NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Appendix R

Flooding

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Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Technical working paper: Flooding

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Prepared for

Transport for NSW

Prepared by

Lyall and Associates

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Note on flood frequency

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having ten per cent AEP, there is a ten per cent probability (or 1 in 10 chance) that there would be floods of greater magnitude each year. As another example, for a flood having a 10 year ARI, there would be floods of equal or greater magnitude once in ten years on average. The approximate correspondence between these two systems is provided in the table below.

Annual Exceedance Probability (AEP) per cent	**Average Recurrence Interval (ARI) years**
0.2	500
0.5	200
1	100
5	20
10	10
20	5
50	2
1 EY(1)	1
2 EY(1)	0.5

1. Floods more frequent than 50% AEP are expressed in terms of the number of exceedances per year (EY).

In this technical working paper the frequency of floods is referred to in terms of their AEP, for example a 1% AEP flood.

The frequencies of peak water levels derived from ocean flooding are also referred to in terms of their AEP; for example, a 1% AEP peak ocean water level.

The technical working paper also refers to the Probable Maximum Flood (PMF). This flood occurs as a result of the Probable Maximum Precipitation (PMP) on the study catchments. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards to rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff. The PMF is defined as the upper limiting value of floods that could reasonably be expected to occur and defines the extent of flood prone land (ie the floodplain).

Glossary of terms and abbreviations

Term	Definition
AEP	Annual exceedance probability. The chance of a rainfall or a flood event exceeding a nominated level in any one year, usually expressed as a percentage. For example, if a peak flood level has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of being exceeded in any one year. The frequency of floods is generally referred to in terms of their AEP or ARI. In this technical working paper the frequency of floods generated by runoff from the study catchments is referred to in terms of their AEP, for example a 1% AEP flood.
Afflux	Increase in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ALS	Airborne Laser Scanning. A type of aerial survey used to measure the elevation of the ground surface.
ARI	Average recurrence interval. An indicator used to describe the frequency of a rainfall or a flood event, expressed as an average interval in years between events of a given magnitude. For example, over a long period of say 200 years, a flood equivalent to or greater than a 20 year ARI event would occur 10 times. A 20 year ARI flood has a one-in-20 chance of occurrence in any one year. See also AEP.
ARR 1987	Australian Rainfall and Runoff (Institute of Engineers Australia 1987)
ARR 2019	Australian Rainfall and Runoff (Geosciences Australia 2019)
BoM	Bureau of Meteorology
Box culvert	A culvert of rectangular cross section
Catchment	The land area draining through the mainstream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
CEMP	Construction environmental management plan. A site specific plan developed for the construction phase of the project to ensure that all contractors and sub-contractors comply with the environmental conditions of approval for the project and that the environmental risks are properly managed.
Climate change	A change in the state of the climate that can be identified (for example by statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period of time, typically decades or longer (IPCC 2007).
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which in turn is based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised (IPCC 2007).
Construction footprint	The land above and below the ground that is required to construct the project.
DCP	Development control plan
DECC	Department of Environment and Climate Change (formerly OEH, now Department of Planning, Industry and Environment (Environment, Energy and Science)
DECCW	Department of Environment, Climate Change and Water (formerly, DECC and OEH, now Department of Planning, Industry and Environment (Environment, Energy and Science)
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s).

Term	Definition
	Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example metres per second (m/s).
DoP	NSW Department of Planning (now Department of Planning, Industry and Environment)
DP	Deposited plan
Drainage	Natural or artificial means for the interception and removal of surface or subsurface water.
DRAINS	A simulation program which converts rainfall patterns to stormwater runoff and generates discharge hydrographs. These hydrographs can then be routed through networks of piped drainage systems, culverts, storages and open channels using the DRAINS software to calculate hydraulic grade lines and analyse the magnitude of overflows. Alternatively, discharge hydrographs generated by DRAINS can be used as inflows to alternative hydraulic models (such as the TUFLOW two-dimensional hydraulic modelling software) to calculate water surface levels and flooding patterns.
Earthworks	All operations involving the loosening, excavating, placing, shaping and compacting of soil or rock.
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
EIS	Environmental impact statement
Embankment	An earthen structure where the road (or other infrastructure) is located above the natural surface.
Fill	The material place in an embankment.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
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 affectation	The extent to which a property or area of land is affected by flooding.
Flood fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood immunity	Relates to the level at which a particular structure would be clear of a certain flood event.
Flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the 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.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (ie flood prone land).
Floodplain Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (FDM), (DIPNR 2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

Term	Definition
Floodway area	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.
Flow velocity	A measure of how fast water is moving, for example, metres per second (m/s).
FPA	Flood planning area. The area of land inundated at the Flood Planning Level.
FPL	Flood planning level. A combination of flood level and freeboard selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans.
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event-related, such as levee and embankment settlement, and other effects such as future climate change. Freeboard is included in the FPL.
GPT	Gross pollutant trap. A device designed to capture pollutants in stormwater runoff prior to discharge into the receiving system. GPT's are typically designed to capture litter and debris but may also capture hydrocarbons, suspended sediments and particle bound pollutants such as nitrogen, phosphorus and heavy metals.
GSDM	Generalised short duration method. A method for estimating the Probable Maximum Precipitation for catchments up to 1000 square kilometres in area.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (FDM), (DIPNR 2005) the hazard is flooding which has the potential to cause damage to the community.
Headwater	The upper reaches of a drainage system.
HHWSS	Highest high water solstice spring. The tide level reached on average once or twice per year.
Hydraulics	The term given to the study of water flow in waterways, in particular the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	The term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Hyetograph	A graph which shows how rainfall intensities or depths vary with time during a storm burst. A design hyetograph shows the distribution of rainfall over a design storm burst.
Local Drainage	Smaller scale drainage systems in urban areas. Commonly defined as areas where the depth of inundation along overland flow paths is less than 150 millimetres during a 1% AEP storm.
IFD	Intensity-Frequency-Duration
IPCC	Intergovernmental Panel on Climate Change
LGA	Local government area
LiDAR	Light Detection and Ranging. A form of aerial survey used to measure ground elevations.
m	Metres

Term	Definition
m AHD	Metres above Australian Height Datum
m^2	Square metres
m^3	Cubic metres
m^3/s	Cubic metres per second
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State's rivers and floodplains.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
OEH	Office of Environment and Heritage (now Department of Planning, Industry and Environment (Environment, Energy and Science)
Overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.
Peak flood level	The maximum water level occurring during a flood event.
PMF	Probable Maximum Flood. The flood that occurs as a result of the Probable Maximum Precipitation (PMP) on a study catchment. The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled 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 (ie the floodplain).
PMP	Probable Maximum Precipitation. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff.
PRM	Probabilistic rational method. A method prescribed in ARR 1987 for the estimation of peak discharges from a rural catchment.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
Project footprint	The land above and below ground required to construct the project, for temporary ancillary construction facilities, and the land required to accommodate permanent infrastructure including shared cycle and pedestrian pathways.
RCBC	Reinforced concrete box culvert
RCP	Reinforced concrete pipe
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the Floodplain Development Manual (DIPNR, 2005) it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RL	Reduced Level. The reduced level is the vertical distance between an elevation and an adopted datum plane such as the Australian Height Datum (AHD).
Roads and Maritime	NSW Roads and Maritime Services (now part of Transport for NSW)
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.

Term	Definition
Scour	The erosion of material by the action of flowing water.
SEARs	Secretary's environmental assessment requirements and specifications for an environmental assessment prepared by the Secretary of the NSW Department of Planning, Industry and Environment under section 115Y of the *Environmental Planning and Assessment Act 1979* (NSW)
SES	NSW State Emergency Services
Spoil	Surplus excavated material
Stage	Equivalent to water level (both measured with reference to a specified datum)
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil/waste.
Surface water	Water flowing or held in streams, rivers and other water bodies in the landscape.
Swale	A shallow, grass-lined drainage channel.
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).

EXECUTIVE SUMMARY

This report deals with the findings of an investigation which was undertaken to assess flooding related issues associated with the construction and operation of the Beaches Link and Gore Hill Freeway Connection project (the project).

This report has been prepared to support the environmental impact statement for the project. Sections 1 to 3 provide details of the background to the assessment, as well as a description of the project works that have the potential to influence flood behaviour in the catchments through which it runs. A more detailed description of the project is contained in Chapter 6 (Project description) of the environmental impact statement.

Existing environment

The project traverses a number of highly urbanised catchments which drain to Middle Harbour, Manly Lagoon and Narrabeen Lagoon. The investigation found that the stormwater drainage systems that control runoff from these catchments are typically of limited capacity. As a result, the land on which the project would be located is presently impacted by both mainstream flooding and major overland flow during periods of heavy rainfall.

Section 4 contains a brief description of the characteristics of the catchments through which the project runs, as well as a description of the nature of mainstream flooding and major overland flow under present day (or pre-project) conditions for events of 10% and 1% Annual Exceedance Probability (AEP), as well as for the Probable Maximum Flood (PMF). Mainstream flooding and major overland flow have been collectively termed ‘flooding’ within this report.

Assessment of construction related impacts

Table 5.1 in Section 5 summarises the flood risk at the proposed construction support sites which are associated with the construction of the project. The assessment found that a number of the construction support sites would be affected by flooding during storms as frequent as 10% AEP. Inundation of these construction support sites by flooding has the potential to:

- Cause damage to the project works
- Cause delays in construction programming
- Pose a safety risk to construction workers
- Detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwater
- Alter the characteristics of flooding in adjacent development.

Construction activities also have the potential to exacerbate flooding conditions in adjacent development. This arises due to the need to locate temporary measures on the floodplain outside the road footprint. A qualitative assessment was carried out to assess the potential impacts the construction activities could have on the characteristics of flooding. The key findings of the investigation are summarised in Table 5.1 in Section 5.

While the majority of the construction support sites would involve works within the floodplain that would need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with the Balgowlah Golf Course construction support site (BL10). There is also the potential for construction activities to impact local catchment runoff, which would require appropriate local stormwater management controls to be implemented during the construction phase of the project. While the short duration nature of construction activities reduces the likelihood that they would be impacted by flood producing rainfall, Section 8 sets out a recommended set of measures for assessing and managing the impact of construction related impacts on flood behaviour.

Assessment of operational related impacts

Inundation of the project by floodwater during its operation has the potential to cause damage to infrastructure, impact on the safe operation of the motorway tunnels and pose a safety risk to road users and motorway operations staff. The project also has the potential to exacerbate flooding conditions in adjacent development. An assessment was carried out of the flood risk to the project in its as-built form, as well as the impact it would have on the characteristics of flooding in adjacent developments.

Table 6.1 in Section 6 provides a summary of the assessed flood risk to the project. A recommended level of flood protection for each project element has been identified with due consideration of the consequences of flooding in accordance with the *NSW Floodplain Development Manual* (NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005) and current Transport for NSW standards.

The assessment found that once constructed, the project would generally have only a minor impact on flood behaviour in adjacent properties for storms with AEP's up to 1% in intensity (refer to Table 6.2 for a summary of key findings). While it would be necessary to carry out further design development during detailed design which is aimed at further reducing the residual impacts of the project on flood behaviour, the nature of the changes in flooding patterns attributable to the project would not have an impact on the future development potential of land located outside the project boundary.

The assessment found that the project has the potential to increase the duration of inundation in parts of the Wakehurst Golf Course and to also increase the frequency flow surcharges the existing stormwater drainage line which crosses Aquatic Drive and runs beneath Aquatic Reserve in Allambie Heights. The assessment also found that the project has the potential to increase the risk of scour in several existing drainage lines which would control runoff originating from the upgraded section of the Wakehurst Parkway.

Projected changes in the intensity of flood producing rainfall, as well as a rise in sea level, have the potential to impact on the characteristics of flooding in the vicinity of the project. The potential impacts of future climate change on flooding were assessed in accordance with the recommended procedures set out in the NSW Department of Planning, Industry and Environment (Environment, Energy and Science) *Floodplain Risk Management Guideline – Practical Considerations of Climate Change* (NSW Department of Environment and Climate Change (DECC), 2007).

The assessment found that potential increases in rainfall intensities associated with future climate change would only have a minor impact on peak 1% AEP flood levels in the vicinity of the project, with the exception of ANZAC Park where levels would be increased by about 0.9 metres. Floodwater

would also surcharge Burnt Bridge Creek at the location of the Burnt Bridge Creek Deviation crossing, thereby causing flooding of the road. While the assessment found that the project would generally only have a minor impact on peak post-climate change 1% AEP flood levels, the lifting of the vertical alignment of Burnt Bridge Creek Deviation at the location where it crosses Burnt bridge Creek has the potential to exacerbate flood behaviour in up to six existing dwellings under post-climate change conditions.

The existing stormwater drainage system which controls runoff from the catchments through which the project runs has the potential to experience a partial blockage by debris during periods of heavy rainfall. An assessment was carried out whereby a 50 per cent blockage factor was applied to the existing stormwater drainage system.

The assessment found that a partial blockage of the existing stormwater drainage system by debris would only have a minor impact on peak 1% AEP flood levels in the vicinity of the project, with the exception of ANZAC Park where levels would be increased by about 1.5 metres and on Burnt Bridge Creek Deviation where a partial blockage of the transverse drainage structure would result in floodwater surcharging onto the road. While the assessment found that the tunnel portals would not be impacted by floodwater should the existing stormwater drainage system experience a partial blockage during storms up to 1% AEP in intensity, it did find that there is the potential for floodwater to enter the tunnel system should such an occurrence occur during an extreme storm event. Based on this finding, it is recommended that an assessment be carried out during detailed design to assess the flood risk in the tunnel system should the existing stormwater drainage system experience a partial blockage during storms that are more intense than 1% AEP. The degree to which the existing stormwater drainage system could block during an extreme storm event should be assessed based on the procedures set out in the latest edition of *Australian Rainfall and Runoff*.

While the procedures set out in the 1987 edition of *Australian Rainfall and Runoff* were used as the basis for carrying out the flooding investigation for the project, a check was carried out to assess whether the adoption of procedures set out in the recently released 2019 edition of the document would alter predicted flood behaviour in its vicinity. The assessment found that the application of the procedures set out in the latest addition of *Australian Rainfall and Runoff* would result in a reduction in peak flows and hence flood levels in the vicinity of the project and that the use of the procedures set out in the earlier edition of the document therefore represents a worse-case scenario in terms of predicted flood behaviour. Section 8 sets out a recommended set of measures for assessing and managing the impact of operational related impacts on flood behaviour.

Assessment of cumulative impacts

Section 7 presents the findings of the investigation which was carried out to assess the potential cumulative impacts the project could have on flood behaviour in combination with other major motorway projects in its vicinity, namely the Western Harbour Tunnel and Warringah Freeway Upgrade project.

While the present investigation found that the project would not exacerbate flooding conditions in existing development that is located in the Willoughby Creek catchment, a similar investigation found that the Western Harbour Tunnel and Warringah Freeway Upgrade project had the potential to increase peak 1% AEP flood levels by up to 16 millimetres in nine residential properties that are located along Cammeray Road, Park Avenue, Fall Street and Grafton Street in Cammeray.

The investigation identified that there are no proposed non-motorway projects that are of a scale that would influence flood behaviour in the vicinity of the project.

Management of impacts

Section 8 sets out the environmental management measures which would be implemented during the detailed design, construction and operation of the project.

While the findings of the initial assessment presented in Section 5 provide an indication of the potential impact construction activities would have on flood behaviour, further investigations would need to be carried out during detailed design with the benefit of more detailed site layouts and staging diagrams. Table 8.1 in Section 8 contains a range of potential measures which will be implemented in order to reduce the impact of construction activities on flood behaviour.

Table 8.1 also sets out the specific measures which will be incorporated into the detailed design of the project in order to mitigate its operational related flood risks. The nature and extent of impacts, and therefore the scope of mitigation measures required, would be subject to further flood assessment during the detailed design phase. Subject to this further flood assessment, additional floor level survey may be required to confirm the extent to which the proposed works would increase flood damages in affected properties and therefore the scope of specific measures that may be required to mitigate the project related impacts.

1 INTRODUCTION

This section provides an overview of the Beaches Link and Gore Hill Freeway Connection (the project), including its key features and location. It also outlines the Secretary's environmental assessment requirements addressed in this technical working paper.

1.1 Overview

The Greater Sydney Commission's *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018) proposes a vision of three cities where most residents have convenient and easy access to jobs, education and health facilities and services. In addition to this plan, and to accommodate for Sydney's future growth the NSW Government is implementing the *Future Transport Strategy 2056* (Transport for NSW, 2018), that sets the 40 year vision, directions and outcomes framework for customer mobility in NSW. The Western Harbour Tunnel and Beaches Link program of works is proposed to provide additional road network capacity across Sydney Harbour and Middle Harbour and to improve transport connectivity with Sydney's Northern Beaches. The Western Harbour Tunnel and Beaches Link program of works include:

- The Western Harbour Tunnel and Warringah Freeway Upgrade project which comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project which comprises a new tolled motorway tunnel connection across Middle Harbour from the Warringah Freeway and the Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of the Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

A combined delivery of the Western Harbour Tunnel and Beaches Link program of works would unlock a range of benefits for freight, public transport and private vehicle users. It would support faster travel times for journeys between the Northern Beaches and areas south, west and north-west of Sydney Harbour. Delivering the program of works would also improve the resilience of the motorway network, given that each project provides an alternative to heavily congested existing harbour crossings.

1.2 The project

Transport for NSW is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Beaches Link and Gore Hill Freeway Connection project, which would comprise two components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, and an upgrade of the Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

A detailed description of these two components is provided in Section 1.4.

1.3 Project location

The project would be located within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas, connecting Cammeray in the south with Killarney Heights, Frenchs Forest and Balgowlah in the north. The project would also connect to both the Gore Hill Freeway and Reserve Road in Artarmon in the west.

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

The mainline tunnels would also have on and off ramps from under Northbridge connecting to the Gore Hill Freeway and Reserve Road east of the existing Lane Cove Tunnel. Surface works would also be carried out at the Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation at Balgowlah and along the Wakehurst Parkway between Seaforth and Frenchs Forest to connect the project to the existing arterial and local road networks.

1.4 Key feature of the project

Key features of the Beaches Link component of the project are shown in Figure 1-1 and would include:

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
- Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
- Northbound and southbound connections between the mainline tunnel under Seaforth and the surface at the Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
    - Eastbound and westbound connections between the mainline tunnel under Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length).
    - An access road connection at Balgowlah between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
    - Upgrade and integration works along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New open space and recreation facilities at Balgowlah
- New and upgraded pedestrian and cyclist infrastructure
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights

- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon, and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed Circuit Television (CCTV) and other traffic management systems.

Key features of the Gore Hill Freeway Connection component of the project are shown in Figure 1-2 and would include:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore & Western Line and T9 Northern Line and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement.

Subject to obtaining planning approval, construction of the project is anticipated to commence in 2023 and is expected to take around five to six years to complete.

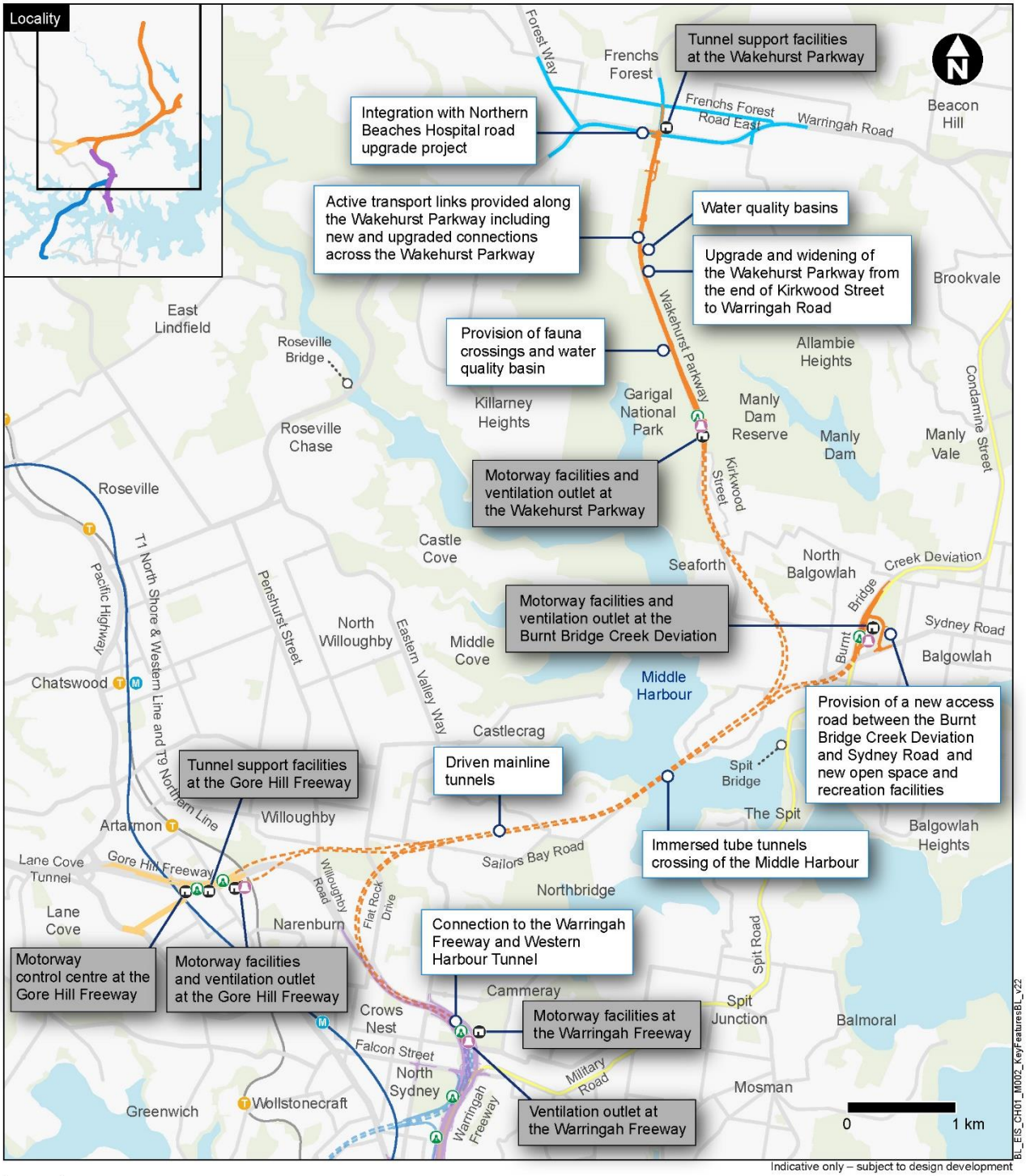

Figure 1-1 Key features of the Beaches Link component of the project

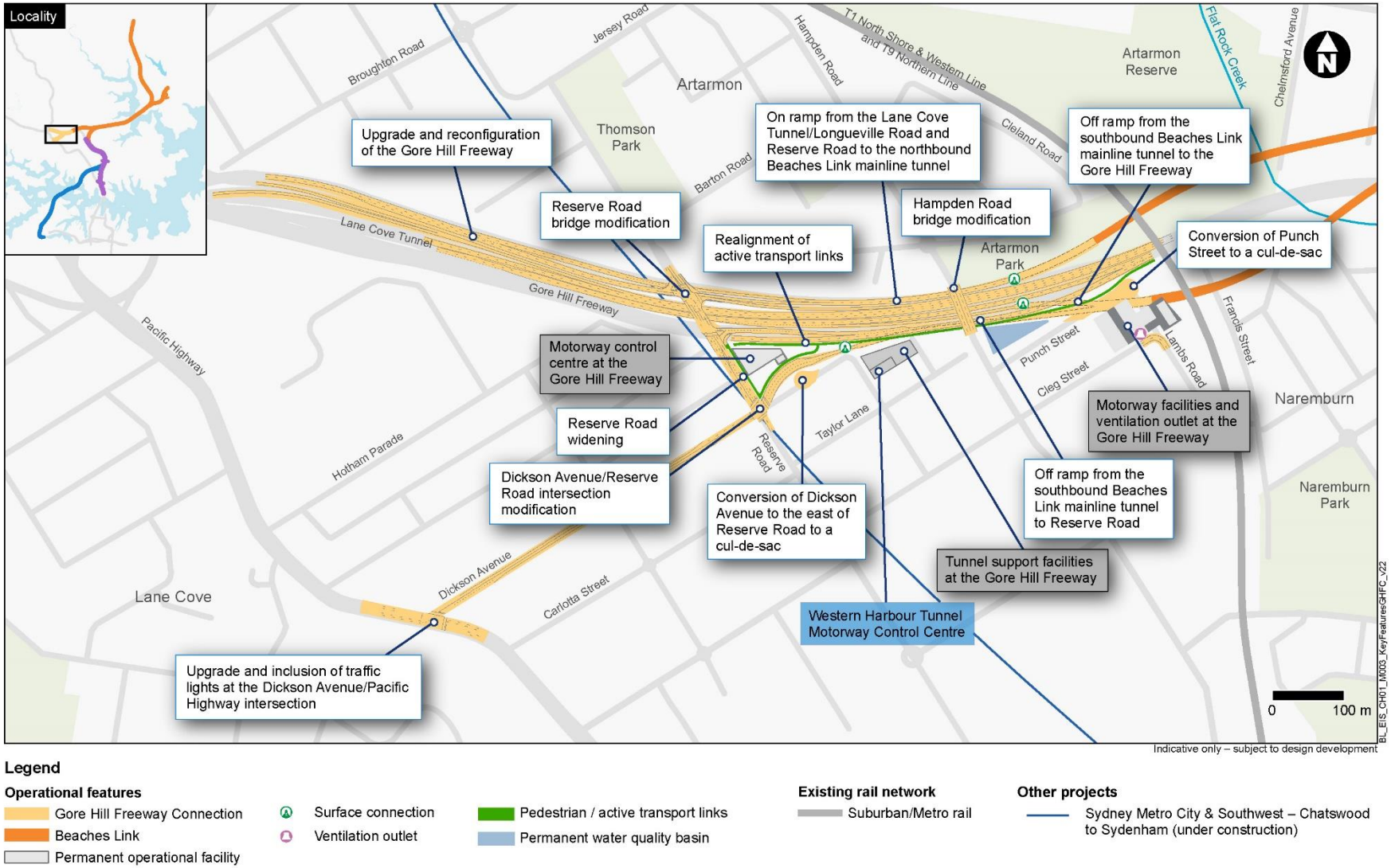

Figure 1-1 Key features of the Gore Hill Freeway component of the project

1.5 Key construction activities

The area required to construct the project is referred to as the construction footprint. The majority of the construction footprint would be located underground within the mainline and ramp tunnels. However, surface areas would also be required to support tunnelling activities and to construct the tunnel connections, tunnel portals, surface road upgrades and operational facilities.

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
  - A motorway control centre at the Gore Hill Freeway in Artarmon
  - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
  - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at the Warringah Freeway (being constructed by the Western Harbour Tunnel and Warringah Freeway Upgrade project), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
  - A wastewater treatment plant at the Gore Hill Freeway in Artarmon
  - Installation of motorway tolling infrastructure
- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of roadside furniture, lighting, signage and noise barriers
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Temporary construction support sites would be required as part of the project (refer to Figure 1-3), and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)
- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work) of the environmental impact statement.

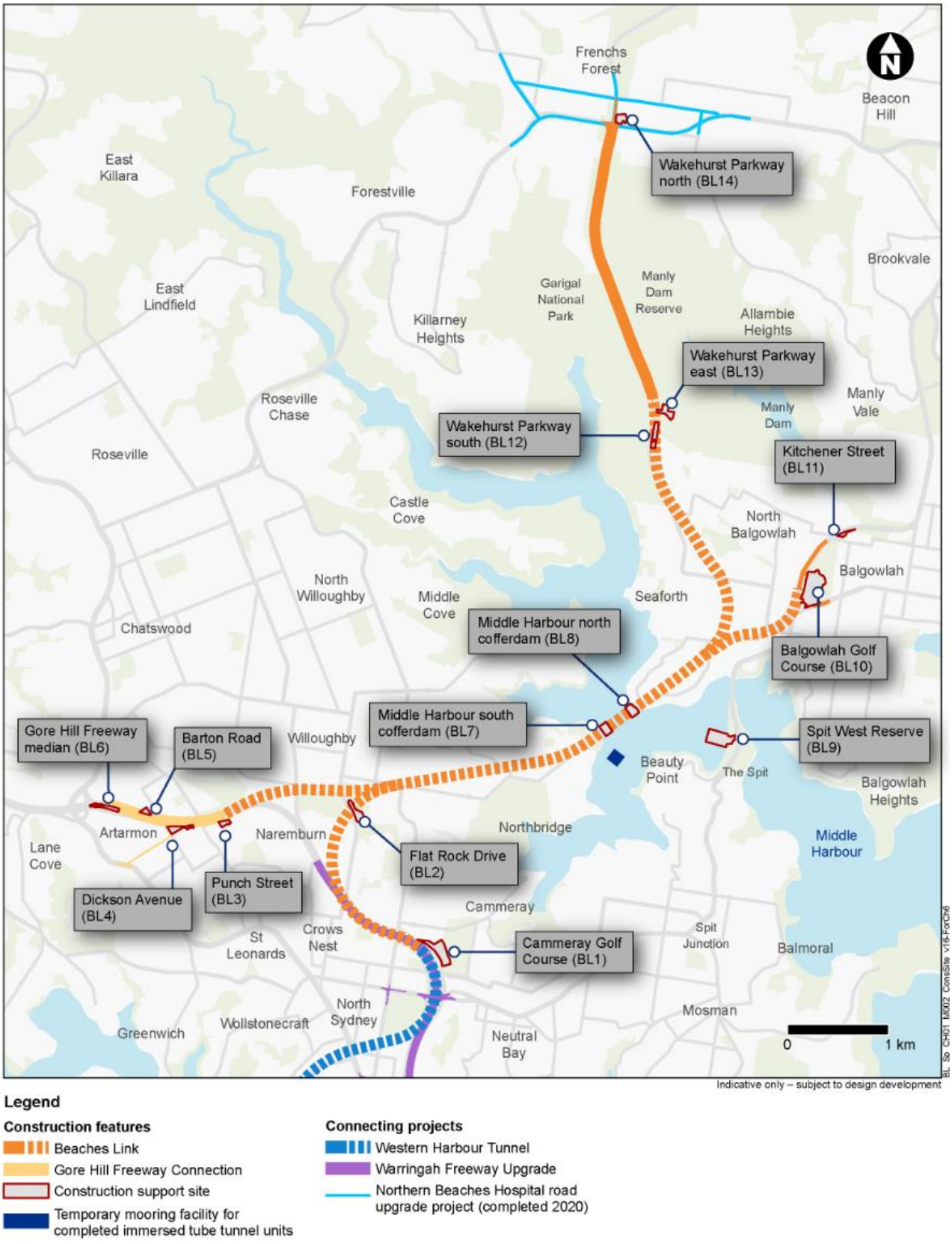

Figure 1-2 Overview of the construction support sites

1.6 Purpose of this technical working paper

This report has been prepared to support the environmental impact statement for the project and to address the environmental assessment requirements of the Secretary of the Department of Planning, Industry and Environment ('the Secretary's environmental assessment requirements').

This technical working paper presents the state of the existing flooding and drainage environment as a baseline and then identifies the potential impacts that may arise from the construction and operation of the project, as well as measures that are aimed at managing the potential impacts.

1.7 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements relating to flooding and drainage, and where these requirements are addressed in this technical working paper, are outlined in Table 1.1.

Table 1.1
Secretary's environmental assessment requirements (SEARS) - flooding

SEARs	Where addressed in this report
11. Flooding The project minimises adverse impacts on existing flooding characteristics. Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure.	
1. The EIS must map the following features relevant to flooding as described in the *NSW Floodplain Development Manual 2005* (NSW Government, 2005) including:	Figures containing maps of features relevant to flooding are listed below.
a) Flood prone land	Figure 4.4 shows the extent of flood prone land in the vicinity of the project (i.e. the extent of land that is susceptible to flooding during a Probable Maximum Flood (PMF) event).
b) Flood planning areas, the area below the flood planning level;	Figure 4.7 shows the extent of land which is located below the 1% Annual Exceedance Probability (AEP) flood level plus 0.5 m (as defined in the relevant Local Environmental Plans).
c) Hydraulic categorisation (floodways and flood storage areas); and	Figure 4.5 shows a preliminary hydraulic categorisation of the 1% AEP design flood into floodway, flood storage and flood fringe areas.
d) Flood Hazard.	Figure 4.6 shows provisional categorisation of the 1% AEP into high and low flood hazard areas.
2. The Proponent must assess and (model where required), the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including:	Section 3 sets out the approach that was adopted to assess the impact the project would have on flood behaviour during both its construction and operation. Section 3.2 describes the methodology that was used to define flood behaviour under present day (i.e. pre-project) conditions, while sections 3.3 and 3.4 describe the methodology that was adopted to assess the impact of the project on flood behaviour during the construction and operational phases of the project, respectively. Section 3.5 sets out the approach that was adopted to assess the impact that future climate change would have on flood behaviour. Sections 5.2, 6.2 and 6.5.2 present the findings of an assessment of the potential impacts of the project on flood behaviour.

SEARs	Where addressed in this report
a) how the tunnel entries and cut-and-cover sections of the tunnels would be protected from flooding during construction works;	Section 5.2 summarises the findings of the assessed flood risk at the construction support sites that would be used to support tunnel excavation and the construction of cut and cover sections of tunnel, while Section 8.2 contains a set of measures which are aimed at managing the flood risk during tunnel construction.
b) any detrimental increases in the potential flood affectation of the project infrastructure and other properties, assets and infrastructure;	Sections 5.2 and 6.2 present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively.
c) consistency (or inconsistency) with applicable Council floodplain risk management plans;	Section 6.4 presents the findings of a review of the project in terms of its consistency with Council floodplain risk management plans.
d) compatibility with the flood hazard of the land;	Section 4.3 describes the existing flood behaviour in the vicinity of the project, including an overview of the provisional flood hazard for a 1% AEP flood. Section 5.1.1 includes discussion on the potential flood hazard at proposed construction support sites, while Section 6.3 includes discussion on the findings of the assessment in terms of the impact that the operation of the project would have on the hazard categorisation of the floodplain.
e) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land;	Section 4.3 describes the existing flood behaviour in the vicinity of the project, including the hydraulic categorisation of the floodplain into floodways, flood storage and flood fringe for a 1% AEP flood. Sections 5.2 and 6.2 describe the impacts on flood behaviour as a result of changes to flow conveyance and flood storage across the floodplain.
f) whether there will be adverse effect to beneficial inundation of the floodplain environment, on, or adjacent to or downstream of the site;	Due to the urbanised nature of the floodplain no areas have been identified where there would be an adverse effect caused by a reduction in inundation. Sections 5.2 and 6.2 present the findings of an assessment of more general impacts of the project on flood behaviour, including changes in the extent of inundation.
g) downstream velocity and scour potential;	Section 5.2 identifies potential impacts that the construction of the project could have on velocity and scour potential, while sections 6.2 and 6.3, as well as Tables 6.2 and 6.3 present the findings of an assessment of the corresponding impacts during the operation of the project.
h) impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council;	Section 6.3 provides an assessment of the proposed works and its impact on transport infrastructure that may be relied upon as part of community emergency management arrangements. Section 8 sets out recommendations for consultation with SES and relevant councils during the development of a Floodplain Management Strategy for the construction and operation of the project. Appendix E of the environmental impact assessment (Community consultation framework) identifies councils and

SEARs	Where addressed in this report
	SES as key stakeholders, with engagement to continue into the next phases of the project.
i) any impacts the development may have on the social and economic costs to the community as consequence of flooding;	Section 5.2 and 6.2 present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively, including consideration of social impacts (such as impacts on emergency response arrangements and disruption to the community) and economic impacts (such as the potential for increases in flood damages in adjacent development due to an increase in above floor inundation).
j) whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and	Section 5.2 identifies potential impacts that the construction of the project could have on erosion, siltation and the stability of watercourses, while sections 6.2 and 6.3, as well as Tables 6.2 and 6.3 present the findings of an assessment of the corresponding impacts during the operation of the project.
k) any mitigation measures required to offset potential flood risks attributable to the project (these mitigation measures must be discussed with the State Emergency Services and Council where appropriate).	Section 8 outlines potential measures to mitigate construction and operational related impacts of the project on flooding conditions (and therefore the potential for increased flood risk) in adjacent development and to manage the risk of flooding to the project. Appendix E of the environmental impact assessment (Community consultation framework) identifies councils and SES as key stakeholders, with engagement to continue into the next phases of the project.
3. The assessment should take into consideration any flood studies undertaken by local government councils, as available.	Section 3.2.1 contains details of previous flood studies that were considered as part of the present investigation.
4. The EIS must assess and model the effect of the proposed development (including fill) on current flood behaviour for the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 6.5.2 provides an assessment of the impact the project would have on flood behaviour under future climate change conditions.

1.8 Study area

The project is located within the following seven (7) catchments:

- Trefoil Creek (a sub-catchment of Narrabeen Lagoon)
- Manly Creek (a sub-catchment of Manly Lagoon)
- Bantry Bay
- Burnt Bridge Creek (a sub-catchment of Manly Lagoon)
- Pearl Bay (within Middle Harbour)
- Flat Rock Creek
- Willoughby Creek.

Figure 1.4 shows the extent of the project works within each of the above catchments.

1.9 Structure of this report

The layout of this technical working paper is as follows:

- **Section 1** provides a brief overview of the project and the purpose of this technical working paper. The section also sets out the flooding and drainage related Secretary's environmental assessment requirements which were issued by the Department of Planning, Industry and Environment for the preparation of the environmental impact statement
- **Section 2** sets out the relevant government legislation, policies and guidelines that were taken into consideration during the assessment. The section also contains a summary of the criteria and standards that have been adopted for the assessment based on consideration of the relevant government legislation, policies and guidelines
- **Section 3** sets out the methodology that has been adopted in the definition of flood behaviour in the vicinity of the project and also the impact the project would have on flood behaviour
- **Section 4** contains a brief description of the catchments through which the project runs, as well as the drainage systems which control runoff in its vicinity. This section of the technical working paper also provides an overview of flooding and drainage patterns under present day (ie pre-project) conditions
- **Section 5** deals with the flood risk at the proposed construction support sites, as well as the impact construction activities would have on flood behaviour
- **Section 6** deals with the impact the project would have on flood behaviour following its construction, as well as details of the hydrologic standard which is proposed for its various components. The section also presents the findings of an assessment of the potential for the project to increase the risk of scour in the receiving drainage lines, the potential impact of future climate change on flood behaviour and the impacts that a partial blockage of the local stormwater drainage system would have on flood behaviour in the vicinity of the project
- **Section 7** describes the potential cumulative impacts on flooding and drainage patterns that would result from the project in combination with other projects in its vicinity
- **Section 8** outlines potential measures to mitigate the construction and operational (ie post-construction) related impacts of the project on flooding conditions in adjacent development and to manage the risk of flooding to the project

- **Section 9** contains a list of references.

Figures referred to in sections 4 and 6 are located at the end of the report.

Annexure A contains a series of figures showing maximum flow velocities and durations of inundation in the vicinity of the proposed tunnel portal, bridge and road surface works for design storms with 10% AEP and 1% AEP.

Annexure B contains a series of figures which show flooding patterns in the vicinity of the proposed tunnel portal, bridges and road surface works for design of 0.5% AEP and 0.2% AEP.

Annexure C contains a set of figures which show the impact a partial blockage of the local stormwater drainage system would have on flood behaviour for a 1% AEP storm event under operation conditions.

The scales on figures referred to in sections 4 to 7 and in Annexures A, B and C are applicable when printed at A3 size.

2 LEGISLATIVE AND POLICY CONTEXT

2.1 Overview

This section of the technical working paper provides an overview of national, state and local government legislation, policies and technical guidelines that have been considered as part of the current assessment. The section also contains a summary of the criteria and standards that have been adopted for the assessment based on consideration of the relevant government legislation, policies and technical guidelines.

2.2 National guidelines

2.2.1 Australian Rainfall and Runoff (ARR)

Australian Rainfall and Runoff (ARR) is a national guideline for the estimation of design flood characteristics in Australia. The application of the procedures, inputs and parameters set out in ARR is an important component in the provision of reliable and robust estimates of design flood behaviour to ensure that projects such as the Western Harbour Tunnel and Warringah Freeway Upgrade are designed in a manner that manages the impact of flooding.

The third edition of ARR was released in 1987 (ARR 1987) (Institute of Engineers Australia [IEAust], 1987), while a fourth edition of ARR was issued during the course of the present investigation (ARR 2019) (Geoscience Australia [GA], 2019). Due to the timing of the release of ARR 2019, hydrologic modelling that has been carried out to support the flood assessment for the project was based on the procedures set out in ARR 1987, which is also consistent with the approach adopted for previous flood studies in the study area.

A sensitivity analysis was carried out as part of the present investigation to compare flood behaviour in the Willoughby Creek catchment based on the procedures set out in ARR 1987 and ARR 2019 for a 1% AEP storm event. The analysis showed that the procedures set out in ARR 2019 result in lower peak flows and flood levels than have been relied upon for the present flood assessment for the project. Further details of the assessment are contained in Section 6.7 of this technical working paper.

2.2.2 Australian Disaster Resillience Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

The *National Strategy for Disaster Resilience* (Council of Australian Governments [COAG], 2011) aims to provide a national, coordinated and cooperative approach to enhance Australia's capacity to withstand and recover from emergencies and disasters. *National Strategy for Disaster Resilience* recognises that disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals.
The *Australian Disaster Resilience Handbook Collection* comprises 12 handbooks that were developed by the Australian Institute for Disaster Resilience (AIDR) to support the *National Strategy for Disaster Resilience* by providing a set of principles, strategies and actions to help the management and delivery of support services in a disaster context.

Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Handbook 7) (AIDR 2017) provides guidance on best practice principles, as presently understood in Australia, for managing flood risk and formulating floodplain management plans. The key aim of Handbook 7 is that floodplains are strategically managed for the sustainable long-term benefit of the community and the environment and to improve community resilience to floods.

The principles set out in both Handbook 7 and the state government-based *Floodplain Development Manual* (FDM) (Department of Infrastructure, Planning and Natural Resources [DIPNR], 2005) have been taken into consideration when establishing the standards adopted for managing the risk of flooding to the project, as well as its impacts on flooding under present day conditions. Section 2.3.1 contains an overview of the FDM while Section 2.5 provides a summary of the assessment criteria and standards that have been adopted for the project.

2.3 State legislation, policies and guidelines

2.3.1 Floodplain development manual (FDM)

The *Floodplain Development Manual* (FDM) (DIPNR, 2005) incorporates the NSW Government's Flood Prone Land Policy, the primary objectives of which are to reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods, whilst also recognising the benefits of use, occupation and development of flood prone land.

The FDM forms the NSW Government's primary technical guidance for the development of sustainable strategies to support human occupation and use of the floodplain, and promotes strategic consideration of key issues including safety to people, management of potential damage to property and infrastructure and management of cumulative impacts of development. Importantly, the FDM promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

Flood and floodplain risk management studies carried out by local councils as part of the NSW Government's Floodplain Management Program are carried out in accordance with the merits based approach promoted by the FDM. A similar merits based approach has been adopted in the assessment of the impacts that the project would have on existing flood behaviour and also in the development of a range of potential measures which would be aimed at mitigating its impact on the existing environment. In accordance with the FDM, the hydraulic and hazard categorisation of the floodplain was also considered when assessing the impact of the project on existing flood behaviour, as well as the impact of flooding to the project and its users.

2.3.2 Guideline on development controls on low risk flood areas

In January 2007 the NSW Government issued Planning Circular PS 07-003 *New guideline and changes to section 117 direction and EP&A Regulation on flood prone land* which provided an overview of its new guideline to the FDM titled *Guideline on Development Controls on Low Flood Risk Areas*. More specifically, the circular provided advice on a package of changes concerning flood-related development controls on residential development on land subject to events above the 1% AEP flood and up to the Probable Maximum Flood (PMF) (ie land that is affected by flooding during events that are greater than 1% AEP in magnitude). These areas are sometimes known as low flood risk areas.

Guideline on Development Controls on Low Flood Risk Areas confirmed that unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the basis for deriving the Flood Planning Level (FPL) for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. The guideline also notes that unless there are exceptional circumstances, councils should not impose flood-related development controls on residential development on land above the residential FPL (low flood risk areas). However, the guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals and airports) and consideration given to evacuation routes and vulnerable developments (such as aged care facilities and schools) in areas above the 1% AEP flood.

2.3.3 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act) and associated regulations set out the system of environmental planning and assessment for the state of New South Wales.

In July 2009 the NSW Minister for Planning issued a list of directions to local councils under section 117(2) of the EP&A Act. *Direction 4.3 - Flood Prone Land* applies to all councils that contain flood prone land within their LGA and requires that:

- A draft Local Environmental Plan (LEP) shall include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the FDM (including the Guideline on Development Controls on Low Flood Risk Areas)
- A draft LEP shall not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone
- A draft LEP shall not contain provisions that apply to the flood planning areas which:
  - Permit development in floodway areas
  - Permit development that will result in significant flood impacts to other properties
  - Permit a significant increase in the development of that land
  - Are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services or
  - Permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development
- A draft LEP must not impose flood-related development controls above the residential FPL for residential development on land, unless a council provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General)
- For the purposes of a draft LEP, a council must not determine a FPL that is inconsistent with the FDM (including the Guideline on Development Controls on Low Flood Risk Areas) unless a council provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

Based on the above requirements, the assessment of the impacts the project would have on existing flood behaviour and also the future development potential of flood affected land outside the project corridor relates to:

- All storms with AEPs up to 1% in intensity in the case of residential type development (and by default commercial and industrial type development)
- Storms with AEPs greater than 1% in intensity in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities and schools).

2.3.4 Floodplain risk management guidelines

Scientific evidence shows that climate change is expected to lead to sea level rise and an increase in flood-producing rainfall intensities. The significance of these effects on flood behaviour would vary depending on geographic location and local topographic conditions. Climate change impacts on flood-producing rainfall events show a trend for larger scale storms and increased depths of rainfall. Future impacts on sea levels are likely to result in a continuation of the rise in levels which has been observed over the last 20 years.

The NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be carried out based on increases in rainfall intensities of between 10 and 30 per cent. Under current climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP flood. On current projections the increase in rainfalls within the design life of the project is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit.

Based on the recommendations set out in DECC (2007), the 0.5% AEP and 0.2% AEP design storms were adopted as being analogous to an increase in 1% AEP design rainfall intensities of 10 and 30 per cent respectively, for assessing the impact future climate change could have on flooding conditions in the vicinity of the project. This range of potential increases also encompasses the values given in ARR 2019, which suggests a potential increase in rainfall intensities of between 9.1 per cent and 18.6 per cent by 2090 for Representative Concentration Pathways of between 4.5 and 8.5.

Climate Change 2007: The Physical Science Basis. Summary for Policymakers (Intergovernmental Panel on Climate Change (IPCC), 2007) includes trends that indicate that average global sea level rise (not including ice flow melt) may be between 0.18 to 0.59 metres by between 2090 and 2100. Adding to this, the ice flow melt uncertainty of up to 0.2 metres gives an adjusted global range of 0.18 to 0.79 metres.

IPCC (2007) and recent CSIRO modelling (see for example *Projected Changes in Climatological Forcing Conditions for Coastal Erosion in NSW* [McInnes et al, 2007]) indicates that mean sea levels along the NSW coast are expected to rise by more than the global mean. Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 to 0.91 metres by between 2090 and 2100.

In its *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007), the NSW Government recommended sensitivity analyses be carried out to assess the potential impact of sea level rise in the range 0.18 to 0.91 metres, dependent on the relevant project time horizon.

In 2009 the NSW Government released its *Sea Level Rise Policy Statement* (NSW Government, 2009) which supported adaptation to projected sea level rise impacts. The policy statement included sea level rise planning benchmarks for use in assessing potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessment. These benchmarks were a projected rise in sea level (relative to 1990 mean sea level) of 0.4 metres by 2050 and 0.9 metres by 2100, based on work carried out by the IPCC and CSIRO. In its *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010), the NSW Government recommended that these benchmark rises should be used to assess the sensitivity of flood behaviour to future sea level rise.

In 2012 the NSW Government announced its *Stage 1 Coastal Management Reforms* (NSW Government, 2012). As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks, with local councils now having the flexibility to consider local conditions when determining local future hazards.

In the absence of a formal State Government policy on sea level rise benchmarks, the previously recommended rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 have been adopted for assessing the impact future climate change could have on flooding conditions in the vicinity of the project.

2.4 Council policies and guidelines

2.4.1 Flood planning controls

As noted in Section 1.4, the project is located in the local government areas of North Sydney, Willoughby, Mosman and Northern Beaches.

The *Warringah Local Environment Plan 2011* (Warringah LEP 2011) (Warringah Council, 2011)[1], the *Manly Local Environment Plan 2011* (Manly LEP 2013) (Manly Council, 2013)[1] and the *Willoughby Local Environment Plan 2012* (Willoughby LEP 2012) (Willoughby Council, 2019) each contain flood planning clauses that apply to land at or below the Flood Planning Level, which is defined in all three documents as equal to the peak 1% AEP flood level plus 0.5 metres. It is noted that both the *North Sydney Local Environment Plan 2013* (North Sydney LEP 2013) and the *Mosman Local Environment Plan 2012* (Mosman LEP 2012) do not include a definition of the Flood Planning Level.

The approach to flood planning set out in the above LEPs is consistent with the NSW Government's *Guideline on Development Controls on Low Flood Risk Areas* which confirms that unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the basis for deriving the FPLs for residential development.

Clause 6.3 of Warringah LEP 2011 titled "Flood planning" states the following:

[1] While Warringah, Manly and Pittwater Councils merged to form Northern Beaches Council, the Local Environmental Plan of the respective councils still apply to the newly formed local government area.

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

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

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

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

(2) This clause applies to land at or below the flood planning level.

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

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

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

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

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

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

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

(5) In this clause:

flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard."

Similar requirements are set out in Clause 6.3 of Manly LEP 2013 and Willoughby LEP 2012. Both Northern Beaches Council and Willoughby Council require that site specific flood studies be carried out in accordance with the FDM. It is noted that both the North Sydney LEP 2013 and the Mosman LEP 2012 do not include a flood planning clause.

2.4.2 Drainage related standards

North Sydney, Willoughby, Mosman and Northern Beaches councils have all prepared Development Control Plans to guide development in accordance with their respective LEPs that include requirements for the control of runoff discharging from a development. These requirements include the provision of on-site detention in order to mitigate an increase in the quantity of runoff discharging into the respective council's receiving drainage system.

Notwithstanding the above council requirements, there would be a general requirement of the project to manage adverse changes to existing flow behaviour, if they occur. The assessment of flooding and drainage patterns under pre- and post-project conditions is presented in sections 4 and 6 of this technical working paper.

2.5 Summary of adopted assessment criteria and standards

Table 2.1 sets out the flooding and drainage related assessment criteria and standards that have been established for the project with due consideration of the policies and guidelines outlined in the preceding sections of this technical working paper.

In accordance with Handbook 7 and the FDM, the hydrologic standards adopted are based on matching the level of protection to the likelihood and consequence of flooding. A merits based approach has been adopted in the assessment of the impacts the project would have on existing flood behaviour and also in the development of a range of potential measures which are aimed at mitigating its impact on the existing environment.

Table 2.1
Summary of adopted assessment criteria and standards

Aspect	Criterion or standard
Flood risks to the project	
Proposed construction activities	• Construction related flood risks need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the risk exposure occurs. To this end, this technical working paper identifies the risks associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the Flood Management Strategy for the construction of the project.
Tunnel portals and ancillary facilities	• Tunnel portals are to be located above the PMF level or the 1% AEP flood level plus 0.5 metres (whichever is greater). This level of security against ingress is commensurate with the consequence of flooding to the tunnels and the risk to road users and is consistent with the current standard adopted in the design of road and rail tunnels in NSW • The same hydrologic standard would apply to operational tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwater would have the potential to inundate the tunnel or infrastructure that it is reliant upon for its safe operation • The same hydrologic standard would apply to emergency facilities such as motorway control centres, disaster recovery sites and tunnel deluge systems, as well as electrical substations that are reliant for the safe operation of the motorway and its ancillary facilities.
Upgrades and modifications to existing road network	• As a minimum, modifications to existing roads are to be configured to ensure the existing level of flood immunity is maintained and flood depths and hazards are not increased during events up to 1% AEP in magnitude.
Shared pedestrian and cyclist pathways	• A 50% AEP level of flood immunity has been adopted for shared pedestrian and cyclist pathways in accordance with current Transport for NSW standards • Consideration is to also be given to the flood risk to cyclists and pedestrians during larger floods (eg 1% AEP event) as a result of high hazard flooding conditions.
Impact of future climate change on flooding to the project	• The assessment of the potential impact future climate change could have on flood behaviour in the vicinity of the project was based on increases in 1% AEP design rainfall intensities ranging between 10 and 30 per cent in accordance with the NSW Government's Floodplain Risk Management Guideline: Practical Considerations of Climate Change (DECC, 2007)[1]

Aspect	Criterion or standard
	• Sea level rise related impacts were not assessed on the basis that the surface works associated with the project operation lie well above areas that are projected to be impacted by rising sea levels.
Impact of the project on flood behaviour	
Impact of construction activities on flood behaviour	• Construction related flood impacts need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the exposure to the potential impacts occurs. To this end, this technical working paper identifies the potential impacts associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the flood risk management plan for the construction of the project.
Impact of project on flood behaviour in existing development	• Floods up to 1% AEP in magnitude are to be considered in the assessment of measures which are required to mitigate any adverse impacts on flood behaviour attributable to the project • Changes in flood behaviour under larger floods up to the PMF event are also to be assessed in order to identify impacts on critical infrastructure (such as hospitals) and vulnerable development (such as aged care facilities and schools), as well as to identify potentially significant changes in flood hazard as a result of the project.
Impact of the project on flood behaviour under future climate change conditions	• The assessment of the impact of the project on flood behaviour under future climate change conditions was based on assessing the effect of the project on present day flood behaviour during a 0.5 % and 0.2 % AEP event, which is consistent with the requirement of the SEARS[1] • Sea level rise related impacts were not assessed on the basis that the surface works associated with the project operation lie well above areas that are projected to be impacted by rising sea levels.

1. For the purpose of this assessment the 0.5% and 0.2% AEP events were adopted as being analogous to increases in 1% AEP design rainfall intensities of 10 and 30 per cent, respectively.

3 ASSESSMENT METHODOLOGY

3.1 Key tasks

The key tasks comprising the flooding and drainage assessment are broadly described as follows:

- Review of available data including existing flood studies and associated hydrologic and hydraulic models (collectively referred to as 'flood models') within the catchments that are crossed by the project
- Update of the existing flood models where required to more accurately define flooding and drainage behaviour in the vicinity of the project
- Preparation of exhibits showing flood behaviour under present day conditions for design floods with AEPs of 10%, 1%, 0.5% and 0.2%, as well as the PMF
- Assessment of the potential impact the project would have on flood behaviour during its construction and operation
- Assessment of the impact future climate change would have on flood behaviour under operational conditions
- Assessment of the impact a partial blockage of the local stormwater drainage system would have on flood behaviour under operational conditions
- Assessment of potential measures which are aimed at mitigating the risk of flooding to the project and its impact on existing flood behaviour
- Development of hydrologic models to assess the impact the upgrade of the Wakehurst Parkway would have on peak flows and hence scour potential in the receiving drainage lines that drain to Bantry Bay and Manly Creek
- Assessment of potential measures which are aimed at mitigating the risk of scour in the aforementioned receiving drainage lines.

The following sections of this technical working paper set out the methodology which was adopted in the assessment of flooding and drainage behaviour under present day conditions and during both the construction and operational phases of the project.

3.2 Assessment of present day flooding and drainage patterns

3.2.1 Flooding due to catchment runoff

Table 3.1 over lists the existing flood models that were used as the basis for defining the nature of flooding and drainage behaviour in the vicinity of the construction and operational components of the project.

The flood models developed as part of WMA (2016), L&A (2018) and WMA (2018) were updated in order to more accurately define flood behaviour in the vicinity of the project footprint, and in particular flooding in the vicinity of the proposed tunnel portals.

Table 3.1
Source of flood models

Catchment	Source of flood models	Project component
Trefoil Creek	None available(1)	Construction and operation
Manly Creek	*Manly Lagoon Floodplain Risk Management Study and Plan* (WMA Water (WMA,) 2018)	Construction and operation
Bantry Bay	None available(1)	Construction and operation
Burnt Bridge Creek	*Manly Lagoon Floodplain Risk Management Study and Plan* (WMA, 2018)	Construction and operation
Pearl Bay	None available(1)	Construction only
Flat Rock Creek	*Flat Rock Creek Catchment Flood Study and Overland Flow Mapping* (Lyall and Associates (L&A), 2018)	Construction and operation
Willoughby Creek	*North Sydney Flood Study* (WMA, 2016)	Construction and operation

1. The proposed works within the Trefoil Creek, Bantry Bay and Pearl Bay catchments are located at top of the catchment in an area that is not affected by mainstream flooding or major overland flow.

3.2.2 Flooding due to storm tides

The NSW Government's guideline *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (Department of Environment, Climate Change and Water [DECCW], 2010) was prepared to assist councils, the development industry and consultants to incorporate the sea level rise planning benchmarks in floodplain risk management planning for new development. The guideline contains an Annexure on modelling the interaction of catchment and coastal flooding for different classes of tidal waterway. The Annexure may be used to derive scenarios for coincident flooding from those two sources for both present day conditions and conditions associated with future climate change.

For a catchment draining directly to the ocean via trained or otherwise stable entrances such as is the case for the catchments within the study area, the guideline offers the following alternative approaches for selecting storm tidal conditions under present day conditions. In order of increasing sophistication they are:

- A default tidal hydrograph which has a peak RL 2.6 metres AHD for the 1 in 100 year event; or 2.3 metres AHD for the 5% AEP event. This default option is acknowledged by DECCW as providing a conservatively high estimate of tides for these types of entrances. Results achieved with these levels have been determined in the present investigation, however, are only presented as a sensitivity study
- A detailed site-specific analysis of elevated water levels at the ocean boundary. The analysis should include contributions to the water levels such as tides, storm surge, wind and wave set up. The analysis should examine the duration of high tidal levels, as well as their potential coincidence with catchment flooding. This approach requires a more detailed consideration of historic tides and the entrance characteristics, but provides information which is more directly relevant to a particular entrance.

The latter approach has been adopted for defining flooding due to elevated ocean levels for the present investigation. Design still water levels applicable to Sydney Harbour were obtained from the *Fort Denison Sea Level Rise Vulnerability Study* (Department of Environment and Climate Change [DECC], 2008) (refer to Table 3.2). An estimate of the 'extreme tide' design still water level was obtained by extrapolating the design still water level probability curve provided in DECC (2008) and assuming an AEP of 1 in 10,000.

An allowance of 0.3 metres to account for local storm effects such as wind setup and wave conditions was added to the design still water levels to yield the design peak 'storm tide' levels (also shown in Table 3.2) that were adopted for the assessment of storm tide flooding in the study area.

Table 3.2
Adopted peak storm tide levels in Sydney Harbour

Event	Design still water level[(1)] (metres AHD)	Design peak storm tide level[(2)] (metres AHD)
10% AEP	1.34	1.64
1% AEP	1.44	1.74
Extreme	1.6	1.9

1. Source: DECC (2008)
2. Derived by adding 0.3 m to the values presented in DECC (2008).

3.2.3 Definition of present day flood behaviour

Flood behaviour in the vicinity of the project was defined for events with AEPs of between 10% and 0.2% in magnitude, as well as the PMF. Figures were prepared for each event showing the indicative extent and depth of inundation, as well as the direction and relative velocity of flow. Figures were also prepared showing the hydraulic and hazard categorisations during a 1% AEP event, which were defined using the procedures set out in the *NSW Floodplain Development Manual* (DIPNR, 2005).

A description of flood behaviour in the vicinity of the project under present day conditions is presented in Section 4.3, while a summary of the figures that show flood behaviour under present day conditions is contained in Section 4.3.1.

3.3 Assessment of construction related impacts

A qualitative assessment was made of the impact of flooding based on indicative construction areas and activities as provided in the concept design. The locations of surface works, construction support sites and other structures such as temporary noise barriers were overlaid onto the indicative flood extents during a 10% and 1% AEP event, as well as the PMF. This provided an understanding of the likelihood that flooding could occur in the vicinity of construction activities.

An assessment was made on the potential for mainstream flooding to affect the construction process and the potential for construction activities to impact flood behaviour in nearby properties. Consideration was also given to the potential for localised overland flooding to occur in areas of proposed construction.

Section 5 of this technical working paper deals with the impact that flooding could have on construction activities. It also includes an assessment of the impact that construction activities could have on flood behaviour external to the project footprint.

3.4 Assessment of operational related impacts

Burnt Bridge Creek, Flat Rock Creek and Willoughby Creek

The structure of the flood models that were originally developed to define flood behaviour under present day conditions were adjusted to incorporate details of the project under operational conditions. The results of modelling a range of events with AEPs of between 50% and 0.2%, as well as the PMF, were used to prepare a series of figures showing flooding patterns under operational conditions and afflux[2] diagrams showing the impact the project would have on flood behaviour.

In relation to the assessment of post-project flood behaviour along Burnt Bridge Creek, it was assumed that adequate stormwater detention would be incorporated in the design of the project which would ensure that peak flows are not increased in the watercourse for all storms up to 1% AEP in intensity.

Details of the concept design arrangements that were incorporated into the hydraulic models used to define flood behaviour in the vicinity of the project, as well as a description of their impact on flood behaviour is contained in Section 6 of this technical working paper.

Trefoil Creek, Manly Creek and Bantry Bay

The proposed upgrade of Wakehurst Parkway is located in the upper reaches of the Trefoil Creek, Manly Creek and Bantry Bay catchments and generally follows the natural divide between the three catchments.

A set of hydrologic (DRAINS) models were developed to assess the potential for the project to increase peak flows and hence scour potential in the existing drainage lines which presently control runoff from the Wakehurst Parkway. The assessed change in peak flow attributable to the project was used as the basis for identifying the individual drainage lines where the project had the potential to increase peak flows and hence scour potential within the adjacent bushland and to also assess potential mitigation measures.

Sections 4.3.6 and 4.3.7 deal with the derivation of peak flows under present day conditions, while Section 6 deals with the impact that the project would have on peak flows and hence scour potential in the receiving drainage lines. Section 8 sets out the recommended approach to mitigating the impacts of the project on scour potential in the affected receiving drainage lines.

3.5 Impact of future climate change on flood behaviour

The following sections describe the approach that was adopted to assess the potential impact of future climate change on flooding to the project, as well as the impact that the project may have on

[2] Afflux is an increase in peak flood levels caused by a change in floodplain or catchment conditions. A positive afflux represents an increase and conversely a negative afflux represents a decrease in peak flood levels when compared to present day conditions. Differences in peak flood levels of ±0.01 metres (equal to one centimetre or ten millimetres) are considered to be within the accuracy of the hydraulic model. The project is therefore considered to have a negligible or nil effect on flood behaviour in areas where an afflux of ±0.01 metres is shown to be present.

flood behaviour under future climate change conditions. The findings of this assessment are contained in Section 6.4 of this technical working paper.

3.5.1 Impact of future climate change on flooding to the project

Based on the adopted assessment criteria set out in Table 2.1, the following scenarios were adopted as being representative of the likely lower and upper estimates of future climate change related impacts over the design life of the project:

- Scenario 1 – based on an assumed 10 per cent increase in currently adopted design rainfall intensities
- Scenario 2 – based on an assumed 30 per cent increase in currently adopted design rainfall intensities.

Increases in sea level were not included in the above scenarios on the basis that the surface works associated with the project operation lie well above areas that would be impacted by an increase in sea level due to climate change.

3.5.2 Impact of the project on flood behaviour under future climate change conditions

In accordance with the Secretary's environmental assessment requirements, the predicted impact that the project may have on flood behaviour under potential future climate change conditions was based on assessing its effect on present day (ie pre-project) flood behaviour during a 0.5% (1 in 200) and 0.2% (1 in 500) AEP event as proxies for assessing the sensitivity to an increase in rainfall intensity on the 1% AEP event due to future climate change.

3.6 Impact of a partial blockage of major hydraulic structures on flood behaviour

The assessment of the impact that a partial blockage of the local stormwater drainage system may have on flood behaviour was based on the requirements of Willoughby City Council's *Technical Standard No. 3 entitled Attachment 22 – Floodplain Management* (WCC, 2016). In regards the impact that a partial blockage would have on flood behaviour for a 1% AEP design storm event, WCC (2016) requires a 50 per cent blockage factor to be applied to the pipes and box culverts comprising the local stormwater drainage system.

The impact an accumulation of debris on the inlet of the major hydraulic structures that are located along Burnt Bridge Creek Deviation was also assessed given its potential to impact the hydrologic standard of the road and tunnel portal elements of the project.

The findings of the blockage related impact assessment are contained in Section 6.5.

4 EXISTING ENVIRONMENT

4.1 Overview

The following catchments presently contribute runoff to the existing drainage systems and waterways that are located within the project footprint (refer to Figure 1.4):

- Willoughby Creek
- Flat Rock Creek
- Pearl Bay (within Middle Harbour)
- Burnt Bridge Creek (a sub-catchment of Manly Lagoon)
- Bantry Bay
- Manly Creek (a sub-catchment of Manly Lagoon)
- Trefoil Creek (a sub-catchment of Narrabeen Lagoon).

Section 4.2 provides a brief description of each catchment, while Section 4.3 provides a description of the nature of main stream flooding and major overland flow in the vicinity of the project under present day (ie pre-project) conditions. Main stream flooding and major overland flow have collectively been termed 'flooding' within this technical working paper.

4.2 Catchment description

4.2.1 General

The following sections of the technical working paper provide an overview of each catchment that drains to the project corridor with information regarding key drainage features, as well as the source of flows in the existing drainage lines that cross the project.

Figure 4.1 (3 sheets) shows details of the existing drainage systems and catchment features along the project corridor, and should be referred to when reading the following sections of the report.

4.2.2 Willoughby Creek

The Willoughby Creek catchment (refer to Figure 1.4 for extent) drains in a north-easterly direction extending from the Pacific Highway in North Sydney and has a total catchment area of about 1.5 square kilometres (150 hectares) at Grafton Street. The catchment is located within the North Sydney local government area and includes the suburbs of North Sydney, Crows Nest, Neutral Bay, Cremorne and Cammeray.

The Warringah Freeway runs north–south through the middle reaches of the catchment, which predominantly comprises medium density residential development with areas of higher density residential and commercial development also present within its upper reaches. Areas of open space in the catchment include St Leonards Park, ANZAC Park, Cammeray Golf Course and Green Park. Anzac Park School is located on the western (upstream) side of the Warringah Freeway, immediately north of ANZAC Park.

A series of drainage systems comprising pipe and box culvert sections control runoff from the catchment upstream of the Warringah Freeway and converge at ANZAC Park where they discharge into twin 2000 millimetre wide by 1500 millimetre high box culverts where the drainage line crosses under the Warringah Freeway. A series of piped drainage systems that control runoff from the Warringah Freeway discharge directly into the box culvert. This drainage line continues downstream through Cammeray Golf Course as a 2500 millimetre wide by 1500 millimetre high box culvert. At Grafton Street the box culvert outlets into a steep gully in the north-east corner of Primrose Park where it runs along the northern side of the park as a grassed channel before ultimately discharging into Middle Harbour.

4.2.3 Flat Rock Creek

The Flat Rock Creek catchment (refer to Figure 1.4 for extent) drains in an easterly direction from the Pacific Highway in Artarmon and has a total catchment area of about 3.9 square kilometres (390 hectares) at Willoughby Road. The catchment is located within the Willoughby local government area and includes the suburbs of Artarmon, St Leonards, Naremburn, Willoughby, Northbridge and Cammeray.

The catchment is completely urbanised and the natural drainage characteristics have been altered by industrial, residential and commercial development. The construction of the Gore Hill Freeway in 1991 along the route of the original creek altered the natural drainage system and its flood storage characteristics. The T1 North Shore & Western Line and T9 Northern Line runs north–south through the middle reaches of the catchment.

A new trunk drainage system was constructed in conjunction with the Gore Hill Freeway, extending from the Pacific Highway to the North Shore Railway. The Gore Hill Freeway and its drainage system were later upgraded as part of the Lane Cove Tunnel project in 2006.

The trunk drainage system is piped where it runs along the southern side of Gore Hill Freeway from Marsden Street and crosses under the freeway at Hampden Road (denoted as transverse drainage structure XD_FC01 on Figure 4.1, sheet 1). Two transverse drainage structures that control runoff from the catchment to the north of the Gore Hill Freeway discharge into the trunk drainage system along this section (denoted transverse drainage structures XD_FC02 and XD_FC03 on Figure 4.1, sheet 1).

Transverse drainage structure XD_FC01 discharges into an open channel that continues along the northern side of the Gore Hill Freeway to a brick arch culvert under the North Shore Railway. Figure 4.1, sheet 1 shows two transverse drainage structures that control runoff from the southern side of Gore Hill Freeway discharge into the open channel between Hampden Road and the North Shore Railway (denoted transverse drainage structures XD_FC04 and XD_FC05).

The trunk drainage system downstream of the North Shore Railway culvert to Willoughby Road was constructed in the 1930's and was not altered by the construction of the freeway. Between the railway and Chelmsford Avenue, the trunk drainage comprises a low level conduit running beneath a vegetated floodway which caters for surcharge flows. A concrete and brick lined channel with a waterway area of 6.5 to 7.3 square metres comprises the main arm of Flat Rock Creek where it runs from Chelmsford Avenue to Willoughby Road.

As part of the trunk drainage for the Gore Hill Freeway, Artarmon Reserve was converted to a dual purpose playing field/retarding basin. The objective was to reduce the peaks of major stormwater flows which originate from the northern portion of the catchment, in order to offset the increase in peak flows generated by the freeway. The retarding basin was later modified as part of the Lane Cove Tunnel project in order to offset the impact that the widening of the Gore Hill Freeway would otherwise have had on peak flows in Flat Rock Creek.

At Willoughby Road, flows are conveyed through a stone arch bridge. During major flood events, the Willoughby Road bridge conveys flows derived from the Flat Rock catchment, as well as surcharges from one of its tributaries. A major box culvert commences at the downstream face of the bridge and runs beneath Hallstrom Park before discharging to an open channel 150 metres to the east of Flat Rock Drive.

4.2.4 Pearl Bay

The Pearl Bay catchment (refer to Figure 1.4 for extent) drains in a westerly direction, extending from the Spit Road in Mosman and has a total catchment area of about 27 hectares. The catchment is located within the Mosman local government area.

The Spit West Reserve construction support site (BL9) is proposed to be located at the northern end of the catchment within Spit West Reserve.

4.2.5 Burnt Bridge Creek

The Burnt Bridge Creek catchment (refer to Figure 1.4 for extent) drains in an easterly direction from Wakehurst Parkway and has a total catchment area of about 3.4 square kilometres (340 hectares) at Condamine Street. The catchment covers the Northern Beaches local government area and includes the suburbs of Seaforth, North Balgowlah, Balgowlah, Manly Vale and Fairlight.

Burnt Bridge Creek Deviation runs north-south from Sydney Road to Condamine Street through the middle reaches of the catchment which predominantly comprises low and medium density residential development. Commercial development is mainly located along Condamine Street and Sydney Road. Open space is predominantly located within the middle and lower reaches of the catchment and includes Balgowlah Golf Course, Manly Golf Club, Manly West Park and LM Graham Reserve.

The main arm of Burnt Bridge Creek comprises a vegetated channel that extends from Clontarf Street in the west to Condamine Street in the east and includes culvert crossings at Brook Road, Burnt Bridge Creek Deviation and Kitchener Street. The culvert crossing of Burnt Bridge Creek Deviation is denoted transverse drainage structure XD_BC01 on Figure 4.1, sheet 2 and comprises twin 3600 millimetre wide by 3600 millimetre high box culverts and twin 2400 millimetre wide by 2400 millimetre high box culverts. East (downstream) of Condamine Street the creek is drained by a box culvert that discharges into a vegetated channel that runs along the northern side of Manly West Park and through the Manly Golf Club before discharging into Manly Lagoon at Pittwater Road.

A series of piped drainage lines cross Burnt Bridge Creek Deviation between Serpentine Road and Abingdon Street (denoted transverse drainage structures XD_BC02, XD_BC03, XD_BC04 and XD_BC05 on Figure 4.1, sheet 2). The piped drainage lines control runoff from the catchment to the north of Burnt Bridge Creek Deviation and discharge into Burnt Bridge Creek along its northern bank.

4.2.6 Bantry Bay

The Bantry Bay catchment (refer to Figure 1.4 for extent) drains in a southerly direction from Warringah Road and has a total catchment area of about 4.8 square kilometres (480 hectares). Residential development is located in the upper northern and western portions of the catchment, while the Garigal National Park covers the majority of the middle and lower portions of the catchment.

The section of the project that runs along Wakehurst Parkway between Grattan Crescent and Kirkwood Street generally follows the catchment divide between Bantry Bay and Manly Creek.

Figure 4.1, sheet 2 shows the locations of three minor drainage lines (denoted as BB DL01, BB DL02 and BB DL03) which presently control runoff from a section of the Wakehurst Parkway which would be upgraded as part of the project.

4.2.7 Manly Creek

The Manly Creek catchment drains in a south easterly direction, extending from Warringah Road in the north and has a total catchment area of about 18.2 square kilometres (1820 hectares) at Manly Lagoon (refer to Figure 1.4 for extent).

Figure 4.1, sheet 3 shows that Manly Creek runs in a southerly direction to the east of Wakehurst Parkway. A series of piped crossings along Wakehurst Parkway control runoff from the residential development and nature reserve to the west of the road. The largest of these piped drainage systems comprises a 2400 millimetre wide by 1800 millimetre high box culvert and a 750 millimetres diameter pipe that are located about 140 metres south of Warringah Road, and a 1200 millimetre diameter pipe that is located immediately south of Yarraman Avenue. The piped crossings discharge into receiving drainage lines that feed into Manly Creek, the locations of which are also shown on Figure 4.1, sheet 3 (denoted MC DL01, MC DL02, MC DL03, MC DL04, MC DL05, MC DL06 and MC DL07).

Figure 4.1, sheet 2 shows the location of Manly Dam, which was originally constructed across Manly Creek in the late 1800's to supply drinking water to the local area. The dam continued to supply drinking water until 1936, after which time it became an important recreational facility for the local area and beyond. The dam has a capacity of approximately 2000 megalitres and its water body is sheltered and deep (in most parts) with a surface area of approximately 0.3 square kilometers (30 hectares).

4.2.8 Trefoil Creek

A relatively small section of the project, along Wakehurst Parkway at its connection to Frenchs Forest Road East, is located within the headwaters of the Trefoil Creek catchment, runoff from which discharges into Middle Creek. Figure 1.4 shows the extent of the Trefoil Creek catchment, which is about 0.97 square kilometres (97 hectares) at its confluence with Middle Creek.

Trefoil Creek is fed by several piped drainage systems which discharge to the steep sided valley to the east of Wakehurst Parkway and north of Frenchs Forest Road East. These piped drainage systems control runoff from sections of Frenchs Forest Road East, Wakehurst Parkway and Bantry Bay Road, as well as the north east portion of the Northern Beaches Hospital.

4.3 Description of existing flooding and drainage behaviour

4.3.1 General

The following sections of the technical working paper provide a brief description of patterns of both main stream flooding and major overland flow under present day (ie pre-project) conditions in the vicinity of both the construction and operational components of the project. Reference is made in the following discussion of the proposed construction support sites, details of which are set out in Section 5 of this technical working paper. The following figures are also referred to in the following discussion:

- Figures 4.2, 4.3 and 4.4 (ten sheets each) show the indicative extent and depth of inundation in the vicinity of the project footprint for a 10% and 1% AEP design storm, as well as the PMF event, respectively
- Figures 4.5 and 4.6 (ten sheets each) show the preliminary hydraulic categorisation and provisional hazard of land for a 1% AEP storm event, respectively
- Figure 4.7 (ten sheets) shows the extent of the flood planning area which has been defined as land which lies below the 1% AEP flood level plus 0.5 metres
- Annexure A contains a series of figures showing maximum flow velocities and durations of inundation in the vicinity of the proposed tunnel portal, bridge and road surface works north of Sydney Harbour for design storms with AEPs of 10% and 1%. This data have principally been used to assess the impact that the project would have on flow velocities (and hence scour potential) and durations of inundation
- Annexure B contains a series of figures that show patterns of main stream flooding and major overland flow in the vicinity of the proposed tunnel portal, bridge and road surface works north of Sydney Harbour for design storms with AEPs of 0.5% and 0.2%, noting that these two storm events have been used as proxies for assessing the impact that the project would have on flood behaviour under potential future climate change conditions (refer to Section 6.3 for further details)
- Table 6.3 in Section 6 contains a table which sets out the peak flows in the receiving drainage lines which control runoff along the section of the Wakehurst Parkway which would be upgraded as part of the project for design storms with AEPs of 50%, 10% and 1%.[3] The locations where peak flows are quoted are shown on Figures 4.2 and 4.3 (sheets 7, 8, 9 and 10).

Flood behaviour has been defined using the hydrologic and hydraulic models that were developed as part of the studies listed in Table 3.1, with minor changes made to the latter in order to improve the definition of flooding patterns within the extent of the project surface works footprint.

[3] Note that the peak flows set out in Table 6.3 at the end of Section 6 were derived from the hydrologic (DRAINS) model that was developed as part of the present study, not the models that were developed as part of WMA (2018).

4.3.2 Willoughby Creek

Up to 1% AEP

During a 10% AEP event, flow would surcharge the trunk drainage system that forms the main arm of Willoughby Creek and overtop the sag in Ernest Street to the east of Lytton Street to a maximum depth of about 0.5 metres, increasing to 0.7 metres during a 1% AEP. Existing residential development located on the southern side of Ernest Street is also affected by flooding due to surcharge of the trunk drainage system. The main flow path which runs between St Leonards Park and ANZAC Park principally operates as a low hazard floodway, although high hazard areas are located in the vicinity ANZAC Park, principally due to the depth of ponding that occurs in this area.

Flow that surcharges the tributary branch of Willoughby Creek that runs between Miller Street and Anzac Avenue along the northern boundary of Anzac Park Public School would overtop Anzac Avenue to a maximum depth of about 0.2 metres during a 10% AEP event, increasing to 0.5 metres during a 1% AEP event.

Overland flow from Ernest Street and Anzac Avenue would collect at the low point in ANZAC Park before entering the trunk drainage system that runs under the Warringah Freeway. The depth of ponding in ANZAC Park would occur to a maximum of 2.1 metres and 3.5 metres during a 10% and 1% AEP event, respectively, which is sufficient to result in hazardous flooding conditions to persons and property.

Floodwaters that collect in ANZAC Park would pond against the noise wall that runs along the western side of the Warringah Freeway to a maximum depth of about three metres during a 1% AEP event. If the noise wall were to fail under this weight of water then floodwater would inundate the Miller Street off-ramp to a maximum depth of about two metres and would also extend across the northbound carriageways of the freeway.

During a 1% AEP storm event, a low and high hazard floodway would form to the north (downstream) of the road corridor in Cammeray Golf Course. The floodway area also extends east into existing residential development which is located along Fall Street and Grafton Street.

PMF

Floodwaters that collect in ANZAC Park would build up to a level that overtops the noise wall that runs along the western side of the Warringah Freeway, where it would pond across the full width of the freeway before surcharging across its eastern side and into Cammeray Golf Course.

ANZAC Park would be inundated to a maximum depth of seven metres, while the carriageways of the Warringah Freeway would be inundated over a length of about 350 metres and to a maximum depth of five metres. The flood walls associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate environmental impact assessment and approval) would prevent the ingress of floodwater to the road tunnels for events up to the PMF.

4.3.3 Flat Rock Creek

Up to 1% AEP

During a 10% AEP event flow in excess of the capacity of the existing stormwater drainage system (transverse drainage structure XD_FC1) would pond in the cul-de-sac of George Place to a maximum depth of about 1 metre. During a 1% AEP event, flow would pond to a maximum depth of 1.5 metres before discharging in a south-easterly direction through the adjoining industrial development and onto the eastbound carriageway of the Gore Hill Freeway.

The eastbound carriageway of the Gore Hill Freeway acts as an overland flowpath during a 1% AEP event, conveying flows that surcharge transverse drainage structures XD_FC1 and XD_FC2 in the vicinity of George Place and Reserve Road. Depths of overland flow would typically be less than 0.2 metres, but could reach up to 0.4 metres at two locations.

During a 10% AEP event, flow that surcharges the trunk drainage system in McLachlan Avenue travels in an easterly direction along the shared bicycle path to the south of the Gore Hill Freeway before discharging onto the westbound carriageway north of Hotham Street.

The westbound carriageway of the Gore Hill Freeway acts as an overland flowpath during a 1% AEP event, conveying flow that surcharges the drainage systems in McLachlan Avenue, Hotham Parade and Whiting Street. Flow along the eastbound carriageway collects at the sag below the Reserve Road overpass and ponds to a maximum depth of 0.7 metres before continuing in a southerly direction.

During a 1% AEP event, flow that surcharges transverse drainage structures XD_FC3, XD_FC4 and XD_FC5 also contributes to overland flow travelling east along the eastbound carriageway of the Gore Hill Freeway.

PMF

The main carriageways and various entry and exit ramps of the Gore Hill Freeway are inundated by floodwater that discharges from the north at George Place, Reserve Road, and Simpson Street, and from the south at McLachlan Avenue, Hotham Parade Whiting Street, Herbert Street and Punch Street.

While the majority of flow that discharges from George Place is conveyed in an easterly direction along the eastbound carriageway, a portion of this flow discharges onto the central carriageways where it enters the Lane Cove Tunnel.

Similarly, while the majority of flow that discharges from McLachlan Avenue is conveyed in an easterly direction along the westbound carriageway, a portion of the flow discharges onto the central carriageways where it would enter the Lane Cove Tunnel.

The section of Gore Hill Freeway between Reserve Road and the North Shore Railway is inundated across its full width. Depths of flow are typically 1.2 metres or less, but would reach a maximum of 1.8 metres at one location.

Flood levels upstream (west) of the T1 North Shore & Western Line and T9 Northern Line are controlled by the rail underpass, which constricts overland flow travelling along the Gore Hill Freeway.

4.3.4 Pearl Bay

The area of Spit West Reserve where the Spit West Reserve construction support site (BL9) is proposed to be located would be inundated by overland flow that is conveyed along the southbound carriageway of Spit Road and discharges into the reserve via the carpark entry from Spit Road for events up to the PMF.

4.3.5 Burnt Bridge Creek

Up to 1% AEP

The existing culvert crossing of Burnt Bridge Creek at Burnt Bridge Creek Deviation (refer to transverse drainage structure XD_BC1 on Figure 4.3, sheet 6) has a hydrologic standard in excess of 1% AEP under ideal flow conditions.

While flow would generally be confined to the incised valley through which Burnt Bridge Creek runs between Brook Road and Kitchener Street, residential development that is located on the southern overbank of the creek in Brook Road, Hope Street and Burnt Bridge Creek Deviation would be inundated by floodwater during a 1% AEP event.

Flow that surcharges transverse drainage structures XD_BC2, XD_BC3 XD_BC4 and XD_BC5 would pond behind the noise wall that runs along the western side of Burnt Bridge Creek Deviation between Serpentine Crescent and Kitchener Street, with a portion of this flow discharging onto Burnt Bridge Creek Deviation via openings which are present in the noise wall adjacent to Kitchener Street during a 10% AEP event.

Flow would overtop the western bank of Burnt Bridge Creek immediately upstream of Kitchener Street and discharge onto the southbound carriageway of Burnt Bridge Creek Deviation during a 10% AEP event.

PMF

Flow in excess of transverse drainage structure XD_BC1 overtops Burnt Bridge Creek Deviation to a maximum depth of about one metre. A portion of this flow re-enters Burnt Bridge Creek to the east of the road corridor, while the remaining flow travels in a northerly direction along both the northbound and southbound carriageways.

Flow that surcharges transverse drainage structures XD_BC2, XD_BC3 XD_BC4 and XD_BC5 would pond behind the noise wall that runs along the western side of Burnt Bridge Creek Deviation before discharging onto the road in the vicinity of the Kitchener Street bridge.

Flow would overtop the western bank of Burnt Bridge Creek immediately upstream of Kitchener Street where it discharges onto both the northbound and southbound carriageways of Burnt Bridge Creek Deviation. The depth of flow along Burnt Bridge Creek Deviation would reach a maximum of about two metres in the vicinity of the Kitchener Street bridge.

4.3.6 Bantry Bay

The section of Wakehurst Parkway between Grattan Crescent and Kirkwood Street generally follows the catchment divide between Manly Creek and Bantry Bay and therefore is not affected by mainstream flooding or major overland flow.

4.3.7 Manly Creek

Up to 1% AEP

During a 1% AEP event, flow that surcharges the piped drainage system in Wakehurst Parkway at its intersection with Warringah Road would inundate the road to relatively shallow depths that are typically 0.1 metres or less.

Flow that discharges from the drainage system at the northern end of Bantry Bay Road would pond at the inlet of the 1050 millimetre diameter pipe that crosses Wakehurst Parkway about 140 metres south of Warringah Road. During a 1% AEP flow would pond at the inlet to a maximum depth of over two metres but would not surcharge onto the road.

During a 1% AEP event, flow that surcharges the two pipe crossings of Wakehurst Parkway between Garner Avenue and Yarraman Avenue would inundate the road to depths that are typically 0.2 metres or less.

Flow that discharges from the drainage system at the eastern end of Yarraman Avenue would pond at the inlet of the 1200 millimetre diameter pipe that crosses Wakehurst Parkway immediately to its south. During a 1% AEP event, flow would pond at the inlet to a maximum depth of over two metres but would not surcharge onto the road.

PMF

While the hydraulic model developed as part of WMA (2018) for the PMF event has been configured in a way that applied inflows downstream of Wakehurst Parkway and therefore does not show flooding to the road corridor or any of the areas upstream, flow would inundate Wakehurst Parkway at the locations described above to a greater depth during more extreme storm events.

4.3.8 Trefoil Creek

The section of the project along Wakehurst Parkway that is located within the Trefoil Creek catchment is not impacted by mainstream flooding or major overland flow.

Wakehurst Parkway was recently upgraded as part of the Northern Beaches Network Connectivity and Enhancements project. Figure 4.1, sheet 10, shows the layout of the upgraded drainage system along Wakehurst Parkway, which has been designed to control runoff from the local catchment during storms up to 10% AEP in magnitude. During a 1% AEP event overland flow would occur along the kerbside lanes of Wakehurst Parkway due to surcharge of the drainage system.

5 ASSESSMENT OF CONSTRUCTION IMPACTS

This section provides an assessment of the flood risk at the proposed construction support sites which are associated with the construction of the project:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

This section also provides an overview of the potential impacts that the proposed construction activities could have on flood behaviour. A range of potential measures aimed at managing the flood risk and mitigating the impact of construction activities on flood behaviour are discussed in Section 8.

5.1 Potential flood risks at construction support sites

Without the implementation of appropriate management measures, the inundation of the construction support sites by floodwater has the potential to:

- Cause damage to the project works and delays in construction programming
- Pose a safety risk to construction workers
- Detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- Obstruct the passage of floodwater and overland flow through the provision of temporary measures such as site sheds, stockpiles, noise walls and flood protection walls, which in turn could exacerbate flooding conditions in existing development located outside the construction footprint.

Table 5.1 provides a summary of the proposed activities, as well as the assessed flood risk at the construction support sites that are associated with the construction of the project. Figure 5.1 (10 sheets) shows the extent to which floods of varying magnitude affect each construction support site, while Figure 5.2 (6 sheets) shows the indicative depth and extent of inundation in their vicinity for floods with AEPs of 10% and 1%. Figure 5.3 (6 sheets) shows the provisional flood hazard and preliminary hydraulic categorisation of the floodplain in the vicinity of each construction support site for a 1% AEP flood event. Further details of each construction support site and its associated facilities and activities is provided in Chapter 6 (Construction work) of the environmental impact statement.

5.1.1 Construction support site facilities

A range of site facilities including offices, staff amenities, workshops and parking are proposed at the construction support sites that are associated with the project, with the exception of the Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8), which are located on Middle Harbour.

With the exception of the Gore Hill Freeway median (BL6), Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites, all of the locations that have been identified for the proposed construction support sites are affected by flooding, whether that is as a result of main stream flooding, overland flow or ocean storm tides (refer to Table 5.1).

While the majority of the construction support sites would be subject to flooding during a 10% AEP storm event, depths of inundation are generally relatively shallow and of a short duration. The exception is the Flat Rock Drive construction support site (BL2), where depths of flow are greater than 0.5 metres in a 10% AEP flood event. Elevated water levels in Middle Harbour could also result in the partial inundation of the Spit West Reserve construction support site (BL9).

Site facilities located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would therefore be necessary to locate site facilities outside high hazard areas with safe evacuation routes. All construction support sites include land that is located outside areas of high hazard that would be suitable for site facilities.

5.1.2 Spoil management and stockpile areas

The construction of the project would generate a significant amount of spoil which would need to be temporarily stored in stockpile areas. Stockpiles for tunnel excavation would be all within acoustic sheds or underground within the excavated tunnel areas. Stockpiles would be located at Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Dickson Avenue (BL4), Balgowlah Golf Course (BL10), Wakehurst Parkway south (BL12), and Wakehurst Parkway Upgrade sites. Details on stockpiles associated with surface works are outlined in Chapter 24 (Resource use and waste management) on the environmental impact statement.

Stockpiles located on the floodplain have the potential to obstruct floodwater and alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into the receiving drainage lines and waterways.

While the majority of these sites are affected by flooding to varying degrees (refer to Table 5.1), there would typically be suitable areas outside the 10% AEP flood extent that could be used to stockpile material.

5.1.3 Tunnel excavation

Tunnel excavation would be supported from the Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites. A description of the likely tunnel excavation process is provided in Chapter 6 (Construction) of the environmental impact statement. The operation of the roadheaders would involve the use of pumps at the tunnel low points, and potentially mobile sumps at the cutting

face to collect tunnelling water, groundwater ingress and stormwater runoff from the tunnel openings. The Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites would include a temporary water treatment plant to treat water that is collected in the tunnel during construction.

While the tunnel excavation arrangement would be designed to accommodate a nominal amount of stormwater runoff, the potential for the ingress of floodwater to the tunnel excavations during their construction poses a safety risk to construction workers. It also has the potential to cause damage to machinery and delays in the project timetable if not adequately managed.

The flood standard adopted at each tunnel opening during construction would need to be developed during detailed design, taking into consideration the duration of construction, the magnitude of potential inflows and the potential risks to the project works and personnel. Protection of the tunnel entries during construction through the provision of physical barriers, for example, would also need to be designed so as not to exacerbate flood behaviour in adjacent development. Section 5.2 provides an assessment of the potential impacts of the proposed tunnel construction on existing flood behaviour, while Section 8 sets out measures which could be implemented to mitigate the impact of tunnelling activities on flood behaviour.

5.1.4 Construction of cut-and-cover structures

The construction of cut and cover structures would be carried out at the Cammeray Golf Course (BL1), Punch Street (BL3), Dickson Avenue (BL4), Balgowlah Golf Course (BL10) and Wakehurst Parkway south (BL12) construction support sites. Similar to the construction of the driven tunnels, the potential for ingress of floodwater into the open excavations poses a significant risk to personal safety, as well as having the potential to cause damage to machinery and delays to the project timetable.

The ability for floodwater which ponds in ANZAC Park in the Willoughby Creek catchment to discharge on Warringah Freeway in the vicinity of the proposed cut and cover sections of tunnel is constrained by the presence of the solid noise wall which runs along its southern side. Any leakage of floodwater through the noise wall could potentially cause flooding of the freeway in the vicinity of the cut and cover sections of tunnel. Furthermore, once overtopping of the noise wall occurs (for example in a PMF event), then the depth of inundation in the vicinity of the cut and cover sections of tunnel would exceed 1 metre.

Stormwater which surcharges the existing stormwater drainage system to the south of the Gore Hill Freeway in the Flat Rock Creek catchment has the potential to impact cut and cover operations which form part of the Gore Hill Freeway Connection project.

Stormwater which surcharges the existing stormwater drainage system to the west of Burnt Bridge Creek Deviation in the Burnt Bridge Creek catchment has the potential to impact cut and cover operations which form part of the Beaches Link project.

The provision of temporary barriers in combination with the permanent solid barriers/flood walls which are proposed around the trough structures would need to be provided to prevent floodwater from entering the open excavations at the above locations.

Cut and cover operations at Wakehurst Parkway are not subject to flooding due to the road being located along a natural ridgeline.

Section 5.2 provides an assessment of the potential impacts of the proposed construction of the cut and cover structures on existing flood behaviour, while Section 8 sets out measures which could be implemented to mitigate the impact of tunnelling activities on flood behaviour.

5.1.5 Surface earthworks

While surface earthworks are associated with activities within the confines of most construction support sites, the main areas of surface earthworks are associated with the Gore Hill Freeway Connection project, as well as the upgrades of Burnt Bridge Creek Deviation and Wakehurst Parkway.

Surcharge of the existing drainage along the Gore Hill Freeway occurs during a 1% AEP, when the depth of flow along the northern and southern sides of the freeway exceed about 0.3 metres.

While floodwater is generally confined to the inbank area of Burnt Bridge Creek and its immediate overbank area in the vicinity of the project, several major overland flow paths develop during storms which result in the surcharge of the existing stormwater drainage system.

As Wakehurst Parkway generally runs along the top of a natural ridge line, it is not subject to flooding. Rather, the road corridor is impacted by surface runoff which is generated by a number of relatively small catchments which are located on its eastern and western sides.

The inundation of the surface earthworks by floodwater has the potential to cause scour of disturbed surfaces and the transport of sediment and construction materials into the receiving waterways. It would therefore be necessary to plan, implement and maintain measures which are aimed at managing the diversion of floodwater either through or around the construction areas (refer to Section 8 for further details).

5.1.6 Bridge construction

New bridge works are limited to the pedestrian bridge and shared user bridge upgrade at Wakehurst Parkway, the construction of which would be managed from the Wakehurst Parkway north construction support site (BL14).

The proposed pedestrian and shared user bridges along Wakehurst Parkway are not at risk of being flooded during construction.

5.2 Potential impacts of construction activities on flood behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both present day and operational conditions. This is because the construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures outside the operational project footprint which would be removed following the completion of construction activities.

A qualitative assessment was carried out of the potential impacts construction activities could have on flood behaviour, the key findings of which are summarised in Table 5.1.

While the majority of the construction support sites would involve works within the floodplain that would need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with the Balgowlah Golf Course construction support site (BL10) and the adjacent new and improved open space and recreation facility works. There is also the potential for all construction activities to impact local catchment runoff, which would require appropriate local stormwater management controls to be implemented during the construction phase of the project.

Without mitigation the construction of the project has the potential to result in changes in flood behaviour that may result in social and economic cost impacts to the community by exacerbating the impact of flooding to property and infrastructure as well as disruption to the community.

While the findings of the assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be carried out during detailed design, as layouts and staging diagrams are further developed. Consideration would also need to be given to setting an appropriate hydrologic standard for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature and therefore the likelihood of a flood of a given AEP occurring during the construction period.

Prior to construction, measures which are aimed at mitigating the impacts of construction activities on flood behaviour would be investigated. A range of measures which will be implemented to mitigate the potential construction related impacts of the project are outlined in Section 8.

Table 5.1
Summary of assessed flood risks and potential impacts associated with proposed construction support sites

Construction support site	Catchment	Threshold of flooding[1]	Proposed construction activities[2]					Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil management[4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks		
Cammeray Golf Course (BL1)	Willoughby Creek	PMF	✓	✓	✓	✓	✓	• Refer to figures 5.1 (sheet 2), 5.2 (sheet 1) and 5.3 (sheet 1) • Cammeray Golf Course construction support site (BL1) would be subject to very shallow sheet flow during heavy rainfall events, principally due to runoff generated from within its extent Overland flow discharging through the Cammeray Golf Course construction support site (BL1) during storms up to 1% AEP in intensity is classified as low hazard flood fringe • During a PMF event, floodwater would surcharge the Warringah Freeway where it would discharge through the Cammeray Golf Course construction support site (BL1) at depths of up to 0.5 m.	• If appropriate connections to existing trunk drainage system are not incorporated into the design of the project, then the provision of hard stand areas within the confines of the Cammeray Golf Course construction support site (BL1) has the potential to exacerbate flooding conditions in existing residential development that is located along Warringa Road, Falls Street, Cammeray Road and Grafton Street • Construction activities within the confines of the Cammeray Golf Course construction support site (BL1) have the potential to obstruct flow which surcharges the Warringah Freeway during a PMF, thereby exacerbating flooding conditions in existing development that is located on the western side of the freeway • Floodwater originating from ANZAC Park, as well as from within the Warringah Freeway corridor has the potential to impact tunnel works that are proposed adjacent to Cammeray Golf Course.

Construction support site	Catchment	Threshold of flooding[1]	Proposed construction activities[2]					Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil management[4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks		
Flat Rock Drive (BL2)	Flat Rock Creek	More frequent than 10% AEP	✓	✓	✓		✓	• Refer to figures 5.1 (sheet 3), 5.2 (sheet 1) and 5.3 (sheet 1) • The Flat Rock Drive construction support site (BL2) would be subject to flooding during storms more frequent than 10% AEP • Flooding occurs in the south-west corner of the Flat Rock Drive construction support site (BL2) during storms which result in the surcharge of the existing transverse drainage of Flat Rock Drive • The Flat Rock Drive construction support site (BL2) also spans an incised natural watercourse which drains from the north.	• Changes in natural surface levels within the confines of the Flat Rock Drive construction support site (BL2) have the potential to alter flooding patterns in the area, which in turn could impact on construction activities, as well as the hydrologic standard of Flat Rock Drive • Flooding has the potential to impact the covered section of the decline and the spoil shed, both of which are located across the incised natural watercourse which drains from the north • Construction activities within the Flat Rock Drive construction support site (BL2) would not have an impact on flood behaviour in existing development.
Punch Street (BL3)	Flat Rock Creek	More frequent than 10% AEP	✓	✓	✓	✓	✓	• Refer to figures 5.1 (sheet 4), 5.2 (sheet 2) and 5.3 (sheet 2) • Shallow overland flow discharges in a northerly direction along Lambs Road which it is intercepted by a series of kerb inlet pits that are located at the eastern end of Punch Street.	• Alterations to existing road levels to facilitate access to the Punch Street construction support site (BL3) has the potential to cause minor flooding within the proposed spoil shed and incline • Due to the topography in the area, activities within the Punch Street construction support site (BL3) would not have an impact on flood behaviour in adjacent residential development.

Construction support site	Catchment	Threshold of flooding[1]	Proposed construction activities[2]					Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil management[4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks		
Dickson Avenue (BL4)	Flat Rock Creek	More frequent than 10% AEP	✓	✓	✓	✓	✓	• Refer to figures 5.1 (sheet 4), 5.2 (sheet 2) and 5.3 (sheet 2) • Parts of the Dickson Avenue construction support site (BL4) are subject to relatively shallow sheet flow during storms which result in the surcharge of the existing stormwater drainage system.	• Due to the relatively shallow nature of the flow, activities within the confines of the Dickson Avenue construction support site (BL4) would not have an impact on flood behaviour in adjacent commercial and industrial development.
Barton Road (BL5)	Flat Rock Creek	Less frequent than 1% AEP	✓				✓	• Refer to figures 5.1 (sheet 4), 5.2 (sheet 2) and 5.3 (sheet 2) • The Barton Road construction support site (BL5) is subject to relatively shallow overland flow during very rare and extreme storm events.	• Due to the relatively shallow nature of the flow, activities within the Barton Road construction support site (BL5) would not have an impact on flood behaviour in adjacent residential development.
Gore Hill Freeway median (BL6)	Flat Rock Creek	Not flooded	✓				✓	• Refer to figures 5.1 (sheet 4), 5.2 (sheet 2) and 5.3 (sheet 2) • The Gore Hill Freeway median construction support site (BL6) is generally flood free.	• Activities within the Gore Hill Freeway median construction support site (BL6) would not have an impact on flood behaviour in adjacent residential development.
Middle Harbour south cofferdam (BL7)	-	Potentially subject to wave action during elevated water levels in Middle Harbour			✓		✓	• Refer to figures 5.1 (sheet 5), 5.2 (sheet 3) and 5.3 (sheet 3) • Flooding of the Middle Harbour south cofferdam construction support site (BL7) is principally limited to elevated water levels in Middle Harbour • Wave action due to coincident high winds could exacerbate flooding conditions at the Middle Harbour south cofferdam	• Activities within the confines of the Middle Harbour south cofferdam construction support site (BL7) would not have an impact on water levels in Middle Harbour.

Construction support site	Catchment	Threshold of flooding[1]	Proposed construction activities[2]					Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil management[4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks		
								construction support site (BL7) during periods of elevated water levels in Middle Harbour.	
Middle Harbour north cofferdam (BL8)	-	Potentially subject to wave action during elevated water levels in Middle Harbour			✓		✓	• Refer to figures 5.1 (sheet 5), 5.2 (sheet 3) and 5.3 (sheet 3) • Flooding of the Middle Harbour north cofferdam construction support site (BL8) is principally limited to elevated water levels in Middle Harbour • Wave action due to coincident high winds could exacerbate flooding conditions at the Middle Harbour north cofferdam (BL8) construction support site during periods of elevated water levels in Middle Harbour.	• Activities within the confines of the Middle Harbour north cofferdam construction support site (BL8) would not have an impact on water levels in Middle Harbour.
Spit West Reserve (BL9)	-	Potentially subject to wave action during elevated water levels in Middle Harbour	✓	✓	✓			• Refer to figures 5.1 (sheet 5), 5.2 (sheet 4) and 5.3 (sheet 4) • Flooding of the Spit West Reserve construction support site (BL9) is principally limited to elevated water levels in Middle Harbour • Wave action due to coincident high winds could exacerbate flooding conditions at the Spit West Reserve construction support site (BL9) during periods of elevated water levels in Middle Harbour.	• Activities within the confines of the Spit West Reserve construction support site (BL9) would not have an impact on water levels in Middle Harbour.
Balgowlah Golf Course (BL10)	Burnt Bridge Creek	More frequent	✓	✓	✓	✓	✓	• Refer to figures 5.1 (sheet 6), 5.2 (sheet 5) and 5.3 (sheet 5)	• Activities within the extent of the Balgowlah Golf Course construction

Construction support site	Catchment	Threshold of flooding[1]	Proposed construction activities[2]					Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil management[4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks		
		than 10% AEP						• The Balgowlah Golf Course construction support site (BL10) is impacted by major overland flow which discharges through Balgowlah Oval from Sydney Road • Flooding is of low hazard nature along the major overland flow path which forms in Balgowlah Golf Course.	support site (BL10) have the potential to impact flood behaviour along Sydney Road and in adjoining parts of the golf course • Activities external to the construction support site have the potential to impact flood behaviour in existing development that is located immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek and along the eastern side of the Balgowlah Golf Course.
Kitchener Street (BL11)	Burnt Bridge Creek	More frequent than 10% AEP	✓	✓				• Refer to figures 5.1 (sheet 6), 5.2 (sheet 5) and 5.3 (sheet 5) • While the Kitchener Street construction support site (BL11) is located on land which generally lies above peak 1% AEP flood levels, it would be subject to shallow inundation during extreme storm events.	• Activities within the extent of the Kitchener Street construction support site (BL11) would have a minimal effect on flood behaviour.
Wakehurst Parkway south (BL12)	Manly Creek and Bantry Bay	Not flooded	✓	✓		✓	✓	• Refer to figures 5.1 (sheet 7), 5.2 (sheet 6) and 5.3 (sheet 6) • The Wakehurst Parkway south construction support site (BL12) is not subject to flooding.	• The provision of hard stand areas within the confines of the Wakehurst Parkway south construction support site (BL12) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the adjacent bushland and golf course.

Construction support site	Catchment	Threshold of flooding[1]	Proposed construction activities[2]					Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil management[4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks		
Wakehurst Parkway east (BL13)	Bantry Bay	Not flooded	✓	✓	✓		✓	• Refer to figures 5.1 (sheet 8), 5.2 (sheet 6) and 5.3 (sheet 6) • The Wakehurst Parkway east construction support site (BL13) is not subject to flooding.	• The provision of hard stand areas within the confines of the Wakehurst Parkway east construction support site (BL13) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the adjacent bushland and Wakehurst Parkway Golf Course.
Wakehurst Parkway north (BL14)	Manly Creek	Not flooded	✓	✓			✓	• Refer to figures 5.1 (sheet 10), 5.2 (sheet 6) and 5.3 (sheet 6) • The Wakehurst Parkway north construction support site (BL14) is not subject to flooding.	• The provision of hard stand areas within the confines of the Wakehurst Parkway north construction support site (BL14) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the pavement drainage system of Warringah Road.

Notes:

1 The assessed threshold of flooding is based on present day conditions

2 Refer to Section 5 for a description of flood risks associated with each construction activity

3 Site facilities include site offices, staff amenities, stores and laydown, workshops, temporary substations and parking

4 Spoil management includes stockpiling and treatment of excavated material.

6 ASSESSMENT OF OPERATIONAL IMPACTS

This section provides an assessment of the flood risk to the project and the impact it would have on flood behaviour during operation. The findings of an assessment into the potential impact of future climate change and impacts of a partial blockage of the local stormwater drainage system on flood behaviour under operational conditions are also presented.

While the project incorporates measures that are aimed at mitigating the impact that it would have on flood behaviour, there are a number of residual impacts that would need to be investigated during further design development. This section identifies and describes the nature of the residual impacts, while a range of potential measures which are aimed at managing the flood risk and further mitigating the residual impacts of the project on flood behaviour are discussed in Section 8.

6.1 Potential flood risk to the project and its impacts on flood behaviour

Figures 6.1, 6.2 and 6.3 (7 sheets each) show flood behaviour in the vicinity of the proposed tunnel portal, bridge and surface road works for design storms for the 10% AEP, 1% AEP and PMF events respectively, while Table 6.1 at the end of this section summarises the assessed flood risk at the various project components and the recommended level of flood protection based on the adopted hydrologic standards outlined in Section 2.5.

6.1.1 Tunnel portals

While a series of measures have been incorporated into the design of the project which would prevent the ingress of floodwater to the proposed tunnels for events up to the PMF, a sensitivity analysis identified that there is the potential for floodwater to enter the tunnel system via the Gore Hill Freeway and Burnt Bridge Deviation portals should the stormwater drainage system experience a partial blockage during an extreme storm event. Further details of the sensitivity analysis, including the recommendation for a risk based assessment to be undertaken during detailed design are set out in Section 6.6.

The existing stormwater drainage system would also be upgraded as part of the project so as to divert local catchment runoff around the proposed trough structures.

6.1.2 Road bridges

The existing road bridges that would be upgraded as part of the project are all high level structures that would only be subject to relatively shallow sheet flow during storms which surcharge the pavement drainage system.

6.1.3 Pedestrian and shared user bridges

The two proposed bridges over the Wakehurst Parkway are high level structures that would not be subject to flooding.

6.1.4 Surface road works

<u>Willoughby Creek Catchment</u>

Major flooding of the Warringah Freeway during storms up to 1% AEP in intensity is prevented by the presence of a continuous solid concrete noise wall which runs along the northern side of ANZAC Park. Depths of ponding in ANZAC Park would increase from a maximum of about two metres during a 10% AEP storm event to a maximum of about 3.2 metres during a 1% AEP storm event.

Overtopping of the noise wall would occur during a PMF event, when floodwater would pond to a maximum depth of about five metres and extend across the full width of the Warringah Freeway.

Flat Rock Creek Catchment

Flooding of the surface road works during storms up to 1% AEP in intensity would occur at the location where both the Gore Hill Freeway westbound off ramp to Epping Road and Pacific Highway, and the Gore Hill Freeway eastbound entry ramp to the Beach Link Tunnel runs under Reserve Road. Depths of ponding across the westbound and eastbound lanes of the Gore Hill freeway at these two locations would exceed 1 metre and 0.6 metres, respectively, during a 1% AEP storm event.

Floodwater which ponds across the Gore Hill Freeway eastbound entry ramp to the Beaches Link Tunnel would eventually reach a depth where it would commence to flow in a southerly direction beneath the Reserve Road eastbound on ramp to the Gore Hill Freeway via a new bridge structure, where it would discharge onto the eastbound carriageway of the Lane Cove Tunnel. Flow discharging onto the eastbound carriageway of the Lane Cove Tunnel at this location would discharge in an easterly direction where it would gradually be intercepted by the new pavement drainage system.

Burnt Bridge Creek Catchment

While the surface road works would be subject to relatively shallow sheet flow as a result of stormwater which surcharges the existing pavement drainage system to the south of the crossing of Burnt Bridge Creek, greater depths of inundation would be experienced to the north of the tunnel portals as a result of flow which surcharges both the existing and proposed stormwater drainage system. Floodwater would also discharge onto Burnt Bridge Creek Deviation at the location of the Burnt Bridge Creek crossing during storms that are more intense than about 0.2% AEP.

It is noted that Burnt Bridge Creek Deviation is subject to flooding immediately to the north of the project as a result of floodwater which surcharges Burnt Bridge Creek during storms that are more frequent than 1% AEP.

Trefoil Creek, Manly Creek and Bantry Bay Catchments

Inundation of the Wakehurst Parkway during storms up to 1% AEP in intensity would be limited to flow which surcharges the new pavement drainage system given the road generally follows the natural divide between the Manly Creek and Bantry Bay catchments.

6.1.5 Tunnel support facilities

Finished ground levels would be raised above the level of the PMF at the location of the tunnel support facilities that would be constructed as part of the project.[1]

6.1.6 Motorway control centre

The motorway control centre that is proposed at the Gore Hill Freeway in the Flat Rock Creek catchment is located on land which generally lies above the level of the PMF. Provision has been

[1] While the finished ground level at the location of the Beaches Link tunnel support facilities has been set above the PMF level on Burnt Bridge Creek, the area is potentially subject to major overland flow which approaches it from the south. Measures would therefore need to be incorporated into the design of the project to divert this flow around the tunnel support facility.

incorporated into the design of the motorway control centre to prevent the ingress of floodwater to the building for events up to the PMF.

6.2 Potential Impacts of the project on flood behaviour

Figures 6.4, 6.5 and 6.6 (4 sheets each) show the impact that the project would have on extent and depth of inundation for design storms for the 10% AEP, 1% AEP and PMF events respectively, while Figure 6.7 (5 sheets) shows the extent of new road pavement which has been assumed to contribute to flow in the receiving drainage lines that are located along the upgraded section of the Wakehurst Parkway.[1]

Annexure A contains a set of figures showing maximum flow velocities and duration of inundation under present day and operational conditions for 10% and 1% AEP storm events, while Annexure B contains a set of figures showing flood behaviour under present day and operational conditions for 0.5% and 0.2% AEP storm events.

Table 6.2 at the end of this section summarises the potential impacts that the project would have on flood behaviour, while Table 6.3 shows the change in peak flow which would be attributable to the project in the receiving drainage lines that are located along the Wakehurst Parkway absent any mitigation measures for storms up to 1% AEP in intensity.

Given the minor impact that the project would have on flood behaviour under operational conditions, it is not expected that changes in flooding patterns would result in significant change to the social and economic costs of flooding.

6.2.1 External to road corridor

6.2.1.1 Storms up to 1% AEP in Intensity

The project would generally result in a neutral or beneficial effect on flood behaviour external to the road corridor for storm events up to 1% AEP in intensity, with the following exceptions:

Burnt Bridge Creek Catchment

- Along the main arm of Burnt Bridge Creek downstream of the Kitchener Street bridge where peak 10% flood levels would be increased at six residential properties in the range 10-50 millimetres.

Bantry Bay Catchment

- While peak flows could potentially be increased in receiving drainage line BB DL01 (refer comparison of flows set out in Table 6.3 at the end of Section 6), there is no existing development that would be impacted by the change in flow regime.

[1] Note that the figures which show the impact that the project would have on flood behaviour identify changes in flood behaviour at a number of locations that are remote from the proposed works. These impacts are considered to be an artefact of the flood model and are deemed not to be a result of the project.

Manly Creek Catchment

- While peak flows could potentially be increased in receiving drainage lines MC DL01, MC DL04 and MC DL07, there is no existing development other than the Wakehurst Golf Course and Aquatic Reserve that would be impacted by the change in flow regime.

  Increases in the rate and volume of runoff discharging to receiving drainage line MC DL01 has the potential to cause prolonged inundation of parts of the Wakehurst Golf Course during periods of heavy rain.

  Increases in the rate of runoff discharging to MC DL07 has the potential to increase the frequency of surcharge of the existing stormwater drainage system which runs across Aquatic Drive and under Aquatic Reserve, thereby increasing the frequency and depth of overland flow that is experienced across the road and in the reserve during periods of heavy rain.

The project would have the following impacts on maximum flow velocities and durations of inundation external to the road corridor for storms up to 1% AEP in intensity:

Flat Rock Creek Catchment

- **Impact on maximum flow velocities** - Along the main arm of Flat Rock Creek downstream of the T1 North Shore and Western Line and T9 Northern Line crossing, where maximum flow velocities would be increased by a maximum of about 0.1 metres per second.

Burnt Bridge Creek Catchment

- **Impact on maximum flow velocities** – The extension of the existing transverse drainage structure under Burnt Bridge Creek Deviation in combination with minor works within the inbank area of the watercourse immediately downstream of the road crossing has the potential to increase flow velocities by up to 1 m/s.

  While changes in landform within the Balgowlah Golf Course have the potential to increase flow velocities, the nature of the flow in this area would be altered when compared to present day conditions as a result of the proposed changes in landform.

- **Impact on duration of inundation** – Along the main arm of Burnt Bridge Creek Deviation where the duration of inundation would be reduced slightly when compared to present day conditions.

  While the project has the potential to alter the duration of inundation within the Balgowlah Golf Course when compared to present day conditions, the nature of the flow in this area would be altered significantly due to the proposed changes in landform.

Bantry Bay and Manly Creek Catchments

- **Impact on maximum flow velocities** - The concentration of flow at discrete locations along the widened section of the Wakehurst Parkway has the potential to increase peak flows and hence flow velocities in drainage line BB DL01 in the Bantry Bay catchment and drainage lines MC DL01, MC DL04, MC DL06 and MC DL07 in the Manly Creek catchment.

  Conversely, the upgrade of the Wakehurst Parkway has the potential to decrease peak flows and hence flow velocities in drainage lines BB DL02 and BB DL03 in the Bantry Bay catchment and drainage lines MC DL02, MC DL03, and MC DL05 in the Manly Creek catchment.

- **Impact on duration of inundation** - The concentration of flow at discrete locations along the widened section of the Wakehurst Parkway has the potential to increase peak flows and hence the duration over which flow is experienced in drainage line BB DL01 in the Bantry Bay catchment and drainage lines MC DL01, MC DL04, MC DL06 and MC DL07 in the Manly Creek catchment.

  Conversely, the upgrade of the Wakehurst Parkway has the potential to decrease peak flows and hence the duration over which flow is experienced in drainage lines BB DL02 and BB DL03 in the Bantry Bay catchment and drainage lines MC DL02, MC DL03, and MC DL05 in the Manly Creek catchment.

6.2.1.2 Storms more intense than 1% AEP[1]

The project would generally result in a neutral or beneficial effect on flood behaviour external to the road corridor for storm events that are more intense than 1% AEP, with the following exceptions:

Flat Rock Creek Catchment

- While the project would generally not have an impact of flood behaviour external to the road corridor for storms of between 1% and 0.2% AEP in intensity, the project has the potential to increase peak flood levels by up to about 50 millimetres in existing commercial development that is located in George Place and by a maximum of about 110 millimetres in existing residential development that is located along the main arm of Flat Rock Creek to the east of the rail corridor during a PMF event.[2]

Burnt Bridge Creek Catchment

- While the project would generally not have an impact of flood behaviour external to the road corridor for storms of between 1% and 0.5% AEP in intensity, the project has the potential to increase peak flood levels by up to about 0.5 metres in up to six existing dwellings that are located immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek during more extreme storm events.[3] Increases in peak flood levels would occur during storms that surcharge the transverse drainage structure given the vertical alignment of the road would be lifted as part of the project.
- Minor increases of up to 50 mm in peak flood levels would be experienced in 15 residential properties that are located on either side of the road corridor in Boronia Street, Myrtle Street and Kitchener Street during a PMF event. Larger increases of up to about 600 mm would be experienced in six residential properties that are located along the northern side of Kitchener Street and at the western end of Balgowlah Road, noting the impacts are confined to the immediate vicinity of Burnt Bridge Creek where it runs through the affected properties.

[1] Note that the impacts that are shown on the report figures fairly remote from the road corridor are considered to be artefacts of the hydraulic model rather than impacts that are attributable to the project.

[2] Note that the impacts that are shown to be attributable to the project downstream of the rail corridor during storms that are more intense than 1% AEP would need to be confirmed during further design development due to there being instabilities in the hydraulic model which could not be resolved during the preparation of the EIS.

[3] While floor level survey would be required in order to assess whether the project would significantly increase the flood hazard in the six affected dwellings, it is noted that the depth of above-ground inundation associated with three of the affected dwellings exceeds 2 metres in a PMF event under present day conditions.

Bantry Bay and Manly Creek Catchments

- The impacts would be similar to those described above for storms that are up to 1% AEP in intensity.

6.2.2 Internal to road corridor

6.2.2.1 Storms up to 1% AEP in Intensity

Internal to the road corridor, the project would exacerbate flooding conditions during storms up to 1% AEP in intensity at the following locations:

Flat Rock Creek Catchment

- At the location of a newly formed sag which would be located beneath the Reserve Road overpass on the Gore Hill Freeway westbound off ramp to Epping Road and the Pacific Highway. During a 1% AEP storm event, floodwater would pond across the two lane carriageway to a maximum depth of about 1.6 metres
- At the location of a newly formed sag which would be located beneath the Reserve Road overpass on the Gore Hill Freeway eastbound on ramp to the Beaches Link tunnel. During a 1% AEP storm event, floodwater would pond across the two lane carriageway to a maximum depth of about 0.6 metres
- Along the eastbound lanes of the Lane Cove Tunnel and Gore Hill Freeway carriageways extending from the Reserve Road interchange to a location east of the North Shore Railway overpass. Depths of flow along the two carriageways would be a maximum of about 300 millimetres in a 1% AEP storm event.

Burnt Bridge Creek Catchment

- While the flood modelling carried out as part of this study indicates that the depth of flow in the road corridor would be increased as part of the project, improvements to the existing pavement drainage system, the features of which were not incorporated in the flood models, would be aimed at controlling runoff under post-upgrade conditions.

6.2.2.2 Storms more intense than 1% AEP

Internal to the road corridor, the project would exacerbate flooding conditions during storms that are more intense than 1% AEP at the following locations:

Flat Rock Creek Catchment

- Generally along the length of the Gore Hill Freeway road corridor extending from a location about 450 m west of the Reserve Road overpass to a location about 500 m east of the T1 North Shore & Western Line and T9 Northern Line crossing.

6.3 Potential impacts of the project on scour potential

The project has the potential to cause scour in Burnt Bridge Creek, as well as the receiving drainage lines that are located along the Wakehurst Parkway due to the following reasons:

- Increases in the rate of flow (and hence the depth and velocity of flow) associated with:
  - The enlargement of transverse drainage structures
  - The discharge of runoff from the widened carriageway
  - Changes in the distribution of flow along the project corridor
- Increases in the velocity of flow where it discharges from pipe outlets or newly lined sections of channel
- The concentration of flow resulting from the formalisation of the drainage system within the project corridor.

Increases in the rate of flow in the receiving drainage lines could result in a lowering of the stream bed through a process of headwater erosion, as well as a possible widening of the watercourse through a process of bank erosion. The lining of channels and the concentration of flow could also result in localised scour in the receiving drainage lines at the downstream limit of the drainage works.

Scour of Burnt Bridge Creek and the receiving drainage lines that are located along the Wakehurst Parkway has the potential to increase the turbidity of flow discharging to Bantry Bay and Manly Dam and to a lesser extent Manly Lagoon.

6.4 Consistency with council and state government flood plans and policies

In accordance with the Secretary's environmental assessment requirements, a flood planning area has been defined by the current assessment through mapping the extent of land which lies below the peak 1% AEP flood level plus 0.5 metres under present day conditions. The flood planning area shown on Figure 4.7 (10 sheets) is based on mainstream flooding along the major creeks and tributaries that are crossed by the project, as well as the main paths associated with major overland flow. It should be noted that the flood modelling carried out for the assessment was developed for the specific purpose of assessing the flood risks and impacts associated with the project and therefore should be taken as preliminary only in terms of defining the flood planning area across the broader extent of flood prone land within the catchments that are crossed by the project.

The findings of the assessment presented in Section 6.2 of this technical working paper show that the project would have only a minor impact on peak 1% AEP flood levels. As a result, the project would have no significant impact on the extent of the flood planning area and therefore the area of land to which clause 6.3 of Manly LEP 2013, Warringah LEP 2011 and Willoughby LEP 2012 would apply. While North Sydney LEP 2013 and Mosman LEP 2012 do not contain a definition of the flood planning level, the project would have no significant impact on the extent of the flood planning area were the two councils to adopt the same definition as set out in clause 6.3 of Manly LEP 2013, Warringah LEP 2011 and Willoughby LEP 2012.

While a floodplain risk management study and plan has only been prepared for the Manly Creek catchment, the findings of the assessment presented in Section 6.2 of this technical working paper show that the project would have only a minor impact on peak flood levels external to the road corridor.

NSW State Emergency Service maintains two local units at Station Street, Naremburn and Quirk Road, Balgowlah, both of which are not affected by the project related flood impacts:

Provided the flood mitigation measures set out in Section 8 of this technical working paper are incorporated into the design of the project, then it would not increase the flood hazard in existing

development for all events up to the 1% AEP event. It would also not have an adverse impact on NSW State Emergency Service's emergency response arrangements.

6.5 Impact of future climate change on flood behaviour

6.5.1 Impact of future climate change on flooding to the project

Annexure B of this technical working paper contains a series of figures which show flood behaviour under present day and project operation conditions for design storms with AEPs of 0.5% and 0.2%. Also included are a series of figures which show the impact that an increase in the intensity of a 1% AEP storm event would have on flooding patterns under project operation conditions. As previously mentioned, the 0.5% AEP and 0.2% AEP storms have been used as proxies to assess the impact that a 10% and 30% increase in 1% AEP rainfall intensities would have on flood behaviour in the vicinity of the project.

Impacts on flood behaviour associated with a potential increase in the rainfall intensities are summarised as follows:

Willoughby Creek Catchment

- While depths of ponding would be increased in ANZAC Park, they would not be deep enough to overtop the continuous concrete noise wall which runs along its northern side
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the road tunnels via their portals for events up to the PMF, increases in the depth of flow associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at Warringah Freeway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Flat Rock Creek Catchment

- The rate at which flow approaches the Gore Hill Freeway from the urbanised catchments which lie to its north and south would increase, resulting in an increase in the depth of flow along several of its lanes
- As the operational facilities and ancillary infrastructure at the Gore Hill Freeway would be designed to prevent the ingress of floodwater to the building during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the road tunnels via their portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Burnt Bridge Creek Catchment

- Floodwater would surcharge the existing transverse drainage structure on Burnt Bridge Creek during storms that are more intense than about 0.2% AEP
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the road tunnels via their portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project

- As the motorway facilities and ventilation outlet at the Burnt Bridge Creek Deviation would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Bantry Bay Catchment

- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the road tunnels via their portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at Wakehurst Parkway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Manly Creek Catchment

- Surcharge of the new pavement and transverse drainage could occur as a result of an increase in rainfall intensities. As the project generally runs along the catchment divide, surcharge of the proposed drainage is unlikely to result in an increase in the flood risk to road users
- As the operational facilities and ancillary structures at Frenchs Forest and Killarney heights at Wakehurst Parkway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Trefoil Creek Catchment

- Surcharge of the new pavement drainage could occur as a result of an increase in rainfall intensities. As the project is located on the catchment divide, surcharge of the proposed drainage is unlikely to result in an increase in the flood risk to road users.

6.5.2 Impact of the project on flood behaviour under future climate change conditions

While the project would generally have a similar impact on flood behaviour to that described above for a 1% AEP storm event under present day conditions for the assessed climate change scenarios, it would increase peak post-climate change 1% AEP flood levels in the following areas:

Burnt Bridge Creek Catchment

- Immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek, where peak post-climate change 1% AEP flood levels could be increased by up to 250 millimetres, with the impacts extending into eleven residential properties that are located on either side of the watercourse
- Immediately downstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek, where peak post-climate change 1% AEP flood levels could be increased by up to 200 millimetres, noting that no existing or future development would be impacted as a result of these changes.

6.6 Impact of a partial blockage of the local stormwater drainage system on flood behaviour

The mechanism and geometrical characteristics of blockages in the piped system are difficult to quantify and would no doubt be different for each storm event. Realistic scenarios would be limited to one or two pipes becoming partially blocked during a storm event. However, for the purposes of this technical working paper, analyses were carried out with the cross sectional areas of all pipes and conduits reduced by 50% for the 1% AEP storm event. This represents a case which is well beyond a blockage scenario which could reasonably be expected to occur and is presented for illustrative purposes.

The impact that a partial blockage of the local stormwater drainage system and the extended culverts under the Burnt Bridge Creek Deviation would have on peak 1% AEP flood levels in the vicinity of the project is shown on Figure C.1 (4 sheets) in Annexure C. The key findings of the assessment were as follows:

Willoughby Creek Catchment

- While peak 1% AEP flood levels would be increased by about 1.5 metres in ANZAC Park, they would not be high enough to overtop the proposed flood walls which would border the proposed tunnel portals.

Flat Rock Creek Catchment

- While peak 1% AEP flood levels would be increased in the road corridor, they would not be high enough to cause floodwater to enter the proposed tunnel portals.

Burnt Bridge Creek Catchment

- Flow would surcharge the existing Burnt Bridge Creek transverse drainage structure on Burnt Bridge Creek Deviation, where it would discharge across both the northbound and southbound lanes before re-entering the creek on the eastern (downstream) side of the road corridor. There would be a minor increase in the depth of overland flow discharging north along Link Road.

Bantry Bay Catchment

- A partial blockage of the new pavement drainage system would result in the minor inundation of the Wakehurst Parkway at the major sag in the road which is located a short distance to the north of the tunnel portals. For example, flow would pond across the road until it reached the height of the adjacent footpath before discharging into the adjacent bushland.

Manly Creek Catchment

- A partial blockage of the new pavement drainage system would result in the minor inundation of the Wakehurst Parkway at the location of the two major sags in the road. For example, flow would pond across the road at these two locations until it reached the height of the adjacent footpath before discharging into the adjacent bushland
- A partial blockage of the transverse drainage may result in floodwater discharging onto the surface of the Wakehurst Parkway where it would pond at the location of the two major sags in the road. In this instance, flow would pond across the road until it reached the height of the adjacent footpath before discharging into the adjacent bushland.

While the tunnel system would not be impacted by flooding should the existing stormwater drainage system experience a partial blockage during storms up to 1% AEP in intensity, the present investigation did find that there is the potential for floodwater to enter it should a partial blockage occur during more extreme storm events. For example, a partial blockage of the stormwater drainage system during a PMF event would result in flow discharging to the tunnel system at the location of the Gore Hill Freeway connection, while floodwater would commence to enter it via the Burnt Bridge Creek Deviation tunnel portals. Based on this finding, it is recommended that a risk assessment be carried out during further design development to assess the flood risk in the tunnel system should the stormwater drainage system experience a partial blockage during storms that are more intense than 1% AEP. The degree to which the stormwater drainage system could block during an extreme storm event should be assessed based on the procedures set out in ARR 2019.

6.7 Application of ARR 2019 to design flood estimation

As mentioned, ARR 2019 was released during the preparation of the environmental impact statement. As a result, the procedures set out in ARR 1987 have been used as the basis of carrying out the flooding investigation for the project, noting the approach is consistent with the flood studies that have been carried out to date in the catchments through which it runs.

As the procedures set out in ARR 2019 will be used by councils to carry out new flood studies and to update previous studies, a sensitivity study was carried out as part of the present investigation to assess the likely changes that would occur in predicted flood behaviour in the vicinity of the project where it runs through the Willoughby Creek catchment.

The procedures set out in ARR 2019 were applied to the hydrologic models that relate to the Willoughby Creek, Bantry Bay and Manly Creek (upper reaches only) catchments, and both them and the TUFLOW model in the case of the Willoughby Creek catchment run for the 1% AEP storm event. The investigation found there would be a reduction in the rate of runoff which would be generated by the various catchments, which in turn would result in a reduction in peak flood levels. This finding would apply to the adjacent catchments through which the project runs given the similar level of development in the area.

Based on the above finding, the adoption of the procedures set out in ARR 1987 represents a worse-case scenario in terms of assessing flood behaviour in the vicinity of the project.

Table 6.1
Summary of flood risks to the project

Catchment	Project infrastructure	Recommended level of flood protection	Assessed flood risk
Willoughby Creek	Tunnel portals	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figures 6.1, 6.2 and 6.3 (refer to sheet 2 in series) show operational flooding patterns during 10% AEP, 1% AEP and PMF events, respectively • A series of measures have been incorporated into the design of the project to prevent the ingress of floodwater to the Beaches Link tunnels for events up to the PMF.
	Motorway facilities and ventilation outlet at the Warringah Freeway	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figures 6.1, 6.2 and 6.3 (refer to sheet 2 in series) show operational flooding patterns during 10% AEP, 1% AEP and PMF events, respectively • Finished ground levels at the motorway facilities site have been raised above the peak PMF level • Provision has been built into the design of the motorway facilities to manage flow which surcharges Ernest Street immediately to the south of the support facility.
Flat Rock Creek	Tunnel portals	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figures 6.1, 6.2 and 6.3 (refer to sheets 3 and 4 in series) show operational flooding patterns during 10% AEP, 1% AEP and PMF events, respectively • A series of measures have been incorporated into the design of the project which would prevent the ingress of flow which surcharges the pavement drainage system along Gore Hill Freeway from entering the Beaches Link tunnels for events up to the PMF.
	Operational facilities and ancillary infrastructure at the Gore Hill Freeway	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Provision has been incorporated into the design of the operational facilities and ancillary infrastructure to prevent the ingress of floodwater to the Beaches Link tunnels for events up to the PMF event.
	Road bridge works	Pavement Drainage - 10% AEP	• Reserve Road bridge would be subject to relatively minor sheet flow during storms which surcharge the pavement drainage system.
	Surface road works	Transverse Drainage - 1% AEP Pavement Drainage - 10% AEP	• The Gore Hill Freeway westbound off ramp to Epping Road and the Pacific Highway would be inundated by up to about 1 m in a 1% AEP where it runs under the Reserve Road interchange. The ponding would occur as a result of a sag which is formed by a change in grade of the off ramp • The Gore Hill Freeway eastbound entry ramp to the Beaches Link tunnels would be inundated by up to about 0.6 m in a 1% AEP where it runs under the Reserve Road interchange. The ponding would occur as a result of a sag which is formed by a change in grade of the on ramp

Catchment	Project infrastructure	Recommended level of flood protection	Assessed flood risk
			• The eastbound carriageway of both the Lane Cove Tunnel and Gore Hill Freeway would be inundated to a maximum depth of about 0.3 m in a 1% AEP storm event. The two carriageways would act to divert overland flow around the eastbound entry portal to the Beaches Link tunnels.
Burnt Bridge Creek	Tunnel portals	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figures 6.1, 6.2 and 6.3 (refer to sheet 5 in series) show operational flooding patterns during 10% AEP, 1% AEP and PMF events, respectively • A series of measures have been incorporated into the design of the project which would prevent the ingress of flow which surcharges the pavement drainage system along Burnt Bridge Creek Deviation from entering the Beaches Link tunnels for events up to the PMF.
	Motorway facilities and ventilation outlet at the Burnt Bridge Creek Deviation	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Finished ground levels at the motorway facilities site have been raised above the peak PMF level.
	Surface road works	Transverse Drainage - 1% AEP Pavement Drainage - 10% AEP	• While the surface road works would be subject to relatively shallow sheet flow as a result of stormwater which would surcharge the existing pavement drainage system to the south of the crossing of Burnt Bridge Creek, greater depths of inundation would be experienced to the north of the tunnel portals as a result of flow which surcharges both the existing and proposed stormwater drainage system • Floodwater would surcharge the inlet of the existing transverse drainage structure on Burnt Bridge Creek Deviation during storms that are more intense than about 0.2% AEP, inundating both the northbound and southbound carriageways immediately to the north of the tunnel portal.
Bantry Bay	Tunnel portals	PMF or 1% AEP plus 0.5 m (whichever is greater)	• A series of measures have been incorporated into the design of the project which would prevent the ingress of flow which surcharge the new pavement drainage system to the Beaches Link tunnels for events up to the PMF.
	Motorway facilities and ventilation outlet at the Wakehurst Parkway	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Finished ground levels at the motorway facilities site have been raised above the peak PMF level.
	Surface road works	Transverse Drainage - 1% AEP Pavement Drainage - 10% AEP	• The Wakehurst Parkway would be subject to relatively shallow sheet flow due to surcharge of the pavement drainage system during storms greater than 10% AEP in intensity.

Catchment	Project infrastructure	Recommended level of flood protection	Assessed flood risk
Manly Creek	Surface road works	Transverse Drainage - 1% AEP Pavement Drainage - 10% AEP	• The Wakehurst Parkway would be subject to relatively shallow sheet flow due to surcharge of the pavement drainage system during storms greater than 10% AEP in intensity.
	Pedestrian and shared user bridge works	50% AEP	• The proposed bridges over the Wakehurst Parkway are high level structures that would not be subject to flooding.
	Operational facilities and ancillary infrastructure at the Wakehurst Parkway	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Provision has been incorporated into the design of the operational facilities and ancillary infrastructure at Frenchs Forest and Killarney Heights to prevent the ingress of floodwater to the Beaches Link tunnels for events up to the PMF event.
Trefoil Creek	Surface road works	Transverse Drainage - 1% AEP Pavement Drainage - 10% AEP	• The Wakehurst Parkway would be subject to relatively shallow sheet flow due to surcharge of the pavement drainage system during storms greater than 10% AEP in intensity.

Table 6.2
Summary of the impacts of the project on flood behaviour

Catchment	Assessed concept design arrangement	Assessed impacts on flood behaviour
Willoughby Creek	• Tunnel portals • Motorway facilities and ventilation outlet at the Warringah Freeway	• Figures 6.4, 6.5 and 6.6 (refer to sheet 2 in series) show the flood impacts under operational conditions during 10% AEP, 1% AEP and PMF events, respectively • There are no assessed impacts of the project on flood behaviour on Willoughby Creek.
Flat Rock Creek	• Tunnel portals • Operational facilities and ancillary structures at the Gore Hill Freeway • Road bridge works • Surface road works.	• Figures 6.4, 6.5 and 6.6 (refer to sheets 3 and 4 in series) show the flood impacts under operational conditions during 10% AEP, 1% AEP and PMF events, respectively • While the project would not increase peak flood levels in existing development for all storms up to 1% AEP in intensity, it has the potential to increase peak flood levels by up to about 50 mm in existing commercial development that is located in George Place and by a maximum of about 110 mm in existing residential development that is located along the main arm of Flat Rock Creek to the east of the rail corridor during a PMF event. [*Note that the impacts that are shown to be attributable to the project downstream of the rail corridor during storms that are more intense than 1% AEP would need to be confirmed during further design development due to there being instabilities in the hydraulic model which could not be resolved during the preparation of the EIS*]. • The project would increase flow velocities along the main arm of Flat Rock Creek by about 0.1 m/s during storms that are up to 1% AEP in intensity.
Burnt Bridge Creek	• Tunnel portals • Motorway facilities and ventilation outlet at the Burnt Bridge Creek Deviation • Road bridge works • Surface road works.	• Figures 6.4, 6.5 and 6.6 (refer to sheet 5 in series) show the flood impacts under operational conditions during 10% AEP, 1% AEP and PMF events, respectively • Peak flood levels along the main arm of Burnt Bridge Creek would generally be reduced as a result of the project for all storms up to 1% AEP in intensity, with only minor increases in peak 10% AEP flood levels of no more than 50 mm potentially occurring in three residential properties that are located along the northern side of Kitchener Street and at the western end of Balgowlah Road, noting the increases are confined to the immediate vicinity of Burnt Bridge Creek where it runs through the affected properties • Peak flood levels immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek would be increased by up to about 0.5 m during storms that surcharge the inlet of the existing transverse drainage structure, noting that this would only occur during storms that are more intense than 0.2% AEP, or as a result of a partial blockage of the transverse drainage structure. As a result, the depth of inundation in up to six existing dwellings would be increased as a result of the project. The increase is a result of the lifting of the vertical alignment of the road at this location

Catchment	Assessed concept design arrangement	Assessed impacts on flood behaviour
		• The project has the potential to increase depths of inundation in 15 residential properties that are located in Boronia Street, Myrtle Street and Kitchener Street by up to 50 mm during a PMF event. Larger increases of up to about 600 mm could potentially be experienced in six residential properties that are located along the northern side of Kitchener Street and at the western end of Balgowlah Road, noting these larger impacts are confined to the immediate vicinity of Burnt Bridge Creek where it runs through the affected properties. • Flow velocities immediately upstream and downstream of the Brunt Bridge Creek Deviation crossing of Burnt Bridge Creek would be increased by a maximum of about 1 m/s due to changes in channel geometry downstream of the road crossing • The project has the potential to increase the scour potential within the inbank area of Burnt Bridge creek due to the concentration of flow and increases in flow velocities. Disturbance of the inbank area of the creek also has the potential to increase the risk of scour along sections of the watercourse. • While flood behaviour would be altered in the Balgowlah Golf Course, this is a function of the proposed landform changes in this area.
Bantry Bay	• Tunnel portals • Motorway facilities and ventilation outlet at the Burnt Bridge Creek Deviation Surface road works.	• Figure 4.1, sheets 2 and 3 show the location of various drainage lines which would receive runoff from road corridor • The project has the potential to increase the rate, volume, velocity and duration of flow discharging to drainage line BB DL01 • Conversely, the project would decrease the rate, volume, velocity and duration of flow discharging to Drainage lines BB DL02 and BL03 • The project has the potential to increase scour potential within drainage line BL DL01 due to the abovementioned increase in flow • No existing development would be impacted by the change in flow regime in the receiving drainage lines

Catchment	Assessed concept design arrangement	Assessed impacts on flood behaviour
Manly Creek	• Surface road works • Pedestrian bridge works • Operational facilities and ancillary structures at the Wakehurst Parkway	• Figure 4.1, sheets 2 and 3 show the location of the various drainage lines which would receive runoff from road corridor • The project has the potential to increase the rate, volume, velocity and duration of flow discharging to drainage lines MC DL01, MC DL04, MC DL06 and MCDL07 • Conversely, the project would decrease the rate, volume, velocity and duration of flow discharging to drainage lines MC DL02, MC DL03 and MCDL05 • The project has the potential to increase scour potential within drainage lines MC DL01, MC DL04 and MC DL06, MC DL 07 due to the abovementioned increase in flow • There is the potential for the project to cause prolonged inundation of parts of the Wakehurst Golf Course during periods of heavy rain • There is the potential for the project to cause the more frequent surcharge of the existing stormwater drainage system which crosses Aquatic Drive and runs beneath Aquatic Reserve. This in turn would increase the frequency and depth of overland flow that would be experienced on the road and in the reserve during periods of heavy rain.
Trefoil Creek	• Surface road works.	• There are no assessed impacts of the project on flood behaviour on Trefoil Creek

Table 6.3
Comparison of peak flows in receiving drainage lines located along the Wakehurst Parkway (m^3/s)

Catchment	Drainage Line	Peak Flow Location	50% AEP			10% AEP			1% AEP		
			Present Day Conditions	Operational Conditions	Difference[1,2]	Present Day Conditions	Operational Conditions	Difference[1,2]	Present Day Conditions	Operational Conditions	Difference[1,2]
Bantry Bay	BB DL 01	**BB Q2**	0.48	0.72	0.23 [48%]	0.78	1.14	0.36 [45%]	1.17	1.62	0.46 [39%]
		BB Q1	0.44	0.67	0.23 [53%]	0.67	1.03	0.36 [54%]	0.99	1.46	0.47 [47%]
	BB DL 02	**BB Q3**	0.23	0.21	-0.02 [-10%]	0.39	0.35	-0.04 [-9%]	0.59	0.54	-0.05 [-8%]
		BB Q4	0.39	0.37	-0.02 [-4%]	0.71	0.68	-0.03 [-4%]	1.10	1.06	-0.04 [-4%]
	BB DL 03	**BB Q5**	0.13	0.08	-0.05 [-38%]	0.23	0.15	-0.08 [-35%]	0.41	0.28	-0.13 [-31%]
		BB Q6	0.33	0.25	-0.08 [-24%]	0.59	0.46	-0.14 [-23%]	0.96	0.76	-0.21 [-21%]
Manly Creek	MC DL 01	**MC Q1**	0.78	0.87	0.10 [13%]	1.35	1.47	0.12 [9%]	2.13	2.30	0.17 [8%]
		MC Q2	1.13	1.21	0.08 [7%]	2.09	2.13	0.04 [2%]	3.42	3.45	0.03 [1%]
	MC DL 02	**MC Q3**	0.30	0.06	-0.24 [-81%]	0.46	0.09	-0.37 [-81%]	0.64	0.13	-0.51 [-79%]
		MC Q4	0.35	0.14	-0.21 [-60%]	0.59	0.26	-0.33 [-56%]	0.90	0.40	-0.50 [-55%]
		MC Q5	0.42	0.20	-0.22 [-51%]	0.70	0.37	-0.33 [-48%]	1.06	0.58	-0.48 [-46%]
		MC Q6	0.57	0.36	-0.22 [-38%]	0.97	0.64	-0.33 [-34%]	1.47	0.99	-0.49 [-33%]
		MC Q7	0.86	0.67	-0.18 [-21%]	1.48	1.21	-0.27 [-18%]	2.25	1.89	-0.36 [-16%]

Catchment	Drainage Line	Peak Flow Location	50% AEP			10% AEP			1% AEP		
			Present Day Conditions	Operational Conditions	Difference(1,2)	Present Day Conditions	Operational Conditions	Difference(1,2)	Present Day Conditions	Operational Conditions	Difference(1,2)
	MC DL 03	**MC Q8**	0.31	0.07	-0.24 [-78%]	0.51	0.14	-0.37 [-73%]	0.76	0.22	-0.54 [-71%]
		MC Q9	0.33	0.09	-0.24 [-73%]	0.55	0.18	-0.37 [-68%]	0.82	0.29	-0.53 [-65%]
		MC Q10	0.37	0.14	-0.24 [-63%]	0.62	0.26	-0.36 [-58%]	0.93	0.42	-0.51 [-55%]
	MC DL 04	**MC Q11**	3.45	4.55	1.10 [32%]	6.16	8.04	1.88 [30%]	9.79	12.77	2.97 [30%]
		MC Q12	4.03	4.66	0.63 [16%]	7.20	8.24	1.04 [14%]	11.40	13.06	1.66 [15%]
		MC Q13	4.23	4.86	0.63 [15%]	7.58	8.61	1.03 [14%]	11.99	13.64	1.65 [14%]
	MC DL 05	**MC Q14**	0.52	0.04	-0.48 [-92%]	0.91	0.08	-0.84 [-92%]	1.50	0.11	-1.39 [-93%]
	MC DL 06	**MC Q15**	0.46	0.42	-0.04 [-9%]	0.83	0.75	-0.09 [-11%]	1.29	1.16	-0.13 [-10%]
		MC Q16	0.66	0.68	0.02 [3%]	1.27	1.30	0.04 [3%]	2.12	2.14	0.02 [1%]
	MC DL 07	**MC Q17**	2.09	2.36	0.27 [13%]	3.47	3.95	0.48 [14%]	5.08	5.78	0.70 [14%]
		MC Q18	2.16	2.43	0.27 [12%]	3.68	4.14	0.46 [13%]	5.79	6.40	0.61 [11%]
		MC Q19	3.04	3.13	0.09 [3%]	5.28	5.38	0.10 [2%]	8.31	8.47	0.17 [2%]

1. A positive value represent and increase, and conversely a negative value represents a decrease in peak flow attributable to the project.
2. Values in [ ] represents the percentage increase/decrease in peak flow attributable to the project.

7 ASSESSMENT OF CUMULATIVE IMPACTS

This section presents the findings of an assessment of the potential impacts the project would have on flood behaviour in combination with other projects in its vicinity. The assessment was based on impacts during the operation of the project only, given the short term nature of exposure to potential flood impacts during the construction of the project together with the general requirement to manage adverse impacts on existing development.

7.1 Other motorway projects

7.1.1 Western Harbour Tunnel and Warringah Freeway Upgrade

The flood impact assessment set out in this technical working paper assumes that the Western Harbour Tunnel and Warringah Freeway Upgrade project forms part of baseline (ie pre-project) flooding conditions (ie it assumes that construction of the Western Harbour Tunnel and Warringah Freeway Upgrade project precedes that of the project).

While the present investigation found that the project would not exacerbate flooding conditions in existing development that is located in the Willoughby Creek catchment, a similar investigation found that the Western Harbour Tunnel and Warringah Freeway Upgrade project had the potential to increase peak 1% AEP flood levels by up to 16 millimetres in nine residential properties that are located along Cammeray Road, Park Avenue, Fall Street and Grafton Street in Cammeray.

7.2 Other non-motorway projects

There are no other proposed non-motorway projects that are of a scale that would influence flood behaviour in the vicinity of the project.

8 MANAGEMENT OF IMPACTS

The environmental management measures that would be implemented to minimise flooding and drainage related impacts of the project during construction and operation are presented in Table 8.1 below.

Table 8.1
Summary of environmental management measures

Impact	Phase	Environmental management measure	Project component
Impact of the project on flood behaviour	Design	Where flood levels in the 1% AEP event are predicted to increase at any residential, commercial and/or industrial buildings as a result of operation of the project, it is recommended a floor level survey is carried out. If the survey indicates existing buildings would experience above floor inundation during a 1% AEP event as a result of the project, further refinements should be made (as required) to the design of permanent project components to minimise the potential for impacts.	BL/GHF
	Design	Impact of the project on flood behaviour during operation should be confirmed during further project development. This should include the consideration of future climate change and a partial blockage of the local stormwater drainage system.	BL/GHF
Impacts of construction sites on flood behaviour	Design and construction	It is recommended that detailed construction planning considers flood risk at construction sites and construction support sites. This should include: • A review of site layout and staging of construction activities to avoid or minimise obstruction of overland flow paths and limit the extent of flow diversion required • Identification of measures to not worsen flood impacts on the community and on other property and infrastructure during construction up to and including the 1% AEP flood event where reasonable and feasible • Measures to mitigate alterations to local runoff conditions due to construction activities.	BL/GHF
Impact of the project on scour potential	Design	Measures should be assessed during detailed design which are aimed at reducing as far as is practical the risk of increased scour in the receiving drainage lines that are located along the Wakehurst Parkway. Scour countermeasures should also be provided at the outlet of new or upgraded transverse and longitudinal drainage lines.	BL/GHF
Flooding impacts to tunnel excavation	Construction	Entries to tunnel excavations, including cut-and-cover sections of tunnel, should be protected against frequent flooding by locating openings outside flood prone areas, and/or the provision of local bunding and flood protection barriers.	BL/GHF
	Construction	The flood standard adopted at each tunnel entry during construction should be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to personal safety and the project works.	BL/GHF
Flood impacts to construction sites	Construction	It is recommended spoil stockpiles should be located in areas which are not subject to frequent inundation by floodwater, ideally outside the 10% AEP flood extent. The exact level of flood risk accepted at stockpile sites will	BL/GHF

Impact	Phase	Environmental management measure	Project component
		depend on the duration of stockpiling operations, the type of material stored, the nature of the receiving drainage lines and also the extent to which it would impact flooding conditions in adjacent development.	
Flood impacts to construction sites	Construction	Site facilities should be located outside high flood hazard areas based on a 1% AEP flood.	BL/GHF
Impact of flooding on the project	Construction and operation	Flood emergency management measures for construction and operation of the project should be prepared in consultation with State Emergency Services and relevant councils and incorporated into relevant environmental and/or safety management documentation.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

9 REFERENCES

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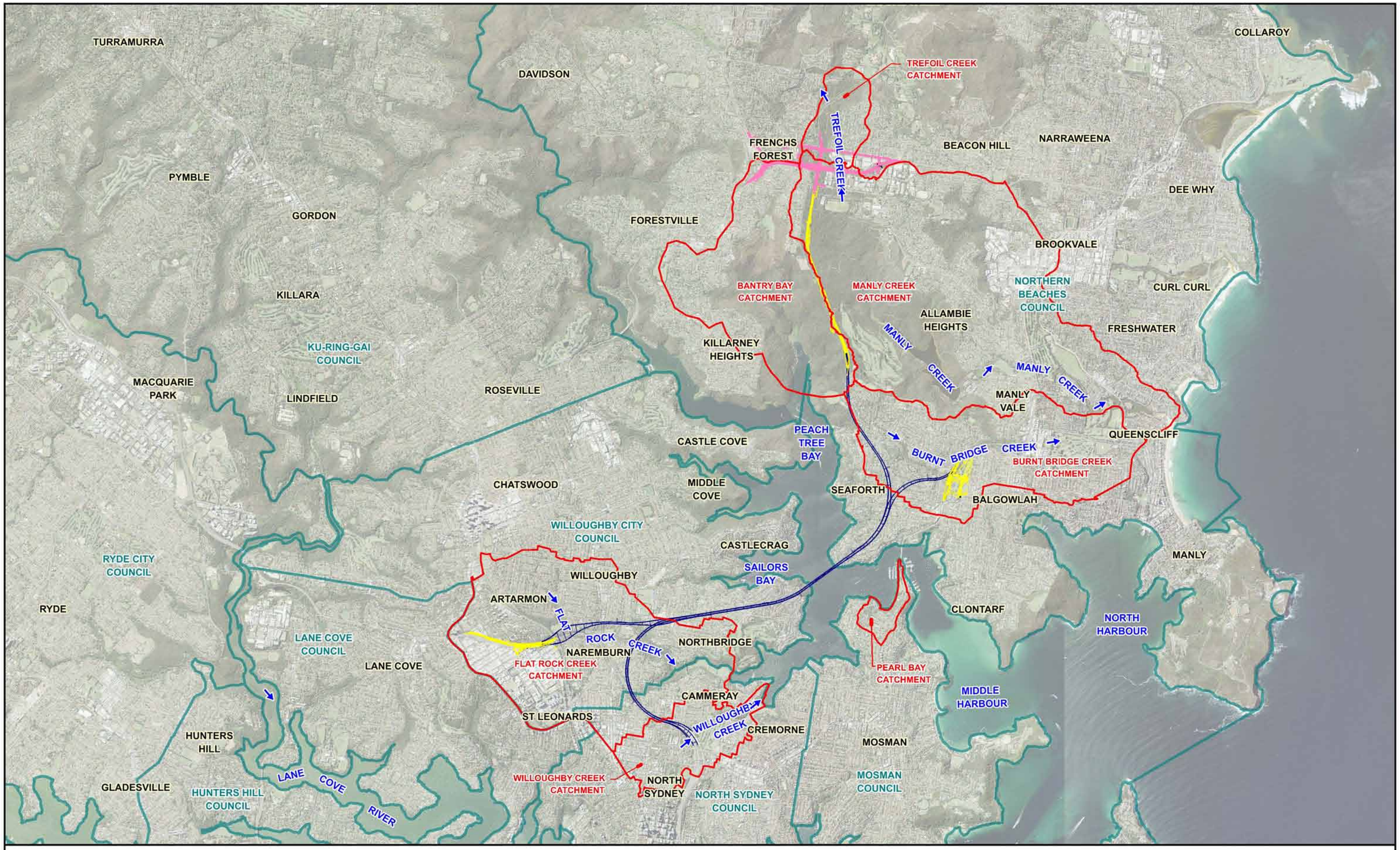
Figures



N

500 0 500 1000 1500m

Scale: 1:50,000

LEGEND

LGA Boundary

Catchment Boundary

Proposed BL & GHFC Tunnel Road Works

Proposed BL & GHFC Surface Works

Northern Beaches Hospital Surface Road Works

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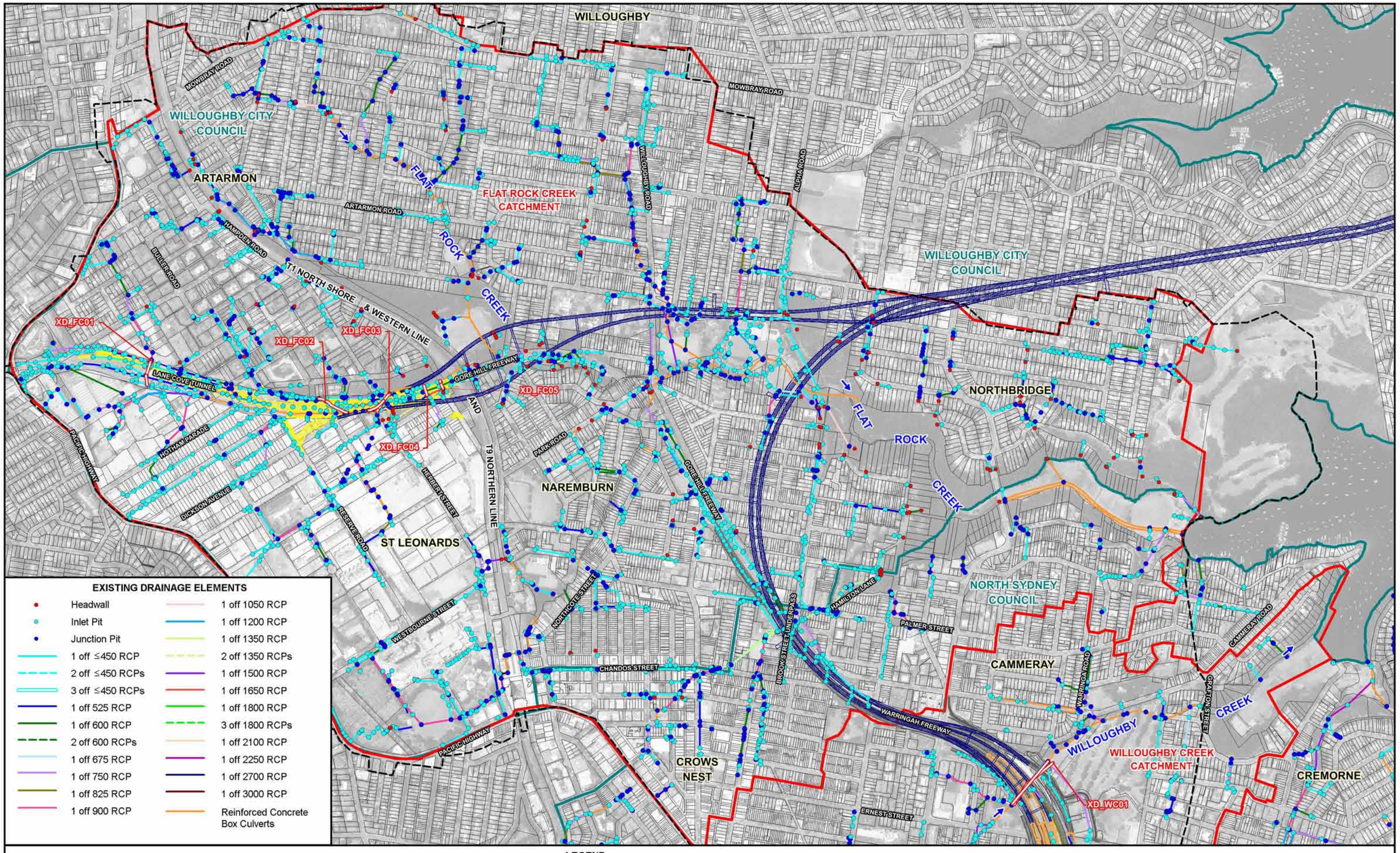
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 1.4

CATCHMENT PLAN



EXISTING DRAINAGE ELEMENTS

Headwall	1 off 1050 RCP
Inlet Pit	1 off 1200 RCP
Junction Pit	1 off 1350 RCP
1 off ≤450 RCP	2 off 1350 RCPs
2 off ≤450 RCPs	1 off 1500 RCP
3 off ≤450 RCPs	1 off 1650 RCP
1 off 525 RCP	1 off 1800 RCP
1 off 600 RCP	3 off 1800 RCPs
2 off 600 RCPs	1 off 2100 RCP
1 off 675 RCP	1 off 2250 RCP
1 off 750 RCP	1 off 2700 RCP
1 off 825 RCP	1 off 3000 RCP
1 off 900 RCP	Reinforced Concrete Box Culverts

N

120 0 120 240 360 m

Scale: 1:12,000

LEGEND

- Two-Dimensional Model Boundary
- LGA Boundary
- Catchment Boundary
- XD_FC01 Existing Transverse Drainage and Identifier
- Proposed BL & GHFC Tunnel Road Works
- Proposed BL & GHFC Surface Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.1
(Sheet 1 of 3)

EXISTING DRAINAGE LAYOUT

EXISTING DRAINAGE ELEMENTS

Headwall	1 off 525 RCP	1 off 900 RCP	1 off 1650 RCP	1 off 3000 RCP	Reinforced Concrete Box Culverts
Inlet Pit	1 off 600 RCP	1 off 1050 RCP	1 off 1800 RCP		
Junction Pit	2 off 600 RCPs	1 off 1200 RCP	3 off 1800 RCPs		
1 off ≤450 RCP	1 off 675 RCP	1 off 1350 RCP	1 off 2100 RCP		
2 off ≤450 RCPs	1 off 750 RCP	2 off 1350 RCPs	1 off 2250 RCP		
3 off ≤450 RCPs	1 off 825 RCP	1 off 1500 RCP	1 off 2700 RCP		

BANTRY BAY
JOINS SHEET 3
BB DL03
BB DL02
BB DL01
BB DL01
BANTRY BAY CATCHMENT
ALLAMBIE HEIGHTS
WAKEHURST GOLF COURSE
MANLY CREEK CATCHMENT
NORTHERN BEACHES COUNCIL
MANLY DAM
MANLY
WARRINGAH GOLF COURSE
CREEK
MANLY VALE
CAMPBELL PARADE
SEAFORTH OVAL
JUDITH STREET
INSET
NORTHERN BEACHES COUNCIL
SEAFORTH
SEAFORTH CRESCENT
SPIT BRIDGE
WAKEHURST PARKWAY
CASTLE CIRCUIT
GLONTARF STREET
NORTH BALGOWLAH
WOODBINE STREET
BURNT BRIDGE CREEK CATCHMENT
CONDOVER RESERVE
KENNETH ROAD
GONDAMINE STREET
QUIRK ROAD
ADDISCOMBE ROAD
BURNT
BRIDGE
CREEK
BANGAROO STREET
XD_BC04
XD_BC03
XD_BC05
BURNT BRIDGE CREEK DEVIATION
KITCHENER STREET
XD_BC01
XD_BC02
MANLY GOLF COURSE
FAIRLIGHT
WEST STREET
MIDDLE HARBOUR
SPIT WEST RESERVE
PARRIWI HEAD
BEAUTY POINT
PEARL BAY
FRENCHS FOREST ROAD
DALWOOD AVENUE
REDMAN STREET
PEACOCK STREET
FRENCHS FOREST ROAD
SYDNEY ROAD
BAY STREET
SPIT ROAD
PEARL BAY CATCHMENT
SEAFORTH
BALGOWLAH
MANLY ROAD
MOSMAN
MOSMAN COUNCIL
REFER TO INSET
PONSONBY PARADE
NORTH HARBOUR

N
120 0 120 240 360 m
Scale: 1:12,000

LEGEND

- Two-Dimensional Model Boundary
- LGA Boundary
- Catchment Boundary
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line
- Proposed BL & GHFC Tunnel Road Works
- Proposed BL & GHFC Surface Works

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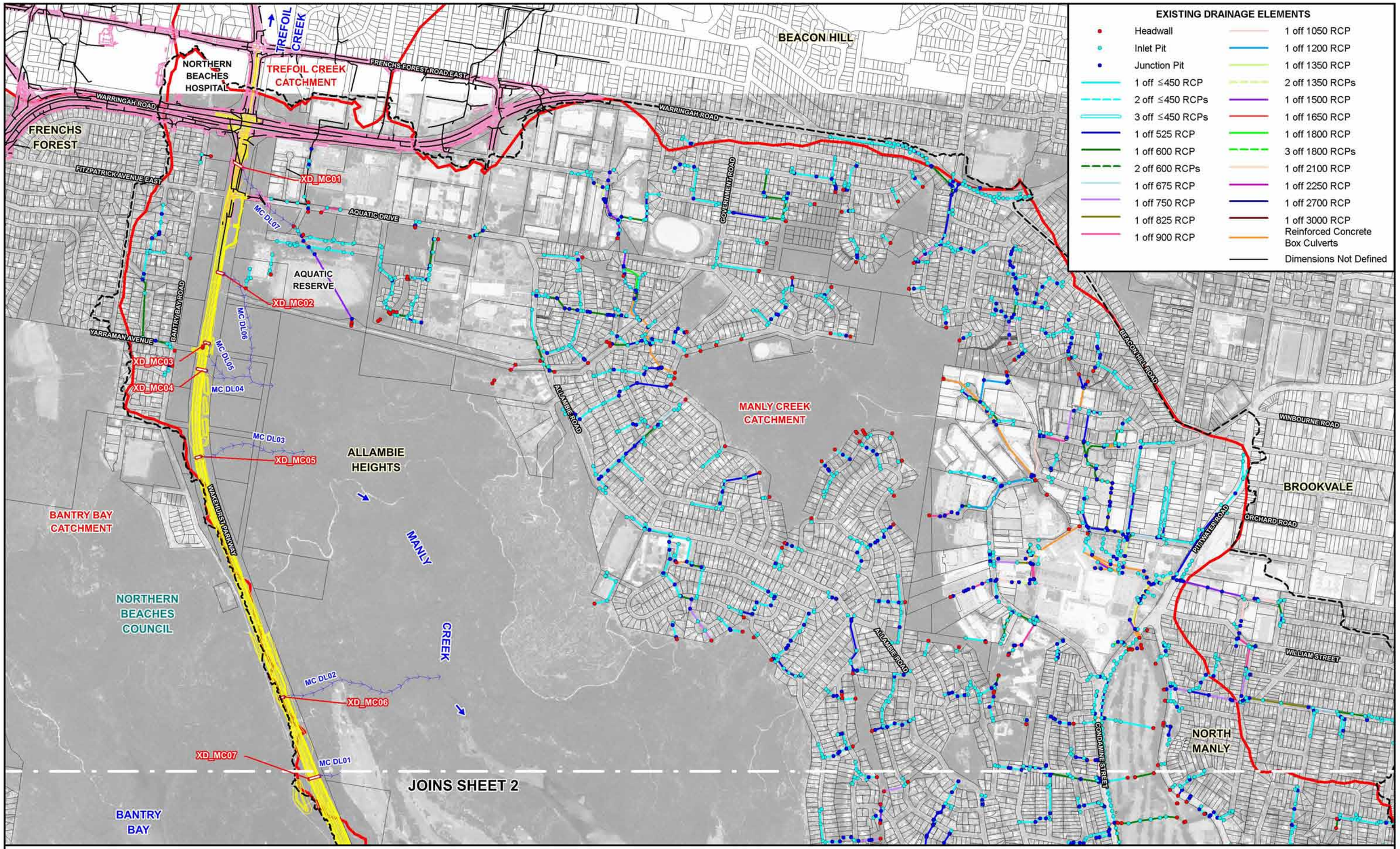
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.1
(Sheet 2 of 3)

EXISTING DRAINAGE LAYOUT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.1
(Sheet 3 of 3)

EXISTING DRAINAGE LAYOUT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00

REFER SHEET 10
REFER SHEET 9
REFER SHEET 8
REFER SHEET 7
REFER SHEET 6
REFER SHEET 5
REFER SHEET 4
REFER SHEET 3
REFER SHEET 2

BL14 BL13 BL12 BL11 BL10 BL9 BL8 BL7 BL6 BL5 BL4 BL3 BL2 BL1

TREFOIL CREEK
MANLY CREEK
BURNT BRIDGE CREEK
FLAT ROCK CREEK
WILLOUGHBY CREEK
TEMPORARY MOORING FACILITY

FRENCHS FOREST
BEACON HILL
NARRAWEENA
DEE WHY
BROOKVALE
NORTHERN BEACHES COUNCIL
CURL CURL
FRESHWATER
QUEENSCLIFF
MANLY VALE
ALLAMBIE HEIGHTS
EAST KILLARA
FORESTVILLE
EAST LINDFIELD
KILLARNEY HEIGHTS
ROSEVILLE CHASE
ROSEVILLE
LINDFIELD
KU-RING-GAI COUNCIL
BANTRY BAY
CASTLE COVE
CHATSWOOD
CHATSWOOD WEST
MIDDLE COVE
SEAFORTH
FAIRLIGHT
BALGOWLAH
CASTLECRAG
MANLY
BALGOWLAH HEIGHTS
WILLOUGHBY
WILLOUGHBY CITY COUNCIL
LANE COVE NORTH
LANE COVE WEST
LANE COVE
LANE COVE COUNCIL
ARTARMON
NORTHBRIDGE
NAREMBURN
CAMMERAY
ST LEONARDS
CREMORNE
MOSMAN
MOSMAN COUNCIL
NORTH HARBOUR
MIDDLE HARBOUR
RIVERVIEW
GREENWICH
CROWS NEST
NORTHWOOD
LANE COVE RIVER

WARRINGAH ROAD
PITTWATER ROAD
WAKEHURST PARKWAY
ARCHBOLD ROAD
PACIFIC HIGHWAY
EASTERN VALLEY WAY
FRENCHS FOREST ROAD
SYDNEY ROAD
EPPING ROAD
LANE COVE TUNNEL
WARRINGAH FREEWAY
SPIT ROAD
MILITARY ROAD
GORDON STREET

N

400 0 400 800 1200 m

Scale: 1:40,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- BL2 Construction Support Site and Identifier
- Project Surface Road Works Footprint
- Driven Tunnel
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 1 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

NAREMBURN

WILLOUGHBY CITY COUNCIL

NORTH SYDNEY COUNCIL

WILLOUGHBY CREEK CATCHMENT

CROWS NEST

CAMMERAY

GLENMORE STREET
WILLOUGHBY ROAD
RHODES AVENUE
BROOK STREET
MCBURNEY STREET
DODDS STREET
MARKS STREET
MERRENBURN ROAD
FRED HUTLEY RESERVE
TRIBUTARY
STREET
HAMILTON LANE
HAMILTON RESERVE
BROOK
CORE HILL FREEWAY
PALMER STREET
WHEATLEIGH STREET
BROOK STREET UNDERPASS
ARMSTRONG STREET
KYNGDON STREET
WEST STREET
ABBOTT STREET
JENKINS STREET
CHANDOS STREET
MATTHEW STREET
ATCHISON STREET
DEVONSHIRE STREET
ST THOMAS REST PARK
ROSALIND STREET
HOLTERMANN STREET
ERNEST STREET
ANZAC PARK PUBLIC SCHOOL
ANZAC AVENUE
ANZAC PARK
WHT AND BL VENTILATION OUTLETS
MILLER STREET
PALMER STREET
CARTER STREET
BELLEVUE STREET
LUMSDEN STREET
AMHERST STREET
ECHO STREET
WARRINGA ROAD
MORDEN STREET
BELLS AVENUE
GREEN PARK
CAMMERAY ROAD
CREEK
WILLOUGHBY
FALL STREET
GRAFTON STREET
CAMMERAY GOLF COURSE
PARK AVENUE
EARLE STREET
GRASMERE ROAD
SUTHERLAND STREET
CAMMERAY PARK
WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES
WARRINGAH FREEWAY
XD_WC01
BL1
MORTLOCK RESERVE
MIDDLE HARBOUR
PINE ST

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

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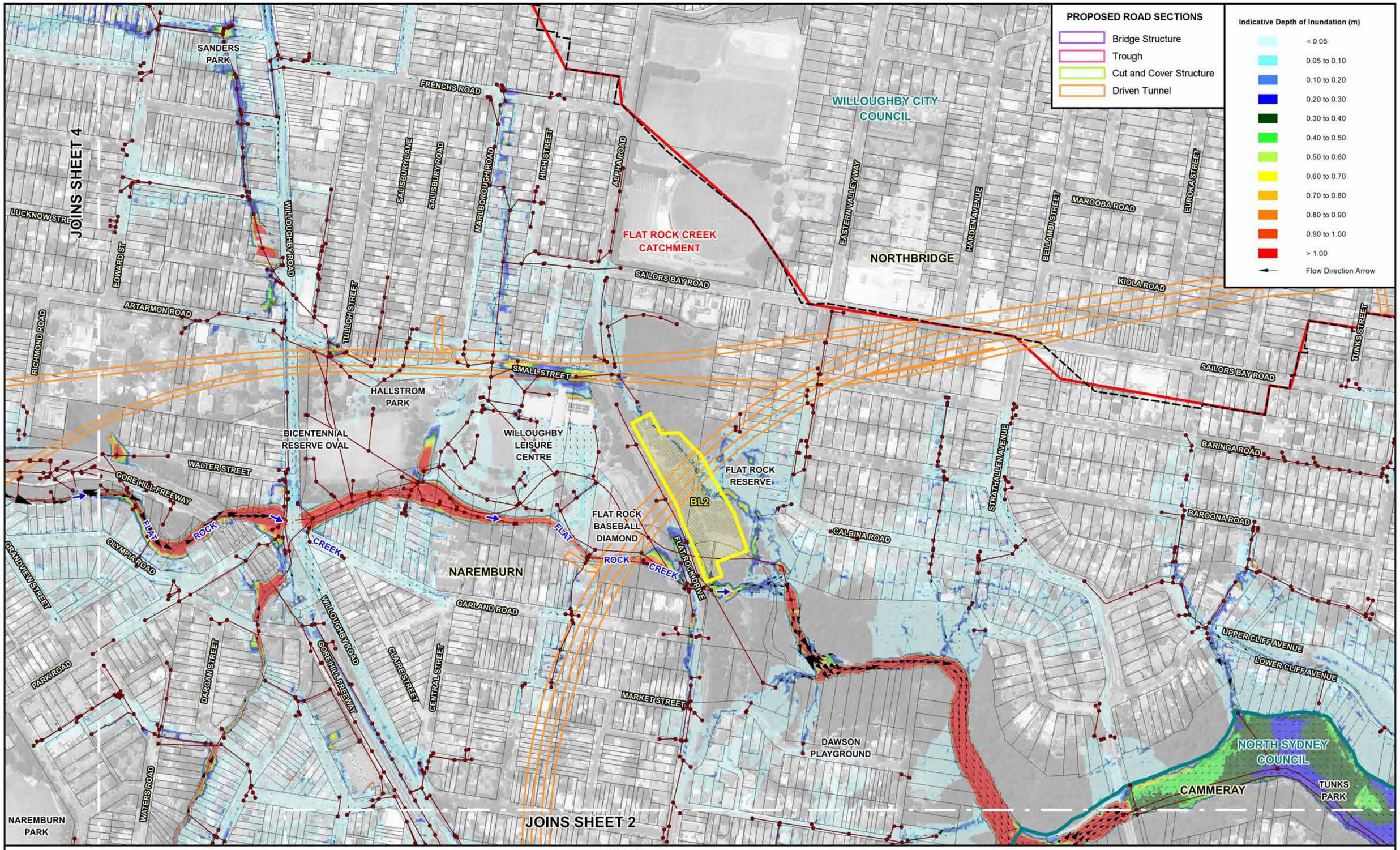
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 2 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 3 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

ELSIE WEARN PARK
ELIZABETH ST
TINDALE ROAD
ARTARMON ROAD
SYDNEY STREET
CAMERON AVENUE
FLAT ROCK CREEK CATCHMENT
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
FLAT ROCK CREEK
LUCKNOW STREET
BURRA ROAD
ARTARMON ROAD
LANE COVE NORTH
WICKHAM PARK
BROUGHTON ROAD
JERSEY ROAD
T1 NORTH SHORE & WESTERN LINE AND T9 NORTHERN LINE
CHELMSFORD AVENUE
RICHMOND ROAD
PACIFIC HIGHWAY
GEORGE PLACE
RESERVE RD
THOMSON PARK
ARTARMON
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
CLELAND ROAD
ARTARMON RESERVE
MILNER ROAD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
BL6
XD_FC01
BL5
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
RESERVE ROAD INTERCHANGE
PARKES ROAD
XD_FC04
XD_FC05
GORE HILL FREEWAY
NAREMBURN
GRANDVIEW STREET
MARDEN STREET
MALACHLAN AVENUE
XD_FC02
XD_FC03
PUNCH STREET
BL3
LAMB ST ROAD
STATION STREET
PARK ROAD
BL4
HERBERT STREET
WASHAM STREET
LANE COVE
ROTHAM PARADE
WHITING STREET
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
ST LEONARDS
CLARENDON STREET
CLEG ST
RESERVE ROAD
DICKSON AVENUE
JOINS SHEET 3
NAREMBURN PARK

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 4 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel
- Immersed Tube Tunnel

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

THE HIGHTOR
CASTLECRAG
LINDEN WAY
CHEYNE WALK
WILLOUGHBY COUNCIL
PEACH TREE BAY
SAILORS BAY
SEAFORTH CRES
NORTHERN BEACHES COUNCIL
PRINCES PROMENADE
ALAN AVENUE
SEAFORTH
RICHMOND ROAD
ASHTON AVENUE
SEAFORTH CRES
SEAFORTH BLUFF
BL8
BL7
MINNAMURRA ROAD
MINIMBAH ROAD
CLIVE PARK
BYORA CRESCENT
TYCANNAH ROAD
DALMENY ROAD
WILLOUGHBY COUNCIL
SAILORS BAY ROAD
NORTHBRIDGE
BOURMAC AVENUE
COOLAWIN ROAD
MIOWERA ROAD
MIDDLE HARBOUR
TEMPORARY MOORING FACILITY
BEAUTY POINT
DELECTA AVENUE
MOSMAN COUNCIL
BEAUTY POINT ROAD
MOSMAN
BAY STREET
PINDARI AVENUE
MARSALA STREET
PEARL BAY AVENUE
PEARL BAY CATCHMENT
BL9
SPIT ROAD
SPIT WEST RESERVE
PARRIWI HEAD
MIDDLE HARBOUR

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

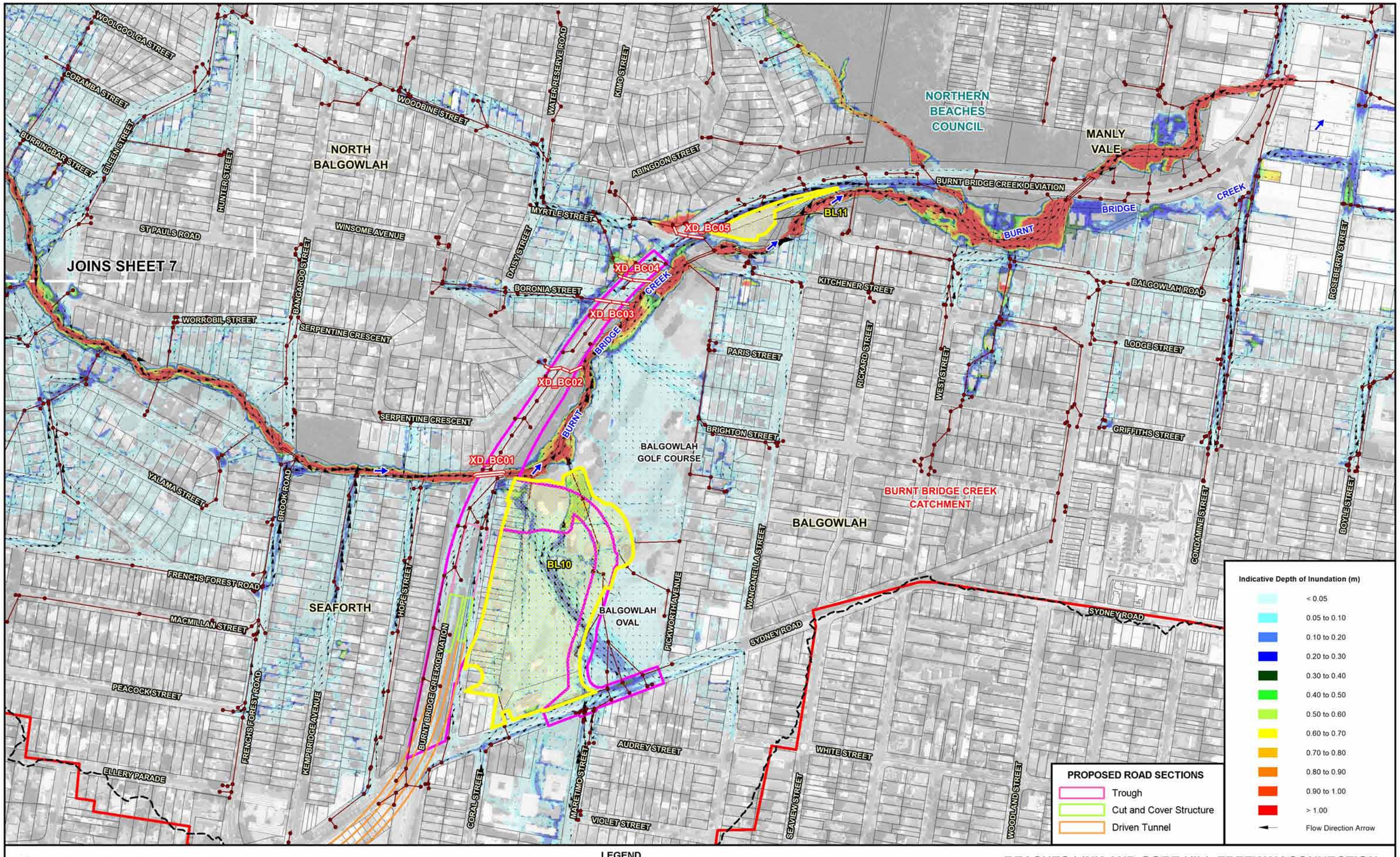
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 5 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 6 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

BB Q4
BB DL02
BL13
BL12
XD_BB03
SEAFORTH
BB DL01
BB Q2
BB Q1
KIRKWOOD STREET
WAKEHURST GOLF CLUB
JOINS SHEET 8
BANTRY BAY CATCHMENT
BANTRY BAY RESERVE
ALLAMBIE HEIGHTS
MANLY CREEK CATCHMENT
JUDITH STREET
SEAFORTH OVAL
MANNING STREET
WATERVIEW STREET
BURNT STREET
UPPER CLONTARF STREET
MONS ROAD
BALGOWLAH PUBLIC SCHOOL
WARRINGAH STREET
BARDOO AVENUE
ALTO AVENUE
GLOUCESTER STREET
NORTHERN BEACHES COUNCIL
NORTH BALGOWLAH
CARRAWEEN AVENUE
EURELLA AVENUE
PRINCE EDWARD ROAD
BURNT BRIDGE CREEK CATCHMENT
WOODBINE STREET
WOOLGOOLGA RESERVE
YEOLAND POINT
URUNGA STREET
JOINS SHEET 6
MIDDLE HARBOUR
CASTLE CIRCUIT
WOOLGOOLGA STREET
CLONTARF STREET
LISTER AVENUE
CORAMBA STREET
EXPLOSIVES RESERVE
WILLOUGHBY COUNCIL
FROMELLES AVENUE
BURRINGBAR STREET
EILEEN STREET
WAKEHURST PARKWAY
BARINGA AVENUE
HUNTER STREET
CASTLE COVE
ACACIA ROAD
ST PAULS ROAD

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Existing Transverse Drainage and Identifier
- BB03 Peak Flow Location and Identifier
- Existing Drainage Line

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 7 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

JOINS SHEET 9

JOINS SHEET 7

MC Q7
MC Q6
MC Q5
MC Q4
MC Q3
MC DL02
XD_MC06
WAKEHURST PARKWAY
MANLY CREEK
ALLAMBIE HEIGHTS
MC Q2
MC Q1
MC DL01
XD_MC07
KILLARNEY HEIGHTS
MANLY CREEK CATCHMENT
NORTHERN BEACHES COUNCIL
MANLY DAM
BANTRY BAY CATCHMENT
BB Q6
BB Q5
BB DL03
XD_BB01
BANTRY BAY
BB Q3
XD_BB02
BB Q4
BB DL02
BL13
BL12
XD_BB03
SEAFORTH
BB Q2
BB Q1
BB DL01
BB DL01
KIRKWOOD STREET
WAKEHURST GOLF CLUB

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Existing Transverse Drainage and Identifier
- MC Q24 Peak Flow Location and Identifier
- Existing Drainage Line

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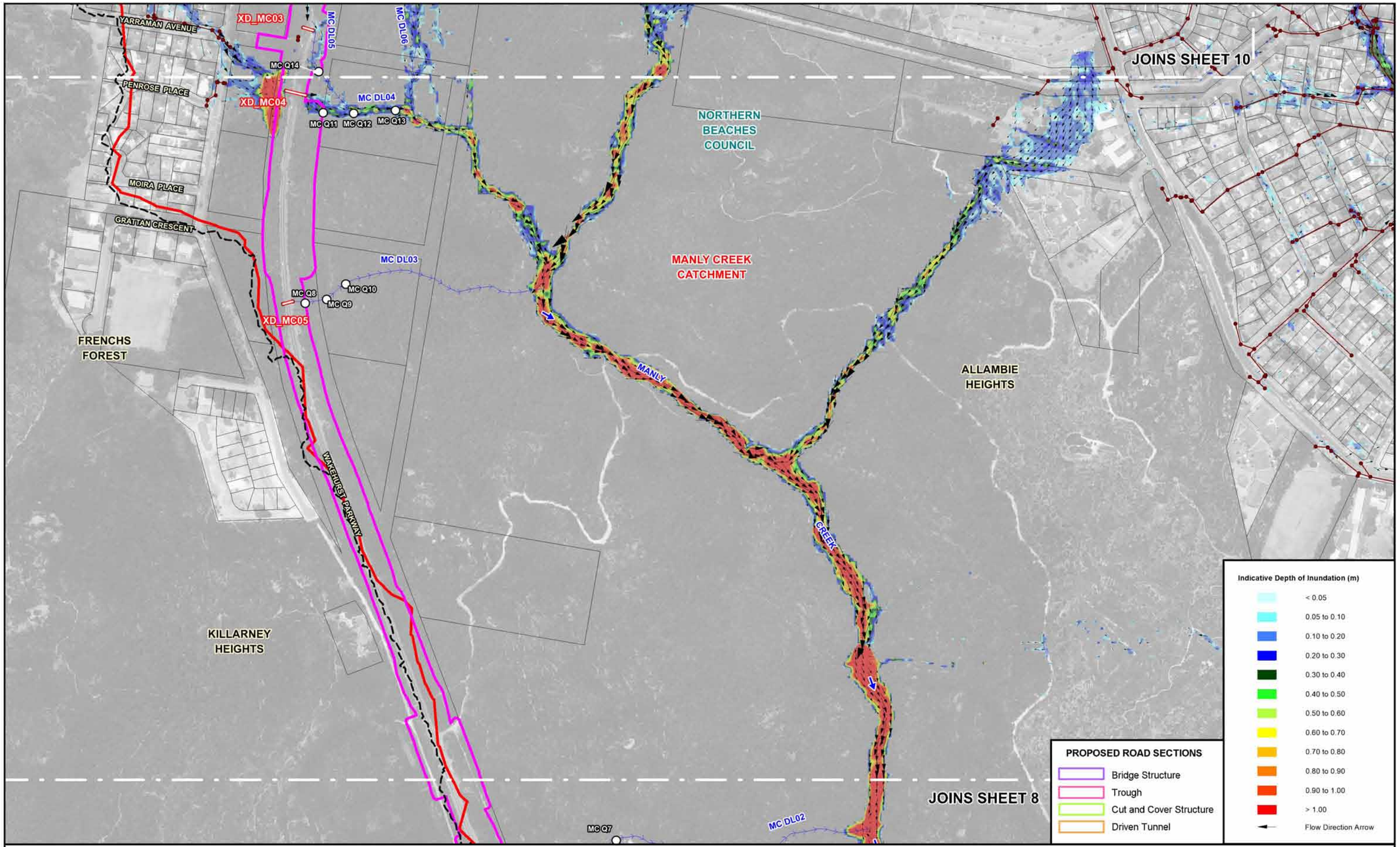
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 8 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- XD_MC03 Existing Transverse Drainage and Identifier
- MC Q13 Peak Flow Location and Identifier
- Existing Drainage Line

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 9 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

FRENCHS FORESTROAD WEST
FRENCHS FORESTROAD EAST
TREFOIL CREEK
TREFOIL CREEK CATCHMENT
ROMFORD ROAD
HURDIS AVENUE
HARMSTON AVENUE
INVERNESS AVENUE
PATANGA ROAD
DAREEN STREET
FRENCHS FOREST
NORTHERN BEACHES HOSPITAL
WAKEHURST PARKWAY
BL14
WARRINGAH ROAD
NORTHERN BEACHES COUNCIL
KARINGAL CRESCENT
AKORA STREET
PRIMROSE AVENUE
XD_MC01
MC Q17
MC DL07
FITZPATRICK AVENUE
MC Q18
MANLY CREEK CATCHMENT
RODBOROUGH ROAD
ALLAMBIE ROAD
BANTRY BAY CATCHMENT
RANGERS RETREAT ROAD
BANTRY BAY ROAD
AQUATIC DRIVE
MC DL07
MC Q19
PARNI PLACE
GARNER AVENUE
ALLAMBIE HEIGHTS
XD_MC02
MC Q15
AQUATIC RESERVE
MC DL06
MC Q16
KANYA STREET
WAKEHURST PARKWAY
MC DL05
MC DL06
XD_MC03
YARRAMAN AVENUE
JOINS SHEET 9

Indicative Depth of Inundation (m)
< 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
Flow Direction Arrow

PROPOSED ROAD SECTIONS
Bridge Structure
Trough
Cut and Cover Structure
Driven Tunnel

N
50 0 50 100 150 m
Scale: 1:5,000

LEGEND
Limit of Main Stream Flooding and Major Overland Flow Mapping
Existing Drainage System
LGA Boundary
Catchment Boundary
BL2 Construction Support Site and Identifier
Project Surface Road Works Footprint
Northern Beaches Hospital Surface Road Works
XD_MC03 Existing Transverse Drainage and Identifier
MC Q12 Peak Flow Location and Identifier
Existing Drainage Line

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.2
(Sheet 10 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
10% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00

REFER SHEET 10
REFER SHEET 9
REFER SHEET 8
REFER SHEET 7
REFER SHEET 6
REFER SHEET 5
REFER SHEET 4
REFER SHEET 3
REFER SHEET 2

BL1 BL2 BL3 BL4 BL5 BL6 BL7 BL8 BL9 BL10 BL11 BL12 BL13 BL14

TREFOIL CREEK
MANLY CREEK
BURNT BRIDGE CREEK
ROCK CREEK
WILLOUGHBY CREEK
FLAT ROCK CREEK

TEMPORARY MOORING FACILITY

BEACON HILL
NARRAWEENA
FRENCHS FOREST
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
FRESHWATER
KILLARNEY HEIGHTS
BANTRY BAY
KU-RING-GAI COUNCIL
ROSEVILLE CHASE
MANLY VALE
ROSEVILLE
LINDFIELD
QUEENSCLIFF
CASTLE COVE
FAIRLIGHT
SEAFORTH
MIDDLE COVE
CHATSWOOD
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
BALGOWLAH
CASTLECRAG
MANLY
WILLOUGHBY
BALGOWLAH HEIGHTS
LANE COVE NORTH
ARTARMON
LANE COVE WEST
NORTH HARBOUR
NORTHBRIDGE
LANE COVE
NAREMBURN
LANE COVE COUNCIL
CAMMERAY
MIDDLE HARBOUR
ST LEONARDS
CREMORNE
MOSMAN
RIVERVIEW
CROWS NEST
GREENWICH
MOSMAN COUNCIL
NORTHWOOD

WARRINGAH ROAD
PITTWATER ROAD
ARCHBOLD ROAD
PACIFIC HIGHWAY
GORDON STREET
FRENCHS FOREST ROAD
SYDNEY ROAD
EASTERN VALLEY WAY
EPPING ROAD
LANE COVE TUNNEL
WARRINGAH FREEWAY
SPIT ROAD
MILITARY ROAD
WAKEHURST PARKWAY

N

400 0 400 800

Scale: 1:40,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- BL2 Construction Support Site and Identifier
- Project Surface Road Works Footprint
- Driven Tunnel
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 1 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

DODDS STREET

MCBURNEY STREET

BROOK STREET

MARKS STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

TRIBUTARY

STREET

HAMILTON LANE

HAMILTON RESERVE

BROOK

PALMER STREET

GORE HILL FREEWAY

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

CHANDOS STREET

MATTHEW STREET

ATCHISON STREET

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

JENKINS STREET

ABBOTT STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

MILLER STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

WARRINGAH FREEWAY

XD_WC01

BL1

NORTH SYDNEY COUNCIL

PINE ST

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

LUMSDEN STREET

AMHERST STREET

MORDEN STREET

BELLS AVENUE

ECHO STREET

WARRINGA ROAD

GREEN PARK

CAMMERAY GOLF COURSE

CAMMERAY

CAMMERAY PARK

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY ROAD

CREEK

WILLOUGHBY

FALL STREET

EARLE STREET

PARK AVENUE

GRAFTON STREET

GRASMERE ROAD

SUTHERLAND STREET

MORTLOCK RESERVE

MIDDLE HARBOUR

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

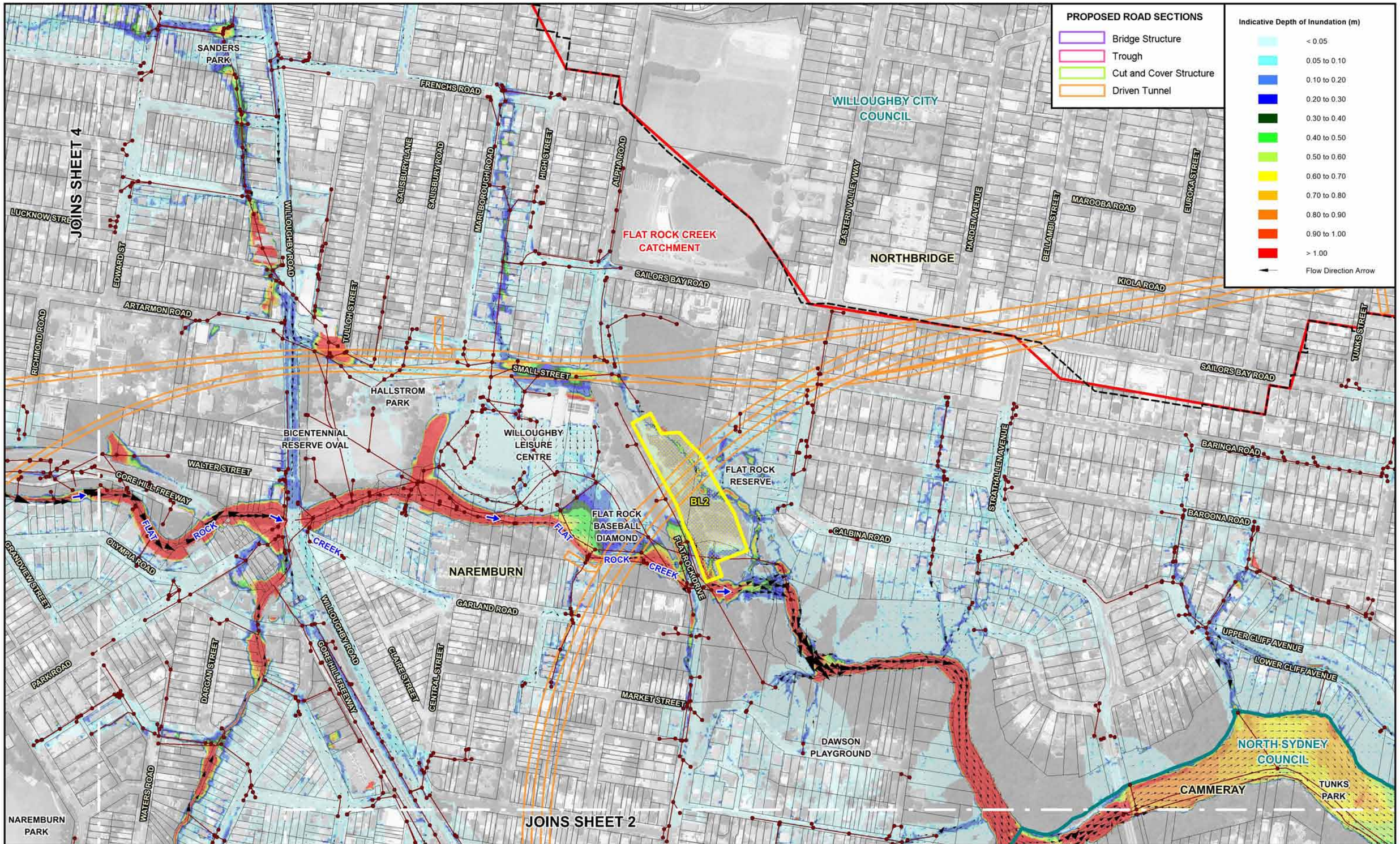
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 2 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 3 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

LANE COVE NORTH
LANE COVE
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
ARTARMON
ST LEONARDS
NAREMBURN
NAREMBURN PARK
FLAT ROCK CREEK CATCHMENT
ELSIE WEARN PARK
WICKHAM PARK
THOMSON PARK
CLELAND PARK
ARTARMON RESERVE
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
RESERVE ROAD INTERCHANGE
T1 NORTH SHORE & WESTERN LINE AND T9 NORTHERN LINE
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
GORE HILL FREEWAY
PACIFIC HIGHWAY
ARTARMON ROAD
CAMERON AVENUE
BURRA ROAD
TINDALE ROAD
ELIZABETH ST
SYDNEY STREET
FLAT ROCK CREEK
LUCKNOW STREET
CHELMSFORD AVENUE
RICHMOND ROAD
JERSEY ROAD
BROUGHTON ROAD
GEORGE PLACE
RESERVE RD
MILNER ROAD
BARTON ROAD
HAMPDEN ROAD
CLELAND ROAD
PARKES ROAD
PUNCH STREET
LAMBS ROAD
GRANDVIEW STREET
STATION STREET
PARK ROAD
HERBERT STREET
WATHAM STREET
CLEG ST
RESERVE ROAD
MARDEN STREET
McLACHLAN AVENUE
HOTHAM PARADE
WHITING STREET
CLAREDON STREET
DICKSON AVENUE
BL2
BL3
BL4
BL5
BL6
XD_FC01
XD_FC02
XD_FC03
XD_FC04
XD_FC05
JOINS SHEET 3

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 4 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel
- Immersed Tube Tunnel

Indicative Depth of Inundation (m)
- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

THE HIGHTOR
CASTLECRAG
LINDEN WAY
CHEYNE WALK
WILLOUGHBY COUNCIL
SEAFORTH CRES
NORTHERN BEACHES COUNCIL
PRINCES PROMENADE
ALAN AVENUE
ASHTON AVENUE
RICHMOND ROAD
SEAFORTH
SEAFORTH CRES
SEAFORTH BLUFF
PEACH TREE BAY
SAILORS BAY
BL8
BL7
BL9
MIDDLE HARBOUR
SPIT ROAD
SPIT WEST RESERVE
PARRIWI HEAD
MINNAMURRA ROAD
BYORA CRESCENT
MINIMBAH ROAD
CLIVE PARK
TYCANNAH ROAD
DALMENY ROAD
WILLOUGHBY COUNCIL
SAILORS BAY ROAD
NORTHBRIDGE
BOURMAC AVENUE
COOLAWIN ROAD
MIOWERA ROAD
TEMPORARY MOORING FACILITY
BEAUTY POINT
DELECTA AVENUE
MOSMAN COUNCIL
BEAUTY POINT ROAD
MOSMAN
BAY STREET
PINDARI AVENUE
MARSALA STREET
PEARL BAY AVENUE
PEARL BAY CATCHMENT

N
50 0 50 100 150 m
Scale: 1:5,000

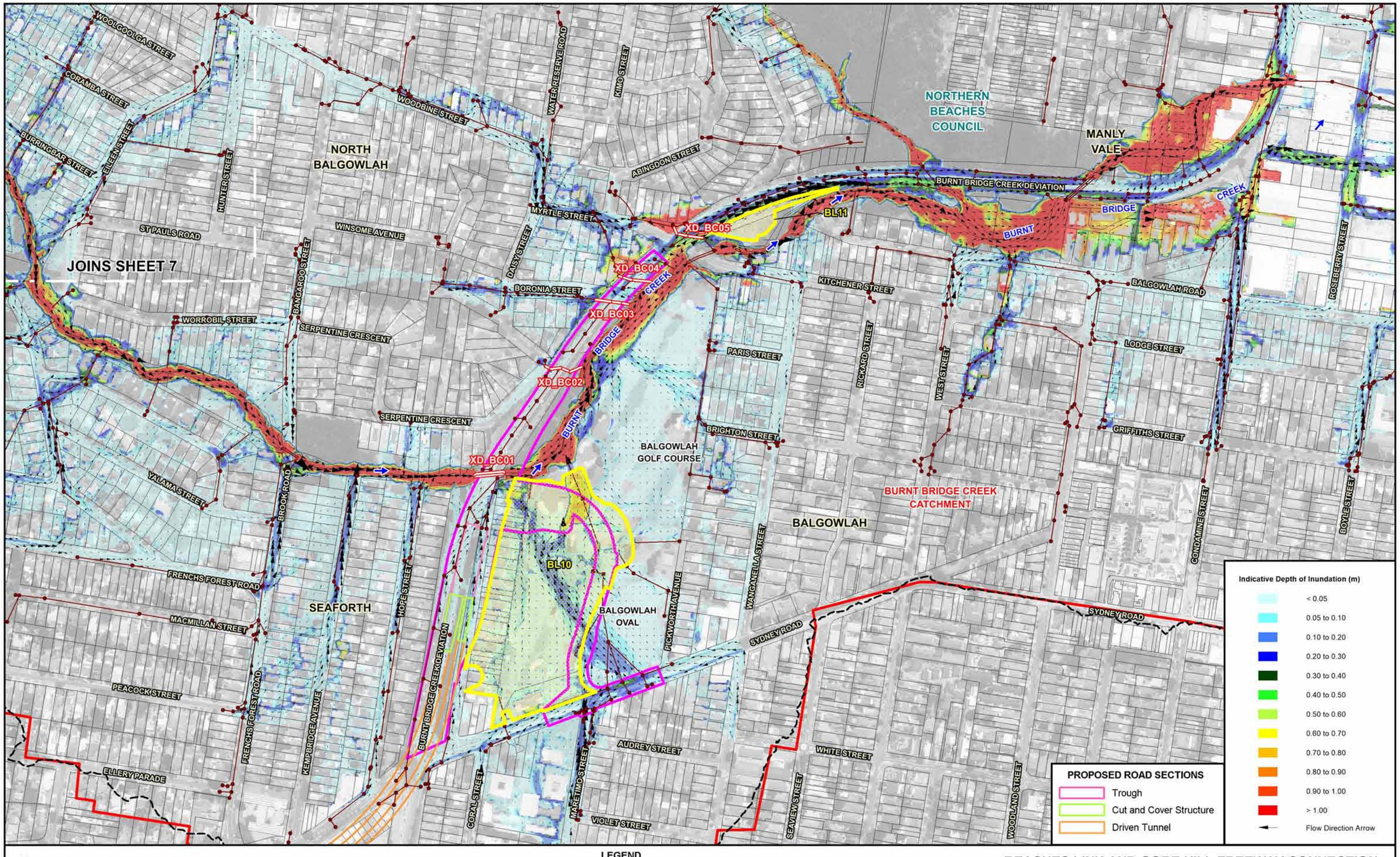
LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 5 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 6 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

BB Q4
BB DL02
BL13
BL12
XD_BB03
SEAFORTH
BB DL01
BB Q2
BB Q1
KIRKWOOD STREET
WAKEHURST GOLF CLUB
JOINS SHEET 8
BANTRY BAY CATCHMENT
BANTRY BAY RESERVE
ALLAMBIE HEIGHTS
MANLY CREEK CATCHMENT
JUDITH STREET
SEAFORTH OVAL
MANNING STREET
WATERVIEW STREET
BURNT STREET
UPPER CLONTARF STREET
MONS ROAD
BALGOWLAH PUBLIC SCHOOL
WARRINGAH STREET
BARDOO AVENUE
ALTO AVENUE
GLOUCESTER STREET
NORTHERN BEACHES COUNCIL
NORTH BALGOWLAH
GARRAWEEN AVENUE
EURELLA AVENUE
PRINCE EDWARD ROAD
BURNT BRIDGE CREEK CATCHMENT
WOODBINE STREET
WOOLGOOLGA RESERVE
YEOLAND POINT
URUNGA STREET
JOINS SHEET 6
MIDDLE HARBOUR
CASTLE CIRCUIT
WOOLGOOLGA STREET
CLONTARF STREET
LISTER AVENUE
CORAMBA STREET
EXPLOSIVES RESERVE
WILLOUGHBY COUNCIL
FROMELLES AVENUE
BURRINGBAR STREET
EILEEN STREET
BARINGA AVENUE
WAKEHURST PARKWAY
HUNTER STREET
ACACIA ROAD
ST PAULS ROAD
CASTLE COVE

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Existing Transverse Drainage and Identifier
- BB03 Peak Flow Location and Identifier
- Existing Drainage Line

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 7 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

JOINS SHEET 9

JOINS SHEET 7

MC Q7
MC Q6
MC Q5
MC Q4
MC Q3
MC DL02
XD_MC06
WAKEHURST PARKWAY
MANLY CREEK
ALLAMBIE HEIGHTS
MC Q2
MC Q1
MC DL01
XD_MC07
KILLARNEY HEIGHTS
MANLY CREEK CATCHMENT
NORTHERN BEACHES COUNCIL
MANLY DAM
BANTRY BAY CATCHMENT
BANTRY BAY
BB Q6
BB Q5
BB DL03
XD_BB01
BB Q3
XD_BB02
BB Q4
BB DL02
BL13
BL12
XD_BB03
SEAFORTH
BB DL01
BB Q2
BB Q1
BB DL01
KIRKWOOD STREET
WAKEHURST GOLF CLUB

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

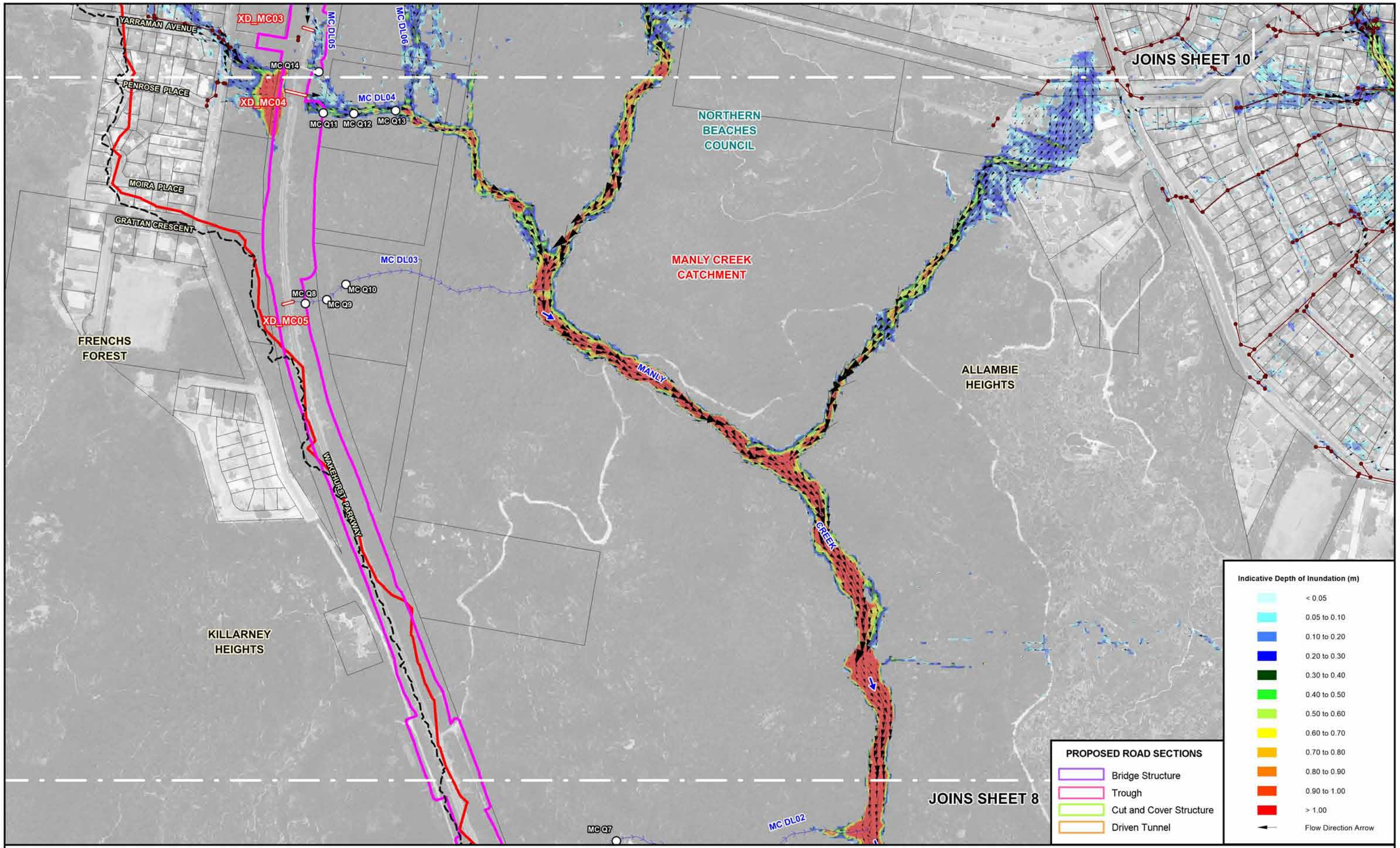
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Existing Transverse Drainage and Identifier
- MC Q24 Peak Flow Location and Identifier
- Existing Drainage Line

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 8 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- XD_MC03 Existing Transverse Drainage and Identifier
- MC Q13 Peak Flow Location and Identifier
- Existing Drainage Line

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 9 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

FRENCHS FORESTROAD WEST
FRENCHS FORESTROAD EAST
TREFOIL CREEK
ROMFORD ROAD
HURDIS AVENUE
HARMSTON AVENUE
INVERNESS AVENUE
PATANGA ROAD
DAREEN STREET
FRENCHS FOREST
NORTHERN BEACHES HOSPITAL
TREFOIL CREEK CATCHMENT
WARRINGAH ROAD
WAKEHURST PARKWAY
BL14
NORTHERN BEACHES COUNCIL
KARINGAL CRESCENT
AKORA STREET
PRIMROSE AVENUE
XD_MC01
MC Q17
MC DL07
FITZPATRICK AVENUE
MC Q18
MANLY CREEK CATCHMENT
RODBOROUGH ROAD
ALLAMBIE ROAD
BANTRY BAY CATCHMENT
RANGERS RETREAT ROAD
BANTRY BAY ROAD
AQUATIC DRIVE
MC DL07
MC Q19
PARNI PLACE
GARNER AVENUE
ALLAMBIE HEIGHTS
XD_MC02
MC Q15
AQUATIC RESERVE
MC DL06
KANYA STREET
MC Q16
WAKEHURST PARKWAY
JOINS SHEET 9
YARRAMAN AVENUE
XD_MC03
MC DL05
MC DL06

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- BL2 Construction Support Site and Identifier
- Project Surface Road Works Footprint
- Northern Beaches Hospital Surface Road Works
- XD_MC03 Existing Transverse Drainage and Identifier
- MC Q12 Peak Flow Location and Identifier
- Existing Drainage Line

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.3
(Sheet 10 of 10)

FLOODING PATTERNS UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00

REFER SHEET 10
REFER SHEET 9
REFER SHEET 8
REFER SHEET 7
REFER SHEET 6
REFER SHEET 5
REFER SHEET 4
REFER SHEET 3
REFER SHEET 2

BL14 BL13 BL12 BL11 BL10 BL9 BL8 BL7 BL6 BL5 BL4 BL3 BL2 BL1

TREFOIL CREEK
MANLY CREEK
BURNT BRIDGE CREEK
ROCK CREEK
WILLOUGHBY CREEK
FLAT

TEMPORARY MOORING FACILITY

BEACON HILL
NARRAWEENA
FRENCHS FOREST
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
CURL CURL
ALLAMBIE HEIGHTS
FRESHWATER
EAST LINDFIELD
KILLARNEY HEIGHTS
BANTRY BAY
KU-RING-GAI COUNCIL
ROSEVILLE CHASE
ROSEVILLE
LINDFIELD
MANLY VALE
QUEENSCLIFF
CASTLE COVE
SEAFORTH
FAIRLIGHT
CHATSWOOD
MIDDLE COVE
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
BALGOWLAH
CASTLECRAG
MANLY
WILLOUGHBY
BALGOWLAH HEIGHTS
LANE COVE NORTH
ARTARMON
LANE COVE WEST
NORTH HARBOUR
NORTHBRIDGE
LANE COVE
NAREMBURN
LANE COVE COUNCIL
CAMMERAY
MIDDLE HARBOUR
ST LEONARDS
CREMORNE
MOSMAN
RIVERVIEW
CROWS NEST
GREENWICH
MOSMAN COUNCIL
NORTHWOOD
LANE COVE RIVER

WARRINGAH ROAD
PITTWATER ROAD
ARCHBOLD ROAD
PACIFIC HIGHWAY
CONDAMINE STREET
FRENCHS FOREST ROAD
SYDNEY ROAD
EASTERN VALLEY WAY
EPPING ROAD
LANE COVE TUNNEL
WARRINGAH FREEWAY
SPIT ROAD
MILITARY ROAD

N

400 0 400 800 1200 m

Scale: 1:40,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- BL2 Construction Support Site and Identifier
- Project Surface Road Works Footprint
- Driven Tunnel
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 1 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

DODDS STREET

BROOK STREET

MCBURNEY STREET

TRIBUTARY

MARKS STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

STREET

HAMILTON LANE

HAMILTON RESERVE

BROOK

CORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

ATCHISON STREET

MATTHEW STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

WEST STREET

MILLER STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

WARRINGAH FREEWAY

XD_WC01

BL1

NORTH SYDNEY COUNCIL

PINE ST

PALMER STREET

MILLER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

BELLEVUE STREET

LUMSDEN STREET

AMHERST STREET

ECHO STREET

WARRINGA ROAD

MORDEN STREET

BELLS AVENUE

GREEN PARK

CAMMERAY ROAD

CREEK

WILLOUGHBY

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

CAMMERAY

GRASMERE ROAD

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY PARK

SUTHERLAND STREET

ERNEST STREET

MORTLOCK RESERVE

MIDDLE HARBOUR

LLEYS RD

Indicative Depth of Inundation (m)

< 0.05	
0.05 to 0.10	
0.10 to 0.20	
0.20 to 0.30	
0.30 to 0.40	
0.40 to 0.50	
0.50 to 0.60	
0.60 to 0.70	
0.70 to 0.80	
0.80 to 0.90	
0.90 to 1.00	
> 1.00	
Flow Direction Arrow	

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

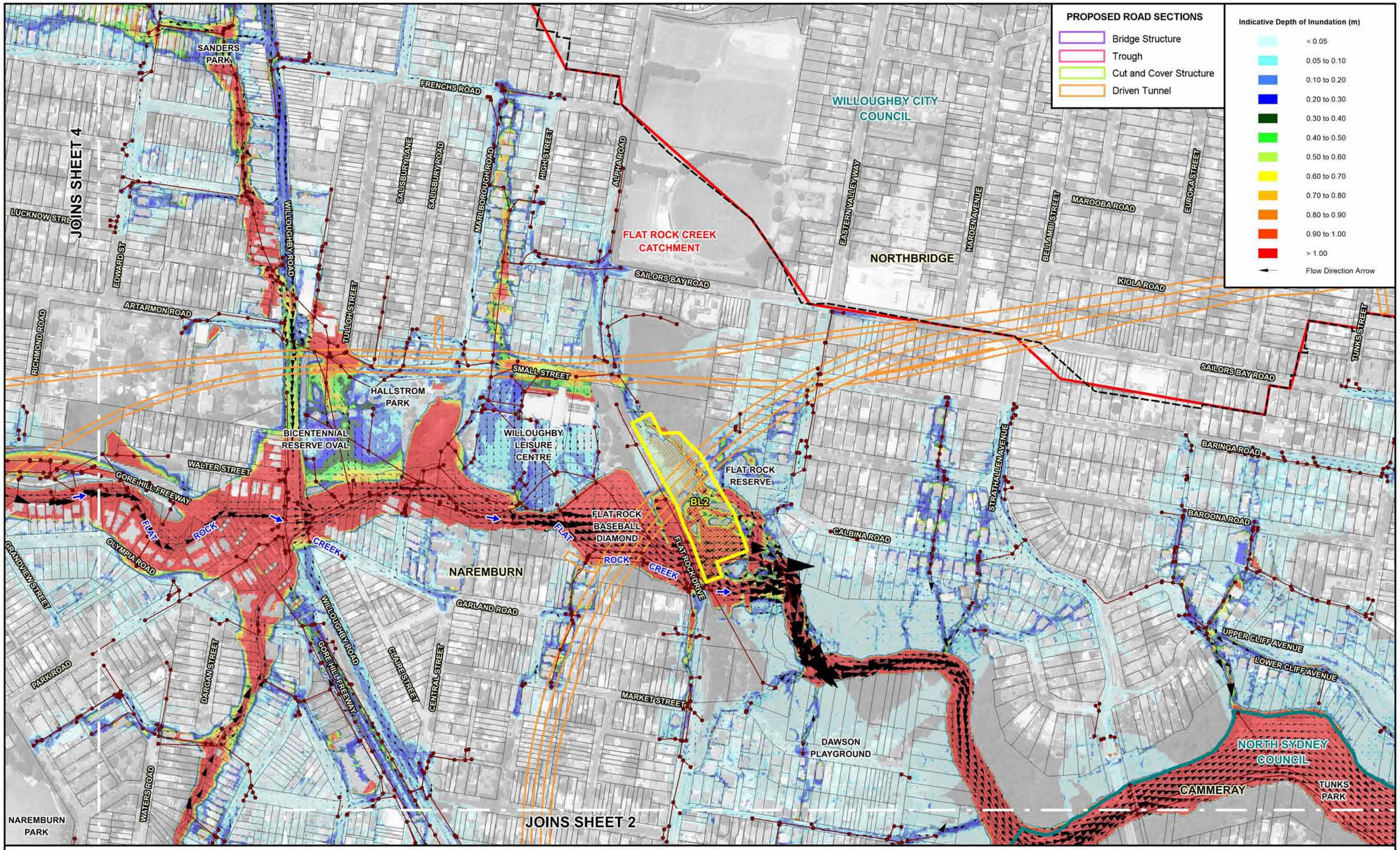
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 2 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 3 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

LANE COVE NORTH
LANE COVE
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
ARTARMON
ST LEONARDS
NAREMBURN
NAREMBURN PARK
CLELAND PARK
THOMSON PARK
ARTARMON RESERVE
ELSIE WEARN PARK
WICKHAM PARK
FLAT ROCK CREEK CATCHMENT
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
RESERVE ROAD INTERCHANGE
PACIFIC HIGHWAY
GEORGE PLACE
BROUGHTON ROAD
JERSEY ROAD
RESERVE RD
MILNER ROAD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
MARDEN STREET
McLACHLAN AVENUE
HOTHAM PARADE
WHITING STREET
DICKSON AVENUE
CLARENDON STREET
BARTON ROAD
HAMPDEN ROAD
T1 NORTH SHORE & WESTERN LINE AND CLELAND ROAD T9 NORTHERN LINE
PARKES ROAD
GORE HILL FREEWAY
PUNCH STREET
LAMBS ROAD
HERBERT STREET
WALTHAM STREET
CLEG ST
RESERVE ROAD
STATION STREET
PARK ROAD
GRANDVIEW STREET
CHELMSFORD AVENUE
RICHMOND ROAD
LUCKNOW STREET
SYDNEY STREET
TINDALE ROAD
ARTARMON ROAD
ELIZABETH ST
CAMERON AVENUE
BURRA ROAD
FLAT ROCK CREEK
BL2
BL3
BL4
BL5
BL6
XD_FC01
XD_FC02
XD_FC03
XD_FC04
XD_FC05
JOINS SHEET 3

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 4 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel
- Immersed Tube Tunnel

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

THE HIGHTOR
CASTLECRAG
LINDEN WAY
CHEYNE WALK
WILLOUGHBY COUNCIL
SEAFORTH CRES
NORTHERN BEACHES COUNCIL
PRINCES PROMENADE
ALAN AVENUE
ASHTON AVENUE
SEAFORTH
RICHMOND ROAD
SEAFORTH CRES
SEAFORTH BLUFF
PEACH TREE BAY
SAILORS BAY
BL8
BL7
BL9
MIDDLE HARBOUR
SPIT ROAD
SPIT WEST RESERVE
PARRIWI HEAD
MINNAMURRA ROAD
MINIMBAH ROAD
CLIVE PARK
BYORA CRESCENT
TYCANNAH ROAD
DALMENY ROAD
WILLOUGHBY COUNCIL
SAILORS BAY ROAD
NORTHBRIDGE
BOURMAC AVENUE
COOLAWIN ROAD
MIOWERA ROAD
TEMPORARY MOORING FACILITY
BEAUTY POINT
DELECTA AVENUE
MOSMAN COUNCIL
BEAUTY POINT ROAD
MOSMAN
BAY STREET
PINDARI AVENUE
MARSALA STREET
PEARL BAY AVENUE
PEARL BAY CATCHMENT

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

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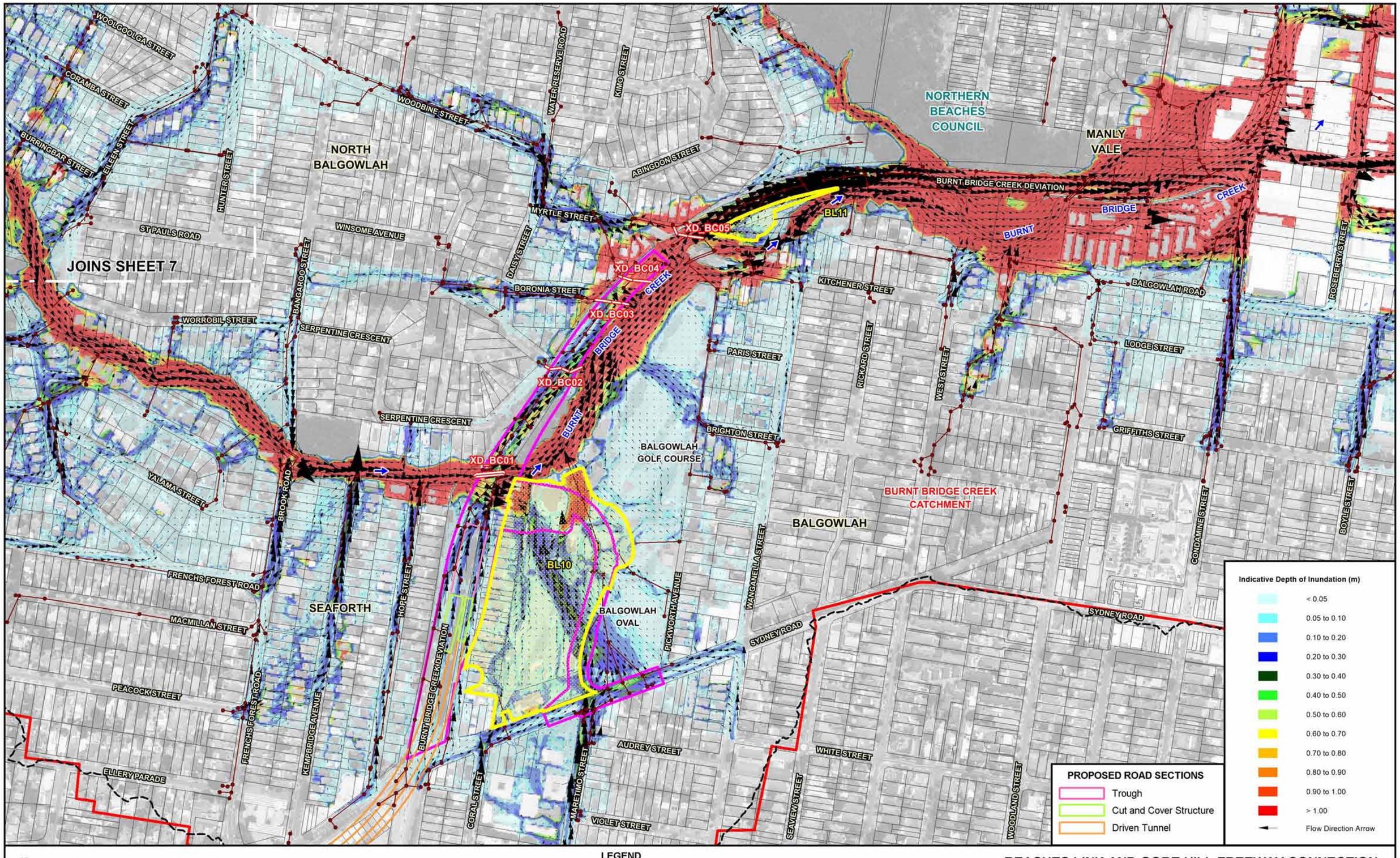
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 5 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 6 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

BB DL02
BB DL01
BB DL01
SEAFORTH
BL12
XD_BB03
BL13
KIRKWOOD STREET
WAKEHURST GOLF CLUB
JOINS SHEET 8
BANTRY BAY CATCHMENT
BANTRY BAY RESERVE
ALLAMBIE HEIGHTS
MANLY CREEK CATCHMENT
JUDITH STREET
SEAFORTH OVAL
MANNING STREET
WATERVIEW STREET
BURNT STREET
UPPER CLONTARF STREET
MONS ROAD
BALGOWLAH PUBLIC SCHOOL
WARRINGAH STREET
BARDOO AVENUE
ALTO AVENUE
GLOUCESTER STREET
NORTHERN BEACHES COUNCIL
NORTH BALGOWLAH
CARRAWEEN AVENUE
EURELLA AVENUE
PRINCE EDWARD ROAD
BURNT BRIDGE CREEK CATCHMENT
WOODBINE STREET
WOOLGOOLGA RESERVE
YEOLAND POINT
URUNGA STREET
JOINS SHEET 6
MIDDLE HARBOUR
CASTLE CIRCUIT
WOOLGOOLGA STREET
CORAMBA STREET
EXPLOSIVES RESERVE
WILLOUGHBY COUNCIL
CLONTARF STREET
LISTER AVENUE
FROMELLES AVENUE
BURRINGBAR STREET
EILEEN STREET
BARINGA AVENUE
HUNTER STREET
CASTLE COVE
WAKEHURST PARKWAY
ACACIA ROAD
ST PAULS ROAD

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Existing Transverse Drainage and Identifier
- Existing Drainage Line

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 7 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

JOINS SHEET 9

JOINS SHEET 7

MC DL02

MC DL01

MC DL03

BB DL01

BB DL02

BB DL01

XD_MC06

XD_MC07

XD_BB01

XD_BB02

XD_BB03

WAKEHURST PARKWAY

KIRKWOOD STREET

MANLY CREEK

ALLAMBIE HEIGHTS

KILLARNEY HEIGHTS

MANLY CREEK CATCHMENT

NORTHERN BEACHES COUNCIL

MANLY DAM

BANTRY BAY CATCHMENT

BANTRY BAY

SEAFORTH

BL12

BL13

WAKEHURST GOLF CLUB

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

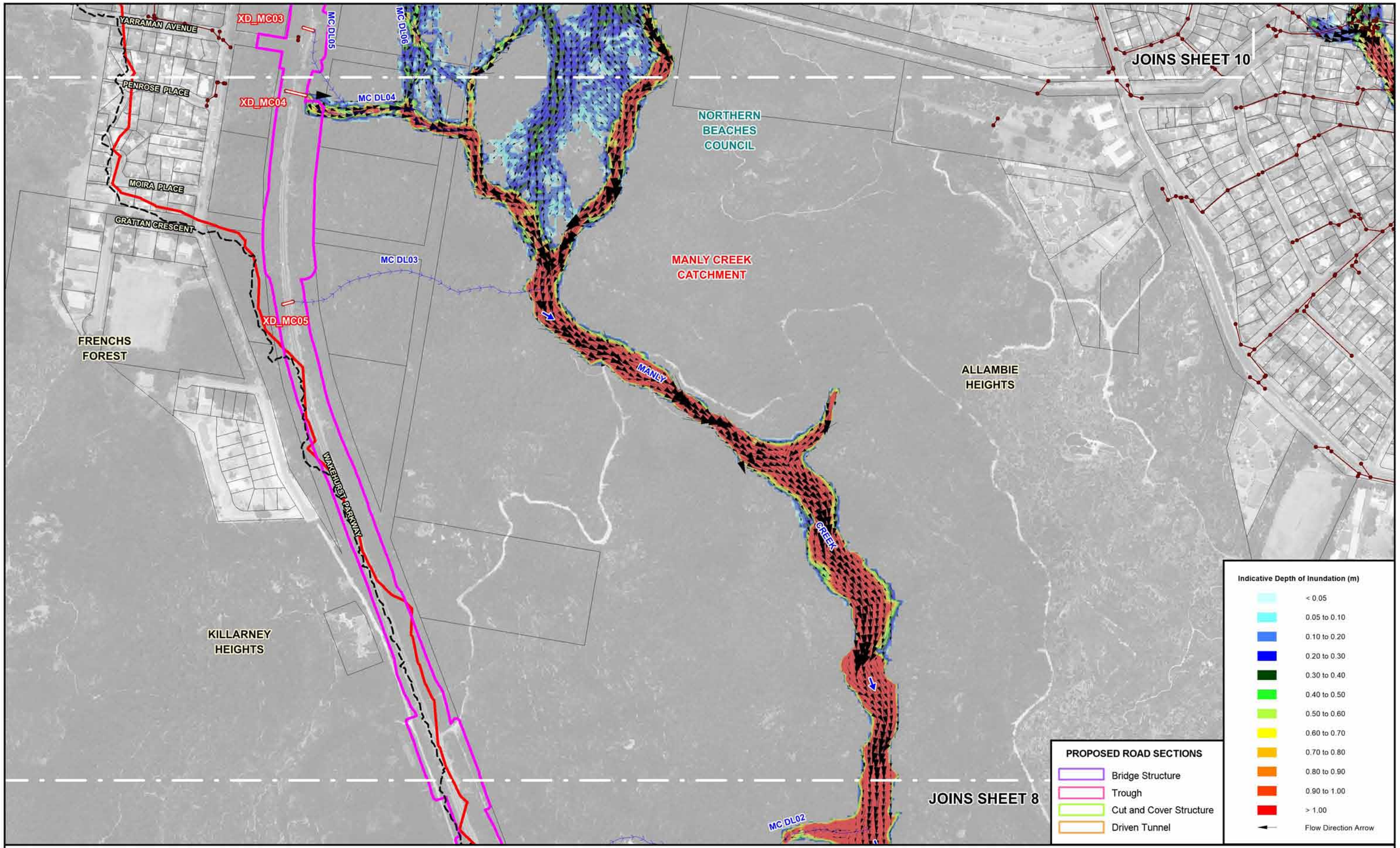
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Existing Transverse Drainage and Identifier
- Existing Drainage Line

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 8 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

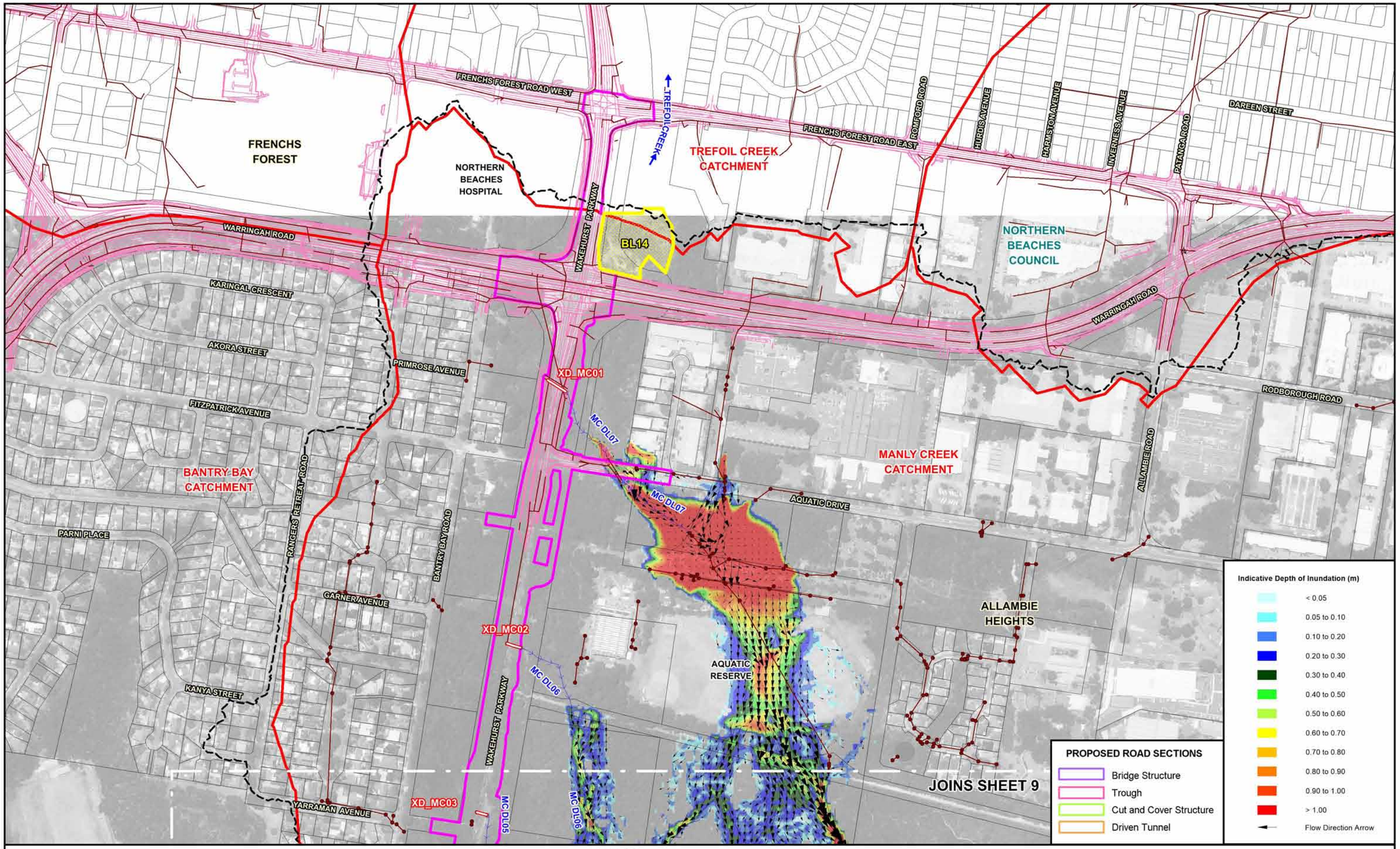
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- XD_MC03 Existing Transverse Drainage and Identifier
- Existing Drainage Line

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 9 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT

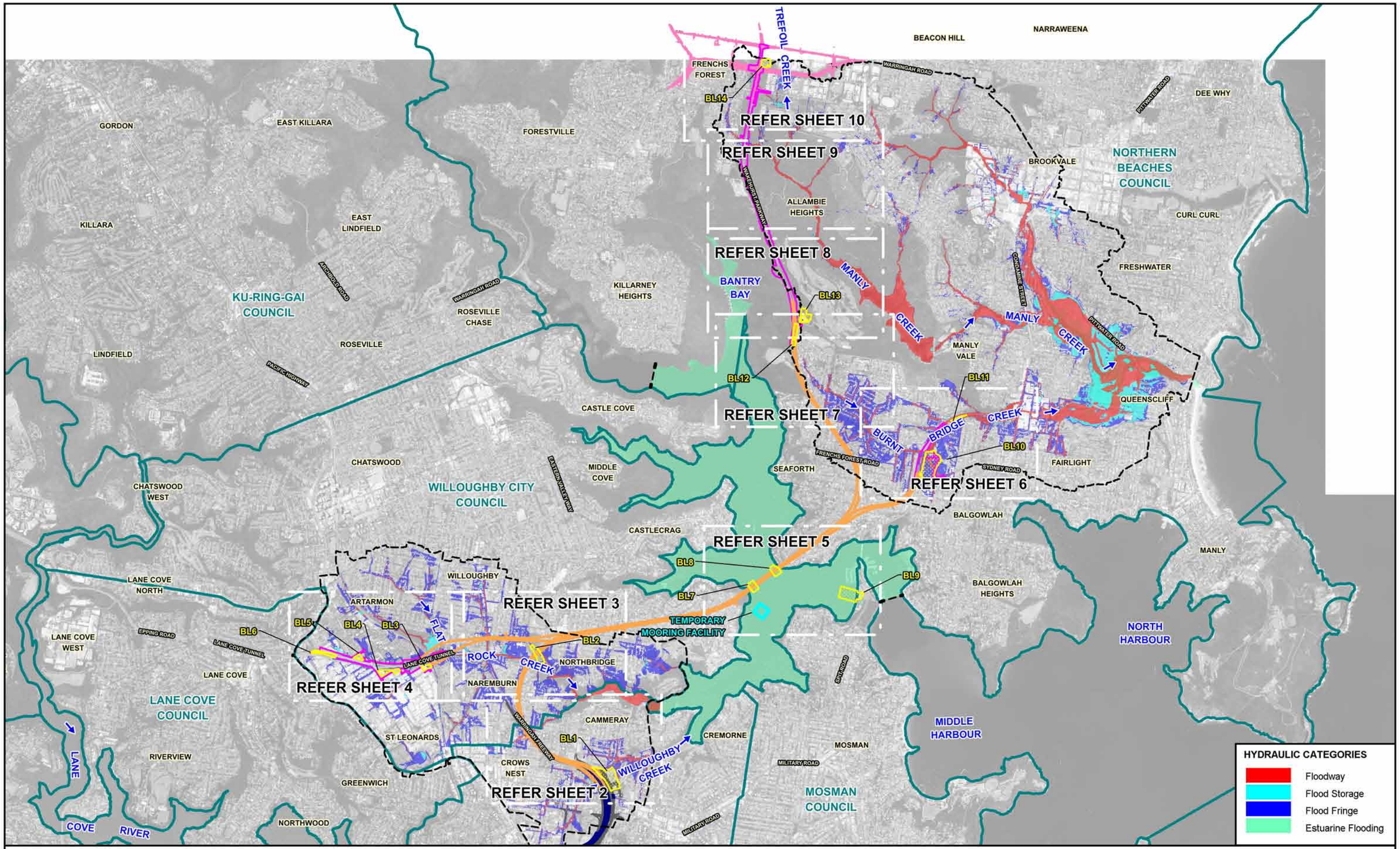


Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.4
(Sheet 10 of 10)

FLOODING UNDER PRESENT DAY CONDITIONS
PMF EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 1 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

DODDS STREET

BROOK STREET

MCBURNEY STREET

TRIBUTARY

MARKS STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

STREET

HAMILTON LANE

HAMILTON RESERVE

BROOK

CORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

ATCHISON STREET

MATTHEW STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

PACIFIC HWY

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

MILLER STREET

NORTH SYDNEY COUNCIL

PINE ST

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

BELLEVUE STREET

LUMSDEN STREET

AMHERST STREET

ECHO STREET

WARRINGA ROAD

MORDEN STREET

BELLS AVENUE

GREEN PARK

CAMMERAY ROAD

WILLOUGHBY

CREEK

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

CAMMERAY

GRASMERE ROAD

XD_WC01

BL1

WARRINGAH FREEWAY

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

MORTLOCK RESERVE

MIDDLE HARBOUR

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HYDRAULIC CATEGORIES

- Floodway
- Flood Storage
- Flood Fringe
- Estuarine Flooding

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 2 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HYDRAULIC CATEGORIES
- Floodway
- Flood Storage
- Flood Fringe
- Estuarine Flooding

JOINS SHEET 4

SANDERS PARK
FRENCHS ROAD
WILLOUGHBY CITY COUNCIL
LUCKNOW STREET
EDWARD ST
WILLOUGHBY ROAD
SALISBURY LANE
SALISBURY ROAD
MARLBOROUGH ROAD
HIGH STREET
ALPHA ROAD
FLAT ROCK CREEK CATCHMENT
EASTERN VALLEY WAY
NORTHBRIDGE
MARDEN AVENUE
BELLAMBI STREET
MAROOBA ROAD
EUROKA STREET
LOWER CLIFF STREET
SAILORS BAY ROAD
KIOLA ROAD
TUNKS STREET
ARTARMON ROAD
RICHMOND ROAD
TULLOH STREET
SMALL STREET
HALLSTROM PARK
BICENTENNIAL RESERVE OVAL
WILLOUGHBY LEISURE CENTRE
WALTER STREET
GORE HILL FREEWAY
FLAT ROCK RESERVE
BL2
STRATHALLEN AVENUE
BARINGA ROAD
BAROONA ROAD
FLAT ROCK BASEBALL DIAMOND
FLAT ROCK CREEK
FLAT ROCK DRIVE
CALBINA ROAD
OLYMPIA ROAD
GRANDVIEW STREET
NAREMBURN
GARLAND ROAD
WILLOUGHBY ROAD
GORE HILL FREEWAY
DARGAN STREET
GLAIRE STREET
CENTRAL STREET
PARK ROAD
MARKET STREET
UPPER CLIFF AVENUE
LOWER CLIFF AVENUE
DAWSON PLAYGROUND
NORTH SYDNEY COUNCIL
CAMMERAY
TUNKS PARK
WATERS ROAD
NAREMBURN PARK
JOINS SHEET 2

N
50 0 50 100 150 m
Scale: 1:5,000

LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

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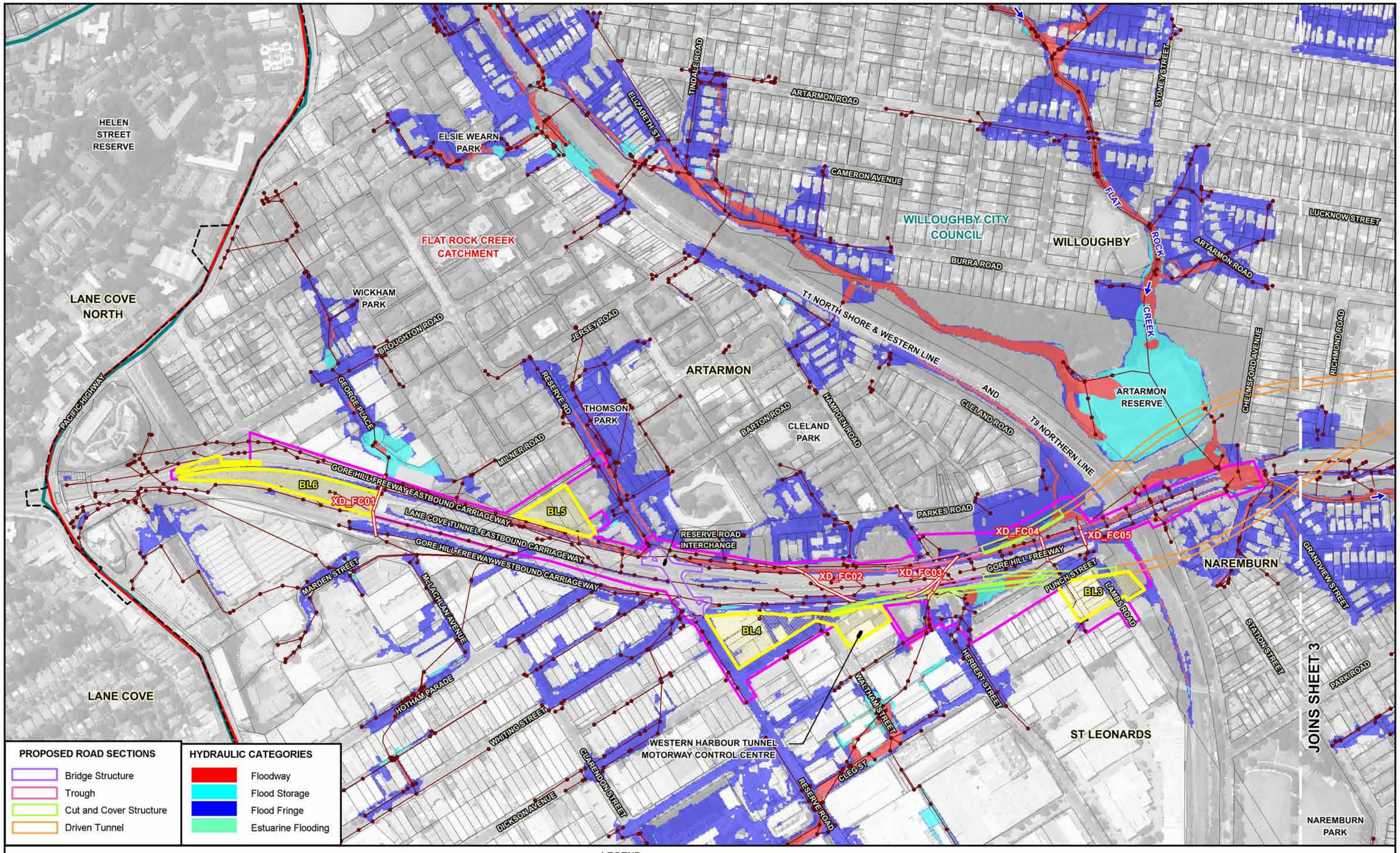
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 3 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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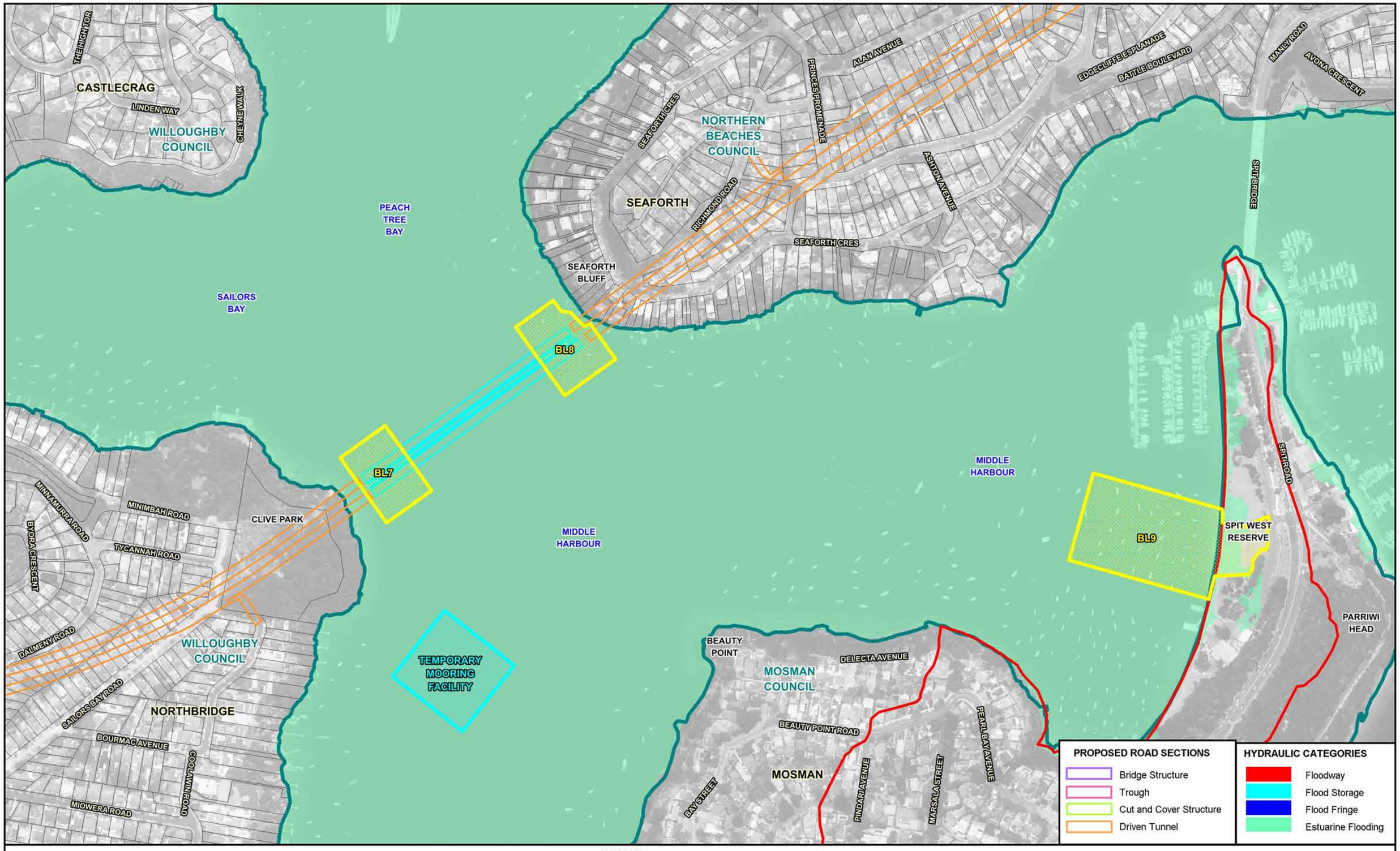
BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 4 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

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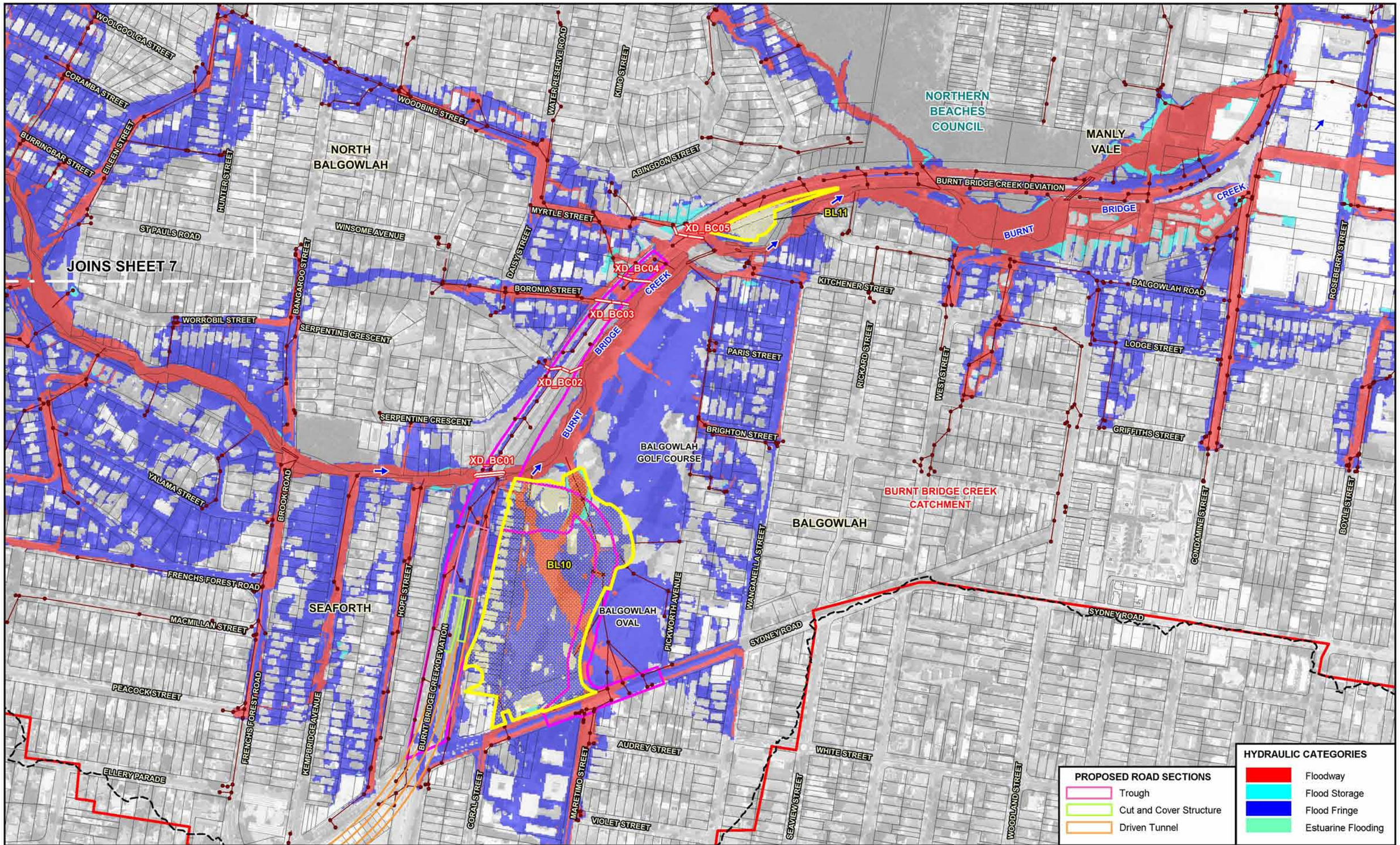
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 5 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

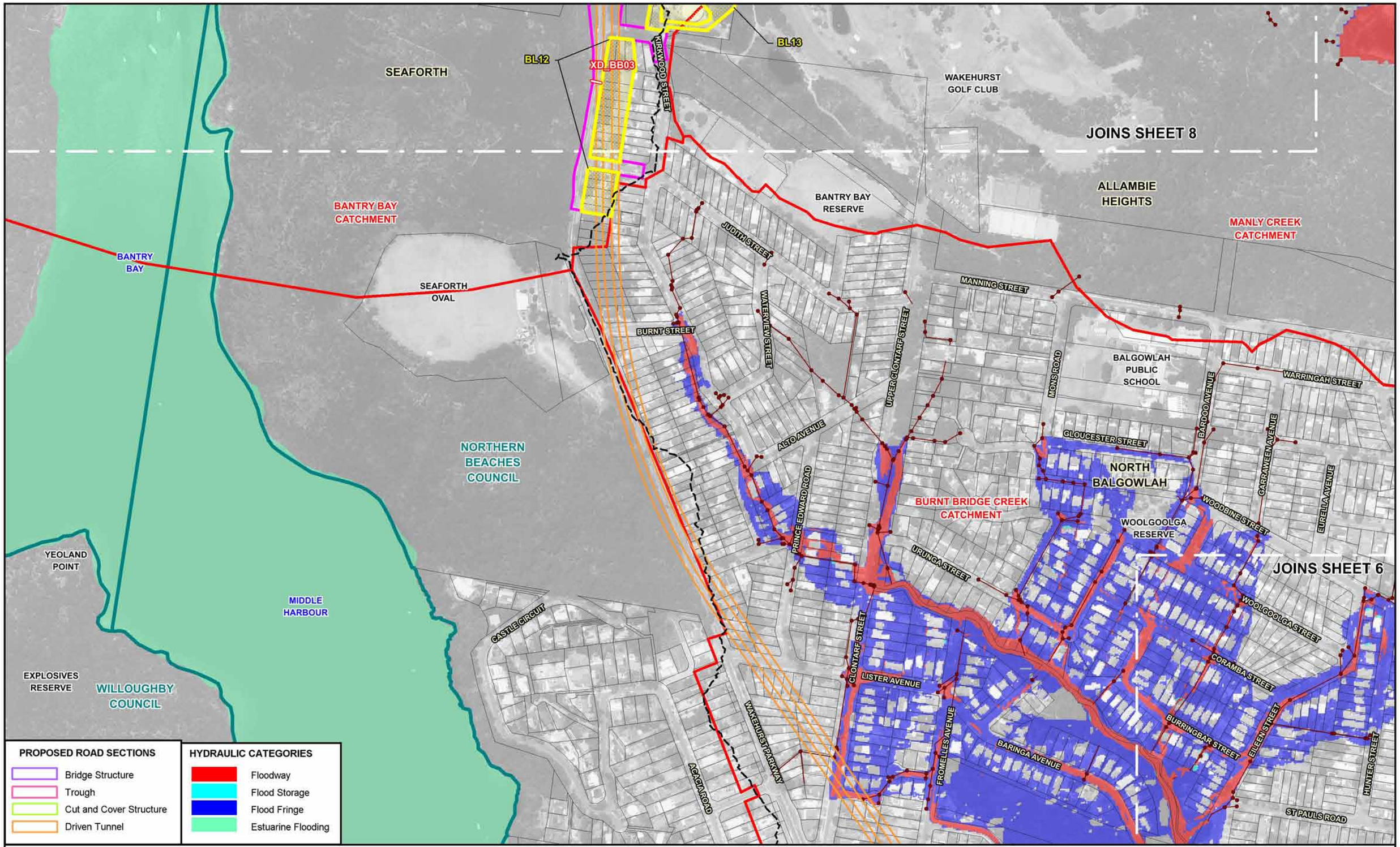


Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 6 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 7 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 9

JOINS SHEET 7

KILLARNEY HEIGHTS

ALLAMBIE HEIGHTS

MANLY CREEK CATCHMENT

BANTRY BAY CATCHMENT

NORTHERN BEACHES COUNCIL

BANTRY BAY

SEAFORTH

WAKEH GOLF

MANLY DAM

MANLY CREEK

WAKEHURST PARKWAY

KIRKWOOD STREET

MC DL02

MC DL01

XD_MC06

XD_MC07

BB DL03

BB DL02

BB DL01

XD_BB01

XD_BB02

XD_BB03

BL12

BL13

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HYDRAULIC CATEGORIES

- Floodway
- Flood Storage
- Flood Fringe
- Estuarine Flooding

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

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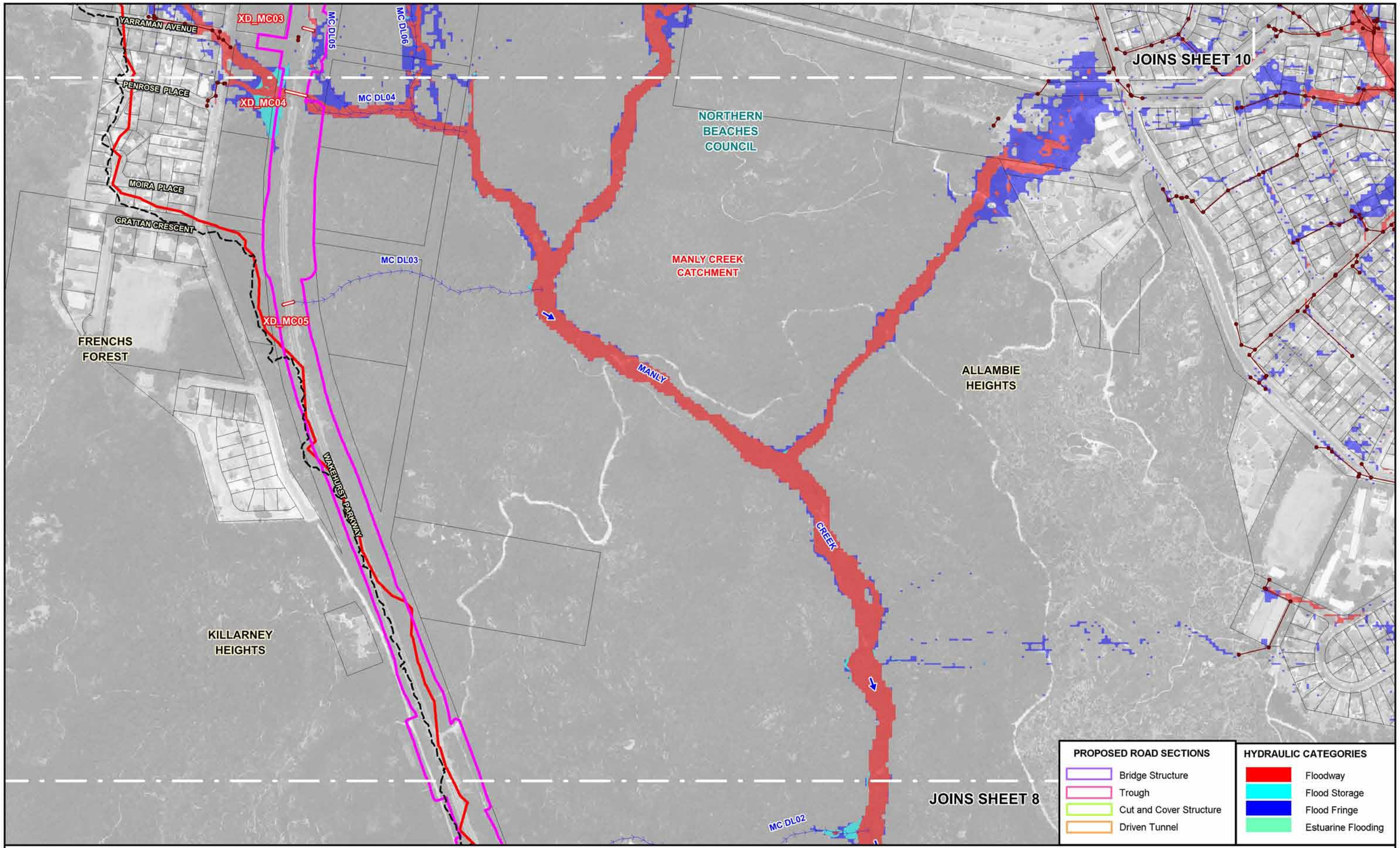
BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 8 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 9 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

FRENCHS FORESTROAD WEST
FRENCHS FORESTROAD EAST
TREFOIL CREEK
TREFOIL CREEK CATCHMENT
ROMFORD ROAD
HURDIS AVENUE
HARMSTON AVENUE
INVERNESS AVENUE
PATANGA ROAD
DAREEN STREET
FRENCHS FORESTNORTHERN BEACHES HOSPITAL
WARRINGAH ROAD
WAKEHURST PARKWAY
BL14
NORTHERN BEACHES COUNCIL
KARINGAL CRESCENT
AKORA STREET
PRIMROSE AVENUE
XD_MC01
FITZPATRICK AVENUE
MC DL07
RODBOROUGH ROAD
BANTRY BAY CATCHMENT
RANGERS RETREAT ROAD
BANTRY BAY ROAD
MANLY CREEK CATCHMENT
ALLAMBIE ROAD
AQUATIC DRIVE
PARNI PLACE
GARNER AVENUE
XD_MC02
ALLAMBIE HEIGHTS
ARNHEM ROAD
AQUATIC RESERVE
MC DL06
KANYA STREET
WAKEHURST PARKWAY
JOINS SHEET 9
YARRAMAN AVENUE
XD_MC03
MC DL05
MC DL06

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HYDRAULIC CATEGORIES
- Floodway
- Flood Storage
- Flood Fringe
- Estuarine Flooding

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Northern Beaches Hospital Surface Road Works
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

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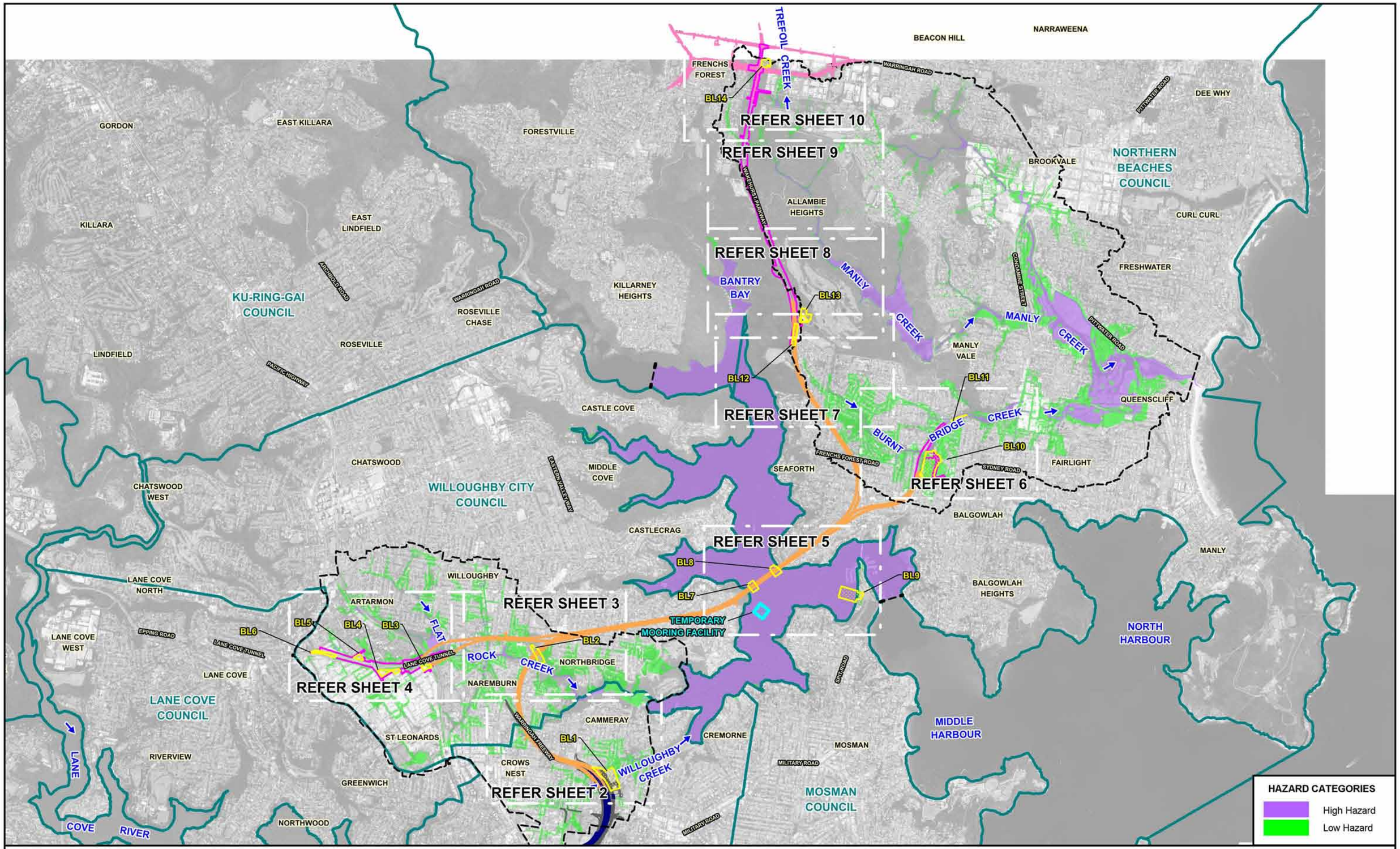
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.5
(Sheet 10 of 10)

PRELIMINARY HYDRAULIC CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 1 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

DODDS STREET

BROOK STREET

MCBURNEY STREET

TRIBUTARY

MARKS STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

STREET

HAMILTON LANE

HAMILTON RESERVE

BROOK

GORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

MATTHEW STREET

ATCHISON STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

PACIFIC HWY

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

MILLER STREET

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

BELLEVUE STREET

LUMSDEN STREET

AMHERST STREET

ECHO STREET

MORDEN STREET

BELLS AVENUE

WARRINGA ROAD

GREEN PARK

CAMMERAY ROAD

WILLOUGHBY

CREEK

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

GRASMERE ROAD

CAMMERAY

XD_WC01

BL1

WARRINGAH FREEWAY

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

PINE ST

NORTH SYDNEY COUNCIL

MORTLOCK RESERVE

MIDDLE HARBOUR

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HAZARD CATEGORIES

- High Hazard
- Low Hazard

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 2 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HAZARD CATEGORIES
- High Hazard
- Low Hazard

JOINS SHEET 4

SANDERS PARK
FRENCHS ROAD
WILLOUGHBY CITY COUNCIL
LUCKNOW STREET
EDWARD ST
WILLOUGHBY ROAD
SALISBURY LANE
SALISBURY ROAD
MARLBOROUGH ROAD
HIGH STREET
ALPHA ROAD
FLAT ROCK CREEK CATCHMENT
EASTERN VALLEY WAY
MARDEN AVENUE
BELLAMBI STREET
MAROOBA ROAD
EUROKA STREET
LOWER LIGH STREET
NORTHBRIDGE
SAILORS BAY ROAD
KIOLA ROAD
ARTARMON ROAD
RICHMOND ROAD
TULLOH STREET
TUNKS STREET
SMALL STREET
HALLSTROM PARK
BICENTENNIAL RESERVE OVAL
WILLOUGHBY LEISURE CENTRE
WALTER STREET
FLAT ROCK RESERVE
BL2
STRATHALLEN AVENUE
BARINGA ROAD
GORE HILL FREEWAY
FLAT ROCK BASEBALL DIAMOND
BAROONA ROAD
CALBINA ROAD
FLAT ROCK DRIVE
OLYMPIA ROAD
GRANDVIEW STREET
NAREMBURN
GARLAND ROAD
WILLOUGHBY ROAD
UPPER CLIFF AVENUE
LOWER CLIFF AVENUE
PARK ROAD
DARGAN STREET
GLARE STREET
CENTRAL STREET
MARKET STREET
DAWSON PLAYGROUND
NORTH SYDNEY COUNCIL
CAMMERAY
TUNKS PARK
WATERS ROAD
NAREMBURN PARK
JOINS SHEET 2

N
50 0 50 100 150 m
Scale: 1:5,000

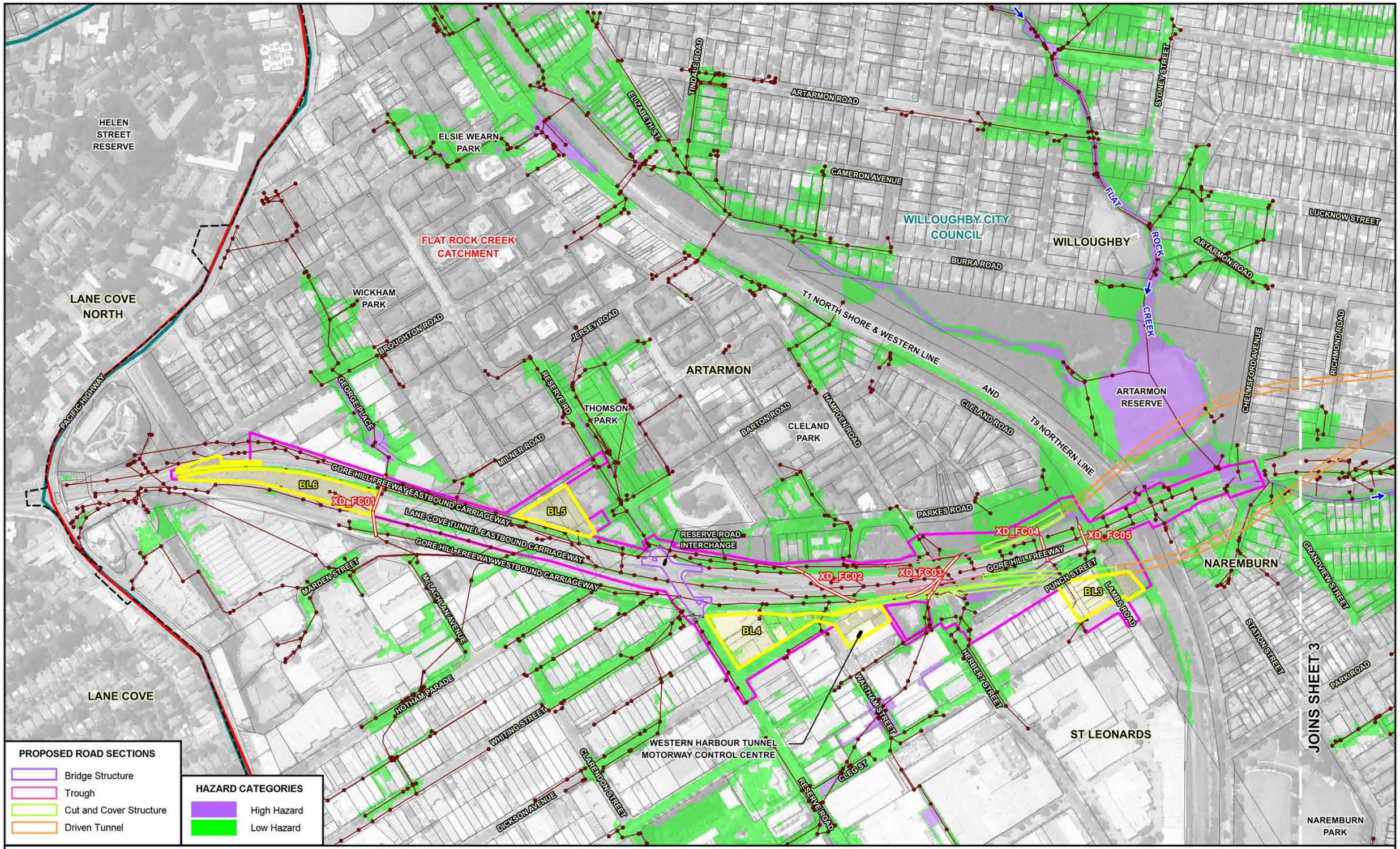
LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 3 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 4 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel
- Immersed Tube Tunnel

HAZARD CATEGORIES
- High Hazard
- Low Hazard

CASTLECRAG
THE HIGHTOR
LINDEN WAY
CHEYNE WALK
WILLOUGHBY COUNCIL
PEACH TREE BAY
SAILORS BAY
NORTHERN BEACHES COUNCIL
SEAFORTH
SEAFORTH CRES
PRINCES PROMENADE
ALAN AVENUE
RICHMOND ROAD
ASHTON AVENUE
SEAFORTH CRES
SEAFORTH BLUFF
SPIT BRIDGE
BL8
BL7
BL9
MIDDLE HARBOUR
MINIMBAH ROAD
CLIVE PARK
MINNAMURRA ROAD
BYORA CRESCENT
TYCANNAH ROAD
DALMENY ROAD
WILLOUGHBY COUNCIL
SAILORS BAY ROAD
NORTHBRIDGE
BOURMAC AVENUE
COOLAWIN ROAD
MIOWERA ROAD
TEMPORARY MOORING FACILITY
SPIT WEST RESERVE
SPIT ROAD
PARRIWI HEAD
BEAUTY POINT
DELECTA AVENUE
MOSMAN COUNCIL
BEAUTY POINT ROAD
MOSMAN
BAY STREET
PINDARI AVENUE
MARSALA STREET
PEARL BAY AVENUE
PEARL BAY CATCHMENT

N
50 0 50 100 150 m
Scale: 1:5,000

LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

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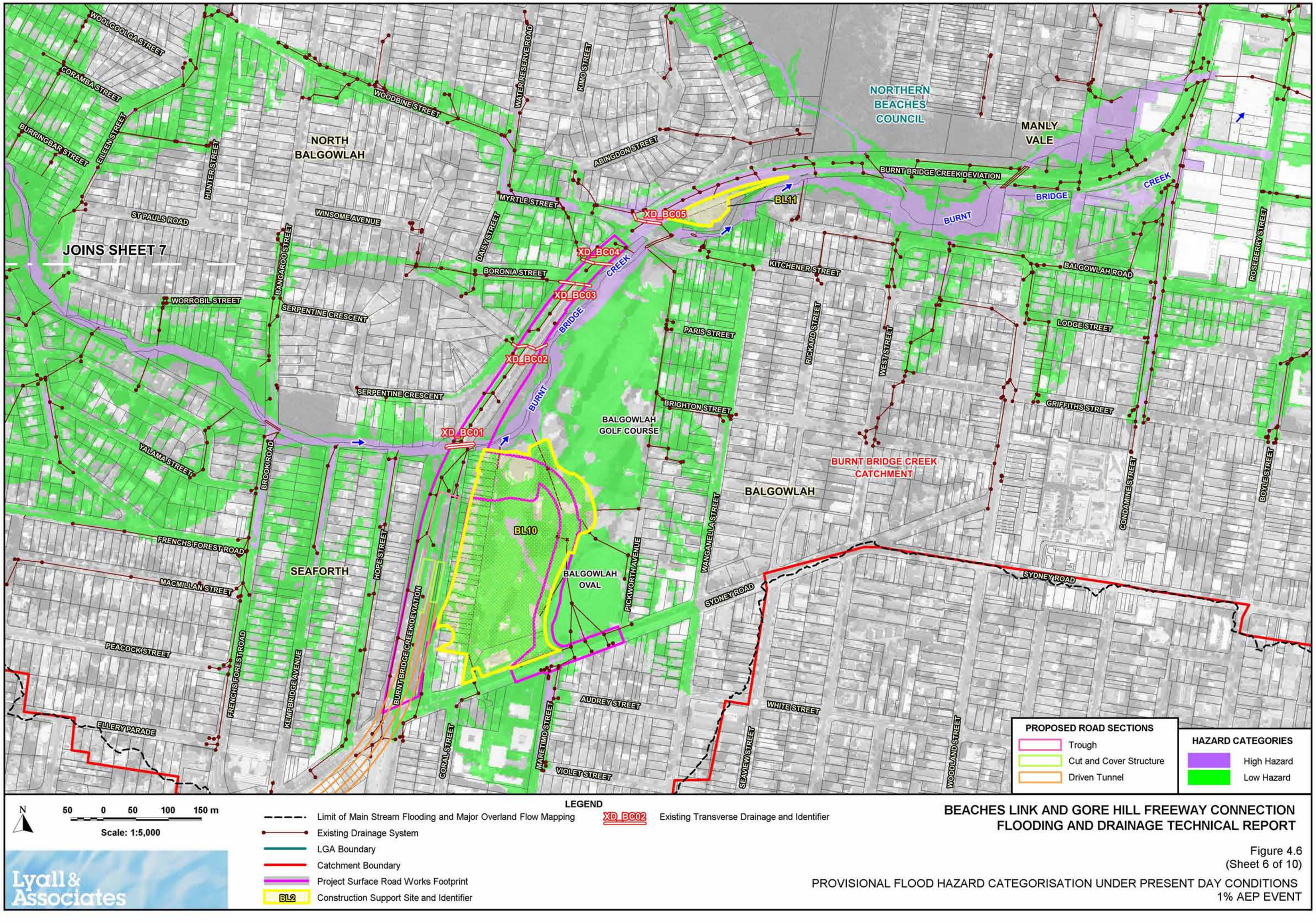
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 5 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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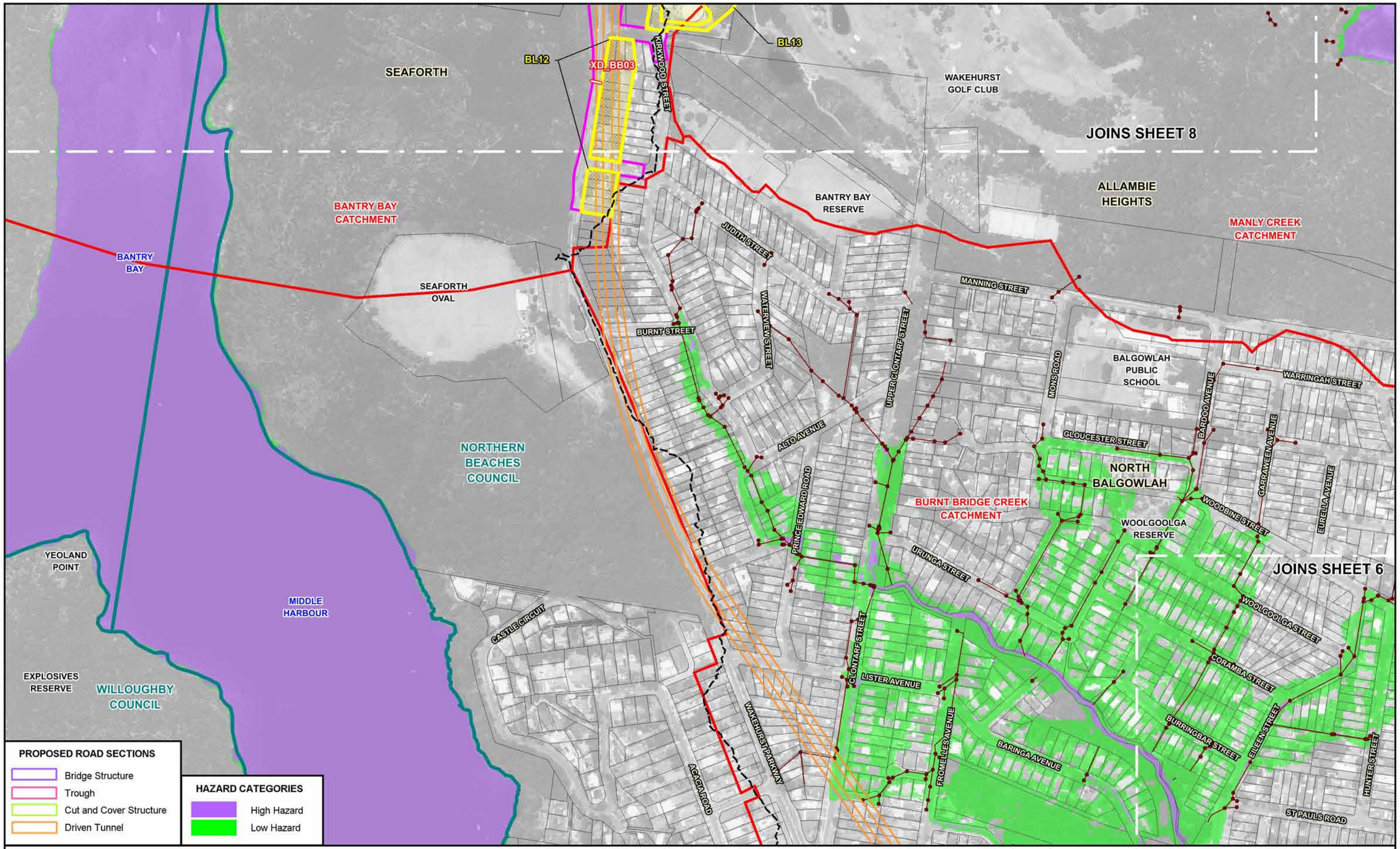
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 6 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 7 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 9

JOINS SHEET 7

MC DL02

MC DL01

BB DL03

BB DL02

BB DL01

BB DL01

XD_MC06

XD_MC07

XD_BB01

XD_BB02

XD_BB03

BL12

BL13

WAKEHURST PARKWAY

WAKEHURST PARKWAY

KIRKWOOD STREET

MANLY CREEK

ALLAMBIE HEIGHTS

KILLARNEY HEIGHTS

MANLY CREEK CATCHMENT

NORTHERN BEACHES COUNCIL

MANLY DAM

BANTRY BAY CATCHMENT

BANTRY BAY

SEAFORTH

WAKEHURST GOLF CLUB

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HAZARD CATEGORIES

- High Hazard
- Low Hazard

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

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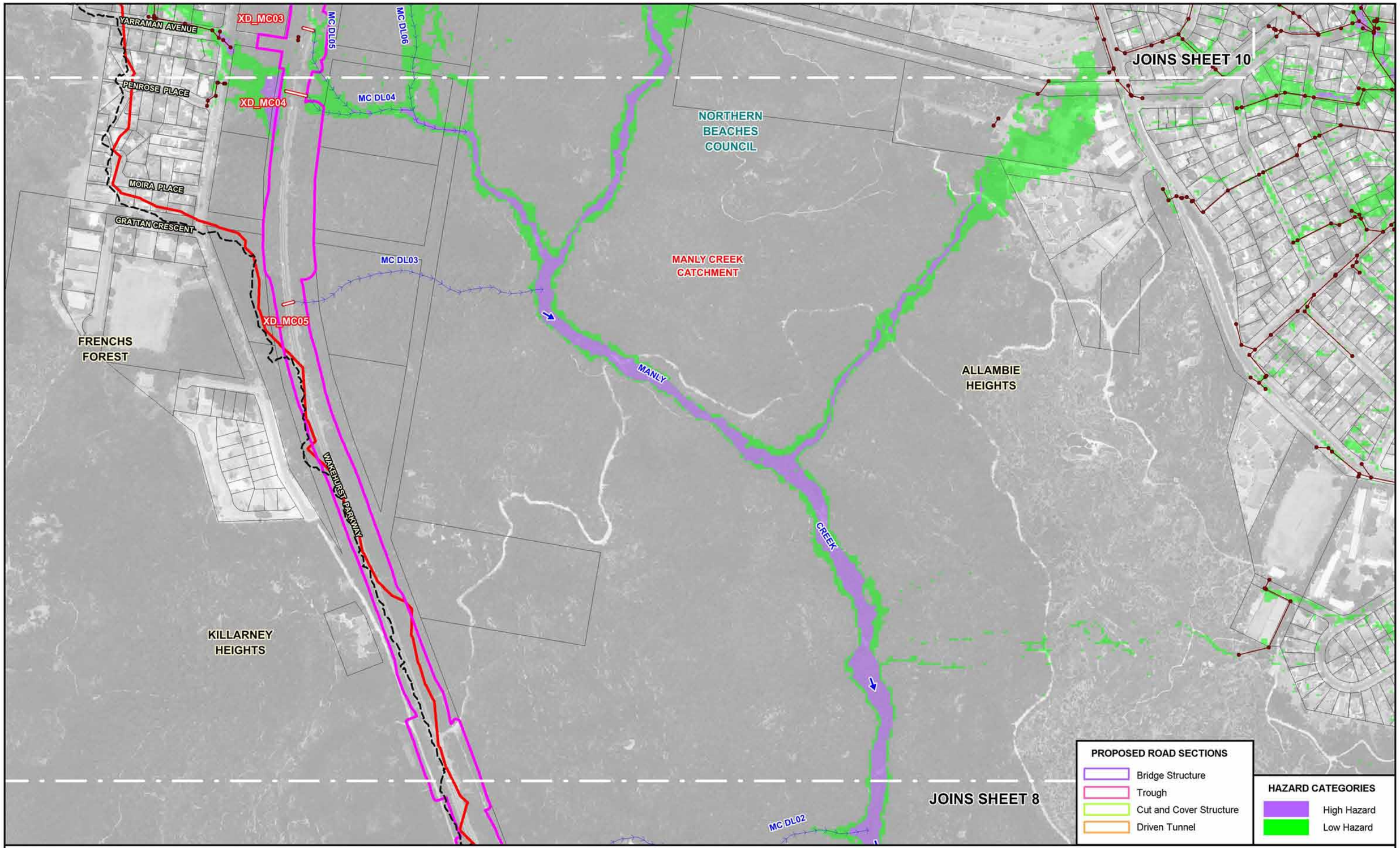
BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 8 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 9 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

FRENCHS FORESTROAD WEST
FRENCHS FORESTROAD EAST
TREFOIL CREEK
TREFOIL CREEK CATCHMENT
ROMFORD ROAD
HURDIS AVENUE
HARMSTON AVENUE
INVERNESS AVENUE
PATANGA ROAD
DAREEN STREET
FRENCHS FOREST
NORTHERN BEACHES HOSPITAL
WAKEHURST PARKWAY
BL14
WARRINGAH ROAD
NORTHERN BEACHES COUNCIL
KARINGAL CRESCENT
AKORA STREET
PRIMROSE AVENUE
XD_MC01
MC DL07
FITZPATRICK AVENUE
RODBOROUGH ROAD
MANLY CREEK CATCHMENT
ALLAMBIE ROAD
BANTRY BAY CATCHMENT
RANGERS RETREAT ROAD
BANTRY BAY ROAD
AQUATIC DRIVE
PARNI PLACE
GARNER AVENUE
XD_MC02
ALLAMBIE HEIGHTS
ARNHEM ROAD
AQUATIC RESERVE
MC DL06
KANYA STREET
WAKEHURST PARKWAY
YARRAMAN AVENUE
XD_MC03
MC DL05
JOINS SHEET 9

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HAZARD CATEGORIES
- High Hazard
- Low Hazard

N

50 0 50 100 150 m

Scale: 1:5,000

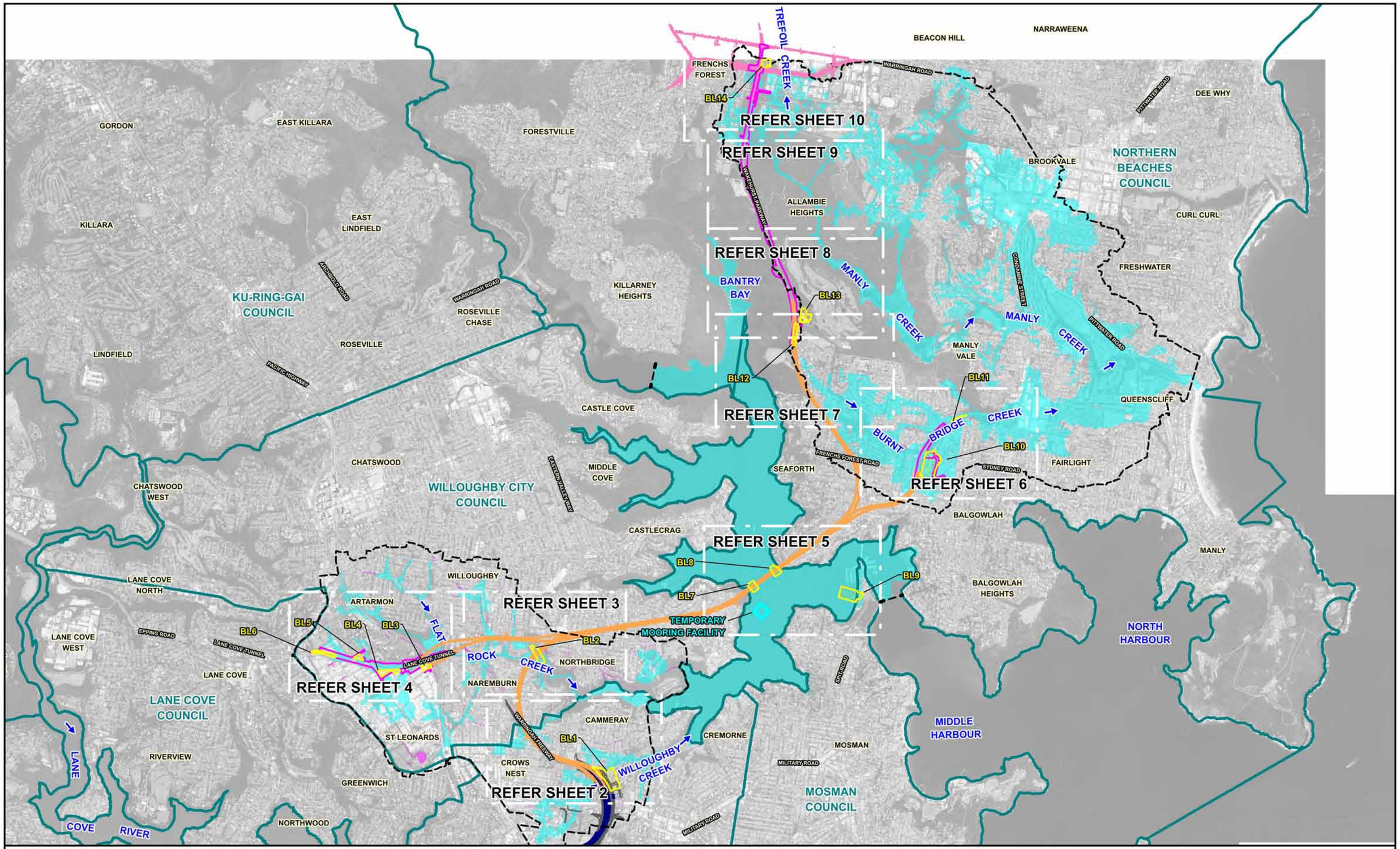
LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Northern Beaches Hospital Surface Road Works
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.6
(Sheet 10 of 10)

PROVISIONAL FLOOD HAZARD CATEGORISATION UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 1 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

MCBURNEY STREET

BROOK STREET

DODDS STREET

MARKS STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

TRIBUTARY

STREET

HAMILTON LANE

HAMILTON RESERVE

BROOK

GORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

ATCHISON STREET

MATTHEW STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

PACIFIC HWY

MILLER STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

NORTH SYDNEY COUNCIL

PINE ST

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

BELLEVUE STREET

LUMSDEN STREET

AMHERST STREET

MORDEN STREET

ECHO STREET

BELLS AVENUE

WARRINGA ROAD

GREEN PARK

CAMMERAY ROAD

WILLOUGHBY

CREEK

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

GRASMERE ROAD

CAMMERAY

XD_WC01

BL1

WARRINGAH FREEWAY

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY PARK

ERNEST STREET

MORTLOCK RESERVE

MIDDLE HARBOUR

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

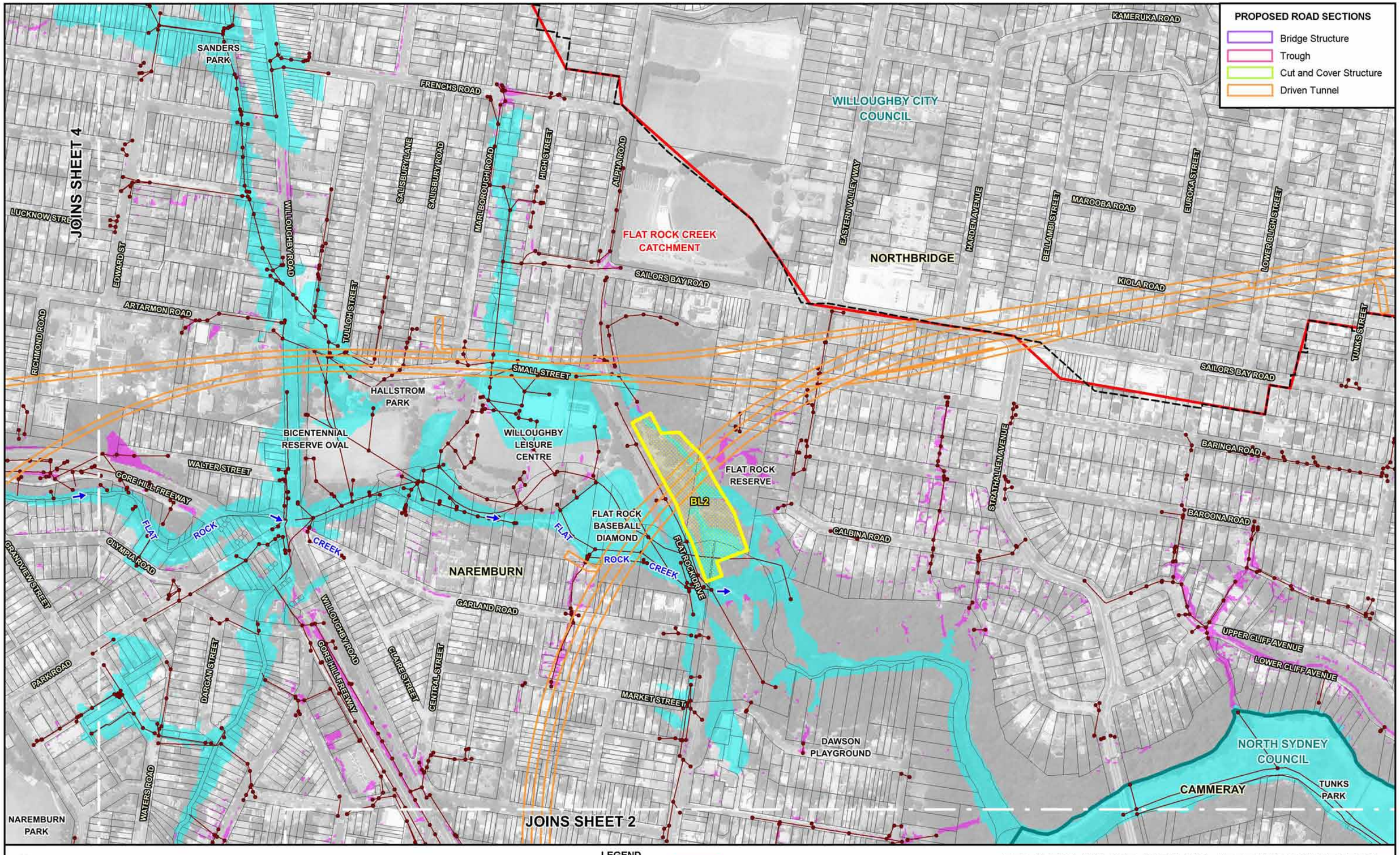
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Flood Planning Area
- Areas Outside of Flood Planning Area Subject to Depths of Overland Flow Greater than 0.1 m
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)
- XD_BC02 Existing Transverse Drainage and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 2 of 10)

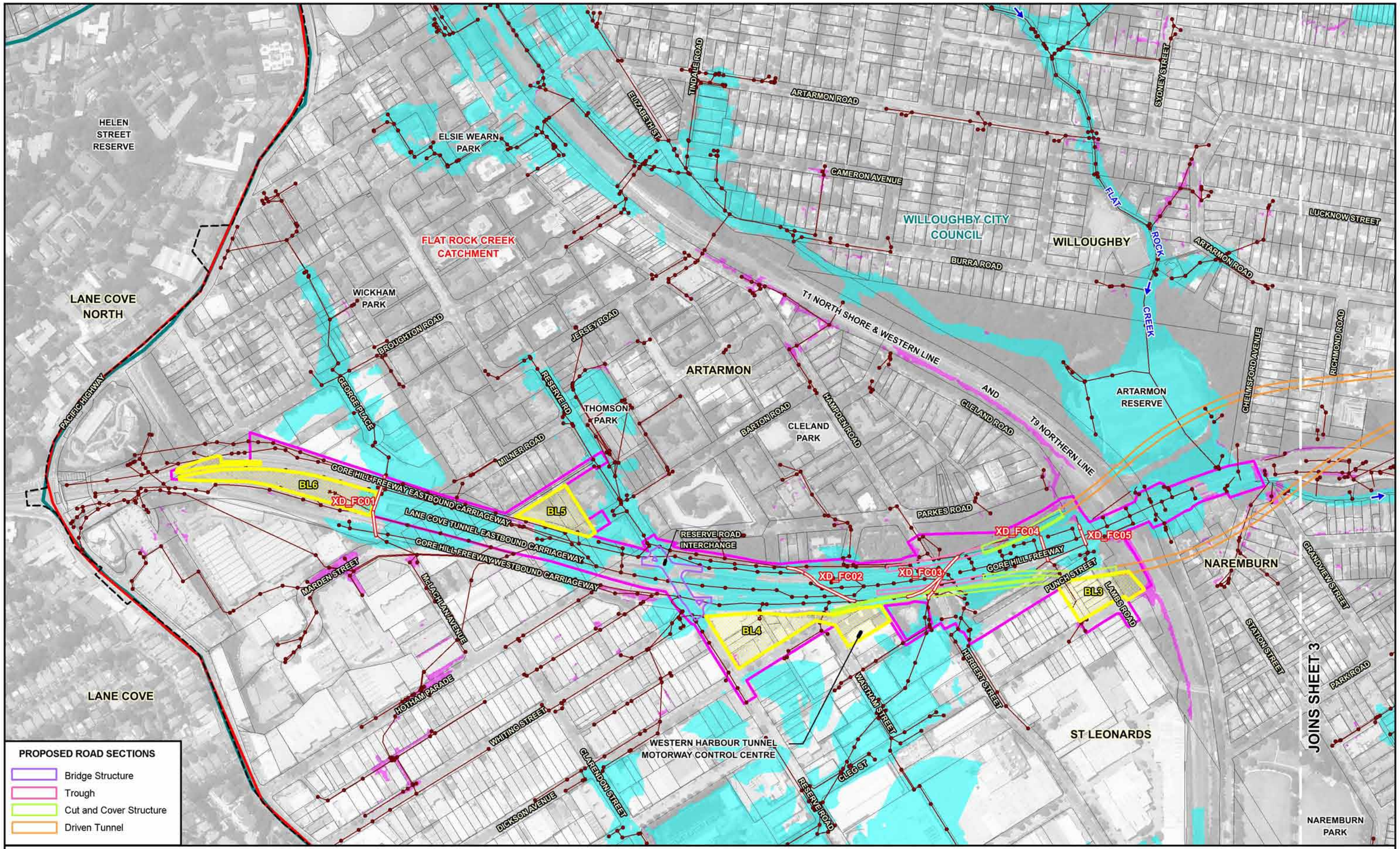
FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 3 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Flood Planning Area
- Areas Outside of Flood Planning Area Subject to Depths of Overland Flow Greater than 0.1 m
- XD_BC02 Existing Transverse Drainage and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 4 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel
- Immersed Tube Tunnel

CASTLECRAG
THE HIGHTOR
LINDEN WAY
CHEYNE WALK
WILLOUGHBY COUNCIL
PEACH TREE BAY
SAILORS BAY
NORTHERN BEACHES COUNCIL
SEAFORTH
SEAFORTH CRES
PRINCES PROMENADE
ALAN AVENUE
EDGECLIFFE ESPLANADE
BATTLE BOULEVARD
RICHMOND ROAD
ASHTON AVENUE
SEAFORTH CRES
SEAFORTH BLUFF
SPIT BRIDGE
BL8
BL7
BL9
MIDDLE HARBOUR
MINNAMURRA ROAD
MINIMBAH ROAD
CLIVE PARK
BYORA CRESCENT
TYCANNAH ROAD
DALMENY ROAD
WILLOUGHBY COUNCIL
TEMPORARY MOORING FACILITY
SAILORS BAY ROAD
NORTHBRIDGE
BOURMAC AVENUE
COOLAWIN ROAD
MIOWERA ROAD
SPIT ROAD
SPIT WEST RESERVE
PARRIWI HEAD
BEAUTY POINT
DELECTA AVENUE
MOSMAN COUNCIL
BEAUTY POINT ROAD
MOSMAN
BAY STREET
PINDARI AVENUE
MARSALA STREET
PEARL BAY AVENUE
PEARL BAY CATCHMENT
MIDDLE HARBOUR

N
50 0 50 100 150 m
Scale: 1:5,000

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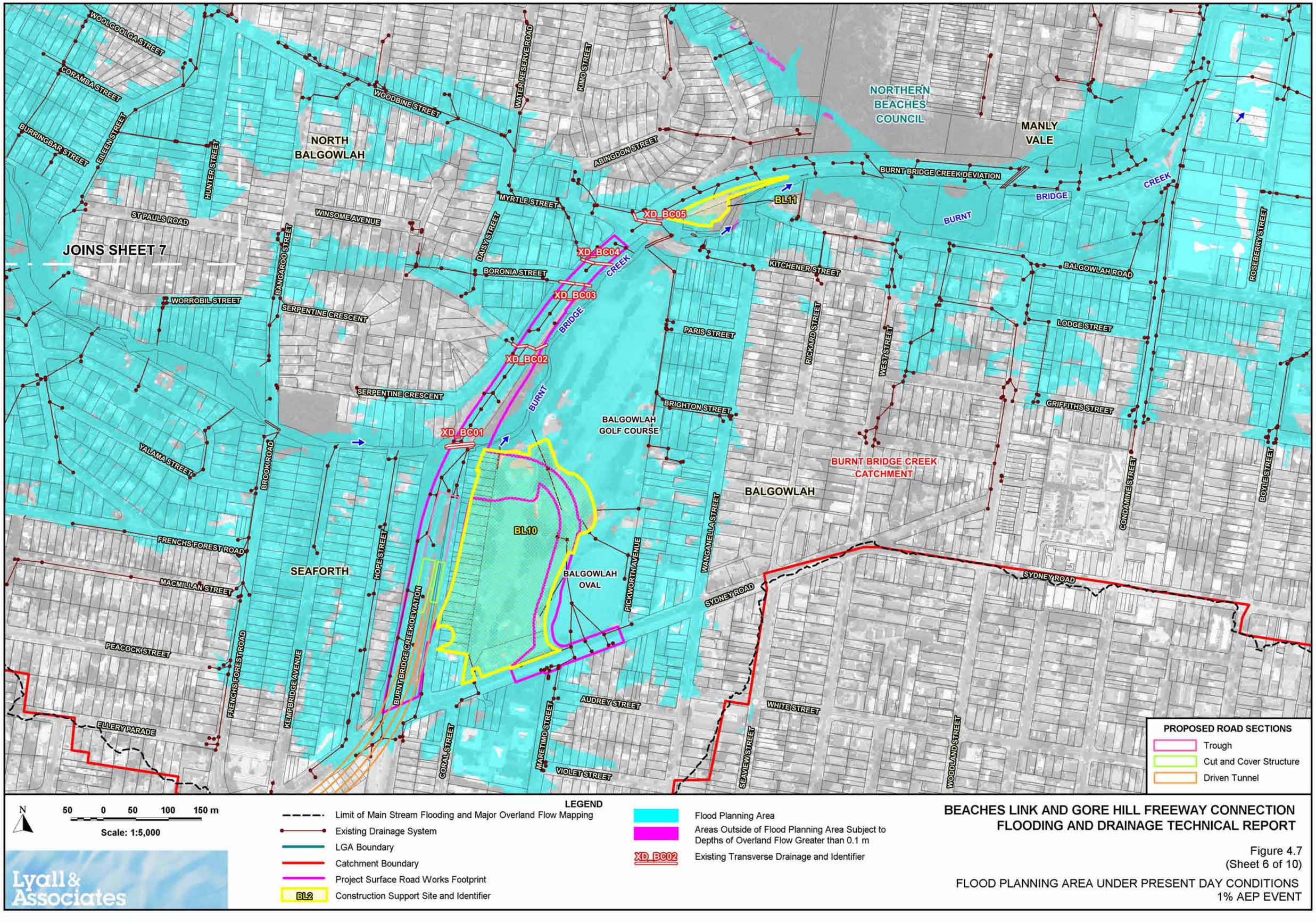
LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Flood Planning Area
- Areas Outside of Flood Planning Area Subject to Depths of Overland Flow Greater than 0.1 m

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 5 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



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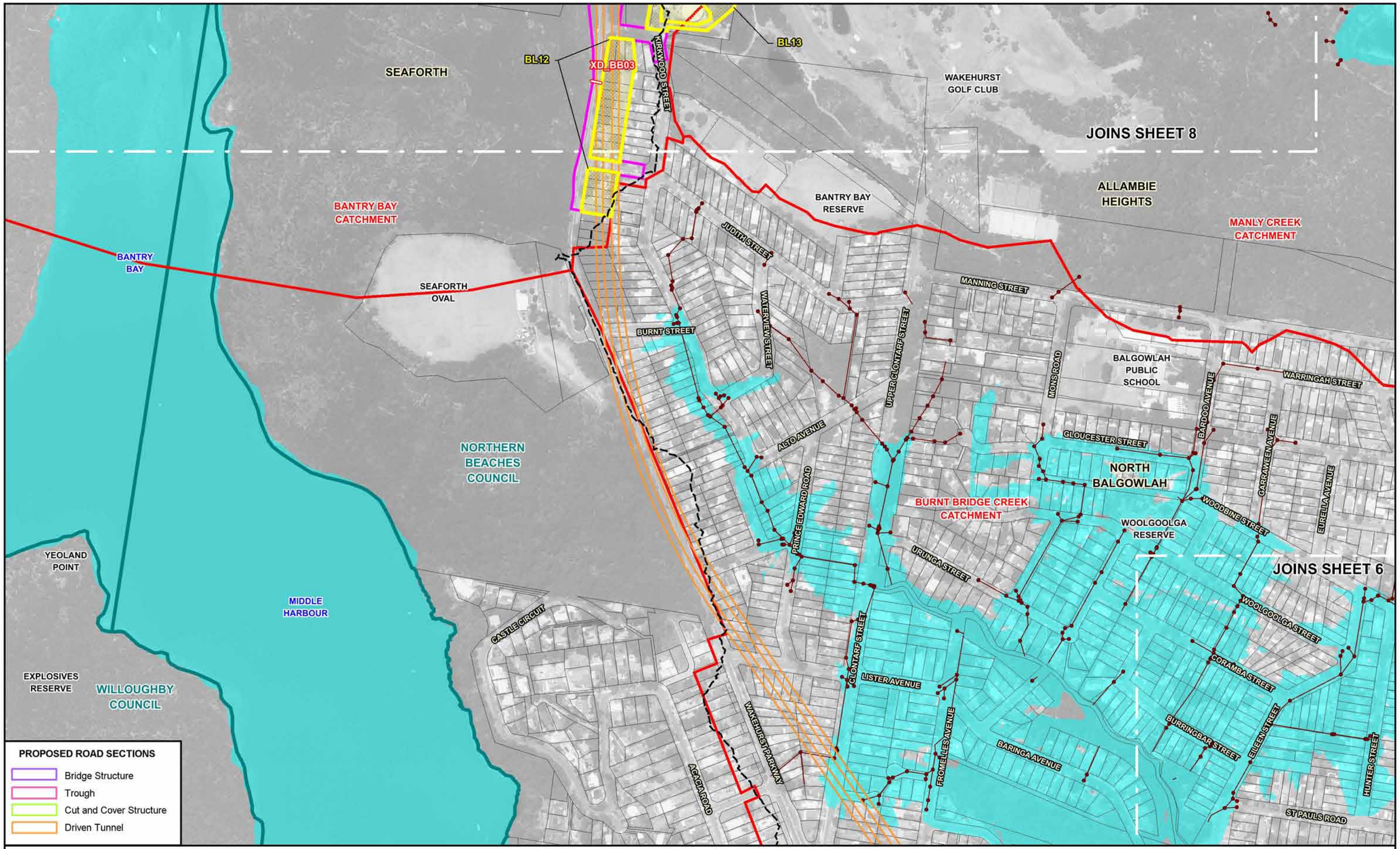
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 6 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT



BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 7 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

JOINS SHEET 9

MC DL02

XD_MC06

WAKEHURST PARKWAY

MANLY CREEK

ALLAMBIE HEIGHTS

KILLARNEY HEIGHTS

MC DL01

XD_MC07

MANLY CREEK CATCHMENT

NORTHERN BEACHES COUNCIL

MANLY DAM

BANTRY BAY CATCHMENT

WAKEHURST PARKWAY

BB DL03

XD_BB01

BANTRY BAY

JOINS SHEET 7

XD_BB02

BL13

BB DL02

BL12

XD_BB03

KIRKWOOD STREET

SEAFORTH

BB DL01

BB DL01

WAKEHURST GOLF CLUB

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

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LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Flood Planning Area
- Areas Outside of Flood Planning Area Subject to Depths of Overland Flow Greater than 0.1 m
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 8 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

YARRAMAN AVENUE
PENROSE PLACE
MOIRA PLACE
GRATTAN CRESCENT
WAKEHURST PARKWAY
XD_MC03
XD_MC04
XD_MC05
MC DL05
MC DL06
MC DL04
MC DL03
MC DL02
JOINS SHEET 10
JOINS SHEET 8
NORTHERN BEACHES COUNCIL
MANLY CREEK CATCHMENT
MANLY
CREEK
FRENCHS FOREST
KILLARNEY HEIGHTS
ALLAMBIE HEIGHTS

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- Flood Planning Area
- Areas Outside of Flood Planning Area Subject to Depths of Overland Flow Greater than 0.1 m
- XD_BC02 Existing Transverse Drainage and Identifier
- Existing Drainage Line

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 9 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4.7
(Sheet 10 of 10)

FLOOD PLANNING AREA UNDER PRESENT DAY CONDITIONS
1% AEP EVENT

INDICATIVE FLOOD EXTENTS
- 10% AEP
- 1% AEP
- PMF

PROPOSED ROAD SECTIONS
- Driven Tunnel

REFER SHEET 10
REFER SHEET 9
REFER SHEET 8
REFER SHEET 7
REFER SHEET 6
REFER SHEET 5
REFER SHEET 4
REFER SHEET 3
REFER SHEET 2

BL14 BL13 BL12 BL11 BL10 BL9 BL8 BL7 BL6 BL5 BL4 BL3 BL2 BL1

TREFOIL CREEK
BANTRY BAY
MANLY CREEK
BURNT BRIDGE CREEK
FLAT ROCK CREEK
WILLOUGHBY CREEK
TEMPORARY MOORING FACILITY

FRENCHS FOREST
BEACON HILL
NARRAWEENA
DEE WHY
BROOKVALE
NORTHERN BEACHES COUNCIL
CURL CURL
FRESHWATER
QUEENSCLIFF
FAIRLIGHT
MANLY
MANLY VALE
ALLAMBIE HEIGHTS
FORESTVILLE
EAST KILLARA
GORDON
KILLARA
EAST LINDFIELD
KU-RING-GAI COUNCIL
LINDFIELD
ROSEVILLE
ROSEVILLE CHASE
KILLARNEY HEIGHTS
CASTLE COVE
SEAFORTH
MIDDLE COVE
CHATSWOOD
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
CASTLECRAG
BALGOWLAH
BALGOWLAH HEIGHTS
WILLOUGHBY
ARTARMON
LANE COVE NORTH
LANE COVE WEST
LANE COVE
LANE COVE COUNCIL
NAREMBURN
NORTHBRIDGE
CAMMERAY
ST LEONARDS
CREMORNE
MOSMAN
MOSMAN COUNCIL
NORTH HARBOUR
MIDDLE HARBOUR
RIVERVIEW
GREENWICH
CROWS NEST
NORTHWOOD
LANE COVE RIVER

WARRINGAH ROAD
PITTWATER ROAD
WAKEHURST PARKWAY
ARCHBOLD ROAD
PACIFIC HIGHWAY
EPPING ROAD
LANE COVE TUNNEL
GORDON STREET
FRENCHS FOREST ROAD
SYDNEY ROAD
EASTERN VALLEY WAY
WARRINGAH FREEWAY
MILITARY ROAD
EAST ROAD

N
400 0 400 800 1200 m
Scale: 1:40,000

LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)
- Proposed BL & GHFC Surface Works
- BL13 Construction Support Site and Identifier
- Northern Beaches Hospital Surface Road Works

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 1 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

DODDS STREET

BROOK STREET

MCBURNEY STREET

TRIBUTARY

MARKS STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

STREET

HAMILTON RESERVE

HAMILTON LANE

BROOK

GORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

ATCHISON STREET

MATTHEW STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

MILLER STREET

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

BELLEVUE STREET

LUMSDEN STREET

AMHERST STREET

MORDEN STREET

ECHO STREET

BELLS AVENUE

WARRINGA ROAD

GREEN PARK

CAMMERAY ROAD

WILLOUGHBY CREEK

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

CAMMERAY

BL1

WARRINGAH FREEWAY

GRASMERE ROAD

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY PARK

SUTHERLAND STREET

ERNEST STREET

NORTH SYDNEY COUNCIL

PINE ST

MORTLOCK RESERVE

MIDDLE HARBOUR

INDICATIVE FLOOD EXTENTS

- 10% AEP
- 1% AEP
- PMF

PROPOSED ROAD SECTIONS

- Open Slot
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)
- Catchment Boundary
- BL1 Construction Site and Identifier

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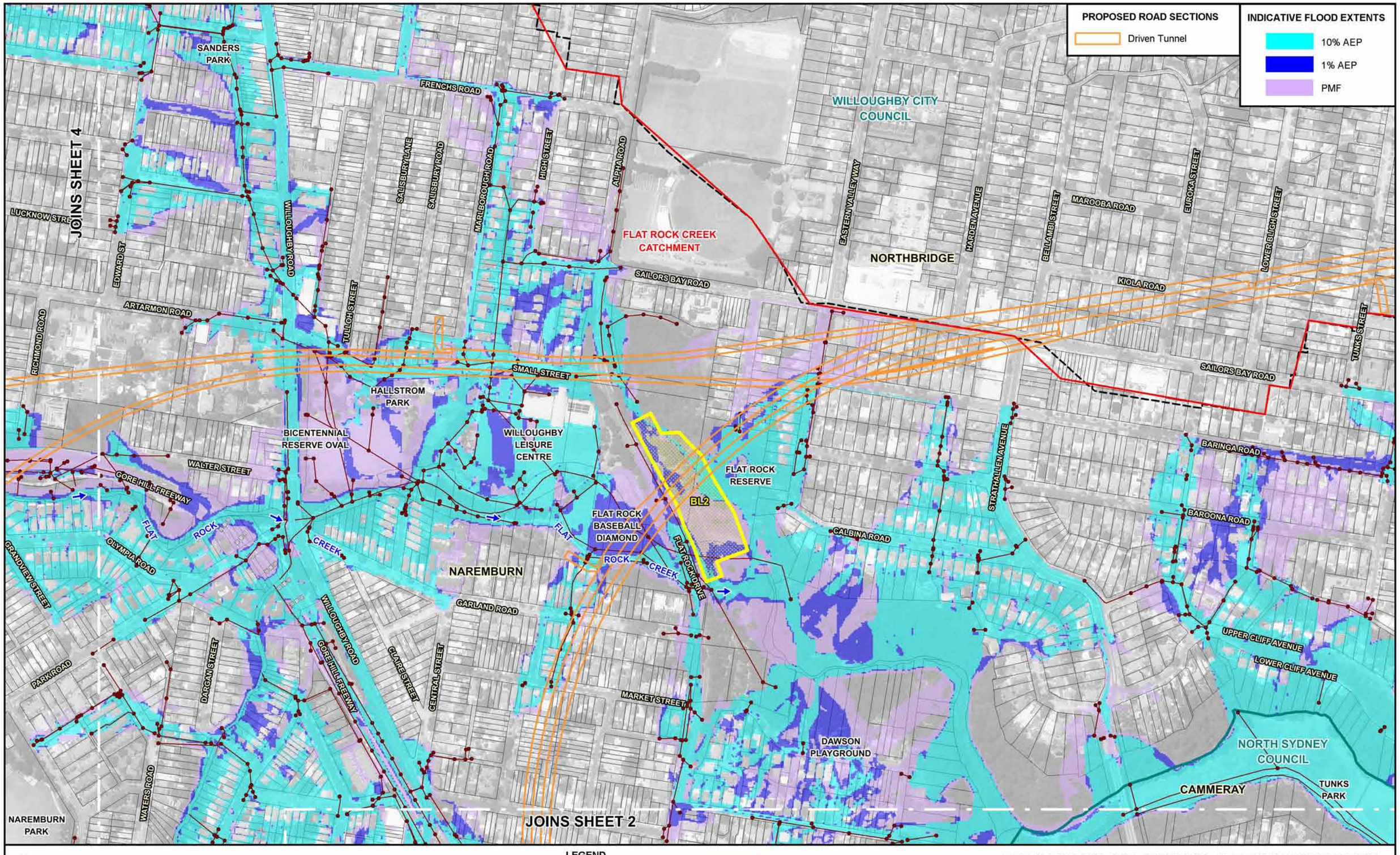
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 2 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 3 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS

INDICATIVE FLOOD EXTENTS

- 10% AEP
- 1% AEP
- PMF

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

HELEN STREET RESERVE
ELSIE WEARN PARK
ELIZABETH ST
TINDALE ROAD
ARTARMON ROAD
SYDNEY STREET
CAMERON AVENUE
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
FLAT ROCK CREEK CATCHMENT
BURRA ROAD
FLAT ROCK CREEK
LUCKNOW STREET
ARTARMON ROAD
LANE COVE NORTH
WICKHAM PARK
BROUGHTON ROAD
JERSEY ROAD
T1 NORTH SHORE & WESTERN LINE
AND
T9 NORTHERN LINE
ARTARMON
ARTARMON RESERVE
CHELMSFORD AVENUE
RICHMOND ROAD
PACIFIC HIGHWAY
GEORGE PLACE
RESERVE RD
THOMSON PARK
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
CLELAND ROAD
MILNER ROAD
BL6
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
BL5
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
RESERVE ROAD INTERCHANGE
PARKES ROAD
GORE HILL FREEWAY
NAREMBURN
GRANDVIEW STREET
PUNCH STREET
BL3
LAMBS ROAD
STATION STREET
PARK ROAD
MARDEN STREET
McLACHLAN AVENUE
BL4
HERBERT STREET
WALTHAM STREET
JOINS SHEET 3
LANE COVE
HOTHAM PARADE
WHITING STREET
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
CLARENDON STREET
CLEG ST
RESERVE ROAD
ST LEONARDS
DICKSON AVENUE
NAREMBURN PARK

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works
- BL4 Construction Site and Identifier

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 4 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel
- Immersed Tube Tunnel

INDICATIVE FLOOD EXTENTS
- 10% AEP
- 1% AEP
- PMF

CASTLECRAG
THE HIGHTOR
LINDEN WAY
CHEYNE WALK
WILLOUGHBY COUNCIL
NORTHERN BEACHES COUNCIL
SEAFORTH CRES
PRINCES PROMENADE
ALAN AVENUE
ASHTON AVENUE
SEAFORTH
RICHMOND ROAD
SEAFORTH CRES
SEAFORTH BLUFF
SPIT BRIDGE
PEACH TREE BAY
SAILORS BAY
BL8
BL7
BL9
MIDDLE HARBOUR
MINNAMURRA ROAD
MINIMBAH ROAD
CLIVE PARK
BYORA CRESCENT
TYCANNAH ROAD
DALMENY ROAD
WILLOUGHBY COUNCIL
NORTHBRIDGE
SAILORS BAY ROAD
BOURMAC AVENUE
COOLAWIN ROAD
MIOWERA ROAD
TEMPORARY MOORING FACILITY
SPIT ROAD
SPIT WEST RESERVE
PARRIWI HEAD
BEAUTY POINT
DELECTA AVENUE
MOSMAN COUNCIL
BEAUTY POINT ROAD
MOSMAN
BAY STREET
PINDARI AVENUE
MARSALA STREET
PEARL BAY AVENUE
PEARL BAY CATCHMENT

N
50 0 50 100 150 m
Scale: 1:5,000

LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL9 Construction Site and Identifier

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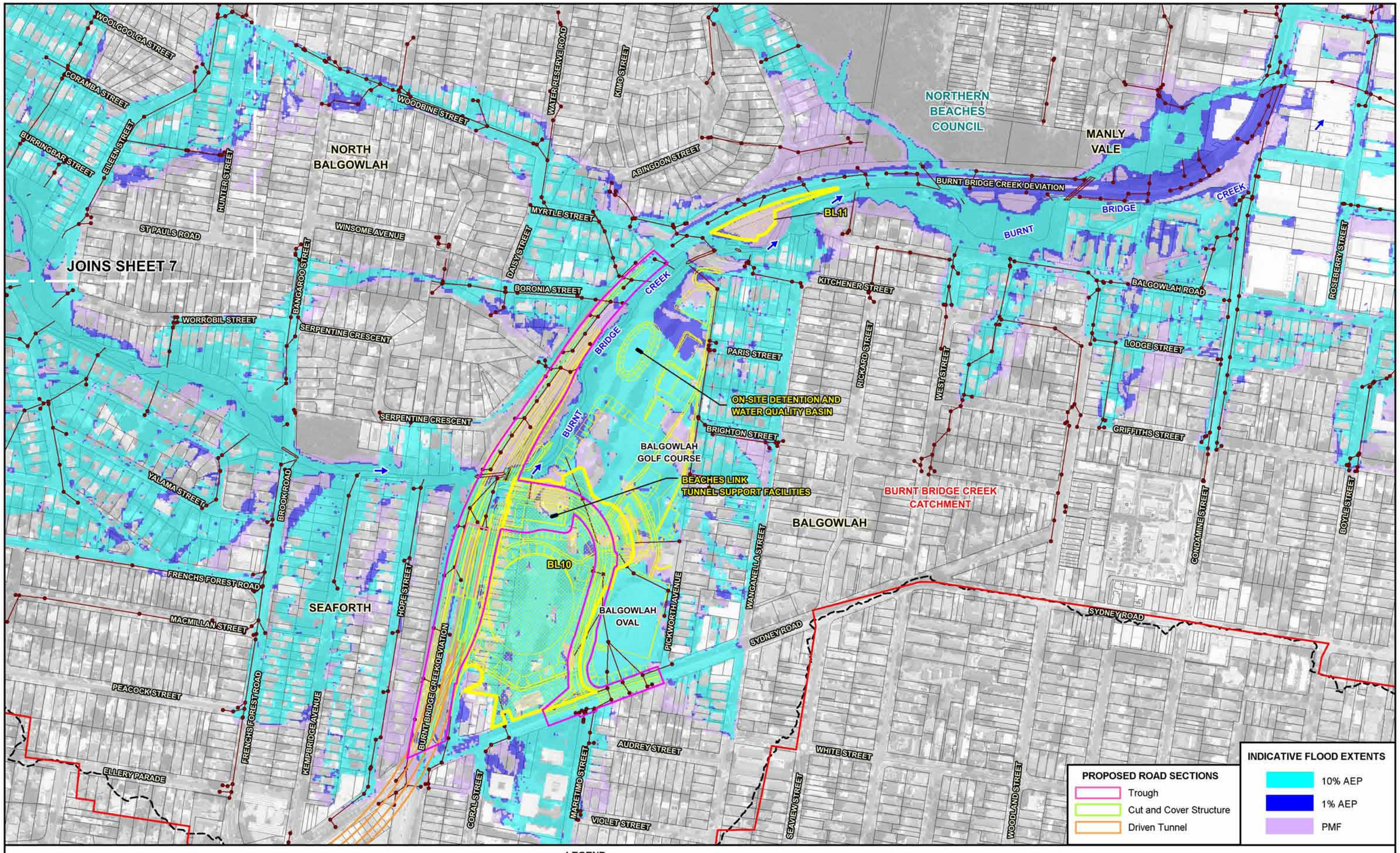
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 5 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 6 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS

INDICATIVE FLOOD EXTENTS
10% AEP
1% AEP
PMF

PROPOSED ROAD SECTIONS
Driven Tunnel

SEAFORTH
BL12
BL13
KIRKWOOD STREET
WAKEHURST GOLF CLUB
JOINS SHEET 8
BANTRY BAY CATCHMENT
BANTRY BAY RESERVE
ALLAMBIE HEIGHTS
MANLY CREEK CATCHMENT
JUDITH STREET
BANTRY BAY
SEAFORTH OVAL
MANNING STREET
WATERVIEW STREET
BURNT STREET
UPPER CLONTARF STREET
MONS ROAD
BALGOWLAH PUBLIC SCHOOL
WARRINGAH STREET
BARDOO AVENUE
GARRAWEEN AVENUE
EURELLA AVENUE
ALTO AVENUE
GLOUCESTER STREET
NORTHERN BEACHES COUNCIL
PRINCE EDWARD ROAD
NORTH BALGOWLAH
BURNT BRIDGE CREEK CATCHMENT
WOODBINE STREET
WOOLGOOLGA RESERVE
YEOLAND POINT
URUNGA STREET
JOINS SHEET 6
MIDDLE HARBOUR
CASTLE CIRCUIT
WOOLGOOLGA STREET
CLONTARF STREET
LISTER AVENUE
CORAMBA STREET
EXPLOSIVES RESERVE
WILLOUGHBY COUNCIL
FROMELLES AVENUE
BURRINGBAR STREET
EILEEN STREET
BARINGA AVENUE
HUNTER STREET
WAKEHURST PARKWAY
ACACIA ROAD
ST PAULS ROAD
CASTLE COVE

N
50 0 50 100 150 m
Scale: 1:5,000

LEGEND
Limit of Main Stream Flooding and Major Overland Flow Mapping
Existing Drainage System
LGA Boundary
Catchment Boundary
Project Surface Road Works Footprint
Proposed BL & GHFC Surface Works
BL13 Construction Site and Identifier

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 7 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS

INDICATIVE FLOOD EXTENTS

- 10% AEP
- 1% AEP
- PMF

PROPOSED ROAD SECTIONS

- Trough
- Cut and Cover Structure
- Driven Tunnel

JOINS SHEET 9

MC DL02

MANLY CREEK

ALLAMBIE HEIGHTS

PROPOSED FAUNA CROSSING

WAKEHURST PARKWAY

PROPOSED FAUNA CROSSING

MC DL01

KILLARNEY HEIGHTS

MANLY CREEK CATCHMENT

NORTHERN BEACHES COUNCIL

MANLY DAM

BANTRY BAY CATCHMENT

WAKEHURST PARKWAY

BEACHES LINK TUNNEL SUPPORT FACILITIES

BB DL03

BANTRY BAY

JOINS SHEET 7

BB DL02

BL12

SEAFORTH

BB DL01

BB DL01

KIRKWOOD STREET

BL13

WAKEHURST GOLF CLUB

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

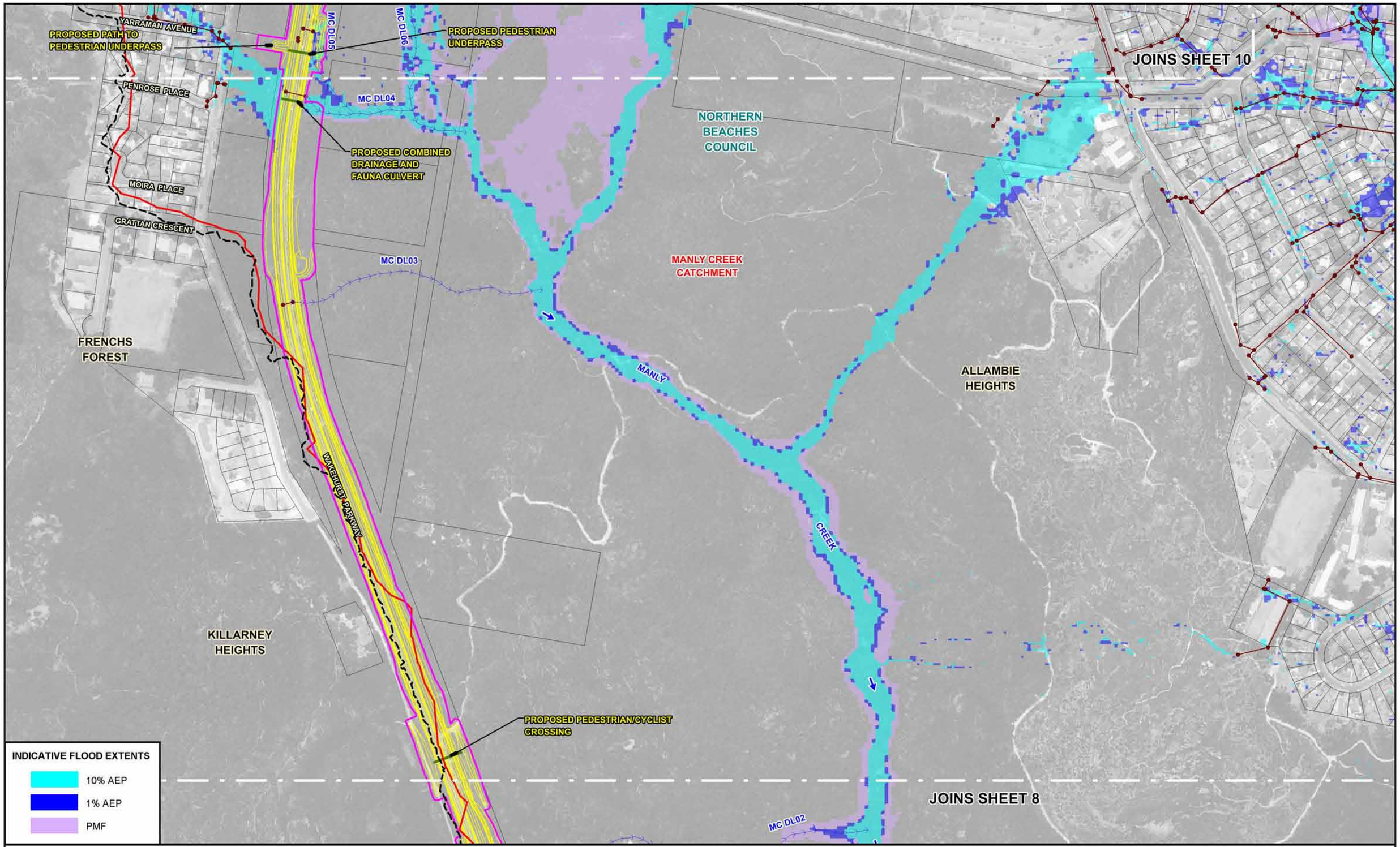
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- Existing Drainage Line
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works
- BL13 Construction Site and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 8 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- Existing Drainage Line
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL13 Construction Site and Identifier

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 9 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS

INDICATIVE FLOOD EXTENTS
10% AEP
1% AEP
PMF

FRENCHS FOREST
NORTHERN BEACHES HOSPITAL
FRENCHS FOREST ROAD WEST
FRENCHS FOREST ROAD EAST
TREFOIL CREEK
TREFOIL CREEK CATCHMENT
ROMFORD ROAD
HURDIS AVENUE
HARMSTON AVENUE
INVERNESS AVENUE
PATANGA ROAD
DAREEN STREET
WARRINGAH ROAD
WAKEHURST PARKWAY
BL14
NORTHERN BEACHES COUNCIL
KARINGAL CRESCENT
AKORA STREET
PRIMROSE AVENUE
FITZPATRICK AVENUE
BEACHES LINK TUNNEL SUPPORT FACILITIES
NEW FOOTBRIDGE
MC DL07
MANLY CREEK CATCHMENT
RODBOROUGH ROAD
ALLAMBIE ROAD
BANTRY BAY CATCHMENT
RANGERS RETREAT ROAD
BANTRY BAY ROAD
PARNI PLACE
AQUATIC DRIVE
FOOTBRIDGE TO BE REMOVED AND REPLACED
GARNER AVENUE
ALLAMBIE HEIGHTS
ARNHEM ROAD
AQUATIC RESERVE
MC DL06
KANYA STREET
JOINS SHEET 9
YARRAMAN AVENUE
PROPOSED PATH TO PEDESTRIAN UNDERPASS
PROPOSED PEDESTRIAN UNDERPASS
MC DL05

N
50 0 50 100 150 m
Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL14 Construction Support Site and Identifier
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Existing Drainage Line

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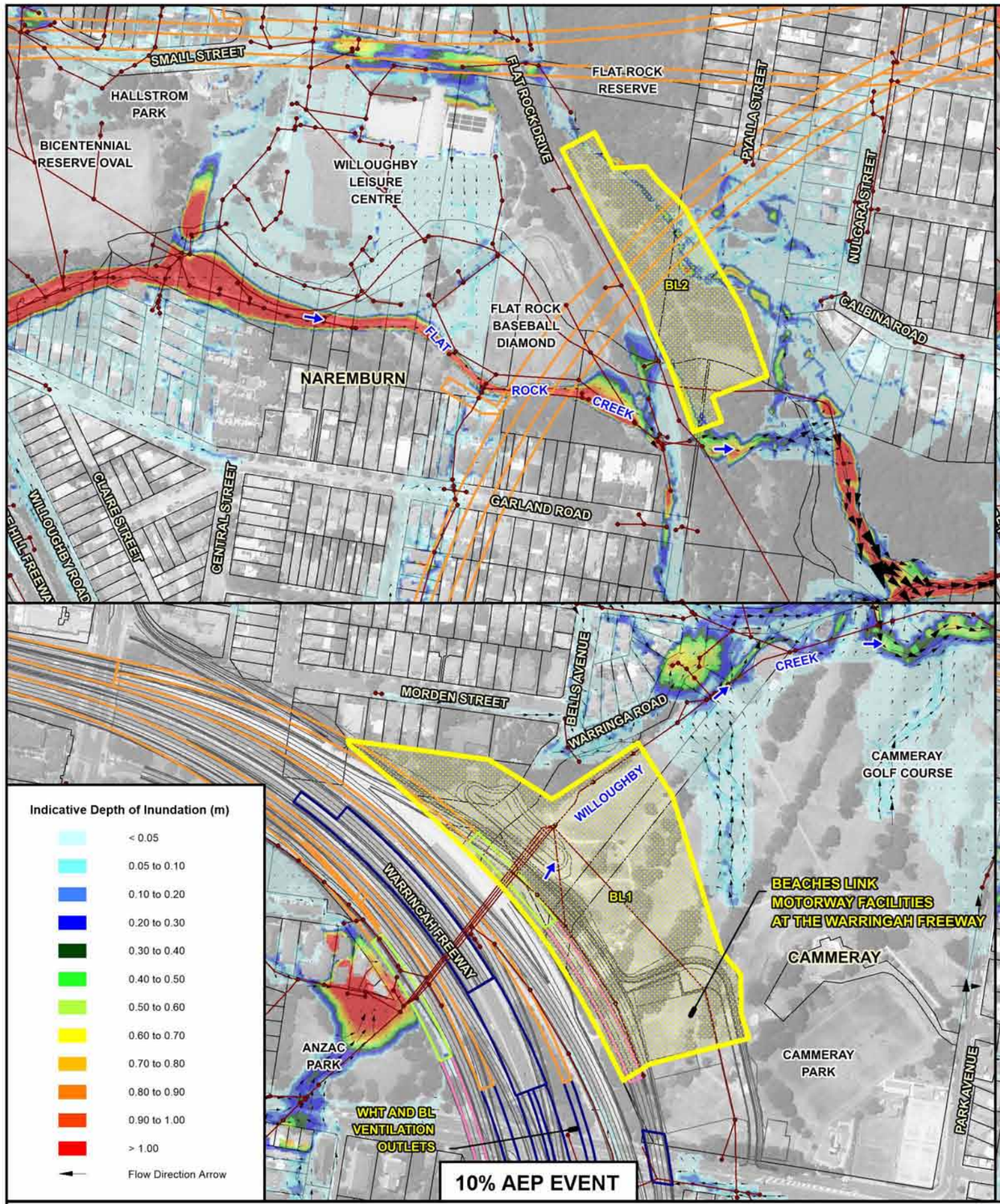
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.1
(Sheet 10 of 10)

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
PRESENT DAY CONDITIONS



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)
- Proposed BL & GHFC Surface Works
- BL1 Construction Support Site and Identifier
- Trough
- Cut and Cover Structure
- Driven Tunnel

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.2
(Sheet 1 of 6)

FLOODING PATTERNS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
10% AND 1% AEP EVENTS

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

BROUGHTON ROAD
MILNER ROAD
RESERVE RD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
BL6
BL5
MARDEN STREET
McLACHLAN AVENUE
HOTHAM PARADE
CLARENDON STREET
WHITING STREET
LANE COVE
PACIFIC HIGHWAY
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
T1 NORTH SHORE & WESTERN LINE AND T9 NORTHERN LINE
ARTARMON RESERVE
PARKES ROAD
RESERVE ROAD INTERCHANGE
GORE HILL FREEWAY
NAREMBURN
LAMBS ROAD
PUNCH STREET
BL3
BL4
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
WALTHAM STREET
HERBERT STREET
CLEG ST
DICKSON AVENUE
RESERVE ROAD
WILLOUGHBY CITY COUNCIL
ST LEONARDS

10% AEP EVENT

1% AEP EVENT

N

40 0 40 80 120 m

Scale: 1:4,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL6 Construction Support Site and Identifier
- Proposed BL & GHFC Surface Works
- Bridge
- Trough
- Cut and Cover Structure
- Driven Tunnel

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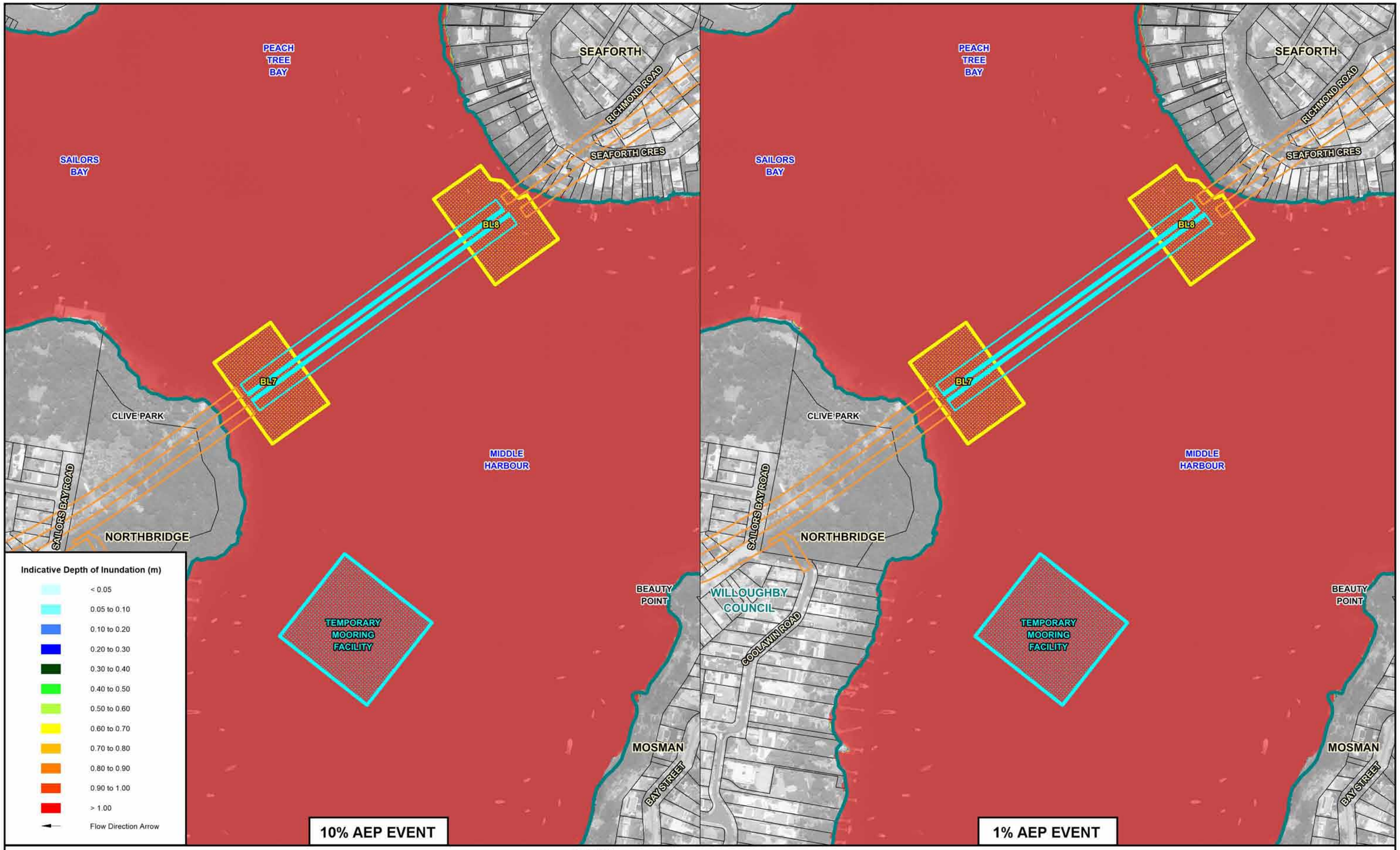
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.2
(Sheet 2 of 6)

FLOODING PATTERNS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
10% AND 1% AEP EVENTS



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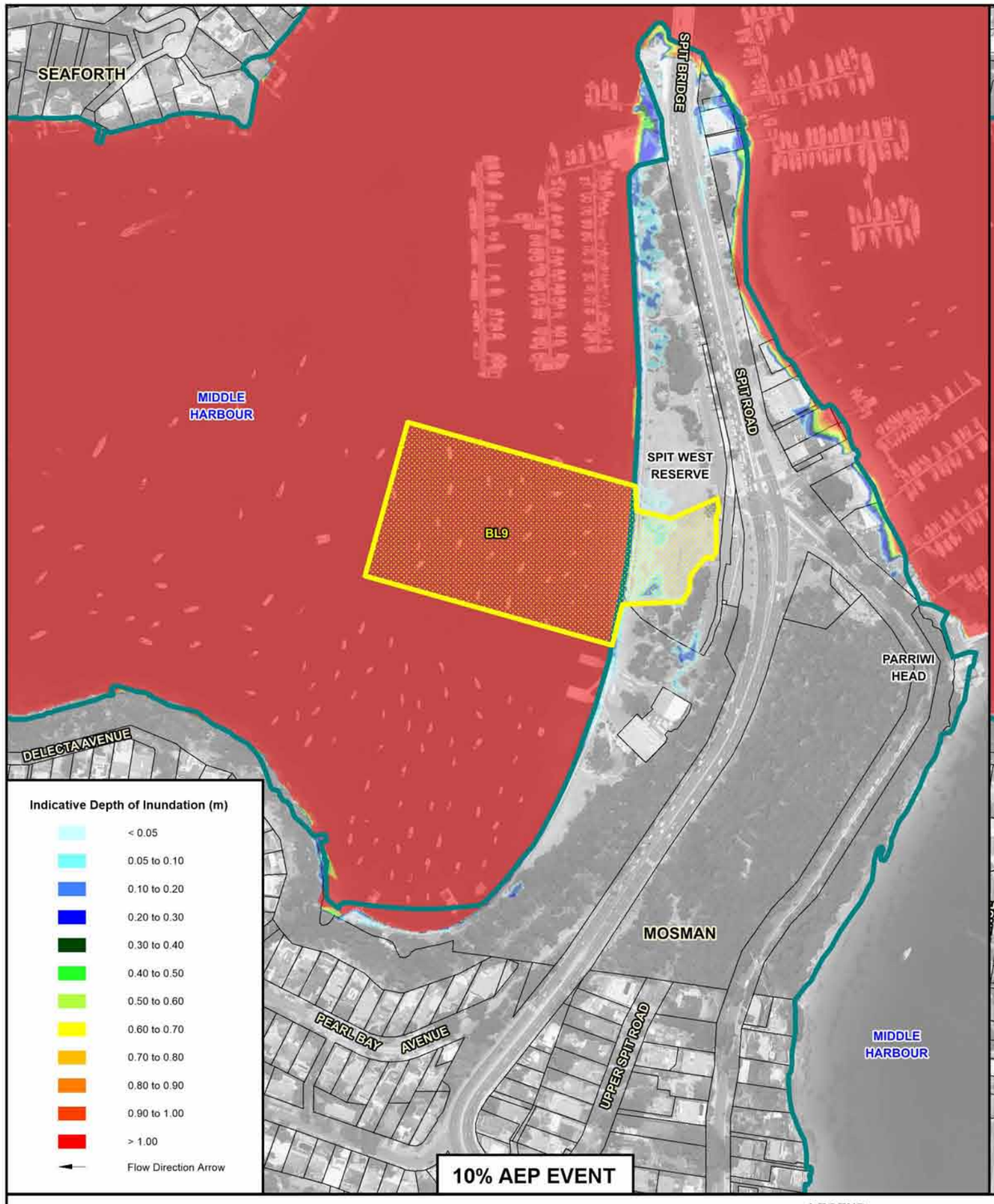
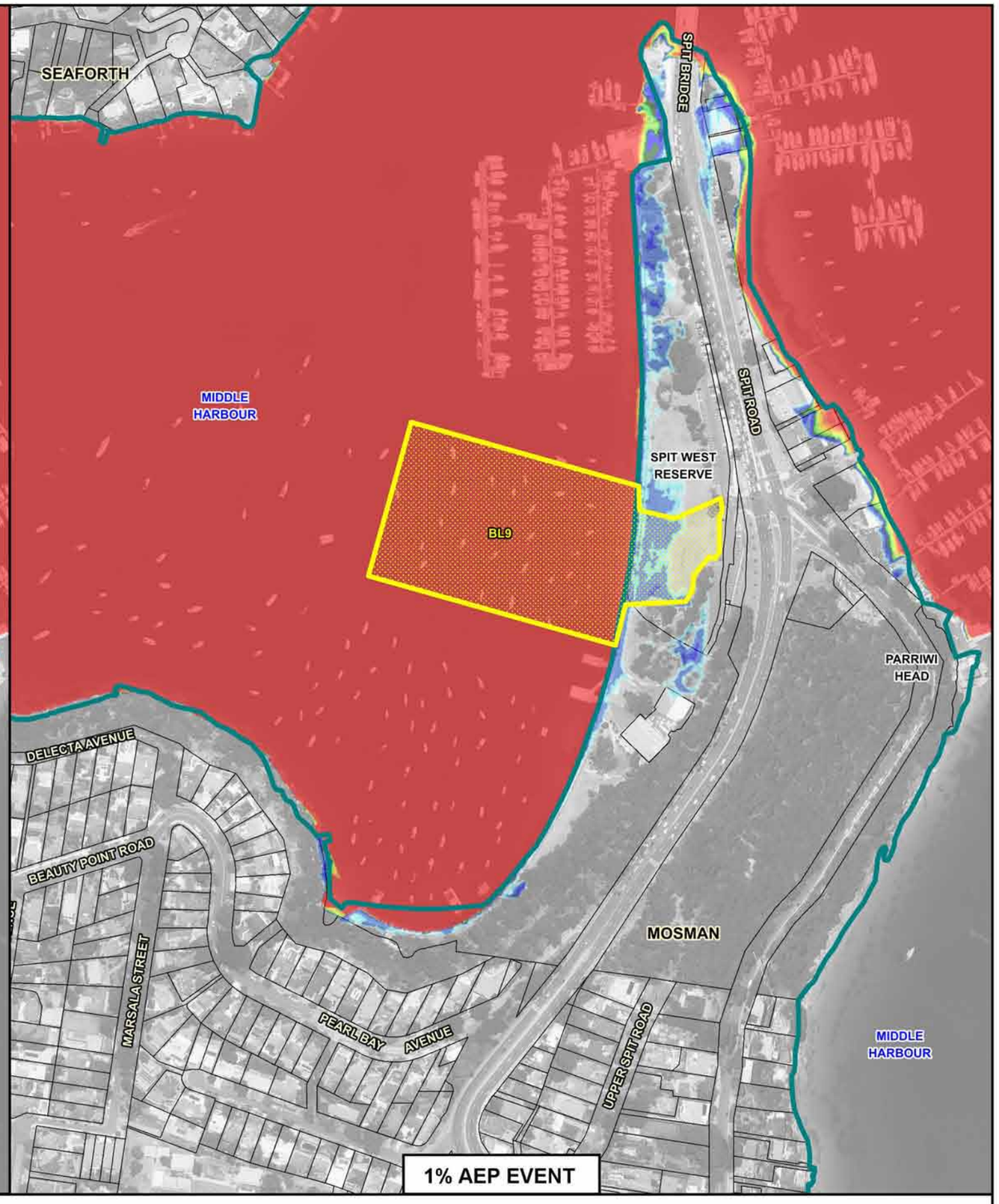
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.2
(Sheet 3 of 6)

FLOODING PATTERNS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
10% AND 1% AEP EVENTS





Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

N

40 0 40 80 120 m

Scale: 1:4,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL9 Construction Site and Identifier

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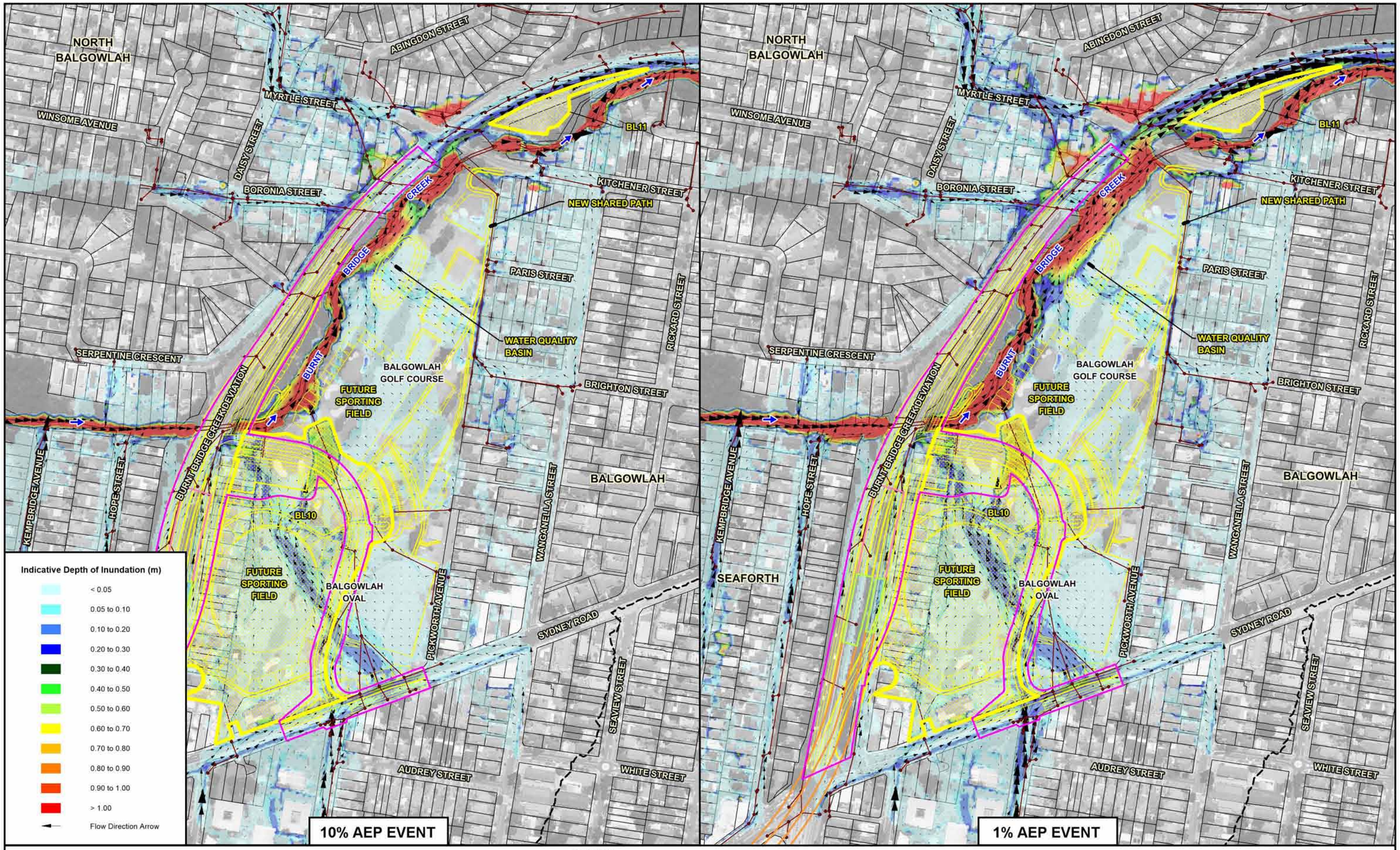
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.2
(Sheet 4 of 6)

FLOODING PATTERNS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
10% AND 1% AEP EVENTS



N

40 0 40 80 120 m

Scale: 1:4,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL10 Construction Support Site and Identifier
- Proposed BL & GHFC Surface Works
- Trough
- Cut and Cover Structure
- Driven Tunnel

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.2
(Sheet 5 of 6)

FLOODING PATTERNS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
10% AND 1% AEP EVENTS

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

TREFOIL CREEK
FRENCHS FOREST ROAD
WAKEHURST PARKWAY
BL14
WARRINGAH ROAD
BANTRY BAY ROAD
PRIMROSE AVENUE
NEW FOOTBRIDGE
WAKEHURST GOLF CLUB
BL13
BB DL02
SEAFORTH
BL12
BB DL01
BB DL01
KIRKWOOD STREET
JUDITH STREET
ALLAMBIE HEIGHTS
BANTRY BAY RESERVE

10% AEP EVENT

1% AEP EVENT

N

40 0 40 80 120 m

Scale: 1:4,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- Existing Drainage Line
- LGA Boundary
- Project Surface Road Works Footprint
- BL14 Construction Support Site and Identifier
- Northern Beaches Hospital Surface Road Works
- Proposed BL & GHFC Surface Works
- Cut and Cover Structure
- Driven Tunnel

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.2
(Sheet 6 of 6)

FLOODING PATTERNS IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES
10% AND 1% AEP EVENTS

MORDEN STREET
BELLS AVENUE
WARRINGA ROAD
CREEK
CAMMERAY GOLF COURSE
WILLOUGHBY
CROWS NEST
NORTH SYDNEY COUNCIL
WARRINGAH FREEWAY
BL1
BEACHES LINK MOTORWAY FACILITIES AT THE WARRINGAH FREEWAY
CAMMERAY
WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES
MILLER STREET
ANZAC PARK PUBLIC SCHOOL
ANZAC AVENUE
ANZAC PARK
CAMMERAY PARK
ERNEST STREET
WHT AND BL VENTILATION OUTLETS
PARK AVENUE
SMALL STREET
HALLSTROM PARK
BICENTENNIAL RESERVE OVAL
WILLOUGHBY LEISURE CENTRE
FLAT ROCK DRIVE
FLAT ROCK RESERVE
PYALLA STREET
NULGARA STREET
BL2
CALBINA ROAD
FLAT ROCK BASEBALL DIAMOND
NAREMBURN
FLAT ROCK CREEK
CENTRAL STREET
GARLAND ROAD

HAZARD CATEGORIES
- High Hazard
- Low Hazard

PROVISIONAL FLOOD HAZARD

HYDRAULIC CATEGORIES
- Floodway
- Flood Storage
- Flood Fringe

PRELIMINARY HYDRAULIC CATEGORISATION

N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)
- Proposed BL & GHFC Surface Works
- BL1 Construction Support Site and Identifier
- Trough
- Cut and Cover Structure
- Driven Tunnel

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.3
(Sheet 1 of 6)

PROVISIONAL FLOOD HAZARD AND PRELIMINARY HYDRAULIC CATEGORISATION OF FLOODPLAIN IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES - 1% AEP EVENT

BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
PARKES ROAD
T1 NORTH SHORE & WESTERN LINE AND T9 NORTHERN LINE
ARTARMON RESERVE
NAREMBURN
RESERVE ROAD INTERCHANGE
GORE HILL FREEWAY
LAMBS ROAD
PUNCH STREET
BL3
BL4
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
WALTHAM STREET
HERBERT STREET
WILLOUGHBY CITY COUNCIL
DICKSON AVENUE
RESERVE ROAD
CLEG ST
ST LEONARDS
BROUGHTON ROAD
MILNER ROAD
RESERVE RD
BL6
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
BL5
MARDEN STREET
McLACHLAN AVENUE
HOTHAM PARADE
CLARENDON STREET
WHITING STREET
PACIFIC HIGHWAY

HAZARD CATEGORIES
- High Hazard
- Low Hazard

PROVISIONAL FLOOD HAZARD

HYDRAULIC CATEGORIES
- Floodway
- Flood Storage
- Flood Fringe

PRELIMINARY HYDRAULIC CATEGORISATION

N

40 0 40 80 120 m

Scale: 1:4,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL6 Construction Support Site and Identifier
- Proposed BL & GHFC Surface Works
- Bridge
- Trough
- Cut and Cover Structure
- Driven Tunnel

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.3
(Sheet 2 of 6)

PROVISIONAL FLOOD HAZARD AND PRELIMINARY HYDRAULIC CATEGORISATION OF FLOODPLAIN IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES - 1% AEP EVENT

PEACH TREE BAY
SEAFORTH
RICHMOND ROAD
SEAFORTH CRES
SAILORS BAY
BL8
BL7
CLIVE PARK
MIDDLE HARBOUR
SAILORS BAY ROAD
NORTHBRIDGE
WILLOUGHBY COUNCIL
COOLAWIN ROAD
TEMPORARY MOORING FACILITY
BEAUTY POINT
MOSMAN
BAY STREET

HAZARD CATEGORIES
- High Hazard
- Low Hazard

PROVISIONAL FLOOD HAZARD

PEACH TREE BAY
SEAFORTH
RICHMOND ROAD
SEAFORTH CRES
SAILORS BAY
BL8
BL7
CLIVE PARK
MIDDLE HARBOUR
SAILORS BAY ROAD
NORTHBRIDGE
WILLOUGHBY COUNCIL
COOLAWIN ROAD
TEMPORARY MOORING FACILITY
BEAUTY POINT
MOSMAN
BAY STREET

PRELIMINARY HYDRAULIC CATEGORISATION

N

40 0 40 80 120 m

Scale: 1:4,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL7 Construction Site and Identifier
- Driven Tunnel
- Immersed Tube Tunnel
- Estuarine Flooding

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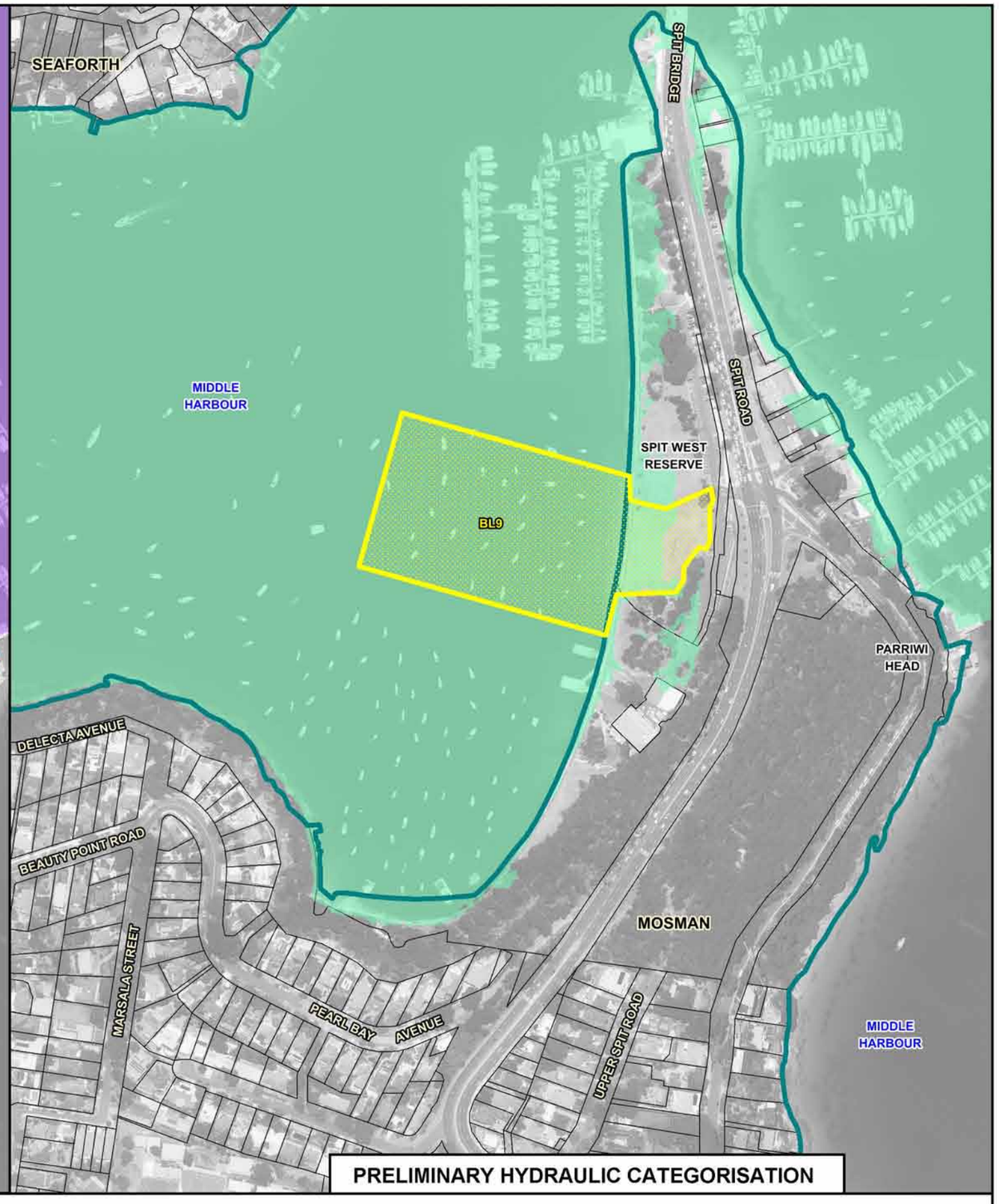
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.3
(Sheet 3 of 6)

PROVISIONAL FLOOD HAZARD AND PRELIMINARY HYDRAULIC CATEGORISATION OF FLOODPLAIN IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES - 1% AEP EVENT



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL9 Construction Site and Identifier
- Estuarine Flooding

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.3
(Sheet 4 of 6)

PROVISIONAL FLOOD HAZARD AND PRELIMINARY HYDRAULIC CATEGORISATION OF FLOODPLAIN IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES - 1% AEP EVENT

NORTH BALGOWLAH
ABINGDON STREET
MYRTLE STREET
WINSOME AVENUE
DAISY STREET
BORONIA STREET
CREEK
BRIDGE
BL11
KITCHENER STREET
NEW SHARED PATH
PARIS STREET
RICKARD STREET
WATER QUALITY BASIN
SERPENTINE CRESCENT
BURNT
BALGOWLAH GOLF COURSE
FUTURE SPORTING FIELD
BRIGHTON STREET
BURNT BRIDGE CREEK DEVIATION
KEMPBRIDGE AVENUE
HOPE STREET
BL10
WANGANELLA STREET
BALGOWLAH
SEAFORTH
FUTURE SPORTING FIELD
BALGOWLAH OVAL
PICKWORTH AVENUE
SYDNEY ROAD
SEAVIEW STREET
AUDREY STREET
WHITE STREET

HAZARD CATEGORIES
- High Hazard
- Low Hazard

PROVISIONAL FLOOD HAZARD

HYDRAULIC CATEGORIES
- Floodway
- Flood Storage
- Flood Fringe

PRELIMINARY HYDRAULIC CATEGORISATION

N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Project Surface Road Works Footprint
- BL10 Construction Support Site and Identifier
- Proposed BL & GHFC Surface Works
- Trough
- Cut and Cover Structure
- Driven Tunnel

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.3
(Sheet 5 of 6)

PROVISIONAL FLOOD HAZARD AND PRELIMINARY HYDRAULIC CATEGORISATION OF FLOODPLAIN IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES - 1% AEP EVENT

TREFOIL CREEK
FRENCHS FOREST ROAD
WAKEHURST PARKWAY
BL14
WARRINGAH ROAD
BANTRY BAY ROAD
PRIMROSE AVENUE
NEW FOOTBRIDGE
WAKEHURST GOLF CLUB
BL13
BB DL02
SEAFORTH
BL12
BB DL01
KIRKWOOD STREET
JUDITH STREET
ALLAMBIE HEIGHTS
BANTRY BAY RESERVE

HAZARD CATEGORIES
High Hazard
Low Hazard

PROVISIONAL FLOOD HAZARD

HYDRAULIC CATEGORIES
Floodway
Flood Storage
Flood Fringe

PRELIMINARY HYDRAULIC CATEGORISATION

N
40 0 40 80 120 m
Scale: 1:4,000

LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- Existing Drainage Line
- LGA Boundary
- Project Surface Road Works Footprint
- BL14 Construction Support Site and Identifier
- Northern Beaches Hospital Surface Road Works
- Proposed BL & GHFC Surface Works
- Cut and Cover Structure
- Driven Tunnel

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5.3
(Sheet 6 of 6)

PROVISIONAL FLOOD HAZARD AND PRELIMINARY HYDRAULIC CATEGORISATION OF FLOODPLAIN
IN VICINITY OF PROPOSED CONSTRUCTION SUPPORT SITES - 1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00

TREFOIL CREEK
FRENCHS FOREST
BEACON HILL
NARRAWEENA
WARRINGAH ROAD
PITTWATER ROAD
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
ARCHBOLD ROAD
KILLARNEY HEIGHTS
BANTRY BAY
MANLY CREEK
GONDAMINE STREET
FRESHWATER
KU-RING-GAI COUNCIL
WARRINGAH ROAD
ROSEVILLE CHASE
ROSEVILLE
LINDFIELD
PACIFIC HIGHWAY
MANLY VALE
QUEENSCLIFF
CASTLE COVE
BURNT BRIDGE CREEK
FRENCHS FOREST ROAD
SYDNEY ROAD
FAIRLIGHT
CHATSWOOD
MIDDLE COVE
SEAFORTH
REFER SHEET 5
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
EASTERN VALLEY WAY
BALGOWLAH
CASTLECRAG
MANLY
WILLOUGHBY
LANE COVE NORTH
ARTARMON
REFER SHEET 3
BALGOWLAH HEIGHTS
NORTH HARBOUR
LANE COVE WEST
EPPING ROAD
LANE COVE TUNNEL
FLAT ROCK CREEK
NORTHBRIDGE
LANE COVE
REFER SHEET 4
NAREMBURN
SPIT ROAD
LANE COVE COUNCIL
CAMMERAY
MIDDLE HARBOUR
ST LEONARDS
CREMORNE
WARRINGAH FREEWAY
MOSMAN
RIVERVIEW
CROWS NEST
MILITARY ROAD
WILLOUGHBY CREEK
LANE COVE RIVER
GREENWICH
REFER SHEET 2
MOSMAN COUNCIL
NORTHWOOD
MILITARY ROAD

N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Driven Tunnel
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.1
(Sheet 1 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
10% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

DODDS STREET

BROOK STREET

MCBURNEY STREET

TRIBUTARY

MARKS STREET

STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

HAMILTON LANE

HAMILTON RESERVE

BROOK

GORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

MATTHEW STREET

ATCHISON STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

MILLER STREET

PINE ST

NORTH SYDNEY COUNCIL

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

BELLEVUE STREET

LUMSDEN STREET

AMHERST STREET

ECHO STREET

MORDEN STREET

BELLS AVENUE

WARRINGAH FREEWAY

MORTLOCK RESERVE

MIDDLE HARBOUR

WARRINGA ROAD

GREEN PARK

CAMMERAY ROAD

CREEK

WILLOUGHBY

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

CAMMERAY

BEACHES LINK MOTORWAY FACILITIES

GRASMERE ROAD

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY PARK

SUTHERLAND STREET

ERNEST STREET

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Open Slot
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

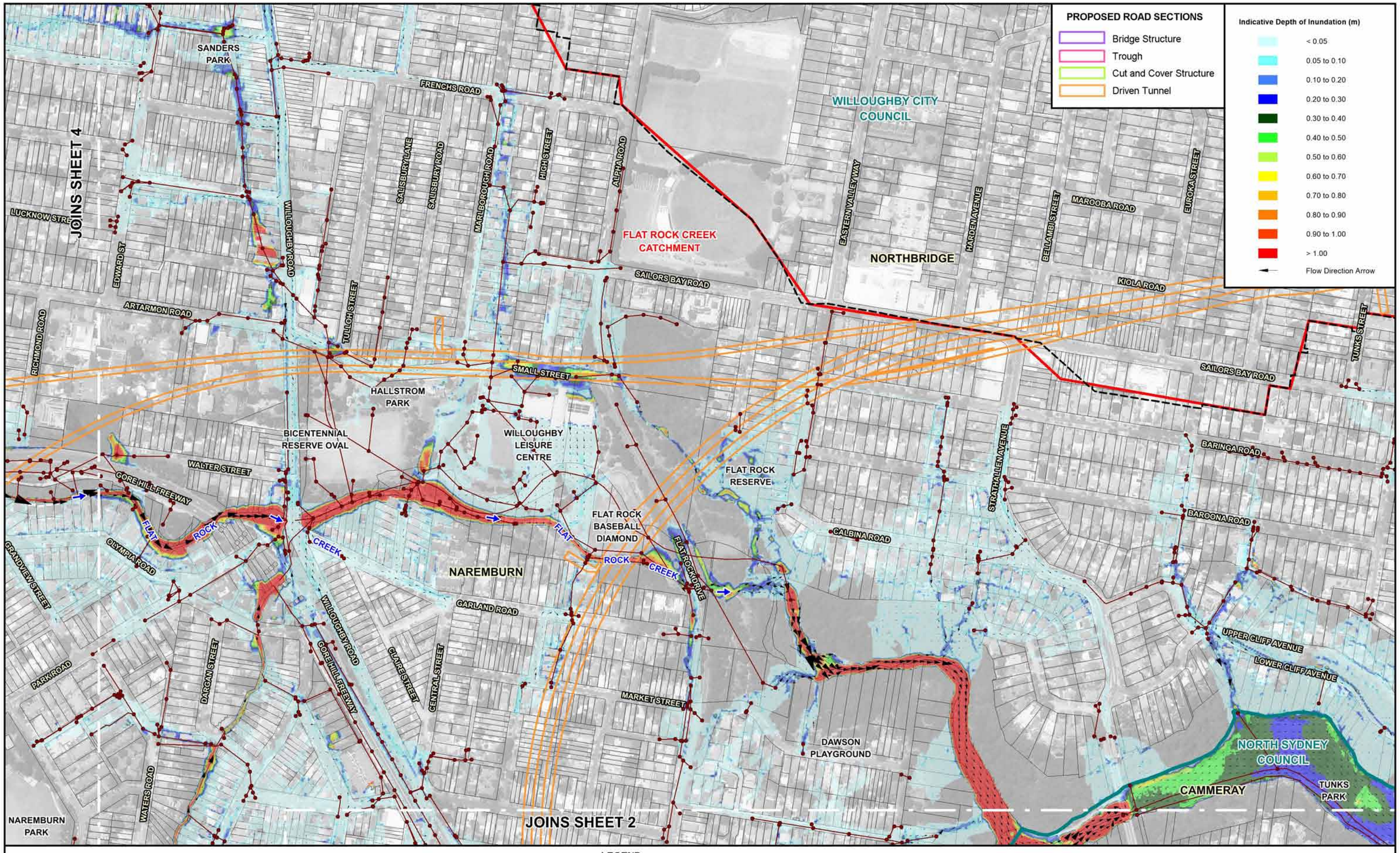
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.1
(Sheet 2 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
10% AEP EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.1
(Sheet 3 of 5)

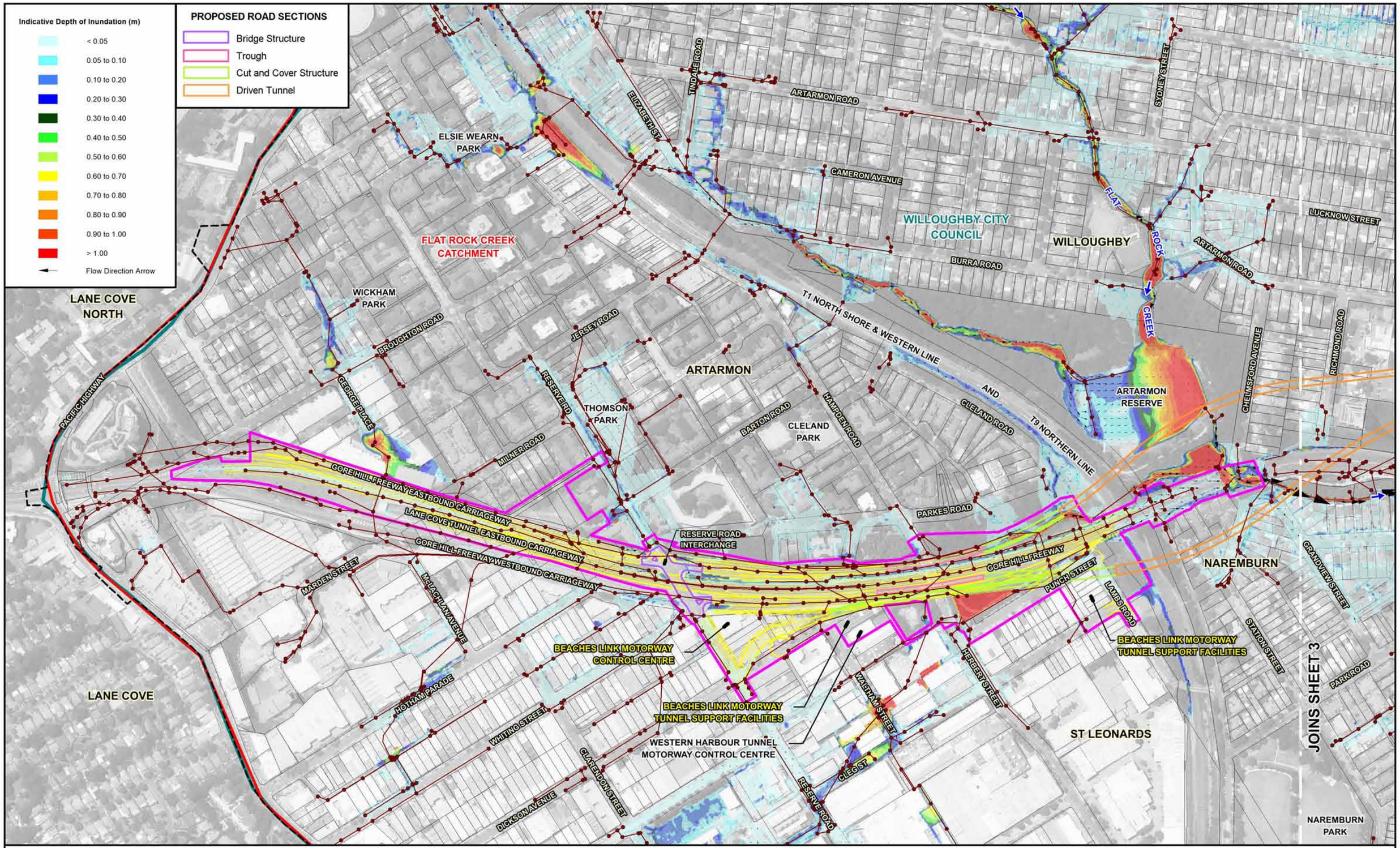
FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
10% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

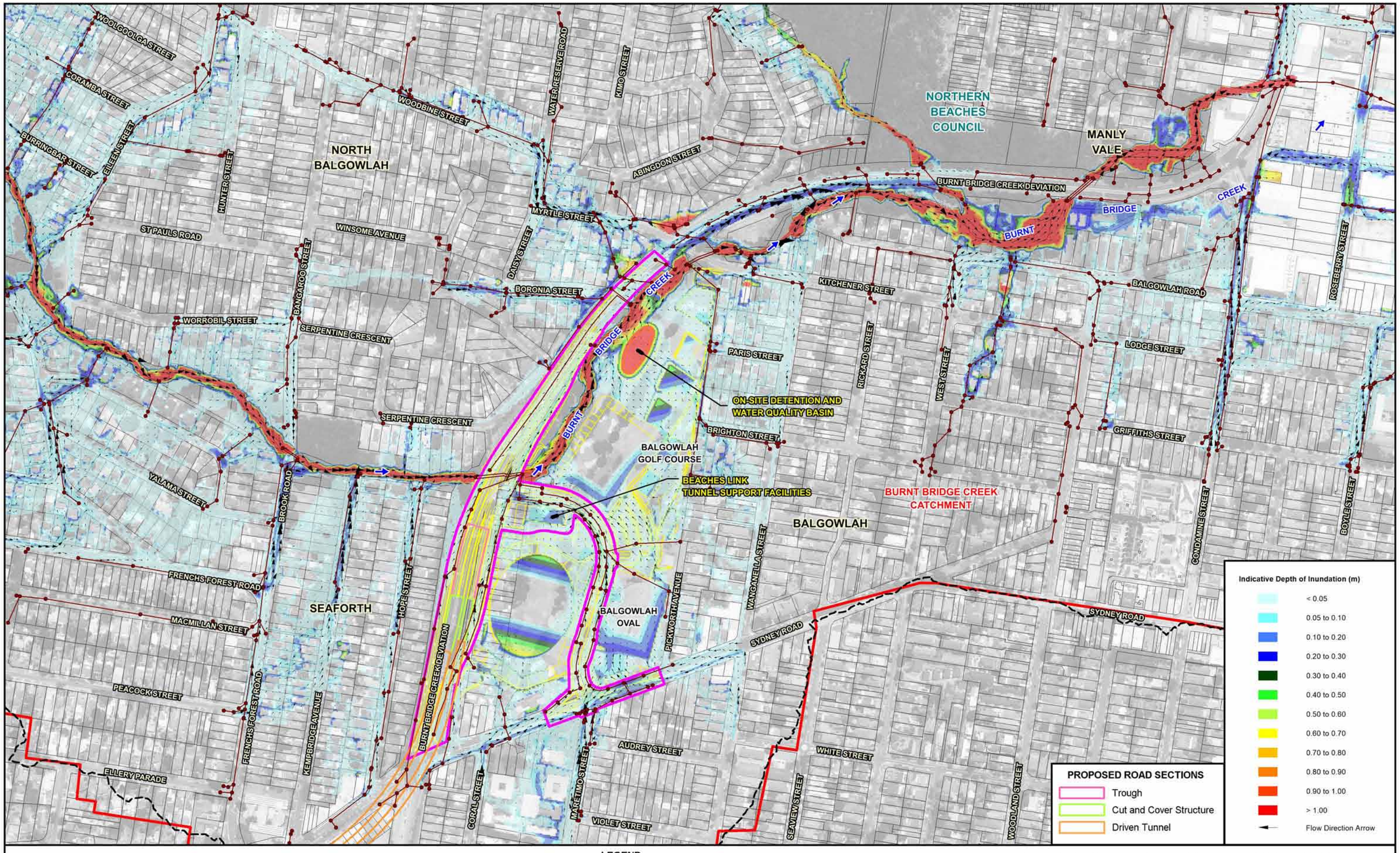
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works
- Driven Tunnel

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.1
(Sheet 4 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
10% AEP EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.1
(Sheet 5 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
10% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00

TREFOIL CREEK
BEACON HILL
NARRAWEENA
FRENCHS FOREST
WARRINGAH ROAD
PITTWATER ROAD
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
ARCHBOLD ROAD
KILLARNEY HEIGHTS
BANTRY BAY
MANLY
CONDAMINE STREET
FRESHWATER
KU-RING-GAI COUNCIL
WARRINGAH ROAD
ROSEVILLE CHASE
CREEK
MANLY
CREEK
ROSEVILLE
MANLY VALE
PITTWATER ROAD
LINDFIELD
PACIFIC HIGHWAY
QUEENSCLIFF
CASTLE COVE
BURNT
BRIDGE
CREEK
FRENCHS FOREST ROAD
CHATSWOOD
MIDDLE COVE
SEAFORTH
SYDNEY ROAD
FAIRLIGHT
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
EASTERN VALLEY WAY
REFER SHEET 5
BALGOWLAH
CASTLECRAG
MANLY
LANE COVE NORTH
WILLOUGHBY
BALGOWLAH HEIGHTS
ARTARMON
REFER SHEET 3
FLAT
NORTH HARBOUR
LANE COVE WEST
EPPING ROAD
LANE COVE TUNNEL
ROCK
CREEK
NORTHBRIDGE
LANE COVE
NAREMBURN
REFER SHEET 4
LANE COVE COUNCIL
CAMMERAY
MIDDLE HARBOUR
ST LEONARDS
CREMORNE
WARRINGAH FREEWAY
MOSMAN
RIVERVIEW
CROWS NEST
MILITARY ROAD
WILLOUGHBY CREEK
LANE COVE RIVER
GREENWICH
REFER SHEET 2
MOSMAN COUNCIL
NORTHWOOD
MILITARY ROAD

N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

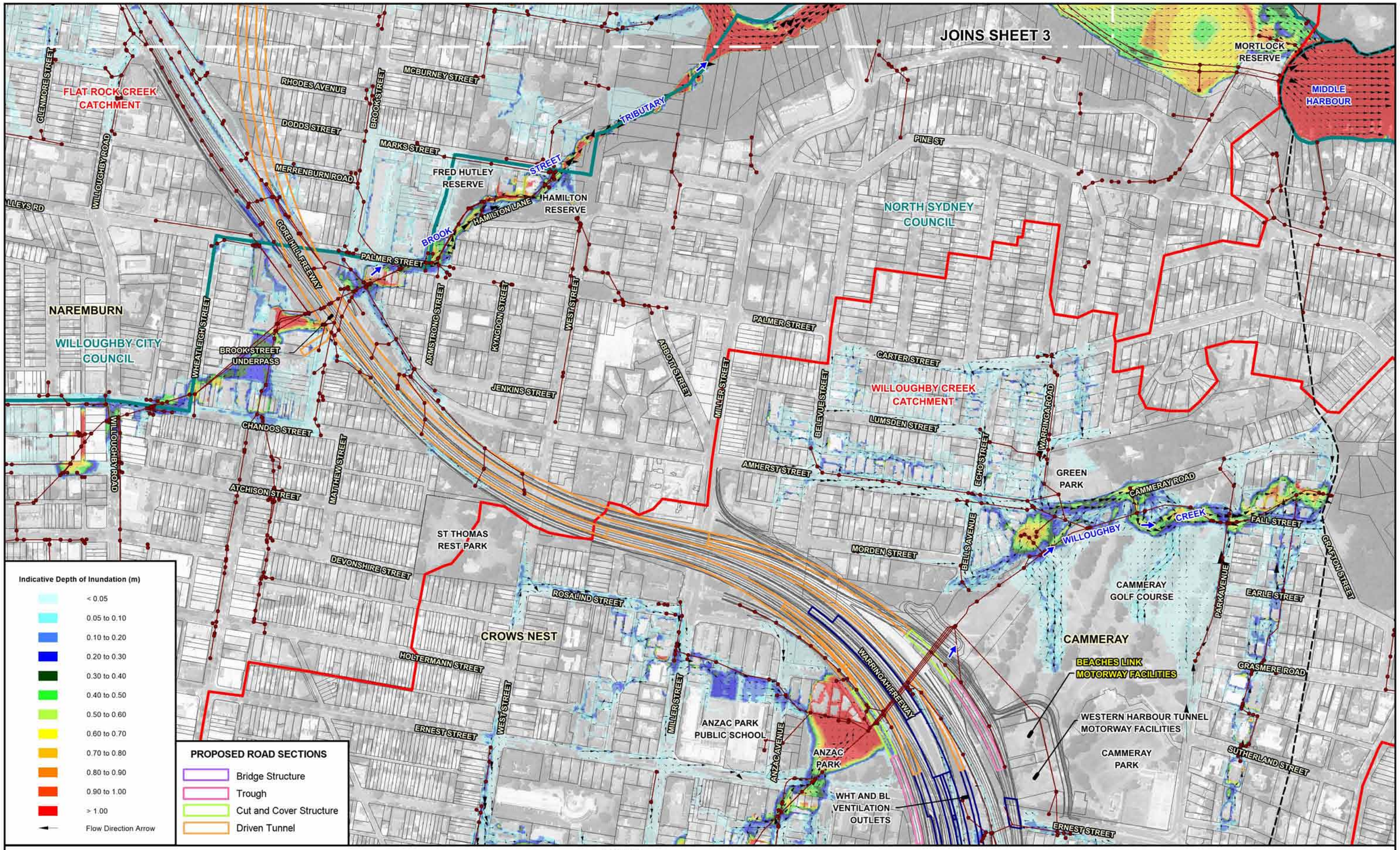
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Driven Tunnel
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.2
(Sheet 1 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
1% AEP EVENT



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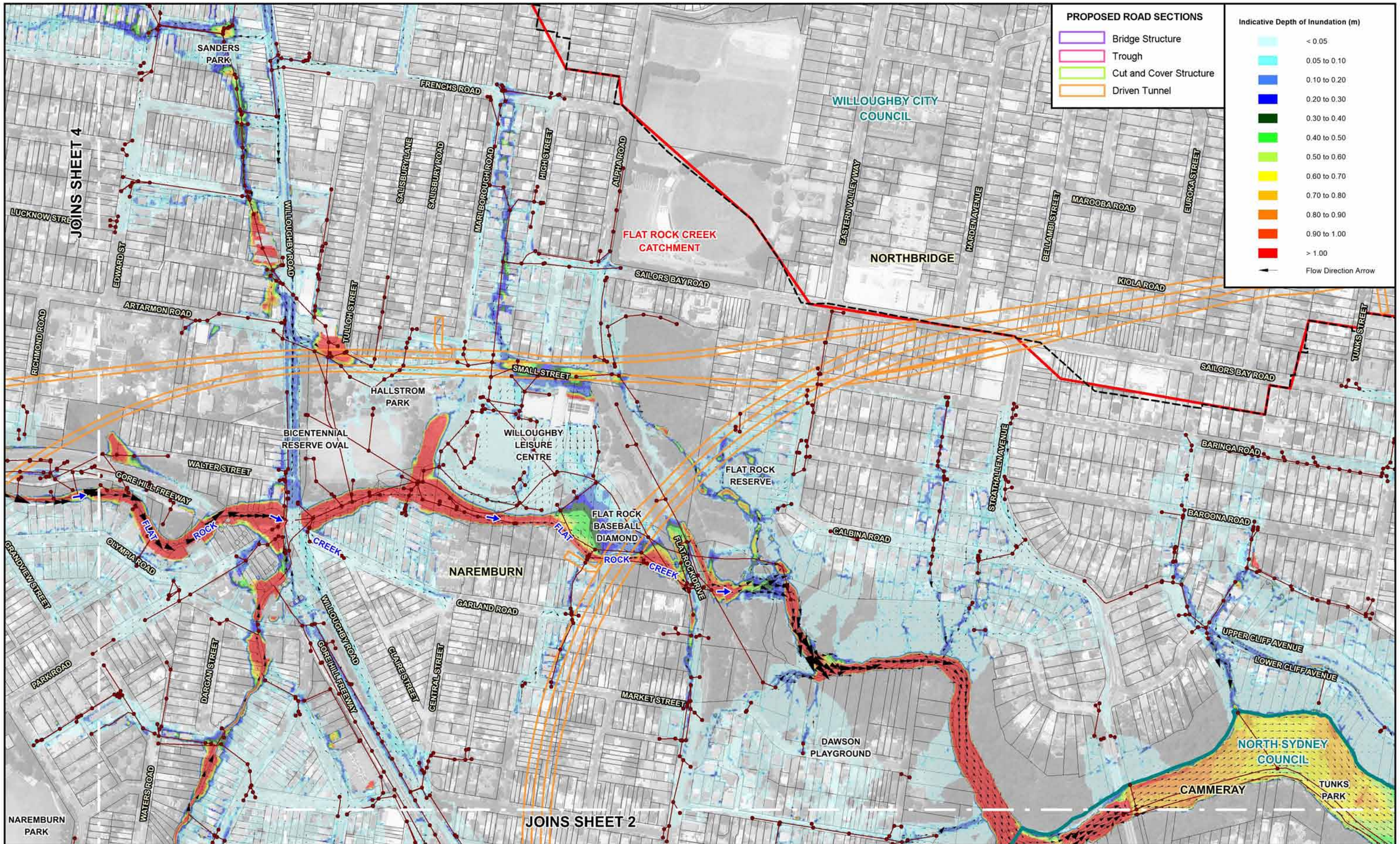
BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.2
(Sheet 2 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.2
(Sheet 3 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

ELSIE WEARN PARK
ELIZABETH ST
TINDALE ROAD
ARTARMON ROAD
SYDNEY STREET
CAMERON AVENUE
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
FLAT ROCK CREEK CATCHMENT
FLAT ROCK CREEK
LUCKNOW STREET
BURRA ROAD
ARTARMON ROAD
LANE COVE NORTH
WICKHAM PARK
BROUGHTON ROAD
JERSEY ROAD
T1 NORTH SHORE & WESTERN LINE AND T9 NORTHERN LINE
ARTARMON
ARTARMON RESERVE
CHELMSFORD AVENUE
RICHMOND ROAD
PACIFIC HIGHWAY
GEORGE PLACE
RESERVE RD
THOMSON PARK
MILNER ROAD
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
CLELAND ROAD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
PARKES ROAD
RESERVE ROAD INTERCHANGE
GORE HILL FREEWAY
PUNCH STREET
LAMBS ROAD
NAREMBURN
GRANDVIEW STREET
STATION STREET
PARK ROAD
MARDEN STREET
MALACHLAN AVENUE
BEACHES LINK MOTORWAY CONTROL CENTRE
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
HERBERT STREET
WALTHAM STREET
HOTHAM PARADE
WHITING STREET
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
ST LEONARDS
CLARENDON STREET
CLEG ST
RESERVE ROAD
DICKSON AVENUE
LANE COVE
JOINS SHEET 3
NAREMBURN PARK

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

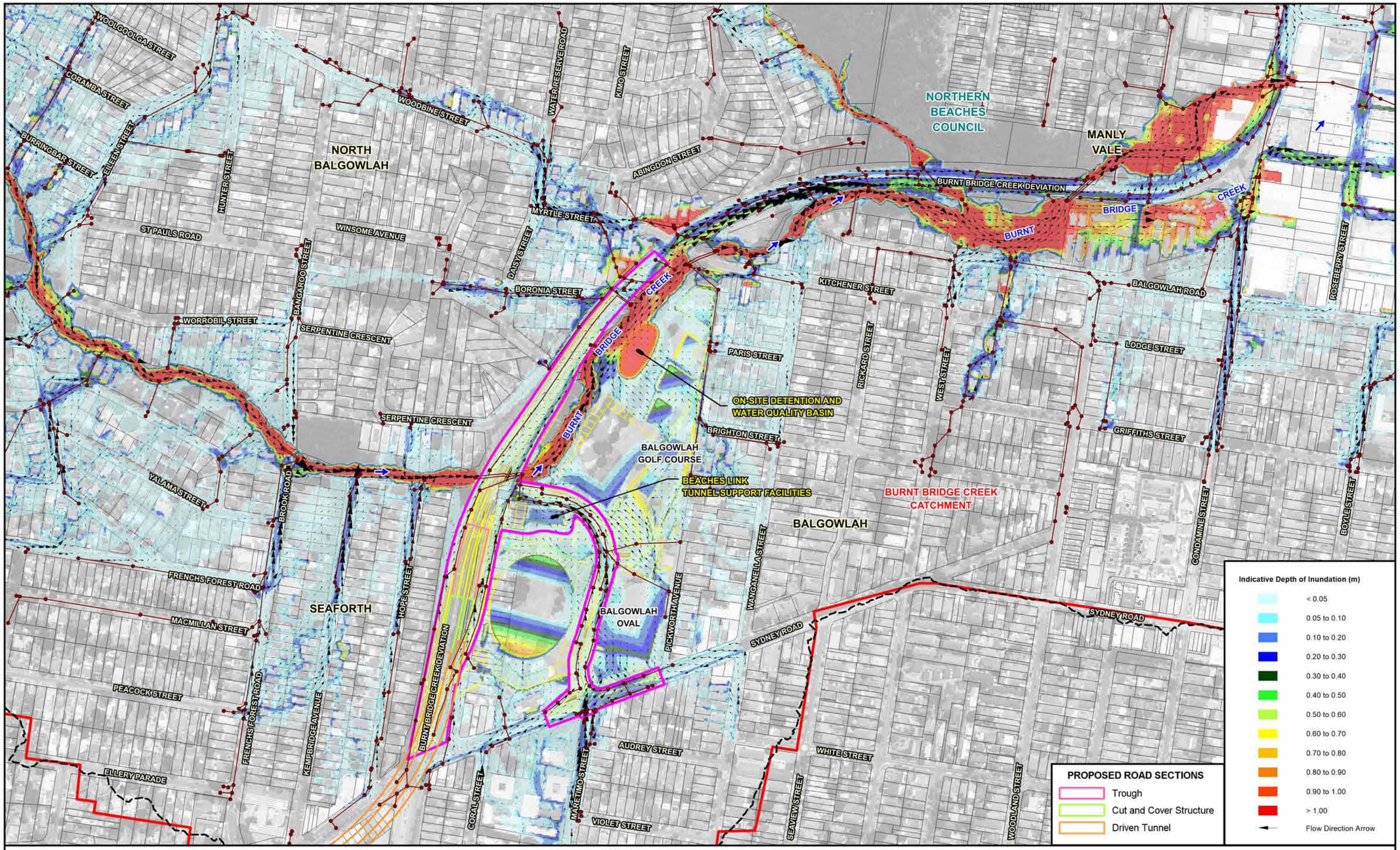
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.2
(Sheet 4 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
1% AEP EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.2
(Sheet 5 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
1% AEP EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00

TREFOIL CREEK
FRENCHS FOREST
BEACON HILL
NARRAWEENA
WARRINGAH ROAD
PITTWATER ROAD
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
ARCHBOLD ROAD
KU-RING-GAI COUNCIL
KILLARNEY HEIGHTS
BANTRY BAY
MANLY CREEK
GONDAMINE STREET
FRESHWATER
ROSEVILLE CHASE
ROSEVILLE
MANLY VALE
LINDFIELD
PACIFIC HIGHWAY
CASTLE COVE
QUEENSCLIFF
BURNT BRIDGE CREEK
FRENCHS FOREST ROAD
SEAFORTH
SYDNEY ROAD
FAIRLIGHT
CHATSWOOD
MIDDLE COVE
EASTERN VALLEY WAY
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
REFER SHEET 5
BALGOWLAH
CASTLECRAG
MANLY
WILLOUGHBY
LANE COVE NORTH
ARTARMON
REFER SHEET 3
BALGOWLAH HEIGHTS
NORTH HARBOUR
LANE COVE WEST
EPPING ROAD
LANE COVE TUNNEL
FLAT ROCK CREEK
NORTHBRIDGE
LANE COVE
REFER SHEET 4
NAREMBURN
LANE COVE COUNCIL
CAMMERAY
GORE HILL FREEWAY
CREMORNE
MIDDLE HARBOUR
ST LEONARDS
MOSMAN
RIVERVIEW
LANE COVE RIVER
CROWS NEST
WILLOUGHBY CREEK
MILITARY ROAD
GREENWICH
REFER SHEET 2
MOSMAN COUNCIL
NORTHWOOD

N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Driven Tunnel
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.3
(Sheet 1 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
PMF EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

MCBURNEY STREET

BROOK STREET

DODDS STREET

MARKS STREET

TRIBUTARY

STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

HAMILTON LANE

HAMILTON RESERVE

BROOK

CORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

ATCHISON STREET

MATTHEW STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

WARRINGAH FREEWAY

MORTLOCK RESERVE

MIDDLE HARBOUR

PINE ST

NORTH SYDNEY COUNCIL

PALMER STREET

CARTER STREET

MILLER STREET

BELLEVUE STREET

WILLOUGHBY CREEK CATCHMENT

LUMSDEN STREET

WARRINGA ROAD

AMHERST STREET

ECHO STREET

GREEN PARK

CAMMERAY ROAD

CREEK

WILLOUGHBY

FALL STREET

GRAFTON STREET

MORDEN STREET

BELLS AVENUE

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

CAMMERAY

BEACHES LINK MOTORWAY FACILITIES

GRASMERE ROAD

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY PARK

SUTHERLAND STREET

ERNEST STREET

Indicative Depth of Inundation (m)

< 0.05	
0.05 to 0.10	
0.10 to 0.20	
0.20 to 0.30	
0.30 to 0.40	
0.40 to 0.50	
0.50 to 0.60	
0.60 to 0.70	
0.70 to 0.80	
0.80 to 0.90	
0.90 to 1.00	
> 1.00	
Flow Direction Arrow	

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
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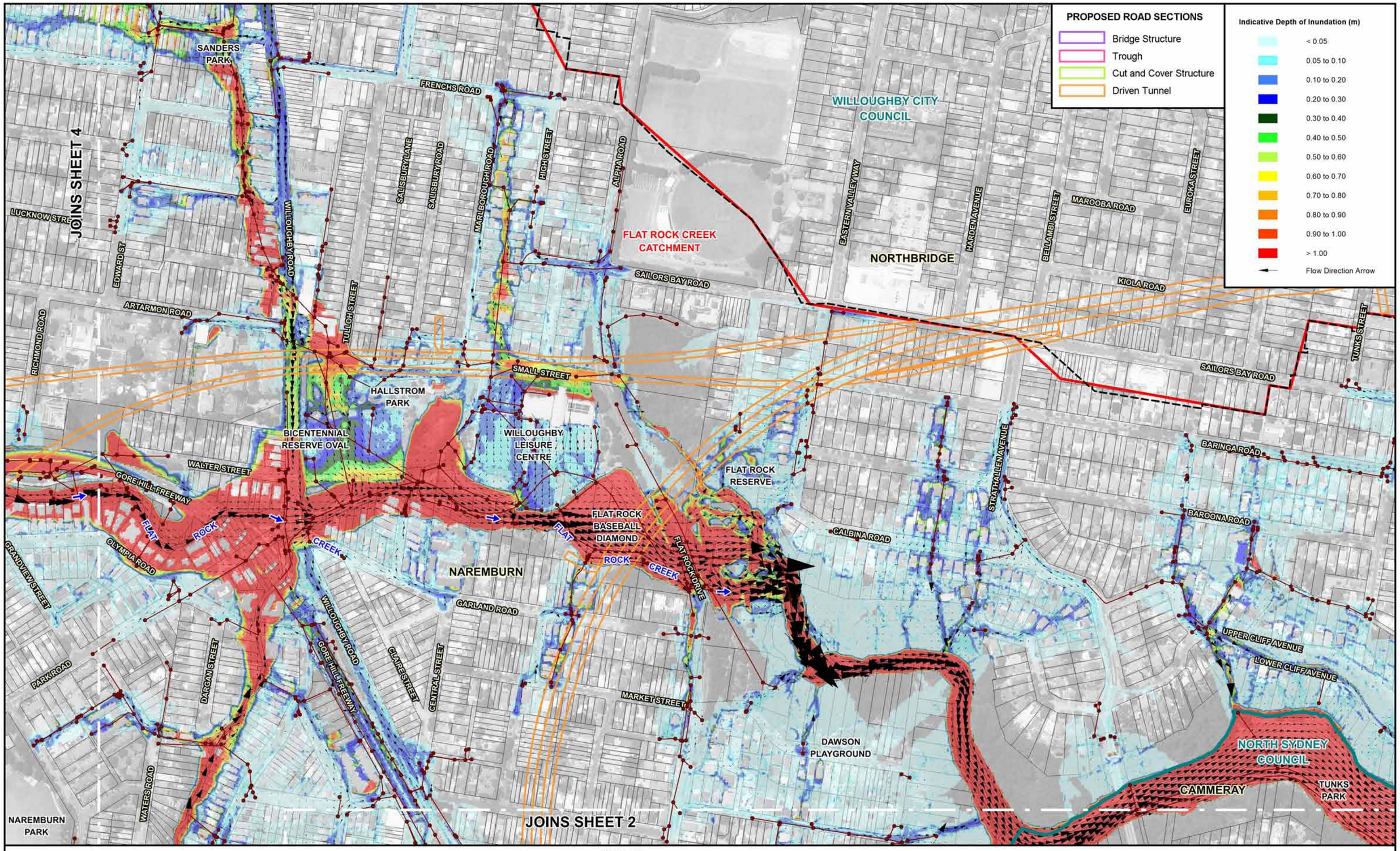
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.3
(Sheet 2 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
PMF EVENT



Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.3
(Sheet 3 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
PMF EVENT

Indicative Depth of Inundation (m)

- < 0.05
- 0.05 to 0.10
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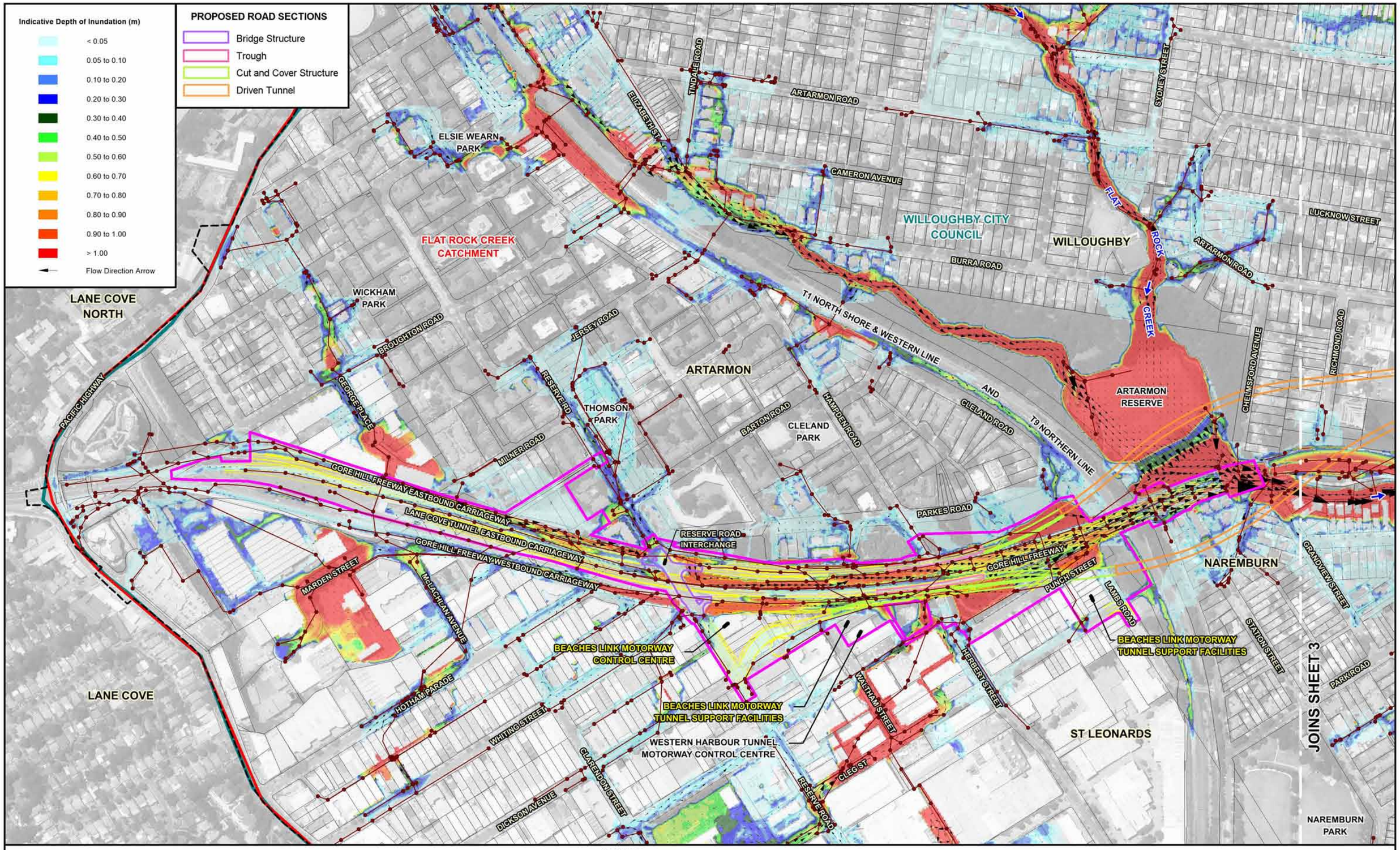
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.60
- 0.60 to 0.70
- 0.70 to 0.80
- 0.80 to 0.90
- 0.90 to 1.00
- > 1.00
- Flow Direction Arrow

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
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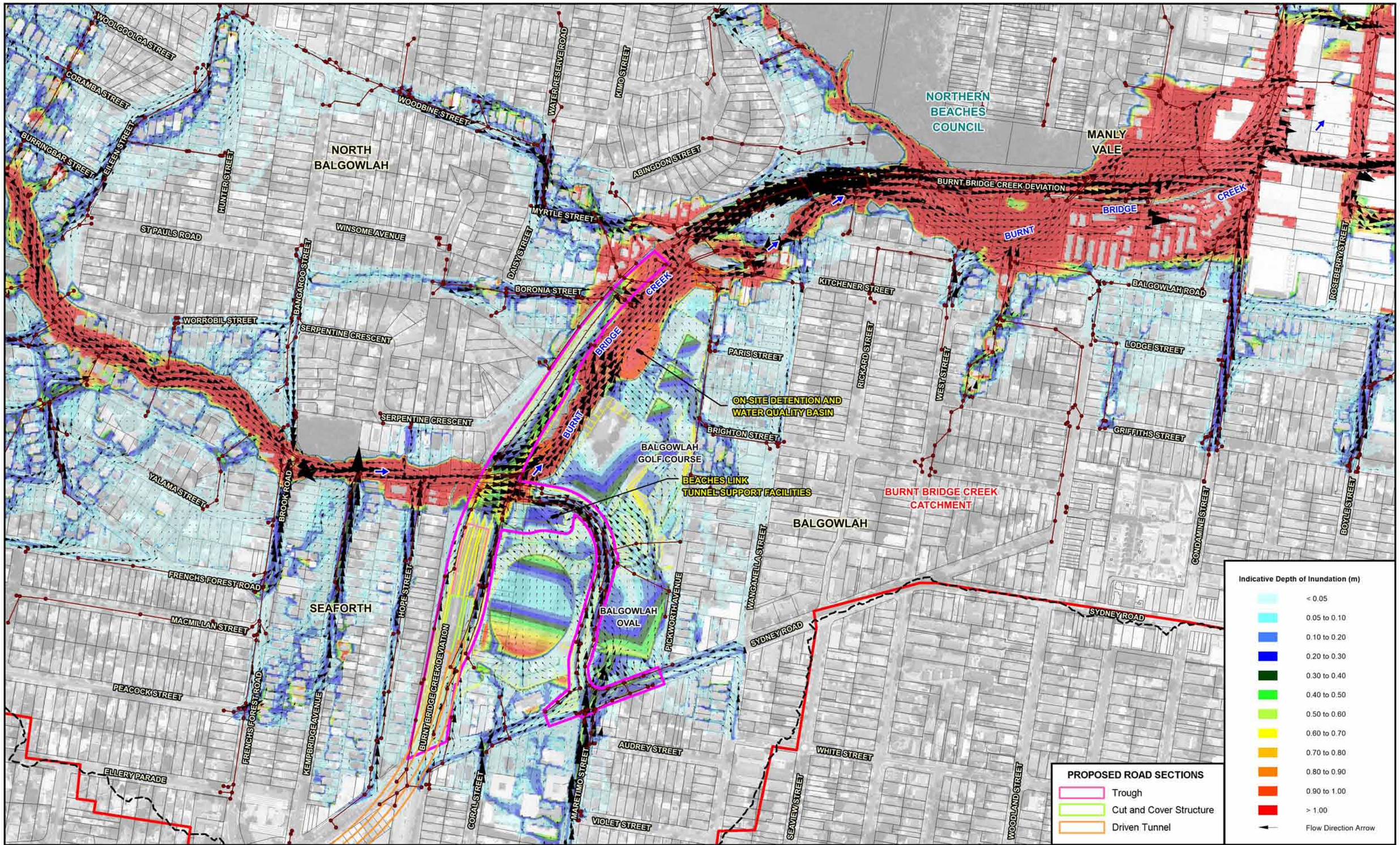
Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.3
(Sheet 4 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
PMF EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.3
(Sheet 5 of 5)

FLOODING PATTERNS UNDER OPERATIONAL CONDITIONS
PMF EVENT

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

TREFOIL CREEK
BEACON HILL
NARRAWEENA
FRENCHS FOREST
WARRINGAH ROAD
PITTWATER ROAD
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
ARCHBOLD ROAD
KILLARNEY HEIGHTS
BANTRY BAY
MANLY CREEK
GONDAMINE STREET
FRESHWATER
KU-RING-GAI COUNCIL
WARRINGAH ROAD
ROSEVILLE CHASE
ROSEVILLE
LINDFIELD
PACIFIC HIGHWAY
MANLY VALE
QUEENSCLIFF
CASTLE COVE
BURNT BRIDGE CREEK
CHATSWOOD
MIDDLE COVE
FRENCHS FOREST ROAD
SEAFORTH
SYDNEY ROAD
FAIRLIGHT
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
EASTERN VALLEY WAY
REFER SHEET 5
BALGOWLAH
CASTLECRAG
MANLY
LANE COVE NORTH
WILLOUGHBY
ARTARMON
REFER SHEET 3
BALGOWLAH HEIGHTS
NORTH HARBOUR
LANE COVE WEST
EPPING ROAD
LANE COVE TUNNEL
FLAT ROCK CREEK
NORTHBRIDGE
LANE COVE
REFER SHEET 4
NAREMBURN
LANE COVE COUNCIL
CAMMERAY
ST LEONARDS
CREMORNE
MOSMAN
MIDDLE HARBOUR
WARRINGAH FREEWAY
RIVERVIEW
CROWS NEST
WILLOUGHBY CREEK
LANE COVE RIVER
GREENWICH
REFER SHEET 2
MOSMAN COUNCIL
MILITARY ROAD
NORTHWOOD

N

400 0 400 800 1200 m

Scale: 1:40,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Driven Tunnel
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.4
(Sheet 1 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
10% AEP EVENT

JOINS SHEET 3

FLAT ROCK CREEK CATCHMENT

GLENMORE STREET

WILLOUGHBY ROAD

RHODES AVENUE

MCBURNEY STREET

BROOK STREET

DODDS STREET

MARKS STREET

TRIBUTARY

STREET

MERRENBURN ROAD

FRED HUTLEY RESERVE

HAMILTON LANE

HAMILTON RESERVE

BROOK

GORE HILL FREEWAY

PALMER STREET

NAREMBURN

WILLOUGHBY CITY COUNCIL

WHEATLEIGH STREET

BROOK STREET UNDERPASS

ARMSTRONG STREET

KYNGDON STREET

WEST STREET

ABBOTT STREET

JENKINS STREET

CHANDOS STREET

MATTHEW STREET

ATCHISON STREET

ST THOMAS REST PARK

DEVONSHIRE STREET

ROSALIND STREET

CROWS NEST

HOLTERMANN STREET

ERNEST STREET

MILLER STREET

ANZAC PARK PUBLIC SCHOOL

ANZAC AVENUE

ANZAC PARK

WHT AND BL VENTILATION OUTLETS

WARRINGAH FREEWAY

NORTH SYDNEY COUNCIL

PALMER STREET

CARTER STREET

WILLOUGHBY CREEK CATCHMENT

LUMSDEN STREET

AMHERST STREET

ECHO STREET

BELLS AVENUE

MORDEN STREET

WARRINGA ROAD

GREEN PARK

CAMMERAY ROAD

WILLOUGHBY

CREEK

FALL STREET

GRAFTON STREET

CAMMERAY GOLF COURSE

PARK AVENUE

EARLE STREET

CAMMERAY

BEACHES LINK MOTORWAY FACILITIES

GRASMERE ROAD

WESTERN HARBOUR TUNNEL MOTORWAY FACILITIES

CAMMERAY PARK

SUTHERLAND STREET

ERNEST STREET

PINE ST

MORTLOCK RESERVE

MIDDLE HARBOUR

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

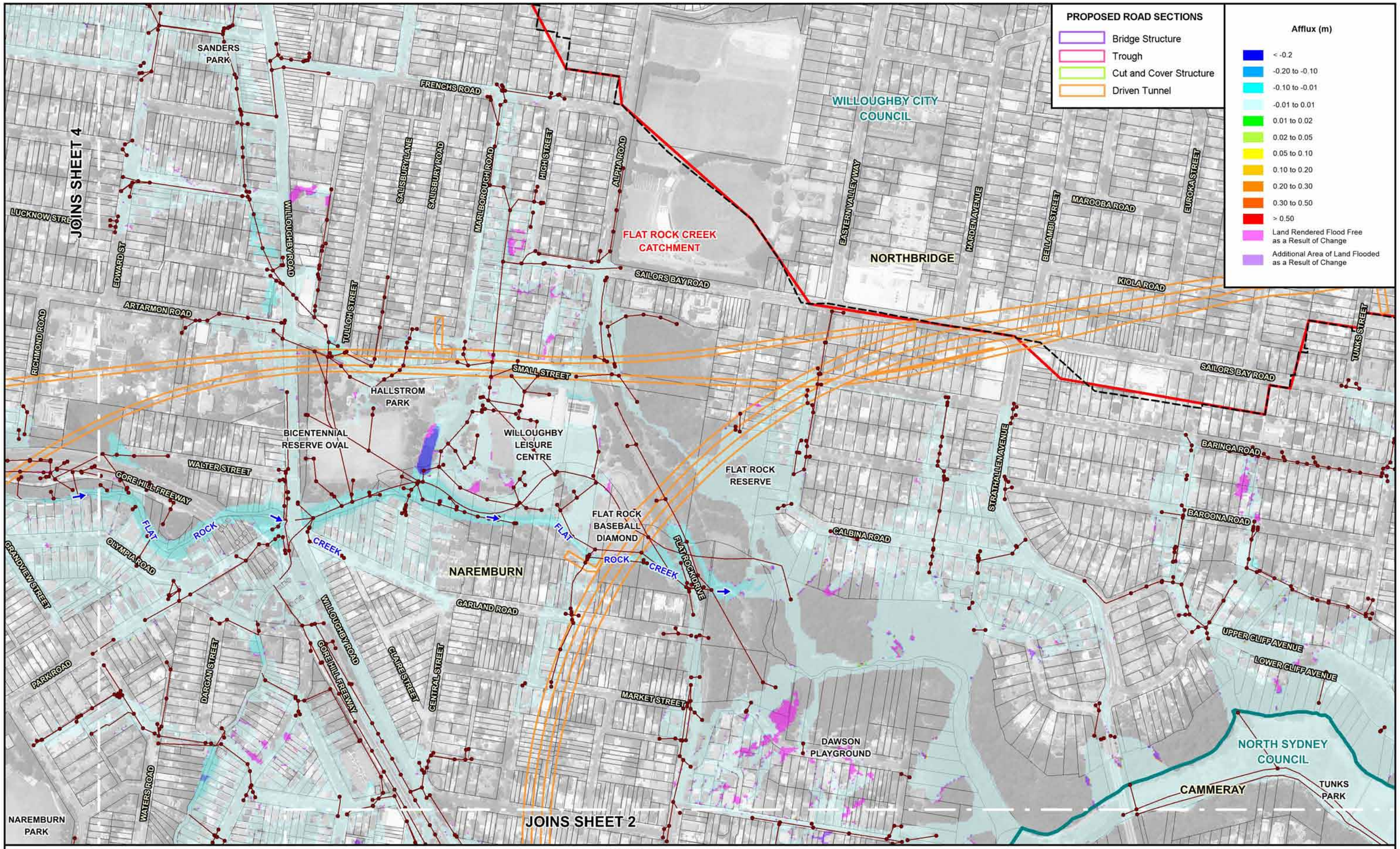
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.4
(Sheet 2 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
10% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.4
(Sheet 3 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
10% AEP EVENT

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

ELSIE WEARN PARK
ELIZABETH ST
TINDALE ROAD
ARTARMON ROAD
SYDNEY STREET
CAMERON AVENUE
FLAT ROCK CREEK CATCHMENT
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
BURRA ROAD
LUCKNOW STREET
ARTARMON ROAD
LANE COVE NORTH
WICKHAM PARK
BROUGHTON ROAD
JERSEY ROAD
T1 NORTH SHORE & WESTERN LINE
AND
T9 NORTHERN LINE
ARTARMON
ARTARMON RESERVE
CHELMSFORD AVENUE
RICHMOND ROAD
PACIFIC HIGHWAY
GEORGE PLACE
RESERVE RD
THOMSON PARK
MILNER ROAD
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
CLELAND ROAD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
PARKES ROAD
RESERVE ROAD INTERCHANGE
GORE HILL FREEWAY
PUNCH STREET
LAMBS ROAD
NAREMBURN
GRANDVIEW STREET
STATION STREET
PARK ROAD
MARDEN STREET
MALACHLAN AVENUE
BEACHES LINK MOTORWAY CONTROL CENTRE
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
HOTHAM PARADE
WHITING STREET
CLARENDON STREET
DICKSON AVENUE
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
WALTHAM STREET
HERBERT STREET
CLEG ST
RESERVE ROAD
ST LEONARDS
JOINS SHEET 3
LANE COVE
NAREMBURN PARK

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

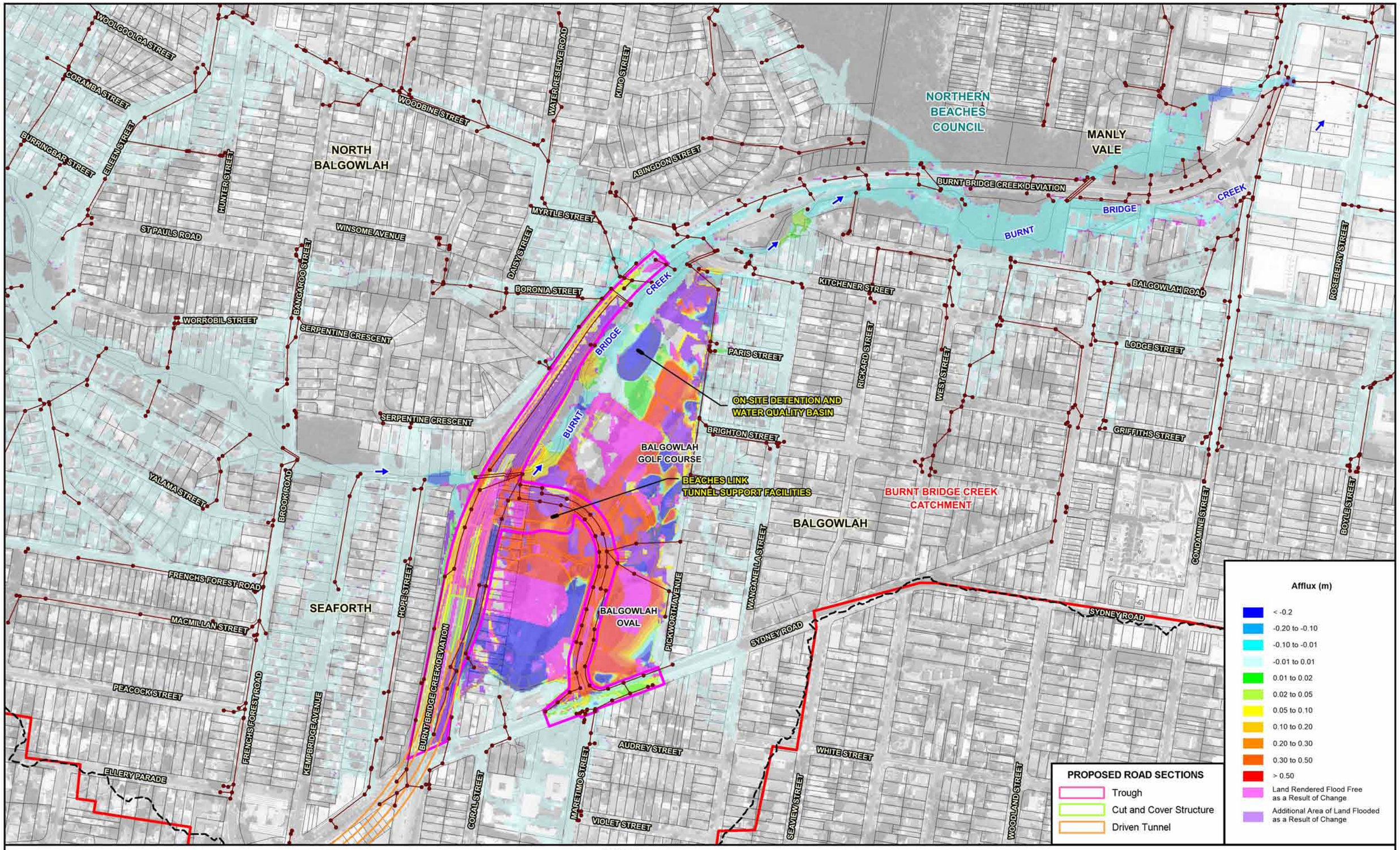
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.4
(Sheet 4 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
10% AEP EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.4
(Sheet 5 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
10% AEP EVENT

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

TREFOIL CREEK
BEACON HILL
NARRAWEENA
FRENCHS FOREST
WARRINGAH ROAD
PITTWATER ROAD
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
ARCHBOLD ROAD
KU-RING-GAI COUNCIL
KILLARNEY HEIGHTS
BANTRY BAY
MANLY CREEK
GONDAMINE STREET
FRESHWATER
WARRINGAH ROAD
ROSEVILLE CHASE
ROSEVILLE
LINDFIELD
PACIFIC HIGHWAY
MANLY VALE
QUEENSCLIFF
CASTLE COVE
BURNT BRIDGE CREEK
FRENCHS FOREST ROAD
SEAFORTH
SYDNEY ROAD
FAIRLIGHT
CHATSWOOD
MIDDLE COVE
EASTERN VALLEY WAY
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
REFER SHEET 5
BALGOWLAH
CASTLECRAG
MANLY
WILLOUGHBY
BALGOWLAH HEIGHTS
LANE COVE NORTH
ARTARMON
REFER SHEET 3
FLAT ROCK CREEK
NORTH HARBOUR
LANE COVE WEST
EPPING ROAD
LANE COVE TUNNEL
NORTHBRIDGE
LANE COVE
REFER SHEET 4
NAREMBURN
LANE COVE COUNCIL
CAMMERAY
MIDDLE HARBOUR
ST LEONARDS
CREMORNE
WARRINGAH FREEWAY
MOSMAN
RIVERVIEW
CROWS NEST
WILLOUGHBY CREEK
MILITARY ROAD
LANE COVE RIVER
GREENWICH
REFER SHEET 2
MOSMAN COUNCIL
NORTHWOOD

N

400 0 400 800 1200 m

Scale: 1:40,000

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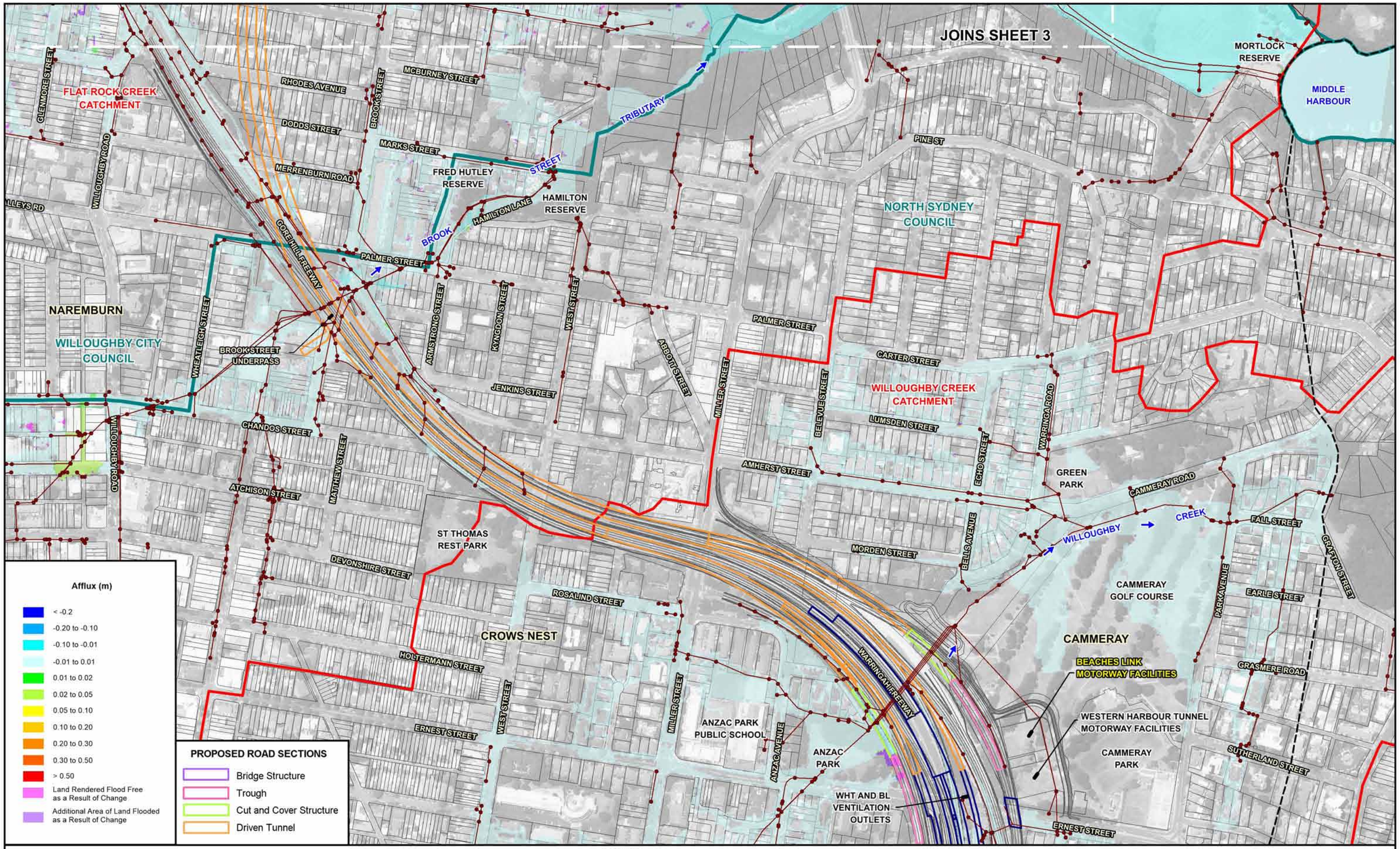
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Driven Tunnel
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.5
(Sheet 1 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP EVENT



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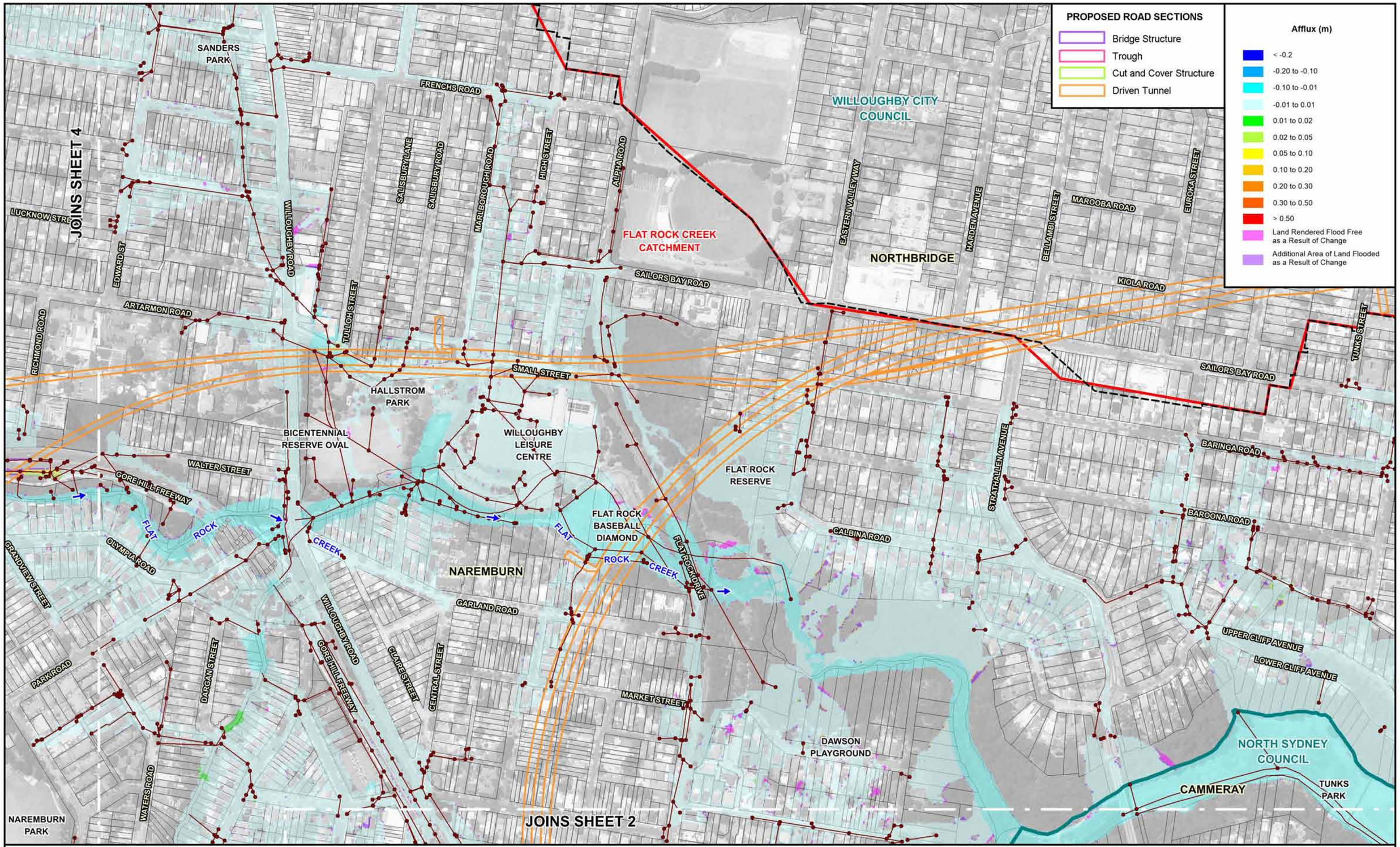
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.5
(Sheet 2 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.5
(Sheet 3 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP EVENT

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

ELSIE WEARN PARK
ELIZABETH ST
TINDALE ROAD
ARTARMON ROAD
SYDNEY STREET
CAMERON AVENUE
FLAT ROCK CREEK CATCHMENT
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
BURRA ROAD
FLAT ROCK CREEK
LUCKNOW STREET
ARTARMON ROAD
LANE COVE NORTH
WICKHAM PARK
BROUGHTON ROAD
JERSEY ROAD
T1 NORTH SHORE & WESTERN LINE
AND
T9 NORTHERN LINE
ARTARMON
ARTARMON RESERVE
CHELMSFORD AVENUE
RICHMOND ROAD
PACIFIC HIGHWAY
GEORGE PLACE
RESERVE RD
THOMSON PARK
MILNER ROAD
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
CLELAND ROAD
PARKES ROAD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
RESERVE ROAD INTERCHANGE
GORE HILL FREEWAY
PUNCH STREET
LAMBS ROAD
NAREMBURN
GRANDVIEW STREET
MARDEN STREET
MALACHLAN AVENUE
BEACHES LINK MOTORWAY CONTROL CENTRE
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
STATION STREET
PARK ROAD
HOTHAM PARADE
WHITING STREET
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
WALTHAM STREET
HERBERT STREET
ST LEONARDS
JOINS SHEET 3
LANE COVE
CLARENDON STREET
CLEG ST
RESERVE ROAD
DICKSON AVENUE
NAREMBURN PARK

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

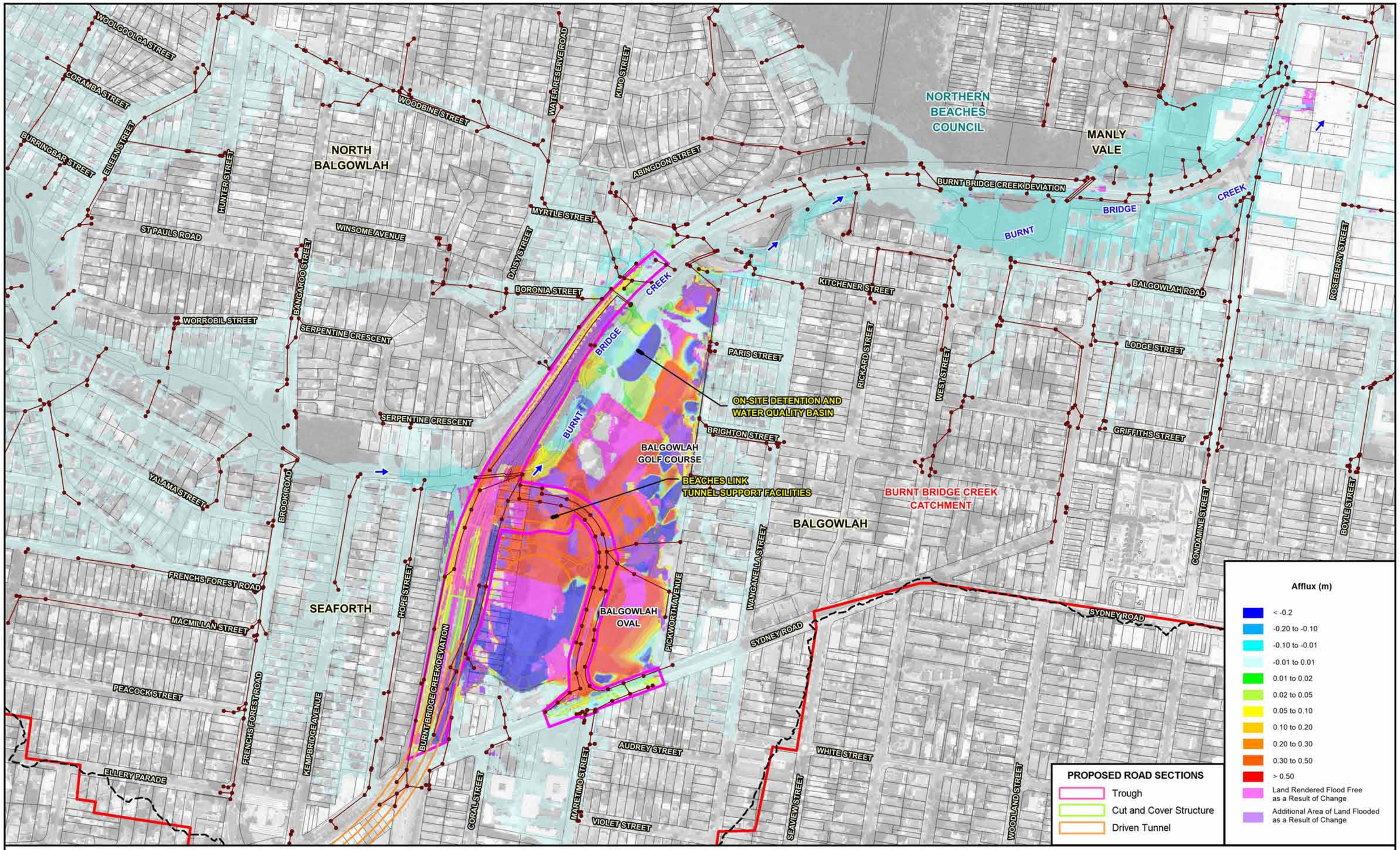
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.5
(Sheet 4 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.5
(Sheet 5 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP EVENT

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

TREFOIL CREEK
FRENCHS FOREST
BEACON HILL
NARRAWEENA
WARRINGAH ROAD
PITTWATER ROAD
DEE WHY
EAST KILLARA
FORESTVILLE
BROOKVALE
NORTHERN BEACHES COUNCIL
WAKEHURST PARKWAY
ALLAMBIE HEIGHTS
CURL CURL
EAST LINDFIELD
ARCHBOLD ROAD
KU-RING-GAI COUNCIL
KILLARNEY HEIGHTS
BANTRY BAY
MANLY CREEK
GONDAMINE STREET
FRESHWATER
ROSEVILLE CHASE
ROSEVILLE
LINDFIELD
PACIFIC HIGHWAY
MANLY VALE
QUEENSCLIFF
CASTLE COVE
BURNT BRIDGE CREEK
FRENCHS FOREST ROAD
SEAFORTH
SYDNEY ROAD
FAIRLIGHT
CHATSWOOD
MIDDLE COVE
EASTERN VALLEY WAY
CHATSWOOD WEST
WILLOUGHBY CITY COUNCIL
REFER SHEET 5
BALGOWLAH
CASTLECRAG
MANLY
WILLOUGHBY
LANE COVE NORTH
ARTARMON
REFER SHEET 3
BALGOWLAH HEIGHTS
NORTH HARBOUR
LANE COVE WEST
EPPING ROAD
LANE COVE TUNNEL
FLAT ROCK CREEK
NORTHBRIDGE
LANE COVE
REFER SHEET 4
NAREMBURN
LANE COVE COUNCIL
CAMMERAY
MIDDLE HARBOUR
ST LEONARDS
CREMORNE
MOSMAN
WARRINGAH FREEWAY
RIVERVIEW
CROWS NEST
WILLOUGHBY CREEK
LANE COVE RIVER
GREENWICH
REFER SHEET 2
MOSMAN COUNCIL
MILITARY ROAD
NORTHWOOD

N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

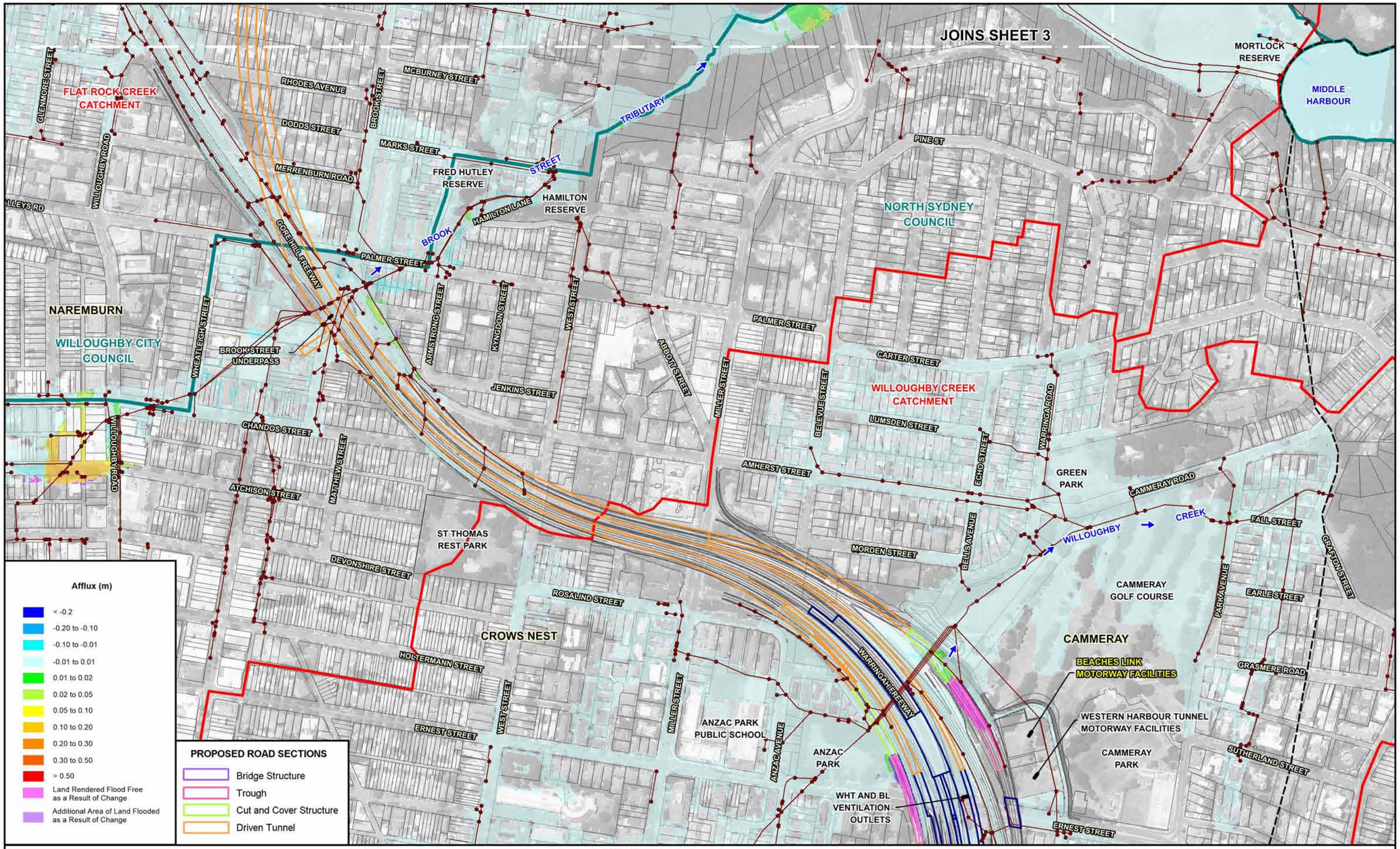
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Limit of Estuarine Flood Mapping
- LGA Boundary
- Project Surface Road Works Footprint
- Driven Tunnel
- Proposed BL & GHFC Surface Works
- Northern Beaches Hospital Surface Road Works
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.6
(Sheet 1 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Western Harbour Tunnel and Warringah Freeway Upgrade Surface Road Works
- Western Harbour Tunnel (Including Trough and Cut and Cover Structures)

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BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.6
(Sheet 2 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF EVENT

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

JOINS SHEET 4

SANDERS PARK
FRENCHS ROAD
WILLOUGHBY CITY COUNCIL
LUCKNOW STREET
EDWARD ST
WILLOUGHBY ROAD
SALISBURY LANE
SALISBURY ROAD
MARLBOROUGH ROAD
HIGH STREET
ALPHA ROAD
FLAT ROCK CREEK CATCHMENT
EASTERN VALLEY WAY
MARDEN AVENUE
BELLAMBI STREET
MAROOBA ROAD
EUROKA STREET
NORTHBRIDGE
SAILORS BAY ROAD
KIOLA ROAD
ARTARMON ROAD
RICHMOND ROAD
TULLOH STREET
TUNKS STREET
SMALL STREET
HALLSTROM PARK
BICENTENNIAL RESERVE OVAL
WILLOUGHBY LEISURE CENTRE
BARINGA ROAD
WALTER STREET
GORE HILL FREEWAY
FLAT ROCK RESERVE
STRATHALLEN AVENUE
FLAT ROCK BASEBALL DIAMOND
BAROONA ROAD
CALBINA ROAD
FLAT ROCK CREEK
FLAT ROCK DRIVE
OLYMPIA ROAD
GRANDVIEW STREET
NAREMBURN
GARLAND ROAD
UPPER CLIFF AVENUE
LOWER CLIFF AVENUE
PARK ROAD
DARGAN STREET
WILLOUGHBY ROAD
GORE HILL FREEWAY
CLARKE STREET
CENTRAL STREET
MARKET STREET
DAWSON PLAYGROUND
NORTH SYDNEY COUNCIL
CAMMERAY
TUNKS PARK
WATERS ROAD
NAREMBURN PARK
JOINS SHEET 2

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary

Lyall & Associates

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.6
(Sheet 3 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF EVENT

Afflux (m)

- < -0.2
- -0.20 to -0.10
- -0.10 to -0.01
- -0.01 to 0.01
- 0.01 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.50
- > 0.50
- Land Rendered Flood Free as a Result of Change
- Additional Area of Land Flooded as a Result of Change

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

ELSIE WEARN PARK
ELIZABETH ST
TINDALE ROAD
ARTARMON ROAD
SYDNEY STREET
CAMERON AVENUE
FLAT ROCK CREEK CATCHMENT
WILLOUGHBY CITY COUNCIL
WILLOUGHBY
BURRA ROAD
LUCKNOW STREET
ARTARMON ROAD
LANE COVE NORTH
WICKHAM PARK
BROUGHTON ROAD
JERSEY ROAD
T1 NORTH SHORE & WESTERN LINE
AND
T9 NORTHERN LINE
ARTARMON
ARTARMON RESERVE
CHELMSFORD AVENUE
RICHMOND ROAD
PACIFIC HIGHWAY
GEORGE PLACE
RESERVE RD
THOMSON PARK
MILNER ROAD
BARTON ROAD
CLELAND PARK
HAMPDEN ROAD
CLELAND ROAD
GORE HILL FREEWAY EASTBOUND CARRIAGEWAY
LANE COVE TUNNEL EASTBOUND CARRIAGEWAY
GORE HILL FREEWAY WESTBOUND CARRIAGEWAY
PARKES ROAD
RESERVE ROAD INTERCHANGE
GORE HILL FREEWAY
PUNCH STREET
LAMBS ROAD
NAREMBURN
GRANDVIEW STREET
STATION STREET
PARK ROAD
MARDEN STREET
McLACHLAN AVENUE
BEACHES LINK MOTORWAY CONTROL CENTRE
BEACHES LINK MOTORWAY TUNNEL SUPPORT FACILITIES
HOTHAM PARADE
WHITING STREET
CLAREDON STREET
DICKSON AVENUE
WESTERN HARBOUR TUNNEL MOTORWAY CONTROL CENTRE
WARATAH STREET
HERBERT STREET
CLEG ST
RESERVE ROAD
ST LEONARDS
LANE COVE
JOINS SHEET 3
NAREMBURN PARK

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Modelled Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- Proposed BL & GHFC Surface Works

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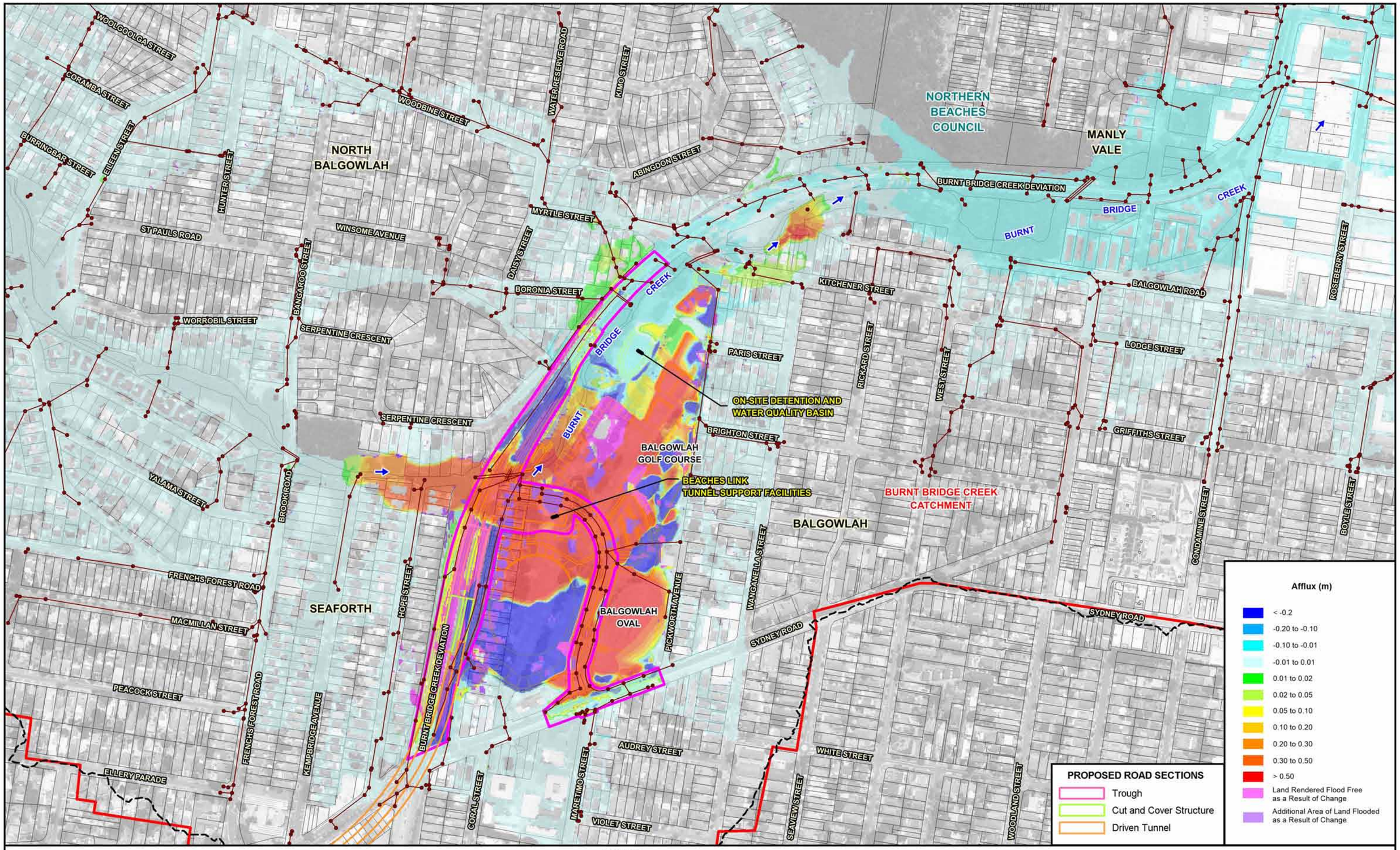
BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.6
(Sheet 4 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF EVENT



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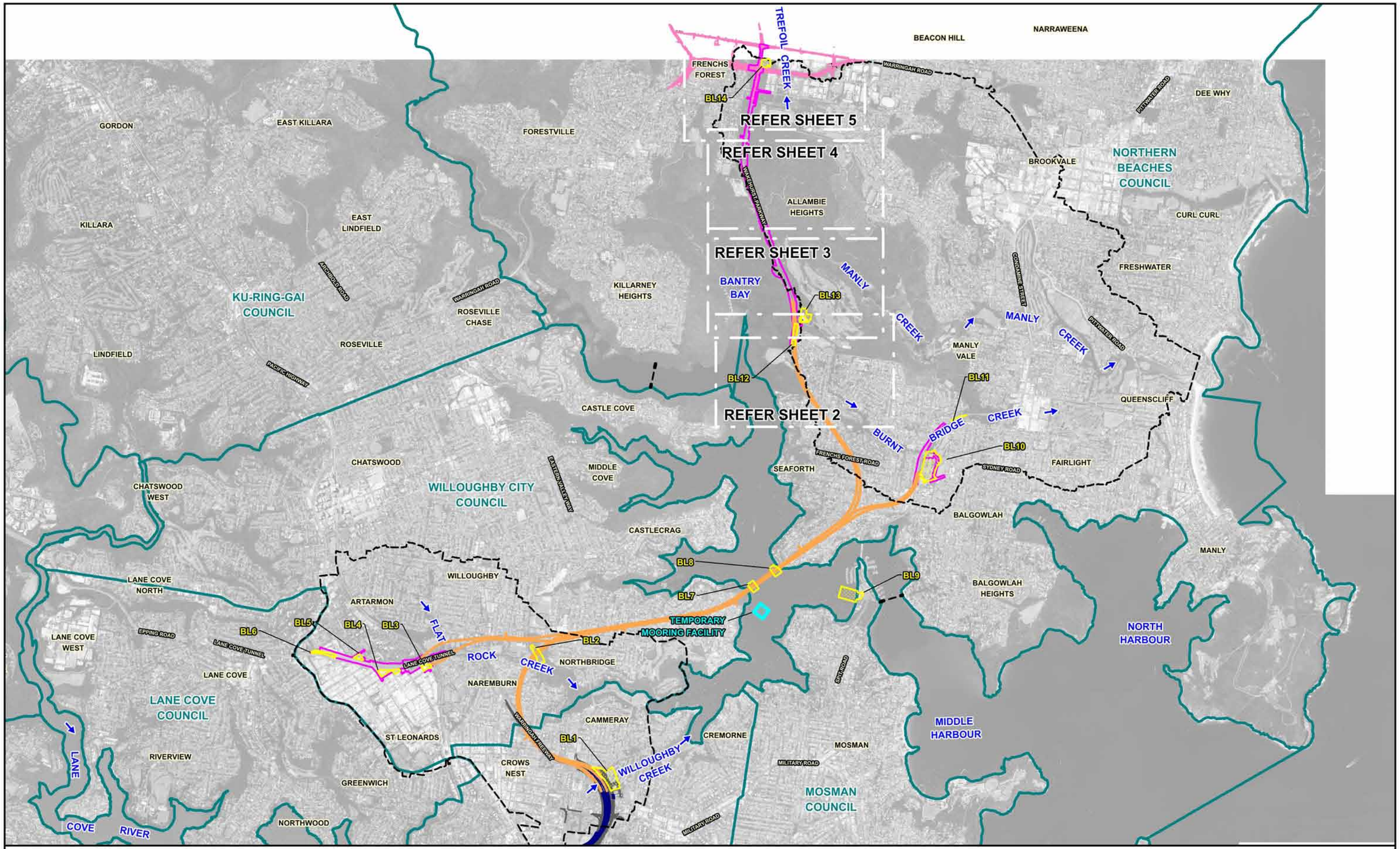
BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.6
(Sheet 5 of 5)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF EVENT



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BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.7
(Sheet 1 of 5)

PAVEMENT DRAINAGE STRATEGY
WAKEHURST PARKWAY UPGRADE

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

BB Q4
BB DL02
BB DL01
BB DL01
SEAFORTH
BL12
XD_BB03
BB Q2
BB Q1
BL13
KIRKWOOD STREET
WAKEHURST GOLF CLUB
JOINS SHEET 3
ALLAMBIE HEIGHTS
BANTRY BAY RESERVE
BANTRY BAY CATCHMENT
MANLY CREEK CATCHMENT
BANTRY BAY
SEAFORTH OVAL
JUDITH STREET
MANNING STREET
WATERVIEW STREET
BURNT STREET
UPPER CLONTARF STREET
MONS ROAD
BALGOWLAH PUBLIC SCHOOL
WARRINGAH STREET
BARDOO AVENUE
GLOUCESTER STREET
ALTO AVENUE
PRINCE EDWARD ROAD
NORTHERN BEACHES COUNCIL
NORTH BALGOWLAH
BURNT BRIDGE CREEK CATCHMENT
WOODBINE STREET
GARRAWEEN AVENUE
EURELLA AVENUE
WOOLGOOLGA RESERVE
URUNGA STREET
YEOLAND POINT
MIDDLE HARBOUR
CASTLE CIRCUIT
CLONTARF STREET
WOOLGOOLGA STREET
LISTER AVENUE
CORAMBA STREET
EXPLOSIVES RESERVE
WILLOUGHBY COUNCIL
FROMELLES AVENUE
BARINGA AVENUE
BURRINGBAR STREET
EILEEN STREET
HUNTER STREET
CASTLE COVE
WAKEHURST PARKWAY
ACACIA ROAD
ST PAULS ROAD

N

50 0 50 100 150 m

Scale: 1:5,000

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LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Proposed Transverse Drainage and Identifier
- BB Q3 Peak Flow Location and Identifier
- Existing Drainage Line
- Proposed Design String
- Extent of Catchment Controlled by Future Pavement Drainage System
- Pavement Drainage Outlet Location

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.7
(Sheet 2 of 5)

PAVEMENT DRAINAGE STRATEGY
WAKEHURST PARKWAY UPGRADE

PROPOSED ROAD SECTIONS

- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

JOINS SHEET 4

JOINS SHEET 2

MC Q7
MC Q6
MC Q5
MC Q4
MC Q3
MC DL02
XD_MC06
WAKEHURST PARKWAY
MANLY
CREEK
ALLAMBIE HEIGHTS
MC Q2
MC Q1
MC DL01
XD_MC07
KILLARNEY HEIGHTS
MANLY CREEK CATCHMENT
NORTHERN BEACHES COUNCIL
MANLY DAM
BANTRY BAY CATCHMENT
BB Q6
BB DL03
BB Q5
XD_BB01
BANTRY BAY
BB Q3
XD_BB02
BB Q4
BB DL02
BL13
KIRKWOOD STREET
BL12
XD_BB03
SEAFORTH
BB DL01
BB Q2
BB Q1
BB DL01
WAKEHURST GOLF CLUB

N

50 0 50 100 150 m

Scale: 1:5,000

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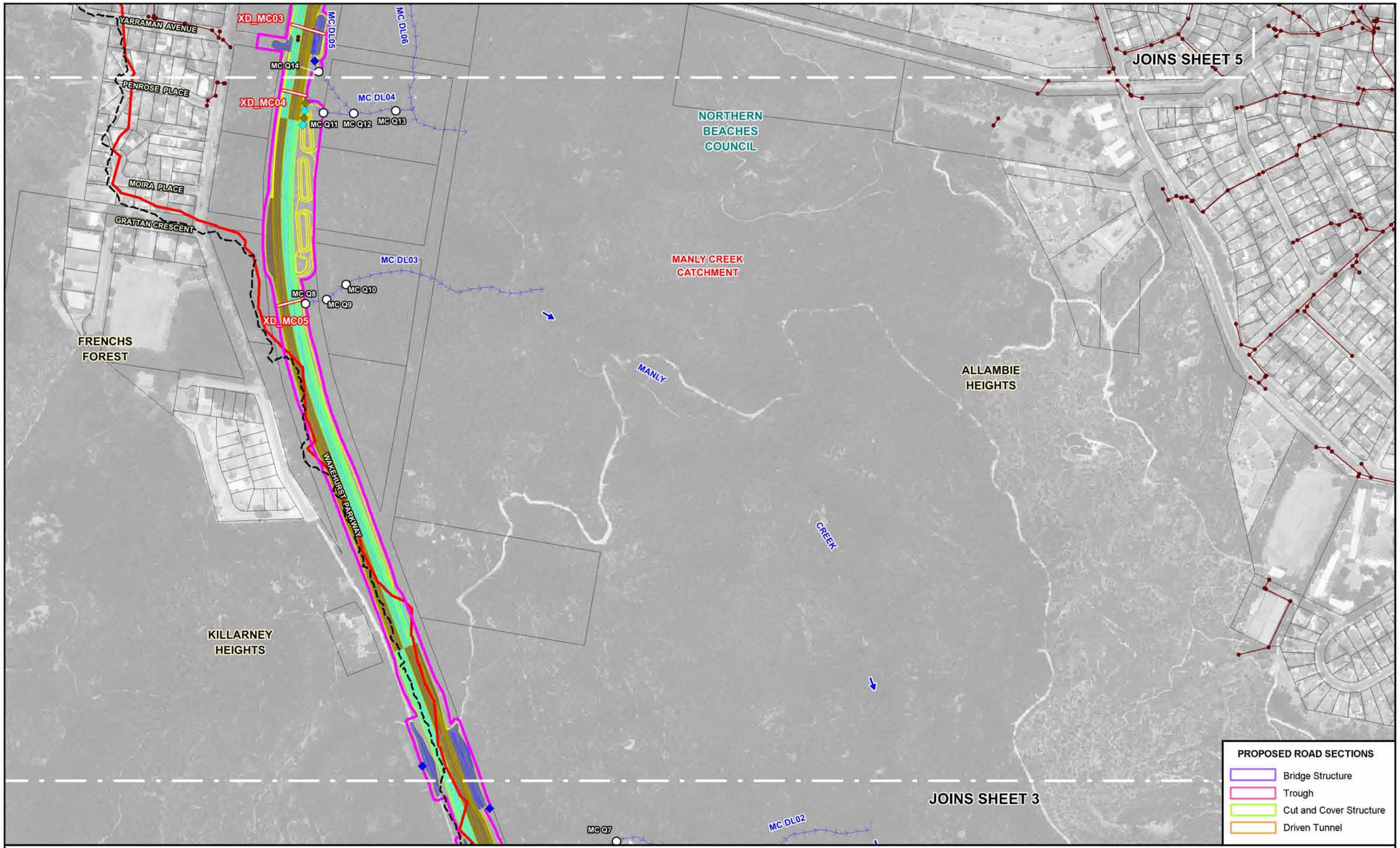
LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- BL2 Construction Support Site and Identifier
- XD_BB03 Proposed Transverse Drainage and Identifier
- MC Q24 Peak Flow Location and Identifier
- Existing Drainage Line
- Proposed Design String
- Extent of Catchment Controlled by Future Pavement Drainage System
- Pavement Drainage Outlet Location

BEACHES LINK AND GORE HILL FREEWAY CONNECTION
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.7
(Sheet 3 of 5)

PAVEMENT DRAINAGE STRATEGY
WAKEHURST PARKWAY UPGRADE



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

LEGEND

- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- Project Surface Road Works Footprint
- XD_MC03 Proposed Transverse Drainage and Identifier
- MC Q13 Peak Flow Location and Identifier
- Existing Drainage Line
- Proposed Design String
- Extent of Catchment Controlled by Future Pavement Drainage System
- Pavement Drainage Outlet Location

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.7
(Sheet 4 of 5)

PAVEMENT DRAINAGE STRATEGY
WAKEHURST PARKWAY UPGRADE

FRENCHS FORESTROAD WEST
FRENCHS FORESTROAD EAST
TREFOIL CREEK
TREFOIL CREEK CATCHMENT
ROMFORD ROAD
HURDIS AVENUE
HARMSTON AVENUE
INVERNESS AVENUE
PATANGA ROAD
DAREEN STREET
FRENCHS FOREST
NORTHERN BEACHES HOSPITAL
WAKEHURST PARKWAY
BL14
WARRINGAH ROAD
NORTHERN BEACHES COUNCIL
KARINGAL CRESCENT
AKORA STREET
PRIMROSE AVENUE
FITZPATRICK AVENUE
XD_MC01
MC Q17
MC DL07
MC Q18
MANLY CREEK CATCHMENT
RODBOROUGH ROAD
ALLAMBIE ROAD
BANTRY BAY CATCHMENT
RANGERS RETREAT ROAD
BANTRY BAY ROAD
AQUATIC DRIVE
MC Q19
PARNI PLACE
GARNER AVENUE
ALLAMBIE HEIGHTS
ARNHEM ROAD
XD_MC02
MC Q15
AQUATIC RESERVE
KANYA STREET
MC DL06
MC Q16
WAKEHURST PARKWAY
XD_MC03
MC DL05
YARRAMAN AVENUE
JOINS SHEET 9

PROPOSED ROAD SECTIONS
- Bridge Structure
- Trough
- Cut and Cover Structure
- Driven Tunnel

N
50 0 50 100 150 m
Scale: 1:5,000

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LEGEND
- Limit of Main Stream Flooding and Major Overland Flow Mapping
- Existing Drainage System
- LGA Boundary
- Catchment Boundary
- BL2 — Construction Support Site and Identifier
- Project Surface Road Works Footprint
- Northern Beaches Hospital Surface Road Works
- XD_MC03 — Proposed Transverse Drainage and Identifier
- MC Q12 — Peak Flow Location and Identifier
- Existing Drainage Line
- Proposed Design String
- Extent of Catchment Controlled by Future Pavement Drainage System
- Pavement Drainage Outlet Location

BEACHES LINK AND GORE HILL FREEWAY CONNECTION FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6.7
(Sheet 5 of 5)

PAVEMENT DRAINAGE STRATEGY
WAKEHURST PARKWAY UPGRADE