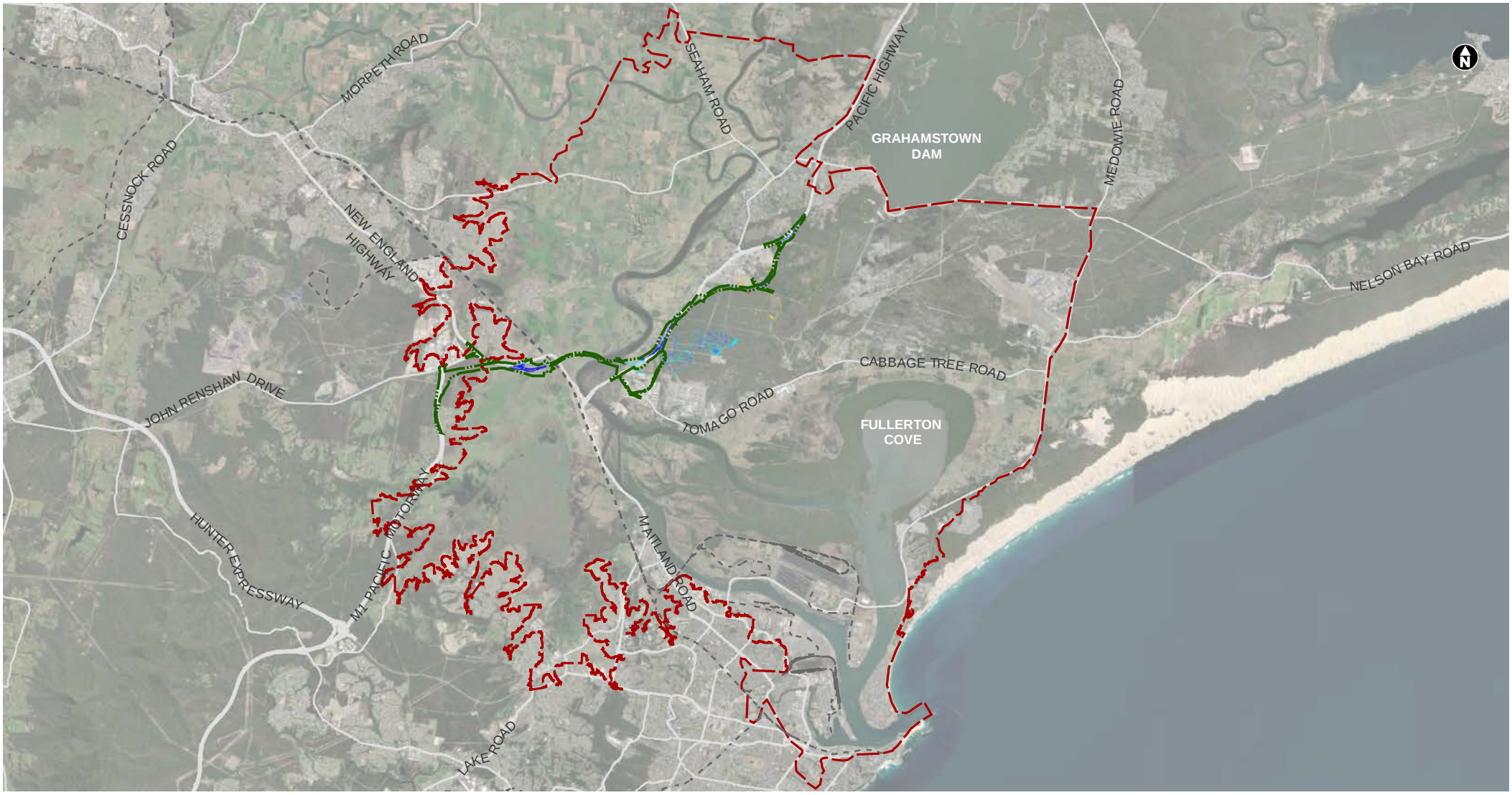


Figure E-15 Change in flood hazard - Operational phase - 5% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_051_E15_ChangeFloodHazard_5_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Change in hazard from existing case

Was high, now dry

Was high, now low

Was low, now dry

Unchanged (not shown)

Was dry, now low

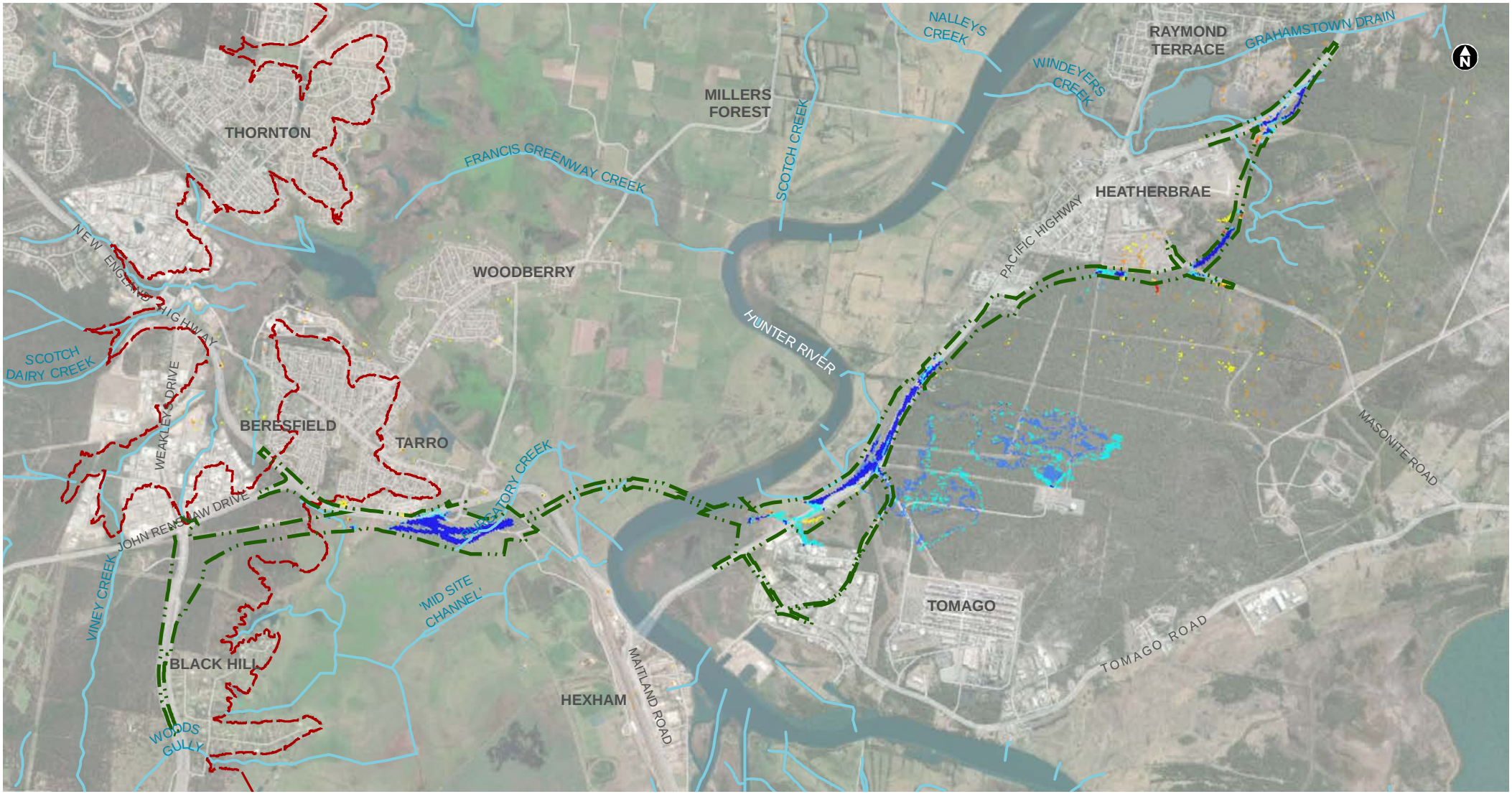
Was low, now high

Was dry, now high

0 4 8km

Figure E-16 Change in flood hazard - Operational phase - 2% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_052_E16_ChangeFloodHazard_2_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

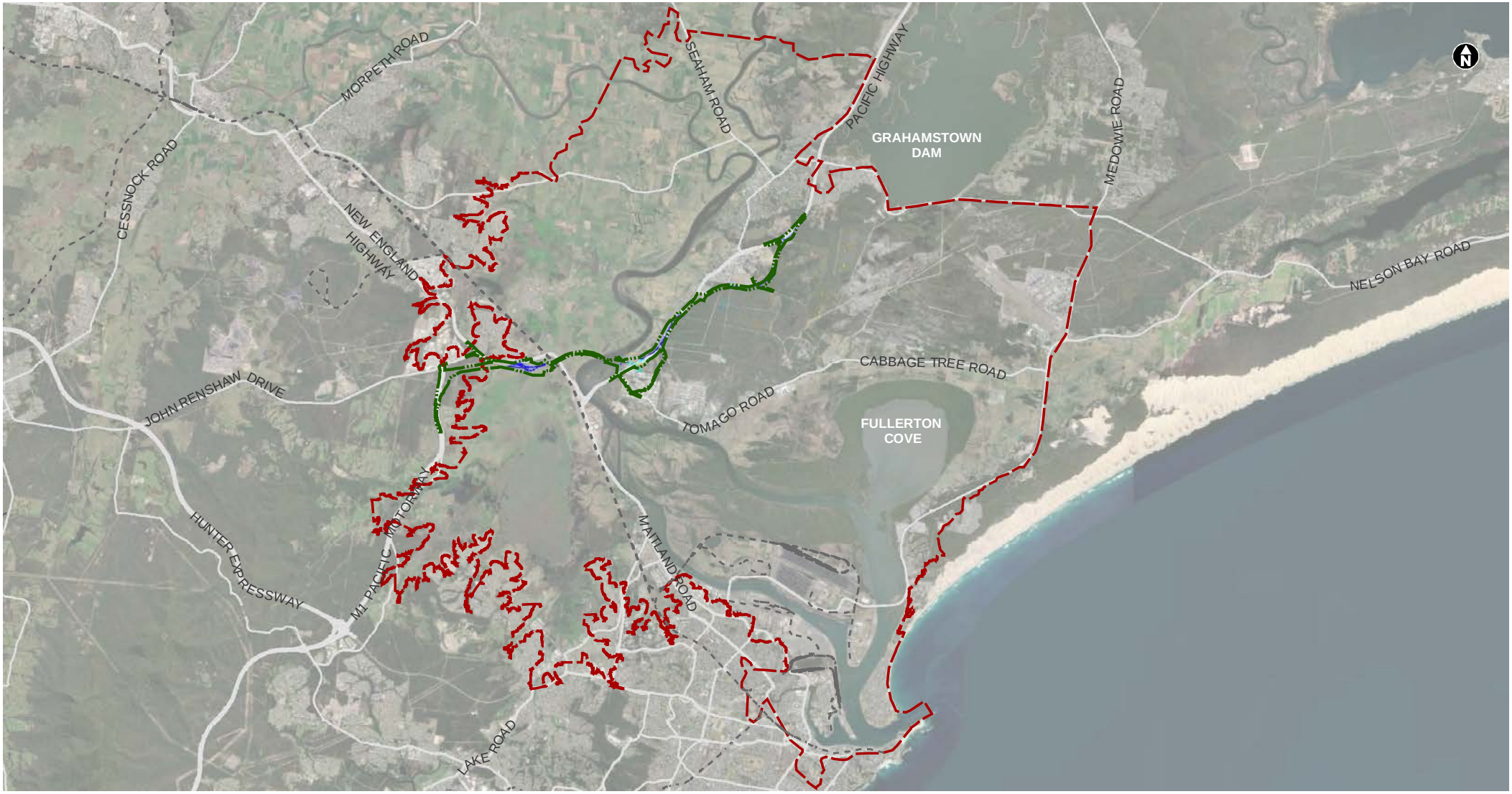
Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 1 2km

Figure E-16 Change in flood hazard - Operational phase - 2% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_052_E16_ChangeFloodHazard_2_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

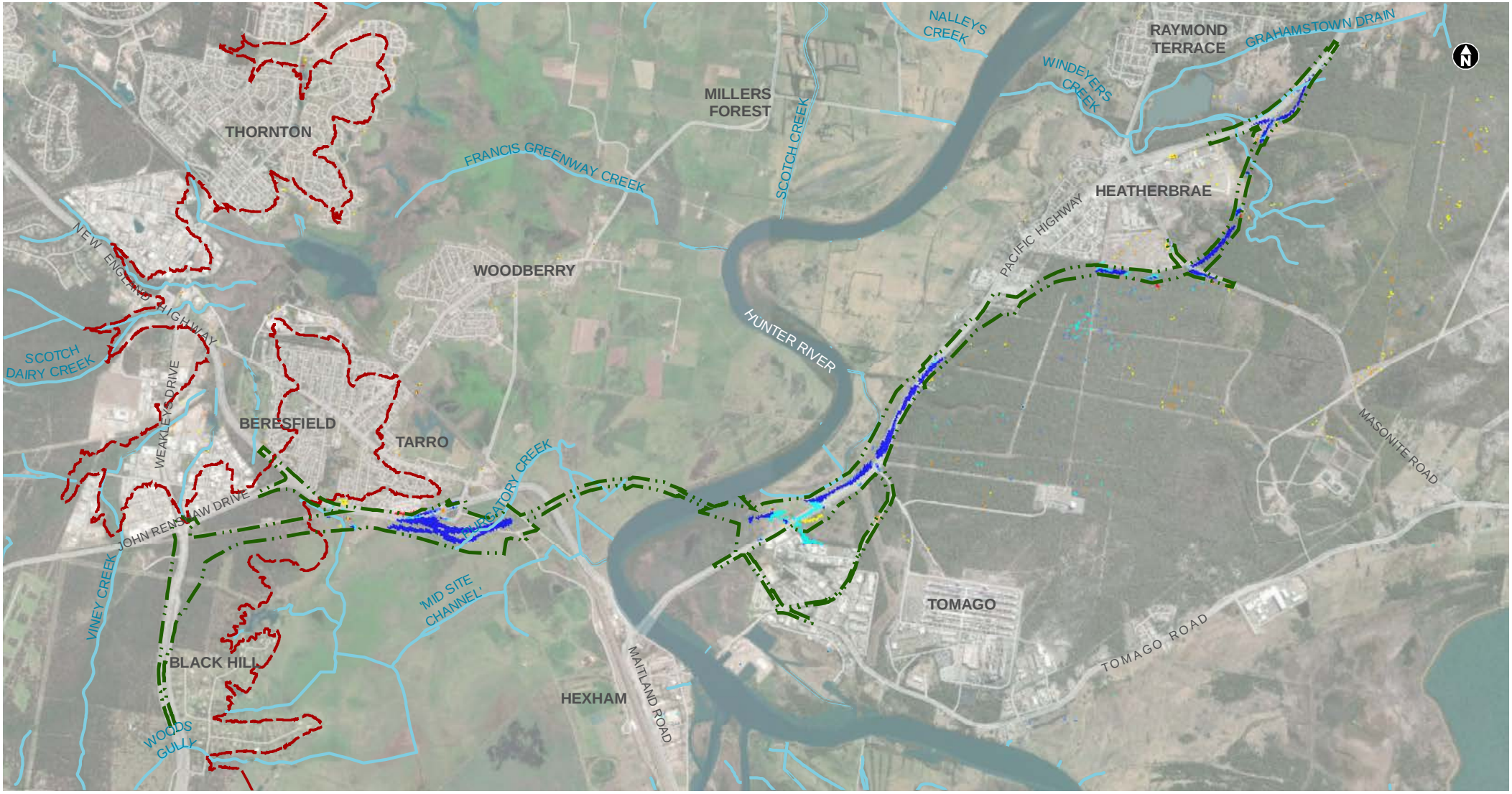
Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 4 8km

Figure E-17 Change in flood hazard - Operational phase - 1% AEP (map 1 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_053_E17_ChangeFloodHazard_1_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

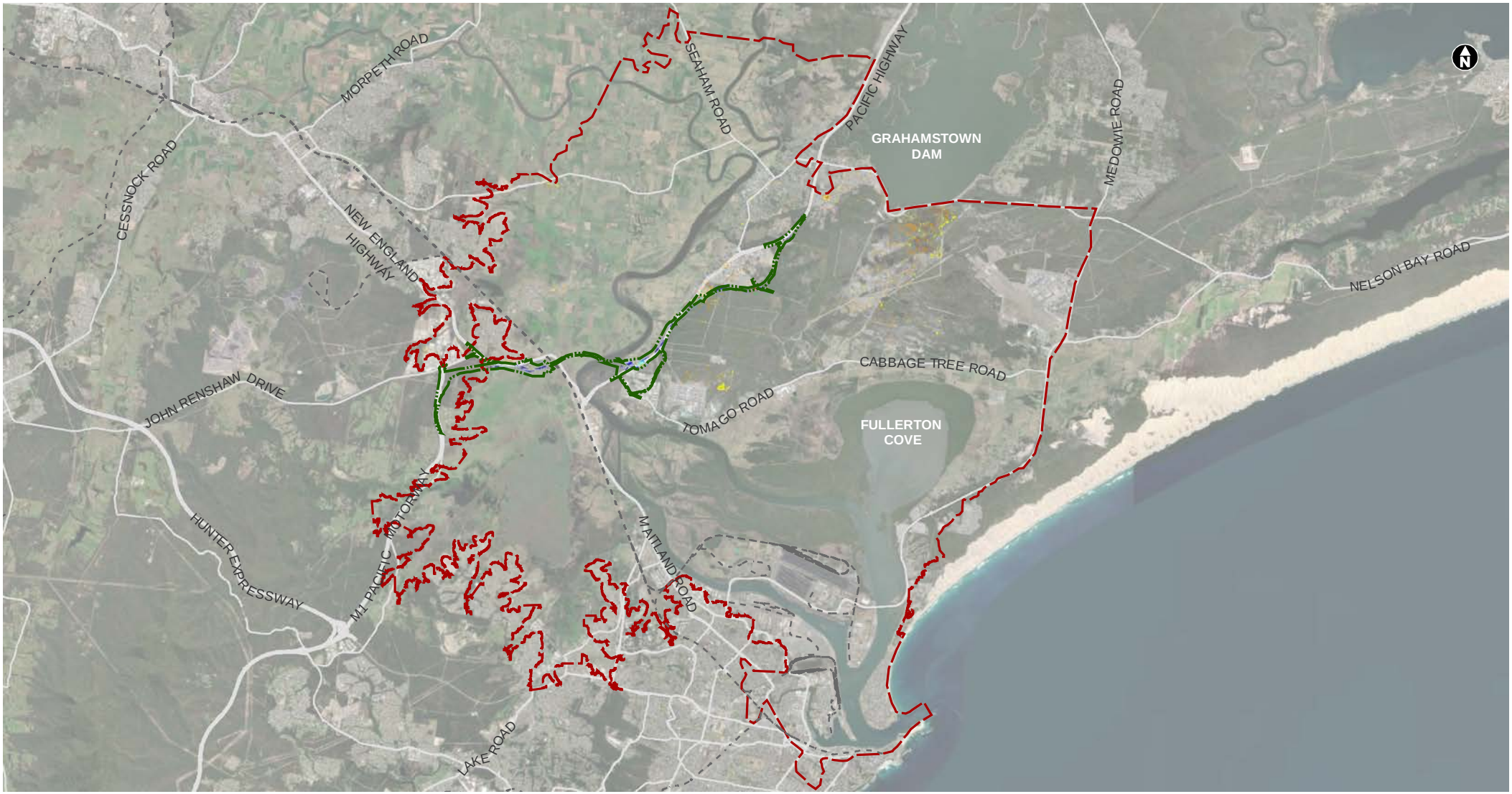
Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 1 2km

Figure E-17 Change in flood hazard - Operational phase - 1% AEP (map 2 of 2)

Date: 4/01/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_053_E17_ChangeFloodHazard_1_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Change in hazard from existing case

Was high, now dry

Was high, now low

Was low, now dry

Unchanged (not shown)

Was dry, now low

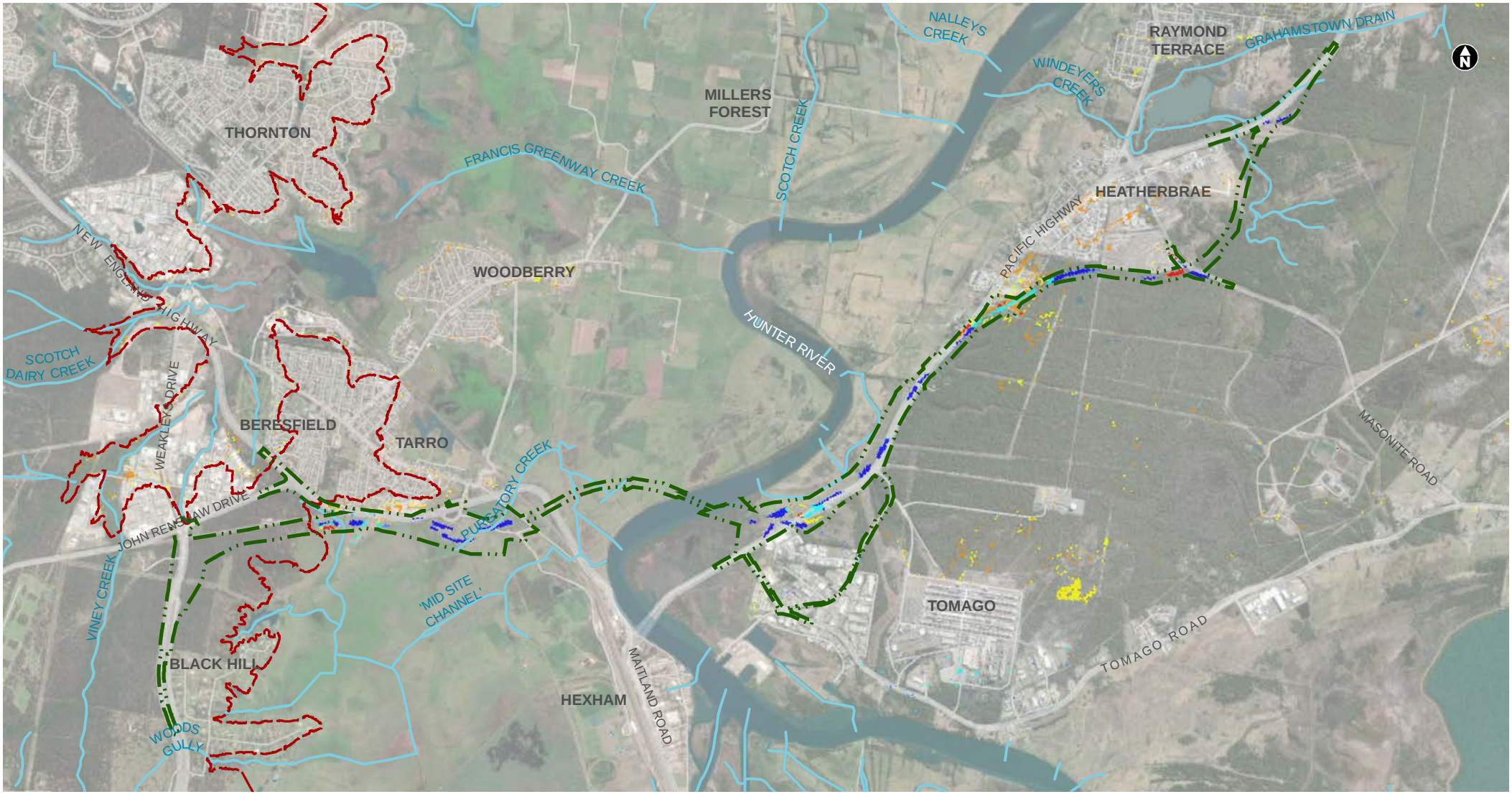
Was low, now high

Was dry, now high

0 4 8km

Figure E-18 Change in flood hazard - Operational phase - Probable maximum flood (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_054_E18_ChangeFloodHazard_ProbMax_Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in hazard from existing case

- Was high, now dry
- Was high, now low
- Was low, now dry
- Unchanged (not shown)
- Was dry, now low
- Was low, now high
- Was dry, now high

0 1 2km

Figure E-18 Change in flood hazard - Operational phase - Probable maximum flood (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_054_E18_ChangeFloodHazard_ProbMax_Operational_JAC_A4L_175000_V02.mxd

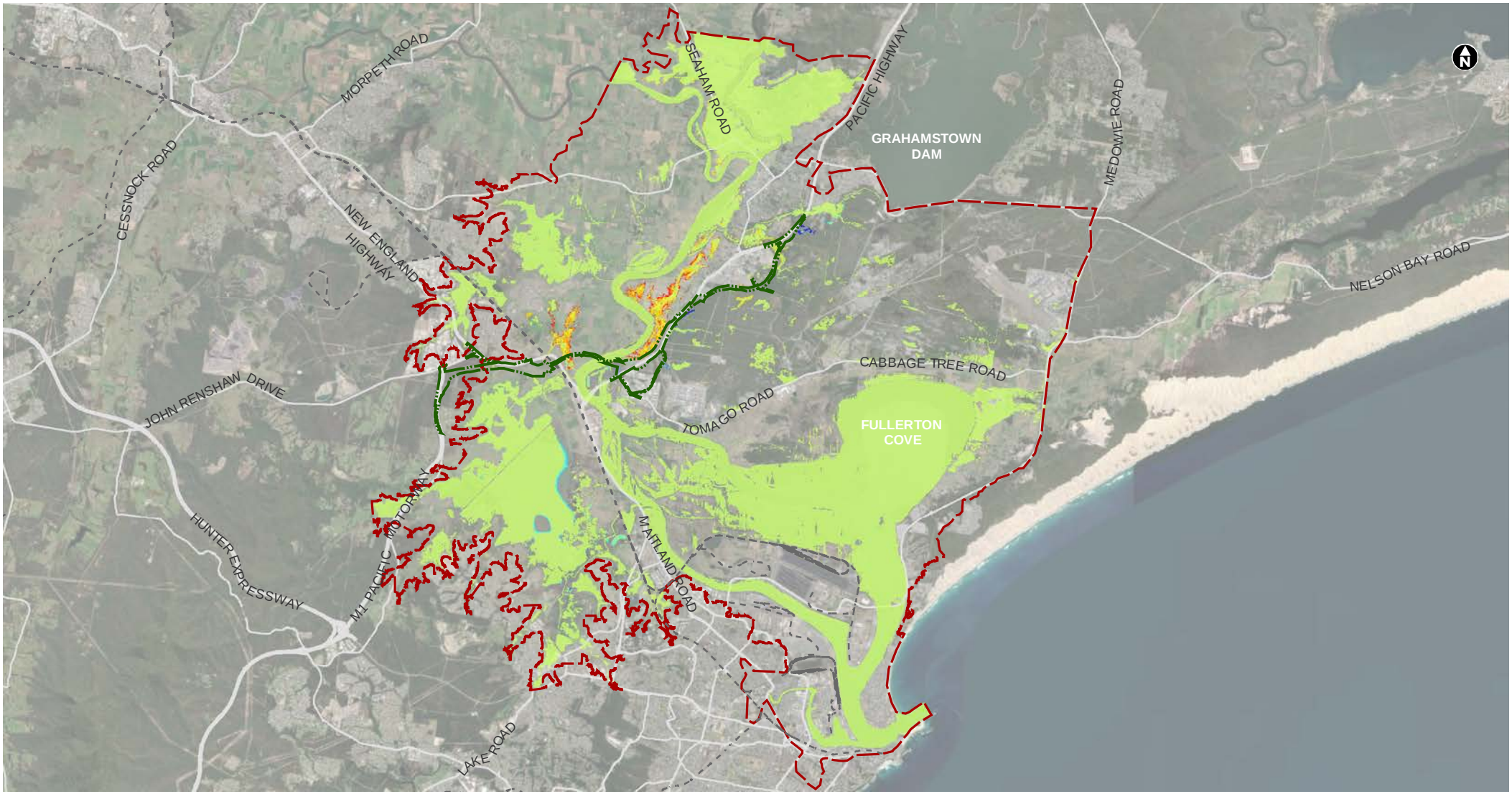
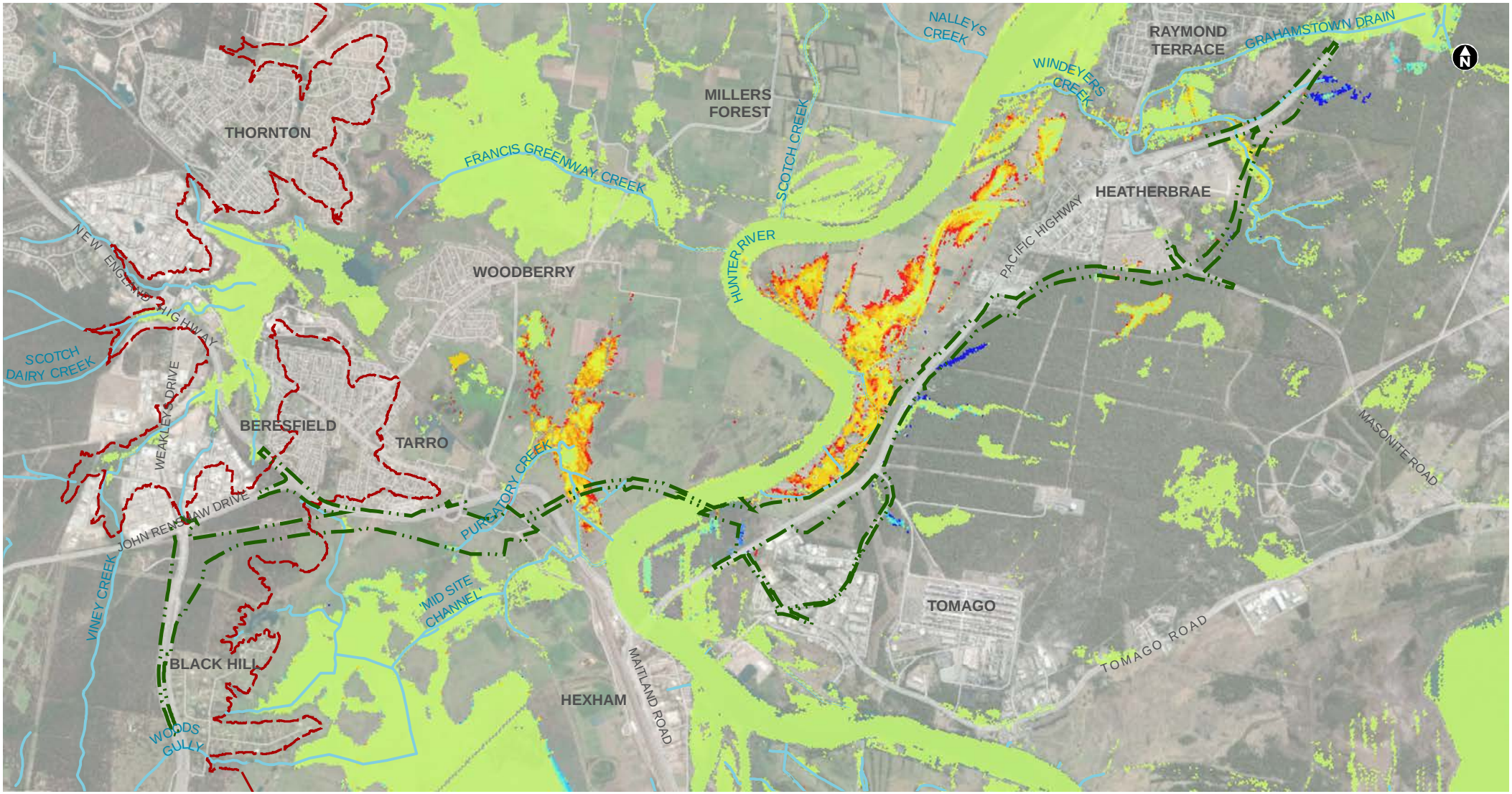


Figure E-19 Change in duration of inundation - Operational phase - 20% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_055_E19_ChangeDurationInundation20Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

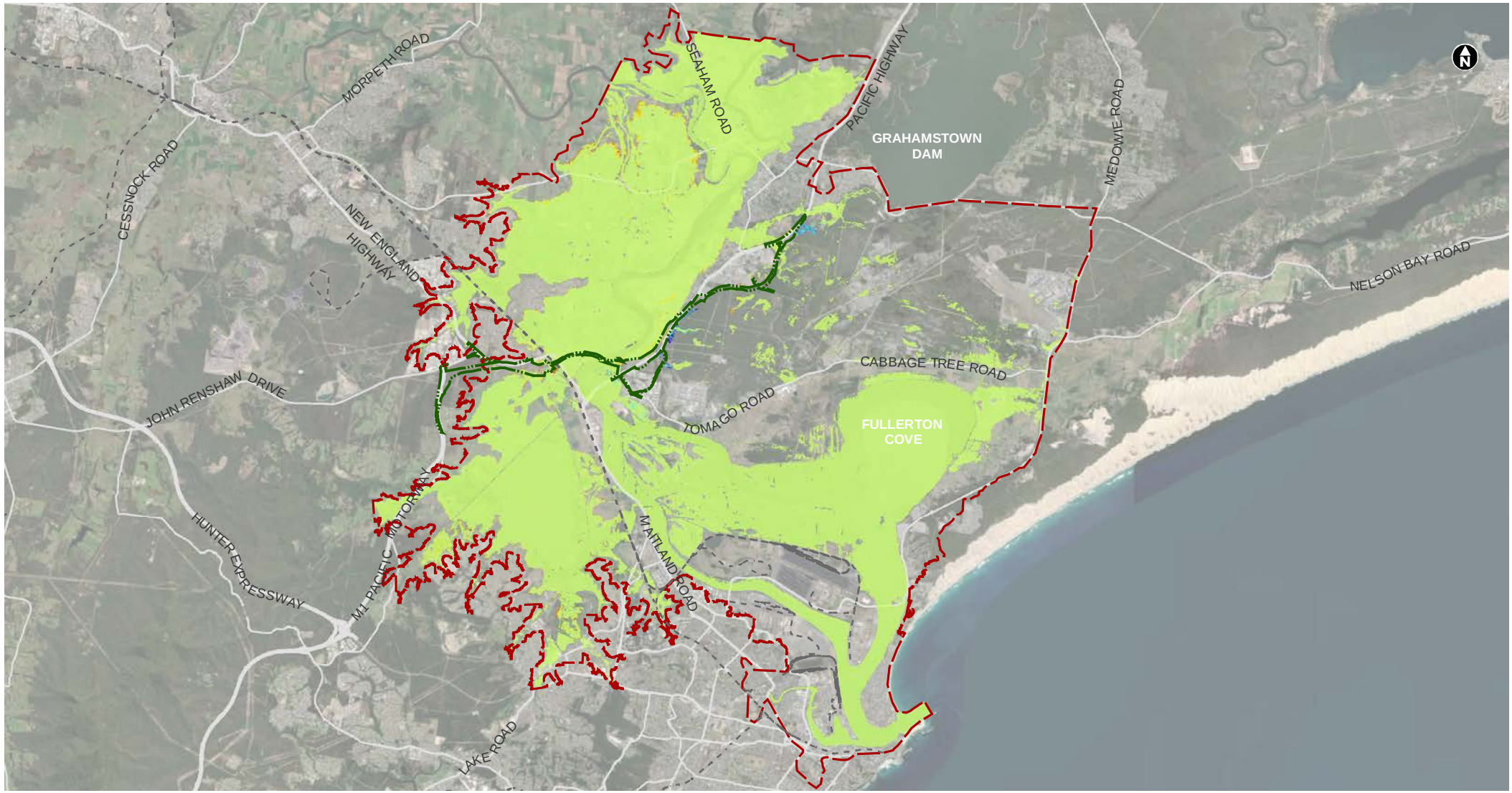
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure E-19 Change in duration of inundation - Operational phase - 20% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_055_E19_ChangeDurationInundation20Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

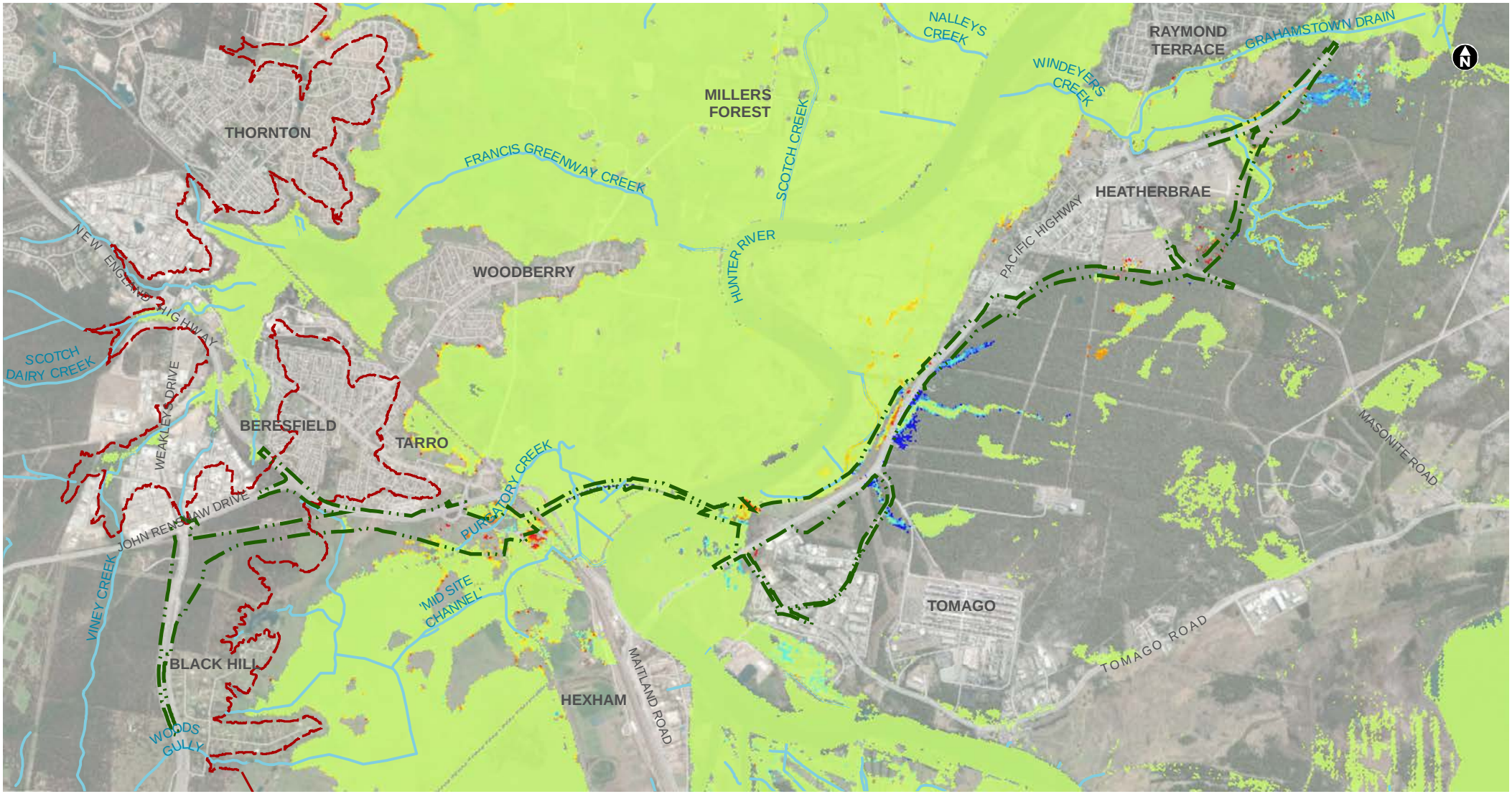
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 4 8km

Figure E-20 Change in duration of inundation - Operational phase - 10% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_056_E20_ChangeDurationInundation10Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

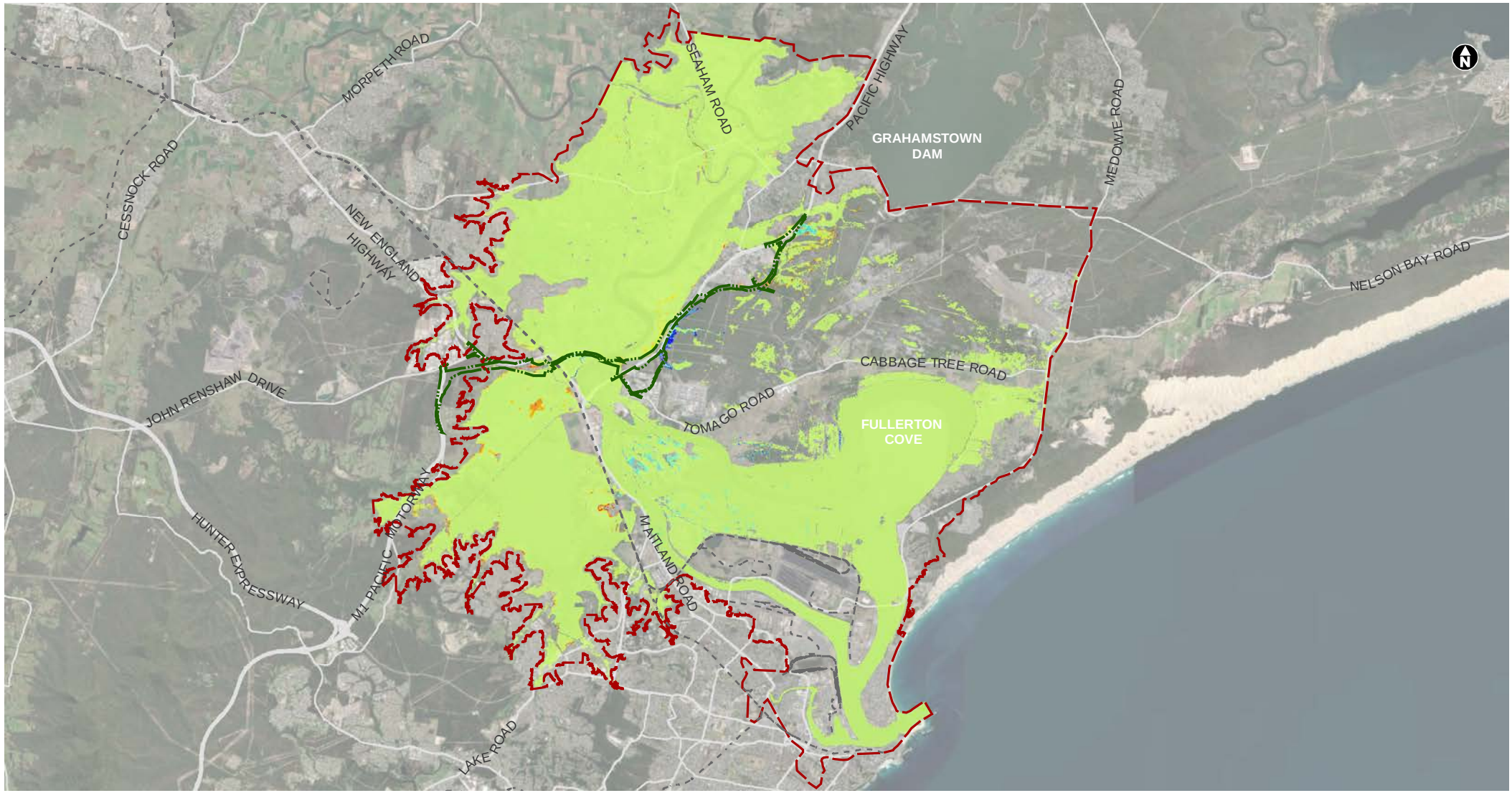
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure E-20 Change in duration of inundation - Operational phase - 10% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_056_E20_ChangeDurationInundation10Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

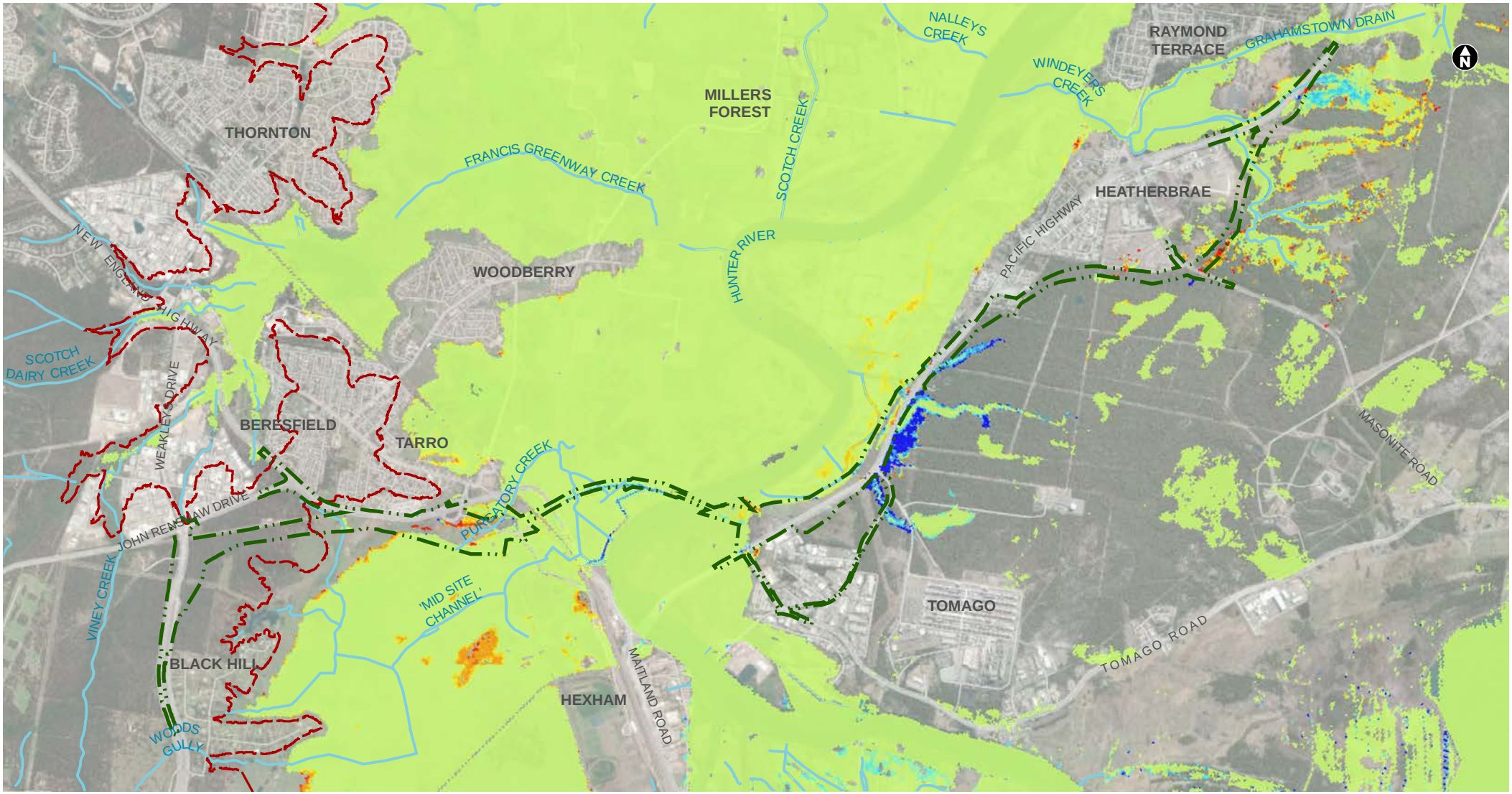
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 4 8km

Figure E-21 Change in duration of inundation - Operational phase - 5% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_057_E21_ChangeDurationInundation5Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

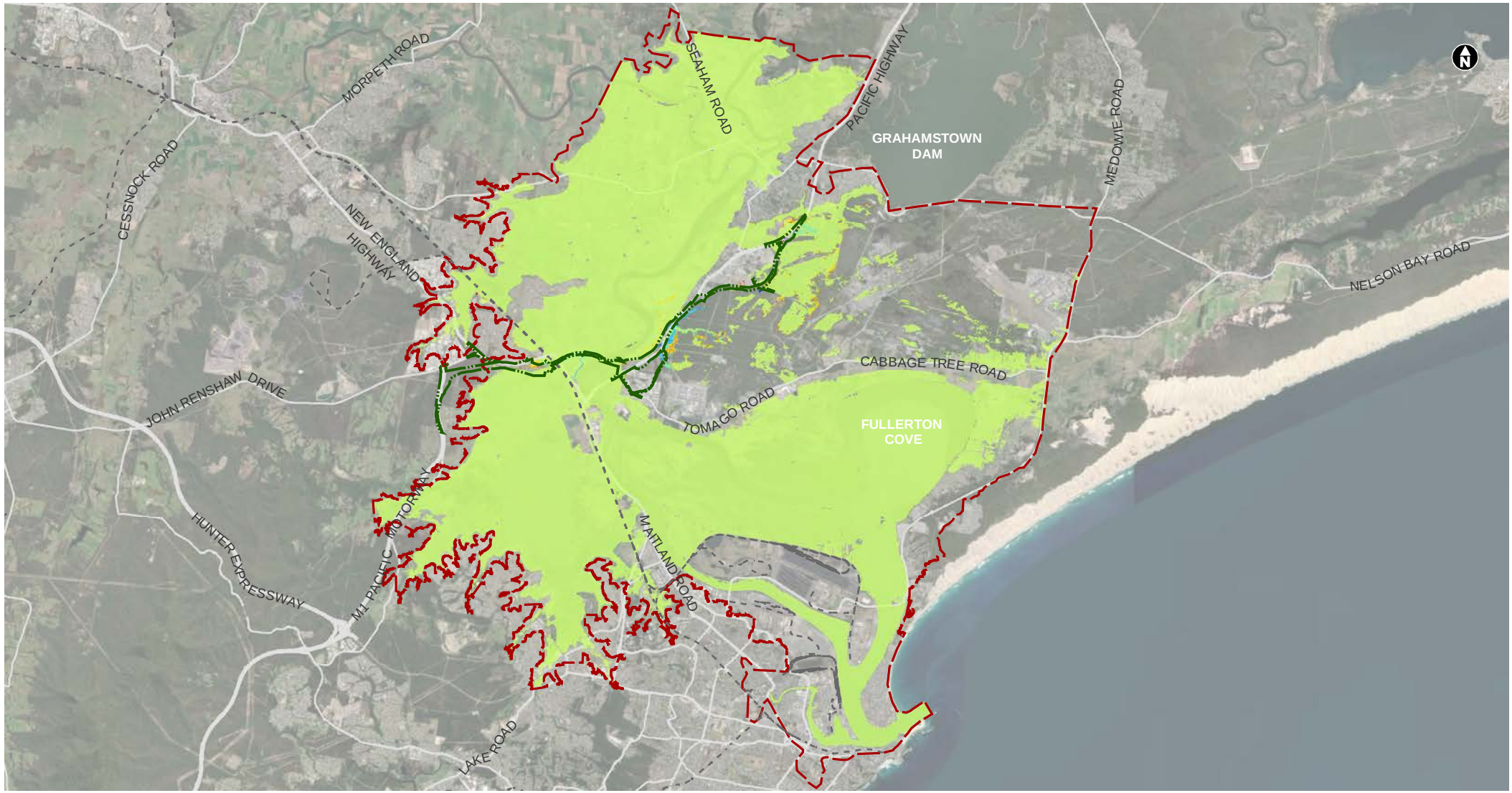
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure E-21 Change in duration of inundation - Operational phase - 5% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_057_E21_ChangeDurationInundation5Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

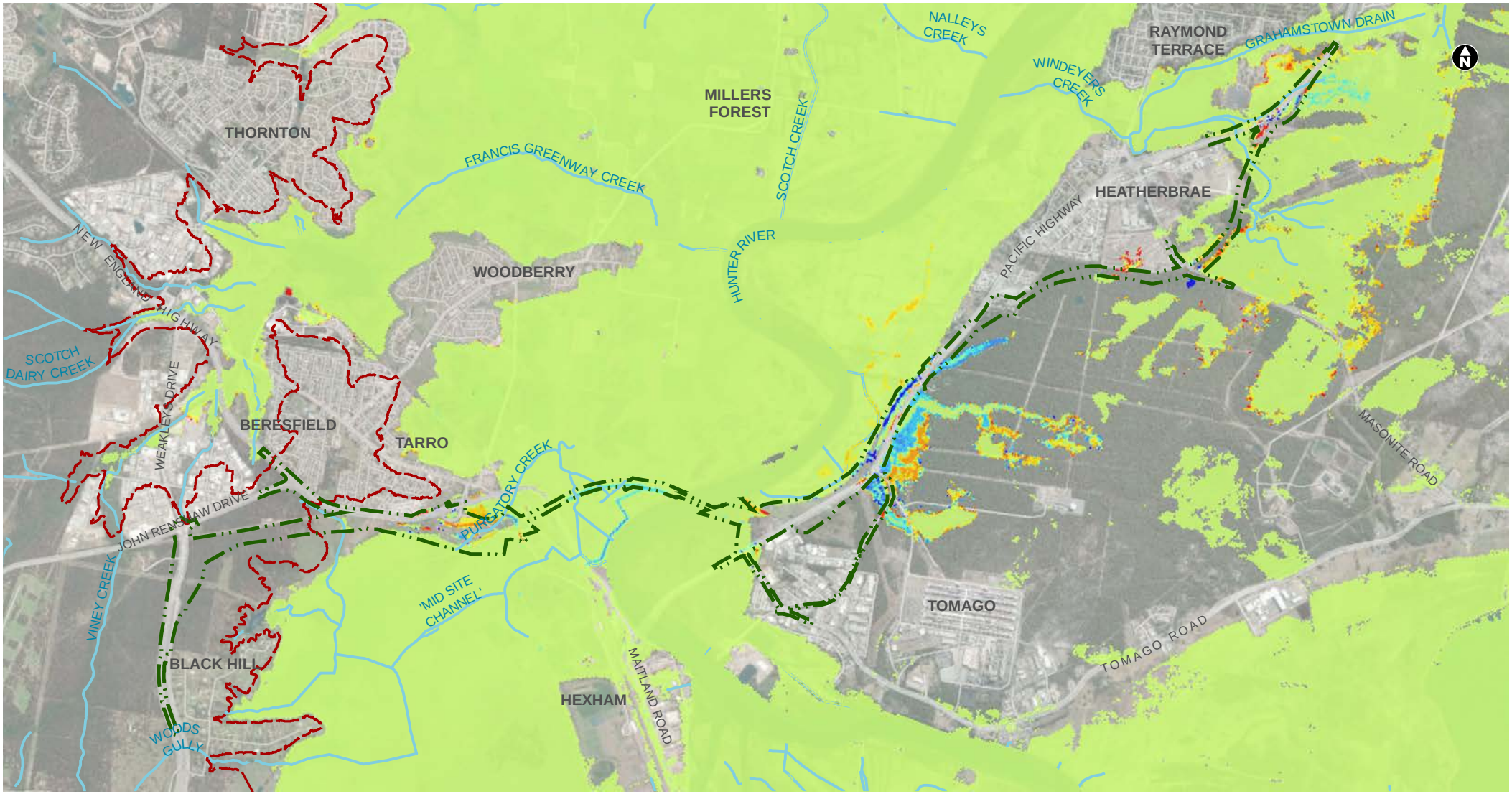
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 4 8km

Figure E-22 Change in duration of inundation - Operational phase - 2% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_058_E22_ChangeDurationInundation2Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

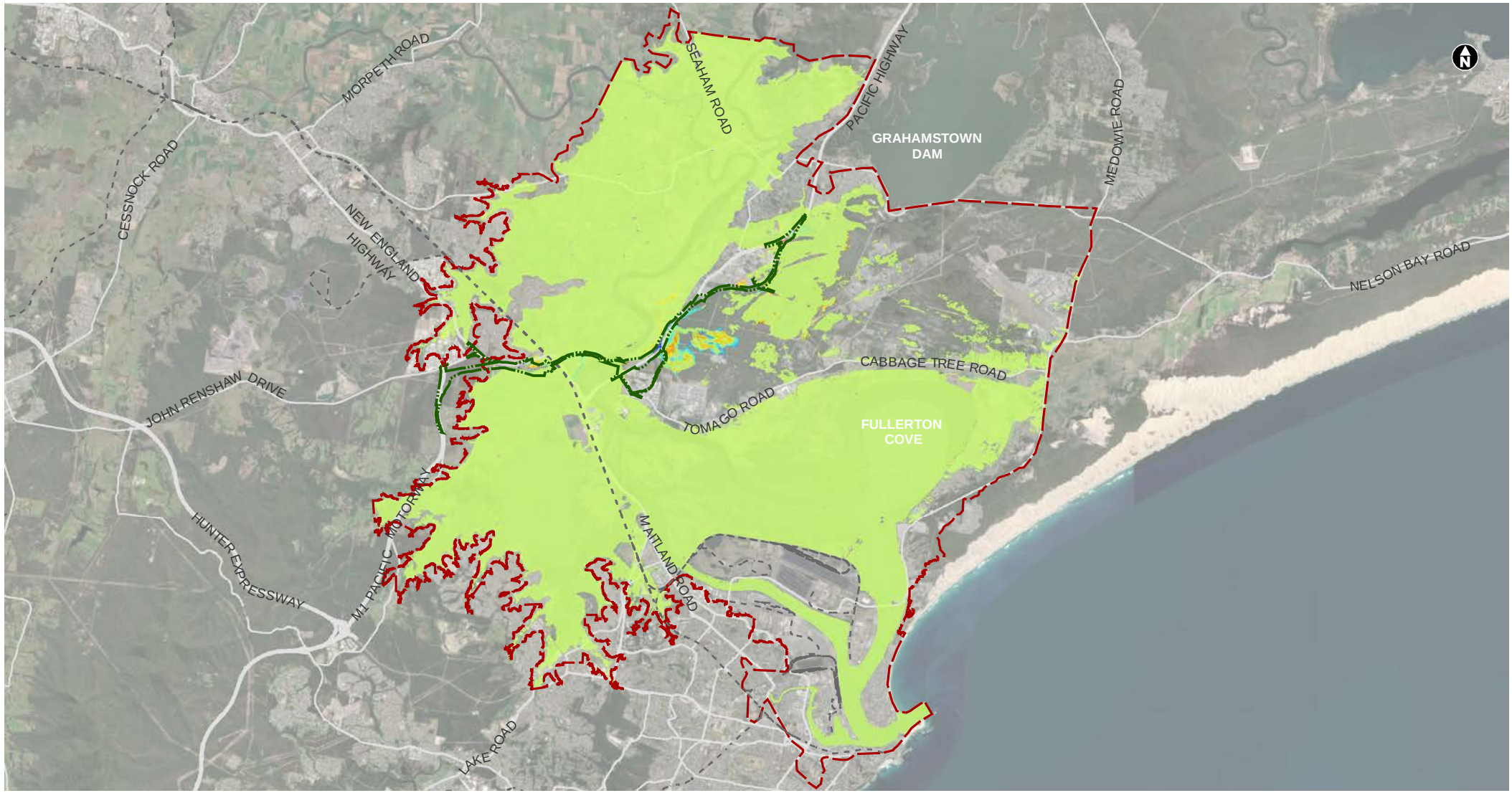
Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure E-22 Change in duration of inundation - Operational phase - 2% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_058_E22_ChangeDurationInundation2Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Change in duration of inundation from existing case (per cent)

< -50

-50 - -30

-30 - -20

-20 - -10

-10 - -5

-5 - 5

5 - 10

10 - 20

20 - 30

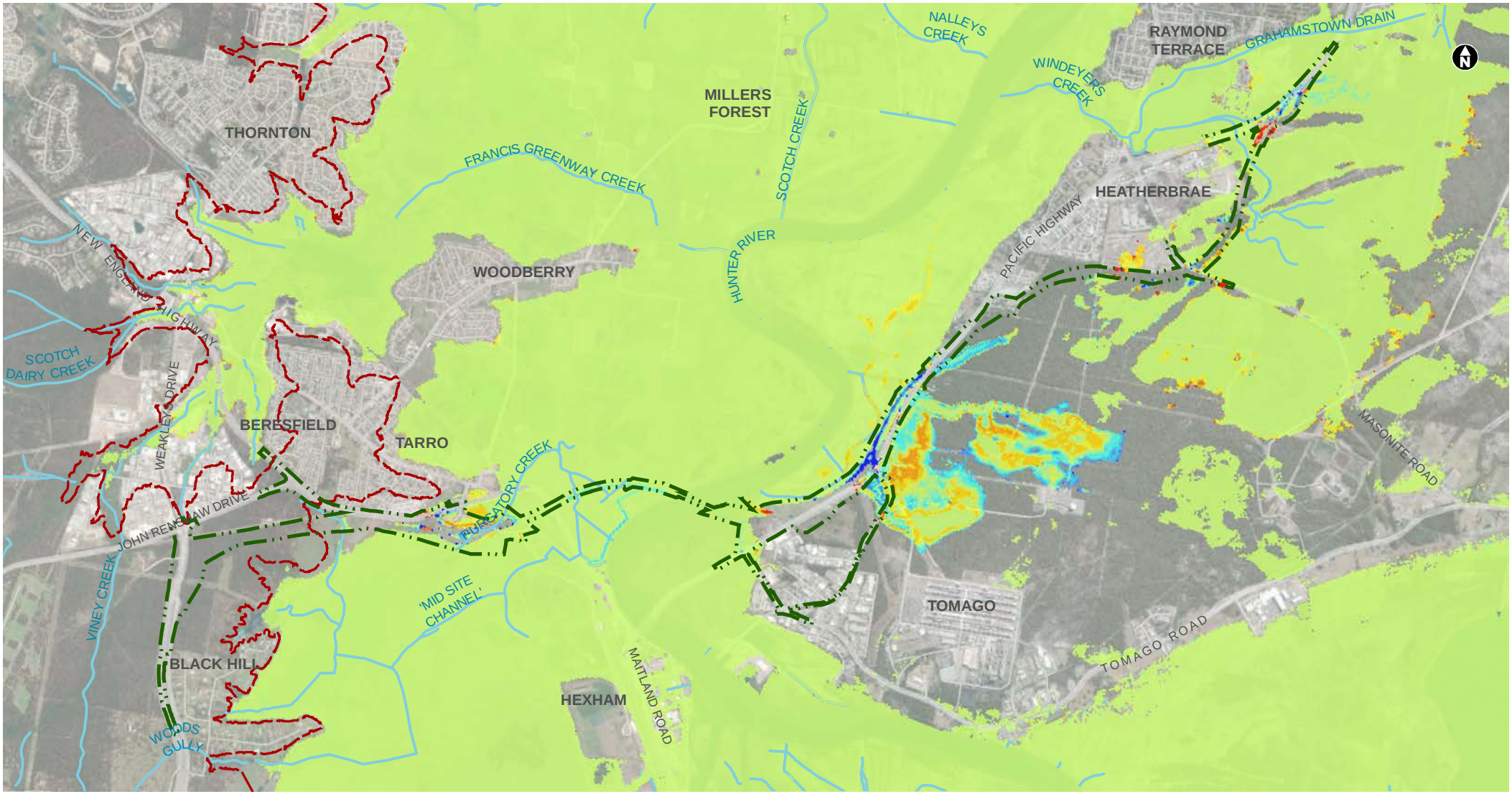
30 - 50

> 50

0 4 8km

Figure E-23 Change in duration of inundation - Operational phase - 1% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_059_E23_ChangeDurationInundation1Operational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in duration of inundation from existing case (per cent)

- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure E-23 Change in duration of inundation - Operational phase - 1% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_059_E23_ChangeDurationInundation1Operational_JAC_A4L_175000_V02.mxd

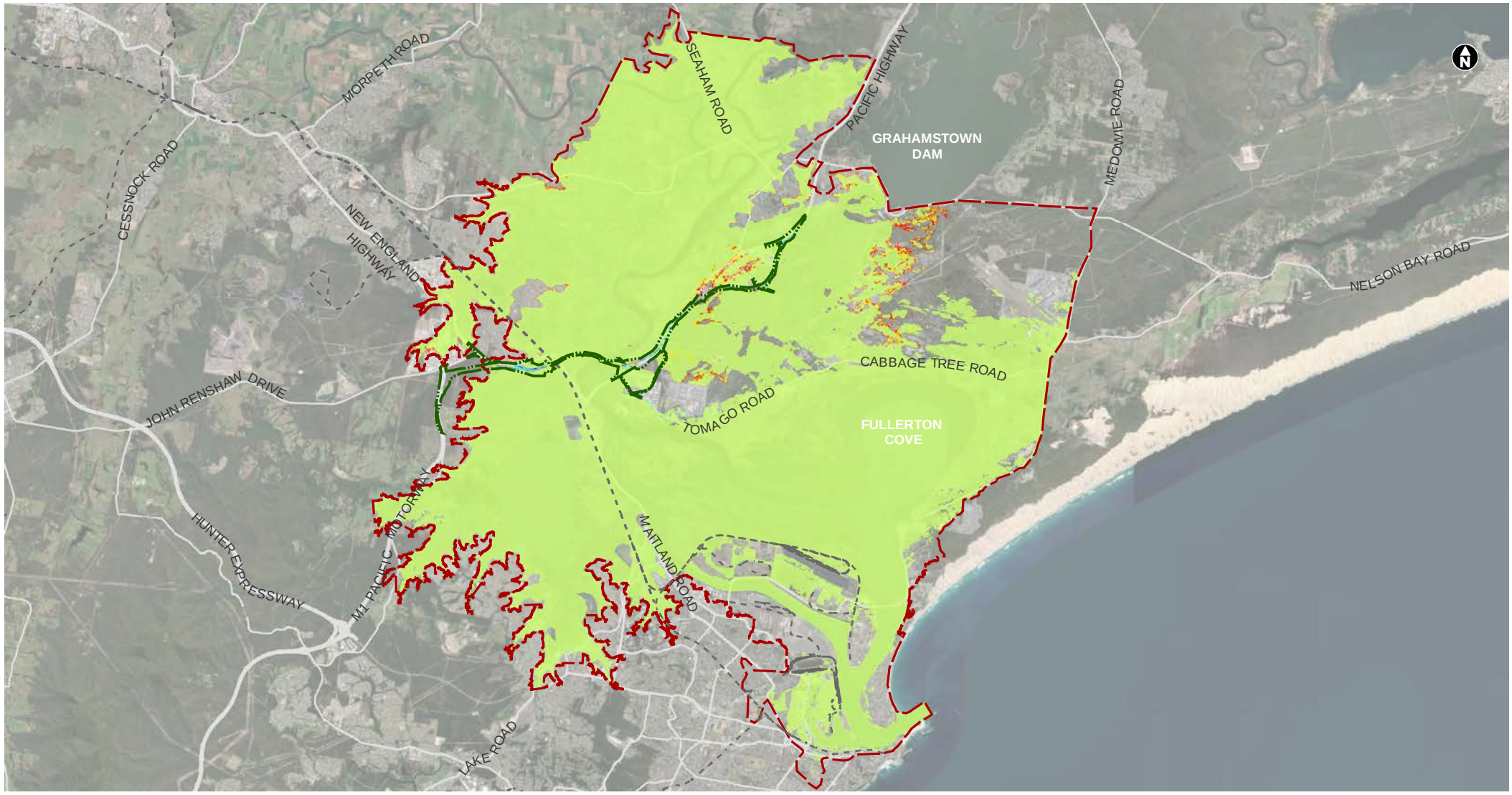
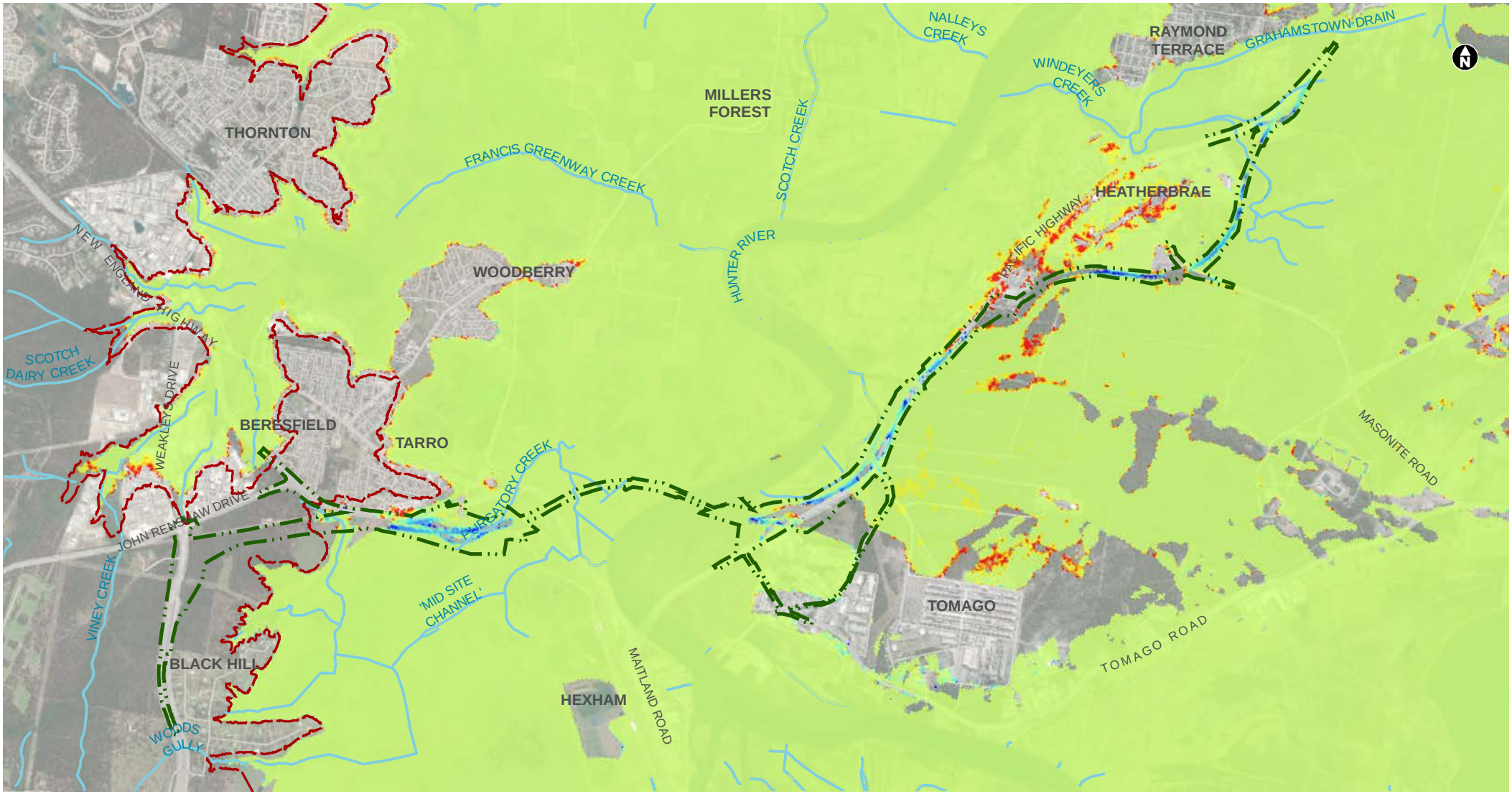


Figure E-24 Change in duration of inundation - Operational phase - Probable maximum flood (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_060_E24_ChangeDurationInundationMaxOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Change in duration of inundation from existing case (per cent)

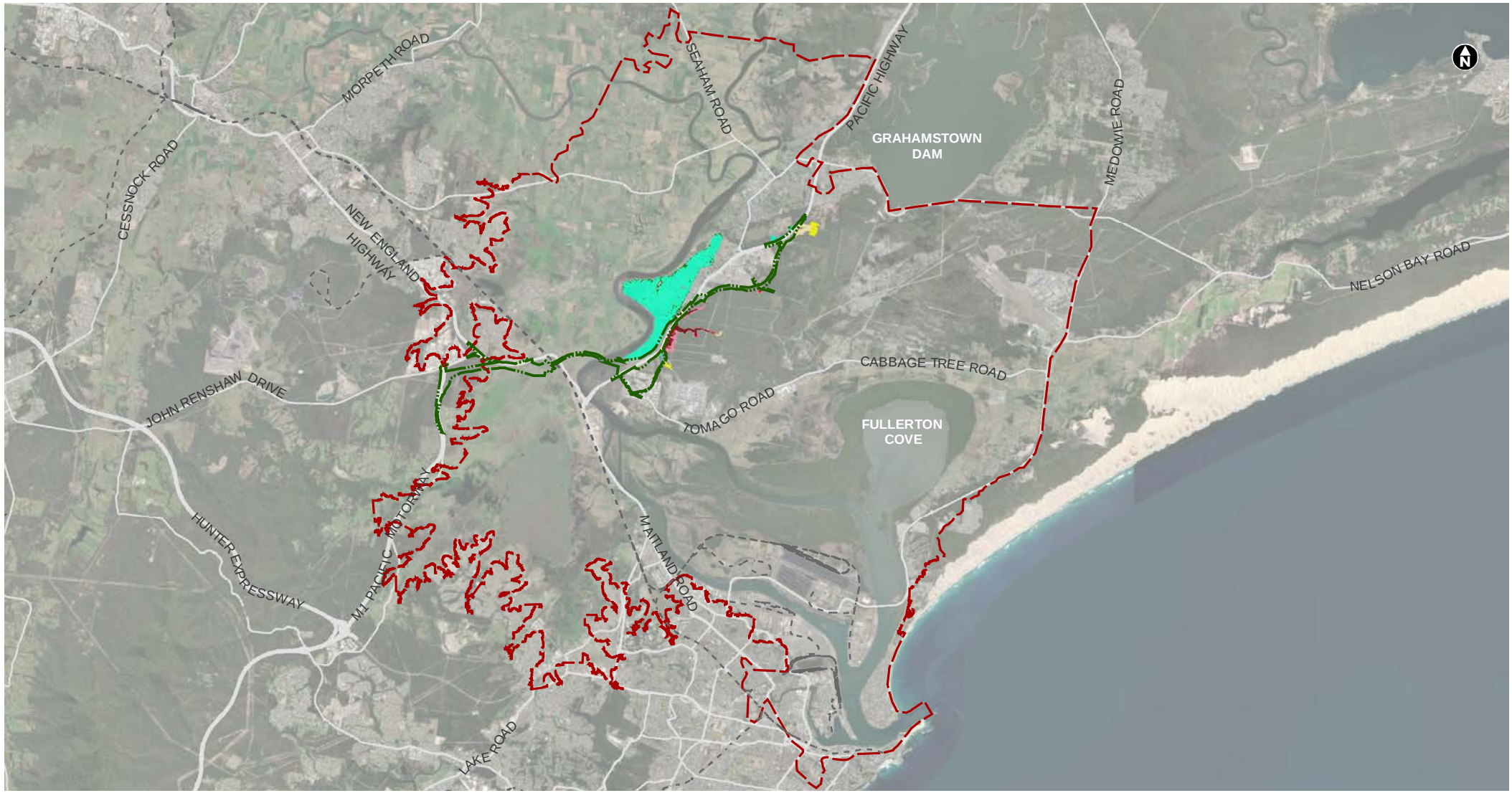
- < -50
- -50 - -30
- -30 - -20
- -20 - -10
- -10 - -5
- -5 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

0 1 2km

Figure E-24 Change in duration of inundation - Operational phase - Probable maximum flood (map 2 of 2)

Date: 15/12/2020 Path: J:\E\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\A230000_CD_HF_060_E24_ChangeDurationInundationMaxOperational_JAC_A4L_175000_V02.mxd

Appendix F Flood impact maps – Culvert blockage



Flooding study area

Operational footprint

Railway

Change in flood level from operational case (m)

< -0.4

-0.4 - -0.25

-0.25 - -0.1

-0.1 - -0.01

-0.01 - 0.01 (not shown)

0.01 - 0.03

0.03 - 0.05

0.05 - 0.1

0.1 - 0.25

0.25 - 0.4

> 0.4

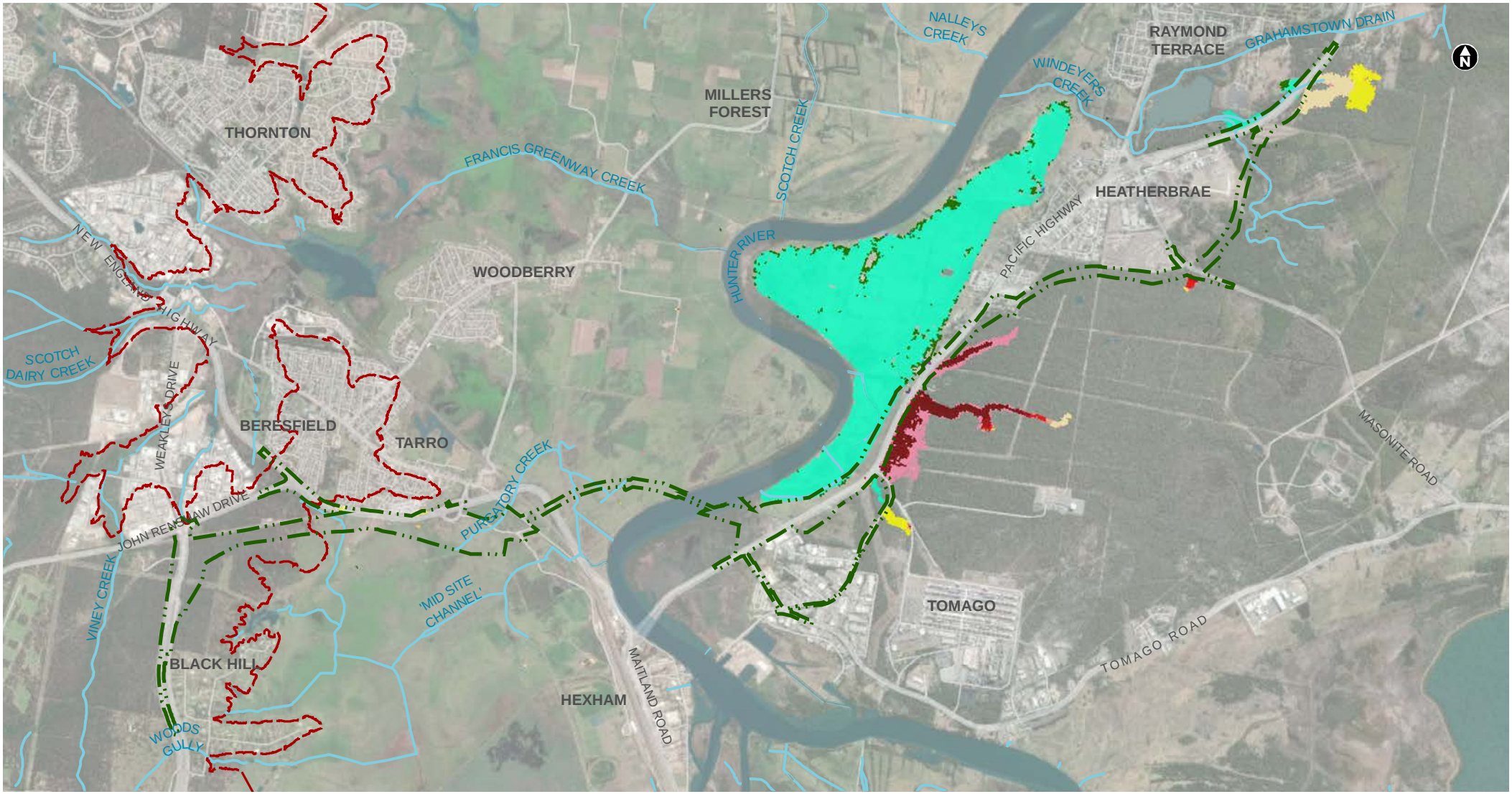
Was wet now dry

Was dry now wet

0 4 8km

Figure F-1 Change in flood level - Operational phase with blockage sensitivity - 20% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_072_I1_FloodLevel20BlockageOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

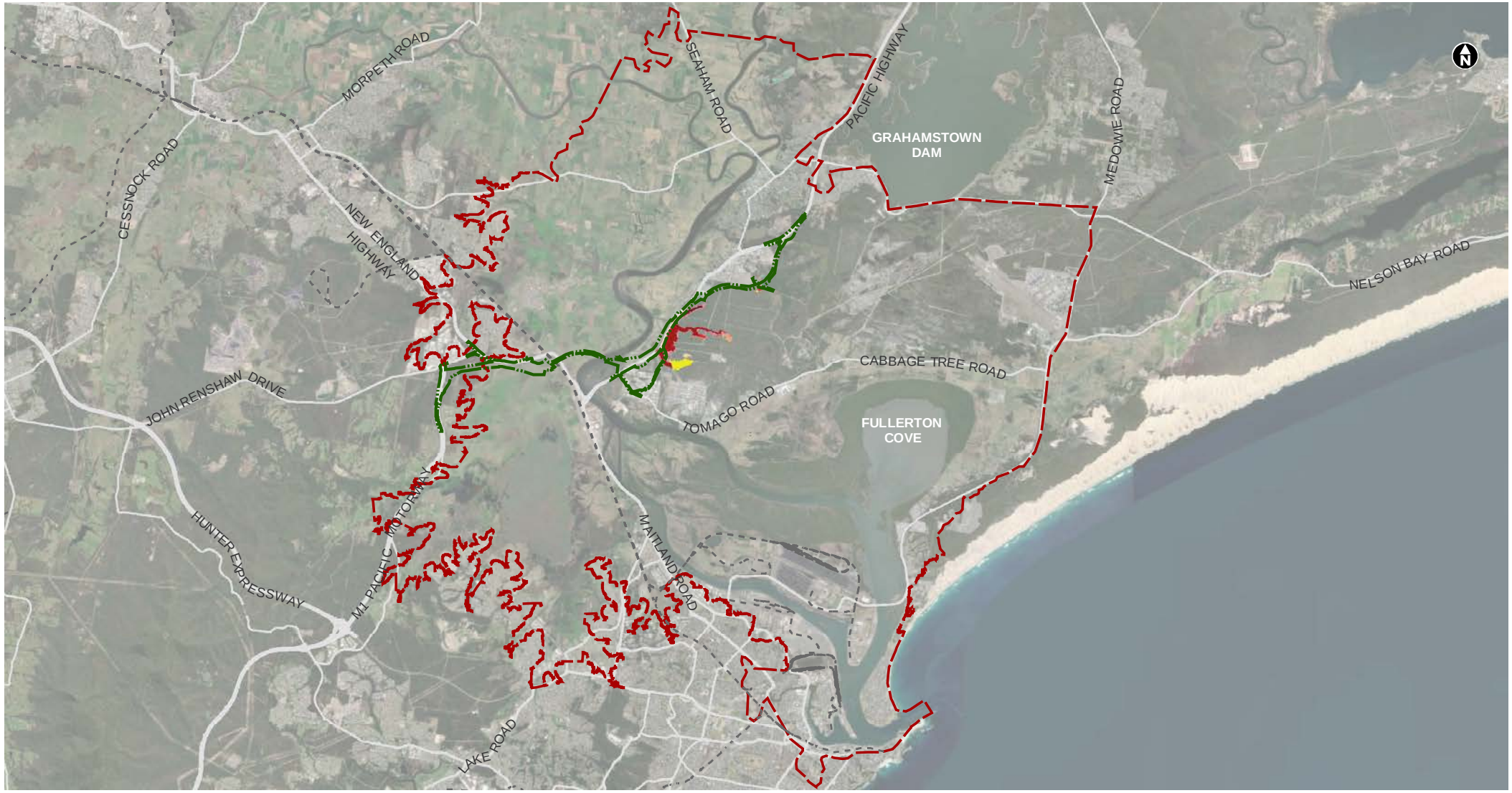
Change in flood level from operational case (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure F-1 Change in flood level - Operational phase with blockage sensitivity - 20% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_072_I1_FloodLevel20BlockageOperational_JAC_A4L_175000_V02.mxd



Flooding study area
Operational footprint
Railway

Change in flood level from operational case (m)

-0.1 - -0.01
-0.01 - 0.01 (not shown)
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.4
> 0.4
Was wet now dry
Was dry now wet

0 4 8km

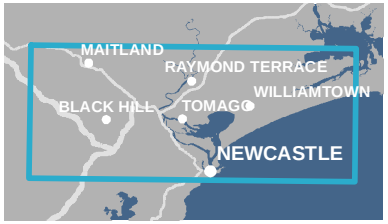
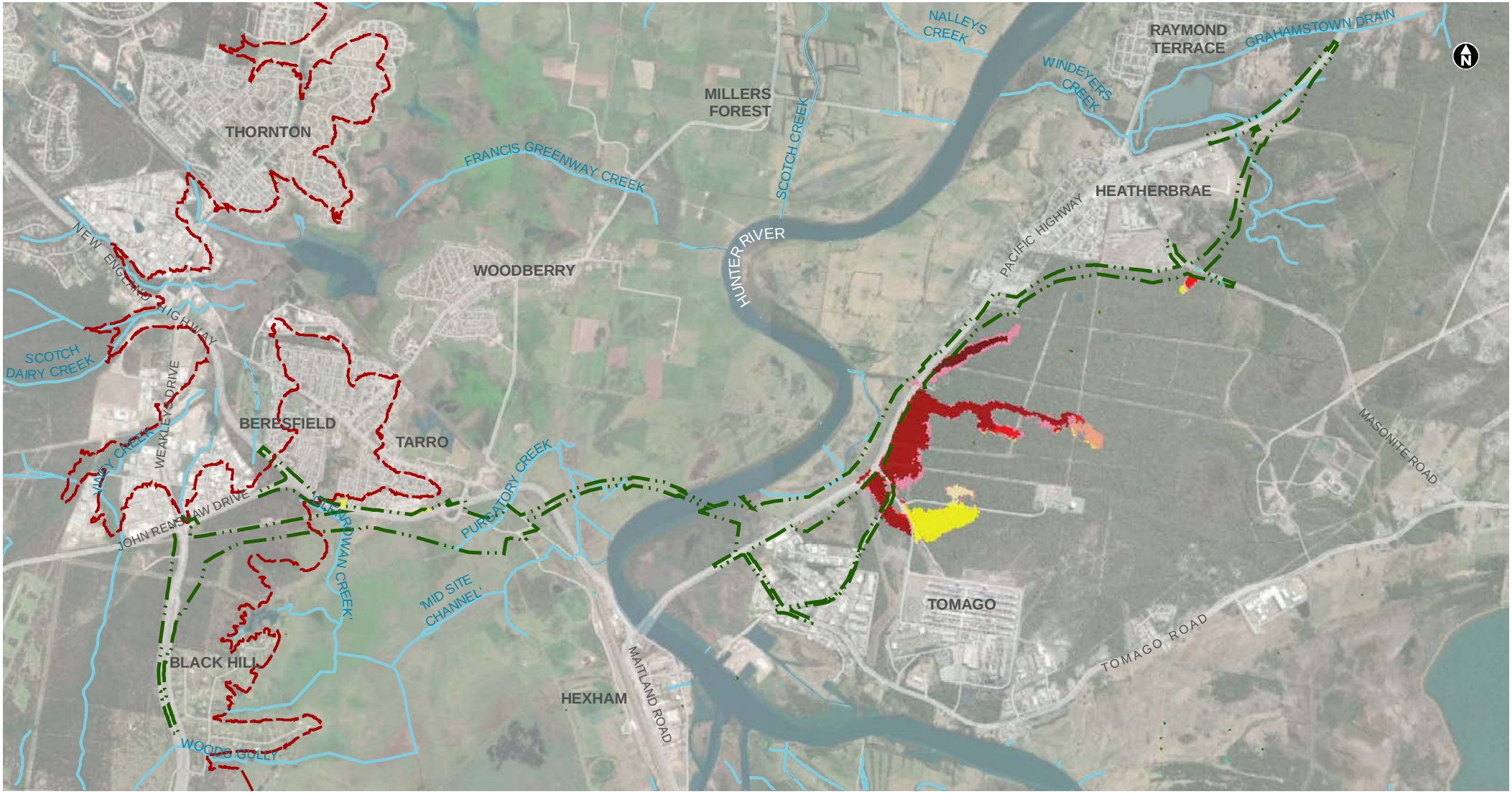


Figure F-2 Change in flood level - Operational phase with blockage sensitivity - 5% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_073_I2_FloodLevel5BlockageOperational_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

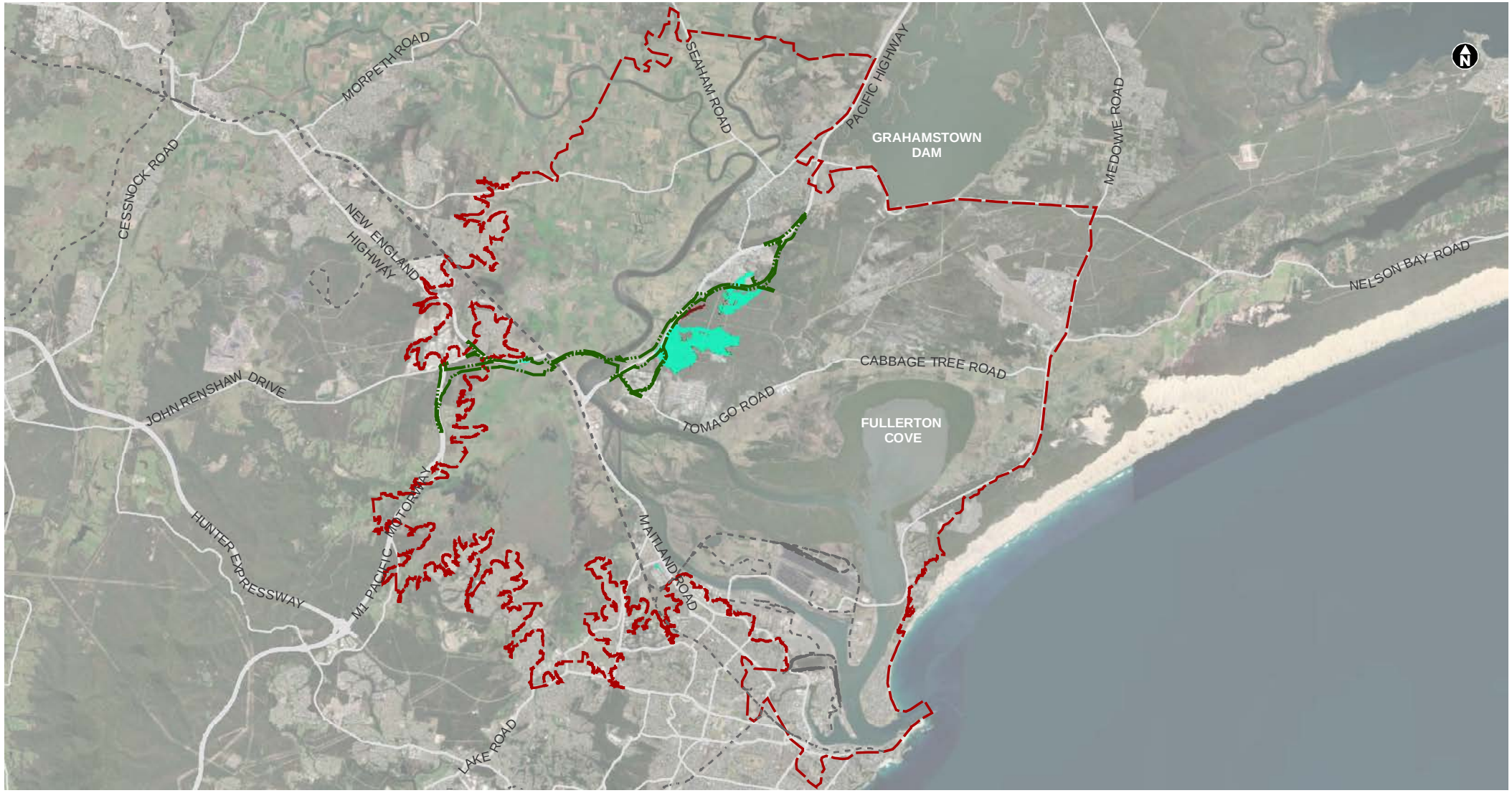
Change in flood level from operational case (m)

- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure F-2 Change in flood level - Operational phase with blockage sensitivity - 5% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_073_I2_FloodLevel5BlockageOperational_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Railway

Change in flood level from operational case (m)

-0.4 - -0.25

-0.25 - -0.1

-0.1 - -0.01

-0.01 - 0.01 (not shown)

0.01 - 0.03

0.03 - 0.05

0.05 - 0.1

0.1 - 0.25

0.25 - 0.4

> 0.4

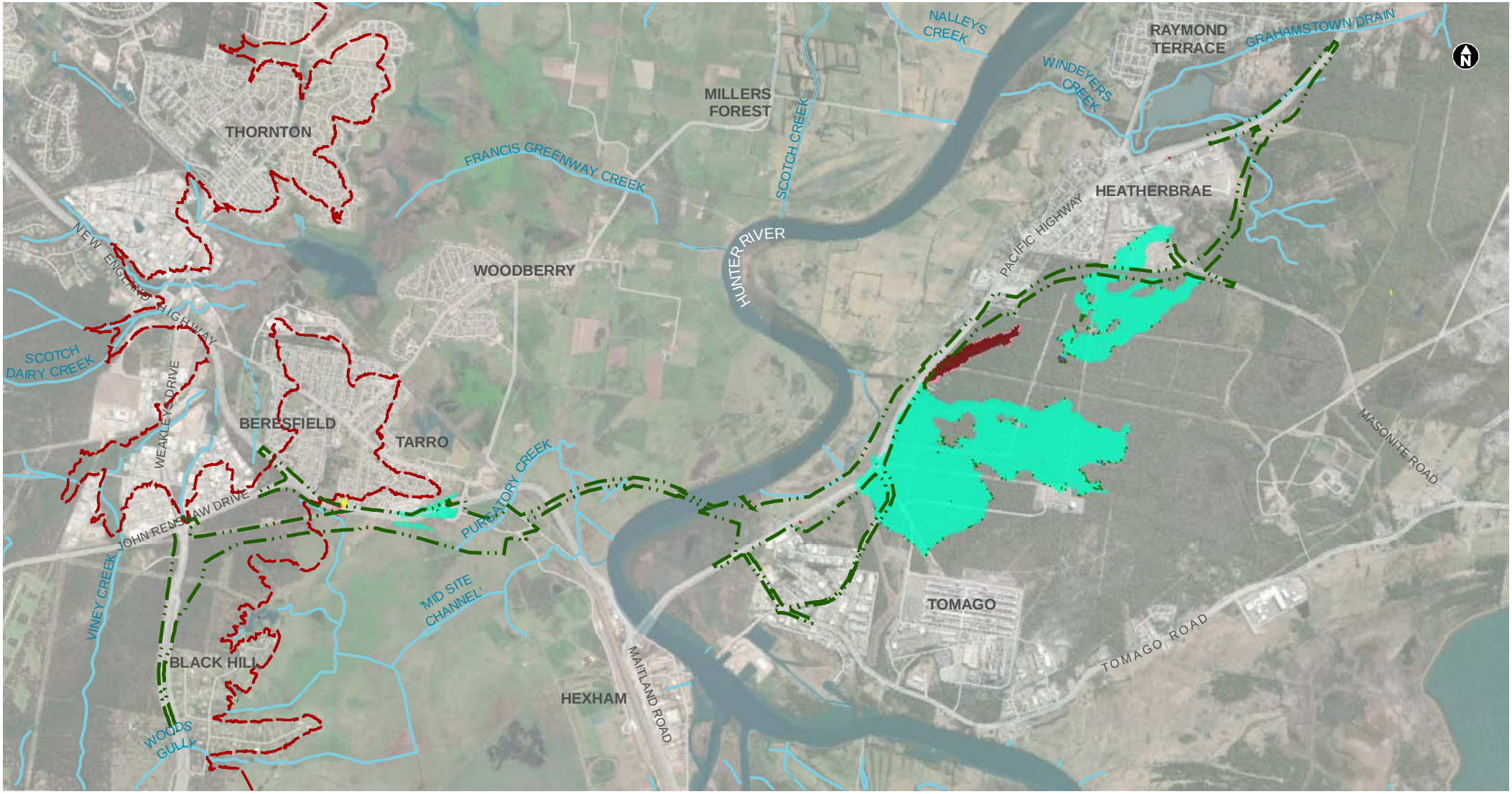
Was wet now dry

Was dry now wet

0 4 8km

Figure F-3 Change in flood level - Operational phase with blockage sensitivity - 1% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_074_I3_FloodLevel1BlockageOperational_JAC_A4L_175000_V01.mxd



Flooding study area

Operational footprint

Change in flood level from operational case (m)

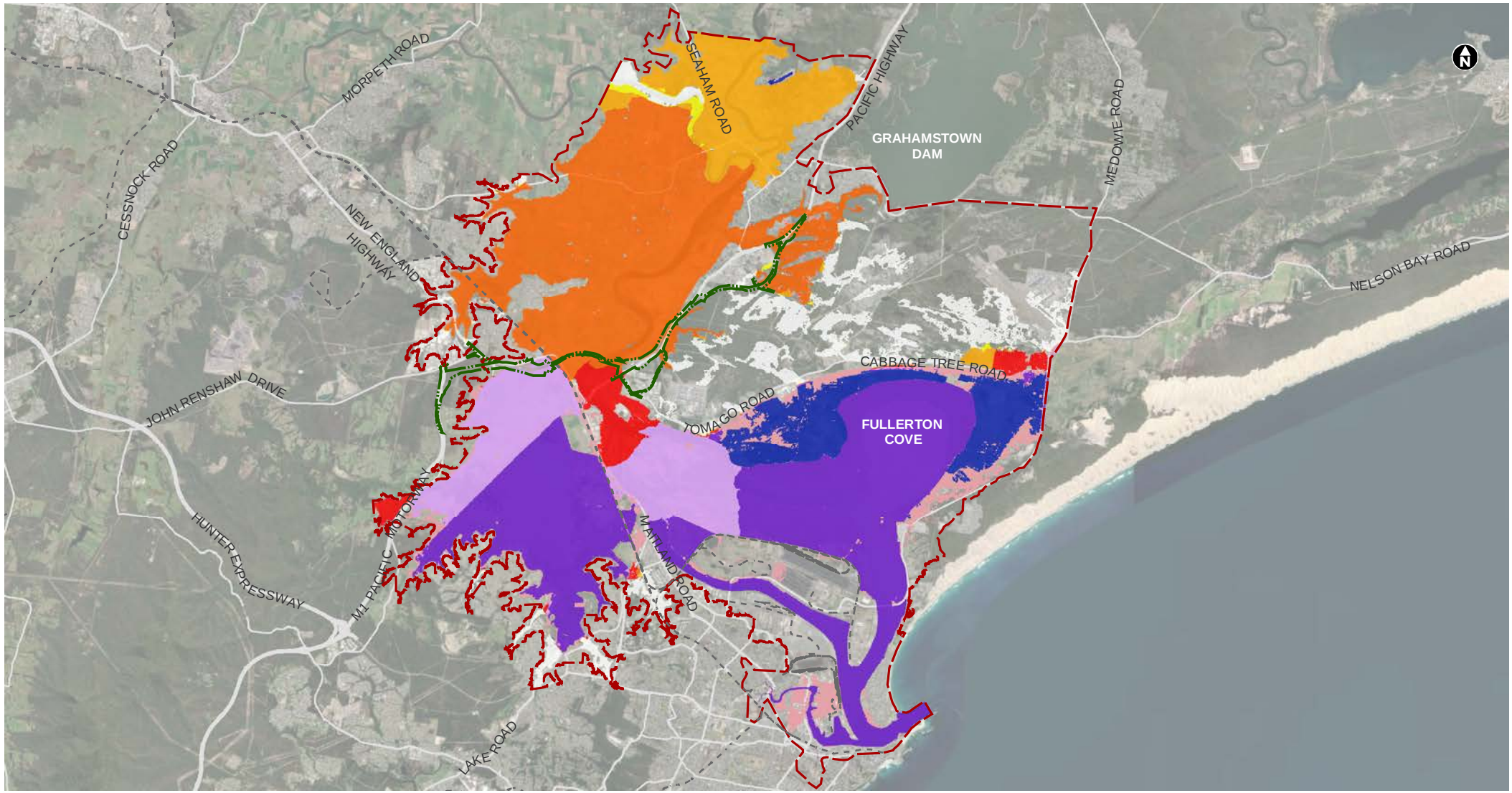
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4
- Was wet now dry
- Was dry now wet

0 1 2km

Figure F-3 Change in flood level - Operational phase with blockage sensitivity - 1% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_074_I3_FloodLevel1BlockageOperational_JAC_A4L_175000_V01.mxd

Appendix G Flood impact maps – Climate change



Flooding study area
Operational footprint
Railway

Was wet now dry
Was dry now wet

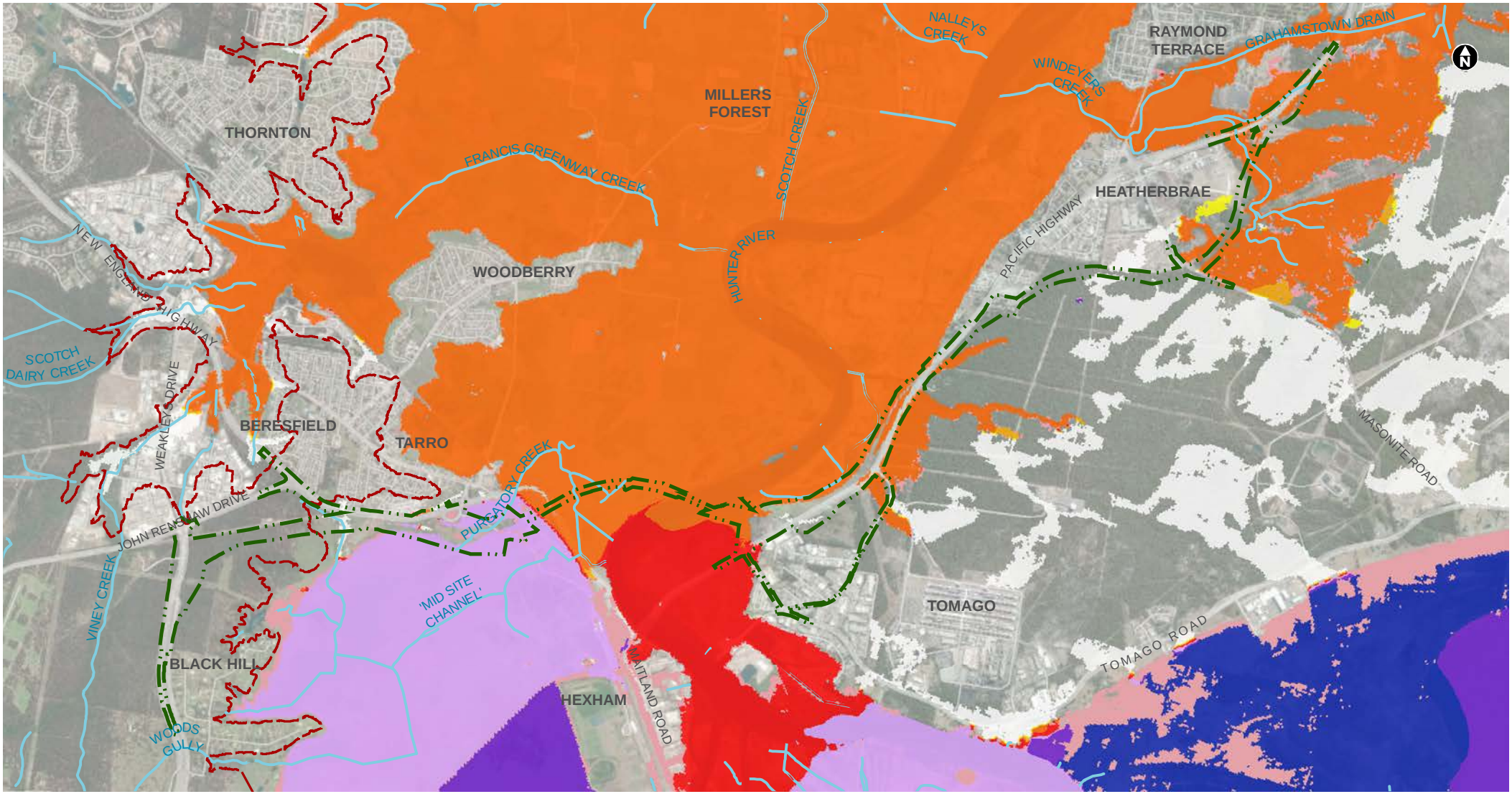
Change in flood level from 5% AEP operational phase (m)

< 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 0.75
0.75 - 1.0
> 1.0

0 4 8km

Figure G-1 Change in flood level - Operational phase with climate change - 5% AEP + 2100 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_063_H1_FloodLevel5ClimateChangeOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Was wet now dry

Was dry now wet

Change in flood level from 5% AEP operational phase (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

0 1 2km

Figure G-1 Change in flood level - Operational phase with climate change - 5% AEP + 2100 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\E\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_063_H1_FloodLevel5ClimateChangeOperational_JAC_A4L_175000_V02.mxd

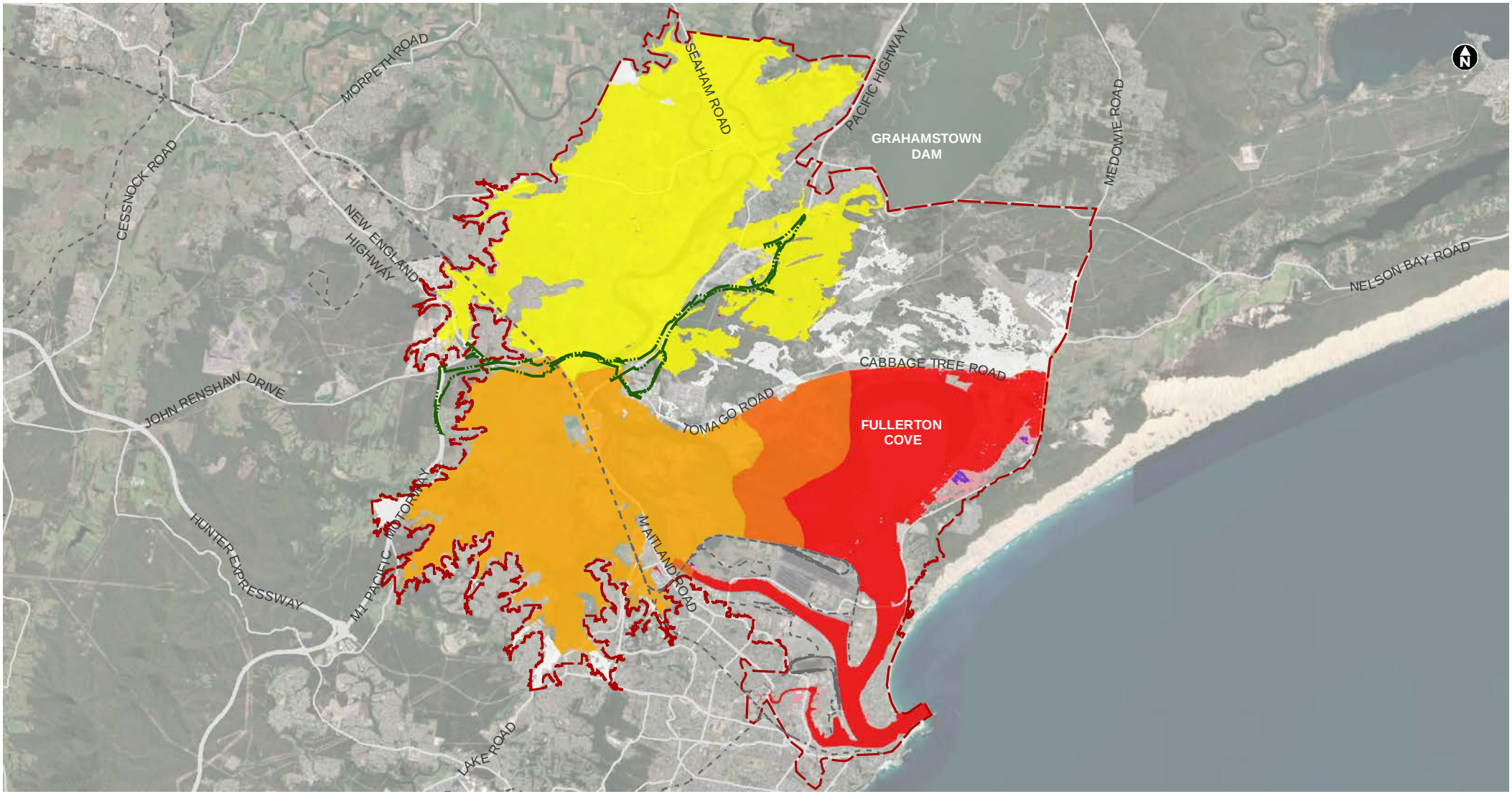


Figure G-2 Change in flood level - Operational phase with climate change - 1% AEP + 2050 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_064_H2_FloodLevel1ClimateChange2050TOperational_JAC_A4L_175000_V02.mxd

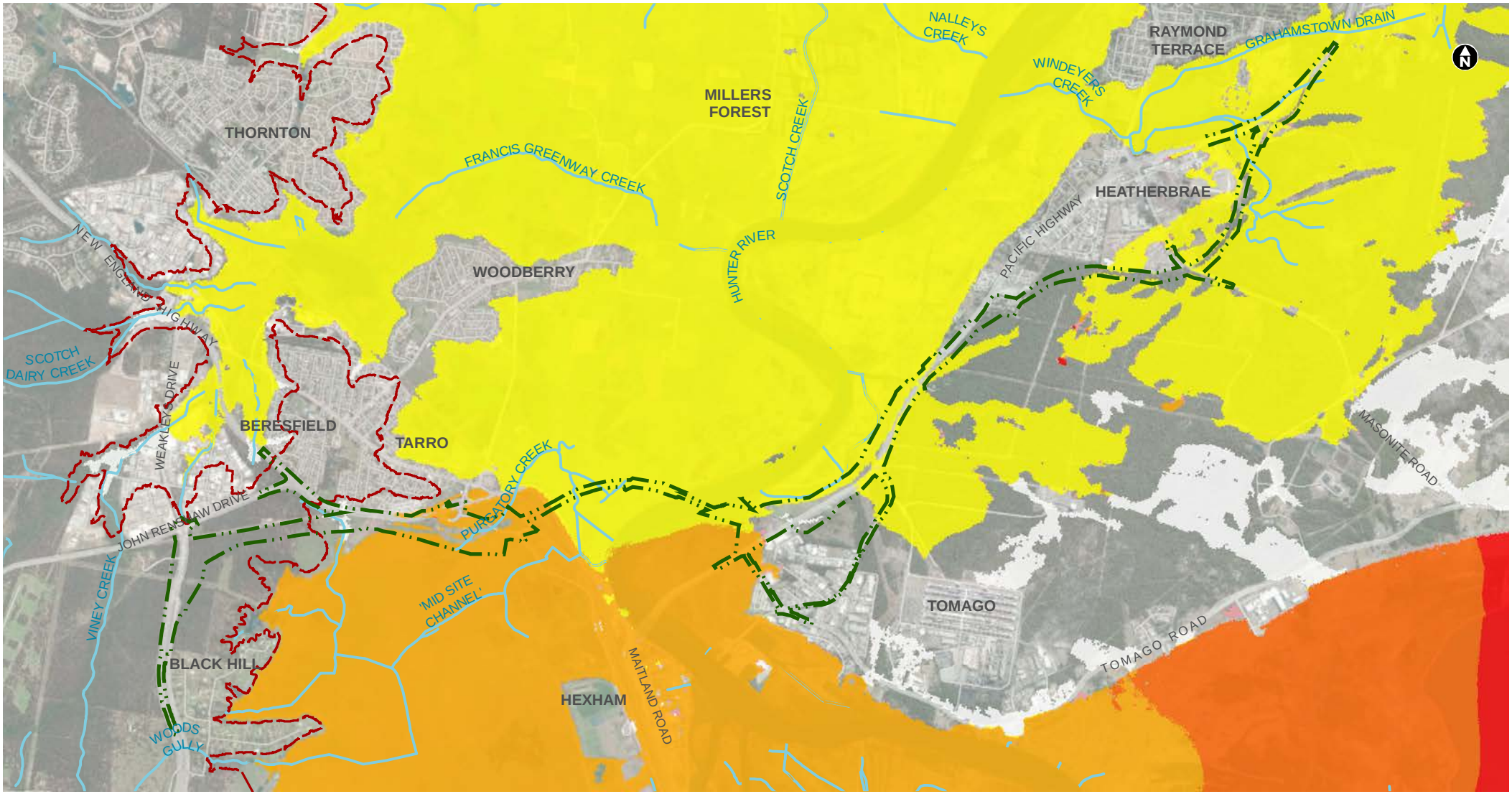
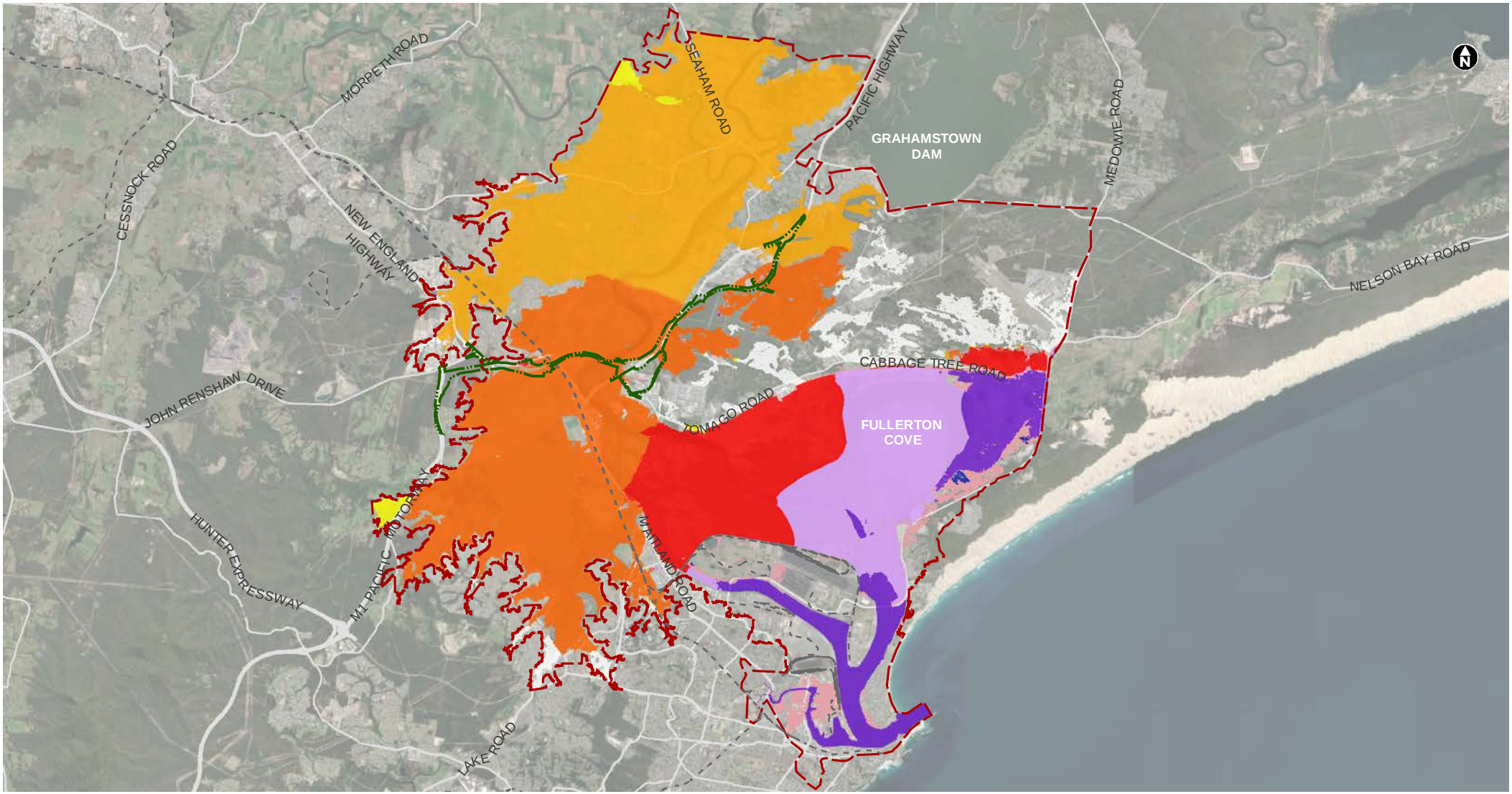


Figure G-2 Change in flood level - Operational phase with climate change - 1% AEP + 2050 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_064_H2_FloodLevel1ClimateChange2050TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Was dry now wet

Change in flood level from 1% AEP operational phase (m)

< 0.01

0.01 - 0.05

0.05 - 0.1

0.1 - 0.2

0.2 - 0.5

0.5 - 0.75

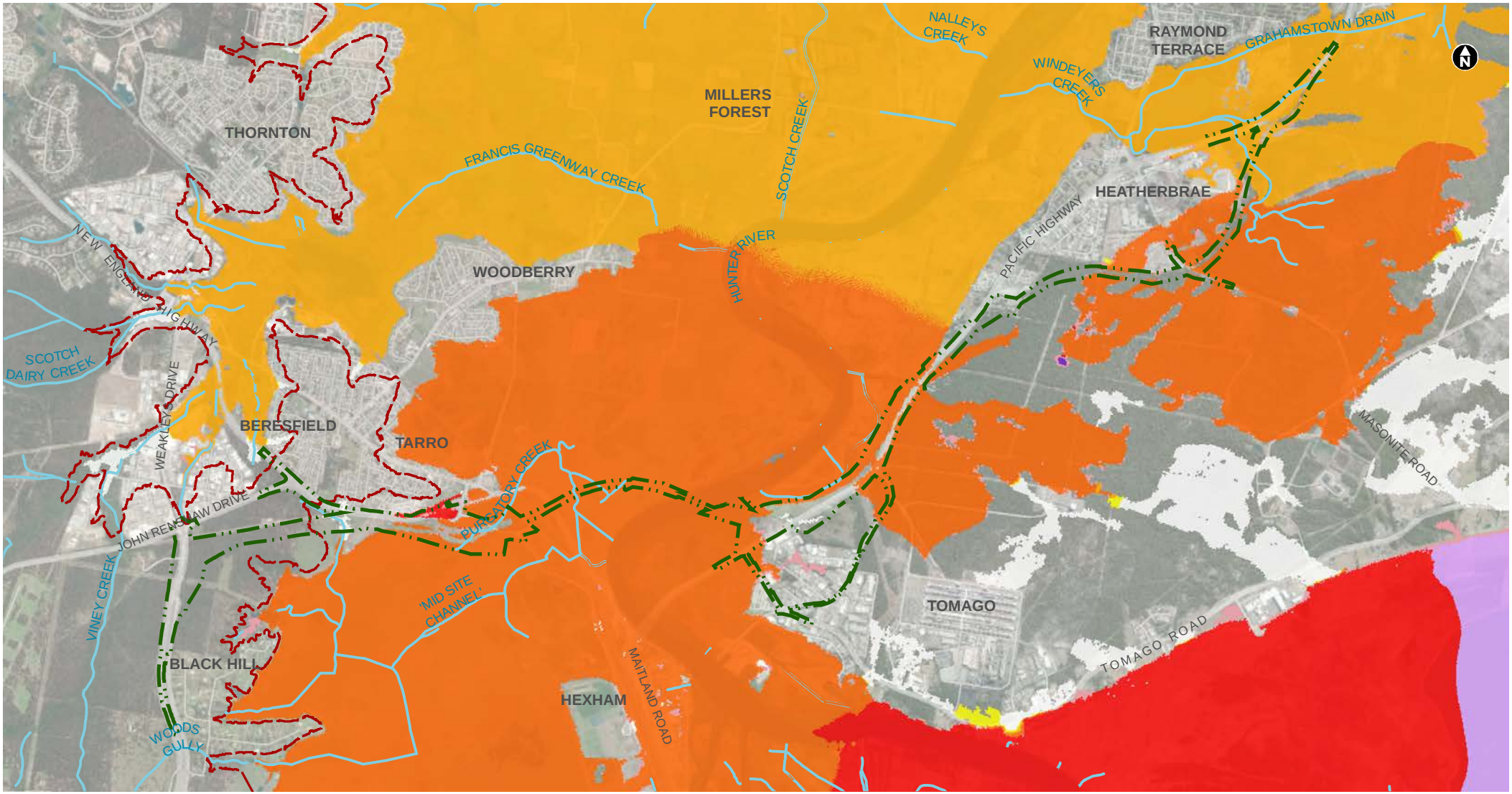
0.75 - 1.0

> 1.0

0 4 8km

Figure G-3 Change in flood level - Operational phase with climate change - 1% AEP + 2100 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\A230000_CD_HF_065_H3_FloodLevel1ClimateChange2100TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Was dry now wet

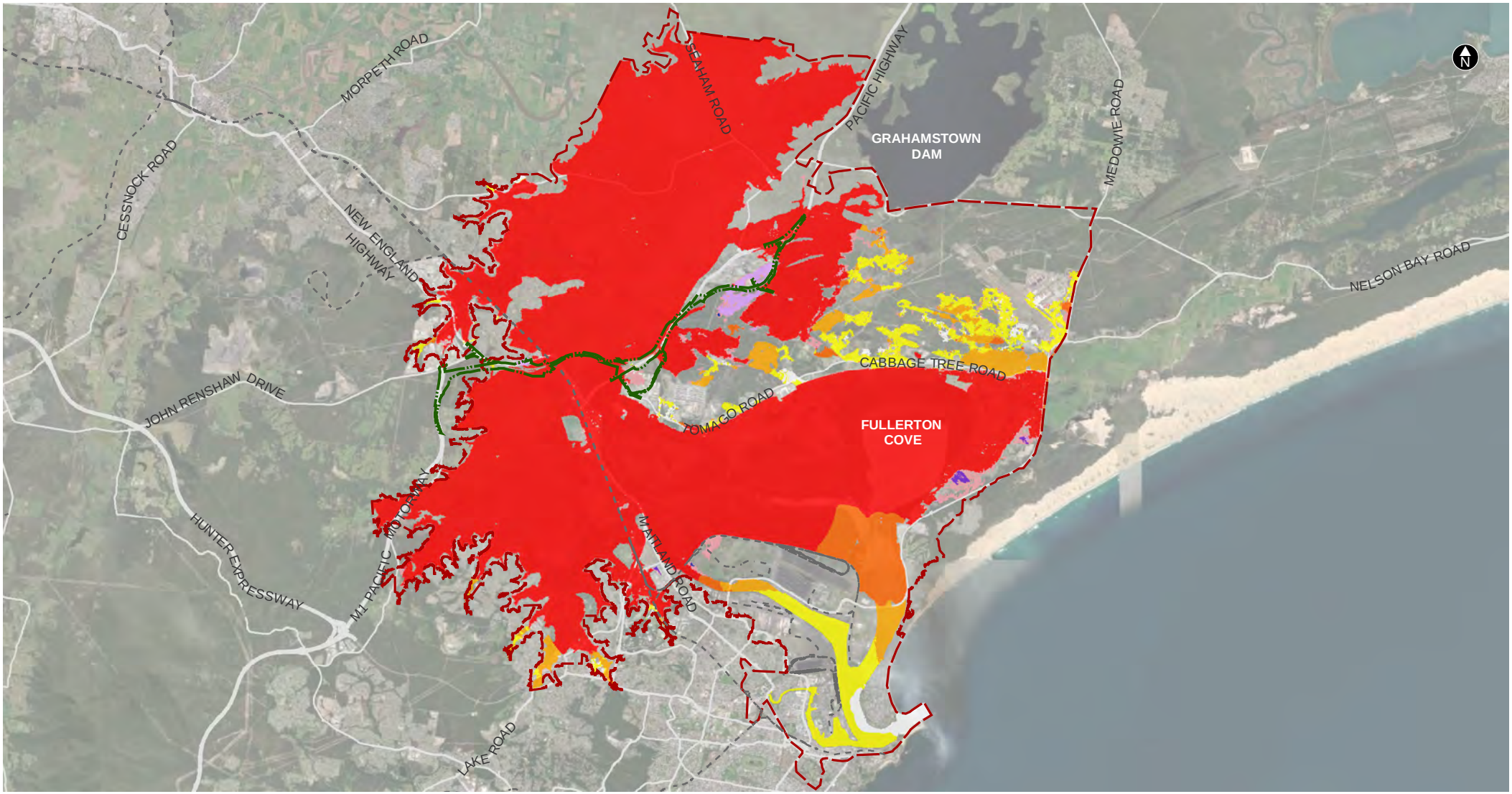
Change in flood level from 1% AEP operational phase (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

0 1 2km

Figure G-3 Change in flood level - Operational phase with climate change - 1% AEP + 2100 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\A230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\A230000_CD_HF_065_H3_FloodLevel1ClimateChange2100TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Was dry now wet

Change in flood level from 1% AEP operational phase (m)

< 0.01

0.01 - 0.05

0.05 - 0.1

0.1 - 0.2

0.2 - 0.5

0.5 - 0.75

0.75 - 1.0

> 1.0

0 4 8km

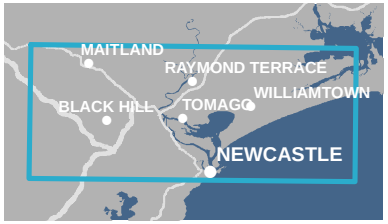


Figure G-4 Change in flood level - Operational phase with climate change - 0.5% AEP (map 1 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_066_H4_FloodLevel05ClimateChangeOperational_JAC_A4L_175000_V03.mxd

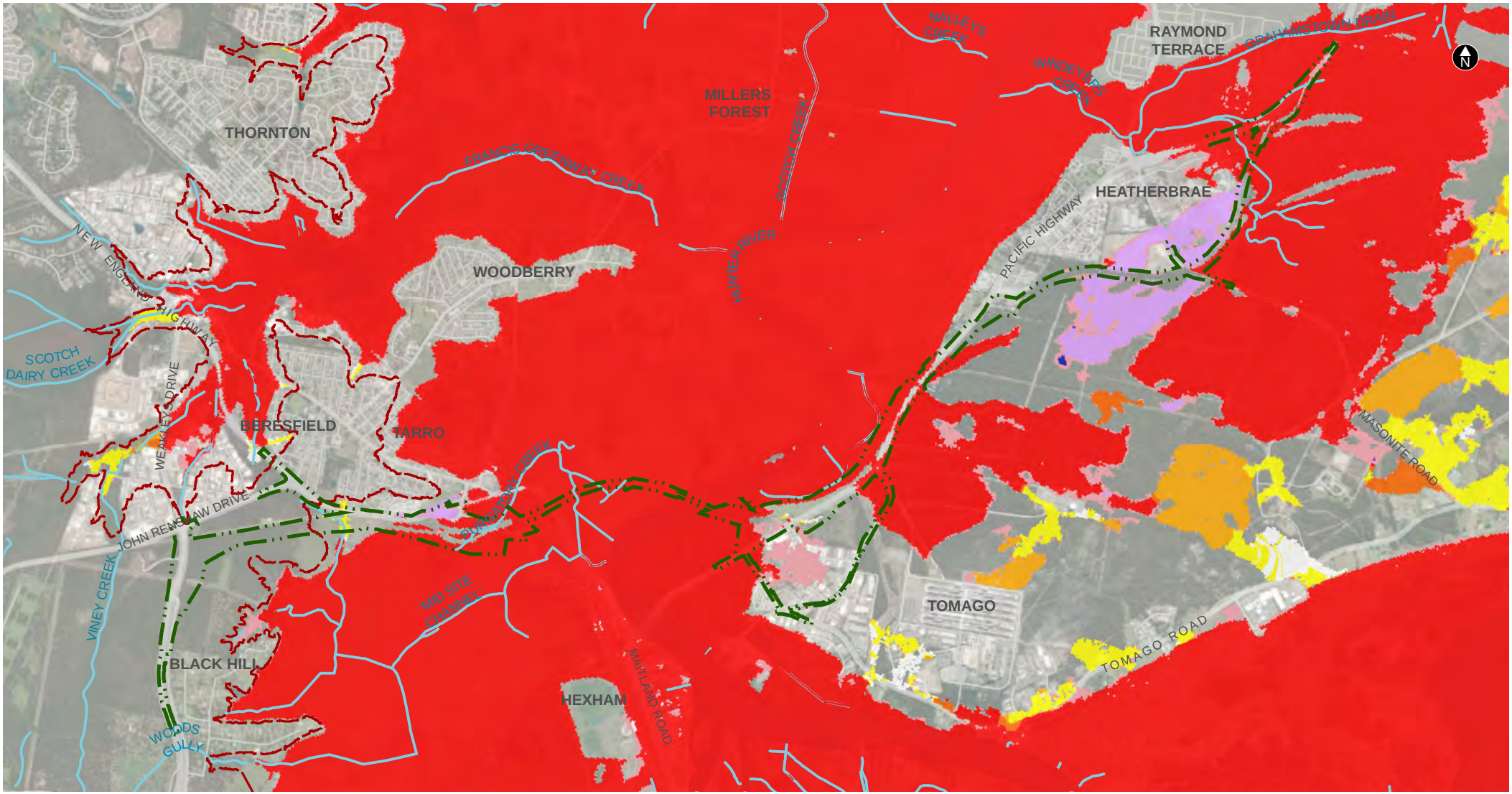


Figure G-4 Change in flood level - Operational phase with climate change - 0.5% AEP (map 2 of 2)

Date: 30/06/2021 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_066_H4_FloodLevel05ClimateChangeOperational_JAC_A4L_175000_V03.mxd

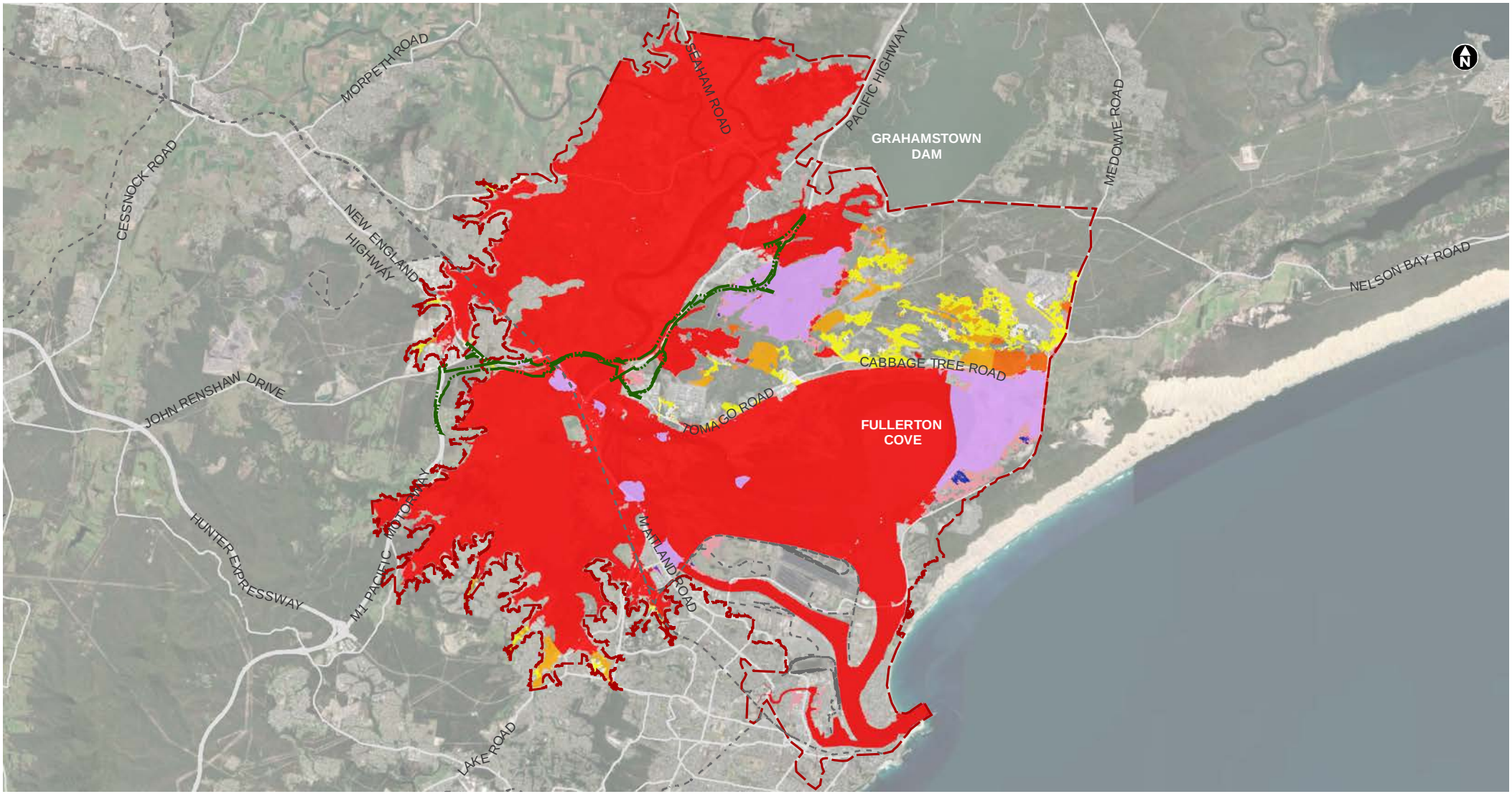
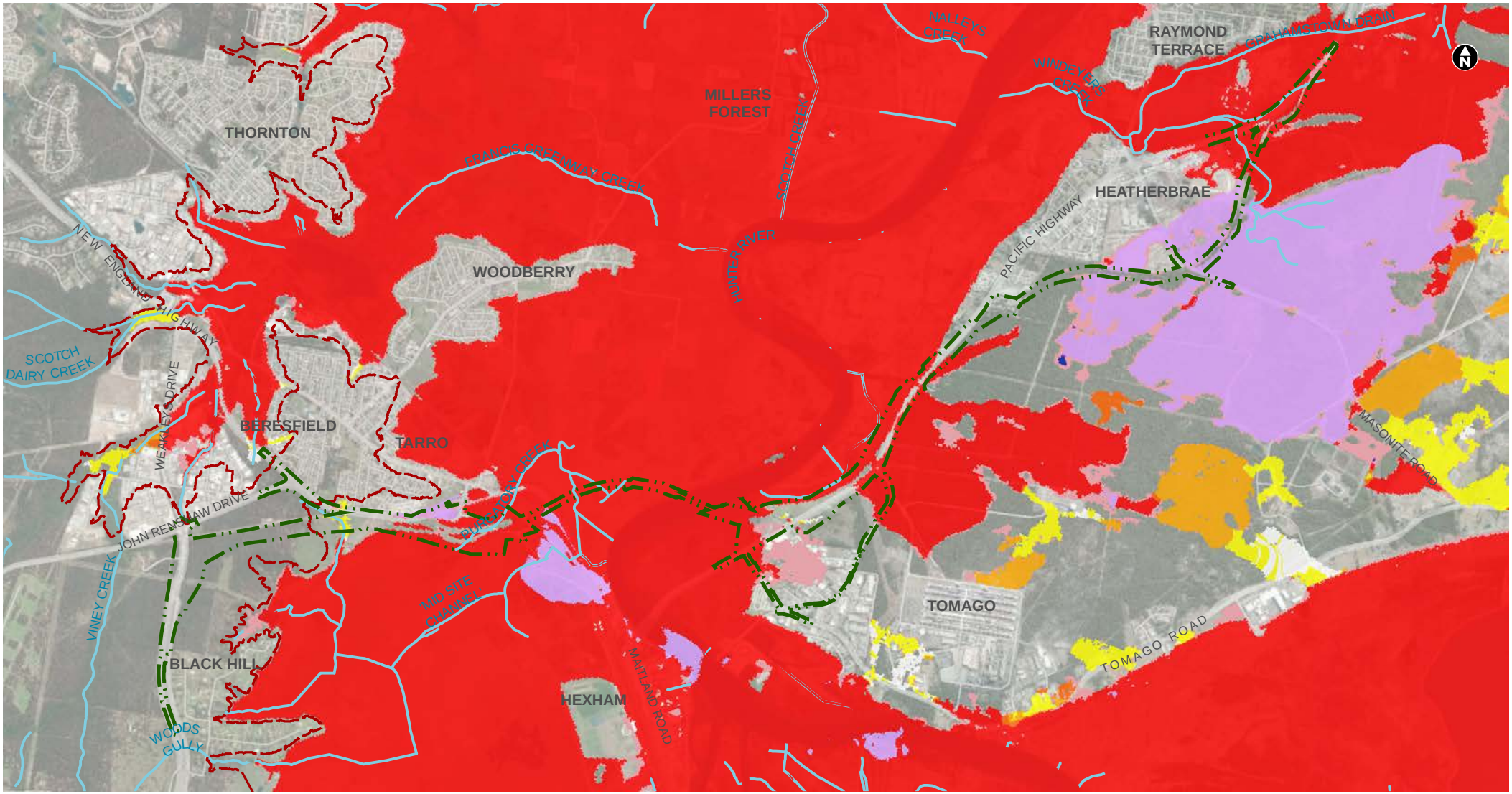


Figure G-5 Change in flood level - Operational phase with climate change - 0.5% AEP + 2050 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_067_H5_FloodLevel05ClimateChange2050TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Was dry now wet

Change in flood level from 1% AEP operational phase (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

0 1 2km

Figure G-5 Change in flood level - Operational phase with climate change - 0.5% AEP + 2050 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_067_H5_FloodLevel05ClimateChange2050TOperational_JAC_A4L_175000_V02.mxd

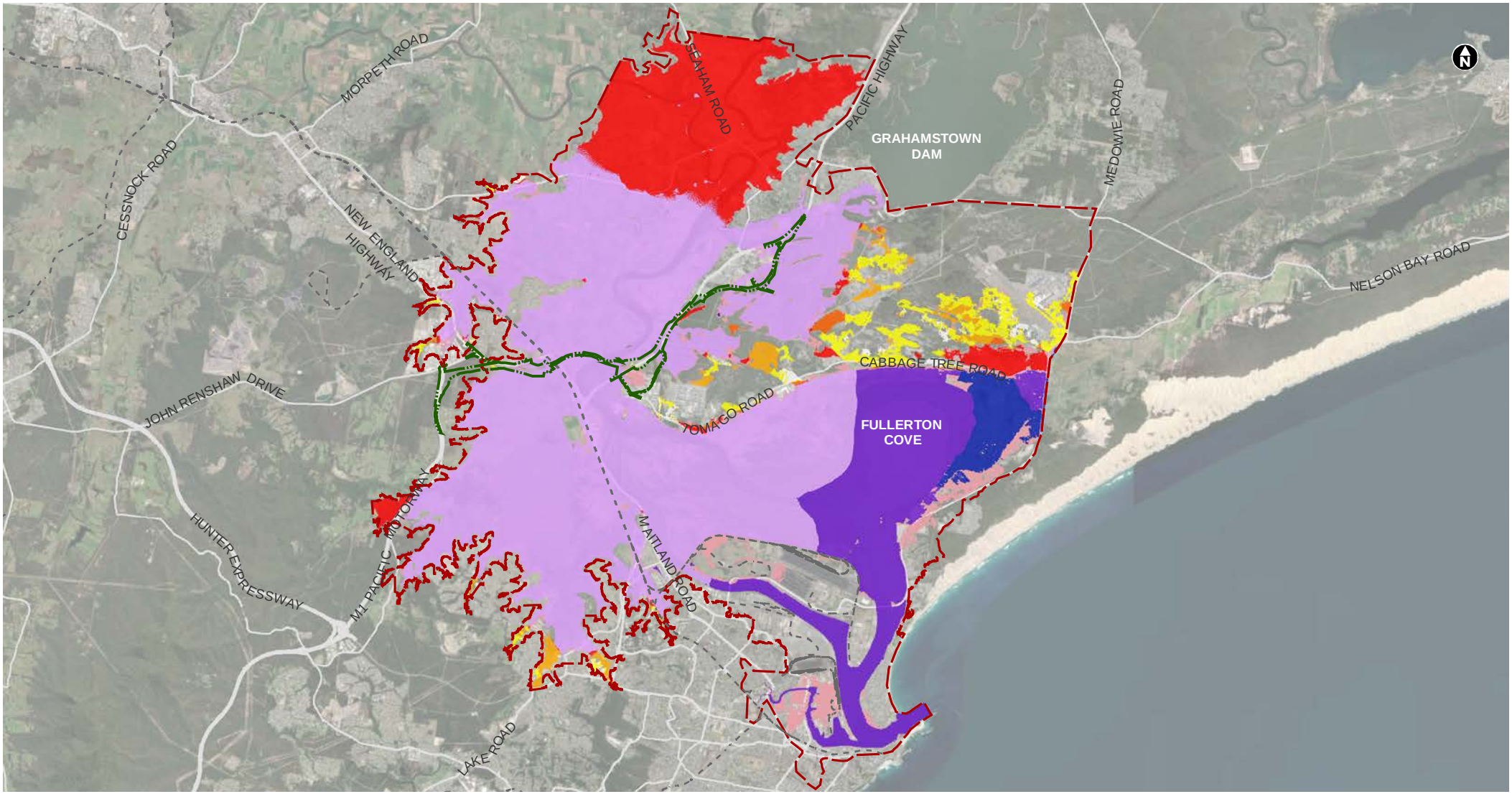


Figure G-6 Change in flood level - Operational phase with climate change - 0.5% AEP + 2100 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_068_H6_FloodLevel05ClimateChange2100TOperational_JAC_A4L_175000_V02.mxd

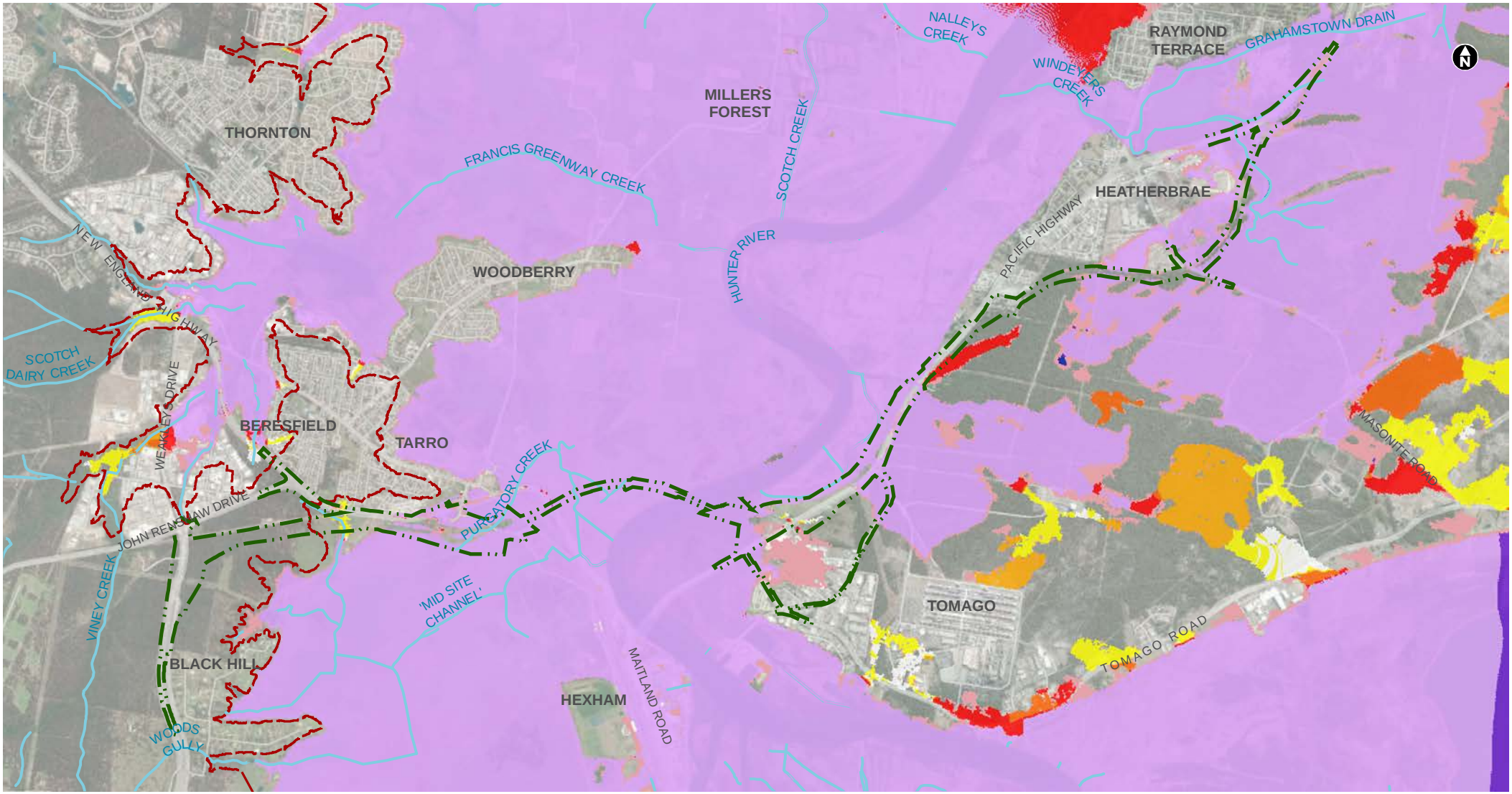
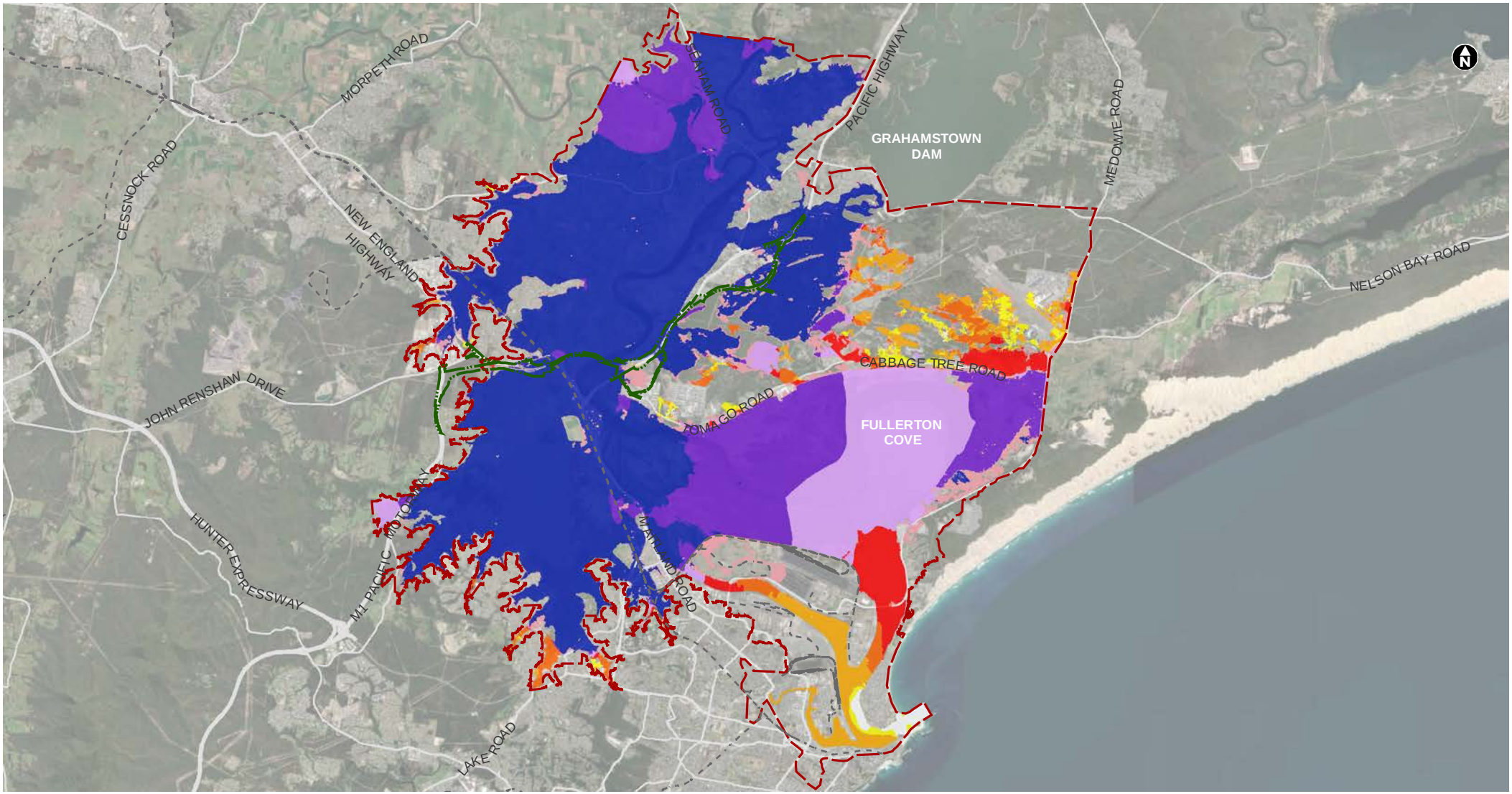


Figure G-6 Change in flood level - Operational phase with climate change - 0.5% AEP + 2100 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_068_H6_FloodLevel05ClimateChange2100TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Railway

Was dry now wet

Change in flood level from 1% AEP operational phase (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

0 4 8km

Figure G-7 Change in flood level - Operational phase with climate change - 0.2% AEP (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_069_H7_FloodLevel02ClimateChangeOperational_JAC_A4L_175000_V02.mxd

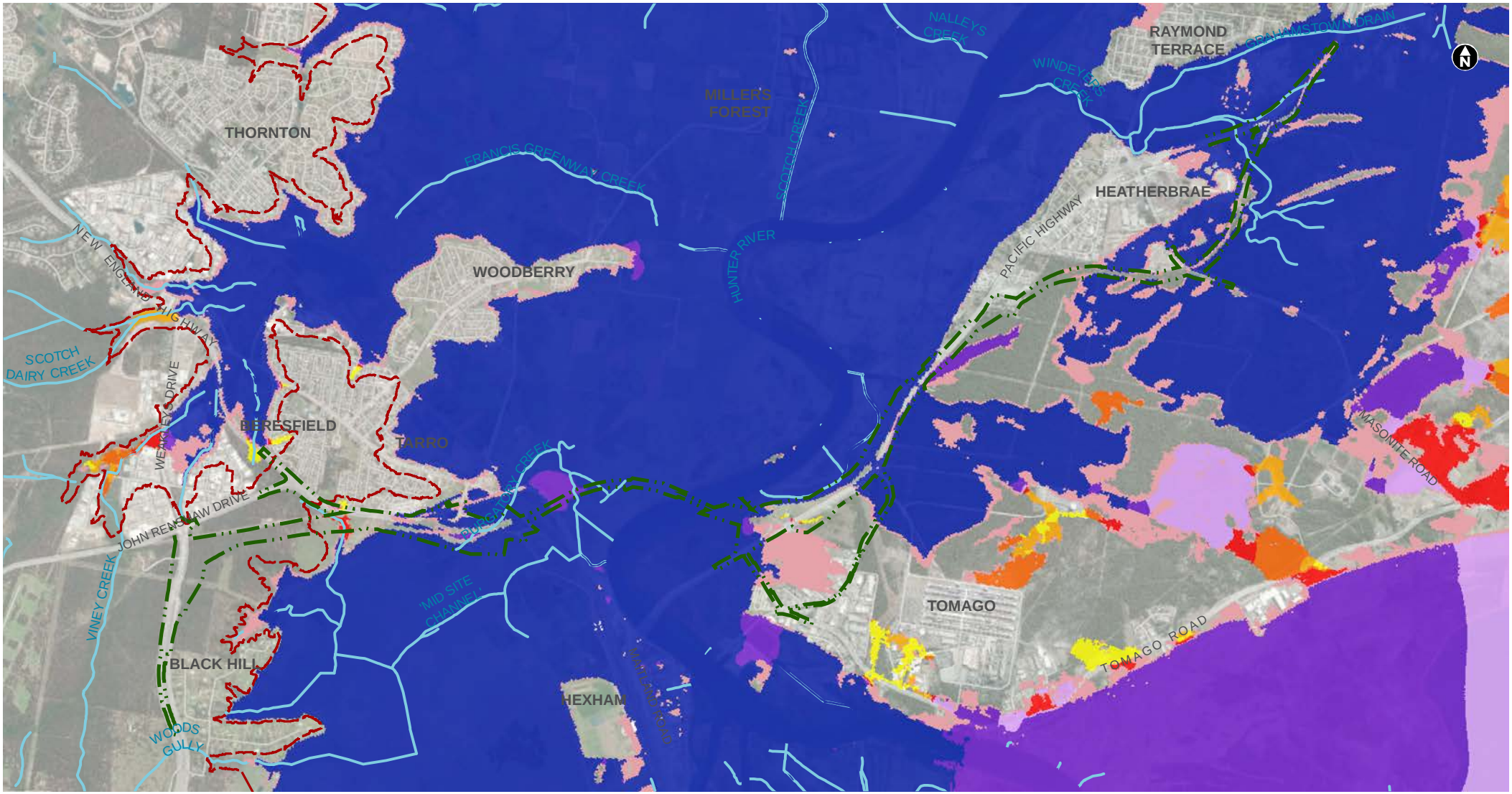


Figure G-7 Change in flood level - Operational phase with climate change - 0.2% AEP (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_069_H7_FloodLevel02ClimateChangeOperational_JAC_A4L_175000_V02.mxd

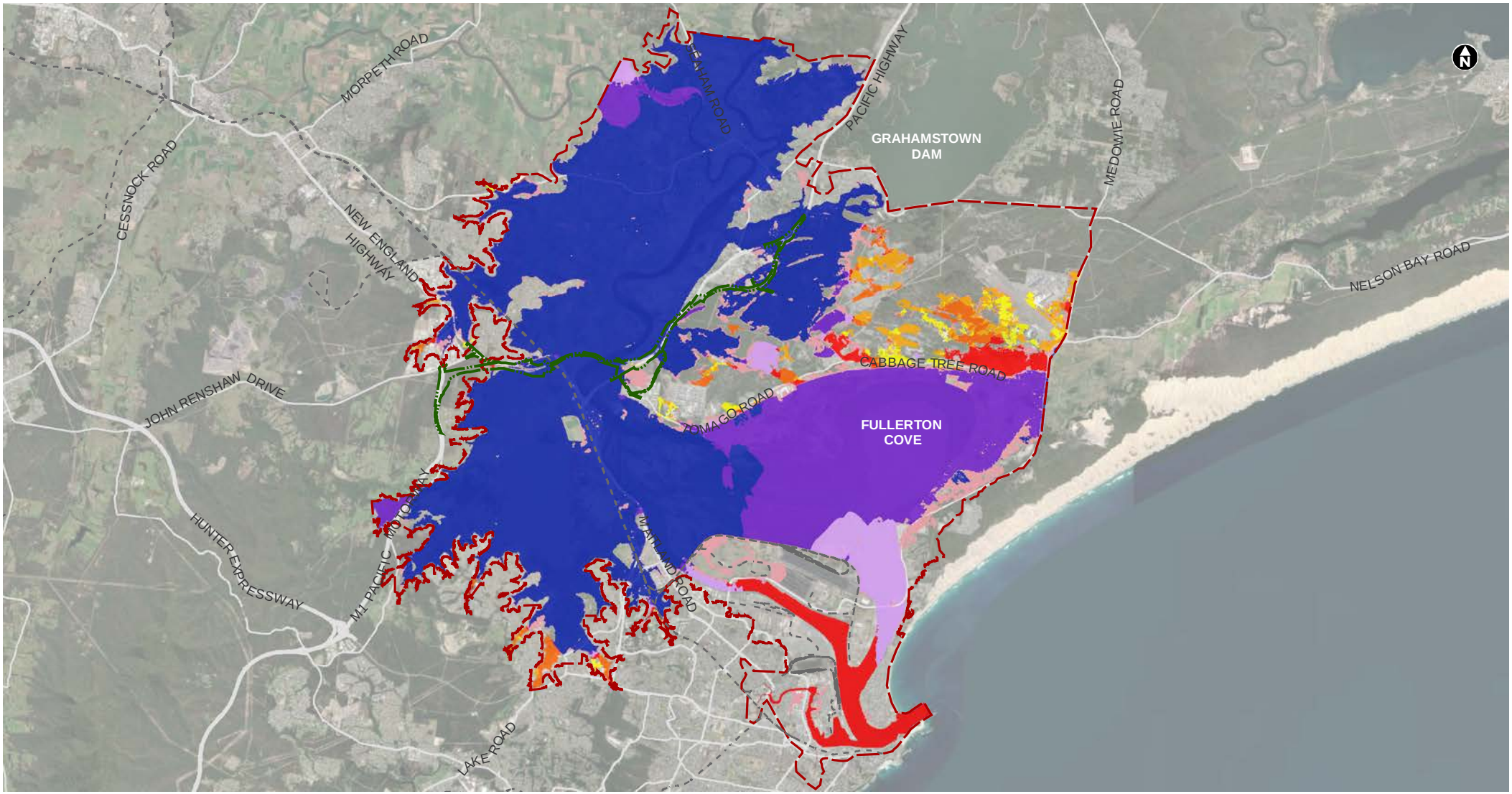
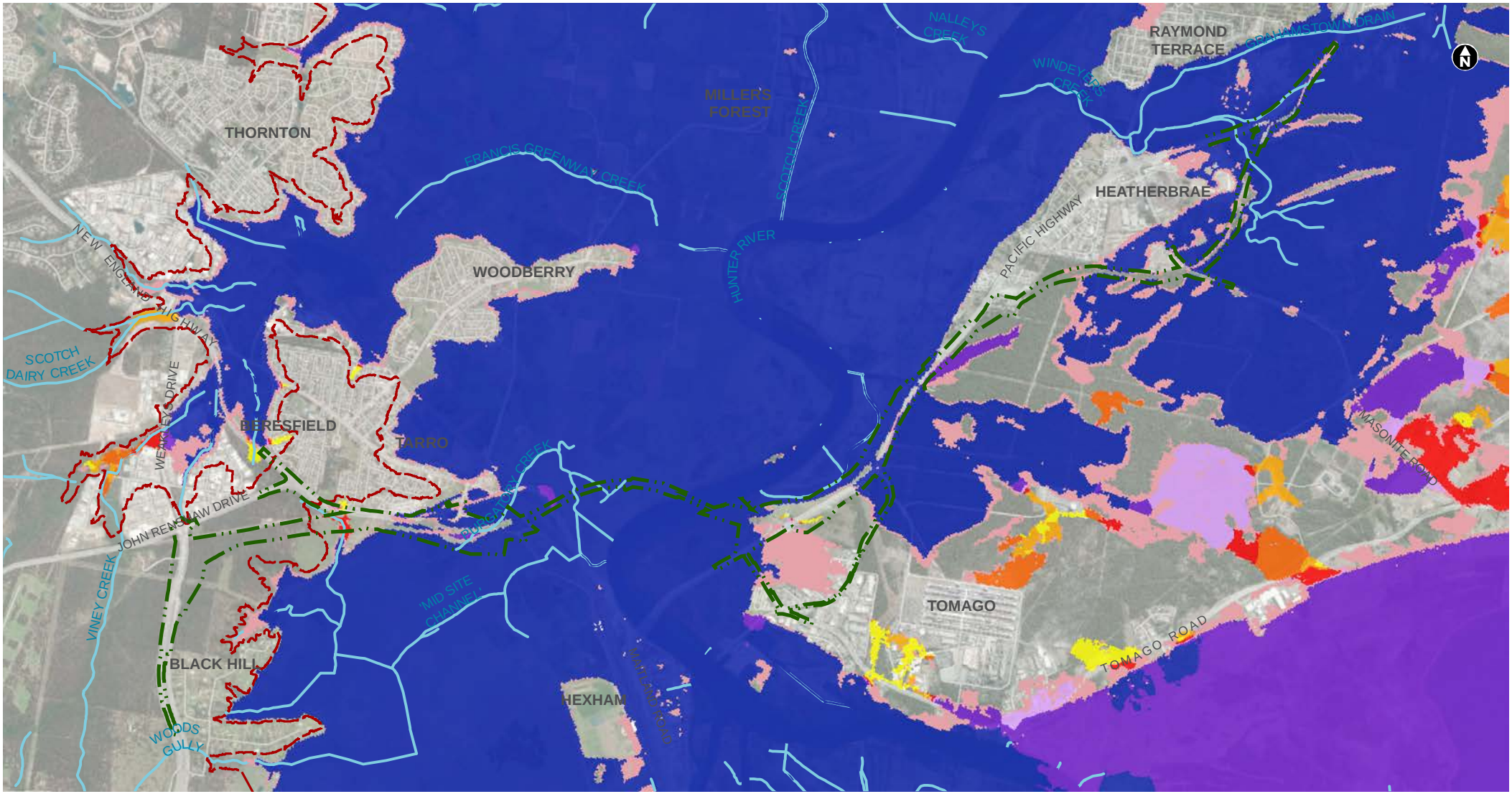


Figure G-8 Change in flood level - Operational phase with climate change - 0.2% AEP + 2050 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_070_H8_FloodLevel02ClimateChange2050TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Was dry now wet

Change in flood level from 1% AEP operational phase (m)

- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

0 1 2km

Figure G-8 Change in flood level - Operational phase with climate change - 0.2% AEP + 2050 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_070_H8_FloodLevel02ClimateChange2050TOperational_JAC_A4L_175000_V02.mxd

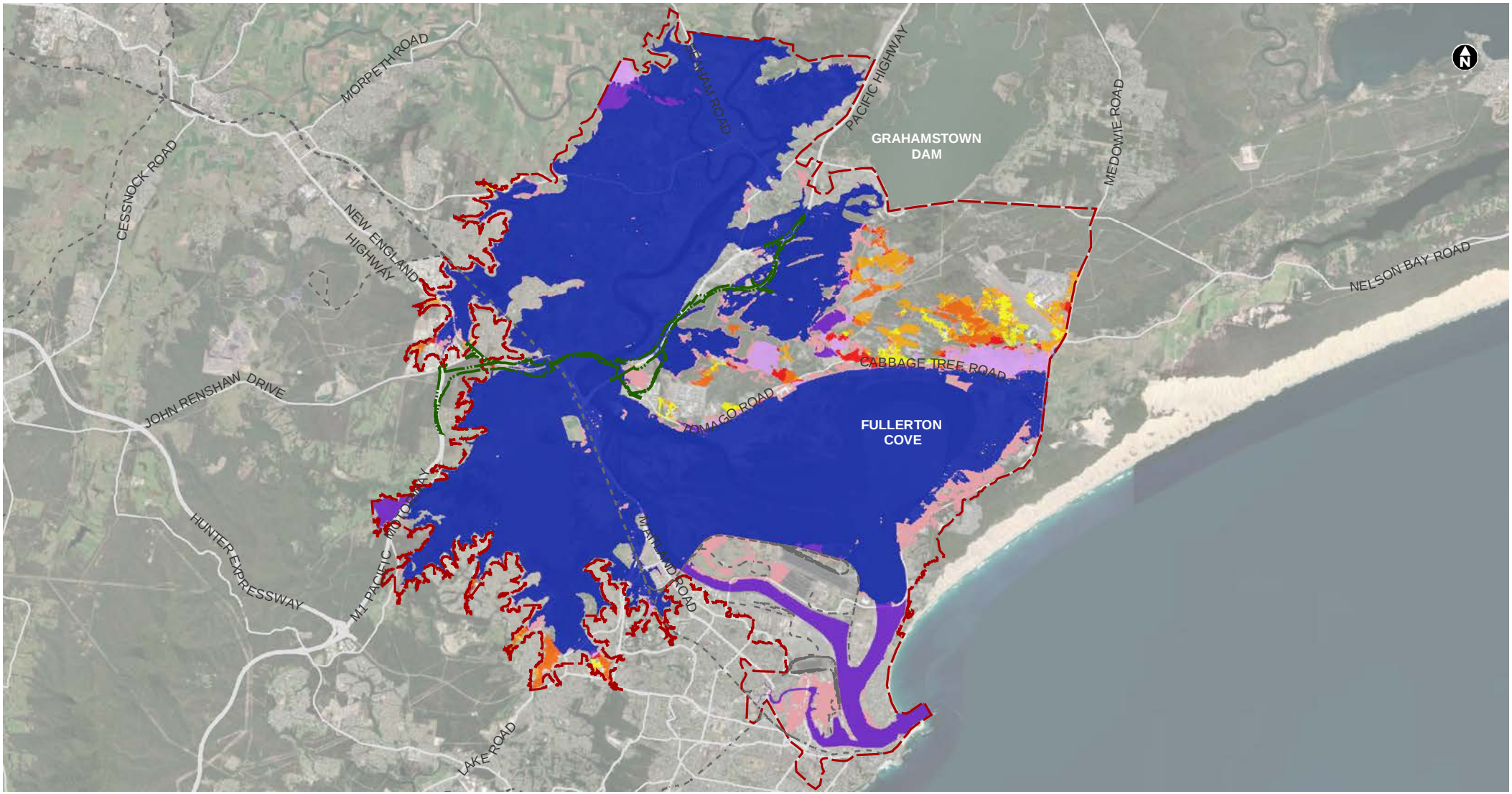
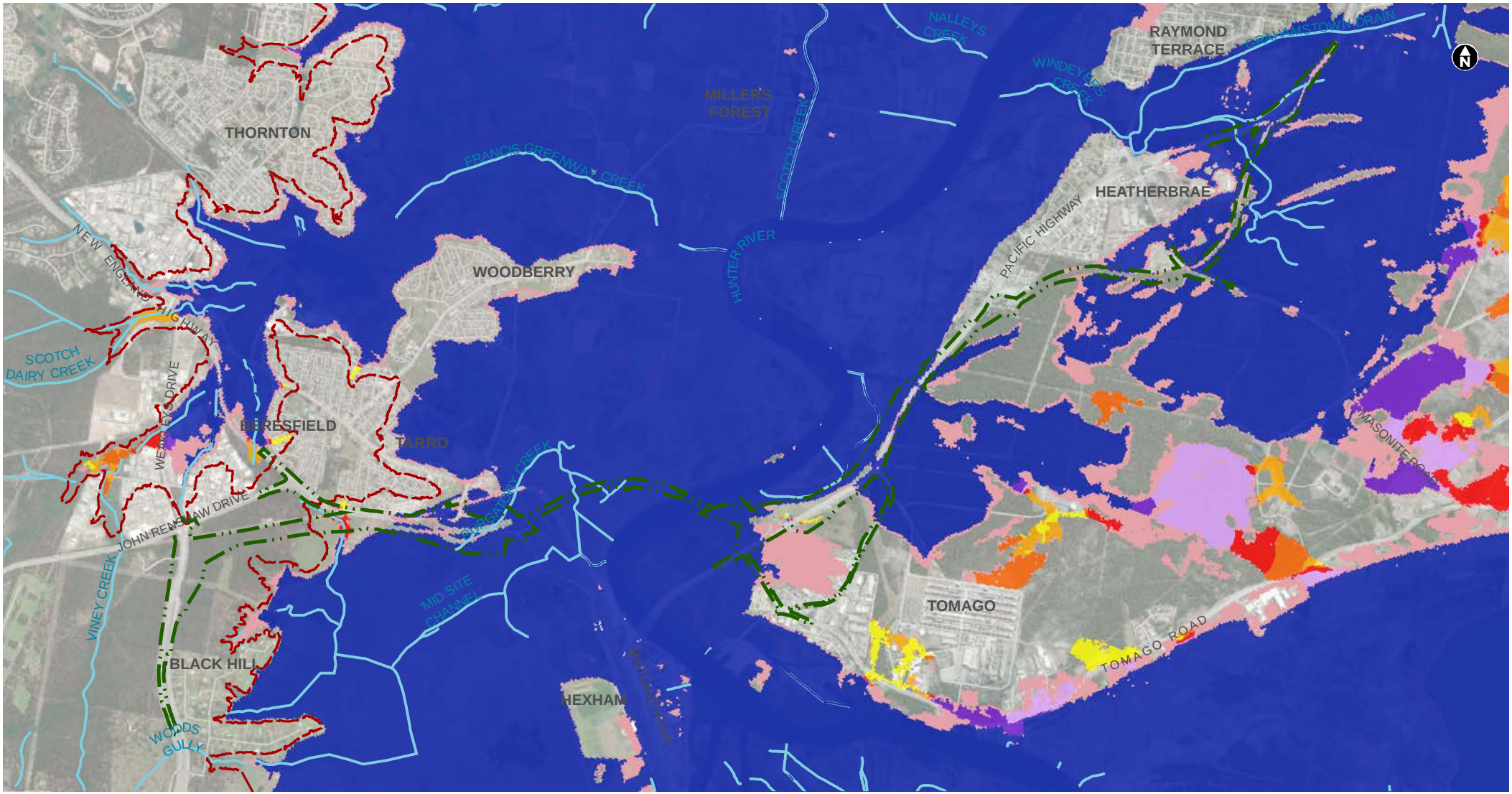


Figure G-9 Change in flood level - Operational phase with climate change - 0.2% AEP + 2100 tide (map 1 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_SpatialGIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_071_H9_FloodLevel02ClimateChange2100TOperational_JAC_A4L_175000_V02.mxd



Flooding study area

Operational footprint

Was dry now wet

Change in flood level from 1% AEP operational phase (m)

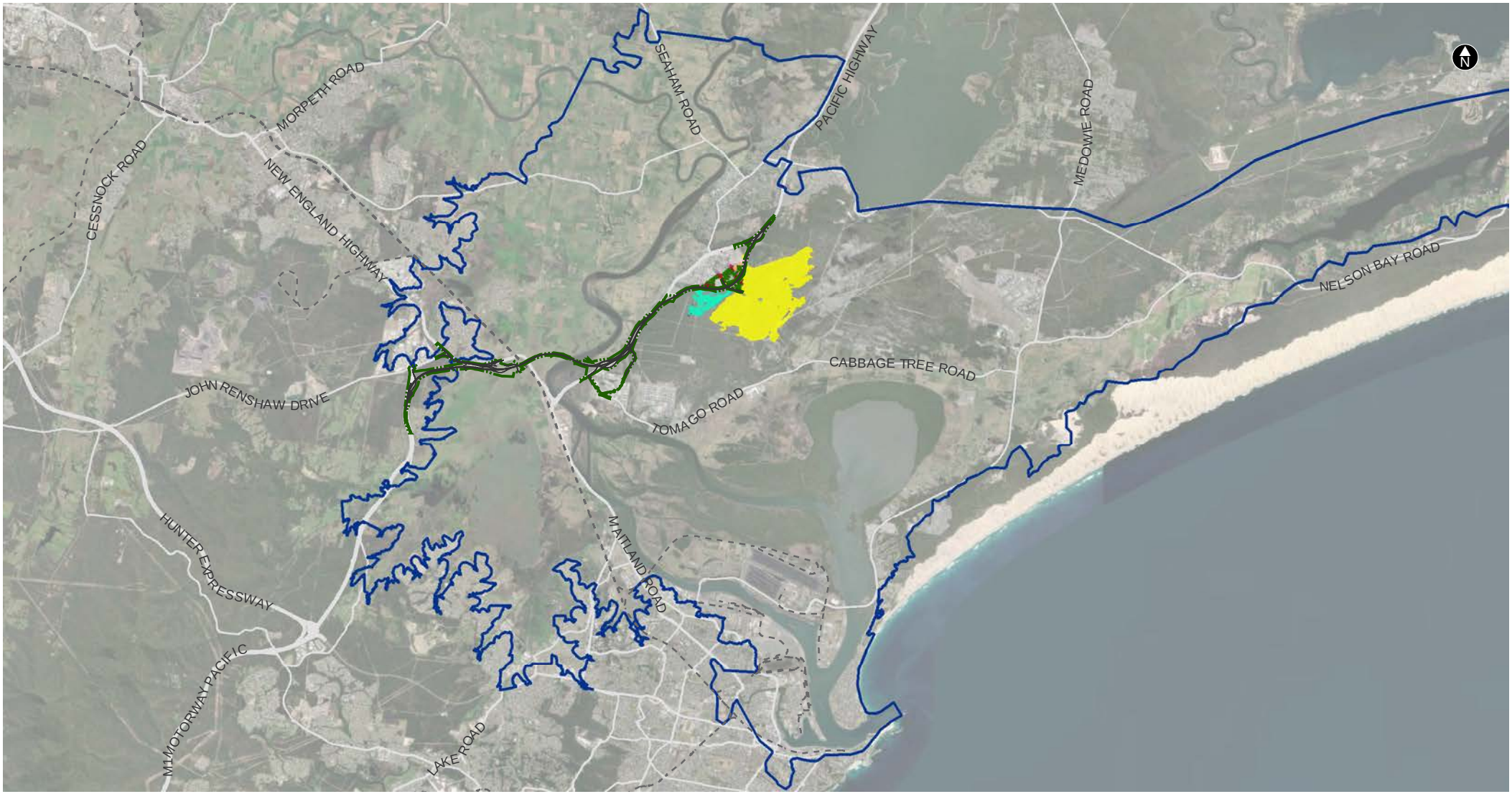
- < 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0
- > 1.0

0 1 2km

Figure G-9 Change in flood level - Operational phase with climate change - 0.2% AEP + 2100 tide (map 2 of 2)

Date: 15/12/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_071_H9_FloodLevel02ClimateChange2100TOperational_JAC_A4L_175000_V02.mxd

Appendix H Flood impact maps – Cumulative impacts



Operational footprint
Limit of mapping
The project
Railway
Was Wet Now Dry
Was Dry Now Wet

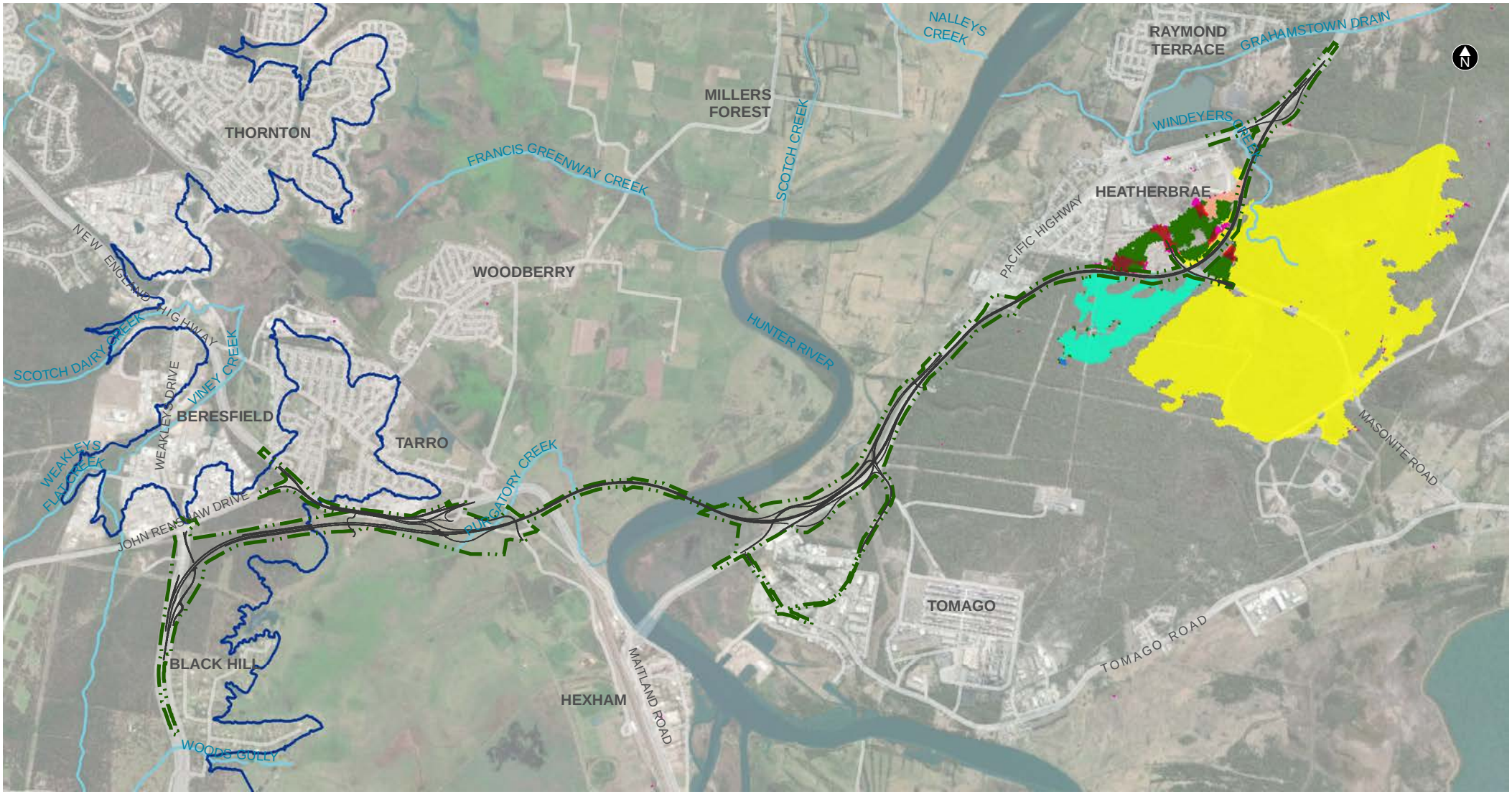
Change in flood level from operational phase (m)

< -0.4
-0.4 - -0.25
-0.25 - -0.1
-0.1 - -0.01
-0.01 - 0.01 (not shown)
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.4
> 0.4

0 4 8km

Figure H-1 Change in flood level - Operational phase plus approved projects - 1% AEP (map 1 of 2)

Date: 8/09/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_081_G1_FloodLevel_1approvedprojects_Operational_JAC_A4L_175000_V01.mxd



Operational footprint
Limit of mapping
The project
Was Wet Now Dry
Was Dry Now Wet

Change in flood level from operational phase (m)

- < -0.4
- -0.4 - -0.25
- -0.25 - -0.1
- -0.1 - -0.01
- -0.01 - 0.01 (not shown)
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.4
- > 0.4

0 1 2km

Figure H-1 Change in flood level - Operational phase plus approved projects - 1% AEP (map 2 of 2)

Date: 8/09/2020 Path: J:\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Hydro_Flooding\IA230000_CD_HF_081_G1_FloodLevel_1approvedprojects_Operational_JAC_A4L_175000_V01.mxd

Appendix I Water balance modelling results

Construction Water Balance - Base Case

(m^3/month)

Construction Month

	1 Aug-24	2 Sep-24	3 Oct-24	4 Nov-24	5 Dec-24	6 Jan-25	7 Feb-25	8 Mar-25	9 Apr-25	10 May-25	11 Jun-25	12 Jul-25	13 Aug-25	14 Sep-25	15 Oct-25	16 Nov-25	17 Dec-25	18 Jan-26	19 Feb-26	20 Mar-26	21 Apr-26	22 May-26	23 Jun-26	24 Jul-26	25 Aug-26	26 Sep-26	27 Oct-26	28 Nov-26	29 Dec-26	30 Jan-27	31 Feb-27	32 Mar-27	33 Apr-27	34 May-27	35 Jun-27	Average ML	Total ML
South of Hunter - Sources																																				
Fresh Inputs	0	0	0	0	0	0	0	0	0	0	0	341	356	425	345	288	311	242	170	191	214	261	306	341	356	425	345	288	311	242	170	191	214	261	306		
Basins	0	0	0	0	0	0	0	0	0	0	0	341	356	425	345	288	311	242	170	191	214	261	306	341	356	425	345	288	311	242	170	191	214	261	306	0.2	6.9
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Slightly Brackish Inputs	0	0	0	0	0	0	0	0	0	141	84	562	586	700	567	474	512	398	280	314	353	430	504	562	586	700	567	474	512	398	280	314	353	430	504		
Basins	0	0	0	0	0	0	0	0	0	0	0	562	586	700	567	474	512	398	280	314	353	430	504	562	586	700	567	474	512	398	280	314	353	430	504	0.3	11.4
Dewatering	0	0	0	0	0	0	0	0	0	141	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.2
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brackish Inputs	0	0	0	0	0	0	0	0	0	185	2662	2389	315	93	5904	68	52	37	41	47	57	66	10239	10242	10257	75	62	68	52	37	41	47	57	66		
Basins	0	0	0	0	0	0	0	0	0	0	0	74	77	92	75	62	68	52	37	41	47	57	66	74	77	92	75	62	68	52	37	41	47	57	66	0.0	1.5
Dewatering	0	0	0	0	0	0	0	0	0	0	185	2588	2312	222	18	5841	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	11.2
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10165	10165	10165	0	0	0	0	0	0	0	0	0	0.9	30.5
Saline Inputs	0	0	0	0	0	0	0	0	0	0	0	36	38	5106	5116	1755	33	26	18	20	23	28	32	36	38	45	37	31	33	26	18	20	23	28	32		
Basins	0	0	0	0	0	0	0	0	0	0	0	36	38	45	37	31	33	26	18	20	23	28	32	36	38	45	37	31	33	26	18	20	23	28	32	0.0	0.7
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	5061	5079	1724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	11.9
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Total Inputs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.7	268.8	3601.8	3369.1	6546.2	6120.4	8419.4	924.2	717.6	505.4	566.6	635.9	775.7	908.7	11178.9	11222.2	11427.6	1023.2	854.3	924.2	717.6	505.4	566.6	635.9	775.7	908.7	2.1	74.2
South of Hunter - Demands																																					
Fresh Demands	0.0	0.0	522.6	522.6	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1753.3	1753.3	1753.3	1753.3	1753.3	1753.3	1664.1	1664.1	1664.1	1664.1	2328.5	2328.5	1686.4	1686.4	1686.4	3102.8	1961.2	544.8	544.8	544.8	522.6		
Potable	0.0	0.0	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	0.5	17.2
Concrete Batching	0.0	0.0	0.0	0.0	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1230.7	1230.7	1230.7	1230.7	1230.7	1230.7	1141.6	1141.6	1141.6	1141.6	1805.9	1805.9	1163.8	1163.8	1163.8	2580.3	1438.7	22.2	22.2	22.2	0.0	1.0	34.6
Slightly Brackish Demands	0	0	0	7918	7918	7918	7918	2403	2403	1949	1949	2260	3082	3082	3847	4685	4685	4685	3920	3920	3609	3609	3609	3225	3942	3942	3942	3942	9745	8924	5664	5664	4779	2235	1949		
Landscaping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4259.4	4259.4	2543.4	2543.4	2543.4	0.0	0.0	0.5	16.1
Dust suppression	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1949.3	1949.3	1949.3	1949.3	2260.5	3081.5	3081.5	3081.5	3920.1	3920.1	3920.1	3920.1	3920.1	3609.0	3609.0	3609.0	3225.1	3225.1	3225.1	3225.1	3225.1	3225.1	2404.1	2404.1	2404.1	1949.3	1949.3	1949.3	2.3	82.1
Pavements	0.0	0.0	0.0	7917.7	7917.7	7917.7	7917.7	453.6	453.6	0.0	0.0	0.0	0.0	0.0	765.0	765.0	765.0	765.0	0.0	0.0	0.0	0.0	0.0	0.0	716.5	716.5	716.5	716.5	2260.5	2260.5	716.5	716.5	286.0	286.0	0.0	1.3	45.0
Brackish Demands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	321.8	321.8	1303.8	1303.8	1303.8	1173.3	1173.3	1173.3	1173.3	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	831.3	0.0	0.0		
Fill conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	321.8	321.8	1303.8	1303.8	1303.8	1173.3	1173.3	1173.3	1173.3	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	851.5	831.3	0.0	0.0	0.6	21.1
Total Demands	0.0	0.0	522.6	8440.2	9581.8	9581.8	9581.8	4067.1	4067.1	3613.5	3935.3	4246.5	6049.5	6049.5	6903.6	7611.8	7611.8	7611.8	6846.8	6524.9	6124.7	6124.7	6124.7	5740.8	7121.6	7121.6	6479.5	6479.5	12282.9	12878.3	8476.7	7060.3	6154.8	2780.1	2471.9	6.2	216.3
South of Hunter Summary																																					
Inputs - Demand (total Surplus / Deficit)	0.0	0.0	-522.6	-8440.2	-9581.8	-9581.8	-9581.8	-4067.1	-4067.1	-3472.8	-3666.5	-644.7	-2680.4	496.7	-783.2	807.6	-6687.6	-6894.2	-6341.4	-5958.3	-5488.7	-5348.9	-5215.9	5438.1	4100.6	4306.0	-5456.3	-5625.2	-11358.7	-12160.7	-7971.3	-6493.6	-5518.8	-2004.4	-1563.2	-4.1	-142.0
Make up water required - potable and concrete	0.0	0.0	522.6	522.6	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1753.3	1753.3	1753.3	1753.3	1753.3	1753.3	1664.1	1664.1	1664.1	1664.1	2328.5	2328.5	1686.4	1686.4	1686.4	3102.8	1961.2	544.8	544.8	544.8	522.6	1.5	51.8
Make up water required - Landscaping, dust suppression, pavements	0.0	0.0	0.0	7917.7	7917.7	7917.7	7917.7	2402.9	2402.9	1808.7	1865.3	2034.6	2846.0	2800.2	3618.6	4494.8	4479.2	4525.3	3807.5	3793.9	3467.3	3436.2	3406.5	2999.2	3706.1	3660.3	3713.7	3751.3	9539.1	8764.1	5551.4	5537.8	4637.1	2062.5	1746.9	4.0	138.5
surplus - fresh and slightly brackish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Make up water required - Fill conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	137.0	0.0	0.0	1058.4	1267.2	0.0	1156.5	1160.2	1164.1	841.2	839.9	837.3	834.9	0.0	0.0	0.0	832.8	835.9	834.6	838.4	842.3	841.2	819.6	0.0	0.0	0.4	15.1
surplus - all	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2340.2	1085.4	0.0	0.0	4730.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9387.6	9390.8	9405.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.7	66.5	1.0	36.5
Total make up required	0.0	0.0	522.6	8440.2	9581.8	9581.8	9581.8	4067.1	4067.1	3472.8	3666.5	3698.7	4510.1	5522.7	6639.0	6248.1	7389.0	7438.8	6724.9	6388.3	5971.4	5937.7	5905.6	4663.4	6034.6	5988.8	6232.8	6273.5	12060.1	12705.3	8354.9	6923.7	6001.5	2607.3	2269.4	5.9	205.5
Discharge to environment (brackish upper limit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3073.5	1849.9	913.1	740.0	5348.0	668.4	519.0	365.5	409.8	459.9	561.0	657.2	10120.9	10155.4	10318.9	740.0	617.8	668.4	519.0	365.5	409.8	459.9	617.8	723.7	1.5	51.3
Disposal (saline)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.2	37.8	5106.3	5115.9	1754.5	33.0	25.6	18.1	20.2	22.7	27.7	32.5	36.2	37.8	45.1	36.5	30.5	33.0	25.6	18.1	20.2	22.7	27.7	32.5	0.4	12.6
North of Hunter - Sources																																					
Fresh Inputs	0	0	0	0	0	0	0	0	0	0	9717	2699	1912	3829	4141	1005	2364	1665	4280	579	649	792	928	1035	1320	2638	1801	885	944	733	516	579	649	792	928		
Basins	0	0	0	0	0	0	0	0	0	0	9717	1664	832	2540	3096	132	1420	932	3764	0	0	0	0	0	240	1349	756	12	0	0	0	0	0	0	0	0.8	26.5
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	1035	1080	1289	1045	872	944	733	516	579	649	792	928	1035	1080	1289	1045	872	944	733	516	579	649	792	928	0.6	20.9
Slightly Brackish Inputs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0		
Basins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brackish Inputs	0	0	0	0	0	0	0	1597	1597	1597	1597	1616	1617	1620	1616	1613	17	13	1347	1348	12	15	17	19	20	24	3688	31	17	13	9	11	12	15	17		
Basins	0	0	0	0	0	0	0	0	0	0	0	19	20	24	19	16	17	13	9	11	12	15	17	19	20	24	19	16	17	13	9	11	12	15	17	0.0	0.4
Dewatering (basins and piers)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1337	1337	0	0	0	0	0	0	3669	15	0	0	0	0	0	0	0	0.2	6.4
Wick drains	0	0	0	0	0	0	0	1597	1597	1597	1597	1597	1597	1597	1597	1597	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	14.4
Saline Inputs	0	0	0	0	0	0	0	0	4531	4531	4531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Basins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Dewatering	0	0	0	0	0	0	0	0	4531	4531	4531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	13.6
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Total Inputs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1596.8	6128.0	6128.0	15845.1	4315.2	3528.2	5449.8	5756.8	2617.5	2381.1	1678.3	5626.9	1926.6	661.3	806.7	945.1	1054.4	1345.3	2661.7	5488.9	916.0	961.1	746.3	525.6	589.3	661.3	806.7	945.1	2.3	82.1
North of Hunter - Demands																																					
Fresh Demands	0.0	0.0	591.2	591.2	1276.2	1276.2	1276.2	1276.2	1276.2	1276.2	2716.9	2716.9	1776.1	4135.2	4135.2	1638.4	1445.7	945.8	836.1	836.1	687.9	1016.3	6804.3	1480.1	1605.4	1274.5	1306.4	1306.4	794.5	591.2	591.2	591.2	591.2	591.2	591.2		
Potable	0.0	0.0	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	0.6	19.5
Concrete Batching	0.0	0.0	0.0	0.0	685.1	685.1	685.1	685.1	685.1	685.1	2125.8	2125.8	1185.0	3544.0	3544.0	1047.2	854.5	354.7	244.9	244.9	96.7	425.1	6213.2	888.9	1014.2	683.4	715.3	715.3	203.3	0.0	0.0	0.0	0.0	0.0	0.0	0.9	30.3
Slightly Brackish Demands	0	0	660	7976	7976	7976	7316	529	529	754	754	754	754	2342	2342	754	1368	1354	740	740	945	1092	1698	1862	2798	2344	2673	2579	1612	998	3404	3901	3901	3901	3901		
Landscaping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1102.0	1102.0	1102.0	614.0	614.0	614.0	0.0	0.0	3385.5	3385.5	3385.5	3385.5	0.5	18.7
Dust suppression	0.0	0.0	0.0	0.0	0.0	0.0	0.0	529.4	529.4	753.7	753.7	753.7	753.7	753.7	753.7	753.7	753.7	740.1	740.1	740.1	515.7	662.5	812.3	665.6	1147.7	1147.7	1196.7	1196.7	997.9	997.9	515.7	515.7	515.7	515.7	515.7	0.6	21.2
Pavements	0.0	0.0	660.0	7976.0	7976.0	7976.0	7316.0	0.0	0.0	0.0	0.0	0.0	0.0	1588.0	1588.0	0.0	614.0	614.0	0.0	0.0	429.3	429.3	885.3	94.0	548.0	94.0	862.0	768.0	0.0	0.0	2888.0	0.0	0.0	0.0	0.0	1.2	43.3
Brackish Demands	0.0	0.0	0.0	0.0	3225.3	3225.3	3225.3	3225.3	3225.3	3702.4	477.1	2907.6	2907.6	2907.6	2907.6	477.1	1478.7	1478.7	1478.7	1478.7	1478.7	1478.7	1001.6	2990.0	6592.7	3666.7	3602.7	2008.0	3020.0	0.0	0.0	0.0	0.0	0.0	0.0		
Fill conditioning	0.0	0.0	0.0	0.0	3225.3	3225.3	3225.3	3225.3	3225.3	3702.4	477.1	2907.6	2907.6	2907.6	2907.6	477.1	1478.7	1478.7	1478.7	1478.7	1478.7	1478.7	1001.6	2990.0	6592.7	3666.7	3602.7	2008.0	3020.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	61.2
Total Demands	0.0	0.0	1251.2	8567.1	12477.5	12477.5	11817.5	5031.0	5031.0	5732.4	3947.7	6378.2	5437.5	9384.5	9384.5	2869.2	4292.1	3778.6	3054.8	3054.8	2634.6	5098.1	15094.6	7008.4	8005.8	5626.2	6999.1	3885.1	2406.3	1589.0	3994.9	4492.4	4492.4	4492.4	4492.4	5.6	194.3
North of Hunter Summary (m3)																																					
Inputs - Demand (total Surplus / Deficit)	0.0	0.0	-1251.2	-8567.1	-12477.5	-12477.5	-11817.5	-3434.2	1097.0	395.6	11897.4	-2063.0	-1909.2	-3934.7	-3627.6	-251.6	-1911.0	-2100.3	2572.0	-1128.3	-1973.2	-4291.3	-14149.6	-5953.9	-6660.5	-2964.6	-1510.2	-2969.1	-1445.2	-842.7	-3469.3	-3903.1	-3831.0	-3685.6	-3547.3	-3.2	-112.2
Make up water required - potable and concrete	0.0	0.0	591.2	591.2	1276.2	1276.2	1276.2	1276.2	1276.2	1276.2	2716.9	2716.9	1776.1	4135.2	4135.2	1638.4	1445.7	945.8	836.1	836.1	687.9	1016.3	6804.3	1480.1	1605.4	1274.5	1306.4	1306.4	794.5	591.2	591.2	591.2	591.2	591.2	1.4	49.8
Make up water required - Landscaping, dust suppression, pavements	0.0	0.0	660.0	7976.0	7976.0	7976.0	7316.0	529.4	529.4	753.7	0.0	0.0	0.0	0.0	0.0	403.3	0.0	238.9	0.0	595.4	782.7	893.7	1465.6	1602.7	2282.0	672.7	1655.5	2348.3	1375.9	814.7	3274.7	3756.6	3738.9	3703.2	3669.2	1.9	67.0
surplus - fresh and slightly brackish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8963.4	1169.1	348.2	520.6	1015.5	0.0	288.2	0.0	3153.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	15.5
Make up water required - Fill conditioning	0.0	0.0	0.0	0.0	3225.3	3225.3	3225.3	2826.1	2826.1	3303.2	0.0	1334.5	2155.3	1981.9	1488.1	0.0	1186.1	1475.3	0.0	138.8	998.6	2986.4	6588.4	3661.9	3597.7	2002.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	48.2
surplus - all	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10083.1	0.0	0.0	0.0	0.0	1135.7	0.0	0.0	3021.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	667.9	31.2	17.3	13.4	9.5	10.6	11.9	14.5	17.0	0.4	15.0
Total make up required	0.0	0.0	1251.2	8567.1	12477.5	12477.5	11817.5	4631.8	4631.8	5333.2	2716.9	4051.4	3931.4	6117.0	5623.3	2041.7	2631.8	2660.0	836.1	1570.3	2469.2	4896.4	14858.4	6744.8	7485.1	3949.3	2961.9	3654.7	2170.4	1405.8	3865.8	4347.7	4330.0	4294.3	4260.4	4.7	165.1
Discharge to environment (brackish upper limit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1197.6	1197.6	1197.6	11280.7	1988.4	2022.2	2182.4	1995.6	2999.6	720.9	559.7	3415.2	442.0	496.0	605.1	708.8	790.8	824.6	984.8	1466.0	697.6	738.1	573.1	403.7	452.6	507.9	619.6	725.8	1.2	41.8
Disposal (saline)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4531.2	4531.2	4531.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	13.6

Construction Water Balance - Dry Scenario

(m^3/month)

	1 Aug-24	2 Sep-24	3 Oct-24	4 Nov-24	5 Dec-24	6 Jan-25	7 Feb-25	8 Mar-25	9 Apr-25	10 May-25	11 Jun-25	12 Jul-25	13 Aug-25	14 Sep-25	15 Oct-25	16 Nov-25	17 Dec-25	18 Jan-26	19 Feb-26	20 Mar-26	21 Apr-26	22 May-26	23 Jun-26	24 Jul-26	25 Aug-26	26 Sep-26	27 Oct-26	28 Nov-26	29 Dec-26	30 Jan-27	31 Feb-27	32 Mar-27	33 Apr-27	34 May-27	35 Jun-27	Average ML	Total ML
South of Hunter - Sources																																				
Fresh Inputs	0	0	0	0	0	0	0	0	0	0	0	101	117	157	123	97	106	61	63	72	100	101	129	101	117	157	123	97	106	61	63	72	100	101	129		
Basins	0	0	0	0	0	0	0	0	0	0	0	101	117	157	123	97	106	61	63	72	100	101	129	101	117	157	123	97	106	61	63	72	100	101	129	0.1	2.5
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Slightly Brackish Inputs	0	0	0	0	0	0	0	0	0	141	84	166	193	259	202	160	175	100	103	119	165	167	213	166	193	259	202	160	175	100	103	119	165	167	213		
Basins	0	0	0	0	0	0	0	0	0	0	0	166	193	259	202	160	175	100	103	119	165	167	213	166	193	259	202	160	175	100	103	119	165	167	213	0.1	4.0
Dewatering	0	0	0	0	0	0	0	0	0	141	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.2
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brackish Inputs	0	0	0	0	0	0	0	0	0	0	185	2610	2337	257	45	5862	23	13	14	16	22	22	28	10187	10190	10199	27	21	23	13	14	16	22	22	28		
Basins	0	0	0	0	0	0	0	0	0	0	0	22	25	34	27	21	23	13	14	16	22	22	28	22	25	34	27	21	23	13	14	16	22	22	28	0.0	0.5
Dewatering	0	0	0	0	0	0	0	0	0	0	185	2588	2312	222	18	5841	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	11.2
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10165	10165	10165	0	0	0	0	0	0	0	0	0	0.9	30.5
Saline Inputs	0	0	0	0	0	0	0	0	0	0	0	11	12	5078	5092	1734	11	6	7	8	11	11	14	11	12	17	13	10	11	6	7	8	11	11	14		
Basins	0	0	0	0	0	0	0	0	0	0	0	11	12	17	13	10	11	6	7	8	11	11	14	11	12	17	13	10	11	6	7	8	11	11	14	0.0	0.3
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	5061	5079	1724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	11.9
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Total Inputs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.7	268.8	2887.3	2660.4	5750.4	5462.1	7853.3	314.9	181.3	186.4	214.3	298.4	300.6	383.5	10464.4	10513.5	10631.8	364.9	288.3	314.9	181.3	186.4	214.3	298.4	300.6	383.5	1.7	61.0
South of Hunter - Demands																																					
Fresh Demands	0.0	0.0	522.6	522.6	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1753.3	1753.3	1753.3	1753.3	1753.3	1753.3	1664.1	1664.1	1664.1	1664.1	2328.5	2328.5	1686.4	1686.4	1686.4	3102.8	1961.2	544.8	544.8	544.8	522.6		
Potable	0.0	0.0	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	0.5	17.2
Concrete Batching	0.0	0.0	0.0	0.0	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1230.7	1230.7	1230.7	1230.7	1230.7	1230.7	1141.6	1141.6	1141.6	1141.6	1805.9	1805.9	1163.8	1163.8	1163.8	2580.3	1438.7	22.2	22.2	22.2	0.0	1.0	34.6
Slightly Brackish Demands	0	0	0	9501	9501	9501	9501	3468	3468	2924	2924	3391	4622	4622	5540	6798	6798	6798	5880	5880	5414	5414	5414	4838	5697	5697	5697	5697	13939	12708	8281	8281	7082	3267	2924		
Landscaping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6389.1	6389.1	3815.1	3815.1	3815.1	0.0	0.0	0.7	24.2
Dust suppression	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2924.0	2924.0	2924.0	2924.0	3390.7	4622.3	4622.3	4622.3	5880.2	5880.2	5880.2	5880.2	5880.2	5413.5	5413.5	5413.5	4837.7	4837.7	4837.7	4837.7	4837.7	4837.7	3606.1	3606.1	3606.1	2924.0	2924.0	2924.0	3.5	123.2
Pavements	0.0	0.0	0.0	9501.2	9501.2	9501.2	9501.2	544.3	544.3	0.0	0.0	0.0	0.0	0.0	918.0	918.0	918.0	918.0	918.0	918.0	0.0	0.0	0.0	0.0	859.8	859.8	859.8	859.8	859.8	2712.6	2712.6	859.8	859.8	343.2	343.2	0.0	1.5	54.0
Brackish Demands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	386.2	386.2	1564.6	1564.6	1564.6	1408.0	1408.0	1408.0	1408.0	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	997.5	0.0	0.0		
Fill conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	386.2	386.2	1564.6	1564.6	1564.6	1408.0	1408.0	1408.0	1408.0	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	1021.8	997.5	0.0	0.0	0.7	25.4
Total Demands	0.0	0.0	522.6	10023.8	11165.4	11165.4	11165.4	5132.5	5132.5	4588.1	4974.3	5441.1	7851.0	7851.0	8858.1	9959.5	9959.5	9959.5	9041.5	8655.3	8099.5	8099.5	8099.5	7523.6	9047.8	9047.8	8405.7	8405.7	16647.6	16832.5	11264.1	9847.6	8624.6	3812.0	3446.6	8.0	278.7
South of Hunter Summary																																					
Inputs - Demand (total Surplus / Deficit)	0.0	0.0	-522.6	-10023.8	-11165.4	-11165.4	-11165.4	-5132.5	-5132.5	-4447.5	-4705.5	-2553.8	-5190.6	-2100.6	-3396.0	-2106.2	-9644.6	-9778.3	-8855.1	-8441.0	-7801.1	-7798.8	-7715.9	2940.8	1465.7	1584.0	-8040.8	-8117.4	-16332.7	-16651.2	-11077.6	-9633.3	-8326.2	-3511.3	-3063.0	-6.2	-217.6
Make up water required - potable and concrete	0.0	0.0	522.6	522.6	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1753.3	1753.3	1753.3	1753.3	1753.3	1753.3	1664.1	1664.1	1664.1	1664.1	2328.5	2328.5	1686.4	1686.4	1686.4	3102.8	1961.2	544.8	544.8	544.8	522.6	1.5	51.8
Make up water required - Landscaping, dust suppression, pavements	0.0	0.0	0.0	9501.2	9501.2	9501.2	9501.2	3468.3	3468.3	2783.3	2840.0	3324.0	4544.6	4518.3	5459.0	6734.0	6728.1	6757.8	5838.7	5832.5	5347.0	5346.5	5328.1	4771.0	5619.8	5593.5	5616.2	5633.3	13869.2	12667.5	8239.5	8233.3	7015.8	3200.2	2838.6	5.7	199.6
surplus - fresh and slightly brackish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Make up water required - Fill conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	201.4	0.0	0.0	1333.7	1540.0	0.0	1402.3	1404.7	1404.6	1017.9	1016.4	1016.3	1014.8	0.0	0.0	0.0	1015.1	1016.5	1016.1	1018.5	1018.4	1017.9	992.1	0.0	0.0	0.5	18.4
surplus - all	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2223.6	772.8	0.0	0.0	4454.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9165.1	9168.7	9177.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0	28.0	1.0	35.0
Total make up required	0.0	0.0	522.6	10023.8	11165.4	11165.4	11165.4	5132.5	5132.5	4447.5	4705.5	4988.2	6208.8	7516.1	8752.2	8487.3	9883.6	9915.8	8996.6	8603.6	8027.5	8027.0	8007.0	6435.1	7948.3	7922.0	8317.7	8336.2	16571.6	16788.8	11219.1	9796.0	8552.6	3745.0	3361.1	7.7	269.9
Discharge to environment (brackish upper limit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2440.1	1024.8	337.6	263.9	4662.6	227.7	131.1	134.8	155.0	215.8	217.4	277.4	9381.6	9420.7	9514.9	263.9	208.5	227.7	131.1	134.8	155.0	215.8	239.4	305.4	1.2	40.3
Disposal (saline)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7	12.4	5077.9	5092.4	1734.3	11.2	6.5	6.7	7.7	10.7	10.7	13.7	10.7	12.4	16.7	13.0	10.3	11.2	6.5	6.7	7.7	10.7	10.7	13.7	0.3	12.1
North of Hunter - Sources																																					
Fresh Inputs	0	0	0	0	0	0	0	0	0	0	9717	1970	1188	3017	3469	427	1742	1117	3954	219	305	307	392	306	596	1825	1129	307	322	185	190	219	305	307	392		
Basins	0	0	0	0	0	0	0	0	0	0	0	306	356	477	373	294	322	185	190	219	305	307	392	306	356	477	373	294	322	185	190	219	305	307	392	0.2	7.4
Dewatering	0	0	0	0	0	0	0	0	0	0	9717	1664	832	2540	3096	132	1420	932	3764	0	0	0	0	0	240	1349	756	12	0	0	0	0	0	0	0	0.8	26.5
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Slightly Brackish Inputs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0		
Basins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brackish Inputs	0	0	0	0	0	0	0	1597	1597	1597	1597	1602	1603	1606	1604	1602	6	3	1341	1341	6	6	7	6	7	9	3676	21	6	3	3	4	6	6	7		
Basins	0	0	0	0	0	0	0	0	0	0	0	6	7	9	7	5	6	3	3	4	6	6	7	6	7	9	7	5	6	3	3	4	6	6	7	0.0	0.1
Dewatering (basins and piers)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1337	1337	0	0	0	0	0	0	3669	15	0	0	0	0	0	0	0	0.2	6.4
Wick drains	0	0	0	0	0	0	0	1597	1597	1597	1597	1597	1597	1597	1597	1597	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	14.4
Saline Inputs	0	0	0	0	0	0	0	0	4531	4531	4531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Basins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Dewatering	0	0	0	0	0	0	0	0	4531	4531	4531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	13.6
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Total Inputs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1596.8	6128.0	6128.0	15845.1	3572.2	2791.2	4622.2	5072.2	2028.9	1747.5	1120.5	5295.2	1560.1	310.3	312.7	398.9	311.4	608.3	1834.1	4804.2	327.3	327.5	188.5	193.9	222.9	310.3	312.7	398.9	2.0	68.4
North of Hunter - Demands																																					
Fresh Demands	0.0	0.0	591.2	591.2	1276.2	1276.2	1276.2	1276.2	1276.2	1276.2	2716.9	2716.9	1776.1	4135.2	4135.2	1638.4	1445.7	945.8	836.1	836.1	687.9	1016.3	6804.3	1480.1	1605.4	1274.5	1306.4	1306.4	794.5	591.2	591.2	591.2	591.2	591.2	591.2		
Potable	0.0	0.0	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	0.6	19.5
Concrete Batching	0.0	0.0	0.0	0.0	685.1	685.1	685.1	685.1	685.1	685.1	2125.8	2125.8	1185.0	3544.0	3544.0	1047.2	854.5	354.7	244.9	244.9	96.7	425.1	6213.2	888.9	1014.2	683.4	715.3	715.3	203.3	0.0	0.0	0.0	0.0	0.0	0.0	0.9	30.3
Slightly Brackish Demands	0	0	792	9571	9571	9571	8779	794	794	1131	1131	1131	1131	3036	3036	1131	1867	1847	1110	1110	1289	1509	2281	2764	4032	3487	3750	3638	2418	1497	4239	5852	5852	5852	5852		
Landscaping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1653.0	1653.0	1653.0	921.0	921.0	921.0	0.0	0.0	5078.3	5078.3	5078.3	5078.3	0.8	28.0
Dust suppression	0.0	0.0	0.0	0.0	0.0	0.0	0.0	794.1	794.1	1130.6	1130.6	1130.6	1130.6	1130.6	1130.6	1130.6	1130.6	1110.1	1110.1	1110.1	773.6	993.7	1218.5	998.4	1721.6	1721.6	1795.0	1795.0	1496.8	1496.8	773.6	773.6	773.6	773.6	0.9	31.8
Pavements	0.0	0.0	792.0	9571.2	9571.2	9571.2	8779.2	0.0	0.0	0.0	0.0	0.0	0.0	1905.6	1905.6	0.0	736.8	736.8	0.0	0.0	515.2	515.2	1062.4	112.8	657.6	112.8	1034.4	921.6	0.0	0.0	3465.6	0.0	0.0	0.0	0.0	1.5	52.0
Brackish Demands	0.0	0.0	0.0	0.0	3870.4	3870.4	3870.4	3870.4	3870.4	4442.9	572.5	3489.1	3489.1	3489.1	3489.1	572.5	1774.4	1774.4	1774.4	1774.4	1201.9	3588.0	7911.2	4400.0	4323.2	2409.6	3624.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Fill conditioning	0.0	0.0	0.0	0.0	3870.4	3870.4	3870.4	3870.4	3870.4	4442.9	572.5	3489.1	3489.1	3489.1	3489.1	572.5	1774.4	1774.4	1774.4	1774.4	1201.9	3588.0	7911.2	4400.0	4323.2	2409.6	3624.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	73.5
Total Demands	0.0	0.0	1383.2	10162.3	14717.8	14717.8	13925.8	5940.8	5940.8	6849.8	4420.0	7336.6	6395.8	10660.5	10660.5	3341.5	5087.5	4567.1	3720.6	3720.6	3178.6	6113.2	16996.4	8644.3	9960.8	7171.5	8680.9	4944.1	3212.3	2087.9	4830.4	6443.0	6443.0	6443.0	6443.0	6.7	235.1
North of Hunter Summary (m3)																																					
Inputs - Demand (total Surplus / Deficit)	0.0	0.0	-1383.2	-10162.3	-14717.8	-14717.8	-13925.8	-4344.0	187.2	-721.8	11425.1	-3764.5	-3604.6	-6038.2	-5588.2	-1312.6	-3340.1	-3446.6	1574.6	-2160.5	-2868.3	-5800.5	-16597.5	-8332.9	-9352.5	-5337.4	-3876.6	-4616.7	-2884.8	-1899.5	-4636.5	-6220.2	-6132.7	-6130.3	-6044.1	-4.8	-166.8
Make up water required - potable and concrete	0.0	0.0	591.2	591.2	1276.2	1276.2	1276.2	1276.2	1276.2	1276.2	2716.9	2716.9	1776.1	4135.2	4135.2	1638.4	1445.7	945.8	836.1	836.1	687.9	1016.3	6804.3	1480.1	1605.4	1274.5	1306.4	1306.4	794.5	591.2	591.2	591.2	591.2	591.2	591.2	1.4	49.8
Make up water required - Landscaping, dust suppression, pavements	0.0	0.0	792.0	9571.2	9571.2	9571.2	8779.2	794.1	794.1	1130.6	0.0	0.0	209.6	377.0	0.0	924.7	367.0	868.6	0.0	1055.4	1212.6	1432.1	2183.0	2687.8	3697.4	2019.6	2901.3	3551.8	2337.4	1450.5	4191.6	5797.1	5775.7	5775.1	5753.9	2.7	95.6
surplus - fresh and slightly brackish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8586.5	609.8	0.0	0.0	152.9	0.0	0.0	0.0	2701.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	12.1
Make up water required - Fill conditioning	0.0	0.0	0.0	0.0	3870.4	3870.4	3870.4	3471.2	3471.2	4043.7	0.0	2478.7	3088.3	3087.7	2935.3	0.0	1773.0	1773.6	0.0	436.2	1200.5	3586.6	7909.4	4398.6	4321.6	2407.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	62.0
surplus - all	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9610.8	0.0	0.0	0.0	0.0	1029.7	0.0	0.0	2267.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.6	20.6	5.9	3.4	3.5	4.0	5.6	5.6	7.2	0.4	13.0
Total make up required	0.0	0.0	1383.2	10162.3	14717.8	14717.8	13925.8	5541.6	5541.6	6450.6	2716.9	5195.6	5074.0	7599.9	7070.4	2563.0	3585.7	3588.0	836.1	2327.6	3101.0	6035.0	16896.7	8566.5	9624.4	5701.5	4207.7	4858.2	3131.9	2041.7	4782.8	6388.3	6366.8	6366.2	6345.1	5.9	207.4
Discharge to environment (brackish upper limit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1197.6	1197.6	1197.6	10808.4	1431.1	1469.4	1561.7	1482.2	2452.1	245.6	141.4	2413.3	167.1	232.8	234.5	299.1	233.5	271.8	364.1	336.2	245.5	251.5	144.8	148.9	171.1	238.3	240.1	306.3	0.8	29.5
Disposal (saline)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4531.2	4531.2	4531.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	13.6

Construction Water Balance - Base Case

(m^3/month)

	1 Aug-24	2 Sep-24	3 Oct-24	4 Nov-24	5 Dec-24	6 Jan-25	7 Feb-25	8 Mar-25	9 Apr-25	10 May-25	11 Jun-25	12 Jul-25	13 Aug-25	14 Sep-25	15 Oct-25	16 Nov-25	17 Dec-25	18 Jan-26	19 Feb-26	20 Mar-26	21 Apr-26	22 May-26	23 Jun-26	24 Jul-26	25 Aug-26	26 Sep-26	27 Oct-26	28 Nov-26	29 Dec-26	30 Jan-27	31 Feb-27	32 Mar-27	33 Apr-27	34 May-27	35 Jun-27	Average ML	Total ML
South of Hunter - Sources																																				
Fresh Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	624	767	863	718	656	833	543	487	480	493	516	574	624	767	863	718	656	833	543	487	480	493	516	574	0.4	15.1
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Slightly Brackish Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	1027	1262	1421	1183	1080	1372	895	802	790	811	849	946	1027	1262	1421	1183	1080	1372	895	802	790	811	849	946	0.7	24.9
Dewatering	0	0	0	0	0	0	0	0	0	141	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.2
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brackish Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	136	166	187	156	142	181	118	106	104	107	112	125	136	166	187	156	142	181	118	106	104	107	112	125	0.1	3.3
Dewatering	0	0	0	0	0	0	0	0	0	0	185	2588	2312	222	18	5841	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	11.2
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10165	10165	10165	0	0	0	0	0	0	0	0	0	0.9	30.5
Saline Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	66	81	92	76	70	88	58	52	51	52	55	61	66	81	92	76	70	88	58	52	51	52	55	61	0.0	1.6
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	5061	5079	1724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	11.9
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Total Inputs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.7	268.8	4440.9	4588.4	7846.6	7231.0	9513.4	2473.8	1613.8	1445.7	1425.3	1463.6	1531.7	1705.5	12018.0	12441.5	12728.0	2133.7	1948.3	2473.8	1613.8	1445.7	1425.3	1463.6	1531.7	1705.5	2.8	98.6
South of Hunter - Demands																																				
Fresh Demands																																				
Potable	0.0	0.0	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	522.6	0.5	17.2
Concrete Batching	0.0	0.0	0.0	0.0	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1141.6	1230.7	1230.7	1230.7	1230.7	1230.7	1230.7	1141.6	1141.6	1141.6	1141.6	1805.9	1805.9	1163.8	1163.8	1163.8	2580.3	1438.7	22.2	22.2	22.2	0.0	1.0	34.6
Slightly Brackish Demands																																				
Landscaping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2129.7	2129.7	1271.7	1271.7	1271.7	0.0	0.0	0.2	8.1
Dust suppression	0.0	0.0	0.0	0.0	0.0	0.0	0.0	974.7	974.7	974.7	974.7	1130.2	1540.8	1540.8	1540.8	1960.1	1960.1	1960.1	1960.1	1960.1	1960.1	1804.5	1804.5	1804.5	1612.6	1612.6	1612.6	1612.6	1612.6	1202.0	1202.0	1202.0	974.7	974.7	974.7	1.2	41.1
Pavements	0.0	0.0	0.0	6334.1	6334.1	6334.1	6334.1	362.9	362.9	0.0	0.0	0.0	0.0	0.0	612.0	612.0	612.0	612.0	0.0	0.0	0.0	0.0	0.0	0.0	573.2	573.2	573.2	573.2	1808.4	1808.4	573.2	573.2	228.8	228.8	0.0	1.0	36.0
Brackish Demands																																				
Fill conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	257.5	257.5	1043.1	1043.1	1043.1	938.7	938.7	938.7	938.7	681.2	681.2	681.2	681.2	681.2	681.2	681.2	681.2	681.2	681.2	681.2	681.2	681.2	665.0	0.0	0.0	0.5	16.9
Total Demands	0.0	0.0	522.6	6856.7	7998.3	7998.3	7998.3	3001.7	3001.7	2638.8	2896.3	3051.8	4248.0	4248.0	4949.1	5264.0	5264.0	5264.0	4652.0	4394.5	4149.9	4149.9	4149.9	3957.9	5195.5	5195.5	4553.3	4553.3	7918.2	8924.2	5689.4	4272.9	3684.9	1748.2	1497.2	4.4	153.9
South of Hunter Summary																																				
Inputs - Demand (total Surplus / Deficit)	0.0	0.0	-522.6	-6856.7	-7998.3	-7998.3	-7998.3	-3001.7	-3001.7	-2498.1	-2627.5	1389.1	340.4	3598.7	2281.9	4249.4	-2790.2	-3650.3	-3206.3	-2969.3	-2686.2	-2618.2	-2444.4	8060.1	7246.0	7532.6	-2419.6	-2605.0	-5444.4	-7310.4	-4243.7	-2847.6	-2221.3	-216.6	208.3	-1.6	-55.3
Make up water required - potable and concrete	0.0	0.0	522.6	522.6	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1664.1	1753.3	1753.3	1753.3	1753.3	1753.3	1753.3	1664.1	1664.1	1664.1	1664.1	2328.5	2328.5	1686.4	1686.4	1686.4	3102.8	1961.2	544.8	544.8	544.8	522.6	1.5	51.8
Make up water required - Landscaping, dust suppression, pav	0.0	0.0	0.0	6334.1	6334.1	6334.1	6334.1	1337.5	1337.5	834.0	890.7	717.4	1033.6	969.7	1677.4	2138.0	2020.9	2212.5	1638.0	1642.5	1478.4	1463.3	1424.5	1199.7	1678.6	1614.7	1710.4	1751.7	4999.5	4780.6	2724.9	2729.4	2149.1	862.2	594.7	2.1	74.9
surplus - fresh and slightly brackish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Make up water required - Fill conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.7	0.0	0.0	773.8	986.1	0.0	893.5	909.2	912.2	655.2	654.5	653.2	650.0	0.0	0.0	0.0	642.2	645.6	636.0	651.7	654.8	655.2	638.3	0.0	0.0	0.3	11.7
surplus - all	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2465.9	1435.3	0.0	0.0	5044.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9619.3	9650.3	9671.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.0	124.7	1.1	38.1
Total make up required	0.0	0.0	522.6	6856.7	7998.3	7998.3	7998.3	3001.7	3001.7	2498.1	2627.5	2381.5	2697.7	3407.7	4416.8	3891.3	4667.7	4875.0	4303.5	4051.0	3797.0	3780.6	3738.7	2863.9	4007.1	3943.2	4039.0	4083.6	7321.9	8535.1	5340.9	3929.3	3332.1	1407.0	1117.3	4.0	138.4
Discharge to environment (brackish upper limit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3806.1	3081.7	1853.6	1543.1	6453.9	1789.1	1167.1	1045.5	1030.8	1058.5	1107.7	1233.4	10959.4	11296.6	11524.8	1543.1	1409.0	1789.1	1167.1	1045.5	1030.8	1058.5	1219.7	1358.2	2.0	70.6
Disposal (saline)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.2	81.3	5152.7	5155.5	1793.6	88.4	57.6	51.6	50.9	52.3	54.7	60.9	66.2	81.3	91.5	76.2	69.6	88.4	57.6	51.6	50.9	52.3	54.7	60.9	0.4	13.5
North of Hunter - Sources																																				
Fresh Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	1892	2325	2618	2179	1990	2526	1648	1476	1456	1495	1564	1742	1892	2325	2618	2179	1990	2526	1648	1476	1456	1495	1564	1742	1.3	45.8
Dewatering	0	0	0	0	0	0	0	0	0	0	9717	1664	832	2540	3096	132	1420	932	3764	0	0	0	0	0	240	1349	756	12	0	0	0	0	0	0	0	0.8	26.5
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Slightly Brackish Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brackish Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	35	43	48	40	36	46	30	27	27	27	29	32	35	43	48	40	36	46	30	27	27	27	29	32	0.0	0.8
Dewatering (basins and piers)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1337	1337	0	0	0	0	0	0	3669	15	0	0	0	0	0	0	0	0.2	6.4
Wick drains	0	0	0	0	0	0	0	1597	1597	1597	1597	1597	1597	1597	1597	1597	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	14.4
Saline Inputs																																				
Basins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Dewatering	0	0	0	0	0	0	0	0	4531	4531	4531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	13.6
Wick drains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Total Inputs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1596.8	6128.0	6128.0	15845.1	5187.9	4796.2	6802.2	6911.8	3755.3	3992.7	2610.3	6604.7	2819.5	1522.1	1592.9	1773.7	1927.1	2613.3	4014.1	6643.8	2053.7	2572.7	1678.3	1503.5	1482.2	1522.1	1592.9	1773.7	3.1	107.4
North of Hunter - Demands																																				
Fresh Demands																																				
Potable	0.0	0.0	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	591.2	0.6	19.5
Concrete Batching	0.0	0.0	0.0	0.0	685.1	685.1	685.1	685.1	685.1	685.1	2125.8	2125.8	1185.0	3544.0	3544.0	1047.2	854.5	354.7	244.9	244.9	96.7	425.1	6213.2	888.9	1014.2	683.4	715.3	715.3	203.3	0.0	0.0	0.0	0.0	0.0	0.0	0.9	30.3
Slightly Brackish Demands																																				
Landscaping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	551.0	551.0	551.0	307.0	307.0	307.0	0.0	0.0	1692.8	1692.8	1692.8	1692.8	0.3	9.3
Dust suppression	0.0	0.0	0.0	0.0	0.0	0.0	0.0	264.7	264.7	376.9	376.9	376.9	376.9	376.9	376.9	376.9	376.9	370.0	370.0	370.0	257.9	331.2	406.2	332.8	573.9	573.9	598.3	598.3	498.9	498.9	257.9	257.9	257.9	257.9	257.9	0.3	10.6
Pavements	0.0	0.0	528.0	6380.8	6380.8	6380.8	5852.8	0.0	0.0	0.0	0.0	0.0	0.0	1270.4	1270.4	0.0	491.2	491.2	0.0	0.0	343.5	343.5	708.3	75.2	438.4	75.2	689.6	614.4	0.0	0.0	2310.4	0.0	0.0	0.0	0.0	0.0	1.0	34.6
Brackish Demands																																				
Fill conditioning	0.0	0.0	0.0	0.0	2580.3	2580.3	2580.3	2580.3	2580.3	2961.9	381.7	2326.1	2326.1	2326.1	2326.1	381.7	1183.0	1183.0	1183.0	1183.0	801.3	2392.0	5274.1	2933.3	2882.1	1606.4	2416.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	49.0
Total Demands	0.0	0.0	1119.2	6971.9	10237.3	10237.3	9709.3	4121.2	4121.2	4615.1	3475.5	5419.9	4479.1	8108.5	8108.5	2396.9	3496.7	2990.0	2389.1	2389.1	2090.5	4083.0	13192.9	5372.4	6050.8	4081.0	5317.4	2826.2	1600.4	1090.1	3159.4	2541.8	2541.8	2541.8	2541.8	4.4	153.4
North of Hunter Summary (m3)																																				
Inputs - Demand (total Surplus / Deficit)	0.0	0.0	-1119.2	-6971.9	-10237.3	-10237.3	-9709.3	-2524.4	2006.8	1512.9	12369.7	-232.0	317.2	-1306.3	-1196.7	1358.4	496.0	-379.7	4215.7	430.4	-568.4	-2490.1	-11419.2	-3445.3	-3437.5	-66.9	1326.4	-772.5	972.3	588.2	-1656.0	-1059.5	-1019.6	-948.9	-768.1	-1.3	-46.0
Make up water required - potable and concrete	0.0	0.0	591.2	591.2	1276.2	1276.2	1276.2	1276.2	1276.2	1276.2	2716.9	2716.9	1776.1	4135.2	4135.2	1638.4	1445.7	945.8	836.1	836.1	687.9	1016.3	6804.3	1480.1	1605.4	1274.5	1306.4	1306.4	794.5	591.2	591.2	591.2	591.2	591.2	591.2	1.4	49.8
Make up water required - Landscaping, dust suppression, pav	0.0	0.0	528.0	6380.8	6380.8	6380.8	5852.8	264.7	264.7	376.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	227.6	283.6	679.0	485.9	736.2	0.0	294.2	1010.0	174.3	86.9	2199.2	1586.7	1576.9	1559.6	1515.2	1.1	38.9
surplus - fresh and slightly brackish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9340.3	1760.2	1036.4	1547.1	1993.5	252.9	1183.5	482.8	3763.1	0.0	0.0	0.0	0.0	0.0	0.0	803.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	22.2
Make up water required - Fill conditioning	0.0	0.0	0.0	0.0	2580.3	2580.3	2580.3	2181.1	2181.1	2562.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	692.6	0.0	0.0	794.4	2384.8	5266.2	2924.7	2871.5	791.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	30.4
surplus - all	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10555.4	1065.6	349.6	865.8	1304.1	1504.4	46.9	0.0	3944.4	181.0	0.0	0.0	0.0	0.0	0.0	0.0	1292.7	51.7	46.3	30.2	27.0	26.7	27.4	28.7	31.9	0.6	21.4
Total make up required	0.0	0.0	1119.2	6971.9	10237.3	10237.3	9709.3	3722.0	3722.0	4215.9	2716.9	2716.9	1776.1	4135.2	4135.2	1638.4	1445.7	1638.4	836.1	842.2	1710.0	3684.8	12749.5	4890.7	5213.1	2066.0	1600.6	2316.4	968.8	678.1	2790.3	2177.9	2168.1	2150.7	2106.3	3.4	119.1
Discharge to environment (brackish upper limit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1197.6	1197.6	1197.6	11753.0	3708.5	3322.8	4062.4	4165.9	4221.6	1976.4	1258.7	5072.0	1292.7	1141.6	1194.7	1330.2	1445.3	1775.6	1999.1	2957.0	1571.3	1975.8	1288.9	1154.6	1138.3	1169.0	1223.3	1362.2	1.9	67.2
Disposal (saline)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4531.2	4531.2	4531.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	13.6

Basin Runoff Calculations

Basin ID	Basin Type	Below SWL	Basin water quality - with GW input (uS/cm)		Construction stage sediment basin catchment area (ha)	Median Runoff (Cv=0.64) (m3/mnth)												Dry Runoff (Cv=0.64) (m3/mnth)												Wet Runoff (Cv=0.64)											
						Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
						Median Monthly Rainfall (mm)	82.0	85.5	102.1	82.7	69.1	74.7	58.0	40.9	45.8	51.4	62.7	73.5	24.2	28.2	37.7	29.5	23.3	25.5	14.7	15.1	17.3	24.1	24.3	31.0	149.8	184.0	207.2	172.5	157.5	200.0	130.4	116.9	115.2	118.3	123.8	137.9
B 00700 M	Temp & Perm.	No	100	Fresh	1.4	734.3	765.6	914.4	741.0	618.7	669.3	519.7	366.0	410.4	460.5	561.8	658.1	216.8	252.4	338.1	264.2	208.8	228.0	131.3	135.0	155.2	216.1	217.7	277.8	1342.0	1648.6	1856.2	1545.2	1411.0	1791.6	1168.7	1047.0	1032.2	1060.0	1109.2	1235.1
B 00700 R	Temp & Perm.	No	100	Fresh	3.7	1940.6	2023.5	2416.5	1958.3	1635.1	1768.9	1373.4	967.3	1084.5	1217.2	1484.7	1739.3	573.1	667.1	893.4	698.3	551.7	602.7	346.9	356.9	410.1	571.2	575.4	734.1	3546.7	4357.1	4905.5	4083.9	3729.0	4734.8	3088.7	2767.0	2727.9	2801.3	2931.6	3264.3
B 00920 M	Temp & Perm.	No	100	Fresh	2	1049.0	1093.8	1306.2	1058.6	883.8	956.2	742.4	522.9	586.2	657.9	802.6	940.2	309.8	360.6	482.9	377.5	298.2	325.8	187.5	192.9	221.7	308.7	311.0	396.8	1917.1	2355.2	2651.6	2207.5	2015.7	2559.4	1669.6	1495.7	1474.6	1514.2	1584.6	1764.5
B 00950 L	Temp. Only	Yes	5,847	Slightly Brackish	1.3	681.8	710.9	849.1	688.1	574.5	621.5	482.6	339.9	381.1	427.6	521.7	611.1	201.3	234.4	313.9	245.4	193.9	211.7	121.9	125.4	144.1	200.7	202.2	257.9	1246.1	1530.9	1723.6	1434.9	1310.2	1663.6	1085.2	972.2	958.5	984.3	1030.0	1146.9
B 01000 L	Temp & Perm.	Yes	5,847	Slightly Brackish	6.1	3199.3	3336.0	3984.0	3228.6	2695.7	2916.3	2264.3	1594.8	1788.0	2006.7	2447.8	2867.5	944.8	1099.8	1473.0	1151.3	909.6	993.6	571.9	588.3	676.2	941.6	948.7	1210.2	5847.2	7183.4	8087.5	6732.8	6147.8	7806.0	5092.2	4561.8	4497.4	4618.4	4833.2	5381.7
B 01120 L	Temp & Perm.	Yes	3,726	Slightly Brackish	0.6	314.7	328.1	391.9	317.6	265.2	286.8	222.7	156.9	175.9	197.4	240.8	282.0	92.9	108.2	144.9	113.2	89.5	97.7	56.3	57.9	66.5	92.6	93.3	119.0	575.1	706.6	795.5	662.2	604.7	767.8	500.9	448.7	442.4	454.3	475.4	529.3
B 01550 L	Temp. Only	No	100	Fresh	8.4	4405.6	4593.8	5486.2	4446.0	3712.1	4015.9	3118.1	2196.1	2462.2	2763.3	3370.8	3948.7	1301.0	1514.4	2028.4	1585.4	1252.6	1368.2	787.6	810.2	931.1	1296.7	1306.4	1666.6	8051.9	9891.8	11136.9	9271.4	8465.9	10749.3	7012.2	6281.9	6193.2	6359.8	6655.5	7410.8
B 02460 L	Temp & Perm.	Yes	3,250	Slightly Brackish	13.9	7290.3	7601.6	9078.4	7357.0	6142.7	6645.3	5159.7	3634.0	4074.4	4572.5	5577.8	6534.1	2152.8	2506.0	3356.5	2623.4	2072.8	2264.0	1303.3	1340.6	1540.8	2145.7	2161.7	2757.8	13324.0	16368.6	18429.0	15342.0	14009.0	17787.6	11603.5	10395.0	10248.2	10524.0	11013.2	12263.1
B 02520 L	Temp & Perm.	No	100	Fresh	1.4	734.3	765.6	914.4	741.0	618.7	669.3	519.7	366.0	410.4	460.5	561.8	658.1	216.8	252.4	338.1	264.2	208.8	228.0	131.3	135.0	155.2	216.1	217.7	277.8	1342.0	1648.6	1856.2	1545.2	1411.0	1791.6	1168.7	1047.0	1032.2	1060.0	1109.2	1235.1
B 02700 M	Temp. Only	No	100	Fresh	0.9	472.0	492.2	587.8	476.4	397.7	430.3	334.1	235.3	263.8	296.1	361.2	423.1	139.4	162.3	217.3	169.9	134.2	146.6	84.4	86.8	99.8	138.9	140.0	178.6	862.7	1059.8	1193.2	993.4	907.1	1151.7	751.3	673.1	663.6	681.4	713.1	794.0
B 02700 R	Temp & Perm.	No	100	Fresh	2	1049.0	1093.8	1306.2	1058.6	883.8	956.2	742.4	522.9	586.2	657.9	802.6	940.2	309.8	360.6	482.9	377.5	298.2	325.8	187.5	192.9	221.7	308.7	311.0	396.8	1917.1	2355.2	2651.6	2207.5	2015.7	2559.4	1669.6	1495.7	1474.6	1514.2	1584.6	1764.5
B 03350 L	Temp. Only	Yes	5,921	Slightly Brackish	1.4	734.3	765.6	914.4	741.0	618.7	669.3	519.7	366.0	410.4	460.5	561.8	658.1	216.8	252.4	338.1	264.2	208.8	228.0	131.3	135.0	155.2	216.1	217.7	277.8	1342.0	1648.6	1856.2	1545.2	1411.0	1791.6	1168.7	1047.0	1032.2	1060.0	1109.2	1235.1
B 03480 R	Temp. Only	Yes	13,041	Brackish	3.2	1678.3	1750.0	2090.0	1693.7	1414.1	1529.9	1187.8	836.6	938.0	1052.7	1284.1	1504.3	495.6	576.9	772.7	604.0	477.2	521.2	300.0	308.6	354.7	494.0	497.7	634.9	3067.4	3768.3	4242.6	3532.0	3225.1	4095.0	2671.3	2393.1	2359.3	2422.8	2535.4	2823.2
B 03750 L	Temp & Perm.	Yes	11,643	Brackish	1.1	576.9	601.6	718.4	582.2	486.1	525.9	408.3	287.6	322.4	361.9	441.4	517.1	170.4	198.3	265.6	207.6	164.0	179.2	103.1	106.1	121.9	169.8	171.1	218.2	1054.4	1295.4	1458.4	1214.1	1108.6	1407.6	918.3	822.6	811.0	832.8	871.6	970.5
B 03800 M	Temp & Perm.	Yes	2,237	Slightly Brackish	9.3	4877.7	5086.0	6074.0	4922.3	4109.9	4446.1	3452.2	2431.4	2726.0	3059.3	3731.9	4371.7	1440.4	1676.7	2245.7	1755.2	1386.8	1514.8	872.0	897.0	1030.9	1435.6	1446.3	1845.1	8914.6	10951.7	12330.2	10264.8	9372.9	11901.0	7763.5	6954.9	6856.7	7041.2	7368.6	8204.8
B 04300 L	Temp. Only	Yes	15,543	Saline	2.1	1101.4	1148.4	1371.6	1111.5	928.0	1004.0	779.5	549.0	615.6	690.8	842.7	987.2	325.2	378.6	507.1	396.3	313.2	342.0	196.9	202.5	232.8	324.2	326.6	416.6	2013.0	2473.0	2784.2	2317.9	2116.5	2687.3	1753.0	1570.5	1548.3	1590.0	1663.9	1852.7
South of Hunter							30839.4	32156.5	38403.5	31121.7	25984.9	28111.1	21826.6	15372.7	17235.5	19342.8	23595.3	27640.7	9106.9	10600.9	14198.6	11097.7	8768.3	9577.3	5513.1	5671.1	6517.9	9076.8	9144.6	11665.9	56363.3	69242.9	77958.5	64900.1	59261.0	75245.2	49085.3	43973.0	43352.1	44518.7	46588.4	51875.7
Fresh							10384.7	10828.2	12931.8	10479.7	8750.0	9466.0	7349.8	5176.5	5803.8	6513.4	7945.3	9307.6	3066.6	3569.7	4781.1	3737.0	2952.6	3225.0	1856.4	1909.7	2194.8	3056.5	3079.3	3928.3	18979.5	23316.5	26251.3	21854.1	19955.2	25337.7	16528.7	14807.2	14598.1	14991.0	15687.9	17468.4
Slightly Brackish							17098.0	17828.3	21291.7	17254.5	14406.6	15585.4	12101.1	8522.9	9555.7	10724.1	13081.7	15324.6	5049.1	5877.4	7872.0	6152.8	4861.3	5309.9	3056.6	3144.2	3613.6	5032.4	5070.0	6467.8	31249.1	38389.8	43221.9	35982.1	32855.6	41717.6	27214.0	24379.6	24035.3	24682.1	25829.6	28761.0
Brackish							2255.3	2351.6	2808.4	2275.9	1900.3	2055.7	1596.2	1124.2	1260.4	1414.5	1725.5	2021.3	666.0	775.2	1038.3	811.6	641.2	700.4	403.2	414.7	476.6	663.8	668.7	853.1	4121.8	5063.7	5701.0	4746.1	4333.7	5502.6	3589.6	3215.7	3170.3	3255.6	3407.0	3793.6
Saline							1101.4	1148.4	1371.6	1111.5	928.0	1004.0	779.5	549.0	615.6	690.8	842.7	987.2	325.2	378.6	507.1	396.3	313.2	342.0	196.9	202.5	232.8	324.2	326.6	416.6	2013.0	2473.0	2784.2	2317.9	2116.5	2687.3	1753.0	1570.5	1548.3	1590.0	1663.9	1852.7
B 07000 L	Temp. Only	No	100	Fresh	5.2	2727.3	2843.8	3396.2	2752.3	2298.0	2486.0	1930.2	1359.5	1524.2	1710.6	2086.7	2444.4	805.4	937.5	1255.7	981.4	775.4	847.0	487.6	501.5	576.4	802.7	808.7	1031.7	4984.5	6123.5	6894.3	5739.5	5240.8	6654.3	4340.9	3888.8	3833.9	3937.0	4120.1	4587.6
B 07300 R	Temp & Perm.	Yes	158	Fresh	2	1049.0	1093.8	1306.2	1058.6	883.8	956.2	742.4	522.9	586.2	657.9	802.6	940.2	309.8	360.6	482.9	377.5	298.2	325.8	187.5	192.9	221.7	308.7	311.0	396.8	1917.1	2355.2	2651.6	2207.5	2015.7	2559.4	1669.6	1495.7	1474.6	1514.2	1584.6	1764.5
B 07450b R OP Rd	Temp. Only	Yes	203	Fresh	1	524.5	546.9	653.1	529.3	441.9	478.1	371.2	261.4	293.1	329.0	401.3	470.1	154.9	180.3	241.5	188.7	149.1	162.9	93.8	96.4	110.8	154.4	155.5	198.4	958.6	1177.6	1325.8	1103.7	1007.8	1279.7	834.8	747.8	737.3	757.1	792.3	882.2
B 07500 L	Temp & Perm.	Yes	346	Fresh	1.8	944.1	984.4	1175.6	952.7	795.5	860.5	668.2	470.6	527.6	592.1	722.3	846.1	278.8	324.5	434.6	339.7	268.4	293.2	168.8	173.6	199.5	277.9	279.9	357.1	1725.4	2119.7	2386.5	1986.7	1814.1	2303.4	1502.6	1346.1	1327.1	1362.8	1426.2	1588.0
B 07800 R	Temp & Perm.	Yes	292	Fresh	0.6	314.7	328.1	391.9	317.6	265.2	286.8	222.7	156.9	175.9	197.4	240.8	282.0	92.9	108.2	144.9	113.2	89.5	97.7	56.3	57.9	66.5	92.6	93.3	119.0	575.1	706.6	795.5	662.2	604.7	767.8	500.9	448.7	442.4	454.3	475.4	529.3
B 07900 R OP Rd	Temp. Only	No	100	Fresh	1.5	786.7	820.3	979.7	793.9	662.9	717.1	556.8	392.2	439.7	493.4	601.9	705.1	232.3	270.4	362.2	283.1	223.7	244.3	140.6	144.7	166.3	231.6	233.3	297.6	1437.8	1766.4	1988.7	1655.6	1511.8	1919.5	1252.2	1121.8	1105.9	1135.7	1188.5	1323.4
B 08000 L	Temp & Perm.	Yes	623	Fresh	2.8	1468.5	1531.3	1828.7	1482.0	1237.4	1338.6	1039.4	732.0	820.7	921.1	1123.6	1316.2	433.7	504.8	676.1	528.5	417.5	456.1	262.5	270.1	310.4	432.2	435.5	555.5	2684.0	3297.3	3712.3	3090.5	2822.0	3583.1	2337.4	2094.0	2064.4	2119.9	2218.5	2470.3
B 08150 L	Temp & Perm.	Yes	652	Fresh	2.3	1206.3	1257.8	1502.2	1217.3	1016.4	1099.6	853.8	601.3	674.2	756.6	922.9	1081.2	356.2	414.7	555.4	434.1	343.0	374.6	215.6	221.8	255.0	355.0	357.7	456.3	2204.7	2708.5	3049.4	2538.6	2318.0	2943.3	1920.0	1720.0	1695.7	1741.4	1822.3	2029.2
B 08360 R	Temp. Only	Yes	802	Fresh	0.9	472.0	492.2	587.8	476.4	397.7	430.3	334.1	235.3	263.8	296.1	361.2	423.1	139.4	162.3	217.3	169.9	134.2	146.6	84.4	86.8	99.8	138.9	140.0	178.6	862.7	1059.8	1193.2	993.4	907.1	1151.7	751.3	673.1	663.6	681.4	713.1	794.0
B 09120 M	Temp & Perm.	Yes	8,832	Brackish	1.1	576.9	601.6	718.4	582.2	486.1	525.9	408.3	287.6	322.4	361.9	441.4	517.1	170.4	198.3	265.6	207.6	164.0	179.2	103.1	106.1	121.9	169.8	171.1	218.2	1054.4	1295.4	1458.4	1214.1	1108.6	1407.6	918.3	822.6	811.0	832.8	871.6	970.5
B 09160 M	Temp & Perm.	No	100	Fresh	0.7	367.1	382.8	457.2	370.5	309.3	334.7	259.8	183.0	205.2	230.3	280.9	329.1	108.4	126.2	169.0	132.1	104.4	114.0	65.6	67.5	77.6	108.1	108.9	138.9	671.0	824.3	928.1	772.6	705.5	895.8	584.3	523.5	516.1	530.0	554.6	617.6
B 09360 L	Temp & Perm.	Yes	317	Fresh	1.5	786.7	820.3	979.7	793.9	662.9	717.1	556.8	392.2	439.7	493.4	601.9	705.1	232.3	270.4	362.2	283.1	223.7	244.3	140.6	144.7	166.3	231.6	233.3	297.6	1437.8	1766.4	1988.7	1655.6	1511.8	1919.5	1252.2	1121.8	1105.9	1135.7	1188.5	1323.4
B 09440 L	Temp & Perm.	Yes	336	Fresh	3.1	1625.9	1695.3	2024.7	1640.8	1370.0	1482.0	1150.7	810.5	908.7	1019.8	1244.0	1457.2	480.1	558.9	748.6	585.1	462.3	504.9	290.7	299.0	343.6	478.5	482.1	615.0	2971.5	3650.6	4110.1	3421.6	3124.3	3967.0	2587.8	2318.3	2285.6	2347.1	2456.2	2734.9
B 10350 R	Temp & Perm.	No	100	Fresh	1.1	576.9	601.6	718.4	582.2	486.1	525.9	408.3	287.6	322.4	361.9	441.4	517.1	170.4	198.3	265.6	207.6	164.0	179.2	103.1	106.1	121.9	169.8	171.1	218.2	1054.4	1295.4	1458.4	1214.1	1108.6	1407.6	918.3	822.6	811.0	832.8	871.6	970.5
B 10400 R	Temp & Perm.	No	100	Fresh	1.4	734.3	765.6	914.4	741.0	618.7	669.3	519.7	366.0	410.4	460.5	561.8	658.1	216.8	252.4	338.1	264.2	208.8	228.0	131.3	135.0	155.2	216.1	217.7	277.8	1342.0	1648.6	1856.2	1545.2	1411.0	1791.6	1168.7	1047.0	1032.2	1060.0	1109.2	1235.1
B 11000 R	Temp. Only	No	100	Fresh	1.2	629.4	656.3	783.7	635.1	530.3	573.7	445.4	313.7	351.7	394.8	481.5	564.1	185.9	216.3	289.8	226.5	178.9	195.5	112.5	115.7	133.0	185.2	186.6	238.1	1150.3	1413.1	1591.0	1324.5	1209.4	1535.6	1001.7	897.4	884.7	908.5	950.8	1058.7
B 11500 R	Temp. Only	No	100	Fresh	2.3	1206.3	1257.8	1502.2	1217.3	1016.4	1099.6	853.8	601.3	674.2	756.6	922.9	1081.2	356.2	414.7	555.4	434.1	343.0	374.6	215.6	221.8	255.0	355.0	357.7	456.3	2204.7	2708.5	3049.4	2538.6	2318.0	2943.3	1920.0	1720.0	1695.7	1741.4	1822.3	2029.2
B 11550 L	Temp. Only	Yes	230	Fresh	1.1	576.9	601.6	718.4	582.2	486.1	525.9	408.3	287.6	322.4	361.9	441.4	517.1	170.4	198.3	265.6	207.6	164.0	179.2	103.1	106.1	121.9	169.8	171.1	218.2	1054.4	1295.4	1458.4	1214.1	1108.6	1407.6	918.3	822.6	811.0	832.8	871.6	970.5
B 11900 R	Temp & Perm.	No	100	Fresh	1.7	891.6	929.7	1110.3	899.8	751.3	812.7	631.0	444.4	498.3	559.2	682.2	799.1	263.3	306.5	410.5	320.9	253.5	276.9	159.4	164.0	188.4	262.4	264.4	337.3	1629.6	2001.9	2253.9	1876.4	1713.3	2175.5	1419.1	1271.3	1253.4	1287.1	1346.9	1499.8
B 11950 R	Temp. Only	Yes	125	Fresh	1.3	681.8	710.9	849.1	688.1	574.5	621.5	482.6	339.9	381.1	427.6	521.7	611.1	201.3	234.4	313.9	245.4	193.9	211.7	121.9	125.4	144.1	200.7	202.2	257.9	1246.1	1530.9	1723.6	1434.9	1310.2	1663.6	1085.2	972.2	958.5	984.3	1030.0	1146.9
B 12460 R	Temp & Perm.	Yes	222	Fresh	4.5	2360.2	2461.0	2939.0	2381.8	1988.6	2151.4	1670.4	1176.5	1319.0	1480.3	1805.8	2115.4	697.0	811.3	1086.6	849.3	671.0	733.0	421.9	434.0	498.8	694.7	699.8	892.8	4313.5	5299.2	5966.2	4966.8	4535.3	5758.6	3756.5	3365.3	3317.8	3407.0	3565.4	3970.1
B 12650 R	Temp & Perm.	Yes	273	Fresh	1.5	786.7	820.3	979.7	793.9	662.9	717.1	556.8	392.2	439.7	493.4	601.9	705.1	232.3	270.4	362.2	283.1	223.7	244.3	140.6	144.7	166.3	231.6	233.3	297.6	1437.8	1766.4	1988.7	1655.6	1511.8	1919.5	1252.2	1121.8	1105.9	1135.7	1188.5	1323.4
B 13450 L	Temp & Perm.	Yes	206	Fresh	1.2	629.4	656.3	783.7	635.1	530.3	573.7	445.4	313.7	351.7	394.8	481.5	564.1	185.9	216.3	289.8	226.5	178.9	195.5	112.5	115.7	133.0	185.2	186.6	238.1	1150.3	1413.1	1591.0	1324.5	1209.4	1535.6	1001.7	897.4	884.7	908.5	950.8	1058.7
B 13850 L	Temp & Perm.	Yes	51	Fresh	0.7	367.1	382.8	457.2	370.5	309.3	334.7	259.8	183.0	205.2	230.3	280.9	329.1	108.4	126.2	169.0	132.1	104.4	114.0	65.6	67.5	77.6	108.1	108.9	138.9	671.0	824.3	928.1	772.6	705.5	895.8	584.3	523.5	516.1	530.0	554.6	617.6
B 13900 L	Temp & Perm.	Yes	54	Fresh	1.1	576.9	601.6	718.4	582.2	486.1	525.9	408.3	287.6	322.4	361.9	441.4	517.1	170.4	198.3	265.6	207.6	164.0	179.2	103.1	106.1	121.9	169.8	171.1	218.2	1054.4	1295.4	1458.4	1214.1	1108.6	1407.6	918.3	822.6	811.0	832.8	871.6	970.5
B 14160 M	Temp & Perm.	Yes	53	Fresh	2.4	1258.8	1312.5	1567.5	1270.3	1060.6	1147.4	890.9	627.5	703.5	789.5	963.1	1128.2	371.7	432.7	579.5	453.0	357.9	390.9	225.0	231.5	266.0	370.5	373.2	476.2	2300.5	2826.2	3182.0	2649.0	2418.8	3071.2	2003.5	1794.8	1769.5	1817.1	1901.6	2117.4
B 14400 M	Temp & Perm.	Yes	185	Fresh	2.5	1311.2	1367.2	1632.8	1323.2	1104.8	1195.2	928.0	653.6	732.8	822.4	1003.2	1175.2	387.2	450.7	603.7	471.8	372.8	407.2	234.4	241.1	277.1	385.9	388.8	496.0	2396.4	2944.0	3314.6	2759.4	2519.6	3199.2	2087.0	1869.6	1843.2	1892.8	1980.8	2205.6
B 14450 M	Temp & Perm.	No	100	Fresh	2.4	1258.8	1312.5	1567.5	1270.3	1060.6	1147.4	890.9	627.5	703.5	789.5	963.1	1128.2	371.7	432.7	579.5	453.0	357.9	390.9	225.0	231.5	266.0	370.5	373.2	476.2	2300.5	2826.2	3182.0	2649.0	2418.8	3071.2	2003.5	1794.8	1769.5	1817.1	1901.6	2117.4
B M 03340	Temp & Perm.	No	100	Fresh	1.35	708.0	738.3	881.7	714.5	596.6	645.4	501.1	352.9	395.7	444.1	541.7	634.6	209.1	243.4	326.0	254.8	201.3	219.9	126.6	130.2	149.6	208.4	210.0	267.8	1294.1	1589.8	1789.9	1490.1	1360.6	1727.6	1127.0	1009.6	995.3	1022.1	1069.6	1191.0
B M 08980	Temp & Perm.	No	100	Fresh	8.9	4667.9	4867.2	5812.8	4710.6	3933.1	4254.9	3303.7	2326.8	2608.8	2927.7	3571.4	4183.7	1378.4	1604.6	2149.1	1679.8	1327.2	1449.6	834.5	858.4	986.5	1373.9	1384.1	1765.8	8531.2	10480.6	11799.8	9823.3	8969.8	11389.2	7429.6	6655.8	6561.8	6738.4	7051.6	7851.9
North of Hunter							32072.0	33441.7	39938.3	32365.5	27023.4	29234.6	22698.9	15987.1	17924.3	20115.9	24538.3	28745.4	9470.9	11024.6	14766.0	11541.2	9118.7	9960.1	5733.4	5897.8	6778.4	9439.6	9510.0	12132.2	58615.9	72010.2	81074.1	67493.9	61629.4	78252.4	51047.0	45730.4	45084.7	46297.9	48450.4	53949.0
Fresh							31495.0	32840.1	39219.9	31783.3	26537.3	28708.7	22290.6	15699.5	17601.9	19754.0	24096.9	28228.3	9300.5	10826.3	14500.4	11333.6	8954.7	9780.9	5630.3	5791.7	6656.4	9269.8	9339.0	11913.9	57561.5	70714.9	79615.7	66279.8	60520.8	76844.8	50128.8	44907.8	44273.7	45465.1	47578.8	52978.5
Slightly Brackish							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brackish							576.9	601.6	718.4	582.2	486.1	525.9	408.3	287.6	322.4	361.9	441.4	517.1	170.4	198.3	265.6	207.6	164.0	179.2	103.1	106.1	121.9	169.8	171.1	218.2	1054.4	1295.4	1458.4	1214.1	1108.6	1407.6	918.3	822.6	811.0	832.8	871.6	970.5
Saline							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Location		Start Date	Earthworks		Pavement layers (select and UZF)			Dust supression			Concrete batching for pavements			Curing of pavements			Concrete batching for bridges			Curing of bridges			Landscaping			Potable water at ancillary sites	
			Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start	Approx Duration (months)	Water usage (ML)
SOUTH OF HUNTER RIVER																											
Black Hill Interchange																											
FILL 11 NORTH	MCBS CH0 - CH400	Jul-25	9	1.665	Oct-25	6	0.272	Jul-25	9	0.529				Dec-25	4.7	0.002							Dec-26	2	0.444			
FILL 11 SOUTH	MCBS CH400 - CH1400	Jul-25	9	1.145	Oct-25	6	0.708	Jul-25	9	1.277				Dec-25	4.7	0.003							Dec-26	2	1.248			
FILL 1	MC10 CH0 - 1040	Jul-25	9	0.087	Oct-25	6	2.080	Jul-25	9	0.994				Dec-25	4.7	0.001							Dec-26	2	0.132			
Bridge 1	MC10 CH1030																			Jan-26	0.2	0.011						
AS1	Ancillary site compound AS1				Nov-24	4	0.768	Mar-25	31	0.283																Oct-24	36	1.764
AS1	Access track				Nov-24	4	0.139	Mar-25	31	0.410																		
AS2	Ancillary site compound AS2				Nov-24	4	1.296	Mar-25	31	0.954																Oct-24	36	1.764
AS2	Access track				Nov-24	4	0.518	Mar-25	31	1.526																		
Sub-total				2.897			5.782			5.973			0.000			0.007			0.000			0.011			1.824			3.528
Main Alignment - Black Hill to Tarro																											
Cut 1	MC10 CH1040 - CH2310	Aug-25	3	0.014	Jan-27	2	1.992	Aug-25	17	10.062				Feb-27	1.1	0.002							Dec-26	5	5.457			
FILL 2A	MC10 CH2310 - CH2600	Aug-25	3	0.644	Jan-27	2	0.248	Aug-25	17	0.916													Dec-26	5	0.408			
Bridge 2	MC10 CH2600																			Jan-26	0.2	0.022						
FILL 2B	MC10 CH2700 - CH3260	Aug-25	3	1.125	Jan-27	2	0.600	Aug-25	17	1.965													Dec-26	5	0.807			
FILL 3A	MC10 CH3260 - CH3500	Aug-25	3	1.164	Jan-27	2	0.248	Aug-25	17	1.015													Dec-26	5	0.492			
Bridge 1	Batch plant location - AS3																Nov-25	2	0.365									
Bridge 2	Batch plant location - AS3																Apr-25	9	0.741									
Bridge 3	Batch plant location - AS3																Jun-26	3	0.353									
Bridge 4	Batch plant location - AS3																Jun-26	3	0.308									
Bridge 5	Batch plant location - AS3																Dec-24	25	26.772									
FILL 11 NORTH	Batch plant location - AS3										Oct-25	6	0.156															
FILL 11 SOUTH	Batch plant location - AS3										Oct-25	6	0.272															
FILL 1	Batch plant location - AS3										Oct-25	6	0.106															
Cut 1	Batch plant location - AS3										Jan-27	2	2.877															
FILL 2A	Batch plant location - AS3																											
FILL 2B	Batch plant location - AS3																											
FILL 3A	Batch plant location - AS3																											
FILL 12	MCES CH0 - CH1168										Aug-26	10	0.222															
FILL 14B	MCEW CH400 - CH800, MCEZ										Aug-26	2	1.329															
FILL 3C	MCA1 CH0 - CH654										Aug-26	10	0.267															
Bridge 3	MC10 CH3500																			Sep-26	0.2	0.007						
Bridge 4	MC10 CH3600																			Sep-26	0.2	0.007						
AS3	Ancillary site compound AS3				Nov-24	4	3.216	Mar-25	31	1.183																Oct-24	36	6.111
AS3	Access track				Nov-24	4	0.634	Mar-25	31	1.865																		
Sub-total				2.946			6.938			17.006			5.230			0.002			28.540			0.036			7.164			6.111
Tarro Interchange																											
FILL 3B	MC10 CH3500 - CH4360	Nov-25	10	4.713	Jan-27	2	0.912	Nov-25	14	2.890													Dec-26	5	1.644			
FILL 12	MCES CH0 - CH1168	Nov-25	17	5.009	Aug-26	10	0.328	Nov-25	8	1.539				Nov-26	7.1	0.003							Dec-26	5	2.061			
FILL 13	MCEN CH1600 - CH2275	Nov-25	7	3.236	Aug-26	2	0.192	Nov-25	8	0.683													Dec-26	5	0.855			
FILL 14B	MCEW CH400 - CH800, MCEZ	Nov-25	17	1.091	Aug-26	10	0.440	Nov-25	8	0.767				Oct-26	0.8	0.017							Dec-26	5	0.681			
FILL 3C	MCA1 CH0 - CH654	Nov-25	7	0.084	Aug-26	2	0.988	Nov-25	8	0.488				Oct-26	8.1	0.003							Dec-26	5	0.312			
AS5	Ancillary site compound AS5				Nov-24	4	3.258	Mar-25	31	0.830																Oct-24	36	1.764
Sub-total				14.132			6.118			7.197			0.000			0.023			0.000			0.000			5.553			1.764
New England Highway																											
FILL 14A	MCEE - New England Highway EB and WB	Nov-25	16	0.324	Aug-26	8	3.444	Nov-25	8	3.071			0.000												1.608			
AS4	Ancillary site compound AS4							Mar-25	31	0.088																Oct-24	36	0.353
Sub-total				0.324			3.444			3.159			0.000			0.000			0.000			0.000			1.608			0.353
Floodplain - south of Hunter River																											
Access track	AS7 to AS9				Nov-24	4	4.943	Mar-25	31	2.931																		
Bridge 5	Main viaduct (from MC10 CH4350)																			Jan-27	0.2	0.488						
AS6	Ancillary site compound AS6				Nov-24	4	2.456	Mar-25	31	0.813																Oct-24	36	1.764
AS6	Access track				Nov-24	4	0.100	Mar-25	31	0.141																		
AS7	Ancillary site compound AS7				Nov-24	4	4.823	Mar-25	31	1.201																Oct-24	36	1.764
AS7	Access track				Nov-24	4	0.060	Mar-25	31	0.085																		
AS8	Ancillary site compound AS8				Nov-24	4	1.700	Mar-25	31	0.300																Oct-24	36	1.764
AS8	Access track				Nov-24	4	0.030	Mar-25	31	0.042																		
AS9	Ancillary site compound AS9				Nov-24	4	7.236	Mar-25	31	1.590																Oct-24	36	1.764
AS9	Access track				Nov-24	4	1.400	Mar-25	31	1.978																		
Sub-total				0.000			22.749			9.082			0.000			0.000			0.000			0.488			0.000			7.056
TOTAL - SOUTH OF HUNTER RIVER				20.298			45.030			42.417			5.230			0.031			28.540			0.536			16.149			18.812

Location		Start Date	Earthworks		Pavement layers (select and UZF)			Dust supression		Concrete batching for pavements			Curing of pavements		Concrete batching for bridges			Curing of bridges			Landscaping			Start	Potable water at ancillary sites	
			Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)	Start date	Approx Duration (months)	Water usage (ML)		Approx Duration (months)	Water usage (ML)
NORTH OF HUNTER RIVER																											
Tomago / Heatherbrae Interchange													0.000														
FILL 4	MC10 CH6900 to CH7370	Jul-25	4	0.384	Dec-25	2	0.464	Jul-25	5	0.337				Jan-26	1.1	0.004							Mar-27	4	0.252			
FILL 10A	MCD0 CH0 - CH700	Jul-25	4	1.487	Dec-25	2	0.160	Jul-25	5	0.313				Jan-26	1.1	0.002							Mar-27	4	0.573			
FILL 10B	MCF0 CH0 - CH600	Jul-25	4	2.003	Dec-25	2	0.296	Jul-25	5	0.488				Jan-26	1.1	0.001							Mar-27	4	0.831			
FILL 18	MC60 CH0 - 200	Jul-25	4	0.021	Dec-25	2	0.116	Jul-25	5	0.028			0.000										Mar-27	4	-0.084			
FILL 9A	MCC0 CH450 to CH1050	Jul-25	4	5.828	Dec-25	2	0.192	Jul-25	5	0.476			0.000										Mar-27	4	0.933			
Bridge 6	MC10 CH7150																			Jan-27	0.2	0.009						
Bridge 7	MC10 CH7350																			Feb-26	0.2	0.005						
CUT 2	MC10 CH7370 to CH7680 MCE0 CH0 to CH850 MC20 CH7360 to CH7880	May-26	3	0.176	Oct-26	1	0.688	May-26	5	0.765				Nov-26	0.6	0.003							Mar-27	4	0.603			
CUT 6	MCC0 CH0 to CH450	May-26	3	0.016	Oct-26	1	0.104	May-26	5	0.143				Nov-26	0.6	0.002							Mar-27	4	0.267			
FILL 10C / FILL 10D	MCG0 CH580 - CH2650 MCH0 CH00 - CH350 MCE0 CH1250 - CH2300	Dec-24	6	4.320	Sep-25	2	1.584	Dec-24	9	3.215				Oct-25	1.3	0.010							Mar-27	4	2.760			
FILL 5A	MC10 CH7900 - CH8160 MCF0 CH0 - CH300	Dec-24	6	2.504	Sep-25	2	0.448	Dec-24	9	0.818				Oct-25	1.3	0.041							Mar-27	4	0.648			
FILL 5B	MC10 CH8160 - CH8300	Dec-24	6	3.236	Sep-25	2	0.128	Dec-24	9	0.250			0.000										Mar-27	4	0.210			
Bridge 8	MC10 CH8350																			Jul-25	0.2	0.033						
FILL 5C	MC10 CH8430 - CH8660 MC10 CH8660 - CH9180	Dec-24	6	4.764	Sep-25	2	0.240	Dec-24	9	0.423			0.000										Mar-27	4	0.327			
FILL 5D	MC80 CH0 - CH280 MC80 CH280 - CH560	Dec-24	6	4.120	Sep-25	2	0.776	Dec-24	9	1.228				Oct-25	1.3	0.001							Mar-27	4	0.843			
FILL 5E	MC10 CH9180 - CH9630 HRBG Access	Dec-25	5	4.628	Aug-26	2	0.548	Dec-25	9	0.871				Sep-26	1.0	0.000							Mar-27	4	0.720			
Bridge 9	MC10 CH9250																			Apr-26	0.2	0.011						
FILL 10E	MCG0 CH2650 - CH2810 MCE0 CH2300 - CH2550	Dec-24	6	0.408	Sep-25	2	0.000	Dec-24	9	0.232				Oct-25	1.3	0.010							Mar-27	4	0.201			
FILL 19	MCE0 CH850 - CH1070 MC90 CH200 - CH1260	Dec-25	5	0.380	Aug-26	2	0.360	Dec-25	9	1.273				Sep-26	1.0	0.001							Mar-27	4	1.107			
Access track	River to AS10/AS11				Nov-24	4	1.895	Mar-25	31	2.678																		
AS10	Ancillary site compound AS10				Nov-24	4	2.736	Mar-25	31	1.007																Oct-24	36	1.764
AS10	Access track				Nov-24	4	0.110	Mar-25	31	0.325																		
AS11	Ancillary site compound AS11				Nov-24	4	1.680	Mar-25	31	0.618																Oct-24	36	1.764
AS11	Access track				Nov-24	4	0.096	Mar-25	31	0.283																		
AS12	Ancillary site compound AS12				Nov-24	4	1.296	Mar-25	31	0.477																Oct-24	36	1.764
AS12	Access track				Nov-24	4	0.048	Mar-25	31	0.141																		
AS13	Ancillary site compound AS13				Nov-24	4	0.624	Mar-25	31	0.230																Oct-24	36	1.764
Sub-total				34.274			14.589			16.618			0.000			0.076			0.000			0.057			10.191			7.056
Main Alignment - Tomago interchange to Masonite Road																												
FILL 6	MC10 CH9630 - CH12150	Aug-26	5	10.028	Feb-27	1	2.616	Aug-26	6	2.522				Jun-26	0.7	0.066							Mar-27	4	2.799			
CUT 3	MC10 CH12150 - CH12380	Aug-26	5	0.012	Feb-27	1	0.272	Aug-26	6	0.370													Mar-27	4	0.552			
AS14	Ancillary site compound AS14				Nov-24	4	1.392	Mar-25	31	0.512																Oct-24	36	1.764
AS15	Ancillary site compound AS15				Nov-24	4	1.008	Mar-25	31	0.371																Oct-24	36	0.353
AS15	Access track				Nov-24	4	0.240	Mar-25	31	0.707																		
Sub-total				10.040			5.528			4.483			0.000			0.066			0.000			0.000			3.351			2.117
Masonite Road																												
FILL 15 NORTH	MCM1 CH0 - CH400	Jun-26	3	0.456	Jul-26	4	0.152	Jun-26	4	0.275				Aug-26	3.1	0.002							Jul-26	6	0.693			
FILL 15 SOUTH	MCM1 CH0 - CH920	Jun-26	3	4.328	Jul-26	4	0.224	Jun-26	4	0.325				Aug-26	3.1	0.002							Jul-26	6	0.756			
Bridge 10	MC10 CH12400																			Sep-26	0.2	0.008						
Bridge 6	Batch plant location - AS16																Aug-26	5	1.017									
Bridge 7	Batch plant location - AS16																Oct-25	3	0.242									
Bridge 8	Batch plant location - AS16																Jun-25	2	1.882									
Bridge 9	Batch plant location - AS16																Feb-26	2	0.296									
Bridge 10	Batch plant location - AS16																Jul-26	2	0.468									
Bridge 11	Batch plant location - AS16																Jun-25	7	3.499									
Bridge 12	Batch plant location - AS16																Jun-26	2	0.297									
FILL 4	Batch plant location - AS16										Dec-25	2	0.326															
FILL 10A	Batch plant location - AS16										Dec-25	2	0.120															
FILL 10B	Batch plant location - AS16										Dec-25	2	0.070															
CUT 2	Batch plant location - AS16										Oct-26	1	0.261															
CUT 6	Batch plant location - AS16										Oct-26	1	0.193															
FILL 10C / FILL 10D	Batch plant location - AS16										Sep-25	2	0.793															
FILL 5A	Batch plant location - AS16										Sep-25	2	3.296															
FILL 5D	Batch plant location - AS16										Sep-25	2	0.084															
FILL 5E	Batch plant location - AS16										Aug-26	2	0.022															
FILL 10E	Batch plant location - AS16										Sep-25	2	0.820															
FILL 19	Batch plant location - AS16										Aug-26	2	0.119															
FILL 7	Batch plant location - AS16										Apr-26	3	1.953															
FILL 8	Batch plant location - AS16										Oct-26	2	0.570															
FILL 16 EAST	Batch plant location - AS16										Jun-26	1	0.328															
FILL 6	Batch plant location - AS16										Jun-26	1	5.311															
FILL 15 NORTH	Batch plant location - AS16										Jul-26	4	0.149															
FILL 15 SOUTH	Batch plant location - AS16										Jul-26	4	0.175															
AS16	Ancillary site compound AS16				Nov-24	4	6.024	Mar-25	31	2.217																Oct-24	36	6.111
AS16	Access track				Nov-24	4	0.024	Mar-25	31	0.071																		
AS17	Ancillary site compound AS17				Nov-24	4	3.600	Mar-25	31	1.325																Oct-24	36	1.764
AS17	Access track				Nov-24	4	0.206	Mar-25	31	0.608																		
AS18	Ancillary site compound AS18				Nov-24	4	1.536	Mar-25	31	0.565																Oct-24	36	0.353
AS18	Access track				Nov-24	4	0.130	Mar-25	31	0.382																		
AS19	Ancillary site compound AS19				Nov-24	4	4.128	Mar-25	31	1.519																Oct-24	36	1.764
AS19	Access track				Nov-24	4	0.034	Mar-25	31	0.099																		
Sub-total				4.784			16.058			7.384			14.591			0.004			7.701			0.008			1.449			9.992
Main Alignment - Masonite Road to Raymond Terrace Interchange																												
FILL 7	MC10 CH12380 - CH13600	May-25	11	5.248	Apr-26	3	1.288	May-25	11	2.468				May-26	2.0	0.024							Jul-26	3	1.464			
Bridge 11	MC10 CH13600																			Jan-26	0.2	0.064						
Access track	Windeyers Creek				Nov-24	4	1.569	Mar-25	10	0.137																		
Sub-total				5.248			2.857			2.604			0.000			0.024			0.000			0.064			1.464			0.000
Raymond Terrace Interchange																												
FILL 8	MC10 CH13930 - CH14750	Oct-26		1.012	Oct-26	2	1.536	Oct-26	2	0.398				Nov-26	1.1	0.007							Jul-26	6	0.969			
FILL 16 WEST	MCRS CH830 - CH1160	May-26	2	1.620	Jun-26	1	0.160	May-26	2	0.090													Jul-26	6	0.333			
FILL 16 EAST	MCRS C0 - CH750	May-26	2	4.232	Jun-26	1	0.296	May-26	2	0.203				Jun-26	0.7	0.004							Jul-26	6	0.816			
FILL 17	MCRN CH0 - CH550	Sep-26	0	0.008	Sep-26	0	0.116	Sep-26	0	0.006			0.000										Jul-26	6	0.117			
Bridge 12	MC10 CH14200																			Aug-26	0.2	0.006						
AS20	Ancillary site compound AS20				Nov-24	4	0.576	Mar-25	31	0.212																Oct-24	36	0.353
AS20	Access track				Nov-24	4	0.144	Mar-25	31	0.424																		
AS21	Ancillary site compound AS21				Nov-24	4	2.736	Mar-25	31	1.007																Oct-24	36	1.764
AS21	Access track				Nov-24	4	0.072	Mar-25	31	0.212																		
Sub-total				6.872			5.636			2.552			0.000			0.011			0.000			0.006			2.235			2.117
TOTAL - NORTH OF HUNTER RIVER				61.218			44.668			33.641			14.591			0.182			7.701			0.135			18.690			21.281
PROJECT TOTALS				81.516			89.698			76.058			19.821			0.214			36.241			0.671			34.839			40.093

Appendix J DRAINS stormwater discharge modelling results

Table J-1 Existing and proposed changes to catchment areas and impervious percentage

Location	Culvert ID	Receiving waterway	Existing Condition		Proposed Condition			
			Catchment Area (ha)	Impervious Percentage	Catchment Area (ha)	Change in Catchment Area	Impervious Percentage	Change in Impervious Percentage
Black Hill Area	N1160B	Unnamed tributary of Viney Creek	121.8	9.8%	119.3	-2.1%	11.6%	18.7%
Tarro Area	C2520 (EXIST)	Glenrowan Creek	16.7	40%	16.9	1.2%	40%	0%
	C2660 (EXIST)	Glenrowan Creek	10.8	60%	10.8	0%	60%	0%
	Glenrowan bridge	Glenrowan Creek	55.5	26.2%	54.3	-2.2%	34.5%	31.7%
	N3500C	Purgatory Creek	39.8	60.1%	41.1	3.2%	61.9%	2.9%
	Purg Ck culvert	Purgatory Creek	334.6	13.2%	335.8	0.4%	17.1%	29.5%
Tomago Area	N7300C	Drainage line through Coastal Wetland to Hunter River	32.8	11.4%	33.0	0.5%	17.7%	55.1%
	N8200C	Unnamed Tributary of Coastal Wetland	151.7	11.2%	152.2	0.3%	12.6%	12.5%
	N9100C	Hunter River Drain	318.0	10.0%	318.4	0.1%	10.9%	8.9%
	N9380C	Tributary to Hunter River Drain	88.8	22.7%	89.0	0.3%	24.9%	9.7%

Location	Culvert ID	Receiving waterway	Existing Condition		Proposed Condition			
			Catchment Area (ha)	Impervious Percentage	Catchment Area (ha)	Change in Catchment Area	Impervious Percentage	Change in Impervious Percentage
Heatherbrae Area	N11040C	Tomago Sandbeds Catchment	27.6	34.8%	27.6	-0.1%	39.7%	14.2%
	N11520C	Tomago Sandbeds Catchment	32.5	17.4%	32.7	0.5%	21.7%	25.0%
	N11920C	Tomago Sandbeds Catchment	9.1	2.0%	9.2	1.2%	7.7%	286.2%
	N12620C	Windeyers Creek	259.5	13.8%	258.4	-0.4%	15.5%	12.2%
	N13020C	Windeyers Creek	3.7	2.0%	3.7	0.9%	13.6%	577.5%
Raymond Terrace Area	N14390	Drainage line draining to Windeyers Creek	252.5	9.7%	251.4	-0.4%	10.2%	5.7%

Table J-2 Estimated changes to stormwater discharge rates, volumes and velocities (50% AEP event)

Location	Culvert ID	Receiving waterway	Existing condition			Proposed condition			Change (absolute)			Change (relative)		
			Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
Black Hill Area	N1160B	Unnamed tributary of Viney Creek	5.30	34,715	N/A	4.02	29,704	N/A	1.28	-5,011	N/A	-24.2%	-14.4%	N/A
Tarro Area	C2520 (EXIST)	Glenrowan Creek	4.22	4597	3.42	4.26	N/A	3.24	0.04	61	-0.18	0.9%	1.3%	-5.3%
	C2660 (EXIST)	Glenrowan Creek	2.293	N/A	3.24	2.303	N/A	2.43	0.01	N/A	-0.81	0.4%	N/A	-25.0%
	Glenrowan bridge	Glenrowan Creek	9.48	N/A	N/A	10.0	N/A	N/A	0.52	N/A	N/A	5.5%	N/A	N/A
	N3500C	Purgatory Creek	6.24	10,314	0.85	9.50	10,833	0.88	3.26	519	0.03	52.2%	5.0%	3.5%
	Purg Ck culvert (See note below)	Purgatory Creek	17.8	137,778	N/A	19.9	144,977	N/A	2.1	7,199	N/A	11.8%	5.2%	N/A
Tomago Area	N7300C	Drainage line through Coastal Wetland to Hunter River	0.90	14,318	N/A	1.71	15,729	N/A	0.82	1,411	N/A	91.1%	9.9%	N/A
	N8200C	Unnamed Tributary of Coastal Wetland	4.43	57,781	N/A	5.01	61,911	N/A	0.58	4,130	N/A	13.1%	7.1%	N/A
	N9100C	Hunter River Drain	3.92	192,751	N/A	3.98	194,009	N/A	0.06	1,258	N/A	1.5%	0.7%	N/A
	N9380C	Tributary to Hunter River Drain	3.72	24,910	1.23	3.98	26,491	1.62	0.26	1,581	0.39	7.0%	6.3%	31.7%

Location	Culvert ID	Receiving waterway	Existing condition			Proposed condition			Change (absolute)			Change (relative)		
			Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
Heatherbrae Area	N11040C	Tomago Sandbeds Catchment	1.79	6,495	0.79	2.14	7,243	1.88	0.35	748	1.09	19.6%	11.5%	138.0%
	N11520C	Tomago Sandbeds Catchment	1.89	9,094	0.85	2.19	9,618	0.67	0.30	524	-0.18	15.9%	5.8%	-21.2%
	N11920C	Tomago Sandbeds Catchment	0.71	2,122	0.78	0.91	2,249	1.55	0.20	127	0.77	28.8%	6.0%	98.7%
	N12620C	Windeyers Creek	6.45	41,489	0.86	7.58	46,287	1.86	1.13	4,798	1.00	17.5%	11.6%	116.3%
	N13020C	Windeyers Creek	0.14	986	0.44	0.22	1,145	1.10	0.08	159	0.66	59.0%	16.1%	150.0%
Raymond Terrace Area	N14390	Drainage line draining to Windeyers Creek	3.06	111,443	N/A	3.11	107,805	N/A	0.05	-3,638	N/A	1.6%	-3.3%	N/A
								Mean Change	0.69	990	0.31	19%	5%	54%
								Min Change	0.01	-5,011	-0.81	-24%	-14%	-25%
								Max Change	3.26	7,199	1.09	91%	16%	150%

Note: Reported peak flows for “Purg Ck culvert”, the existing railway culvert for Purgatory Creek, are based on modelled catchment flows which do not consider the attenuation and reduction in peak flows due to the large floodplain storage area.

Table J-3 Estimated changes to stormwater discharge rates, volumes and velocities (5% AEP event)

Location	Culvert ID	Receiving waterway	Existing condition			Proposed condition			Change (absolute)			Change (relative)		
			Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
Black Hill Area	N1160B	Unnamed tributary of Viney Creek	9.85	98,198	N/A	8.70	90,099	N/A	-1.15	-8,099	N/A	-11.7%	-8.2%	N/A
Tarro Area	C2520 (EXIST)	Glenrowan Creek	9.515	7636	4	9.72	7728	3.75	0.205	92	-0.25	2.2%	1.2%	-6.3%
	C2660 (EXIST)	Glenrowan Creek	5.618	N/A	2.66	5.698	N/A	2.66	0.08	N/A	0.0	1.4%	N/A	0.0%
	Glenrowan bridge	Glenrowan Creek	13.9	N/A	N/A	15	N/A	N/A	1.1	N/A	N/A	7.9%	N/A	N/A
	N3500C	Purgatory Creek	7.96	20,483	0.89	9.50	22,668	0.97	1.54	2,185	0.08	19.3%	10.7%	9.0%
	Purg Ck culvert (See note below)	Purgatory Creek	29.0	217,129	N/A	31.3	225,236	N/A	2.3	8,110	N/A	7.9%	3.7%	N/A
Tomago Area	N7300C	Drainage line through Coastal Wetland to Hunter River	2.23	23,200	0.77	4.22	25,942	2.07	1.99	2,742	1.30	89.2%	11.8%	168.8%
	N8200C	Unnamed Tributary of Coastal Wetland	11.50	111,086	1.04	13.00	118,192	2.46	1.50	7,106	1.42	13.0%	6.4%	136.5%
	N9100C	Hunter River Drain	10.10	355,852	N/A	10.20	358,033	N/A	0.10	2,181	N/A	1.0%	0.6%	N/A
	N9380C	Tributary to Hunter River Drain	9.10	40,201	0.30	9.40	40,933	0.98	0.30	732	0.68	3.3%	1.8%	226.7%

Location	Culvert ID	Receiving waterway	Existing condition			Proposed condition			Change (absolute)			Change (relative)		
			Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
Heatherbrae Area	N11040C	Tomago Sandbeds Catchment	4.52	14,741	1.03	5.22	15,662	2.26	0.70	921	1.23	15.5%	6.2%	119.4%
	N11520C	Tomago Sandbeds Catchment	4.88	16,738	1.08	5.71	17,868	0.93	0.83	1,130	-0.15	17.0%	6.8%	-13.9%
	N11920C	Tomago Sandbeds Catchment	1.77	4,952	0.99	2.17	5,107	1.88	0.40	155	0.89	22.6%	3.1%	89.9%
	N12620C	Windeyers Creek	15.30	134,334	1.14	18.60	133,825	2.43	3.30	-509	1.29	21.6%	-0.4%	113.2%
	N13020C	Windeyers Creek	0.37	2,073	0.60	0.56	2,328	1.39	0.19	255	0.79	49.9%	12.3%	131.7%
Raymond Terrace Area	N14390	Drainage line draining to Windeyers Creek	8.11	287,761	N/A	7.94	285,871	N/A	-0.17	-1,890	N/A	-2.1%	-0.7%	N/A
								Mean Change	0.83	1,079	0.66	16%	4%	89%
								Min Change	-1.15	-8,099	-0.25	-12%	-8%	-14%
								Max Change	3.30	8,110	1.42	89%	12%	227%

Note: Reported peak flows for “Purg Ck culvert”, the existing railway culvert for Purgatory Creek, are based on modelled catchment flows which do not consider the attenuation and reduction in peak flows due to the large floodplain storage area.

Table J-4 Estimated changes to stormwater discharge rates, volumes and velocities (1% AEP event)

Location	Culvert ID	Receiving waterway	Existing condition			Proposed condition			Change (absolute)			Change (relative)		
			Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
Black Hill Area	N1160B	Unnamed tributary of Viney Creek	13.60	148,735	N/A	11.30	137,375	N/A	-2.30	-11,360	N/A	-16.9%	-7.6%	N/A
Tarro Area	C2520 (EXIST)	Glenrowan Creek	14.66	N/A	4.42	14.83	N/A	4.08	0.17	N/A	-0.34	1.2%	N/A	-7.7%
	C2660 (EXIST)	Glenrowan Creek	7.22	N/A	2.88	7.26	N/A	2.88	0.04	N/A	N/A	0.6%	N/A	0.0%
	Glenrowan bridge	Glenrowan Creek	20.7	N/A	0	22.3	N/A	0	1.6	N/A	N/A	7.7%	N/A	N/A
	N3500C	Purgatory Creek	14.66	N/A	4.42	14.83	N/A	4.08	0.17	N/A	-0.34	1.2%	N/A	-7.7%
	Purg Ck culvert (See note below)	Purgatory Creek	45.3	317,458	N/A	48.0	327,742	N/A	2.7	10,284	N/A	6.0%	3.2%	N/A
Tomago Area	N7300C	Drainage Line Through Coastal Wetland to Hunter River	3.50	35,619	N/A	6.38	38,824	N/A	2.88	3,205	N/A	82.3%	9.0%	N/A
	N8200C	Unnamed Tributary of Coastal Wetland	17.40	135,296	N/A	20.70	146,169	N/A	3.30	10,873	N/A	19.0%	8.0%	N/A
	N9100C	Hunter River Drain	17.10	556,390	N/A	16.80	576,077	N/A	-0.30	19,687	N/A	-1.8%	3.5%	N/A
	N9380C	Tributary to Hunter River Drain	13.90	76,242	0.46	14.70	78,526	1.50	0.80	2,284	1.04	5.8%	3.0%	226.1%

Location	Culvert ID	Receiving waterway	Existing condition			Proposed condition			Change (absolute)			Change (relative)		
			Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)	Flow (m^3/s)	Volume (m^3)	Velocity (m/s)
Heatherbrae Area	N11040C	Tomago Sandbeds Catchment	6.97	19,781	1.15	8.17	20,650	2.48	1.20	869	1.33	17.2%	4.4%	115.7%
	N11520C	Tomago Sandbeds Catchment	7.62	22,673	1.20	8.88	23,893	1.07	1.26	1,220	-0.13	16.5%	5.4%	-10.8%
	N11920C	Tomago Sandbeds Catchment	2.79	6,724	1.10	3.33	6,877	2.06	0.54	153	0.96	19.4%	2.3%	87.3%
	N12620C	Windeyers Creek	23.70	99,891	1.32	28.20	116,382	2.73	4.50	16,491	1.41	19.0%	16.5%	106.8%
	N13020C	Windeyers Creek	0.62	3,632	0.70	0.88	3,910	1.54	0.26	278	0.84	42.4%	7.7%	120.0%
Raymond Terrace Area	N14390	Drainage line draining to Windeyers Creek	13.90	440,528	N/A	13.10	458,150	N/A	-0.80	17,622	N/A	-5.8%	4.0%	N/A
								Mean Change	1.00	5,967	0.60	13%	5%	70%
								Min Change	-2.30	-11,360	-0.34	-17%	-8%	-11%
								Max Change	4.50	19,687	1.41	82%	17%	226%

Note: Reported peak flows for “Purg Ck culvert”, the existing railway culvert for Purgatory Creek, are based on modelled catchment flows which do not consider the attenuation and reduction in peak flows due to the large floodplain storage area.

Appendix K Surface water monitoring program

Surface water monitoring program

A surface water monitoring program will be developed as an environmental management measure to observe any potential changes in surface water quality and geomorphic integrity that may be attributable to the project and inform appropriate management responses, refer further to the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS). As part of the monitoring program additional measures to assess potential changes to surface water hydrology conditions in both receiving waterways and sensitive receptors will be included.

The program will include collection of pre-construction (baseline) data to gain an understanding of existing channel geomorphic integrity and water levels in sensitive wetlands. The pre-construction data will be used for comparison to construction and operational monitoring data to characterise and inform an appropriate response to any potential impacts from the project. A brief outline of each stage of the proposed monitoring program (pre-construction, construction and operational) is provided below and describes the location and frequency of monitoring during these periods.

Streamflow

Waterways across the surface water study area are not currently gauged and existing flow regimes have been inferred through examination of various data sources including climate (rainfall) data, catchment characteristics and site inspections. Potential impacts to receiving waterway flow regimes (**Section 5.2.2** and **Section 5.3.1**) resulting from the project are only expected to be minor and hence collection of streamflow data is not required.

Monitoring of potential changes to surface water flows to sensitive wetlands within the study area are similarly not considered necessary as water levels are generally supported by the shallow groundwater systems. In addition, the typically diffuse nature of surface water contributions makes isolation of changes in surface water inflow directly attributable to the project impractical.

Geomorphic integrity

Rates, volumes and velocity of stormwater discharged by the project are estimated to increase during construction and operation of the project (**Section 5.2.2** and **Section 5.3.1** respectively). Key management measures include development of an erosion and sediment control plan (which will be developed as part of the Construction Soils and Water Management Plan (CSWMP)) and appropriate consideration of erosion, scour and energy dissipation in the project design. It is proposed however to conduct additional monitoring of receiving waterways immediately downstream of project discharge locations to ensure that the existing geomorphic integrity is not adversely impacted by stormwater discharges from the project. Any identified issues attributed to the project will be assessed and actions taken as necessary.

Wetlands

Wetland water level monitoring is not currently considered necessary. However, as outlined in **Section 5.3.8**, wetland areas in local catchments upstream of the project and within the Hunter Region Botanic Gardens may be affected by modified transverse drainage arrangements. In the event that detailed design confirms potential permanent changes to water levels in the wetlands, water level monitoring in the wetland may be required to inform assessment of any potential impacts on wetland health.

Pre-construction (baseline) data

Watercourse geomorphic stability survey will be completed for waterways immediately downstream of project discharge locations (refer to **Figure 5-2**) prior to construction to establish a geomorphological baseline and includes:

- Viney Creek (tributary)
- Purgatory Creek
- Drainage line through coastal wetland to Hunter River
- Unnamed tributary of coastal wetland
- Hunter River Drain
- Tributary to Hunter River Drain
- Diffuse drainage lines that feed into the Tomago Sandbeds Catchment to the south of discharge point N11920C
- Windeyers Creek.

Baseline condition assessment will include (but is not necessarily limited to) existing channel bed and bank stability, integrity of existing riparian vegetation, identification of any existing bed and bank modifications, and identification of any existing stormwater discharge locations both up- and downstream. The survey will consider the waterway for up to 50 metres upstream and 200 metres downstream of the project discharge point location.

Construction phase surface water monitoring

Site inspections during construction will be completed periodically (e.g. monthly) for all discharge locations as well as after significant rainfall events (i.e. greater than 40 millimetres) where sediment control basins have surcharged. These inspections would assess channel geomorphic integrity of waterway channels and waterway banks immediately downstream (up to 200 metres) of project discharge locations.

Operational phase surface water monitoring

Site inspections are proposed at all discharge locations at the same frequency and extent as for the construction phase (monthly and following significant rainfall events that result in overflow of water quality basins) for a minimum of twelve months post completion of construction activities. Additional six-monthly inspections are also proposed over a further period of two years as well as following significant rainfall events.

Appendix L Groundwater monitoring program

Groundwater level monitoring program

A groundwater monitoring program will be implemented to monitor for any potential changes to groundwater level that may be attributable to the project and inform appropriate management responses.

The monitoring program will include the collection of additional baseline water level data to build upon the already established baseline dataset that has been collected for this assessment (refer to **Section 4.4.2** and **Appendix A**). The baseline data will be used for comparison to construction and operational monitoring data to characterise and inform an appropriate response to any impacts from the project. An outline of each stage of the monitoring program (pre-construction, construction and operational) is provided in the following sections. It is noted that groundwater quality components of the groundwater monitoring program are covered in the Surface Water and Groundwater Quality Working Paper (Appendix K of the EIS).

Pre-construction (baseline) groundwater data

The project's existing groundwater monitoring network is shown in **Appendix A** and summarised in Table L-1. Table L-1 also summarises which locations have previously had groundwater level monitoring via data logger, and which locations are likely to require decommissioning due to construction of the project.

During the pre-construction phase, groundwater levels would continue to be monitored by data logger at a minimum daily frequency at existing monitoring wells D-PZ-134, D-PZ-221A, D-PZ-221B, D-PZ-438, D-PZ-439B, D-PZ-440A, D-PZ-440B, D-PZ-614 and D-PZ-615B (refer to Figure 2-2 in **Appendix A**). These locations are elected because they all have previously had water levels monitored by data logger and have the most existing baseline data. Groundwater level monitoring has previously occurred at D-PZ-222B, D-PZ-223A and 223B; however, these three locations are not elected for continued collection of baseline data because their historical monitoring via data logger spanned only two months.

The data loggers would be downloaded quarterly and at this time, all existing locations, including locations not monitored via data logger, would be sampled for groundwater level via dip meter.

Table L-1 Monitoring bore summary

Location	Easting	Northing	Interpreted screened hydrogeological unit	Monitored by data logger for EIS	Likely to require decommissioning during construction phase
D-PZ-134	372642	6368469	Tomago Coal Measures	✓	
D-PZ-135	372853	6368499	Tomago Coal Measures		
D-PZ-136	373183	6368558	Tomago Coal Measures		✓
D-PZ-221A	374772	6368470	Hunter alluvium	✓	
D-PZ-221B	374772	6368470	Tomago Coal Measures	✓	
D-PZ-222A	374910	6368425	Hunter alluvium		✓
D-PZ-222B	374910	6368425	Tomago Coal Measures	✓	✓
D-PZ-223A	375480	6368559	Hunter alluvium	✓	✓
D-PZ-223B	375480	6368559	Tomago Coal Measures	✓	✓
D-PZ-324A	378085	6368698	Hunter alluvium		
D-PZ-324B	378085	6368698	Tomago Coal Measures		
D-PZ-438	378543	6368611	Tomago Coal Measures	✓	
D-PZ-439A	379350	6369744	Hunter alluvium		

Location	Easting	Northing	Interpreted screened hydrogeological unit	Monitored by data logger for EIS	Likely to require decommissioning during construction phase
D-PZ-439B	379350	6369744	Hunter alluvium	✓	
D-PZ-440A	379577	6370011	Hunter alluvium	✓	
D-PZ-440B	379577	6370011	Hunter alluvium	✓	
D-PZ-614	383045	6371950	Tomago Sandbeds	✓	
D-PZ-615A	383108	6372474	Tomago Sandbeds		
D-PZ-615B	383108	6372474	Tomago Sandbeds	✓	
D-PZ-616	383271	6372687	Tomago Sandbeds		

Construction phase groundwater monitoring

Before construction, all available groundwater monitoring locations would be reviewed and rationalised as required. Additional monitoring sites or investigation areas may be identified before construction as an outcome of detailed site investigation. For example, confirmation of local groundwater levels may be required at water quality basin locations. Where applicable, sentinel monitoring locations, situated between high risk activities and sensitive receptors may also considered.

During the construction phase, and subject to confirmation at detailed design stage, groundwater level sampling would continue as per the pre-construction phase with the exception of sites to be decommissioned during construction. For sites that would be decommissioned during the construction phase (Table L-1), groundwater level sampling would be carried out up until decommissioning and the decommissioned monitoring locations would not be subsequently replaced.

Operation phase groundwater monitoring

During the operational phase, groundwater level monitoring would be carried out for a minimum period of twelve months to verify that impacts to groundwater during operation are not occurring, or alternatively, inform appropriate management measures. Operation phase groundwater monitoring would notionally be continued at monitoring locations as per the construction phase. Operation phase monitoring would be refined and rationalised based on the results of the construction phase monitoring and anticipated operational phase impacts.