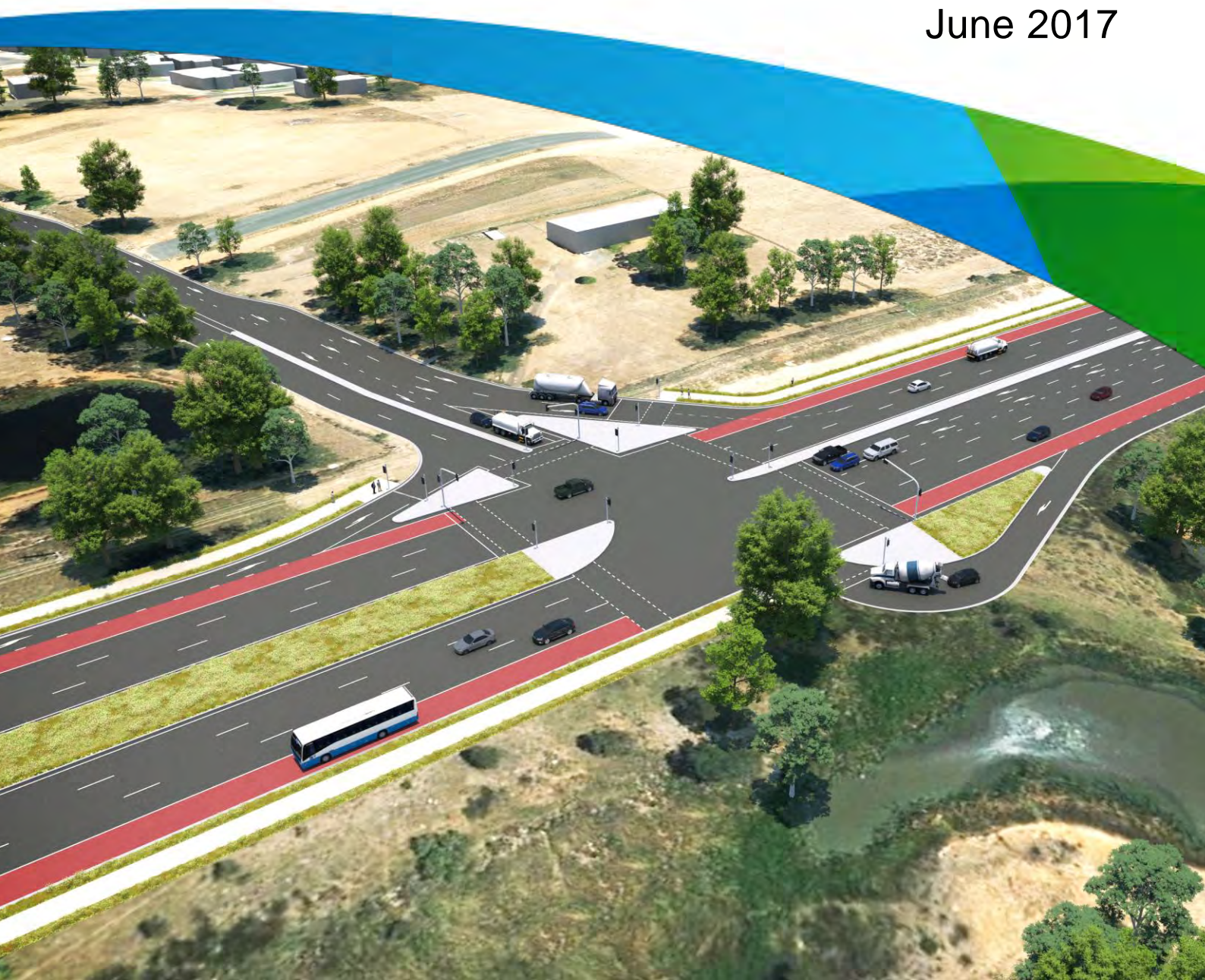


# **The Northern Road Upgrade Mersey Road, Bringelly to Glenmore Parkway, Glenmore Park**

NSW Environmental Impact Statement /  
Commonwealth Draft Environmental Impact Statement

## **Appendix K – Technical working paper: Flooding and hydrology**

June 2017



**THE NORTHERN ROAD UPGRADE  
(BETWEEN 600 m NORTH OF CHAIN-O-PONDS ROAD, MULGOA  
AND GLENMORE PARKWAY, GLENMORE PARK)**

**TECHNICAL WORKING PAPER:  
FLOOD RISK ASSESSMENT**

**March 2017**

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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 five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year. As another example, for a flood having a five year ARI, there would be floods of equal or greater magnitude once in five years on average. The approximate correspondence between these two systems is:

<b>Annual Exceedance Probability (AEP) per cent</b>	<b>Average Recurrence Interval (ARI) years</b>
0.5	200
1	100
5	20
20	5

In this technical working paper the frequency of floods generated by runoff from the study catchments is referred to in terms of their ARI, for example the 100 year ARI flood.

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 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.

## GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
Afflux	Increase/decrease in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
AEP	Annual Exceedance Probability.  The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of a 500 cubic metres per second or larger events occurring in any one year (see also average recurrence interval).
ALS	Airborne Laser Scanning.  A type of aerial survey used to measure the elevation of the ground surface.
AHD	Australian Height Datum.  A common national surface level datum approximately corresponding to mean sea level.
ARI	Average Recurrence Interval.  The average period in years between the occurrence of a flood of a particular magnitude or greater. In a long period of say 1,000 years, a flood equivalent to or greater than a 100 year ARI event would occur 10 times. The 100 year ARI flood has a one per cent chance (i.e. a one-in-100 chance) of occurrence in any one year (see annual exceedance probability).  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 ARI, for example the 100 year ARI flood.
ARR	Australian Rainfall and Runoff (Institute of Engineers Australia, 1998).
BoM	Bureau of Meteorology
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DECC	Department of Environment and Climate Change (now OEH).
DECCW	Department of Environment, Climate Change and Water (now OEH).
DoP	Department of Planning (now DP&E)
DPE	Department of Planning and Environment (formerly DoP)
DSC	Dam Safety Committee



Term	Meaning
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m <sup>3</sup> /s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second [m/s]).
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.
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 fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
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 (i.e. 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.
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.
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.  Typically equal to the 100 year ARI flood level plus a freeboard of 0.5 metres.

Term	Meaning
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 “greenhouse” and climate change. Freeboard is included in the Flood Planning Level.
GSDM	Generalised Short Duration Method.  A method for estimating the Probable Maximum Precipitation for catchments up to 1,000 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.
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.
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.
Merits based approach	The merits based 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.
OEH	Office of Environment and Heritage (formerly DECCW)
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.

Term	Meaning
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 (i.e. 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
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
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 manual 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
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
SW	Sydney Water
Flow Velocity	A measure of how fast water is moving (e.g. metres per second [m/s]).
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.

## **EXECUTIVE SUMMARY**

### **ES1.1 Background and study area**

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to upgrade about 16 km of The Northern Road between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park (project) (refer **Figure 1.1** for route).

This technical working paper forms part of the Environmental Impact Statement (EIS) that has been prepared for the project and deals with the potential flood risks associated with the section which runs from a location 600 m north of Chain-O-Ponds Road to Glenmore Parkway. The flood risk assessment was based on design floods with average recurrence intervals (ARI's) of 2 year, 10 year and 100 year, as well as the Probable Maximum Flood (PMF). This technical working paper also sets out the findings of an assessment of the potential impact a partial blockage of major hydraulic structures, future climate change and a potential failure of a proposed flood retarding basin embankment would have on flooding behaviour in the vicinity of the project. The findings of a similar flood risk assessment which was undertaken for the section of the project which runs between Mersey Road and a location 600 m north of Chain-O-Ponds Road are presented in a technical work paper which is contained in Appendix K.1 of the EIS.

The project would comprise the upgrade of the existing two-lane road to a six-lane divided road where it runs between a location 600 m north of Chain-O-Ponds Road and Bradley Street and an eight-lane divided road where it runs between Bradley Street and Glenmore Parkway. Provision would also be incorporated in the median for an additional travel lane in each direction if required in the future.

The section of the project which runs from a location 600 m north of Chain-O-Ponds Road to Glenmore Parkway generally follows the alignment of an un-named tributary of Surveyors Creek (un-named tributary). **Figure 4.1** shows the alignment of the project relative to the un-named tributary, as well as the extent of the catchments which contribute to flow in the existing transverse drainage network.

### **ES1.2 Pre-project flooding behaviour**

While details of the existing stormwater drainage system in the Commonwealth Department of Defence's (DoD's) Defence Establishment Orchard Hills (DEOH) were not available, it appears that several buildings located near the entrance to the site are subject to flooding during storms as frequent as 2 year ARI (refer **Figure 4.2** and **Figure B1.1**, sheet 1 in **Appendix B**).

The assessment found that during storms which surcharge the inlet of transverse drainage structure EXD4, floodwater will discharge in a northerly direction along the eastern side of The Northern Road where it will join with flow discharging to transverse drainage structure EXD6 (refer **Figure 4.1** for location of existing transverse drainage structures). Floodwater will commence to surcharge The Northern Road for storms with ARI's larger than about 10 years, with about a 200 metre length of the road adjacent to transverse drainage structure EXD6 inundated during a 100 year ARI event, albeit to a relatively shallow depth.

The assessment found that there are several residential properties that are located on the western side of The Northern Road between Bradley Street and Glenmore Parkway that are subject to flooding during a 2 year ARI storm event (refer **Figure 4.2** and **Figure B1.1**, sheet 2 in



**Appendix B).** The assessment also found that the existing dwelling in one of these properties (refer Lot 132 DP1002668 on **Figure 4.3** and **Figure B1.2**, sheet 2 in **Appendix B**) is affected by flooding during a 10 year ARI event, while a further two existing dwellings located in Lot 2 DP1033226 and Lot 10 DP1204969 would be subject to flooding in a 100 year ARI event (refer **Figure 4.4** and **Figure B1.3**, sheet 2 in **Appendix B**). Depths of flooding in the vicinity of the three aforementioned dwellings are relatively shallow (generally less than 200 millimetres for all storms up to 100 year ARI), indicating above-floor inundation, if any, would be even shallower.

During a Probable Maximum Flood (PMF) event, depths of inundation in the vicinity of several dwellings that are located on the western side of The Northern Road between Bradley Street and Glenmore Parkway would exceed 1 metre (refer **Figure 4.5** and **Figure B1.4**, sheet 2 in **Appendix B**).

The assessment found that flooding of a high hazard nature is generally confined to the inbank area of the un-named tributary in a 100 year ARI storm event and therefore does not impact any existing dwellings (refer **Figure 4.7** which shows the provisional flood hazard for the 100 year ARI event).

### **ES1.3 Potential project related impacts**

The project has the potential to impact flooding behaviour and scour potential outside the project corridor should appropriate mitigation measures not be incorporated into its design. **Table 5.1** in **Chapter 5** of this technical working paper describes the potential impacts of the project on flooding behaviour and scour potential, as well measures that could potentially mitigate each identified impact.

Flooding also has the potential to impact on the project, whether as a result of a partial blockage of the transverse drainage or an increase in rainfall intensity associated with future climate change. Consideration of the potential impacts of flooding would therefore need to be taken into consideration when developing the proposed transverse drainage and flood mitigation strategy for the project.

### **ES1.4 Proposed transverse drainage and flood mitigation strategy**

A strategy has been developed which is aimed at mitigating the impact of the project on flooding behaviour and scour potential, as well as providing a minimum 100 year ARI level of flood immunity to the northbound and southbound carriageways of The Northern Road (transverse drainage and flood mitigation strategy). The key features of the transverse drainage and flood mitigation strategy are shown on **Figures 6.1, 6.2** and **6.3** and include:

- The demolition of existing transverse drainage structure EXD1 (refer **Figure 4.1**) which crosses The Northern Road at about **Design Road Chainage (DRC) 14050** and the diversion of flow generated by the upstream catchment along the western side of the project corridor toward the inlet of transverse drainage structure PXD2. Removal of transverse drainage structure EXD1 and the diversion of flow along the western side of the project corridor would reduce the frequency and severity of flooding in the vicinity of the entrance to the DEOH (Commonwealth land).

- Construction of a flood retarding basin on the eastern side of the road between about **DRC 14720** and **DRC 14850** (Commonwealth land). **Figure 6.2** shows the key features of the proposed flood retarding basin at this location. The flood retarding basin would replace an existing dam and comprise the following key features:
  - a 4 metre high earth embankment which would be constructed across the valley between the new road embankment and high ground to the east;
  - a 1200 mm diameter outlet pipe fitted with a 750 mm diameter orifice plate on its inlet; and
  - a spillway which would be constructed in natural ground at the eastern end of the basin embankment.

The basin would attenuate flows generated by the upstream catchment with the aim of offsetting the impact the increase in impervious surface would have on peak flows downstream of its location.

- The realignment of the following sections of the un-named tributary where it runs along the eastern side of The Northern Road on Commonwealth land:
  - from a location opposite the outlet of transverse drainage structure PXD2 to the proposed flood retarding basin;
  - from the outlet of the proposed flood retarding basin to about **DRC 15150**;
  - from about **DRC 15400** to the inlet of transverse drainage structure PXD4.

The need to realign the un-named tributary arises because the widening of The Northern Road along its eastern side would intercept the existing watercourse at the abovementioned locations.

The realigned sections of the un-named tributary would comprise a low flow channel and a benched overbank area which would tie into the existing channel opposite the outlet of transverse drainage structure PXD2, as well as at about **DRC 15150** and **DRC 15400**.

- The construction of a box culvert arrangement where the relocated DEOH security fence would cross the un-named tributary opposite the outlet of transverse drainage structure PXD2. The inlet of the culvert arrangement is to be fitted with a fixed sloping grate arrangement to prevent access to the restricted defence area. **Appendix E** contains a sketch showing typical details of the proposed culvert arrangement. Note that the minimum bar spacing of the fixed sloping grate arrangement would need to be confirmed during detail design, as the measure must prevent access to the restricted defence area by a child. The location of proposed box culvert arrangement is shown on **Figure 6.1** (refer label identifying the location of the “Proposed Security Measure”).
- The demolition and removal of two existing dams that are located on the western side of the project corridor south of Bradley Street (refer **Figure 6.1** for location) and the reinstatement of the natural flow paths. It is noted that works may be required outside the project corridor immediately south of Bradley Street in order to reinstate the natural flow path in this area.
- The construction of a flood bypass channel which would run along the eastern side of The Northern Road (on Commonwealth land) between the inlets of transverse drainage structures PXD4 and PXD5. **Figure 6.3** shows the key features of the proposed flood bypass channel which would convey bypass flows from the inlet of transverse drainage

structure PXD4 during storms with ARI's greater than about 10 years toward the inlet of transverse drainage structure PXD5. The flood bypass channel would be designed to mimic current flooding patterns in the area and therefore prevent adverse flooding conditions from arising in existing residential development that is located on the western side of the project corridor immediately downstream of transverse drainage structure PXD4.

A box culvert arrangement comprising 2 off 3000 millimetre wide by 900 millimetre high RCBC's would need to be provided at the location where the flood bypass channel crosses a gated entrance road which leads into the restricted defence area at about **DRC 15800**.

A bund would also need to be constructed at the northern end of the flood bypass channel in order to prevent flood flows from discharging along the eastern side of The Northern Road beyond the inlet of transverse drainage structure PXD5 during storms with ARI's up to 100 years.

- For the purpose of the present investigation it has been assumed that the existing dam which is located adjacent to the inlet of transverse drainage structure PXD6 in Lot 3 DP711076 would be decommissioned and converted into a grass lined channel. As the decommissioning of the dam would maximise peak flows in the receiving drainage line, it provides for a conservative assumption when assessing the impact the project would have on flooding conditions in existing residential development that is located on the western side of the project corridor.
- The concrete lining of the existing unlined trapezoidal channel (**unlined trapezoidal channel**) which runs along the northern boundary of Lot 132 DP1002668 and Lot 113 DP1015911 (refer **Figure 4.1** for location). Lining of the unlined trapezoidal channel is required in order to increase its hydraulic capacity, as the new pavement drainage system controlling runoff from both carriageways from as far south as transverse drainage structure PXD5 would increase peak flows in the receiving drainage line.

In addition to the above, appropriate scour protection measures would be provided at the inlet and outlet of each transverse drainage structure, as well as at the downstream end of the unlined trapezoidal channel where it joins the unnamed tributary of Surveyors Creek. The scour protection measures would typically comprise dumped rock riprap and/or reno mattress. **Table 6.1** in **Chapter 6** gives the key dimensions of the proposed transverse drainage, as well as the approximate length of the proposed scour protection measures.

### **ES1.5 Post-project flood risk assessment**

**Figures 7.1, 7.2, 7.3 and 7.4** respectively show flooding behaviour in the vicinity of the project under post-project conditions for design events of 2, 10 and 100 year ARI, as well as the PMF. **Figure 7.5** shows design water surface profiles along the un-named tributary extending from the outlet of the stormwater drainage system that crosses the entrance into the DEOH to a location downstream of Glenmore Parkway. Note that the results of the flood modelling incorporate the mitigating effects of the transverse drainage and flood mitigation strategy described in **Chapter 6** of this technical work paper.

The assessment found that the implementation of the proposed transverse drainage and flood mitigation strategy would generally result in a reduction in peak flood levels in the vicinity of the project for storms up to 100 year ARI. While the project would result in minor increases in peak 100 year ARI flood levels upstream of Glenmore Parkway, the affected areas are confined to land owned by the Commonwealth DoD and Transgrid (refer **Figure 7.8** and **Figure C1.7** (2 sheets) in **Appendix C**). Minor increases in peak 100 year ARI flood levels would also occur on the northern (downstream) side of Glenmore Parkway within the Penrith Golf and Recreation Club.

The assessment also found that the extent of high hazard flooding would not be increased as a result of the project (refer **Figure 7.10**).

The impact of a partial blockage of major hydraulic structures on flooding behaviour on the project would be limited to land located on the eastern side of The Northern Road, as well as land located on the southern side of Glenmore Parkway (refer **Figure 7.11**). Flooding conditions would not be exacerbated in the vicinity of any existing dwellings. A minimum 100 year ARI level of flood immunity would also be maintained to both carriageways of The Northern Road.

An increase in the intensity of rainfall as a result of future climate change has the potential to impact the project. For example, a 10 per cent increase in the intensity of 100 year ARI rainfall would cause floodwater to surcharge the proposed flood retarding basin where it would discharge onto the southbound carriageway of the project (refer **Figure 7.12**). While major overtopping of the project would not occur should 100 year ARI rainfall intensities increase by 30 per cent, the width of flow along the southbound carriageway would increase (refer **Figure 7.13**). A more detailed assessment would need to be undertaken during detailed design to determine the climate change related flood risks to the project and to scope requirements for any management measures. The assessment should be undertaken in accordance with the NSW Government's *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (Department of Environment and Climate Change (DECC), 2007).

While failure of the earth embankment that would form part of the proposed flood retarding basin would result in an increase in peak 100 year ARI flood levels of over 500 millimetres on the eastern side of The Northern Road, there is no existing development located in the impact zone (refer **Figure 7.14**). While increases of less than 100 millimetres would occur in the residential properties that are located on the western side of the road between Bradley Street and Glenmore Parkway, there are no existing dwellings located within the impact zone that would experience depths of above-floor inundation of greater than 300 millimetres. Based on this finding, the "Flood" Consequence Category of the proposed flood retarding basin would be "Very Low"<sup>1</sup>, indicating that it would not be deemed to be a "Prescribed Dam" under the Dam Safety Act, 1978. This finding would need to be confirmed during detailed design following confirmation of the final basin outlet and embankment arrangement.

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<sup>1</sup> Derived using the methodology set out in DSC's publication DSC3A entitled "*Consequence Categories for Dams*"



## 1 INTRODUCTION

### 1.1 Overview of The Northern Road Upgrade

The Australian and NSW governments are planning to upgrade The Northern Road as part of the Western Sydney Infrastructure Plan (**WSIP**), a 10 year, \$3.6 billion road investment program (**The Northern Road Upgrade**). The Northern Road Upgrade will deliver new and upgraded roads to support integrated transport in the region and capitalise on the economic benefits from developing a Western Sydney airport at Badgerys Creek. It will also improve safety, increase road capacity and reduce congestion and travel times in the future. The Northern Road Upgrade extends from The Old Northern Road, Narellan to Jamison Road, Penrith and has been divided into the following six sections:

- The Old Northern Road, Narellan to Peter Brock Drive, Oran Park, which covers about 3.3 km.
- Peter Brock Drive, Oran Park to Mersey Road, Bringelly, which covers about 10 km.
- Mersey Road, Bringelly to Eaton Road, Luddenham, which covers about 5.5 km.
- Eaton Road to Littlefields Road, Luddenham, which covers about 4.5 km.
- Littlefields Road, Luddenham to Glenmore Parkway, Glenmore Park, which covers about 6 km.
- Glenmore Parkway, Glenmore Park to Jamison Road, Penrith, which covers about 4 km.

NSW Roads and Maritime Services (**Roads and Maritime**) is seeking approval to upgrade about 16 km of The Northern Road between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park (**project**).

This technical working paper presents the findings of a flood risk assessment that was undertaken for a 3.8 km long section of the project where it runs from a location 600 m north of Chain-O-Ponds Road, Mulgoa to Glenmore Parkway, Glenmore Park. A companion technical working paper has also been prepared which deals with the 12.2 km long section of the project where it runs from Mersey Road, Bringelly and a location 600 m north of Chain-O-Ponds Road, Mulgoa.

### 1.2 Overview of the project

The project comprises the following key features:

- A six-lane divided road between Mersey Road, Bringelly and Bradley Street, Glenmore Park (two general traffic lanes and a kerbside bus lane in each). The wide central median would allow for an additional travel lane in each direction in the future, if required.
- An eight-lane divided road between Bradley Street, Glenmore Park and about 100m south of Glenmore Parkway, Glenmore Park (three general traffic lanes and a kerbside bus lane in each direction separated by a median).
- About eight kilometres of new road between Mersey Road, Bringelly and just south of the existing Elizabeth Drive, Luddenham, to realign the section of The Northern Road that currently bisects the Western Sydney Airport site and to bypasses Luddenham.

- About eight kilometres of upgraded and widened road between the existing Elizabeth Drive, Luddenham and about 100m south of Glenmore Parkway, Glenmore Park.
- Closure of the existing The Northern Road through the Western Sydney Airport site.
- Tie-in works with the following projects:
  - The Northern Road Upgrade, between Peter Brock Drive, Oran Park and Mersey Road, Bringelly (to the south).
  - The Northern Road Upgrade, between Glenmore Parkway, Glenmore Park and Jamison Road, South Penrith (to the north).
- New intersections including:
  - Traffic light intersection connecting the existing The Northern Road at the southern boundary of the Western Sydney Airport, incorporating a dedicated u-turn facility on the western side.
  - Traffic light intersection for service vehicle access to the Western Sydney Airport, incorporating 160m of new road connection to the airport boundary.
  - Traffic light intersection connecting the realigned The Northern Road with the existing The Northern Road (west of the new alignment) south of Luddenham.
  - An un-signalised (give way controlled) intersection connecting the realigned The Northern Road with Eaton Road (east of the new alignment, left in, left out only).
  - A four-way traffic light intersection formed from the realigned Elizabeth Drive, the realigned The Northern Road and the existing The Northern Road, north of Luddenham.
  - A traffic light intersection at the Defence Establishment Orchard Hills entrance, incorporating a u-turn facility.
- New traffic light signals at four existing intersections:
  - Littlefields Road, Luddenham
  - Kings Hill Road, Mulgoa
  - Chain-O-Ponds Road, Mulgoa
  - Bradley Street, Glenmore Park incorporating a u-turn facility.
- Modified intersection arrangements at:
  - Dwyer Road, Bringelly (left in, left out only)
  - Existing Elizabeth Drive, Luddenham (left out only)
  - Gates Road, Luddenham (left in only)
  - Longview Road, Luddenham (left in, left out only)
  - Grover Crescent south, Mulgoa (left in only)
  - Grover Crescent north, Mulgoa (left out only).
- Dedicated u-turn facilities at:
  - The existing The Northern Road at Luddenham, southwest of Elizabeth Drive.

- The existing Elizabeth Drive, Luddenham around 800m east of The Northern Road.
- Chain-O-Ponds Road, Mulgoa.
- Twin bridges over Adams Road, Luddenham.
- Local road changes and upgrades, including:
  - Closure of Vicar Park Lane east of the realigned The Northern Road, Luddenham.
  - Eaton Road cul-de-sac west of the realigned The Northern Road, Luddenham.
  - Eaton Road cul-de-sac east of the realigned The Northern Road, Luddenham.
  - Elizabeth Drive cul-de-sac about 300m east of The Northern Road with a connection to the realigned Elizabeth Drive, Luddenham.
  - Extension of Littlefields Road east of The Northern Road, Mulgoa.
  - A new roundabout on the Littlefields Road extension, Mulgoa.
  - A new service road between the Littlefields Road roundabout and Gates Road, including an un-signalised intersection (give way controlled) at Gates Road, Luddenham.
  - Extension of Vineyard Road, Mulgoa between Longview Road and Kings Hill Road.
  - A new roundabout on the Vineyard Road extension at Kings Hill Road, Mulgoa.
- A new shared path on the western side of The Northern Road and pedestrian paths on the eastern side of The Northern Road where required.
- Drainage infrastructure upgrades.
- Operational ancillary facilities including:
  - Heavy vehicle inspection bays for both northbound and southbound traffic, adjacent to Grover Crescent, Mulgoa and Longview Road, Mulgoa respectively.
  - An incident response facility located on the south-western corner of the proposed four-way traffic light intersection at Elizabeth Drive, Luddenham.
- New traffic management facilities including Variable Message Signs (VMS).
- Roadside furniture and street lighting.
- Utility services relocations.
- Changes to property access along The Northern Road (generally left in, left out only).
- Establishment and use of temporary ancillary facilities and access tracks during construction.
- Property adjustments as required.
- Survey and clearance of undetonated explosive ordinance (UXO) within the Defence Establishment Orchard Hills as required.

### 1.3 Project location

**Figure 1.1** (2 sheets) shows the extent of the project where it runs between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park. The section of the project that runs from Mersey Road, Bringelly to Elizabeth Drive, Luddenham is located within the Liverpool local government area (**LGA**), while the section that runs from Elizabeth Drive, Luddenham to Glenmore Parkway, Glenmore Park is located within the Penrith LGA. Note that this report deals with the section of the project that is located entirely within the Penrith LGA.

### 1.4 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements (**SEARS**) for the project were issued on 9 March 2016, by the Department of Planning and Environment (**DPE**). The requirements relevant to flooding are as follows:

*"identification of potential impacts and benefits of the proposal on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources, 2005), with an assessment of the potential changes to flooding behaviour (levels, velocities and direction) and impacts on bed and bank stability, through flood modelling, and proposed management and mitigation measures;"*

This technical working paper forms part of the Environmental Impact Statement (**EIS**) that is currently being prepared for the project. The key objectives of the flood risk assessment were to:

- Identify the flood risk to the project in its as-built form over the full range of potential flood events.
- Identify the potential impacts of the project on flooding behaviour in areas outside the project corridor.
- Identify measures aimed at reducing the flood risk to the project.
- Identify measures aimed at mitigating the impacts of the project on flooding behaviour in areas outside the project corridor.

### 1.5 Study area

The section of the project extending from a location about 600 m north of Chain-O-Ponds Road is located in the upper reaches of the Surveyors Creek catchment, as shown on **Figure 1.1**. The widening of the road to accommodate the additional trafficable lanes would require the realignment of several sections of an unnamed tributary of Surveyors Creek where it runs through land owned by the Commonwealth Department of Defence (**DoD**). The project also has the potential to alter flooding patterns in the vicinity of existing residential development which is located on both sides of the project corridor south of Glenmore Parkway.

### 1.6 Report structure

**Chapter 2** sets out the flood related statutory and policy context for The Northern Road Upgrade, as well as several industry guidelines that are relevant to the flooding investigation. This chapter also sets out how the relevant government policies and industry guidelines have been taken into account as part of the assessment.



**Chapter 3** sets out the methodology that has been adopted in the definition of flooding behaviour in the vicinity of the project and also in identifying the impact it would have on flooding behaviour. Also presented in this chapter of the technical working paper is the methodology which has been adopted for assessing the impact a partial blockage of major hydraulic structures and also future climate change (increases in rainfall intensity only) would have on flooding behaviour under post-construction conditions. The methodology adopted for assessing measures aimed at mitigating the impact of the project on flooding and also the impact flooding has on the project is also presented in this chapter of the technical working paper.

**Chapter 4** contains a brief description of the Surveyors Creek catchment through which the project runs. This chapter of the technical working paper also provides a description of flooding behaviour in the vicinity of the project under present day (i.e. pre-project) conditions.

**Chapter 5** provides a description of the potential flood and scour related impacts of the project should appropriate mitigation measures not be incorporated into its design.

**Chapter 6** provides details of the proposed transverse drainage and flood mitigation strategy that is aimed at mitigating the potential flood and scour related impacts of the project described in **Chapter 5**.

**Chapter 7** presents the findings of an assessment which was undertaken into the residual flooding related impacts of the project following implementation of the proposed transverse drainage and flood mitigation strategy. Also presented in this chapter of the report are the key findings of an analysis which was undertaken to test the sensitivity of flooding behaviour to:

- a partial blockage of major hydraulic structures;
- potential changes in rainfall intensity associated with future climate change; and
- a potential failure of the earth embankment associated with the proposed flood retarding basin.

**Chapter 7** contains a list of references cited in this technical working paper.

**Appendix A** of this technical working paper contains background to the development and testing of the flood models that were used to define flooding behaviour in the vicinity of the project.

**Appendix B** contains a set of large scale figures showing flooding behaviour in the vicinity of the project under pre-project conditions, while **Appendix C** contain a similarly sized set of figures showing flooding behaviour in the vicinity of the project under post-project conditions, as well as the impact the project would have on flooding behaviour.

**Appendix D** contains a table which provides a comparison of peak flows at key locations under pre- and post-project conditions.

**Appendix E** contains a sketch showing typical details of a box culvert arrangement which has been designed to prevent access to the restricted defence area at the location where the future boundary fence crosses an existing watercourse.

The scales on figures referred to in this technical working paper are applicable when printed at A3 size. The figures referred to in the main body of this technical working paper are located after **Chapter 8** of this technical working paper.

## **2 STATUTORY AND POLICY CONTEXT**

### **2.1 Relevant Government policies and industry guidelines**

Government policies and guidelines that have been considered as part of the current assessment (arranged in date order) include:

- *Flood Prone Land Policy* (NSW Government).
- Section 117(2) Local Planning Direction 4.3 Flood Prone Land (NSW Government).
- Planning circular PS 07-003 *New guideline and changes to section 117 direction and (Environmental Planning and Assessment Regulation on flood prone land* (NSW Government).
- *Guideline on Development Controls on Low Flood Risk Areas* (NSW Government).
- Dam Safety Act, 1978 (NSW Government)
- *Environment Protection and Biodiversity Act 1999* (Commonwealth Government)
- *Australian Rainfall and Runoff* (AR&R) (Institution of Engineers Australia (IEAust), 1998).
- *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (Bureau of Meteorology (BoM), 2003).
- *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005).
- *Floodplain Risk Management Guideline – Practical Considerations of Climate Change* (Department of Environment and Climate Change (DECC), 2007).
- *Penrith Local Environmental Plan 2010*.
- *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (Engineers Australia (EA), 2013),
- *Penrith Development Control Plan 2014* (Penrith DCP 2014).
- *Guidelines for the Content of a Draft Environmental Impact Statement – The Northern Road Upgrade: Mersey Road, Bringelly to Glenmore Parkway, Glenmore Park* (Commonwealth Government)

### **2.2 Commonwealth Government Guidelines**

Following the determination that the project has the potential to have a significant impact on matters of national environmental significance that are protected under Part 3 of the *Environment Protection and Biodiversity Act 1999* (those being *Listed threatened species and communities* (sections 18 and 18A); and *Commonwealth land* (sections 26 and 27A)), the Minister for the Environment and Heritage issued a set of guidelines for the preparation of the EIS (refer *Guidelines for the Content of a Draft Environmental Impact Statement – The Northern Road Upgrade: Mersey Road, Bringelly to Glenmore Parkway, Glenmore Park*).

### **2.3 Floodplain Development Manual**

The Floodplain Development Manual (**FDM**) 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 undertaken 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 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.

## **2.4 State Government planning directions and guidelines**

In January 2007 the NSW Department of Planning (DOP) issued Planning circular PS 07-003 "*New guideline and changes to section 117 direction and (Environmental Planning and Assessment 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 and changes to the Environmental Planning and Assessment Regulation 2000 and section 117 Direction on flood prone land. More specifically, the circular provided advice on a package of changes concerning flood-related development controls on residential development on land above the 100 year ARI flood and up to the Probable Maximum Flood (**PMF**). 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 100 year ARI 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 consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year ARI flood.

In July 2007 the NSW Government's Minister for Planning issued a list of directions to local councils under section 117(2) of the Environmental Planning and Assessment Act 1979. 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 flood planning level 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 flood planning level 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 ARI's up to 100 years in the case of residential type development (and by default commercial and industrial type development) and for storms with ARI's greater than 100 years in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities). The key findings of the assessment in this regard are set out in **Section 6.2**.

## **2.5 State Government Floodplain Risk Management Guidelines**

Scientific evidence shows that climate change would lead to sea level rise and potentially increase 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 resulting depths of rainfall to increase. Future impacts on sea levels are likely to result in a continuation of the rise 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 undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent. Under present day climatic conditions, increasing the 100 year ARI design rainfall intensities by 10 per cent would produce about a 200 year ARI flood; and increasing those rainfalls by 30 per cent would produce about a 500 year ARI 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.

The *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) also contains guidance on strategies which are aimed at managing the impact of future climate change on both existing and proposed development. The guideline includes several examples on how to deal with the ramifications of future climate change which are dependent on location and the potential to effectively and practically manage its impact.

## **2.6 State Government Dam Safety Requirements**

The NSW Dam Safety Committee (**DSC**) under its statutory obligations of the Dam Safety Act, 1978 ensures that all dams are designed and operated to a standard to minimise the risks to the community. The DSC requires all owners of prescribed dams (i.e. where lives may be lost in the event of dam failure) have full responsibility to determine and put in place appropriate actions and programs to ensure ongoing safety of their dams.

The DSC assigns “Consequence Categories” to a dam according to the seriousness and magnitude of the adverse consequences affecting a community which could be expected from that failure. The procedure for assessing Consequence Categories is set out in the DSC’s publication DSC3A, “*Consequence Categories for Dams*” and ANCOLD, “*Guidelines on the Consequence Categories for Dams*”. Two types of dam failure are recognised for the purposes of determining a dam’s Consequence Category, as follows:

- Failures that occur without attendant natural flooding, giving rise to the “Sunny Day” Consequence Category.
- Failures that occur in association with a natural flood, giving rise to the “Flood” Consequence Category.

There are seven possible Consequence Categories for a particular dam ranging between Very Low, through Significant and High, to Extreme. Consequences are based on the “Population at Risk” and probable “Loss of Life”. The DSC uses the Consequence Category to determine whether the dam is “prescribed”. Owners of High Consequence and Extreme Consequence dams are to have in place automatic telemetered monitoring of the storage levels and preferably rainfall and seepage. Measurements of seepage are required to monitor potential piping incidents.

The DSC requires dam-break studies for Significant, High and Extreme Consequence Category dams for the assessment of consequences (i.e. sunny day and flood dam-breaks for events up to the PMF).

The flood mitigation strategy that has been developed for the project incorporates a relatively large flood retarding basin, which if its embankment was to fail, could cause damaging flooding in existing development. While the basin will not store water permanently, there is the possibility that the embankment could fail during a natural flood, giving rise to the need to assess its “Flood” Consequence Category.

**Section 7.6 in Chapter 7** of this technical working paper sets out the findings of a preliminary investigation that was undertaken to assess the impact a potential failure of the basin embankment would have on flooding behaviour, as well as an assessment of its likely “Flood” Consequence Category.

## **2.7 Local Government Flood Related Planning Controls**

As mentioned, this report deals with the section of the project that is located entirely within the Penrith LGA. The *Penrith Local Environment Plan 2010* (Penrith City Council (**PCC**), 2010)) aims to make local environmental planning provisions for land within the Penrith LGA by providing a mechanism and framework for the management, orderly and economic development, and conservation of land in Penrith.

Clause 7.2 of PCC, 2010 titled “Flood Planning”, which applies to land at or below the flood planning level or land located within the “Flood planning area” identified on the Flood planning land map, sets out the following requirements in relation to flooding:

- “(3) Development consent is required for any development on land to which this clause applies.*
- (4) Development consent must not be granted for development on land that is at or below the flood planning level unless the consent authority is satisfied that the development:*
  - (a) is compatible with the flood hazard of the land, and*
  - (b) if located in a floodway, is compatible with the flow conveyance function of the floodway and the flood hazard within the floodway, and*
  - (c) is not likely to adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
  - (d) is not likely to significantly alter flow distributions and velocities to the detriment of other properties or the environment, and*
  - (e) is not likely to adversely affect the safe and effective evacuation of the land and the surrounding area, and*
  - (f) is not likely to significantly detrimentally affect the environment or cause avoidable erosion, destruction of riparian vegetation or affect the restoration and establishment of riparian vegetation, or a reduction in the stability of river banks or waterways, and*
  - (g) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding, and*
  - (h) incorporates appropriate measures to manage risk to life from flood, and*
  - (i) is consistent with any relevant floodplain risk management plan.*
- (5) Development consent must not be granted for development on land identified as “Flood planning land” on the Clause Application Map, unless the consent authority is satisfied that the development will not adversely affect the safe and effective evacuation of the land and the surrounding area.*

- (6) *A word or expression used in this clause has the same meaning as it has in the NSW Government's Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.*
- (7) *In this clause:  
flood planning level means the level of a 1:100 ARI (average recurrence interval)  
flood event plus 0.5 metres freeboard."*

The above approach 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 100 year ARI flood as the basis for deriving the FPL for residential development.

It is noted that the Flood planning land map for the Penrith LGA does not show land in the vicinity of the project as lying at or below the FPL. This is probably due to PCC not having completed detailed flood studies in this area.

**Chapter 6** provides details of the transverse drainage and flood mitigation strategy that has been developed for the project in recognition of the above requirements and guidelines, while **Chapter 7** describes the impact the residual project would have on flooding behaviour following its implementation.

### **3 ASSESSMENT METHODOLOGY**

#### **3.1 Key tasks**

The key tasks comprising the flooding investigation are broadly described below:

- Develop hydrologic and hydraulic models which are to be used to define flood behaviour in the vicinity of the project corridor.
- Run the flood models and prepare exhibits showing flooding behaviour under present day (pre-project) conditions for the 2 year, 10 year and 100 year ARI events, as well as the Probable Maximum Flood (PMF).
- Assess the impacts the project could potentially have on flooding behaviour should appropriate mitigation measures not be incorporated into its design.
- Assess the impact flooding could potentially have on the project should appropriate mitigation measures not be incorporated into its design.
- Develop a preferred set of measures which are aimed at mitigating the impacts of the project on flooding, as well as mitigating the impacts of flooding on the project.
- Assess the residual impact the project would have on flooding behaviour assuming the preferred set of flood mitigation measures is incorporated into its design.
- Assess the impact a partial blockage of major hydraulic structures would have on flooding behaviour under post-construction conditions.
- Assess the impact future climate change would have on flooding behaviour under post-construction conditions.

The following sections of this technical working paper set out the methodology that was adopted in the assessment of flooding behaviour under present day and post-project conditions. Further discussion on the measures that would be required to mitigate the impact of the project on flooding behaviour is contained in **Chapter 6** of this technical working paper.

#### **3.2 Definition of present day flooding behaviour**

In order to define the nature of flooding in the vicinity of the project it was necessary to develop a set of computer based flood models. Both the RAFTS and ILSAX sub-models incorporated in the DRAINS rainfall-runoff modelling software package were used to generate discharge hydrographs for a range of design storm events. The discharge hydrographs were then used as input to a hydraulic model that was developed using the TUFLOW two-dimensional (in plan) hydraulic modelling software to define flooding patterns in the vicinity of the project.

Flooding behaviour in the vicinity of the project corridor was defined for events with ARI's of between 2 and 500 years<sup>2</sup>, as well as the PMF. A brief description of flooding behaviour in the vicinity of the project under present day (pre-project) conditions is presented in **Chapter 4** of this technical working paper.

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<sup>2</sup> Design storms with ARI's of 200 and 500 years formed the basis of the assessment into the potential impacts of future climate change on flooding behaviour given they are analogous to a 10 and 30 per cent increase in the intensity of 100 year ARI rainfall under current climatic conditions, respectively



### **3.3 Sensitivity analyses**

The sensitivity of the hydraulic model was tested to variations in hydraulic roughness to give some guidance on the freeboard which might be adopted in the design of the project. Runs of the hydraulic model were undertaken assuming a 20 per cent increase in hydraulic roughness (compared to the best estimate values given in **Table A3.1** in **Appendix A** of this technical working paper). The findings of the sensitivity analysis in relation to the resulting changes in flooding behaviour are presented in **Section A3.5** in **Appendix A** of this technical working paper.

### **3.4 Comparison with findings of previous studies**

No detailed investigations are available that define flooding behaviour in the upper reaches of Surveyors Creek catchment in the vicinity of the project corridor.

### **3.5 Provisional flood hazard**

Flood hazard categories may be assigned to flood affected areas in accordance with the procedures outlined in the FDM. Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. Flood depths as high as one metre, in the absence of any significant flow velocity, could be considered to represent Low Hazard conditions. Similarly, areas of flow velocities up to two metres per second, but with small flood depths of less than 0.2 metres could also represent Low Hazard conditions.

Provisional Flood Hazard diagrams for the 100 year ARI event based on Diagram L2 in the FDM have been prepared as part of the current investigation (refer **Section 4.4** for further details).

The Flood Hazard assessment presented herein is based on considerations of depth and velocity of flow and is *provisional* only. As noted in the FDM, other considerations such as the rate of rise of floodwaters and access to high ground for evacuation from the floodplain should also be taken into consideration before a final determination of Flood Hazard can be made. These factors are generally taken into account during the preparation of a Floodplain Risk Management Study and Plan for an area.

### **3.6 Minimum hydrologic standards**

The transverse drainage for the project is to provide a minimum 100 year ARI level of flood immunity to the new southbound and northbound carriageways. Scour protection measures are to be incorporated at the inlets and outlets of the upgraded transverse drainage to reduce the risk of scour for storms with ARI's up to 50 years, and to prevent damage of the individual structures for storms with ARI's up to 100 years.

### **3.7 Potential impacts of the project on flooding behaviour**

A qualitative assessment was undertaken into the impacts the project could potentially have on flooding behaviour and the scour potential within the receiving drainage lines should appropriate mitigation measures not be incorporated into its design. The findings of the assessment are set out in **Sections 5.2** and **5.3** of this technical working paper.

### **3.8 Potential impacts of flooding on the project**

A qualitative assessment was undertaken into the impacts flooding could potentially have on the project should appropriate mitigation measures not be incorporated into its design. The findings of the assessment are set out in **Section 5.4** of this technical working paper.

### **3.9 Assessment of potential flood mitigation measures**

A range of measures were assessed which are aimed at mitigating the potential impacts of the project on flooding and the scour potential in the receiving drainage lines, as well as mitigating the potential impacts of flooding on the project.

The mitigating effects of these measures were assessed by altering the structure of the hydrologic and hydraulic models to incorporate details of the project. Background to the changes that were made to the structure of the models is contained in **Section A3.6** in **Appendix A** of this technical working paper.

### **3.10 Residual impacts of the project on flooding behaviour**

The results of modelling the 2 year, 10 year and 100 year ARI events, together with the PMF event under post-project conditions were used to prepare a series of afflux diagrams showing the residual impact of the project on flooding behaviour following implementation of the preferred set of flood mitigation measures.<sup>3</sup> A discussion on the residual impacts of the project on flooding behaviour is contained in **Section 7.2** of this technical working paper.

### **3.11 Residual impacts of flooding on the project**

The results of the modelling described in **Section 7.3** of this technical working paper were used to assess the residual impacts of flooding on the project following implementation of the preferred set of flood mitigation measures. This included a review of the freeboard which would be available to the main carriageways during a 100 year ARI event.

### **3.12 Impact of a partial blockage of major hydraulic structures on flood behaviour**

Engineers Australia's guideline *AR&R Revision projects – project 11 – Blockage of Hydraulic Structures* (EA, 2013) includes guidance on modes of blockage which are likely to be experienced for different hydraulic structures.

In regards to pipe and culvert structures, the guideline recommends the adoption of a 20 per cent blockage factor where the height of a hydraulic structure is less than three metres or its width is less than five metres. The structure of the hydraulic model was adjusted to include a 20 per cent blockage factor which was applied to all major hydraulic structures.

The findings of the blockage related impact assessment are contained in **Section 7.4** of this technical working paper.

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<sup>3</sup> In the context of technical working paper, afflux is the difference in peak flood levels caused by changes to the floodplain. For example, due to a change in the waterway area of the un-named watercourse resulting from the project.

### **3.13 Impact of future climate change on flooding behaviour**

**Section 2.5** of this technical working paper provides background to the derivation of the adopted percentage increase in 100 year ARI design rainfall intensities which were used to assess the potential impact of future climate change on flooding behaviour in the vicinity of the project. Further details on the findings of the climate change impact assessment are contained in **Section 7.5** of this technical working paper.

### **3.14 Impact of basin embankment failure on flooding behaviour**

**Section 2.6** of this technical working paper provides background to the DSC's requirements for assessing the consequences of a potential failure of the earth embankment which will be constructed across the un-named watercourse, as well as the need to categorise the proposed flood retarding basin based on its "Flood" consequence. **Section A4** in **Appendix A** provides background to the methodology that was adopted for undertaking a preliminary assessment of the impact the failure of the earth embankment would have on flooding behaviour. Also set out in this section of the appendix are the steps that were followed to determine its "Flood" Consequence Category. Further discussion on the findings of the assessment are contained in **Section 7.6** of this technical working paper.

## **4 EXISTING ENVIRONMENT**

### **4.1 General**

This chapter of the technical working paper provides a brief description of the catchments that contribute runoff to the existing transverse drainage which are located along the section of The Northern Road that extends from a location 600 m north of Chain-O-Ponds Road to Glenmore Parkway. For discussion purposes, this section of The Northern Road is simply referred to as "The Northern Road".

The location of key features referred to in the following discussion are referenced by their position relative to the master control string for the road design. The location of each key feature relative to the master control string is referred to herein as its "Design Road Chainage" (**DRC**).

### **4.2 Catchment description**

As mentioned, The Northern Road is located in the upper reaches of the Surveyors Creek catchment (refer **Figure 1.1**). Surveyors Creek is a tributary of Peach Tree Creek, the main arm of which joins the Nepean River downstream of Penrith Weir.

While the Surveyors Creek catchment is largely urbanised, the portion that contributes runoff to the existing transverse drainage along The Northern Road is generally rural in nature. **Figure 4.1** shows the extent of the catchments that contribute runoff to the existing transverse drainage along The Northern Road.

A large portion of the catchment that contributes runoff to the existing transverse drainage comprises the Commonwealth DEOH, which is located on the eastern side of the road corridor, while the remainder generally comprises large-lot rural and semi-rural residential type development, which is in private ownership.

Bradley Street has its intersection with The Northern Road at about **DRC 15000**, while the entrance to the DEOH is located at about **DRC 14180**. Several driveways servicing the semi-rural residential properties that are located on both sides of the road corridor also connect onto The Northern Road along its length.

Elevated transmission lines run in an east-west direction through land that is owned by Transgrid and cross the road corridor at about **DRC 15950**.

### **4.3 Description of existing drainage system**

**Table 4.1** over the page provides details of the existing transverse drainage that is located along The Northern Road. Details of the existing transverse drainage structure where Glenmore Parkway crosses an un-named tributary of Surveyors Creek (**un-named tributary**) to the west of its intersection with The Northern Road are also given.

A 900 mm diameter reinforced concrete pipe (**RCP**) crosses The Northern Road at about **DRC 14050** and controls runoff from a 2 hectare catchment that lies on the western side of the road corridor (refer transverse drainage structure EXD1 on **Figure 4.1**). The available ground and aerial based survey shows that a diversion channel has been constructed a short distance to the west of the pipe inlet which diverts flow into a farm dam which is located in the catchment which contributes runoff to transverse drainage structure EXD2.

**TABLE 4.1**  
**DETAILS OF EXISTING TRANSVERSE DRAINAGE**

Cross Drainage Structure Identifier <sup>(1)</sup>	Design Road Chainage	Dimensions / Type <sup>(2)</sup> (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)
EXD1	DRC 14050	1 off 900 RCP	71.55 <sup>(3)</sup>	69.8 <sup>(3)</sup>	2.0
EXD2	DRC 14600	2 off 1200 x 750 RCBC's	62.30	62.07 <sup>(3)</sup>	26.2
EXD3	DRC 14970	2 off 750 RCP's	59.12	58.90	8.4
EXD4	DRC 15700	3 off 2400 x 1500 RCBC's	49.92	49.58	188
EXD5	DRC 15780	1 off 675 RCP	50.06	49.86 <sup>(3)</sup>	1.6
EXD6	-	2 off 1050 RCP's	48.00	47.84	44.6
EXD7	-	7 off 2400 x 1200 RCBC's	45.79	45.59	283

(1) Refer **Figure 4.1** for locations of Transverse Drainage Identifiers.

(2) Assumed dimension/elevation.

(3) RCP = Reinforced Concrete Pipe      RCBC = Reinforced Concrete Box Culvert.

While no pit and pipe data are available for the stormwater drainage system within the DEOH, site inspection indicates that the 900 mm diameter RCP runs in a north-easterly direction downstream of transverse drainage structure EXD1, where it appears to be joined by a number of pipes opposite **DRC 14130**. The piped stormwater drainage system then runs beneath an existing building which is located at the entrance to the DEOH, before crossing an internal access road and discharging to the un-named tributary opposite **DRC 14320**.

The un-named tributary runs in a northerly direction immediately to the east of the road corridor. Three existing dams are located along its length where it runs along the eastern side of the road corridor, the largest of which is located opposite **DRC 14750**. DoD advised that an existing pond that is located on the eastern side of the watercourse opposite **DRC 14650** functions as a final polishing pond for effluent which is treated on-site.

A double-cell 1200 millimetre high by 750 millimetre wide reinforced concrete box culvert (**RCBC**), as well as twin 750 millimetre diameter RCP's cross The Northern Road at **DRC 14600** and **DRC 14970**, respectively (refer location of transverse drainage structures EXD2 and EXD3 on **Figure 4.1**). These structures control runoff from the semi-rural residential properties that lie to the west (upslope) of The Northern Road and contribute to flow in the un-named tributary where it runs along the eastern side of the road corridor on Commonwealth land. It is noted that an existing dam is located on the western (upslope) side of the road corridor, immediately south of Bradley Street. Further discussion on the requirements to mitigate the impact that flow discharging from this dam would have on the project is contained in **Section 5.2**.

A triple-cell 2400 millimetre high by 1500 millimetre wide RCBC arrangement crosses The Northern Road at **DRC 15700** on the un-named tributary, while a single 675 millimetre diameter RCP crosses the road at **DRC 15780** (refer location of transverse drainage structures EXD4 and EXD5 on **Figure 4.1**). Transverse drainage structure EXD4 controls a catchment area of about 188 hectares and has a waterway area of 10.8 square metres, while transverse drainage structure EXD5 controls a catchment area of about 1.6 hectares and has a waterway area of 0.36 square metres

Flow from transverse drainage structures EXD4 and EXD5 discharges through the frontage of two semi-rural residential properties that are located on the western side of the road corridor. Two low level bridges are located on the driveways of these two properties where they cross the un-named tributary.<sup>4</sup> The un-named tributary then crosses two parcels of land that are owned by Transgrid and within which the aforementioned transmission lines are located. Ground levels in the Transgrid owned land are relatively flat, with a large swampy area located adjacent to the road corridor.

North of the Transgrid owned land, the main arm of the un-named tributary runs through several semi-rural residential properties before crossing Glenmore Parkway west of The Northern Road. The transverse drainage structure at this location comprises seven off 2400 millimetre high by 1500 millimetre wide RCBC's and has a waterway area of 25.2 square metres (refer location of transverse drainage structure EXD7 on **Figure 4.1**).

Runoff from a 44.6 hectare catchment which lies to the east of The Northern Road contributes to flow in twin 1050 millimetre diameter pipes which cross The Northern Road about 160 m south of Glenmore Parkway (refer location of transverse drainage structure EXD6 on **Figure 4.1**). Two grassed channels convey runoff that is generated by the upslope catchment to an existing dam which is located on the eastern side of the road corridor within privately owned land, while flow from the dam is conveyed to the inlet of EXD6 by a third grassed channel.

A one metre deep unlined trapezoidal channel (**unlined trapezoidal channel**), which has a base width of about two metres and a top width of about four metres, runs in a westerly direction from the outlet of transverse drainage structure EXD6 to the un-named tributary. Road and Maritime advised that the channel is located in a six metre wide drainage easement where it runs from the road corridor to the un-named tributary. The location of the unlined trapezoidal channel is shown on **Figure 4.1**.

#### **4.4 Description of existing flood behaviour**

**Figures 4.2, 4.3, 4.4 and 4.5** respectively show flooding behaviour in the vicinity of the project under pre-project conditions for design events of 2 year, 10 year and 100 year ARI, as well as the PMF. **Figure 4.6** shows design water surface profiles along the main arm of the unnamed tributary extending from the outlet of the stormwater drainage system that crosses the entrance into the DEOH to a location downstream of Glenmore Parkway. **Figure 4.7** shows the proposed flood hazard categories in the vicinity of the project under pre-project conditions for a 100 year ARI flood event.

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<sup>4</sup> Note that details of these bridges were not available at the time of writing.

Figures of a larger scale showing the nature of flooding in the vicinity of the project are contained in **Appendix B**, while **Table D1** in **Appendix D** gives peak flows at key locations in the drainage system under pre-project conditions.

While minor flooding is shown to occur in the vicinity of the entrance to the DEOH for events as frequent as 2 year ARI, this finding is influenced by the lack of information which is available on the existing stormwater drainage system, the capacity of which may be greater than indicated by the hydraulic model. Depths of inundation are shown to be greatest on the southern side of the entrance road in the vicinity a large building that is located adjacent to the entrance gate.

Minor surcharge of The Northern Road occurs between about **DRC 15270** and **DRC 15330** during a 10 year ARI storm event due to insufficient capacity in a 375 millimetres diameter RCP which runs parallel to the road on its western side at **DRC 15290**. During a 100 year ARI storm event, surcharge of The Northern Road occurs over a slightly longer length due to insufficient capacity in a second 375 millimetres diameter RCP which also runs parallel with the road on its western side at **DRC 15350**. Depths of flow across the road are relatively shallow at less than 50 millimetres for storms up to 100 year ARI.

During storm events as frequent as 2 year ARI, flow in the un-named tributary bypasses the inlets of transverse drainage structures EXD4 and EXD5, where it discharges along the eastern side of the road toward the inlet of EXD6. Surcharge of The Northern Road occurs at the location of the sag in the main carriageway which is located at about **DRC 15980** during a 10 year ARI storm event. While the depth of flow over the road is relatively shallow at less than 50 millimetres, about an 80 metre length of the main carriageway would be inundated during a storm of this return period. While the depth of flow across The Northern Road will not exceed 50 millimetres during a 100 year ARI storm event, the length of carriageway affected by floodwater increases to about 200 metres. A short length of carriageway will also be affected by shallow overtopping at about **DRC 15830** during a 100 year ARI storm event.

An existing dwelling located on the western side of The Northern Road in Lot 132 DP1002668 is affected by both shallow overland flow that originates from the adjacent roadside table drain, as well as floodwater which surcharges the eastern bank of the un-named tributary during a 10 year ARI event. Ponding is shown to occur along the eastern side of the dwelling to a maximum depth of about 100 millimetres during a storm of this return period. During a 100 year ARI storm event, floodwater will surcharge the eastern bank of the un-named tributary, where it will inundate a large portion of Lot 132 DP1002668. Depths of above-ground inundation around the perimeter of the existing dwelling in the property will be between 200-300 millimetres during a storm of this return period.

Floodwater will also surcharge the unlined trapezoidal channel during a 100 year ARI storm event, where it will discharge along the eastern side of the existing dwelling in Lot 2 DP1033226. Depths of above-ground inundation immediately adjacent to the existing dwelling generally range between 100-200 millimetres during a storm of this return period. Floodwater which discharges along the eastern side of the existing dwelling in Lot 2 DP1033226 crosses into Lot 15 DP 26658 before rejoining flow in the un-named tributary immediately south (upstream) of the Glenmore Parkway crossing.

An existing dwelling located on the western overbank of the un-named tributary in Lot 10 DP1204969 is also affected by floodwater which surcharges the un-named tributary during a 100 year ARI storm event, with depths of above-ground inundation generally in the range 100-200 millimetres shown to occur along its southern side.

While flows generated by the catchment which contributes runoff directly to transverse drainage structure EXD6 are confined to the grassed channels which run through Lot 3 DP711076, depths of ponding of greater than 1 m are shown to occur in the property immediately upstream of the transverse drainage structure.

It is noted that the existing dwellings in the following allotments are not subject to flooding due to surcharge of the un-named tributary where it runs between transverse drainage structures EXD4 and EXD7 during storms with ARI's up to 100 years:

- |                     |                    |
|---------------------|--------------------|
| ➤ Lot 7 DP26658     | ➤ Lot 121 DP870188 |
| ➤ Lot 82 DP1055149  | ➤ Lot 122 DP870188 |
| ➤ Lot 81 DP1055149  | ➤ Lot 11 DP1204969 |
| ➤ Lot 111 DP1030865 | ➤ Lot 15 DP26658   |
| ➤ Lot 112 DP1030865 |                    |

During a PMF event, the depth of above-ground inundation would exceed 1 m at the entrance to the DEOH. Depths of above-ground inundation would also exceed 1 m adjacent to the existing dwellings located in the following allotments:

- |                     |                    |
|---------------------|--------------------|
| ➤ Lot 121 DP870188  | ➤ Lot 10 DP1204969 |
| ➤ Lot 132 DP1002668 | ➤ Lot 11 DP1204969 |
| ➤ Lot 2 DP1033226   | ➤ Lot 15 DP26658   |

While The Northern Road would be inundated along most of its length during a PMF event, depths of overtopping would be greatest between transverse drainage structures EXD4 and EXD6. For example, depths of overtopping at the crown in the road would be up to about 200 millimetres along this section of The Northern Road, while at other locations they would generally be less than 50 millimetres.

**Figure 4.7** shows that high hazard flooding conditions are generally confined to the in-bank area of the un-named tributary north (downstream) of about **DRC 15000**. The depth and velocity of flow along the eastern side of The Northern Road north of about **DRC 15980** and in the existing channel which runs along the northern boundary of Lot 132 DP1002668 downstream of transverse drainage structure EXD6 are also sufficient to result in high hazard flooding conditions. Areas of high hazard are also shown to be present in the existing dams, where the depth of ponding would likely exceed one metre during a 100 year ARI storm event.



## **5 ASSESSMENT OF POTENTIAL PROJECT RELATED IMPACTS**

### **5.1 Overview**

This chapter of the technical working paper describes the potential impacts of the project on flooding behaviour and the scour potential within the receiving drainage lines. Also included in this chapter is a description of the potential impacts of flooding on the project. Note that the following assessment assumes that no mitigation measures are incorporated into the design of the project.

### **5.2 Potential impacts of the project on flooding behaviour**

**Table 5.1** over the page summarises the potential impacts of the project on flooding behaviour in areas which lie outside the project corridor should appropriate mitigation measures not be incorporated into its design.

For ease of reference, a brief description of measures that would mitigate the project related impacts are also set out in **Table 5.1**. **Chapter 6** of this technical working paper contains a detailed description of the transverse drainage upgrade and flood mitigation measures which are referred to in **Table 5.1**.

### **5.3 Potential impacts of the project on scour potential**

The project has the potential to cause scour in the receiving drainage lines 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; and
  - changes in the distribution of flow along the project corridor;
- increases in the velocity of flow where it discharges from newly lined sections of channel; and
- 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.

Measures such as dumped rock rip rap protection would need to be incorporated in the design of the project in order to reduce the scour potential in the receiving drainage lines, further details on which are contained in **Chapter 6** of this technical working paper.

**TABLE 5.1**  
**SUMMARY OF POTENTIAL PROJECT RELATED IMPACTS**

Location	Potential Project Related Impact	Potential Mitigation Measure
Land located on the western side of The Northern Road south of Bradley Street	<ul style="list-style-type: none"> <li>➤ If the road is raised to improve its level of flood immunity, then this could increase depths of inundation along the western side of the project corridor in privately owned land due to backwater effects.</li> <li>➤ Widening of the road could impact drainage patterns in the vicinity of the two existing farm dams that are located on the western side of the existing road corridor.</li> <li>➤ Runoff surcharging the existing farm dam on the southern side of Bradley Street could discharge directly onto the road, reducing the hydrologic standard of the new pavement drainage system.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Increase the waterway area of transverse drainage structures EXD1, EXD2 and EXD3.</li> <li>➤ Either decommission the affected dams or implement measures which are aimed at replicating as far as is practicable existing drainage patterns in their immediate vicinity.</li> <li>➤ Construct an earth bund along the southern side of Bradley Street which would direct flow which surcharges the dam toward the inlet of transverse drainage structure EXD3.</li> </ul>
Land located on the eastern side of the project corridor comprising the DEOH site	<ul style="list-style-type: none"> <li>➤ The upgrade of transverse drainage structure EXD1 would increase the rate of flow which discharges into the DEOH site, potentially exacerbating flooding conditions in the vicinity of the existing buildings that are located near its entrance.</li> <li>➤ The discharge of runoff captured by the new pavement drainage system to the existing drainage system in the DEOH could potentially exacerbate flooding conditions in the vicinity of the existing buildings that are located near its entrance</li> <li>➤ The upgrade of transverse drainage structures EXD1, EXD2 and EXD3 could increase the scour potential in the receiving drainage lines.</li> <li>➤ Widening of The Northern Road along its eastern side will encroach on the waterway area of the unnamed tributary of Surveyors Creek.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Redirect flow in transverse drainage structure EXD1 to a locate north (downstream) of the existing buildings.</li> <li>➤ Route the new pavement drainage system north to the outlet of transverse drainage structure EXD2.</li> <li>➤ Provide scour protection in the form of dumped rock rip rap of reno mattress on the outlets of the upgraded transverse drainage structures.</li> <li>➤ Realign the watercourse where it will be impacted by the project.</li> </ul>

**TABLE 5.1 (Cont'd)**  
**SUMMARY OF POTENTIAL PROJECT RELATED IMPACTS**

Location	Potential Project Related Impact	Potential Mitigation Measure
Land located on the eastern side of the project corridor comprising the DEOH (Cont'd)	➤ If the road is raised to improve its level of flood immunity, then this would increase depths of inundation along the eastern side of the project corridor due to backwater effects.	➤ Increase the waterway area of transverse drainage structures EXD4 and EXD5.
Land located on the eastern side of the project corridor between the DEOH site and Wentworth Road	➤ If the road is raised to improve its level of flood immunity and transverse drainage structures EXD4, EXD5 and EXD6 are not upgraded, then flooding conditions in privately owned land would be exacerbated.	➤ Increase the waterway area of transverse drainage structures EXD4, EXD5 and EXD6.
Land located on the western side of the project corridor north of Bradley Street	➤ The upgrade of transverse drainage structures EXD4, EXD5 and EXD6 which is located on the main arm of the unnamed tributary of Surveyors Creek could result in an increase in the rate of flow crossing the road corridor at this location, thereby exacerbating flooding conditions in the vicinity of several existing dwellings.	➤ Develop a transverse drainage strategy which aims to replicate as far as practicable existing flooding patterns on the western side of the project corridor.
	➤ The widening of the existing two-lane road to six lanes would increase peak flows in the receiving drainage lines and potentially exacerbate flooding conditions in existing development.	➤ Concrete line or enlarge the waterway area of the receiving drainage lines. ➤ Provide detention storage to attenuate peak flows.
	➤ The upgrade of transverse drainage structures EXD4, EXD5 and EXD6 could increase the scour potential in the receiving drainage lines.	➤ Provide scour protection in the form of dumped rock rip rap of reno mattress on the outlets of the upgraded transverse drainage structures.
	➤ The concrete lining of the receiving drainage lines could increase the scour potential in the receiving drainage lines at its downstream limit.	➤ Provide scour protection in the form of dumped rock rip rap of reno mattress at the downstream limit of the concrete lined section of channel.
	➤ The widening of the existing two-lane road to six lanes would increase the volume of runoff discharging to the receiving drainage lines, potentially "wetting up" low lying land.	➤ Increase the hydraulic capacity of the low flow drainage system in the affected area ➤ Divert pavement drainage system away from affected area.

#### **5.4 Potential impacts of flooding on the project**

As discussed in **Chapter 4** of this technical working paper, the hydrologic standard of the existing two-lane road is less than the required minimum of 100 year ARI. If the new carriageways are not set above the elevation of the existing two-lane road, then floodwater would inundate the new carriageways in the vicinity of transverse drainage structure EXD6 during storms with ARI's less than 100 years.

A partial blockage of the transverse drainage by debris could result in floodwater surcharging onto the road during storms with ARI's less than 100 year ARI, while increases in rainfall intensity associated with future climate change could also result in the more frequent surcharge of the transverse drainage. There is also the potential for floodwater to erode the road embankment where it runs parallel with the unnamed tributary of the Surveyors Creek.

## **6 ASSESSMENT OF POTENTIAL TRANSVERSE DRAINAGE AND FLOOD MITIGATION MEASURES**

### **6.1 Overview**

This chapter sets out the details of measures that are aimed at mitigating the flooding and drainage related impacts of the project. Included in this chapter are the findings of detailed flood modelling which was undertaken to identify the residual flooding and drainage related impacts of the project following the incorporation of a preferred set of transverse drainage upgrade and flood mitigation measures into its design.

### **6.2 Proposed transverse drainage and flood mitigation strategy**

As set out in **Section 3.9**, the mitigating effects of a range of measures were assessed using the hydrologic and hydraulic models that were representative of post-project conditions. Based on the findings of the assessment, a preferred set of transverse drainage upgrade and flood mitigation measures were identified for incorporation into the design of the project.

**Figure 6.1** shows the location of the key elements which comprise the proposed transverse drainage and flood mitigation strategy for the project, while **Section ES1.4** of the **Executive Summary** provides a brief description of each. **Table 6.1** over page provides details of the individual transverse drainage structures that would form part of the strategy.

Measures would need to be incorporated at the outlet of the upgraded transverse drainage, as well as at the downstream end of the unlined trapezoidal channel in order to reduce the risk of scour in the receiving drainage lines. Scour protection measures would also need to be incorporated on the inlet of the upgraded transverse drainage in order to prevent damage to the structure during major flood events. It is envisaged that scour protection measures would take the form of dumped rock riprap or reno mattress.

To facilitate the widening of Bradley Street it would be necessary to demolish and removal the existing dam that is located on the western side of the project corridor immediately south of Bradley Street (refer **Figure 6.1** for location). The demolition of the dam would involve the removal of the existing earth embankment and the reinstatement of the natural flow path in this area. While the majority of the earth embankment is located within the project corridor, there may be a requirement to reshape the land outside the corridor in order to reinstate the natural flow path in this area.

A second dam that is located on the western side of the project corridor at about **DRC 14350** would also be removed in order to rationalise the drainage system for the project. It is noted that the demolition of this dam and the reinstatement of the natural flow path would not require works outside the project corridor.

**Chapter 7** of this report sets out the findings of a flood risk assessment that was undertaken assuming the proposed transverse drainage and flood mitigation strategy is incorporated into the design of the project.

**TABLE 6.1**  
**DETAILS OF UPGRADED TRANSVERSE DRAINAGE**

Transverse Drainage Structure Identifier <sup>(1)</sup>	Design Road Chainage	Dimensions / Type <sup>(2)</sup> (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)	Peak 100 year ARI Flood Level at Inlet (m AHD)	Maximum 100 year ARI Barrel Velocity (m/s)	Minimum Road Level Adjacent to Inlet (m AHD)	Scour Protection Requirements <sup>(4,5)</sup> (mm)
PXD1	DRC 14030	1 off 900 RCP	72.81	66.82	2.9	73.77	1.90	74.46	3000 [Inlet] 5000 [Outlet]
PXD2	DRC 14520	2 off 1200 RCP's	62.84	61.32	21.1	63.97	2.22	66.43	6100 [Inlet] 6100 [Outlet]
PXD3	DRC 14980	3 off 900 RCP's	59.48	57.11	7.6	60.21	1.83	61.11	3000 [Inlet] 5000 [Outlet]
PXD4	DRC 15710	1 off 3600 x 1500 RCBC	50.70	50.00	185	52.81	3.41	53.30	3000 [Inlet] 6000 [Outlet] <sup>(6)</sup>
PXD5	DRC 15870	1 off 3600 x 1500 RCBC	49.90	49.60	4.9	51.22	2.65	52.57	3000 [Inlet] 6000 [Outlet] <sup>(6)</sup>
PXD6	-	2 off 2100 x 900 RCBC <sup>(3)</sup>	48.25	47.84	37.7	49.71	4.12	51.10	3000 [Inlet] 3600 [Outlet] <sup>(7)</sup>
PXD7	-	7 off 2400 x 1200 RCBC	45.79	45.49	282	47.17	1.53	48.32	3000 [Inlet] 3600 [Outlet]

- (1) Refer **Figure 6.1** for locations of Transverse Drainage Identifiers.
- (2) RCP = Reinforced Concrete Pipe      RCBC = Reinforced Concrete Box Culvert.
- (3) Unlined trapezoidal channel downstream of transverse drainage structure PXD6 to be concrete lined.
- (4) The dimension given in the table is the indicative length of scour protection as measured from the face of the headwall.
- (5) Unless otherwise stated, scour protection requirement derived from Roads and Maritime's standard drawings.
- (6) Source: CC, 2015
- (7) Source: CC, 2014

## **7 POST-PROJECT FLOOD RISK ASSESSMENT**

### **7.1 Overview**

This chapter of the technical working paper deals with the key findings of the investigation in terms of the impact the project would have on flooding behaviour. Also set out in this chapter is an assessment of the impact flooding would have on key components of the project, such as the level of flood immunity of the main carriageways. The findings of an assessment into the impact a partial blockage of major hydraulic structures and future climate change would have on flooding behaviour under post-project conditions are also presented.

**Figures 7.1, 7.2, 7.3 and 7.4** respectively show flooding behaviour in the vicinity of the project in terms of the indicative extent and depth of inundation under post-project conditions for design events of 2, 10 and 100 year ARI, as well as the PMF. **Figure 7.5** shows design water surface profiles along the un-named tributary extending from the outlet of the stormwater drainage system that crosses the entrance into the DEOH to a location downstream of Glenmore Parkway. **Figures 7.6, 7.7, 7.8 and 7.9** respectively show the impact the project would have on flooding behaviour for design events of 2, 10 and 100 year ARI, as well as the PMF. Figures of a larger scale showing the nature of flooding in the vicinity of the project under post-project conditions, as well as the impact the project would have on flooding behaviour are contained in **Appendix C**, while **Table D1** in **Appendix D** provides a comparison of peak flows at key locations along the drainage system under pre- and post-project conditions.

The figures referred to in this chapter show the impact the project would have on flooding behaviour in terms of changes in peak flood levels (commonly referred to as “afflux”). A positive afflux represents an increase and conversely a negative afflux represents a decrease in peak flood levels when compared to pre-project conditions. Differences in peak flood levels of  $\pm 0.01$  metres (equal to 1 centimetre or 10 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 flooding behaviour in areas where an afflux of  $\pm 0.01$  metres is shown to be present. The figures also show the extent of additional land which would be inundated by floodwater, and conversely the extent of land which would be rendered flood free, as a result of the project.

### **7.2 Residual impact of the project on flood behaviour**

#### **7.2.1 Storms up to 100 year ARI**

Implementation of the transverse drainage and flood mitigation strategy set out in **Chapter 6** of this technical working paper would generally result in a reduction in peak flood levels on the eastern and western sides of the project south (upstream) of transverse drainage structure PXD4 for storms with ARI's up to 100 years with the following exceptions:

- Within the existing dam which is located on the western side of the northbound carriageway opposite about **DRC 14360**. While it is noted that the project boundary would be extended west to include the dam, consideration should be given to its removal during detail design.

- Along the western side of the northbound carriageway immediately upstream of the inlet to transverse drainage structure PXD2. It is noted that the project boundary would be extended west where it would encompass a new drainage channel which would convey flow which surcharges the aforementioned dam to the inlet of the transverse drainage structure.
- Within the footprint of the proposed flood retarding basin that would be located on the eastern side of the southbound carriageway between about **DRC 14720** and **DRC 14850**. Increases in peak flood levels associated with the construction of the flood retarding basin would extend outside the proposed project boundary between about **DRC14520** and **DRC 14600** during a 100 year ARI storm event. As the flooding in this area would be of a backwater nature, flow velocities would be relatively mild, hence damage to the boundary fence during a storm of this return period is considered to be low.
- Along the eastern side of the southbound carriageway between about **DRC 15400** and **DRC 15890**. Increases in peak flood levels associated with the relocation of the existing watercourse in this area would extend outside the project corridor. Depths of inundation in the area outside the project boundary would generally be in the range 0-500 millimetres during a 100 year ARI event and of a low hazard nature (refer **Figure 6.10** which shows the provisional flood hazard under post-project conditions). Based on the above, the likelihood of the boundary fence being damaged during a storm of this return period is considered to be low.

Implementation of the strategy would also result in a reduction in peak flood levels on the western side of the project corridor north (downstream) of transverse drainage structure PXD4, with the only exceptions being a minor increase in peak 100 year ARI flood levels at the outlet of transverse drainage structures PXD5 within land owned by Transgrid and transverse drainage structure PXD7 within the Penrith Golf and Recreation Club.

By comparison of the information shown on **Figures 4.7** and **7.10**, changes in flood hazard which are attributable to the project would be limited to the following areas:

- in the vicinity of the proposed flood retarding basin, where the construction of the embankment across the un-named watercourse would increase the depth of inundation resulting in high hazard flooding conditions;
- along the eastern side the road between about **DRC 15400** and **DRC15890**, where high hazard flooding conditions would be present in the realigned section of the un-named watercourse, as well in the flood bypass channel; and
- in Lot 3 DP711076, where the proposed infilling of the existing dam would remove high hazard flooding conditions from a portion of the property.

### **7.2.2 Probable Maximum Flood**

As shown on **Figure 7.9**, peak PMF levels would be reduced near the entrance to the DEOH by up to 200 millimetres, while the construction of the embankment across the un-named watercourse associated with the flood retarding basin would result in an increase in peak flood levels adjacent to the existing effluent polishing pond of greater than 500 millimetres. Water levels in the effluent polishing pond would not be affected by the project due to its elevated position.



While peak flood levels would be increased by more than 500 millimetres on the eastern side of the project between **DRC 15340** and Glenmore Parkway, flooding conditions would not be exacerbated adjacent to the existing dwellings in Lot 3 DP711076 and Lot 1 DP711076.

The project would result in an increase in the rate of flow discharging along the eastern side of the corridor north of about **DRC 15650**. While this would result in a reduction in peak flood levels on the western side of the project corridor of more than 200 millimetres between about **DRC 15650** and **DRC 16050**, the redistribution of flow would result in an increase in peak flood levels of up to 200 millimetres on the southern side of Glenmore Parkway.

### **7.3 Residual impact of flooding on the project**

#### **7.3.1 Storms up to 100 year ARI**

Implementation of the transverse drainage and flood mitigation strategy set out in **Chapter 6** of technical working paper would improve the hydrologic standard of The Northern Road to greater than 100 year ARI.

As flow velocities in the existing and realigned sections of the un-named watercourse are relatively mild, scour of the road embankment should not occur provided adequate grass cover is established and maintained on the road batters. That said, suitable scour protection measures would need to be incorporated in the design of the transverse drainage to prevent damage to road infrastructure.

#### **7.3.2 Probable Maximum Flood**

Surcharge of the road would occur during a PMF event, with the full width of the road formation inundated by floodwater between about **DRC 14640** and Glenmore Parkway. While depths of flow along the northbound and southbound carriageways would be relatively shallow along most of its length (generally in the range 50-300 millimetres), damage could be expected to occur to the road during an extreme storm event.

### **7.4 Impact of a partial blockage of major hydraulic structures on flooding behaviour**

**Figure 7.11** shows the impact a partial blockage of the major hydraulic structures in the vicinity of the project would have on flooding behaviour for the 100 year ARI. While increases in peak flood levels would occur at the inlets to the transverse drainage, they would not be sufficient to cause surcharge of the main carriageways.

The assessment showed that a partial blockage of the existing stormwater drainage system in the vicinity of the entrance to the DEOH could result in an increase of up to 100 millimetres in peak flood levels.

### **7.5 Impact of future climate change on flooding behaviour**

**Figures 7.12** and **7.13** show the impact a potential increase of 10 and 30 per cent in 100 year ARI design rainfall intensities, respectively would have on flooding behaviour in the vicinity of the project.

Increase in peak flood levels resulting from a 10 per cent increase in 100 year ARI design rainfall intensities would generally be in the range 0-50 millimetres, with impacts greater than 50 millimetres shown to occur at the locations set out in **Table 7.1** (refer over page). A 10 per cent increase in 100 year ARI design rainfall intensities would also result in flow surcharging onto the southbound carriageway from the proposed flood retarding basin. Flow surcharging onto the road at this location would discharge in a northerly direction where it would pond in the eastern kerbline of The Northern Road opposite Bradley Street.

Increase in peak flood levels resulting from a 30 per cent increase in 100 year ARI design rainfall intensities would generally be in the range 0-100 millimetres, with impacts greater than 100 millimetres shown to occur at the locations set out in **Table 7.1** over the page. A 30 per cent increase in 100 year ARI design rainfall intensities would also result in flow surcharging onto the southbound carriageway from the proposed flood retarding basin. Flow surcharging onto the road at this location would discharge in a northerly direction where it would pond above the inlet of transverse drainage structure PDX6.

## **7.6 Impact of basin embankment failure on flooding behaviour**

**Figure 7.14** shows the impact a potential failure of the proposed basin embankment during a 100 year ARI storm event would have on flooding behaviour. The investigation found that while peak flood levels would be increased by more than 500 millimetres on the eastern side of The Northern Road south of the transmission easement, increases in peak flood levels on the western side of the road, north (downstream) of the transmission easement would be increased by a maximum of 100 millimetres.

As there are no existing dwellings located within the impact zone that would experience depths of above-floor inundation of greater than 300 millimetres, the “Flood” Consequence Category of the proposed flood retarding basin would be “Very Low”.<sup>5</sup> Based on this finding, the proposed flood retarding basin is not deemed to be a “Prescribed Dam” under the Dam Safety Act, 1978. This finding would need to be confirmed during detailed design following confirmation of the final basin outlet and embankment arrangement.

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<sup>5</sup> Derived using the methodology set out in DSC’s publication DSC3A entitled “*Consequence Categories for Dams*”

**TABLE 7.1**  
**SUMMARY OF CLIMATE CHANGE RELATED IMPACTS**  
**100 YEAR ARI**

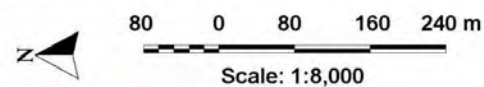
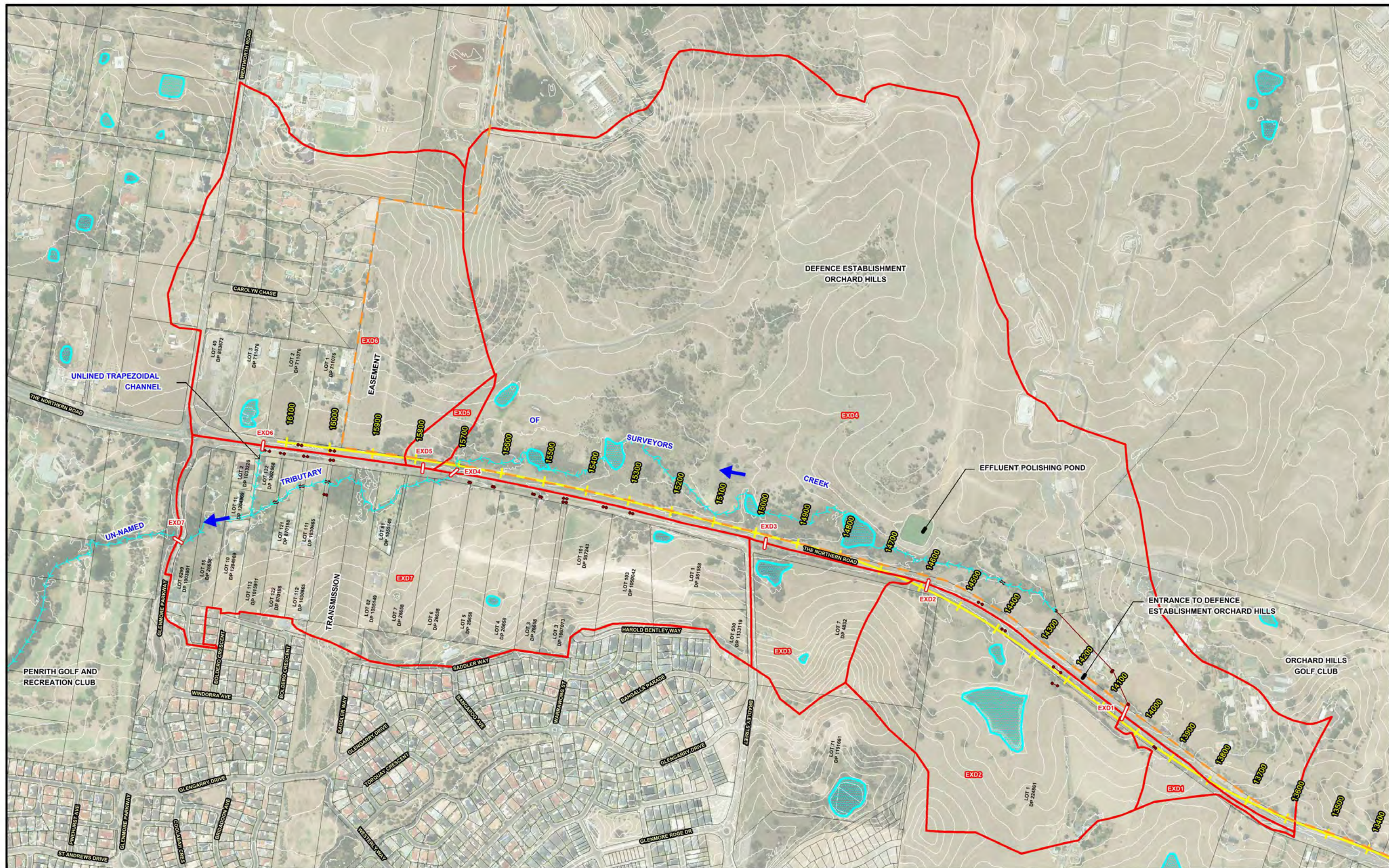
<b>Location</b>	<b>Increase in peak flood levels of greater than 50 mm resulting from of a 10 per cent increase in design rainfall intensities</b>	<b>Increase in peak flood levels of greater than 100 mm resulting from of a 30 per cent increase in design rainfall intensities</b>
Entrance to the DEOH	50-100 millimetres	100-200 millimetres
Within the proposed flood retarding basin	100-200 millimetres	200-300 millimetres
Immediately downstream of the proposed flood retarding basin	50-100 millimetres	100-200 millimetres
Along the realigned section of the un-named watercourse between about <b>DRC 15380</b> and the inlet of transverse drainage structure PXD4	50-100 millimetres	100-200 millimetres
Along the proposed flood bypass channel	50-300 millimetres	greater than 500 millimetre
Adjacent to the inlet of PXD6	50-300 millimetres	greater than 500 millimetre
In the vicinity of the concrete lined channel which would run along the northern side of Lot 132 DP1002668 and Lot 113 DP1015911 between the outlet of transverse drainage structure PXD6 and the un-named tributary	50-100 millimetres	100-200 millimetres
On the southern (upstream) side of Glenmore Parkway	50-200 millimetres	200-500 millimetres

## 8 REFERENCES

- Bureau of Meteorology, 2003. *"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"*.
- CC, 2014 (Catchment & Creeks Pty Ltd). *"Rock Sizing for Multi-Pipe & Culvert Outlets – Stormwater and Waterway Management Practices"* Version 2
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- Dam Safety Committee, NSW (June 2010) *"DSC3A – Consequence Categories for Dams"*.
- Department of Environment and Climate Change, 2007. *"Floodplain Risk Management Guideline: Practical Considerations of Climate Change"*.
- Department of Infrastructure, Planning and Natural Resources, 2005. *"Floodplain Development Manual: the management of flood liable land"*.
- Engineers Australia, 2013 *"AR&R Revision projects – project 11 – Blockage of Hydraulic Structures"*.
- Intergovernmental Panel on Climate Change, 2007. *"Climate Change 2007: The Physical Science Basis. Summary for Policymakers"* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 5 February 2007.
- Penrith City Council, 2010. *"Penrith Local Environment Plan 2010"*
- Penrith City Council, 2014. *"Penrith Development Control Plan 2014"*.
- The Institution of Engineers, Australia, 1998. *"Australian Rainfall and Runoff – A Guide to Flood Estimation"*.

# FIGURES



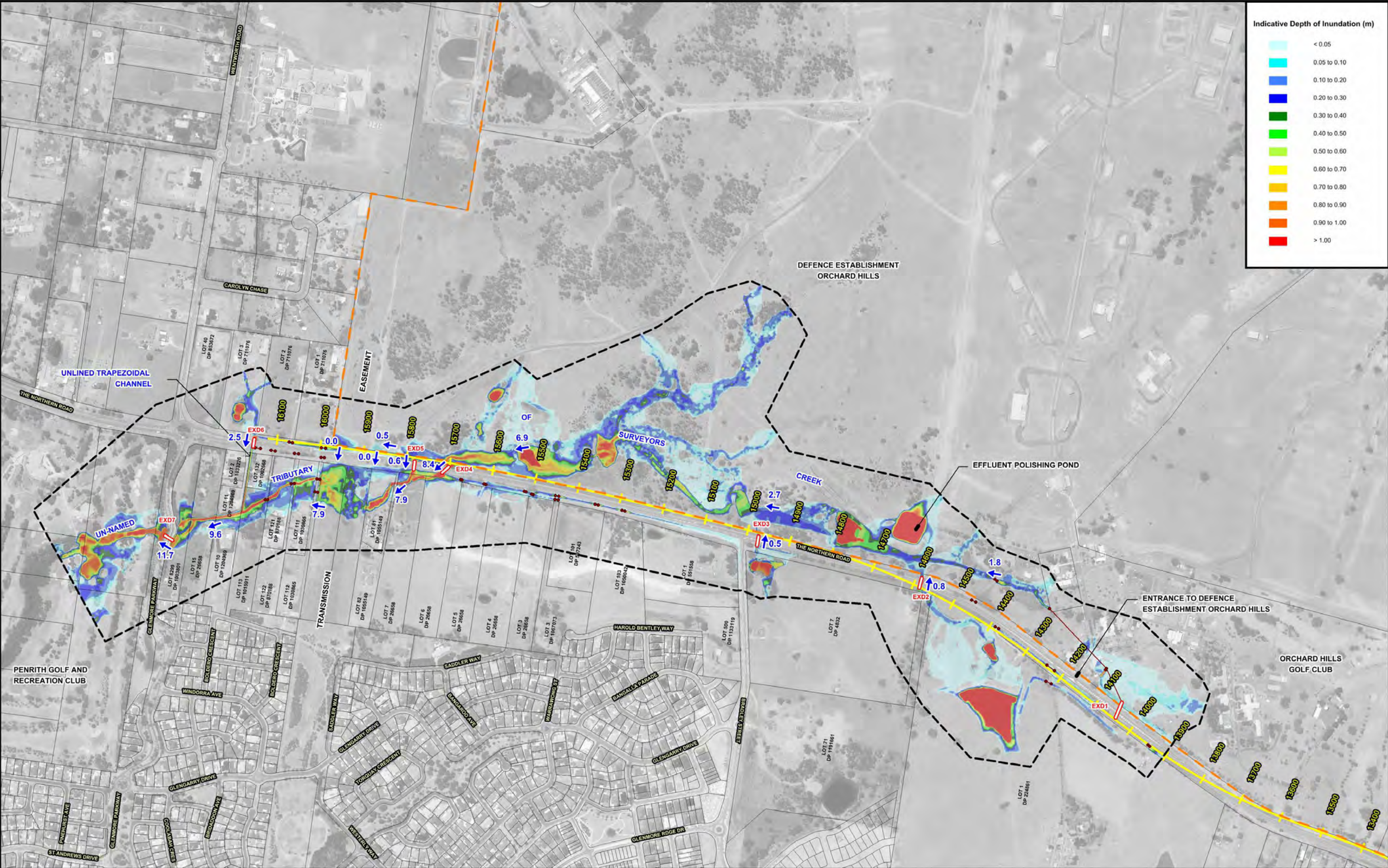


# THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure 4.1

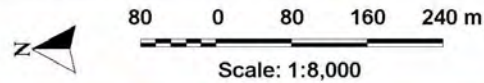
TRANSVERSE DRAINAGE CATCHMENT PLAN  
PRE-PROJECT CONDITIONS





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



**Lycall & Associates**



Existing Transverse Drainage Structure and Identifier

Design Road Control String and Chainage

**LEGEND**



Existing Stormwater Drainage Network

Two-Dimensional Model Extent

Defence Establishment Orchard Hills Boundary

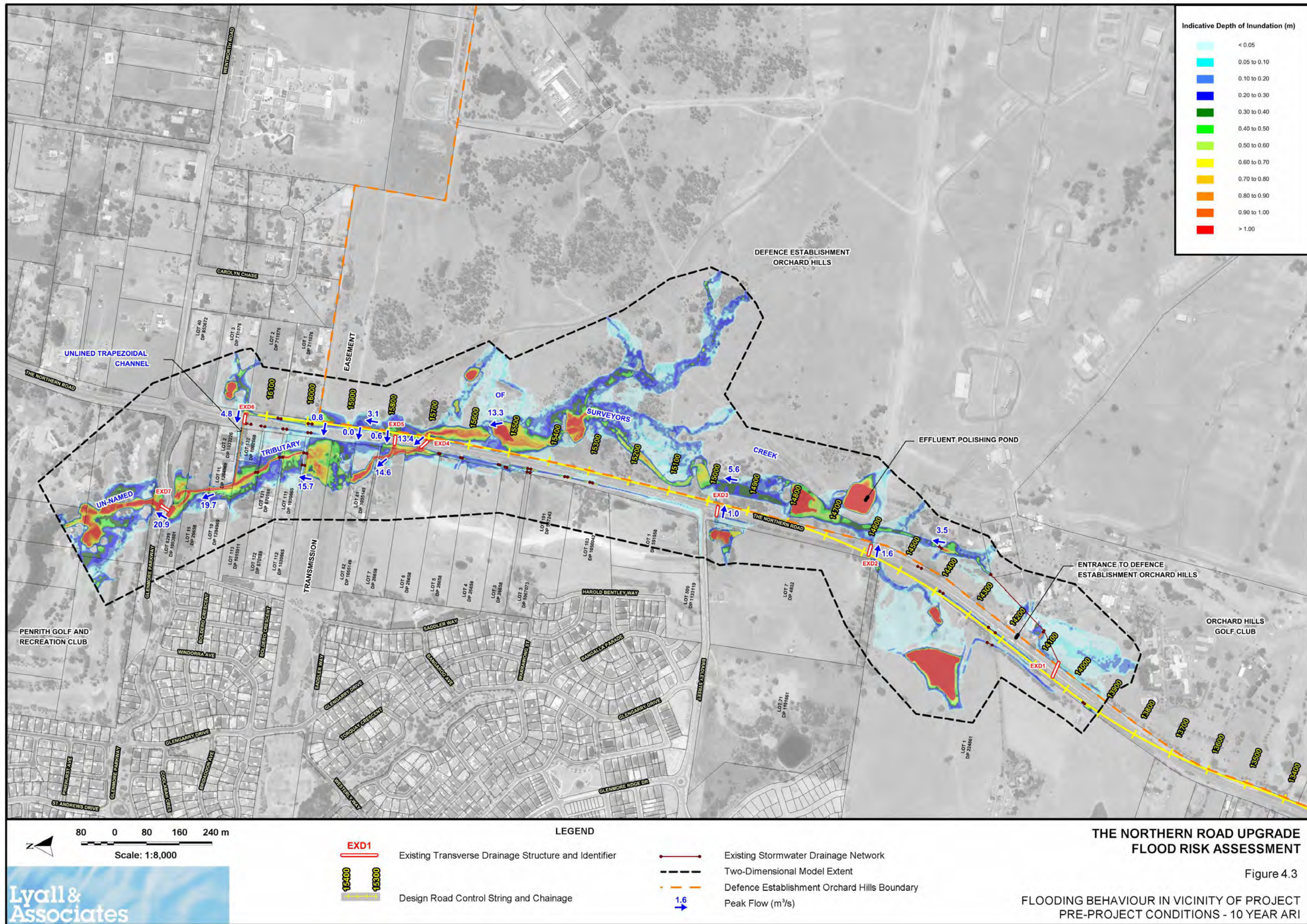
Peak Flow (m³/s)

**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

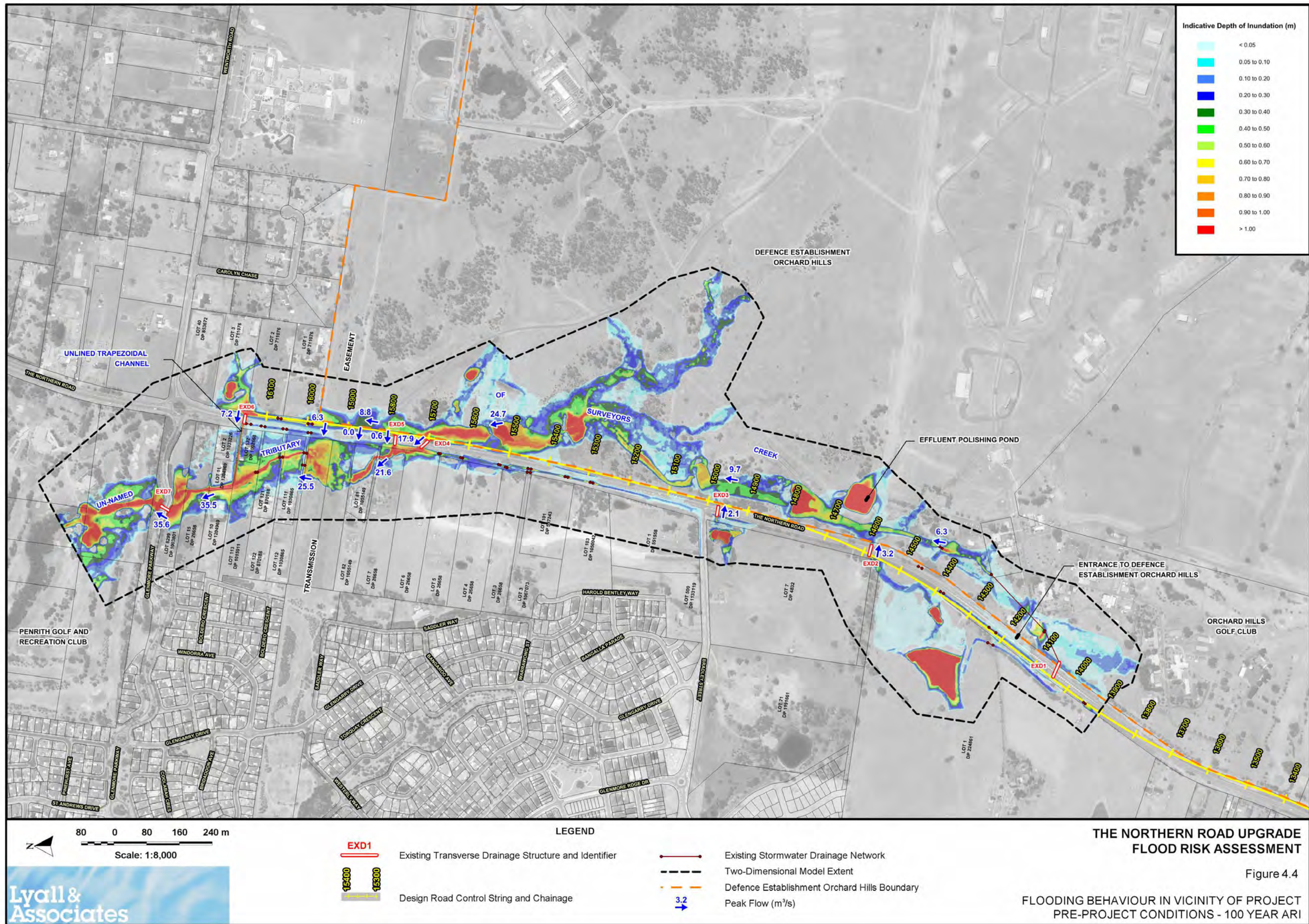
Figure 4.2

FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
PRE-PROJECT CONDITIONS - 2 YEAR ARI

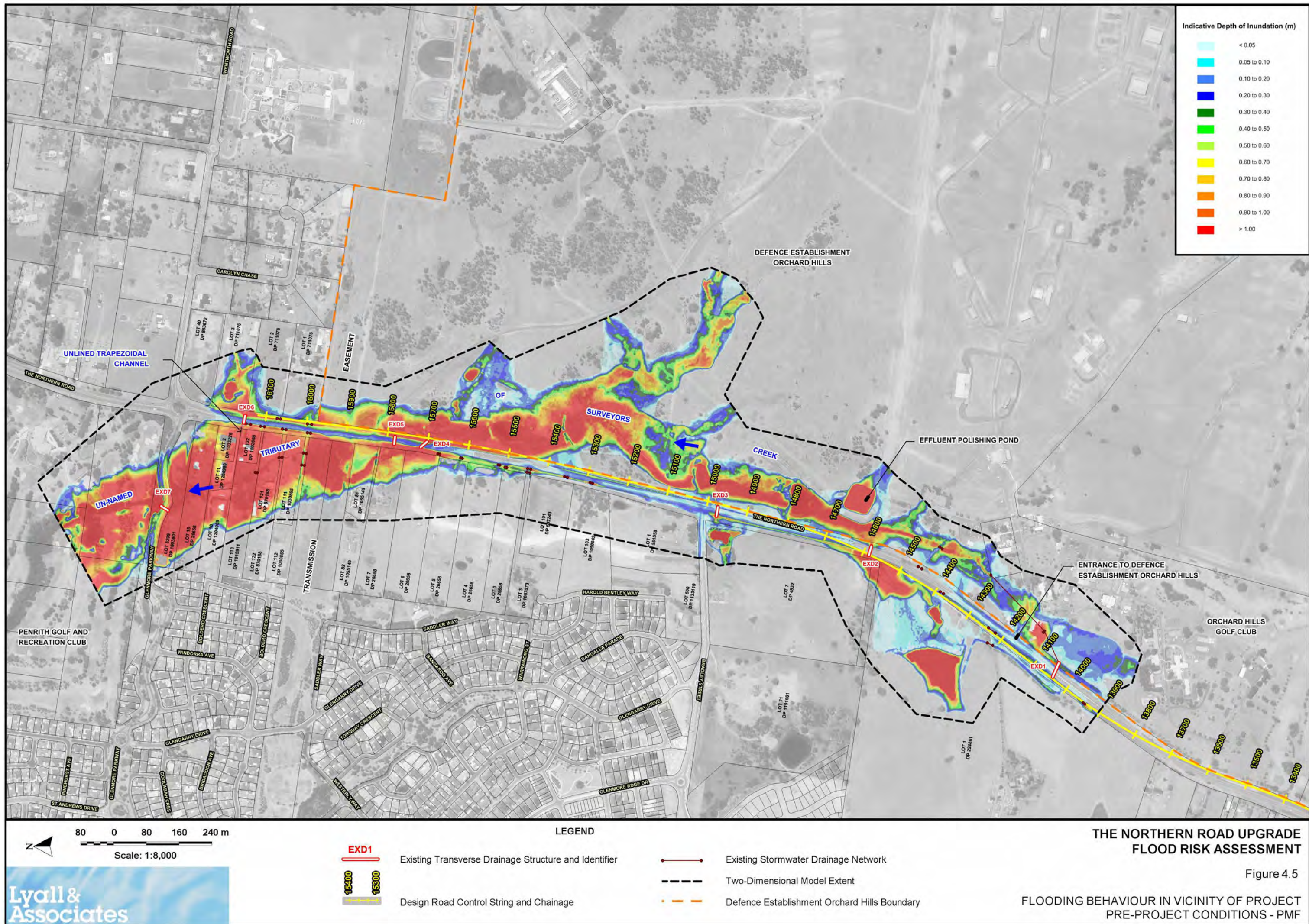




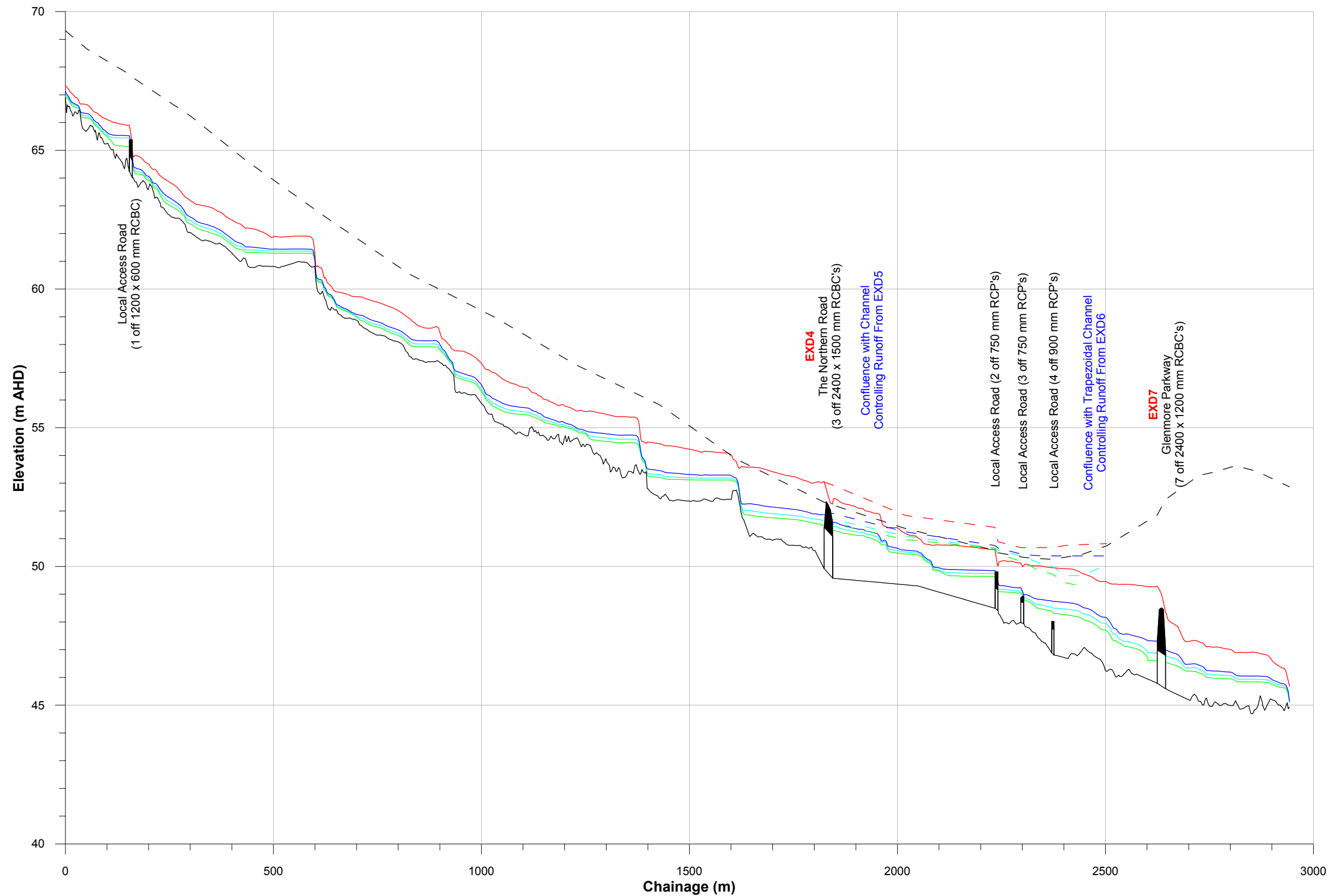










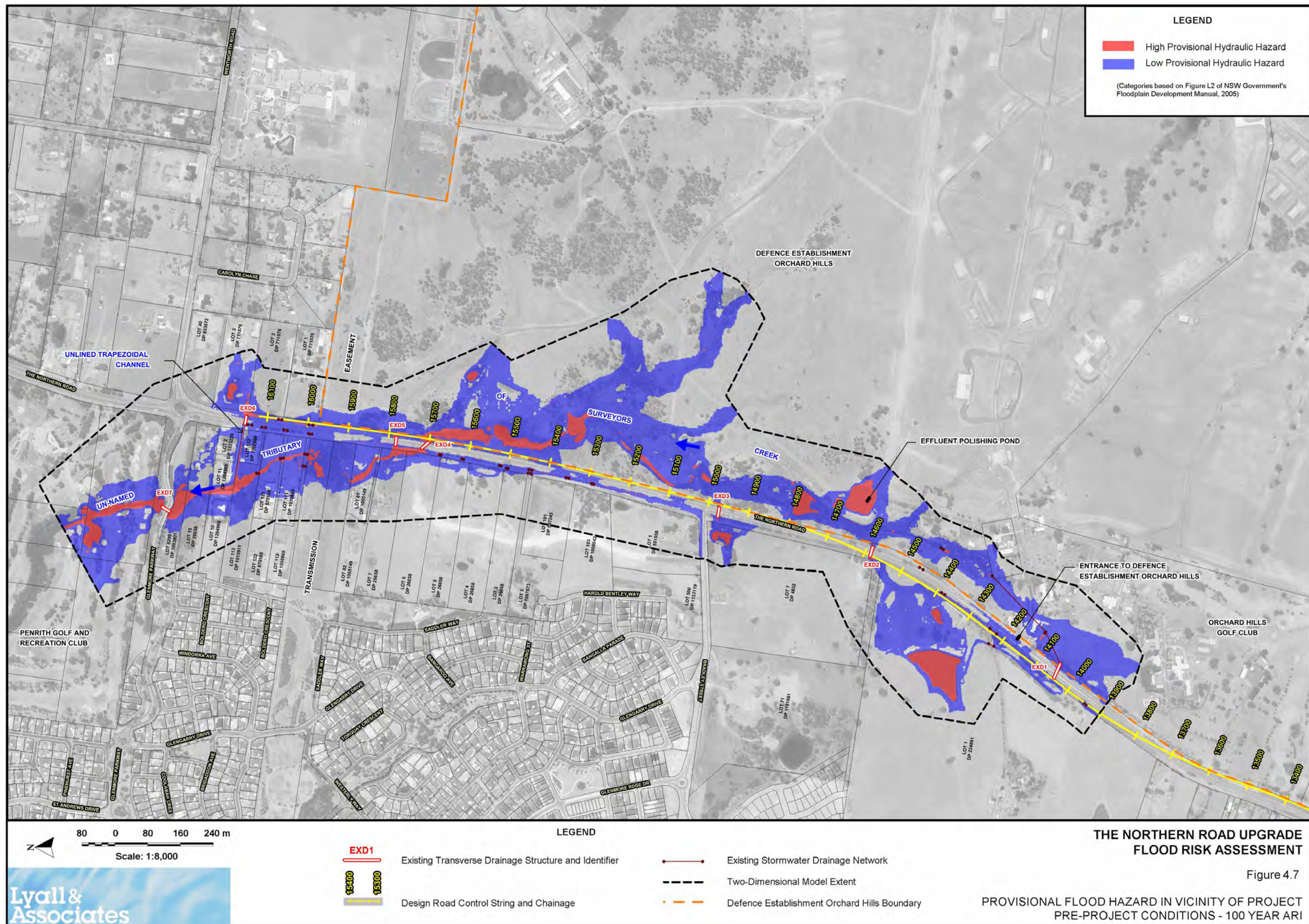


# **THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT**

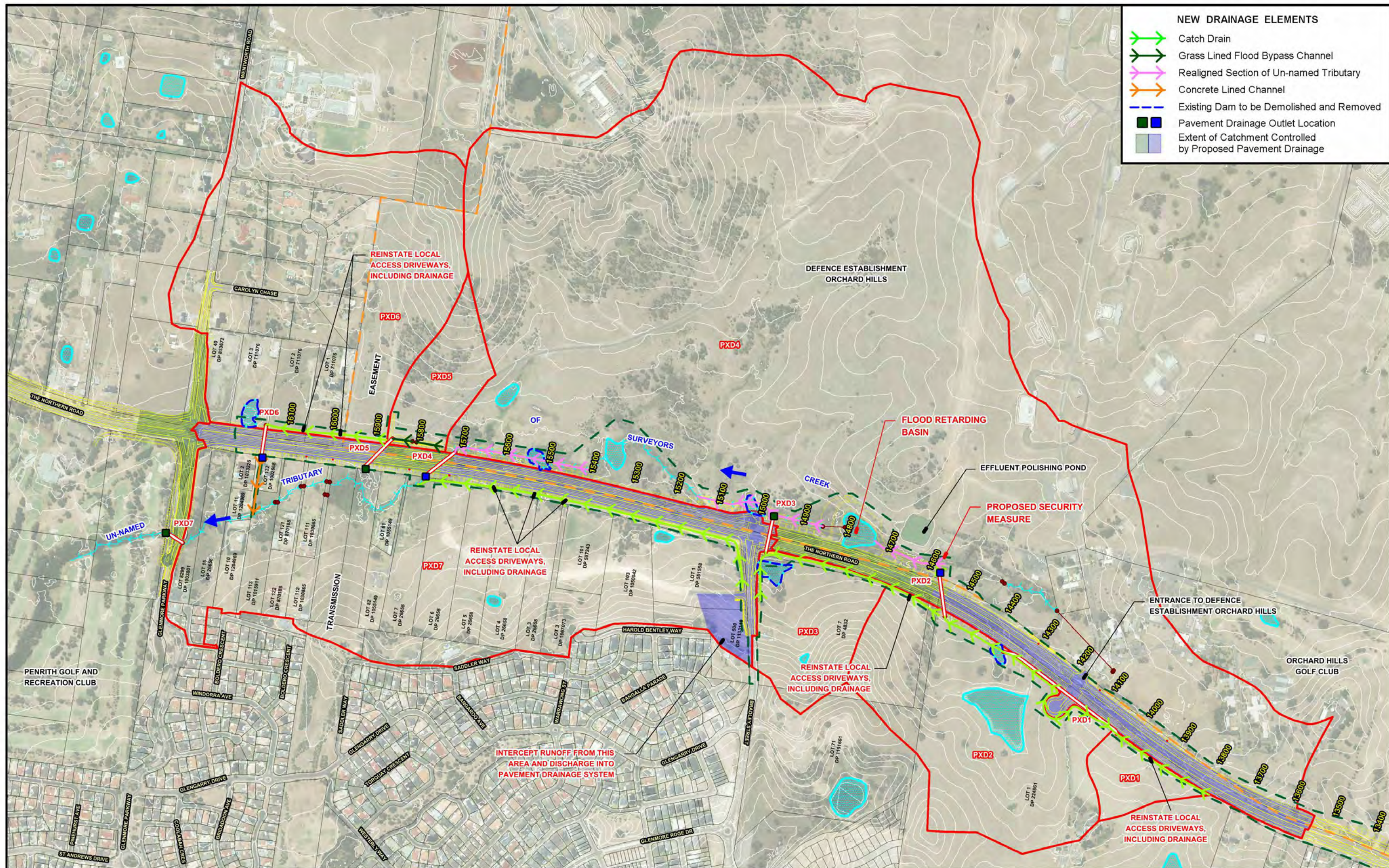
Figure 4.6

DESIGN WATER SURFACE PROFILES  
PRE-PROJECT CONDITIONS









80 0 80 160 240 m  
Scale: 1:8,000

Lycall & Associates

**LEGEND**

Modelled Stormwater Drainage Network  
Proposed Transverse Drainage Structure and Identifier  
Project Boundary  
Design Road Control String and Chainage

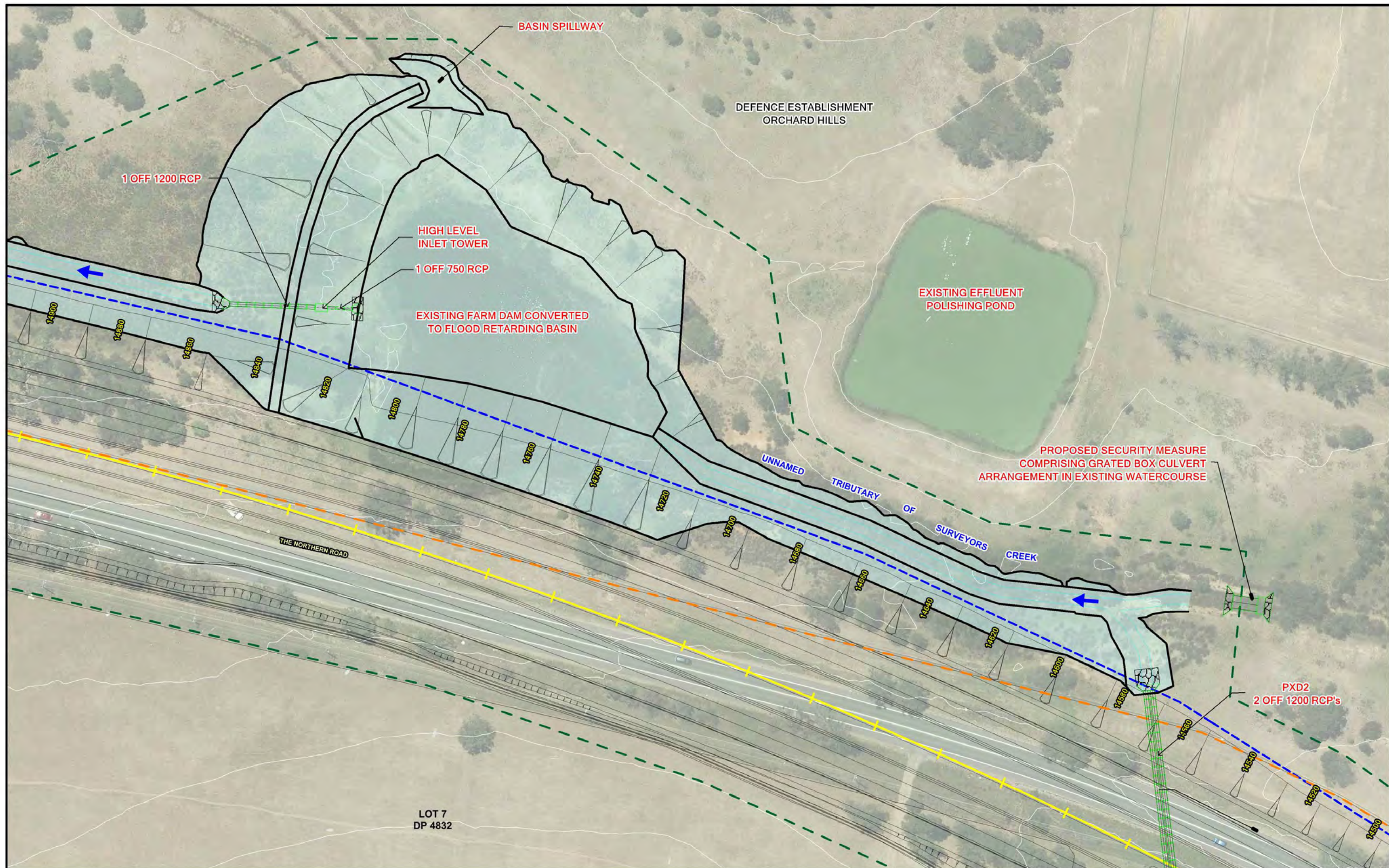
PXD1  
Extent of Catchment Draining into Proposed Transverse Drainage Structure and Identifier  
Defence Establishment Orchard Hills Boundary  
Design Strings  
Existing Dam

## THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure 6.1





TRANSVERSE DRAINAGE CATCHMENT PLAN  
POST-PROJECT CONDITIONS







10 0 10 20 30 m  
Scale: 1:1,000

Lycall & Associates

- LEGEND**
-  Design Strings
  -  Extent of Drainage Improvement Works
  -  Defence Establishment Orchard Hills Boundary
  -  Project Boundary

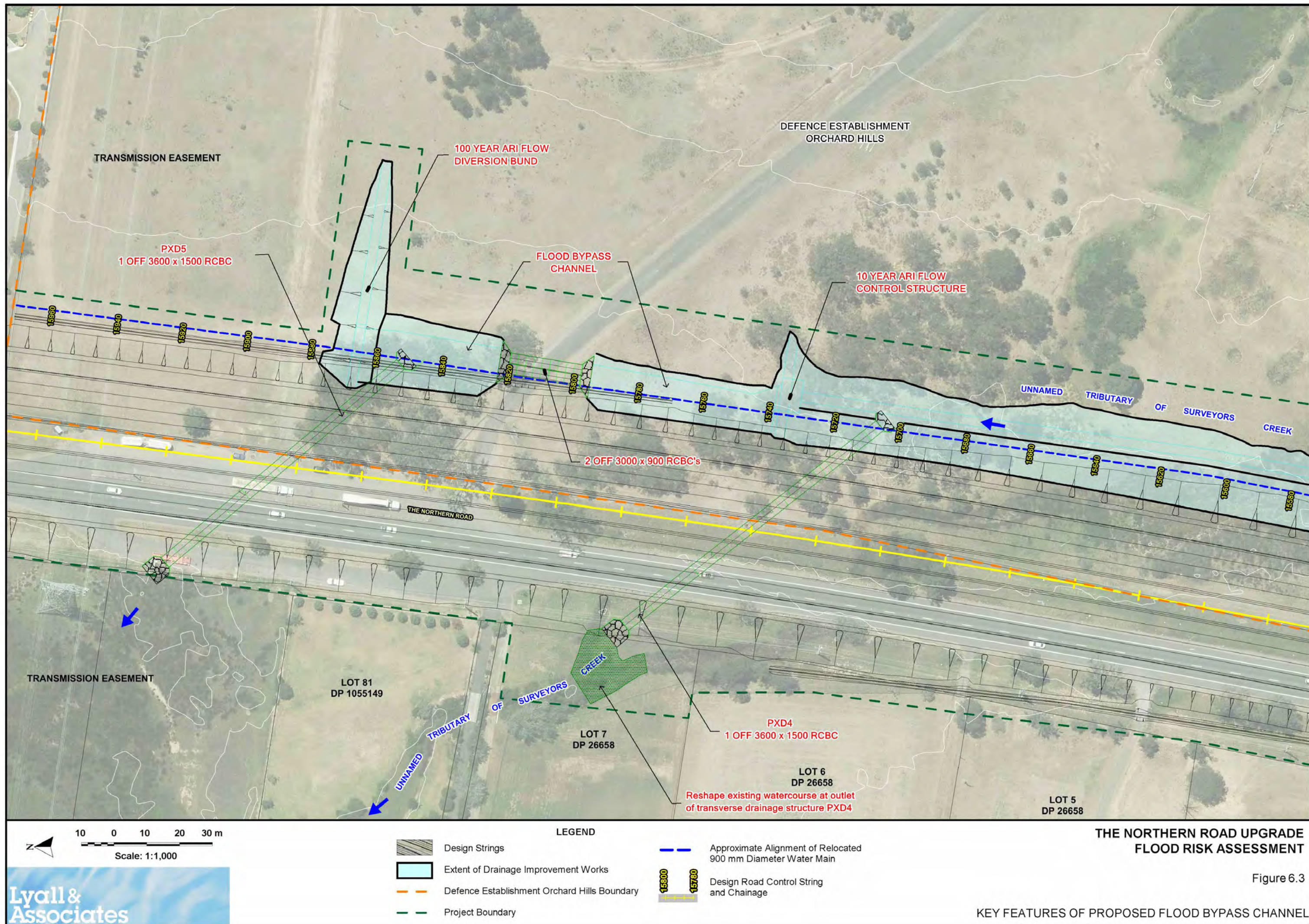
-  Approximate Alignment of Relocated 900 mm Diameter Water Main
-  Design Road Control String and Chainage

## THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

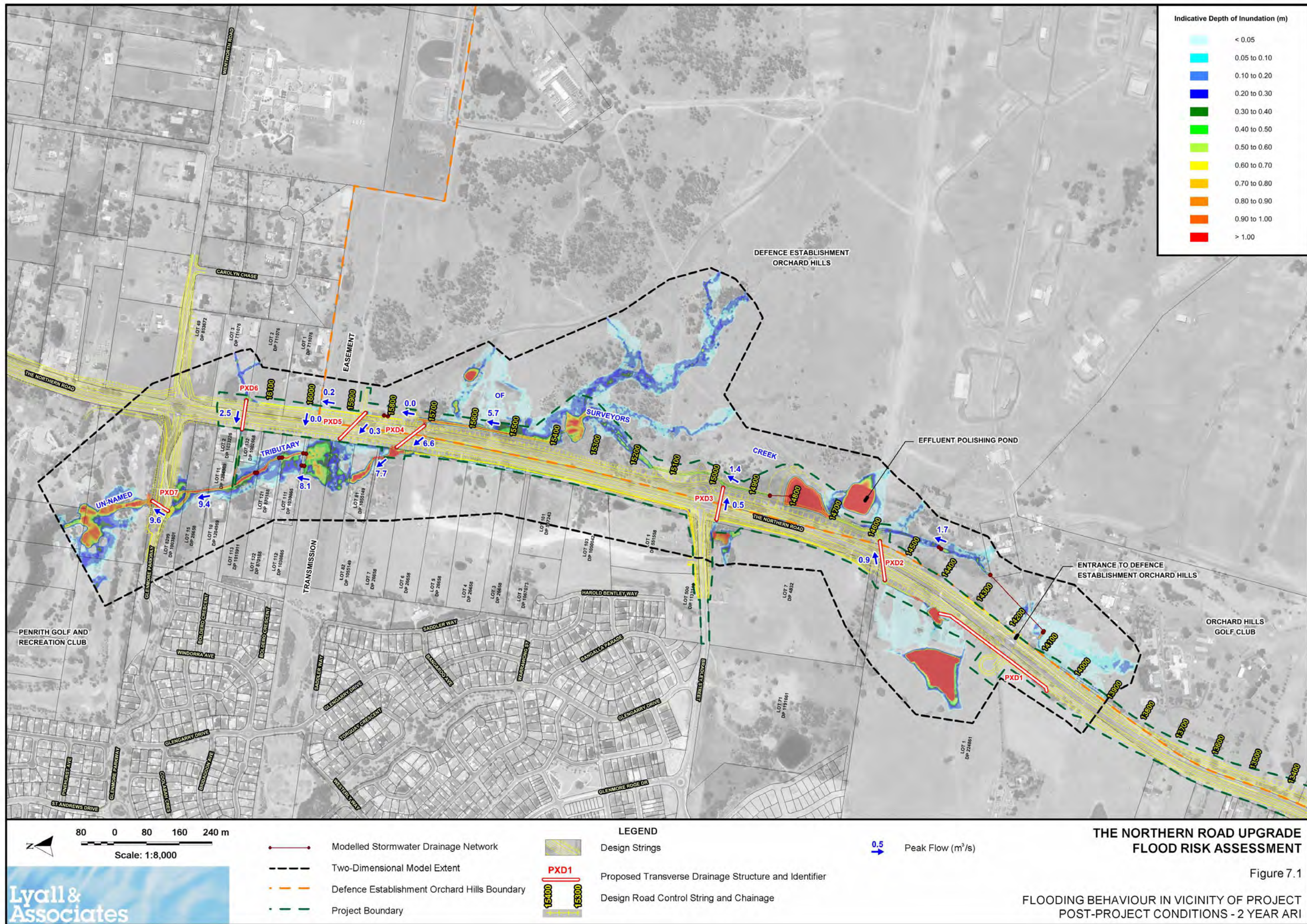
Figure 6.2

KEY FEATURES OF PROPOSED FLOOD RETARDING BASIN





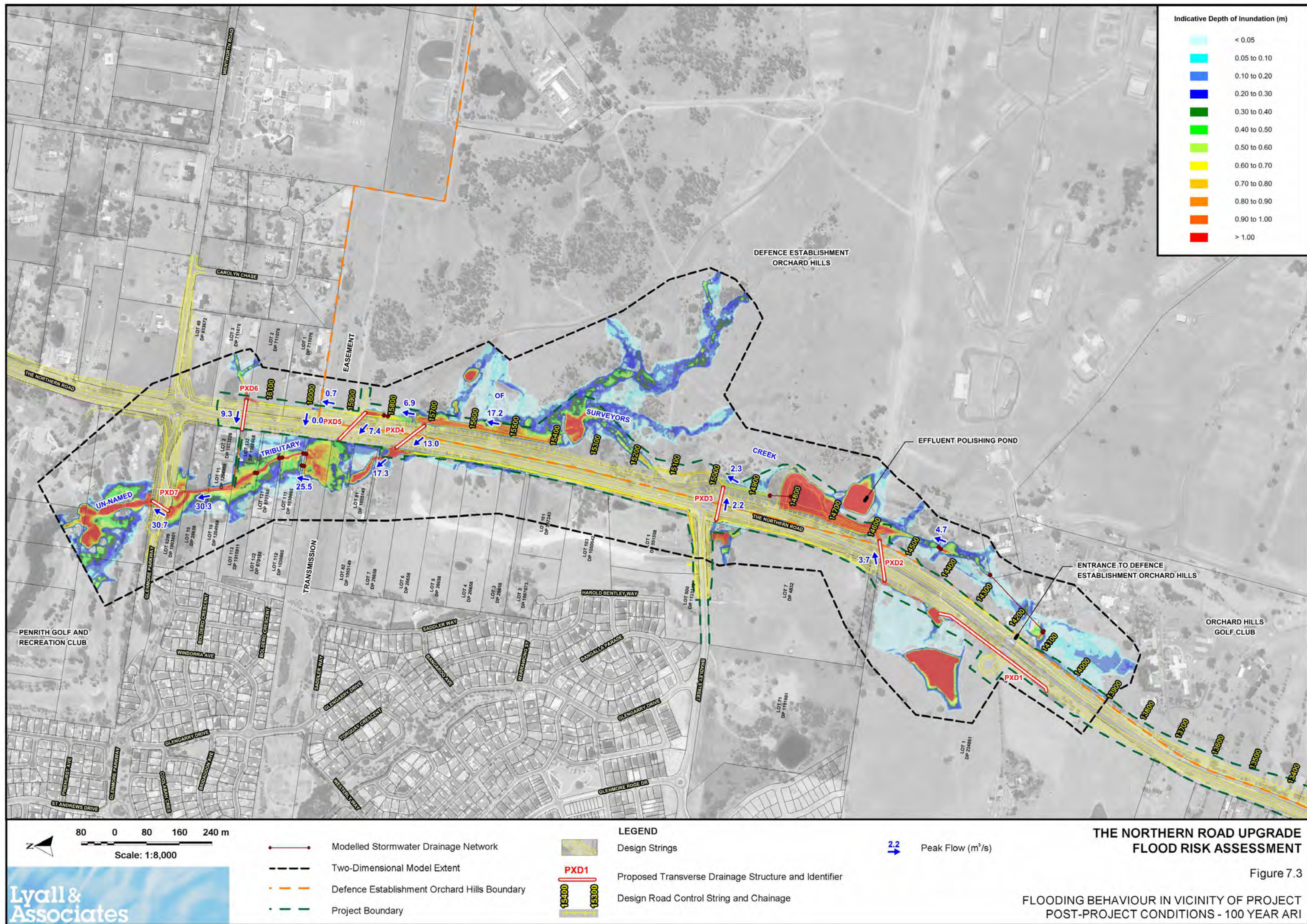




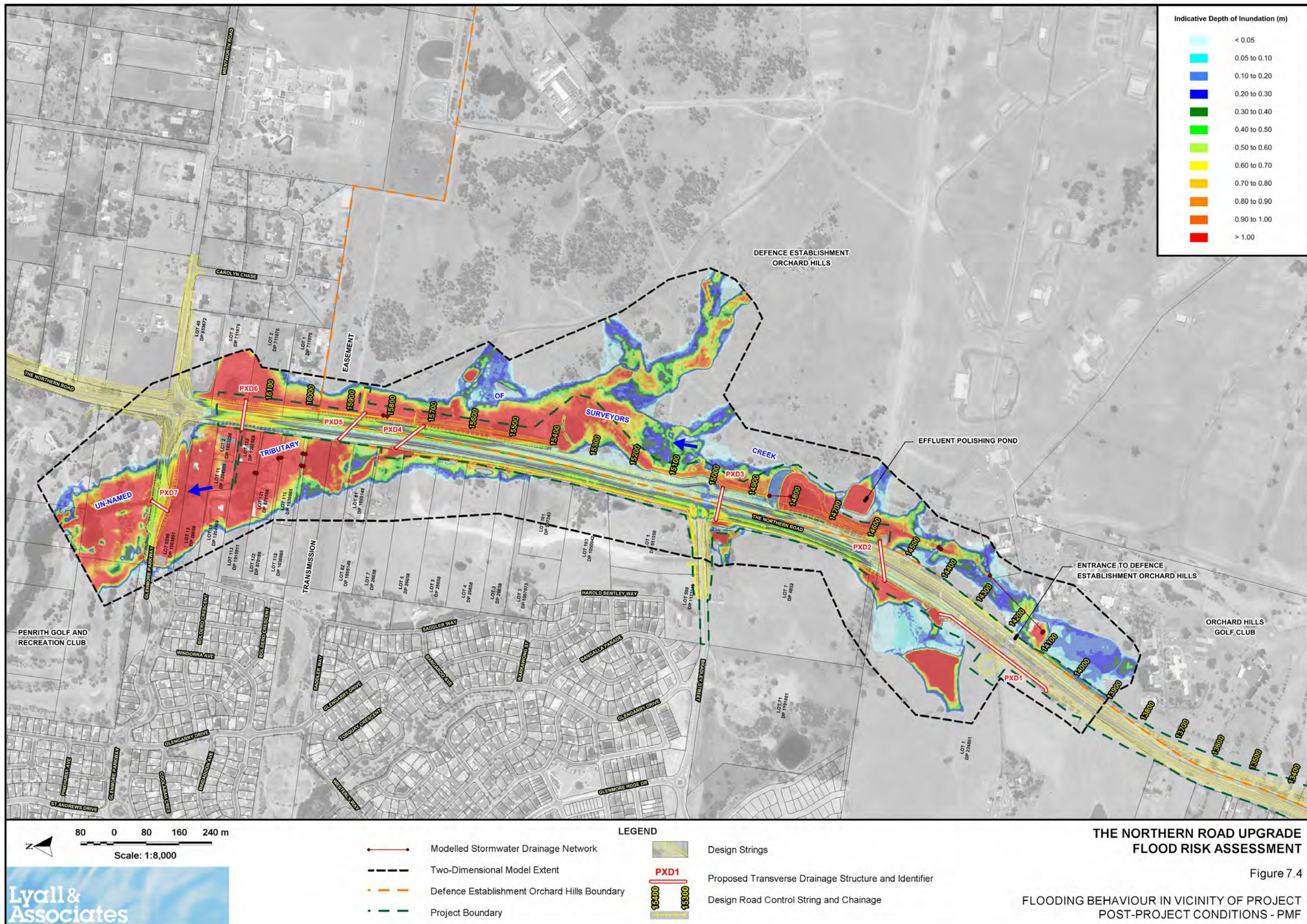




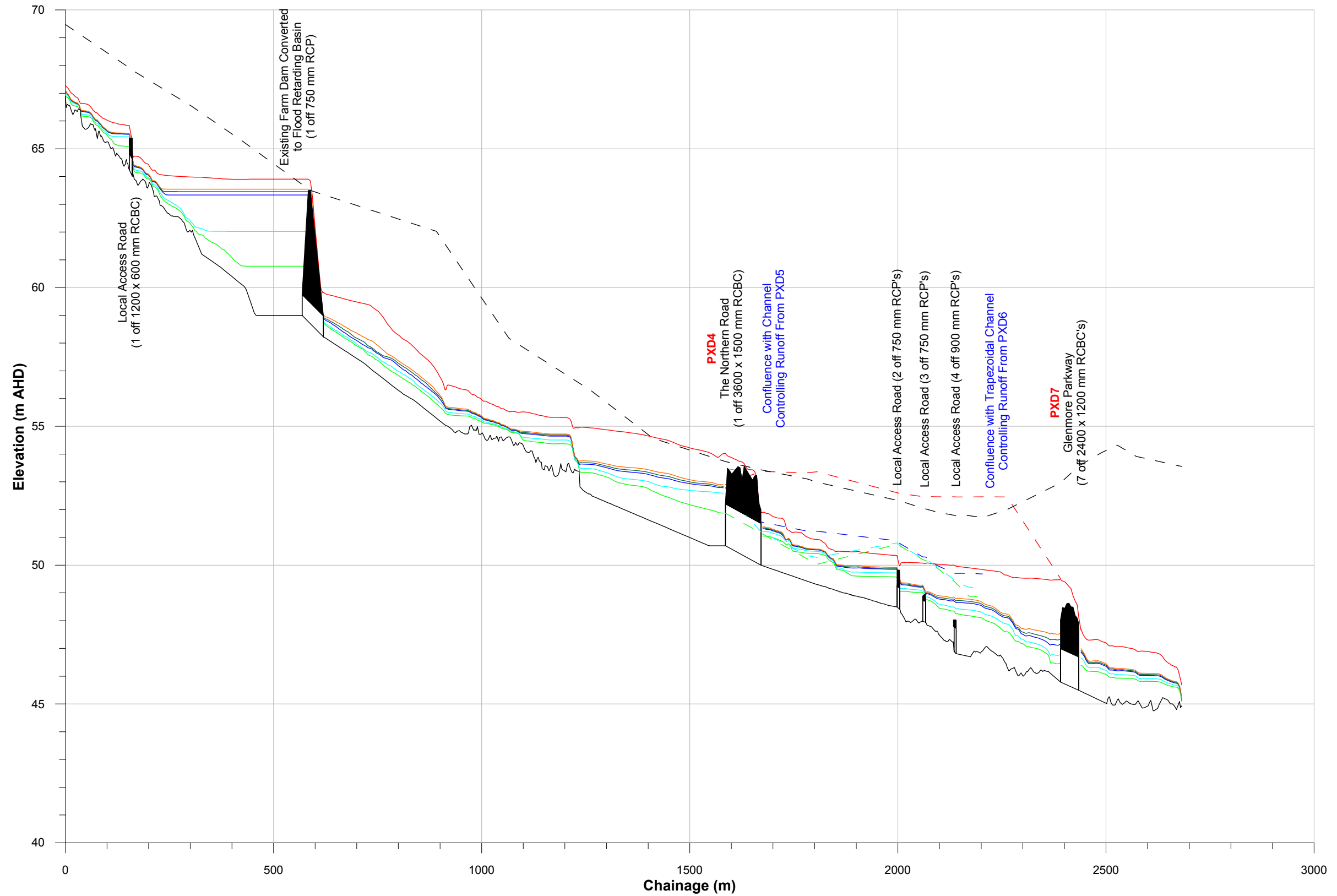












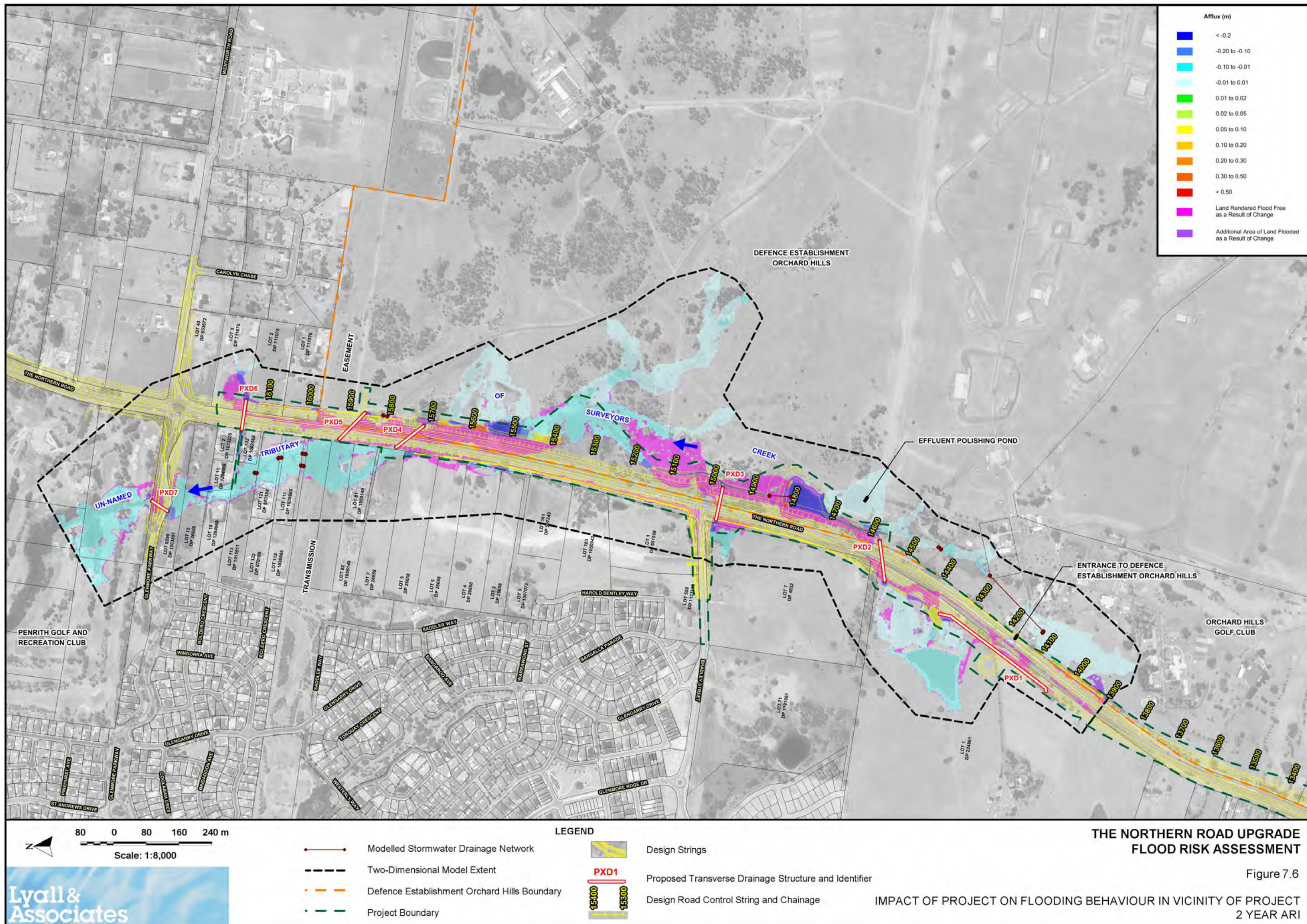
#### LEGEND

Un-Named Tributary of Surveyors Creek	Flow along Eastern Side of The Northern Road
<span style="color: red;">—</span>	<span style="color: red;">- - -</span> PMF
<span style="color: blue;">—</span>	<span style="color: blue;">- - -</span> 100 year ARI
<span style="color: cyan;">—</span>	<span style="color: cyan;">- - -</span> 10 year ARI
<span style="color: green;">—</span>	<span style="color: green;">- - -</span> 2 year ARI
<span style="color: black;">- - - - -</span>	Highest Point along The Northern Road

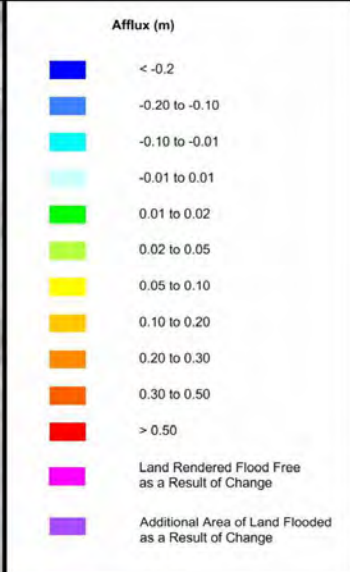
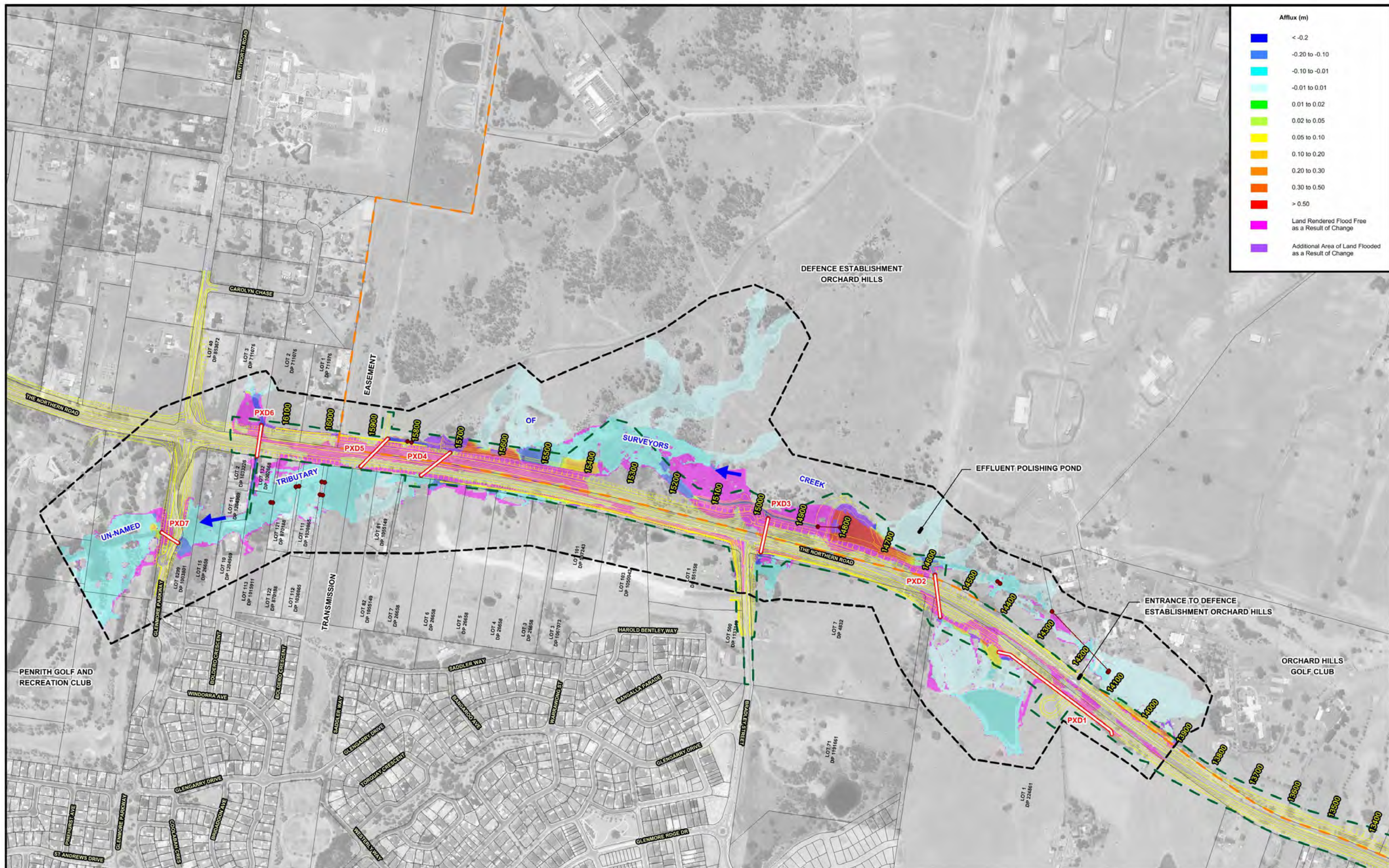
#### NOTE:

1. Analogous to 10 % increase in design 100 year ARI rainfall intensities
2. Analogous to 30 % increase in design 100 year ARI rainfall intensities









80 0 80 160 240 m

Scale: 1:8,000

**Lyall & Associates**

**LEGEND**

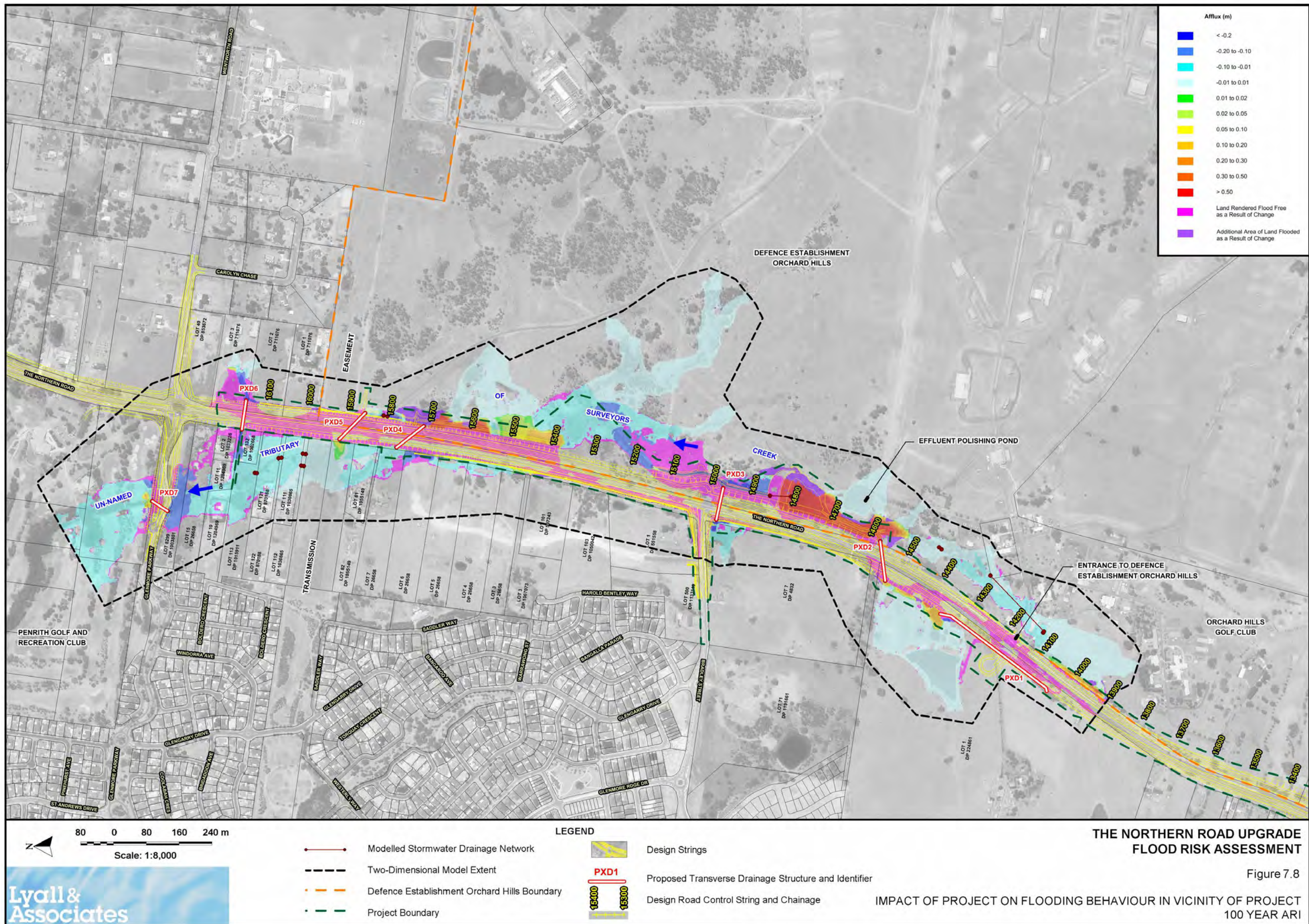
- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
- Defence Establishment Orchard Hills Boundary
- Project Boundary
- Design Strings
- PXD1 Proposed Transverse Drainage Structure and Identifier
- 15400 15300 Design Road Control String and Chainage

**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

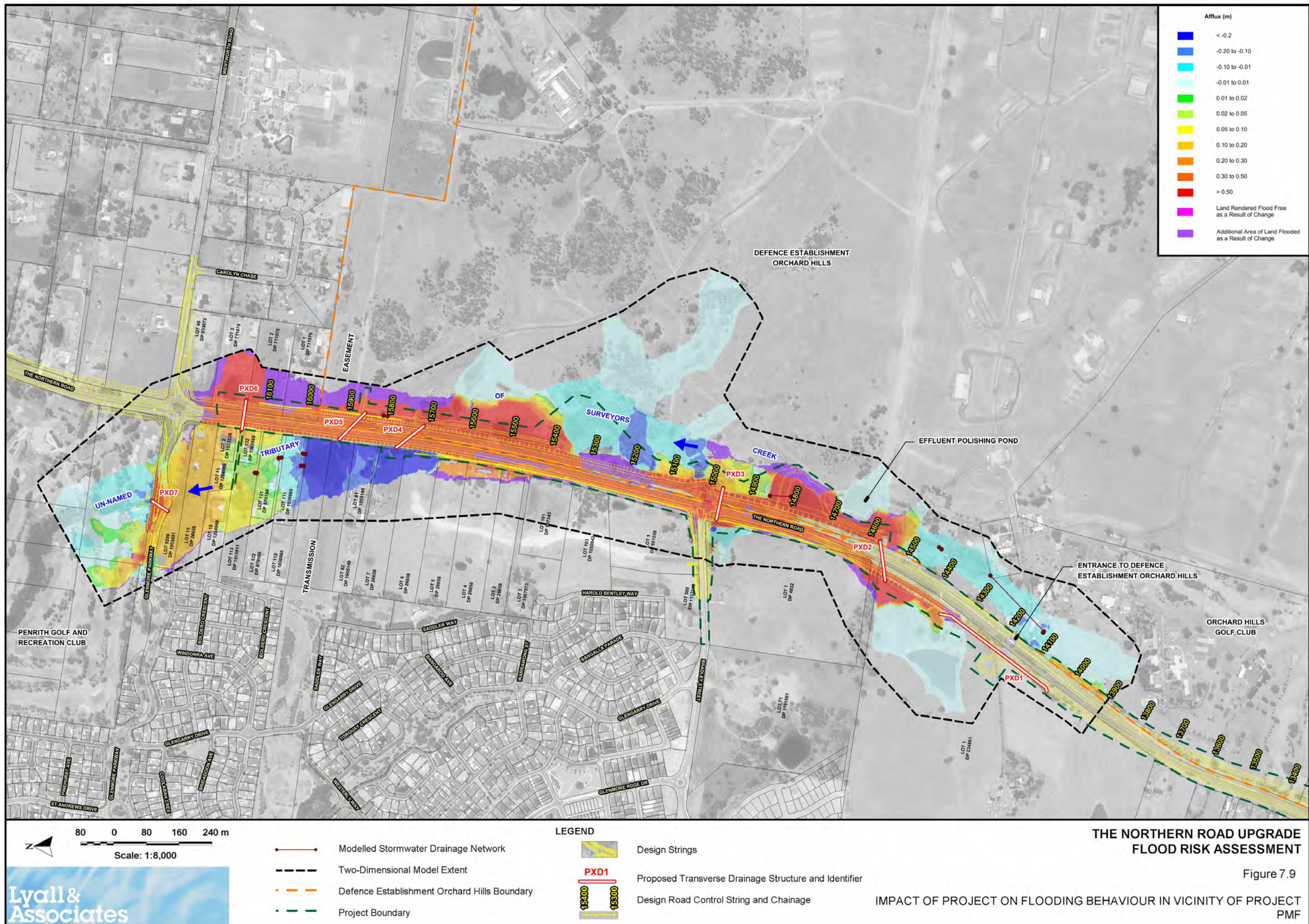
Figure 7.7

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
10 YEAR ARI

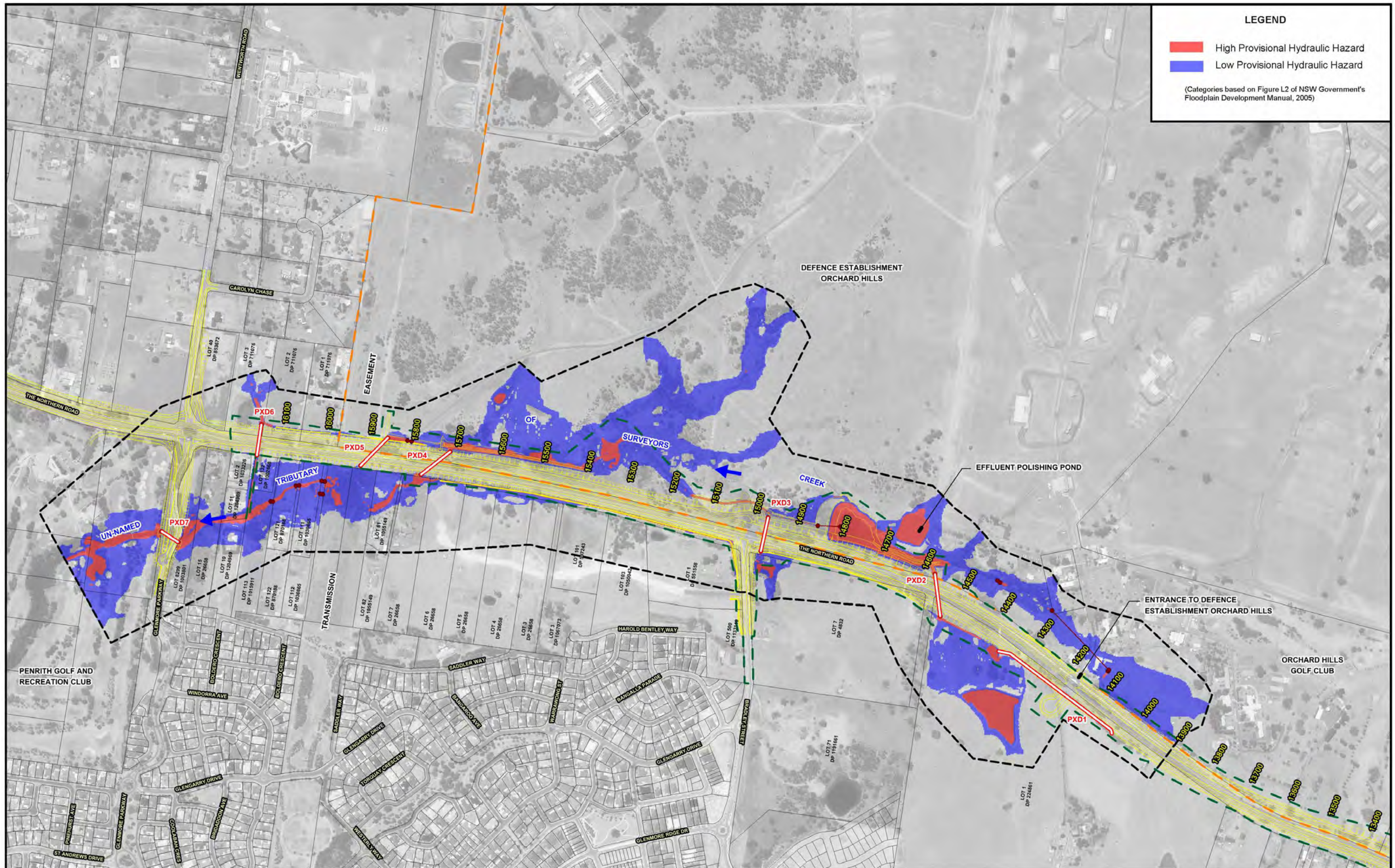












**LEGEND**

High Provisional Hydraulic Hazard

Low Provisional Hydraulic Hazard

(Categories based on Figure L2 of NSW Government's Floodplain Development Manual, 2005)

80 0 80 160 240 m

Scale: 1:8,000

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**LEGEND**

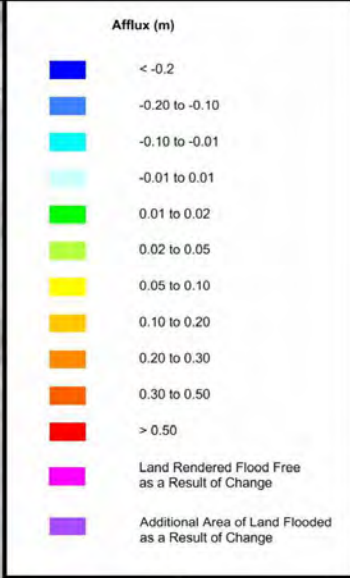
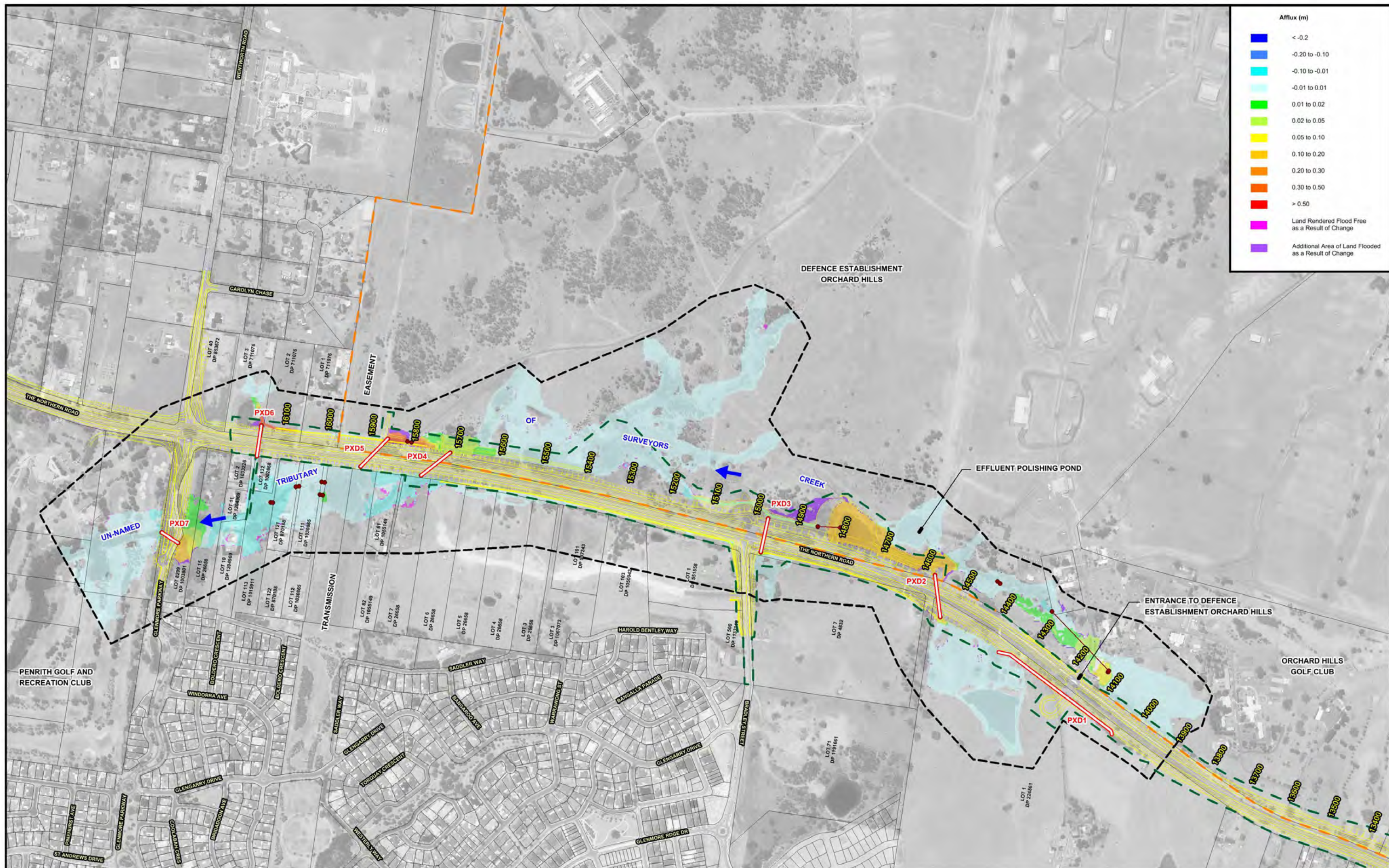
- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
- Defence Establishment Orchard Hills Boundary
- Project Boundary
- Design Strings
- PXD1 Proposed Transverse Drainage Structure and Identifier
- 15400 15300 Design Road Control String and Chainage

**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

Figure 7.10

PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT  
POST-PROJECT CONDITIONS - 100 YEAR ARI





80 0 80 160 240 m

Scale: 1:8,000

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**LEGEND**

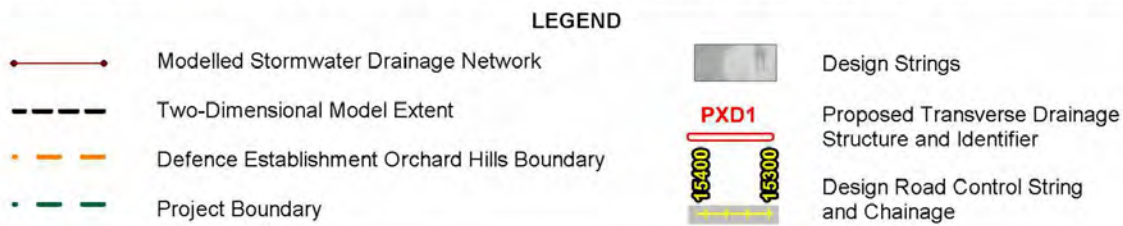
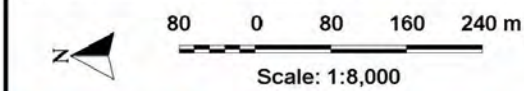
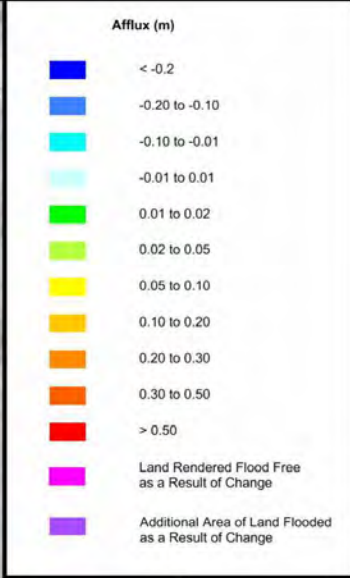
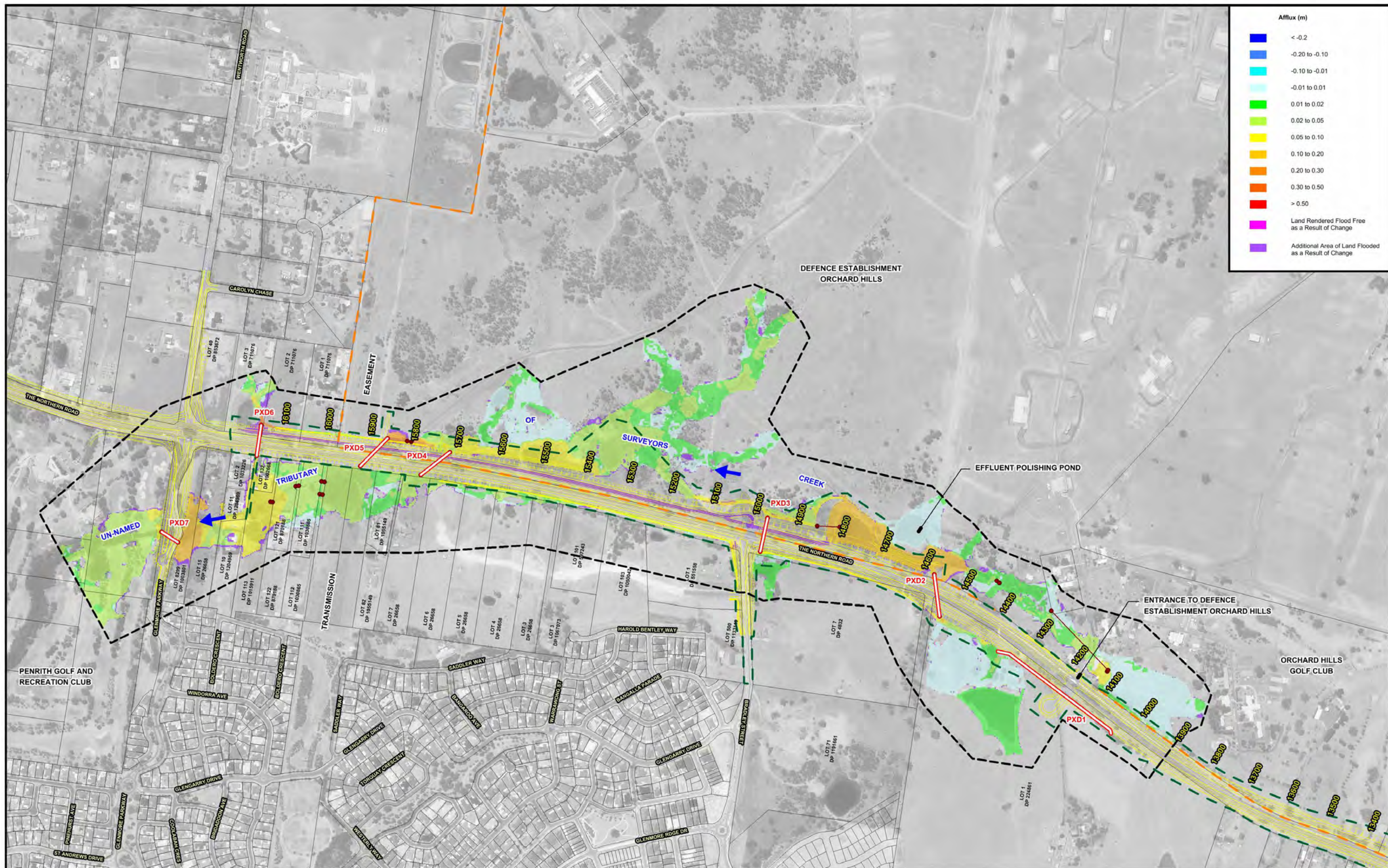
- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
- Defence Establishment Orchard Hills Boundary
- Project Boundary
- Design Strings
- PXD1 Proposed Transverse Drainage Structure and Identifier
- 15400 15300 Design Road Control String and Chainage

**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

Figure 7.11

IMPACT OF PARTIAL BLOCKAGE OF MAJOR HYDRAULIC STRUCTURES ON FLOODING  
BEHAVIOUR IN VICINITY OF PROJECT - POST-PROJECT CONDITIONS - 100 YEAR ARI



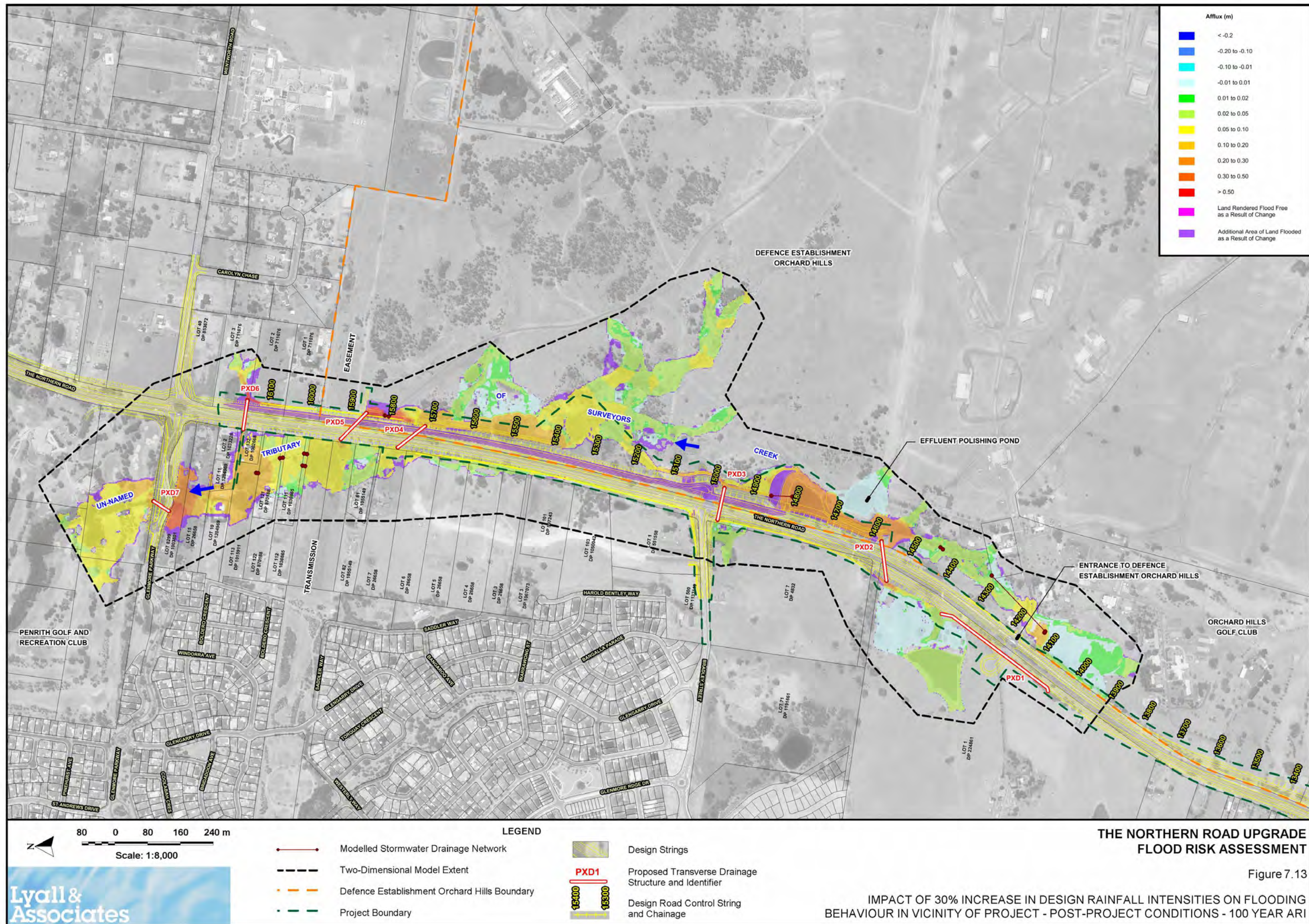


**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

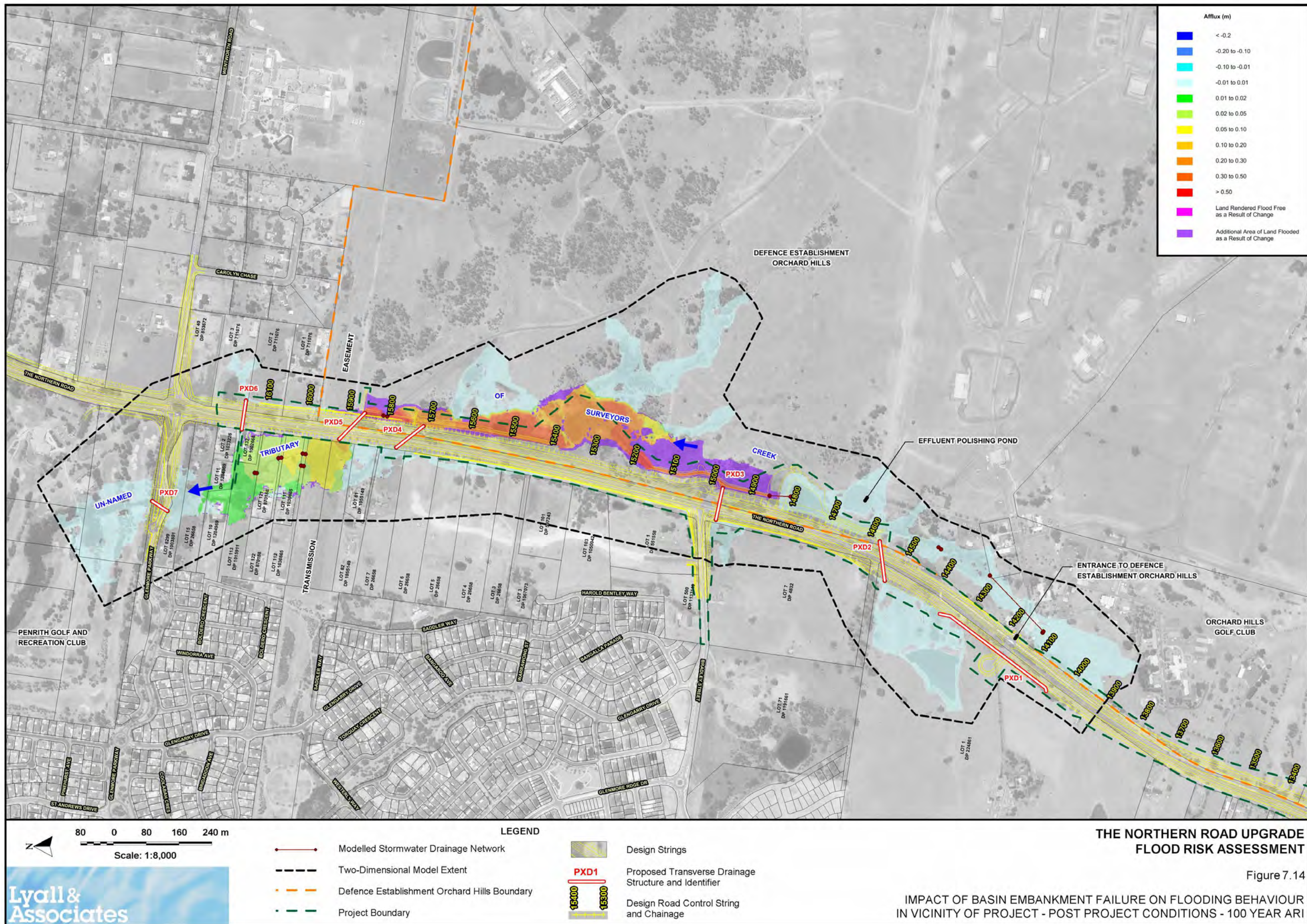
Figure 7.12

IMPACT OF 10% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING  
BEHAVIOUR IN VICINITY OF PROJECT - POST-PROJECT CONDITIONS - 100 YEAR ARI











**APPENDIX A**  
**BACKGROUND TO DEVELOPMENT OF FLOOD MODELS**  
**AND ASSESSMENT OF DAM SAFETY REQUIREMENTS**

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A2.1	Sub-Catchment Comprising Hydrologic Model – Pre-Project Conditions
A2.2	Sub-Catchment Comprising Hydrologic Model – Post-Project Conditions
A3.1	TUFLOW Model Layout – Pre-Project Conditions
A3.2	Sensitivity of Flood Behaviour to 20% Increase in Hydraulic Roughness Values – 100 year ARI

## **A1. SYNOPSIS**

This Appendix provides background to the development of the hydrologic (DRAINS) and hydraulic (TUFLOW) computer models that were developed to define flooding behaviour in the vicinity of the project. This Appendix also provides background to the analysis that was undertaken to assess the impact the potential failure of the embankment which would be associated with the proposed flood retarding basin would have on flooding behaviour.



## **A2. HYDROLOGIC MODEL DEVELOPMENT**

### **A2.1 General**

This chapter of the Appendix provides a brief description of the DRAINS rainfall-runoff model that was developed as part the present investigation to generated design discharge hydrographs which were then used as input to the TUFLOW hydraulic model.

DRAINS is a simulation program which converts rainfall patterns to stormwater runoff and generates discharge hydrographs. These hydrographs are then routed through networks of piped drainage systems, culverts, storages and open channels to calculate hydraulic grade lines and analyse the magnitude of overflows. Alternatively, discharge hydrographs generated by DRAINS can be used as inflows to hydraulic models (such as the TUFLOW two-dimensional hydraulic modelling software) to determine flooding patterns. The latter approach is particularly appropriate for modelling complex flood behaviour involving multiple flow paths and has been used in the present study.

A number of hydrologic sub-models are available within the DRAINS software to simulate the conversion of rainfall to runoff. The RAFTS sub-model was used to assess the runoff characteristics of the semi-rural catchment which contributes to flow in the drainage system in the vicinity of the project, while the ILSAX sub-model was used to assess the runoff characteristics of the upgraded section of The Northern Road.

### **A2.2 DRAINS model layout**

**Figures A2.1** and **A2.2** show the layout of the sub-catchments which comprise the hydrologic models which represent pre- and post-project conditions, respectively. Sub-catchment boundaries were digitised based on contour information derived from the available LiDAR survey data. Sub-catchment slopes applied as input data for the sub-catchments were derived using the average sub-catchment slope. Aerial photography was used to assess the degree of urbanisation present in the sub-catchments which comprise the DRAINS model.

### **A2.3 Design Storms**

#### **A2.3.1 Up to 500 year ARI**

Rainfall intensities for the 2, 10, 20, 100, 200 and 500 year ARI events were derived using procedures outlined in Australian Rainfall and Runoff (**ARR**) (IEAust, 1998) for storm durations ranging between 25 minutes and 12 hours. The design rainfalls were converted into rainfall hyetographs using the temporal patterns presented in ARR.

No Areal Reduction Factor (**ARF**) was applied to the design rainfall intensities obtained from ARR due to the relatively small size of the catchments which drain to the project corridor.

### **A2.3.2 Probable Maximum Flood**

Estimates of Probable Maximum Precipitation (**PMP**) were made using the Generalised Short Duration Method (**GSDM**) as described in the BoM's update of *Bulletin 53* (BoM, 2003). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km<sup>2</sup> in area and storm durations up to 6 hours.

Given the relatively small size of the catchment that contributes to flow in the drainage system in the vicinity of the project (about 283 hectares at transverse drainage structure EXD7), PMP rainfall applicable to the smallest ellipse shown on Figure 6 of BoM, 2003 (i.e. Ellipse A) was used as input to the model.

### **A2.4 Model parameters**

Adopted RAFTS sub-model parameters comprised initial losses of 2 and 15 mm for paved and grassed areas, respectively, while continuing loss rates of 0 and 2.5 mm/h were adopted for paved and grassed areas, respectively.

A storage routing coefficient multiplier (Bx factor) of 1.0 was adopted after comparison of peak discharges from a range of sub-catchments with those derived from the PRM approach.

Lagging was used to model the translation of the discharge hydrographs between sub-catchment outlets within the ILSAX and RAFTS sub-models (referred to as links). This approach required a flow velocity to be assumed in each link. The sensitivity of the results to assumed flow velocities ranging between 1 and 2 m/s was tested for the 100 year ARI critical storm. After consideration of flow path slopes and comparison of results with those derived from the PRM approach, a flow velocity of 1 m/s was adopted for design flood estimation.

Adopted ILSAX sub-model parameters comprised initial losses of 2 and 10 mm for paved and grassed areas, respectively. ILSAX uses the Hortonian loss modelling approach which does not require the user to input a continuing loss rate. Instead, a soil type and antecedent moisture condition (**AMC**) are used to define the continuing loss over time. The soil type was set equal to 3, which corresponds with a soil of comparatively high runoff potential while an AMC of 3 was adopted reflecting rather wet conditions prior to the onset of runoff producing rainfall.

### **A2.5 Comparison of peak flows**

As the un-named tributary is ungauged, it was not possible to calibrate model parameters to reproduce recorded flows. A comparison of the peak flows generated by the hydrologic model representing pre-project conditions was therefore made with the Probabilistic Rational Method (PRM) of flood estimation as described in IEAust, 1998.

The design discharge hydrographs generated by the DRAINS model were routed in TUFLOW to the inlet of transverse drainage structures EXD4 and EXD7. The resulting peak flows were found to be higher than those derived using the PRM for design storms ranging between 2 and 100 year ARI. The adoption of the model parameters set out above will therefore result in the hydraulic model generating conservatively high peak flood levels and lead to the adoption of transverse drainage structures which are slightly larger than would be assessed should the designers rely on peak flows derived using the PRM for sizing the individual structures.

### **A3. HYDRAULIC MODEL DEVELOPMENT**

#### **A3.1 General**

Detailed two-dimensional hydraulic modelling was undertaken using the TUFLOW software to define flooding behaviour in the vicinity of the project.

TUFLOW is a true two-dimensional (in plan), fully dynamic hydraulic modelling system which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave in a drainage system.

The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. TUFLOW solves the equations of flow at each point of a rectangular grid system which represent ground surface elevations throughout the model domain. TUFLOW allows for a dynamic linkage between the floodplain which is modelled by a two-dimensional grid and the creek and stormwater channels which may be modelled in a one-dimensional sense by cross sections normal to the direction of flow. Pipe networks can also be modelled using the software as one-dimensional elements which are linked dynamically to the two-dimensional domain at the location of surface inlet pits and headwalls.

The structure of a TUFLOW model can be adjusted to assess the impact works on the floodplain will have on flooding behaviour. It can also be adjusted to assess the benefits of various flood mitigation measures such as channel improvement works, levees and flood retarding basins.

#### **A3.2 TUFLOW model structure**

The layout of the TUFLOW model which was developed as part of the present investigation to represent pre-project conditions is shown on **Figure A3.1**.

Data provided by Roads and Maritime were used to describe the key features of the local stormwater drainage system in the vicinity of the project corridor. These data were input to the TUFLOW model and included: internal dimensions of pipes and box culverts; number of conduits; and where available, invert levels.

An important consideration of two-dimensional modelling is how best to represent the roads, fences, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive and it is not practicable to use a mesh of very fine elements without incurring very long times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

After initial model testing, a 2 metre grid spacing was found to provide the appropriate balance between the need to define features on the floodplain versus model run times. Grid elevations were based on available LiDAR survey data. Ridge and gully lines were added to the model where the grid spacing was considered too coarse to accurately represent important topographic features which influence the passage of overland flow, such as road centrelines and footpaths. It was important that the model recognised the ability of roads to capture overland flow and act as floodways.

The footprints of a large number of individual buildings located in the two-dimensional model domain were digitised and assigned a high hydraulic roughness value relative to the more hydraulically efficient roads and flow paths through allotments. This accounted for their blocking effect on flow whilst maintaining a correct estimate of floodplain storage in the model. It was not practicable to model the individual fences surrounding the many allotments in the study area. They comprised many varieties (brick, paling colorbond, etc) of various degrees of permeability and resistance to flow. It was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways.

### **A3.3 Model boundary conditions**

Discharge hydrographs generated by DRAINS were applied at the inflow boundaries of the TUFLOW model. These comprised both inflows applied at the external TUFLOW model boundary and internal point source and region inflows<sup>1</sup> as shown on **Figure A3.1**.

The downstream boundary of the TUFLOW model comprised a tailwater level based on normal depth flow conditions. The model extent was selected to ensure the downstream boundary was located a sufficient distance downstream of the project to prevent any influence on flow behaviour within the vicinity of the proposed road works.

### **A3.4 Model parameters**

The main physical parameter represented in TUFLOW is hydraulic roughness, which is required for each of the various types of surfaces comprising the overland flow paths in the two-dimensional domain, as well as for the culverts and pipes which were incorporated in the model as one-dimensional elements. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity, and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as “Manning’s n”.

Hydraulic roughness values adopted for design purposes were selected based on site inspection, past experience and values contained in the engineering literature (refer **Table A3.1** over the page).

### **A3.5 Sensitivity of flood behaviour to increase in hydraulic roughness**

**Figure A3.2** shows the difference in peak flood levels (i.e. the “afflux”) for the 100 year ARI storm resulting from an assumed 20 per cent increase in hydraulic roughness compared to the “best estimate” values given in **Table A3.1** over the page. The afflux is given in colour coded increments in metres. The figure also identifies areas where land is rendered flood free, or where additional areas of land are flooded.

The investigation found that there would only be a minor increase in peak 100 year ARI flood levels along the un-named tributary in the vicinity of the project as a result of a 20 per cent increase in the best estimate hydraulic roughness values set out in **Table A3.1**.

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<sup>1</sup> In parts of the model area, inflow hydrographs were applied over individual regions called “Rain Boundaries”. The Rain Boundaries act to “inject” flow into the one and two-dimensional domains of the TUFLOW model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Rain Boundary as the grid in the two-dimensional model domain becomes wet as a result of overland flow.

**TABLE A3.1**  
**“BEST ESTIMATE” OF HYDRAULIC ROUGHNESS VALUES**  
**ADOPTED FOR TUFLOW MODELLING**

Surface Treatment	Manning's n Value
Reinforced concrete pipes and box culverts	0.015
Roads	0.02
Concrete channel	0.03
Grassed channels and reserves	0.045
Remnant cleared pasture land	0.045
Stands of trees and macrophytes	0.06
Buildings	10

### **A3.6 Adjustments made to TUFLOW model to reflect post-project conditions**

The concept road design model for the project, as well as details of the transverse drainage and flood mitigation strategy were incorporated in the model. The design discharge hydrographs generated by the hydrologic model representing post-project conditions were also applied to the adjusted model in order to:

- assess the impact the project would have on flooding behaviour; and
- assess the flood risks to the project.

**Figures 6.1, 6.2 and 6.3** show the key features of the proposed transverse drainage and flood mitigation strategy for the project, while **Table 6.1** in **Chapter 6** of the report provides details of the upgraded transverse drainage

#### **A4. ASSESSMENT OF POTENTIAL BASIN EMBANKMENT FAILURE**

In order to assess the impact a potential failure of the embankment associated with the proposed flood retarding basin on flooding behaviour it was necessary to undertake a preliminary dam break analysis using the TUFLOW model. The results of the TUFLOW modelling were then used to undertake a preliminary assessment of the “Flood” Consequence Category of the basin.

The stage hydrograph experienced as a result of embankment failure would depend on a number of factors, including:

- The shape of the breach discharge hydrograph at the wall, which is dependent on the rate of erosion of the embankment (a function of the depth of overtopping, the materials used and their state of compaction); as well as the stage versus volume relationship in the impoundment.
- The hydraulic characteristics of the stream between the basin and existing development; as well as the conveyance capacity and flood storage in the channel and floodplain.
- Concurrent flooding in adjacent tributaries.

**Table A4.1** shows the characteristics of the proposed flood retarding basin, as well as the adopted dam break parameters. The time to failure and ultimate breach geometry was determined using the Von Thun and Gillette (1990) relationships developed from a case study of 57 dam failures in the United States of America and documented in Wahl, 1998.

**TABLE A4.1**  
**FLOOD RETARDING BASIN CHARACTERISTICS**  
**AND DAM BREAK PARAMETERS**

Condition	Attribute	Value
As-Designed	Crest Elevation (m AHD)	63.5
	Spillway Elevation (m AHD)	63.0
	Storage Volume at Spillway Level (m <sup>3</sup> )	26,000
Dam Break Parameters <sup>(2)</sup>	Average Breach Width (m)	17.5
	Breach Formation Time (hrs)	0.3
	Breach Side Slope (V:H)	1:1

1. Derived from the Von Thun and Gillette (1990) method contained in Wahl, 1998.

The worst case dam failure scenario was adopted for this scoping study. For this the following assumptions were made:

- The embankment fails in-line with the thalweg of the downstream watercourse; and
- when the water level in a 100 year ARI storm event reaches the elevation of the spillway.

The TUFLOW hydraulic model was used to simulate the failure of the embankment based on the breach parameters in **Table A4.1** and route the flood wave through the drainage system. The findings of the investigation are presented in **Section 7.6** of the technical working paper.



## **A5. REFERENCES**

Bureau of Meteorology, 2003. *"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"*.

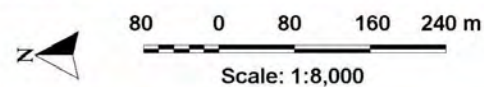
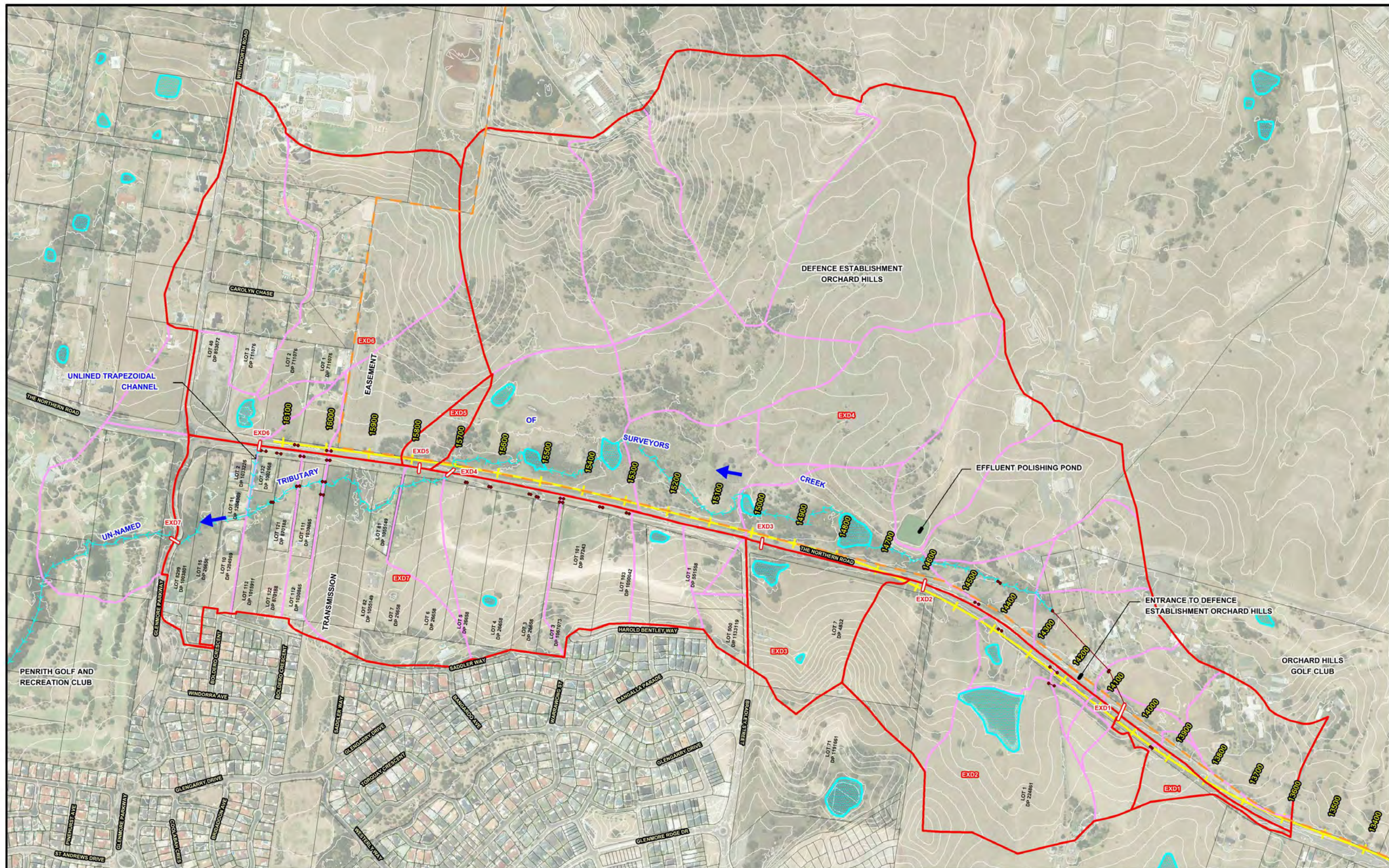
The Institution of Engineers, Australia, 1998. *"Australian Rainfall and Runoff – A Guide to Flood Estimation"*.

Von Thun J. L. and Gillette D. R. (1990), *"Guidance on Breach Parameters – A Needs Assessment."* Un-published U.S. Bureau of Reclamation document, Denver Colorado, 17 p.

Wahl T. L. (1998), *"Prediction of Embankment Breach Parameters."* DSO-98-044, U.S. Department of the Interior, Bureau of Reclamation – Dam Safety Office.

# FIGURES





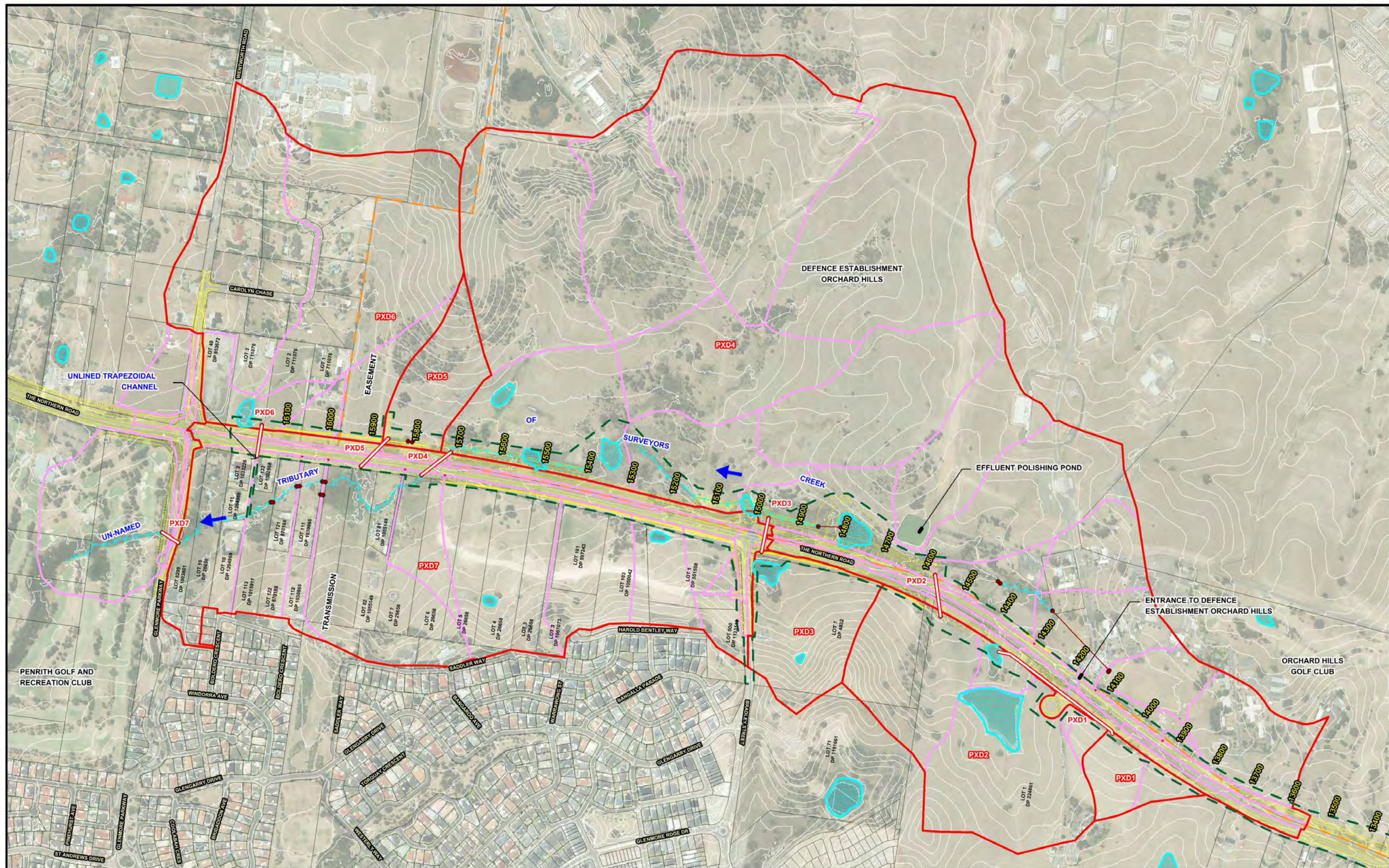
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  - EXD1 Existing Transverse Drainage Structure and Identifier
  - Design Road Control String and Chainage
  - Sub-Catchment Boundary
  - Defence Establishment Orchard Hills Boundary
  - ▨ Existing Dam

## THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure A2.1

SUB-CATCHMENT COMPRISING HYDROLOGIC MODEL  
PRE-PROJECT CONDITIONS



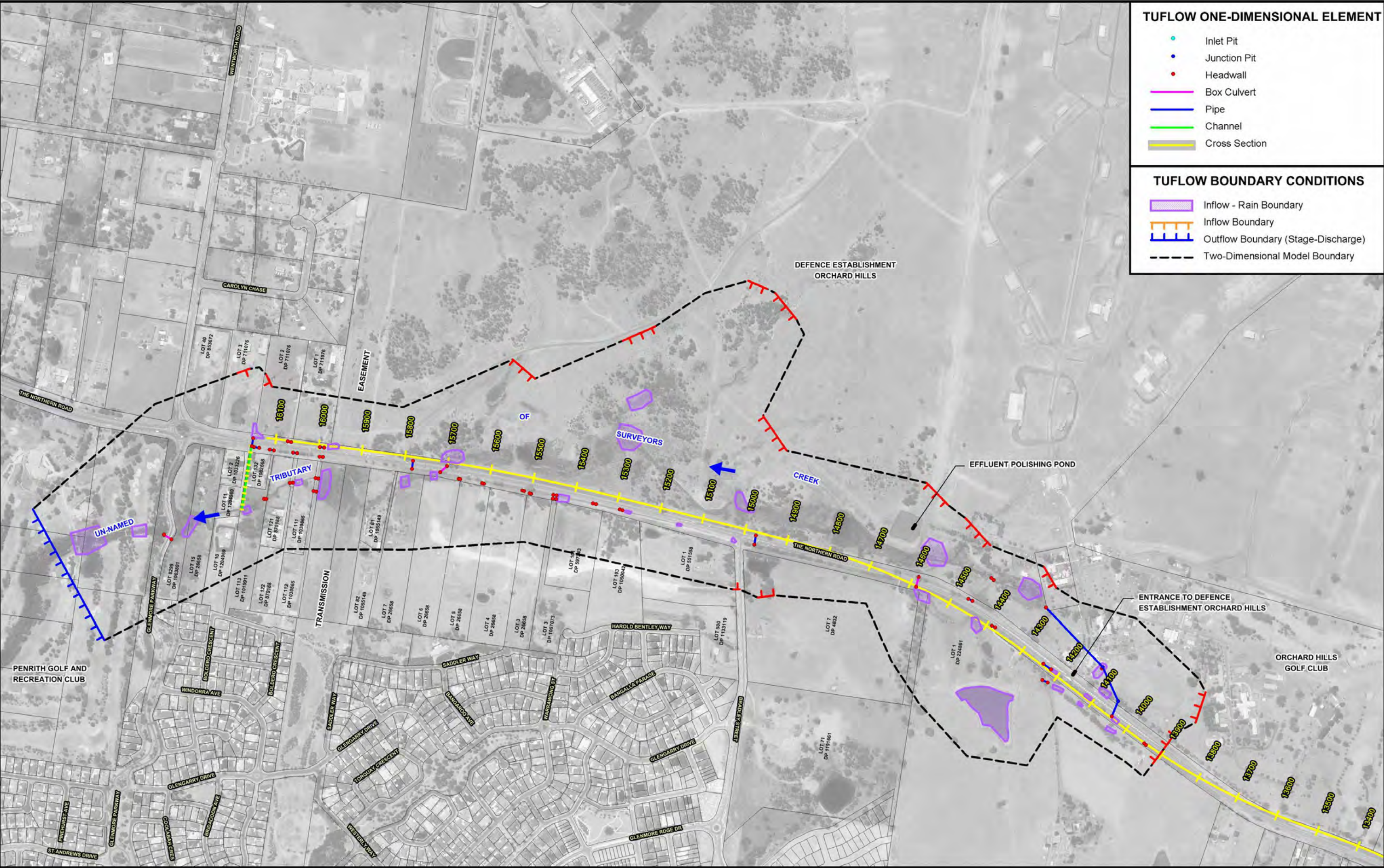


# THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure A2.2

SUB-CATCHMENT COMPRISING HYDROLOGIC MODEL  
POST-PROJECT CONDITIONS





**TUFLOW ONE-DIMENSIONAL ELEMENT**

- Inlet Pit
- Junction Pit
- Headwall
- Box Culvert
- Pipe
- Channel
- Cross Section

**TUFLOW BOUNDARY CONDITIONS**

- Inflow - Rain Boundary
- Inflow Boundary
- Outflow Boundary (Stage-Discharge)
- Two-Dimensional Model Boundary

80 0 80 160 240 m

Scale: 1:8,000

**LEGEND**

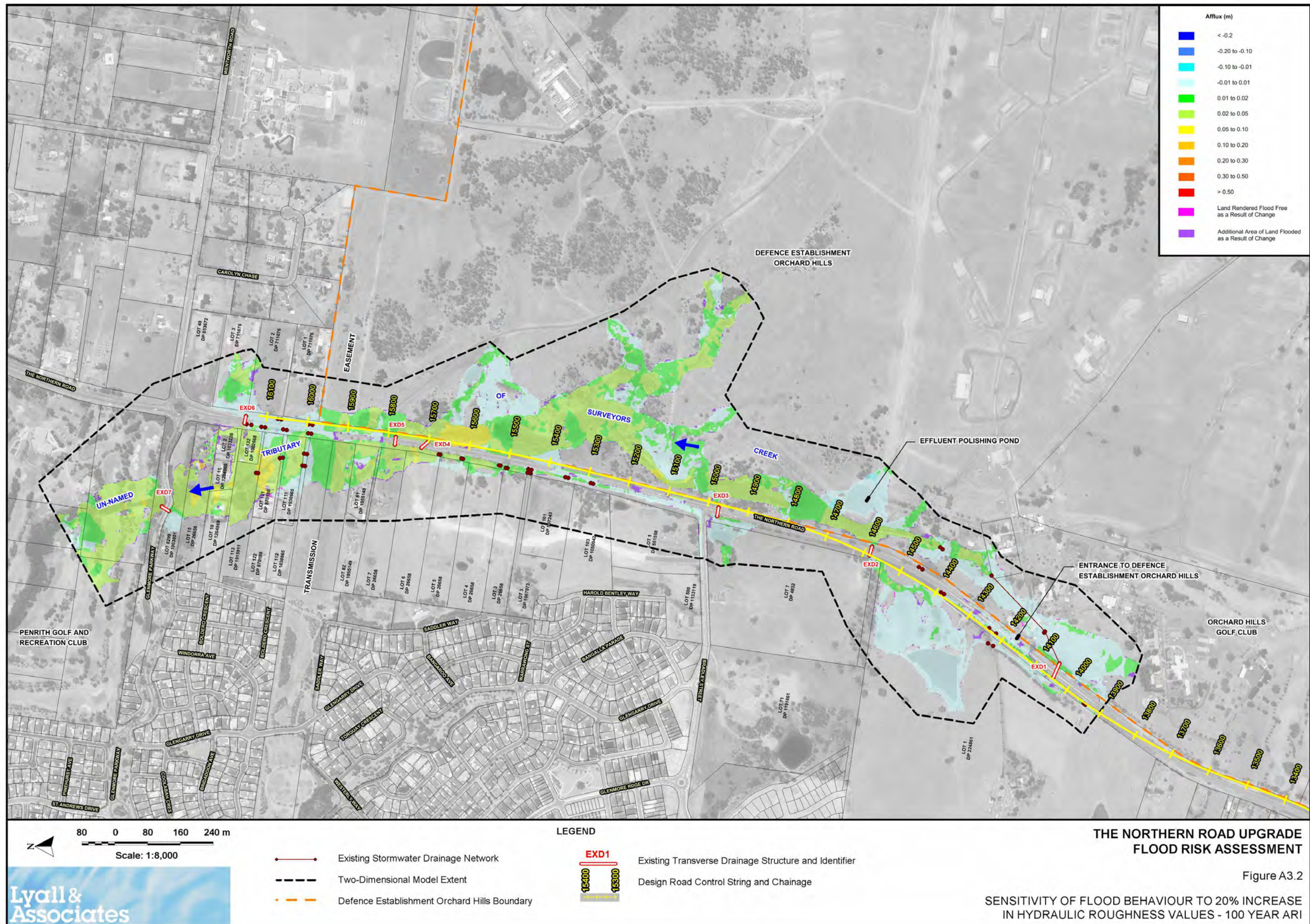
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Design Road Control String and Chainage

**THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT**

Figure A3.1

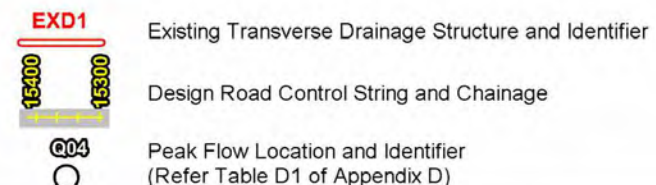
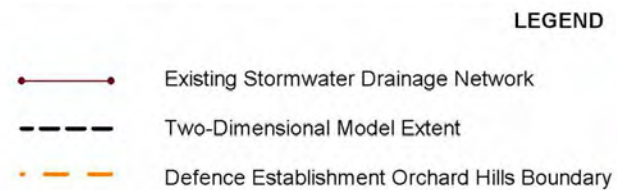
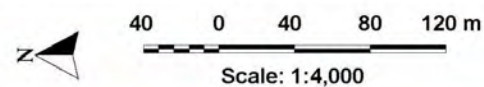
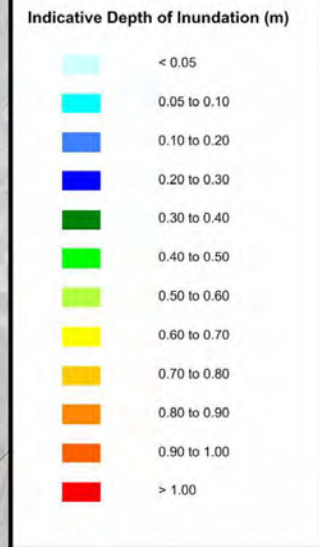
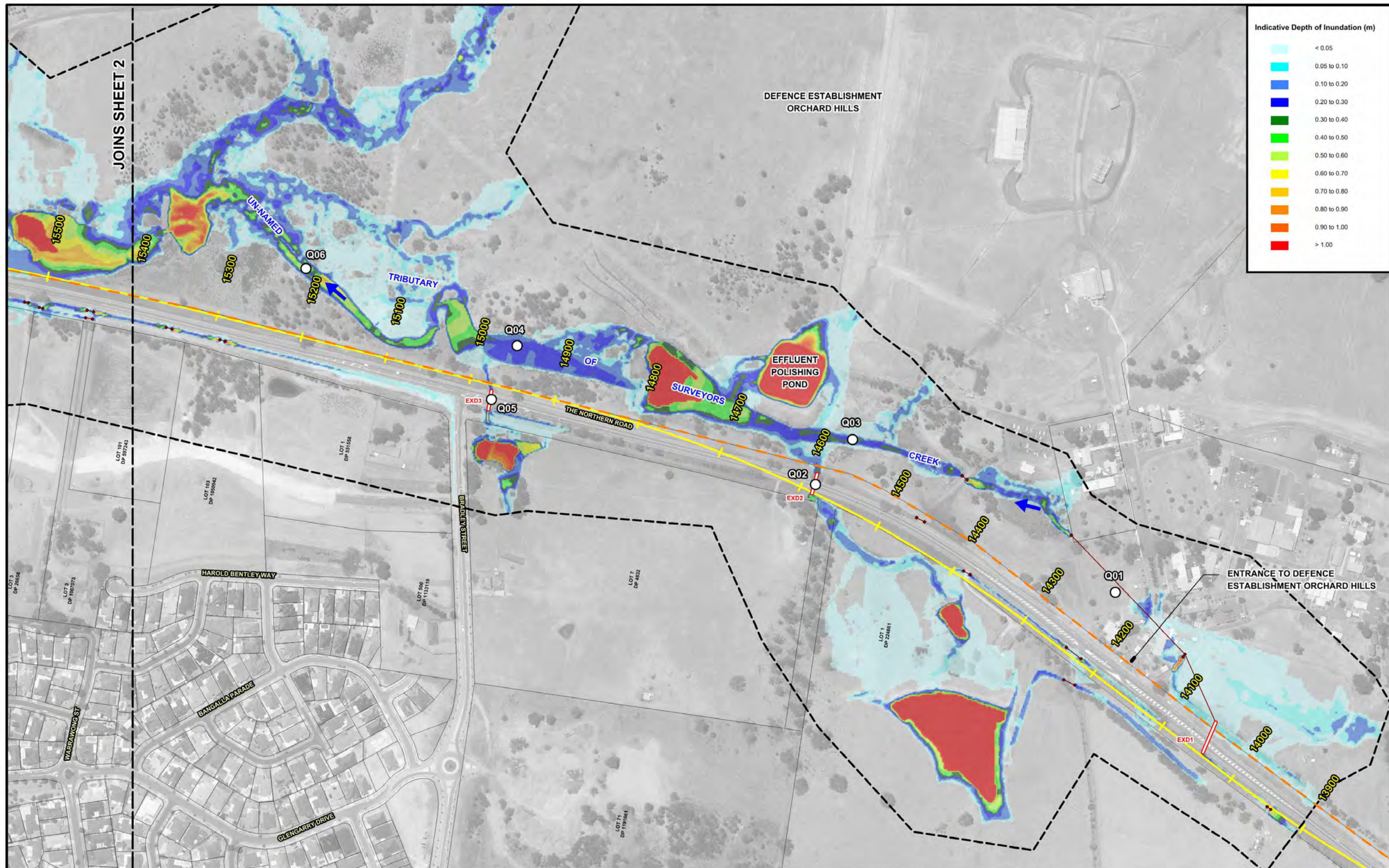






**APPENDIX B**  
**FIGURES SHOWING TUFLOW MODEL RESULTS**  
**PRE-PROJECT CONDITIONS**



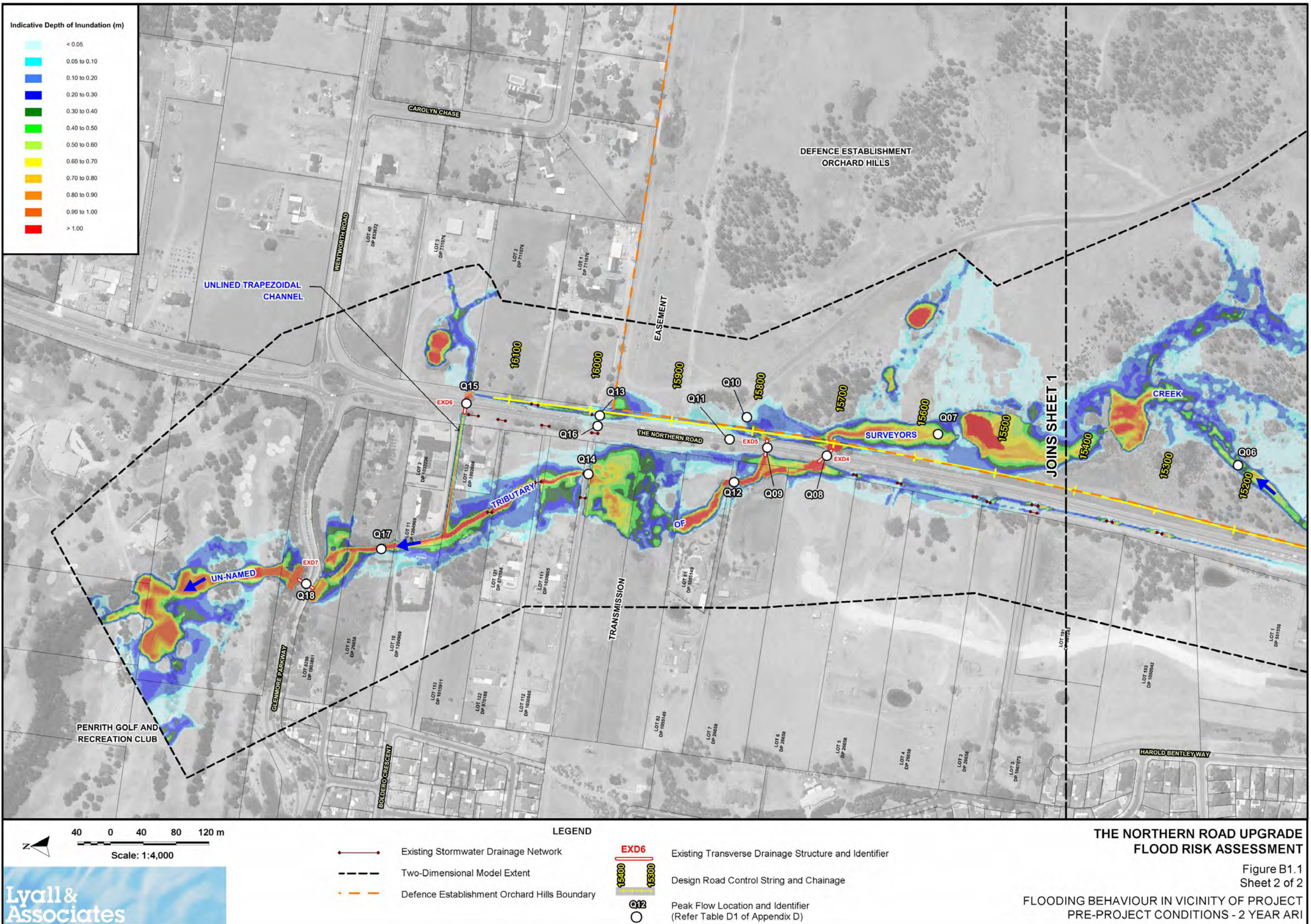


# THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

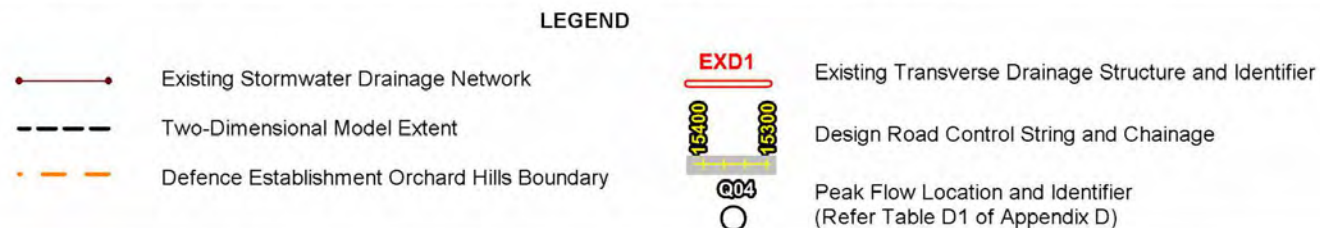
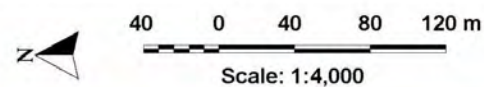
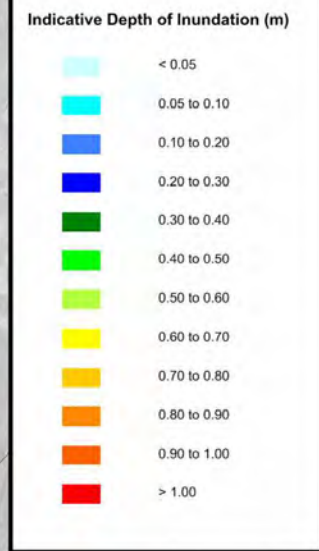
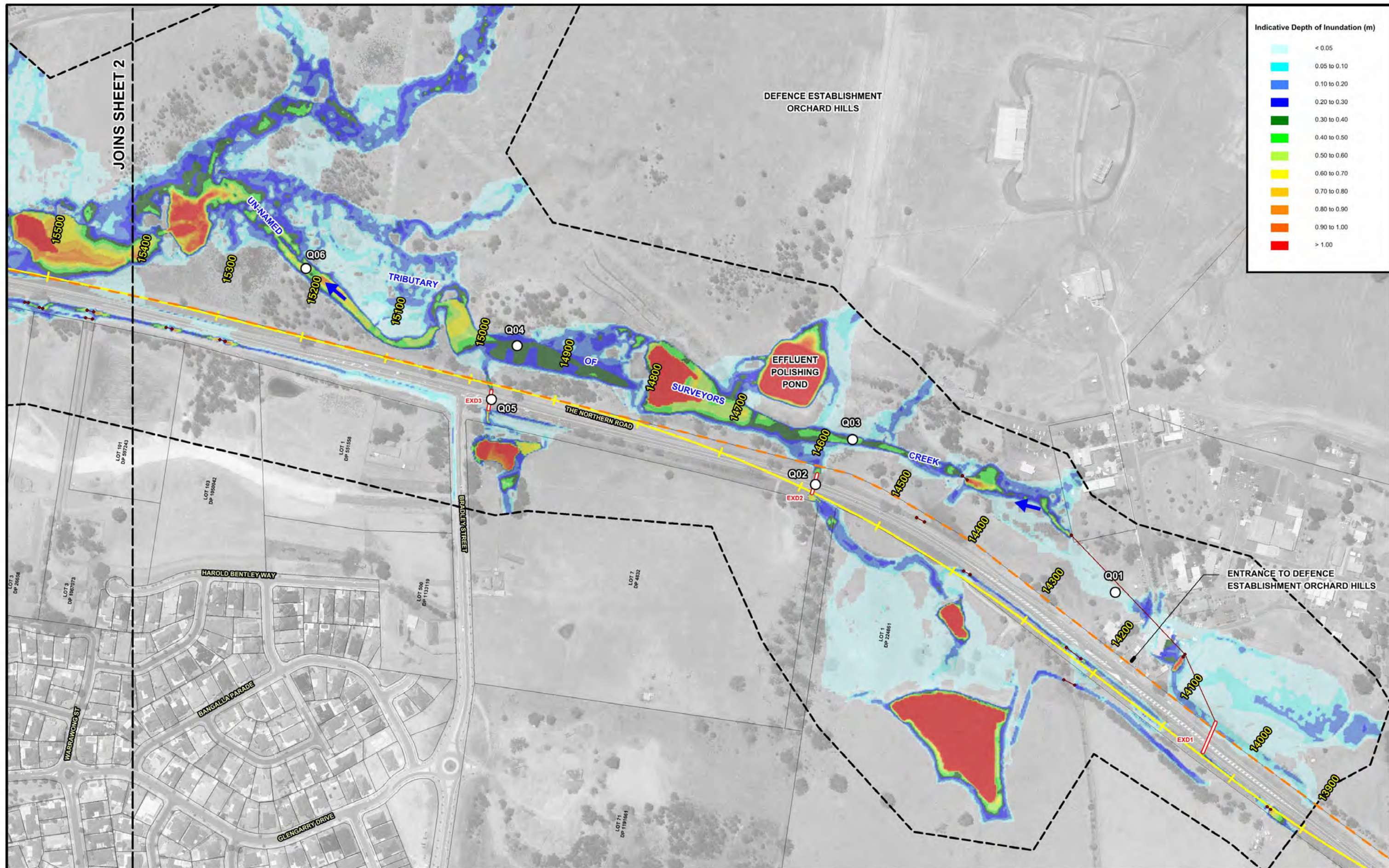
Figure B1.1  
Sheet 1 of 2

FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
PRE-PROJECT CONDITIONS - 2 YEAR ARI









# THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

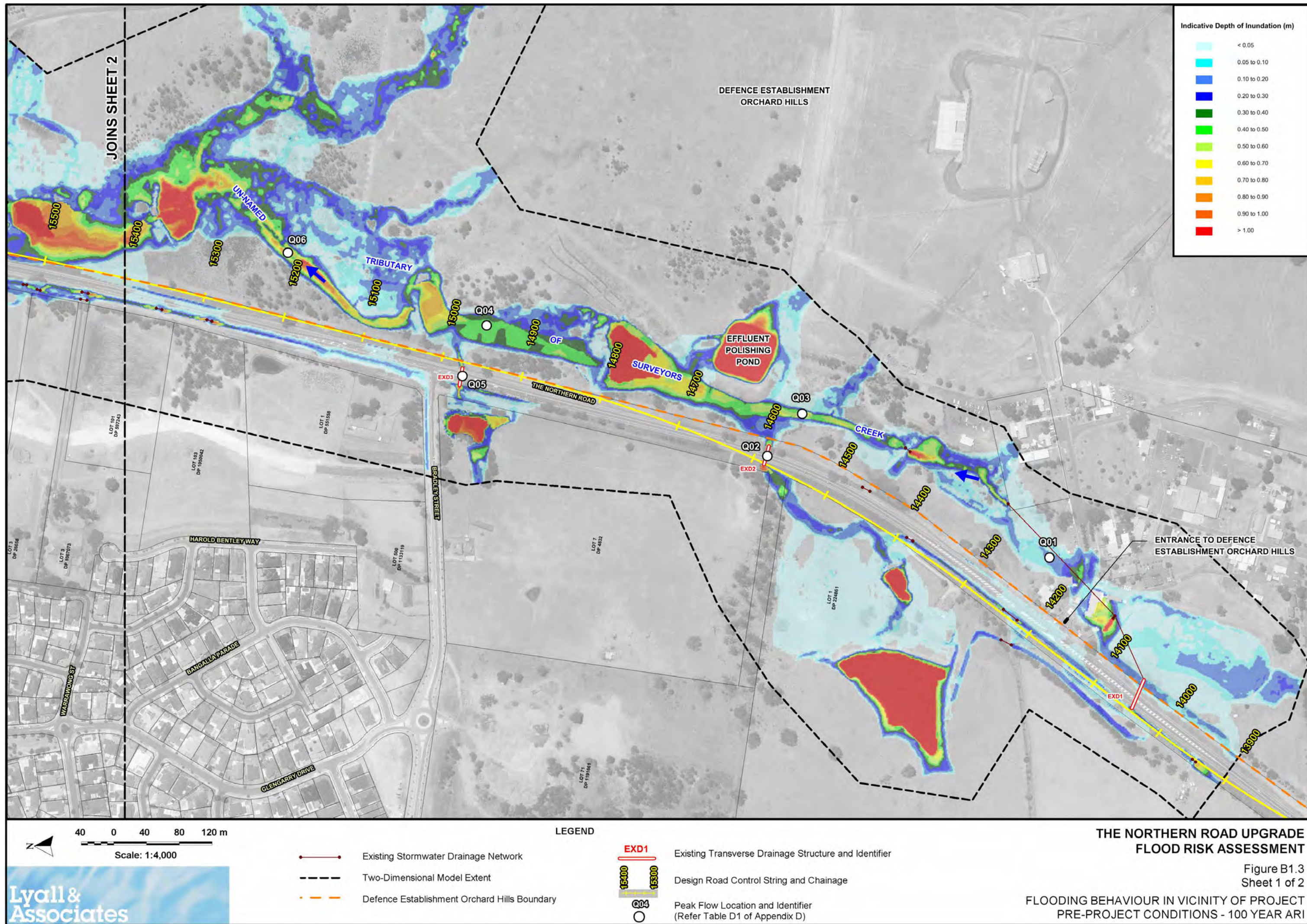
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Sheet 1 of 2

FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
PRE-PROJECT CONDITIONS - 10 YEAR ARI

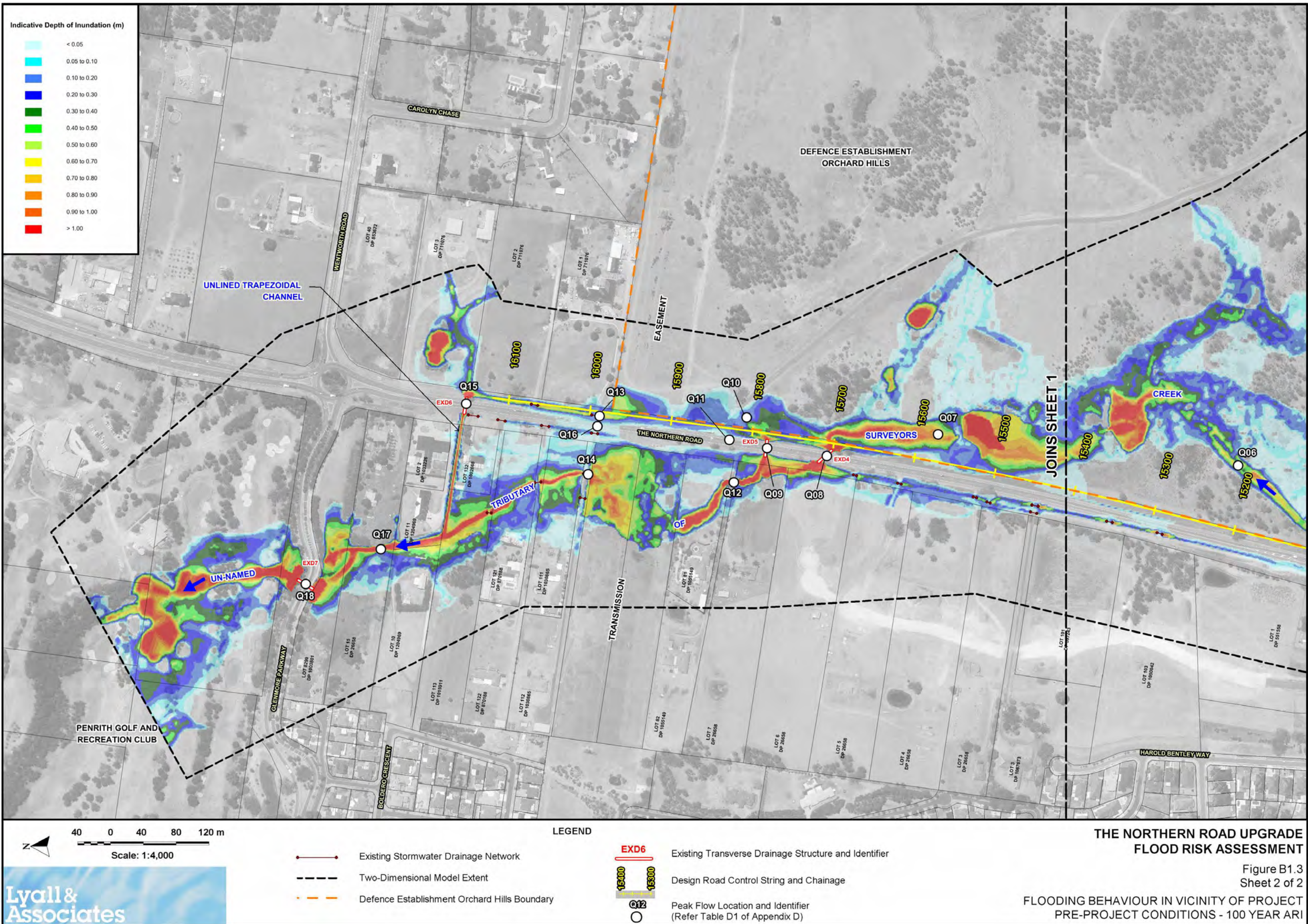




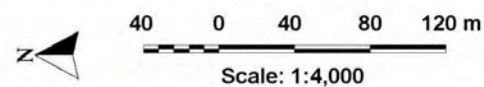
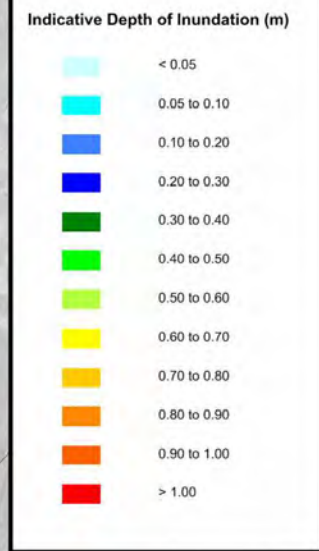
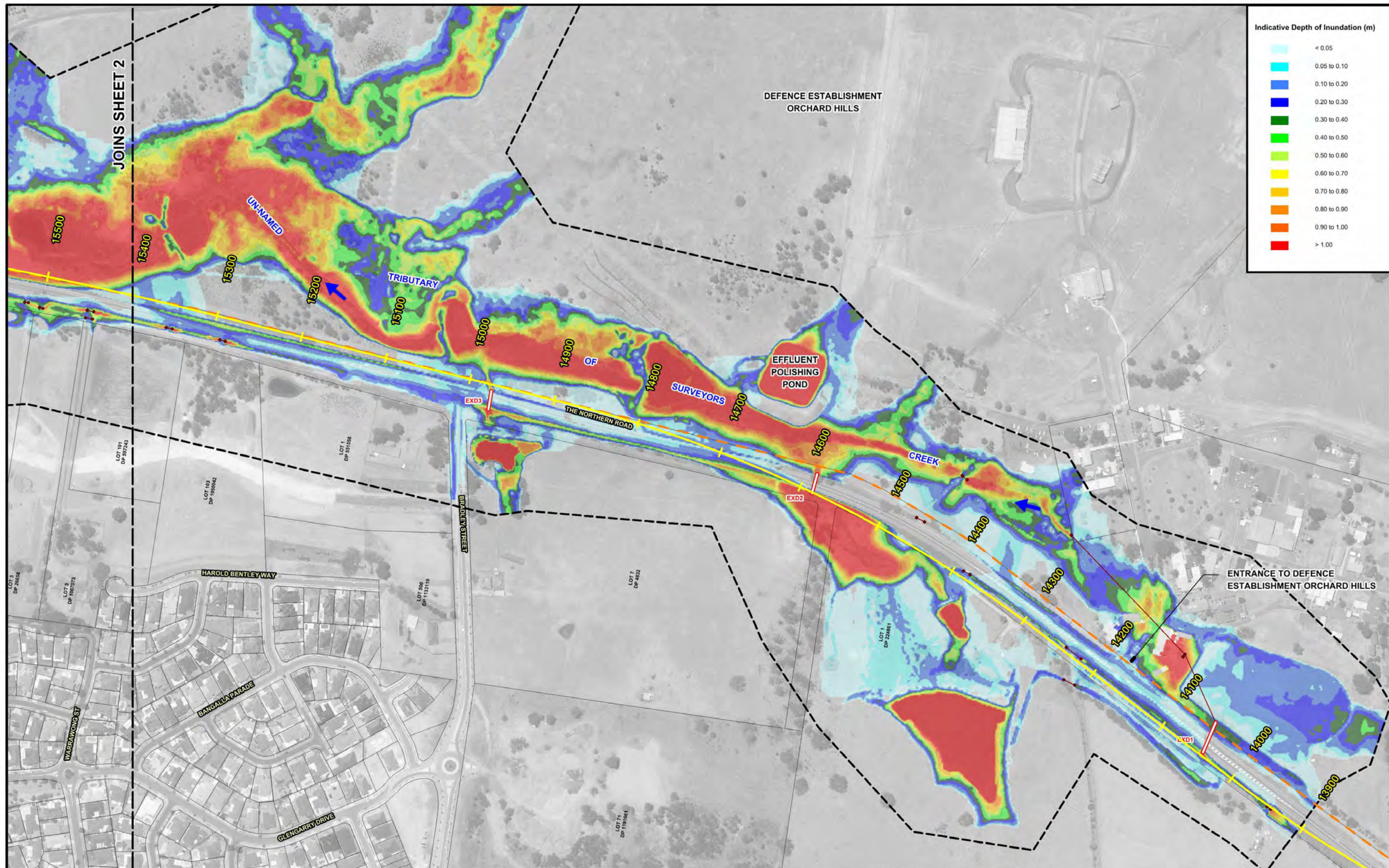












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  - Defence Establishment Orchard Hills Boundary

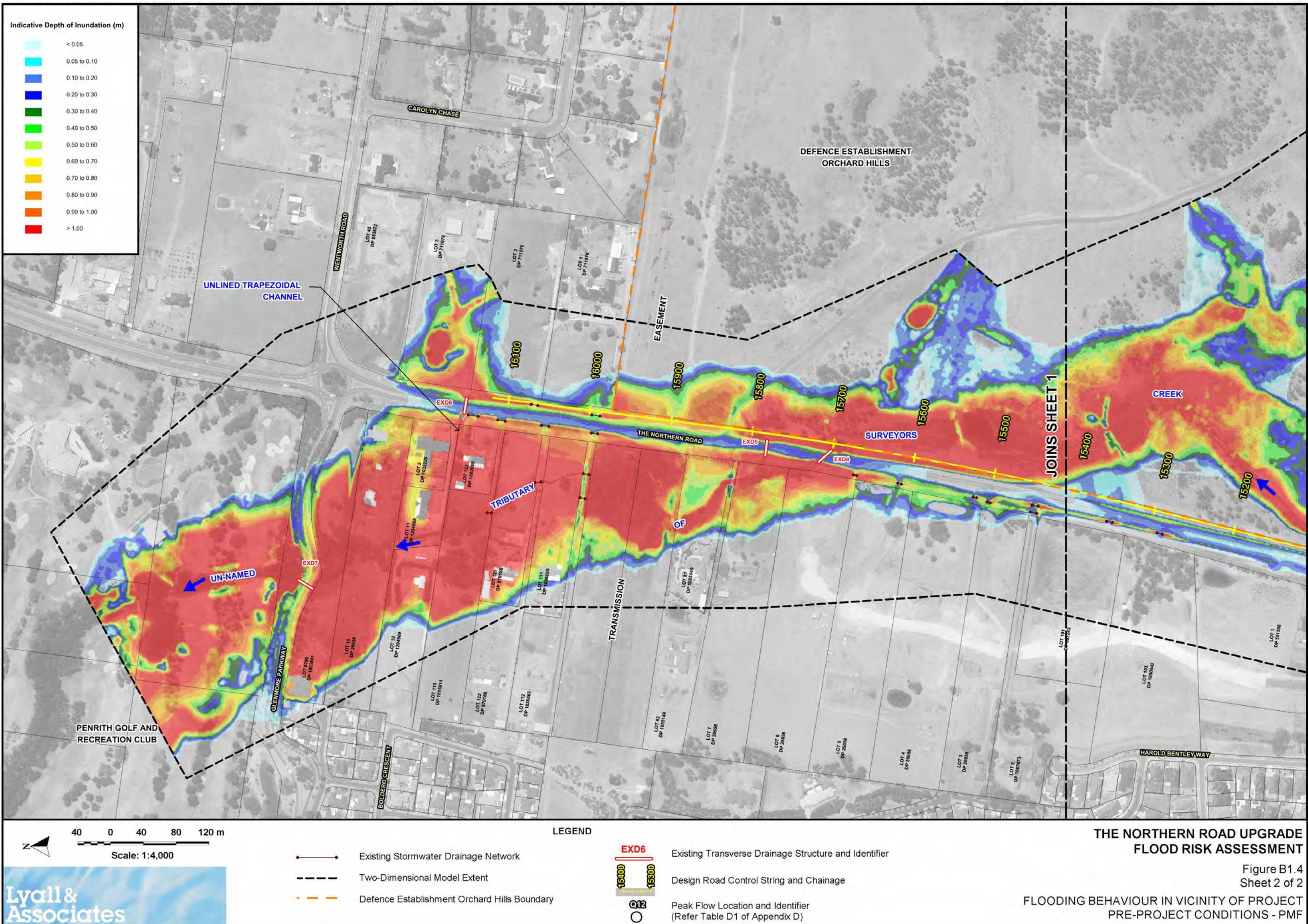
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- Design Road Control String and Chainage
- Q04  
Peak Flow Location and Identifier  
(Refer Table D1 of Appendix D)

# THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure B1.4  
Sheet 1 of 2

FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
PRE-PROJECT CONDITIONS - PMF

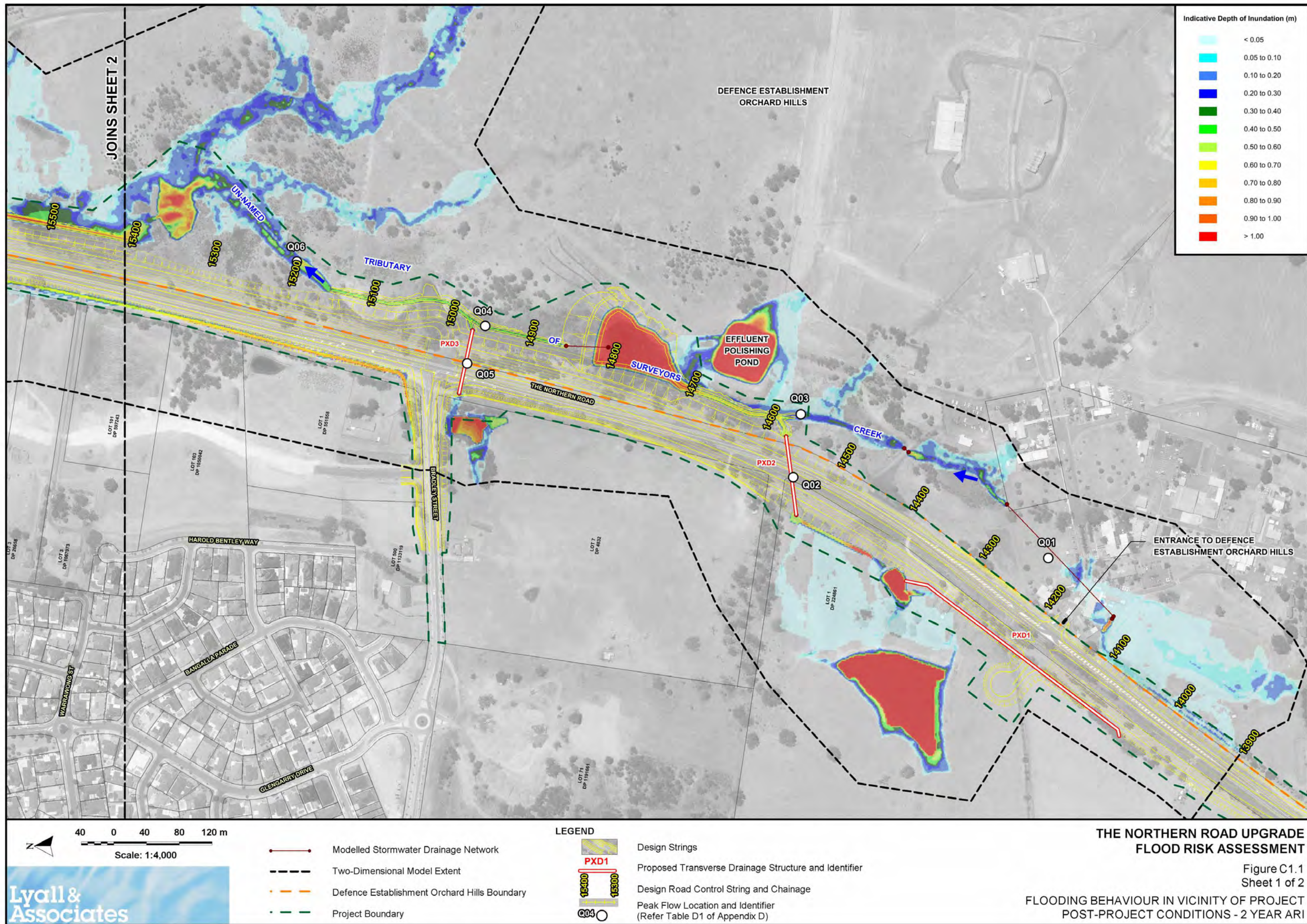




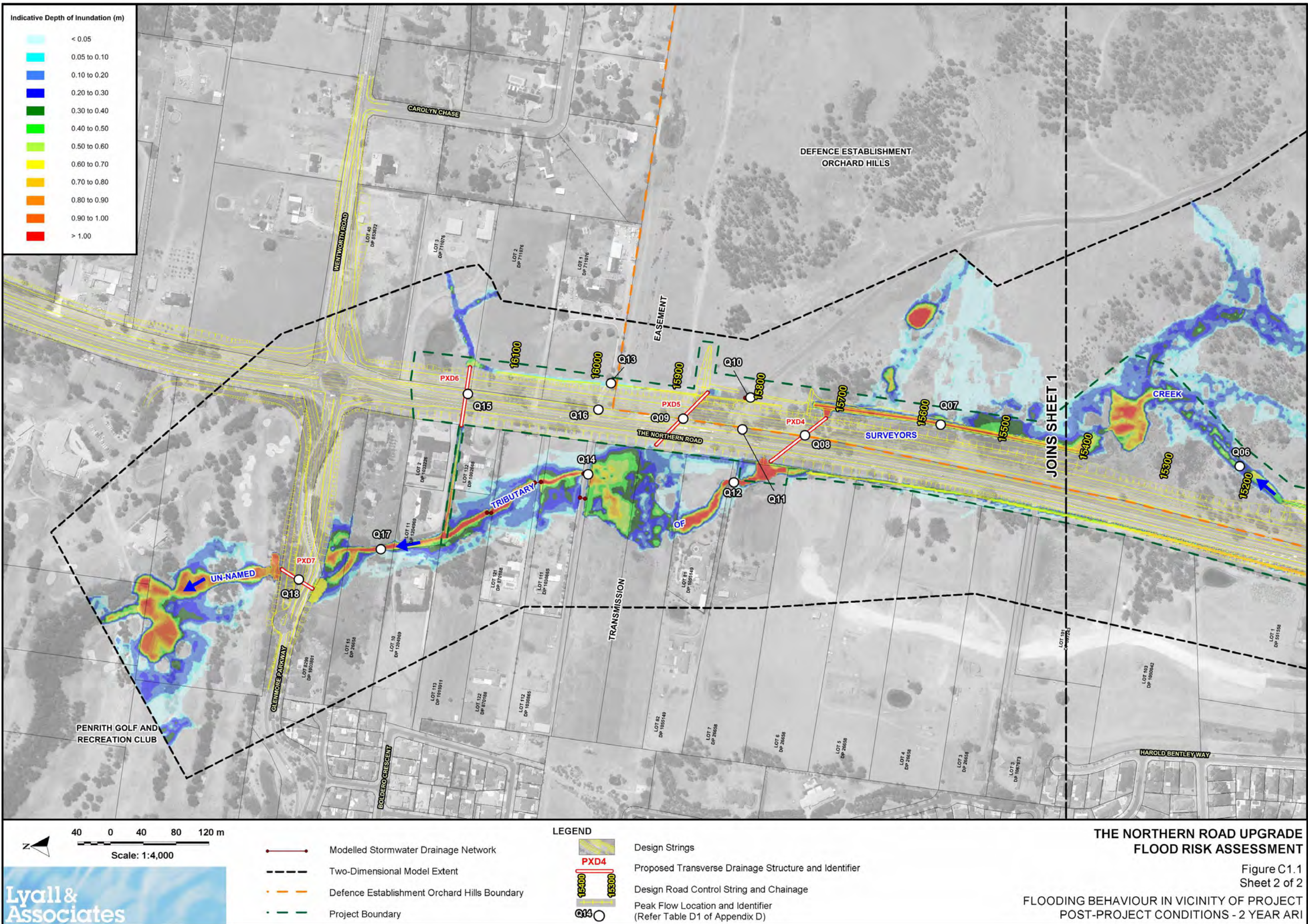


**APPENDIX C**  
**FIGURES SHOWING TUFLOW MODEL RESULTS**  
**POST-PROJECT CONDITIONS**

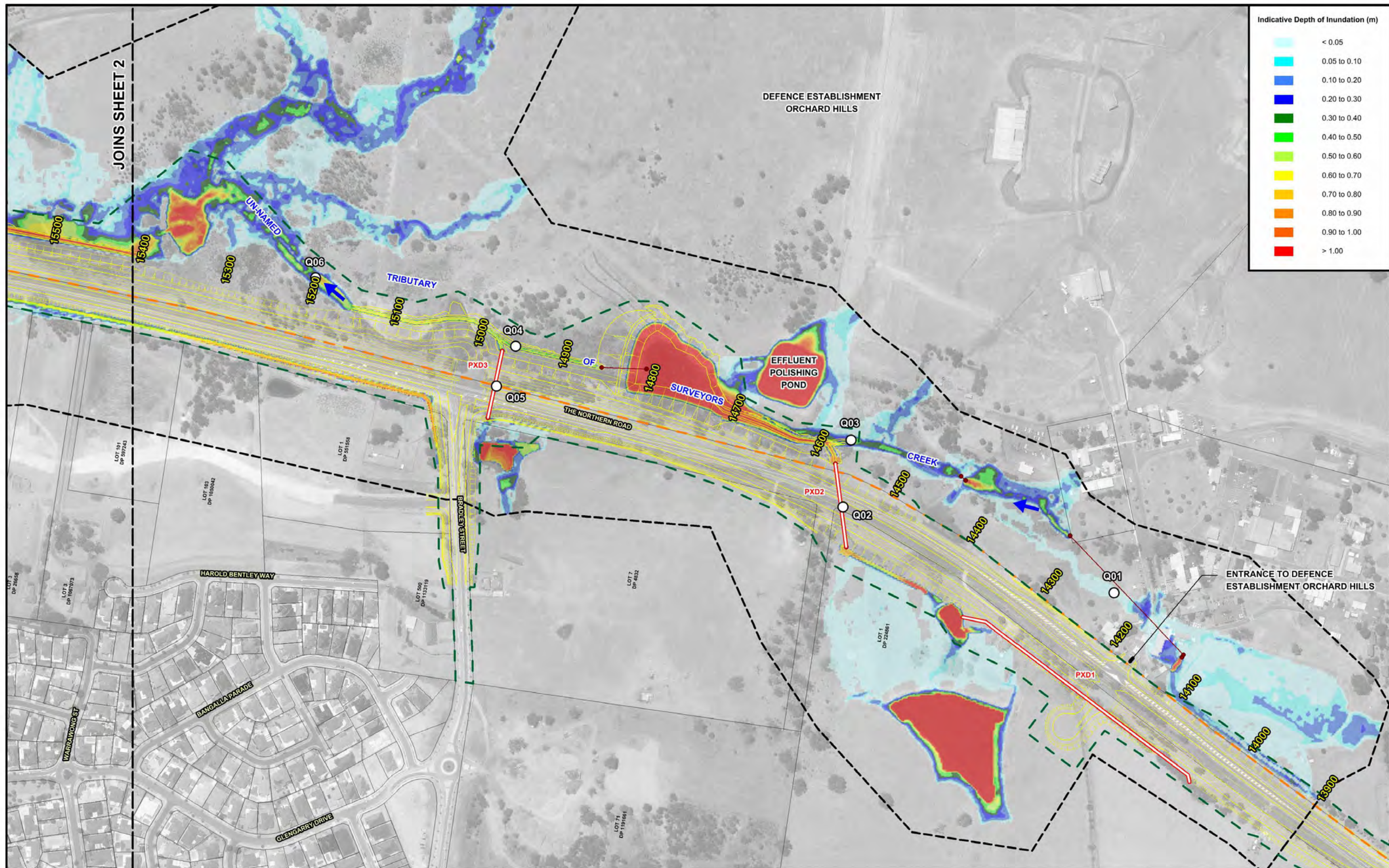




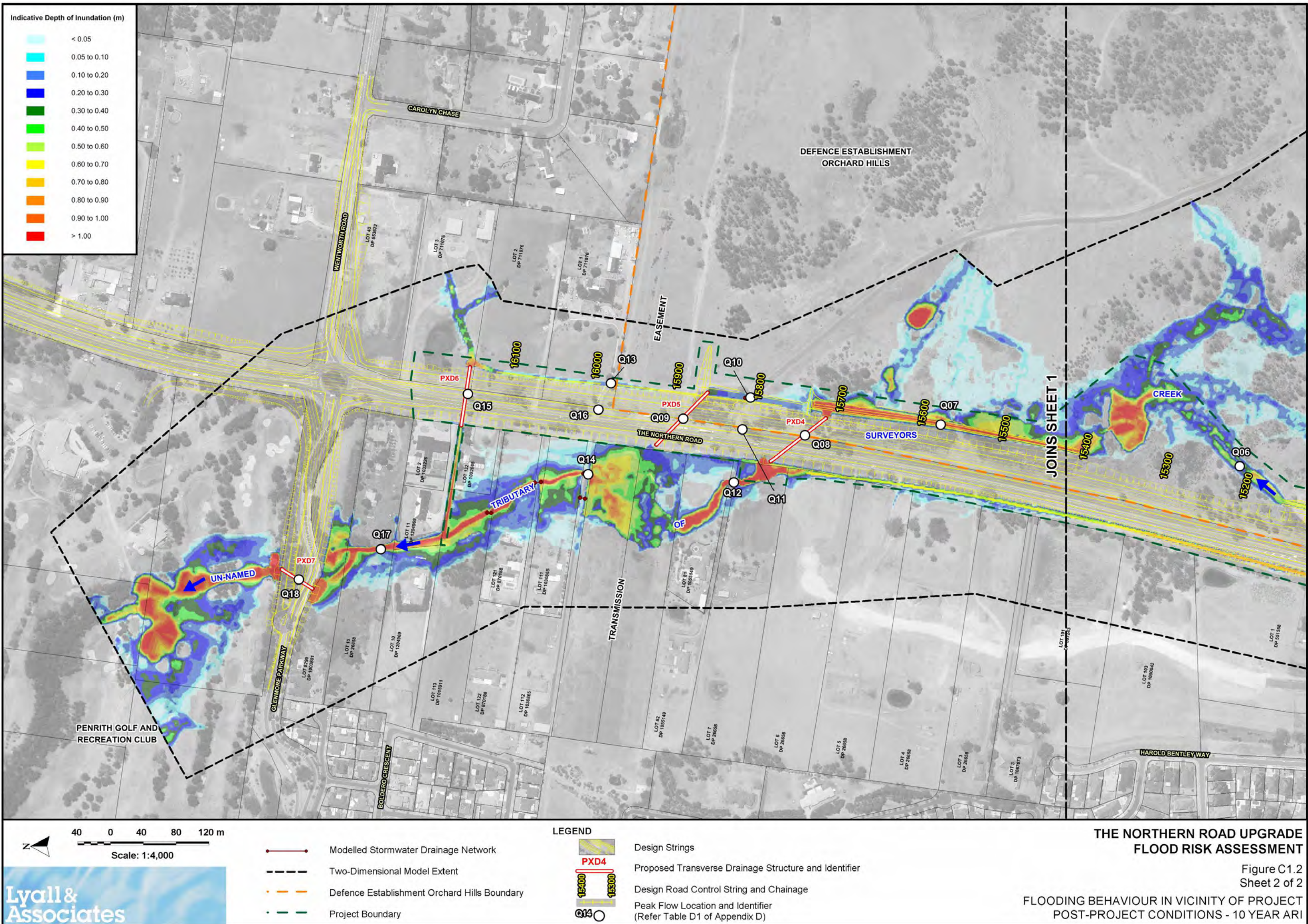




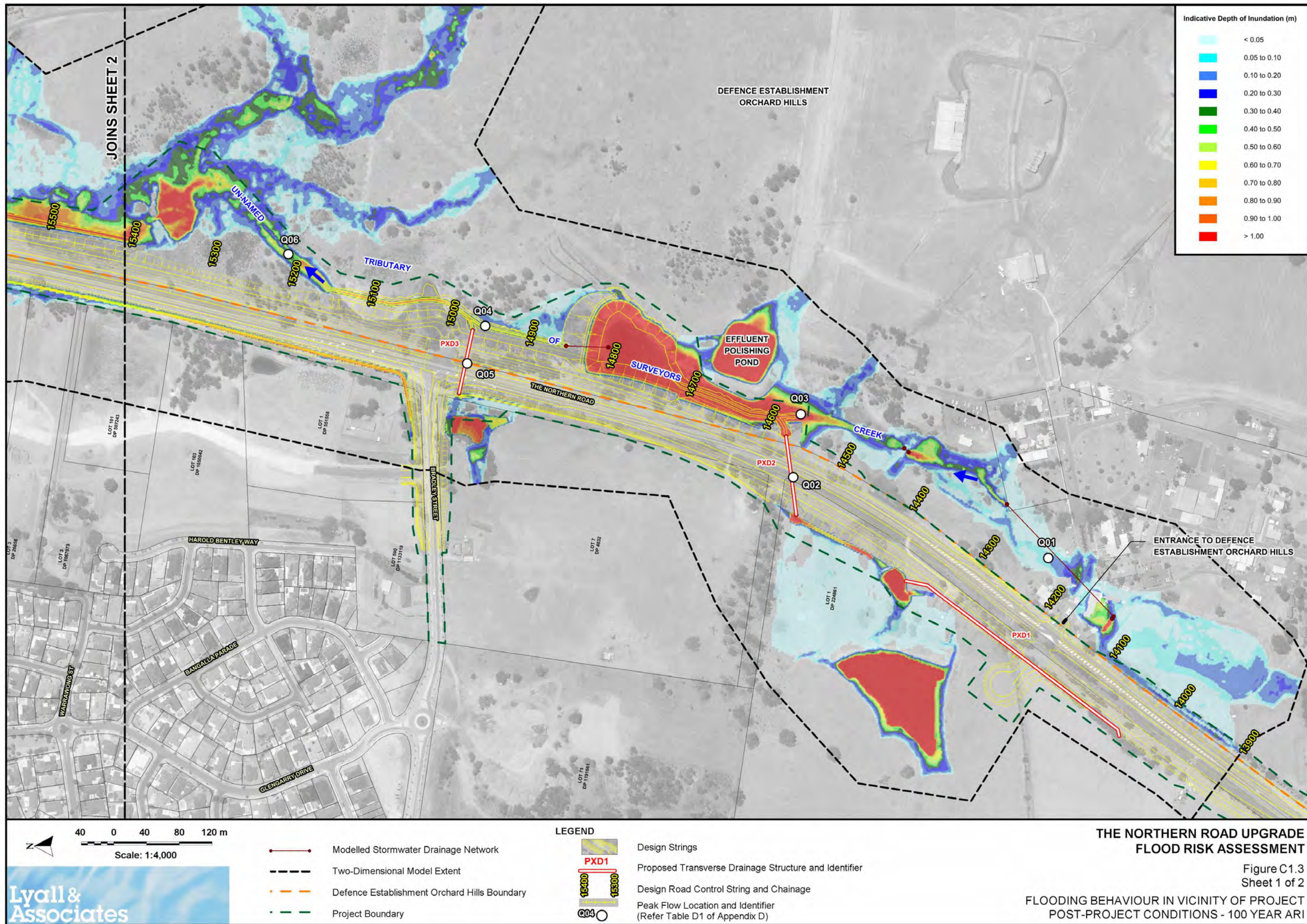




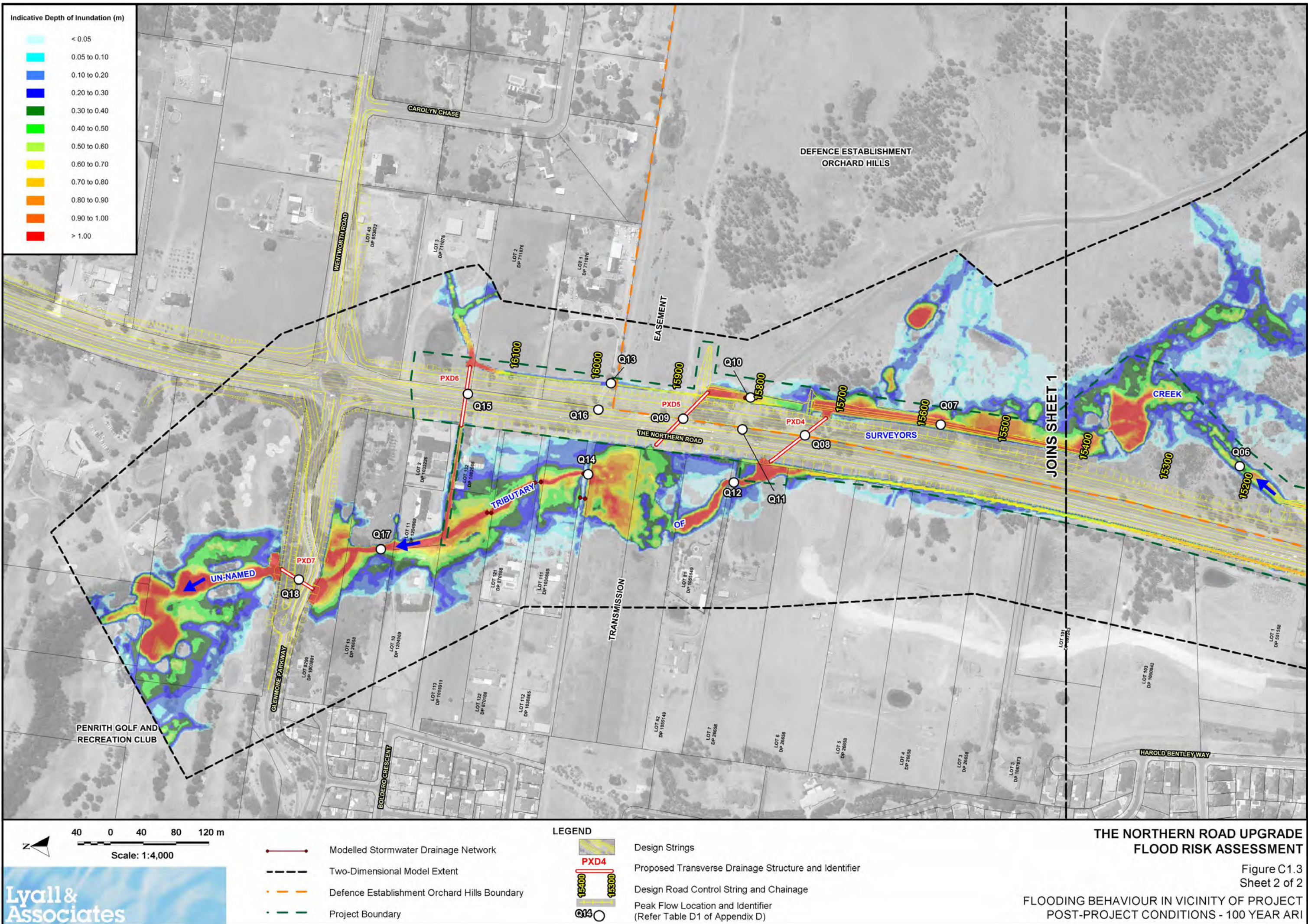




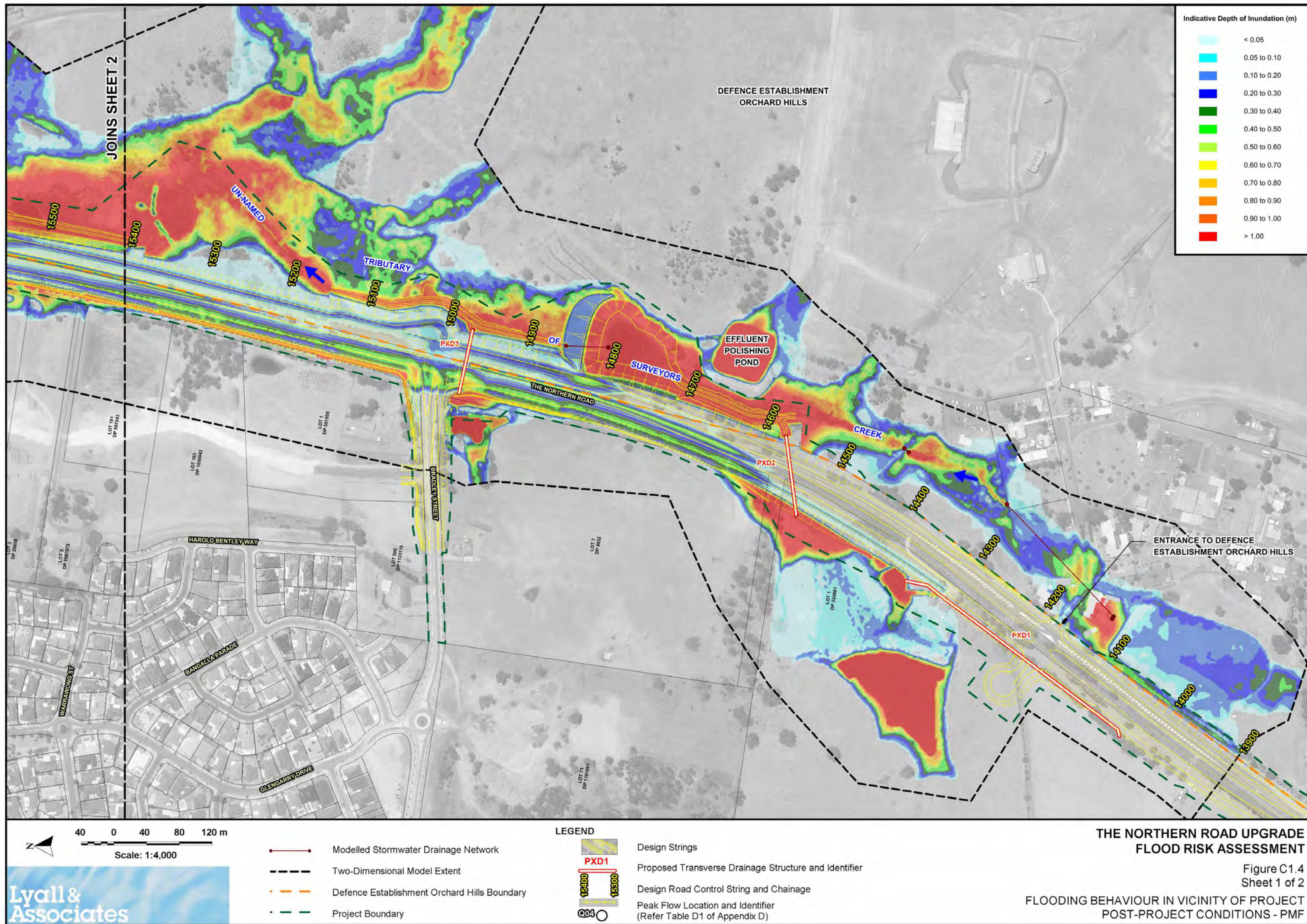




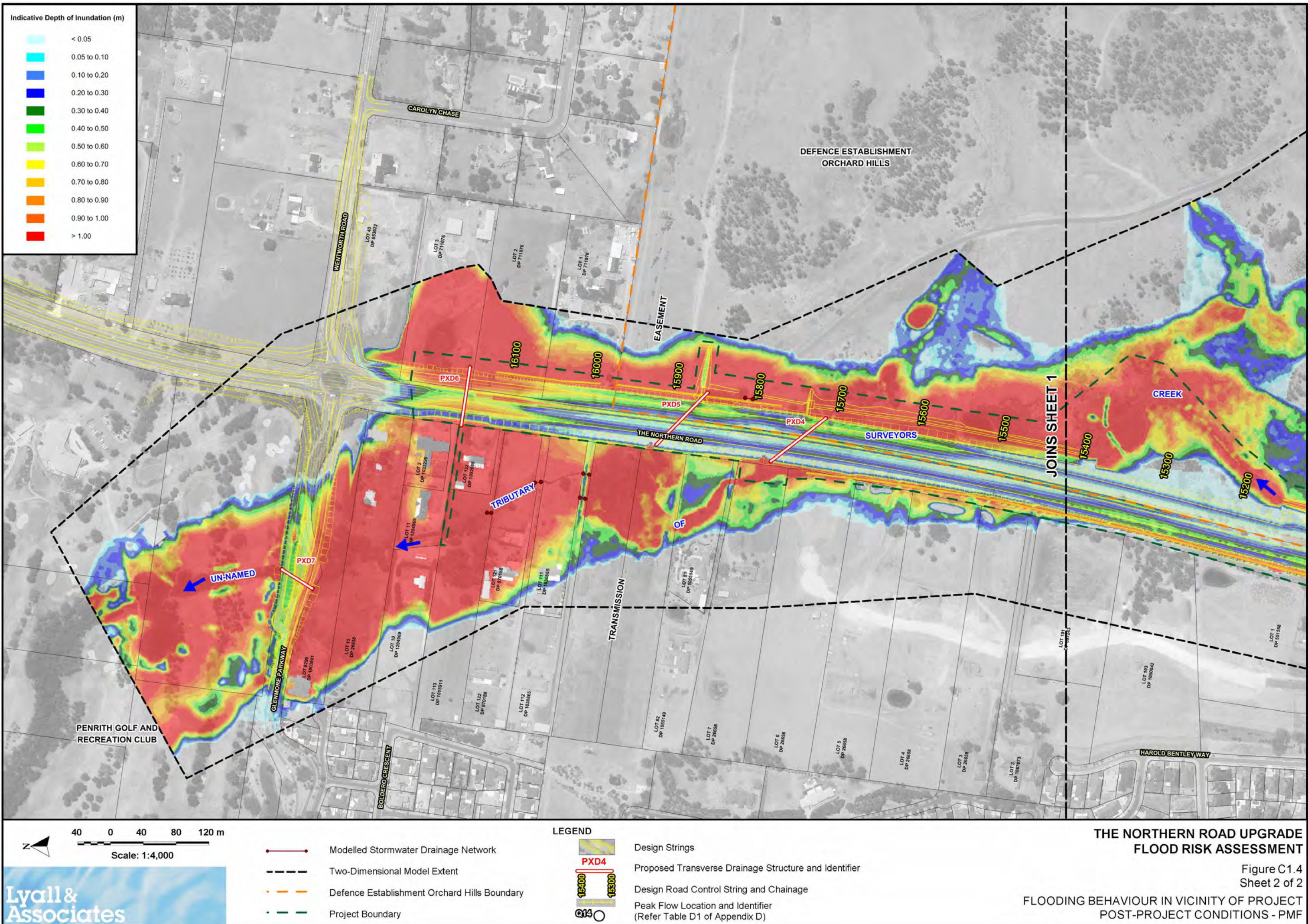




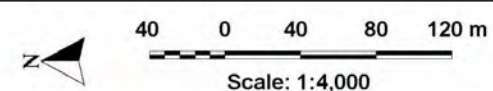
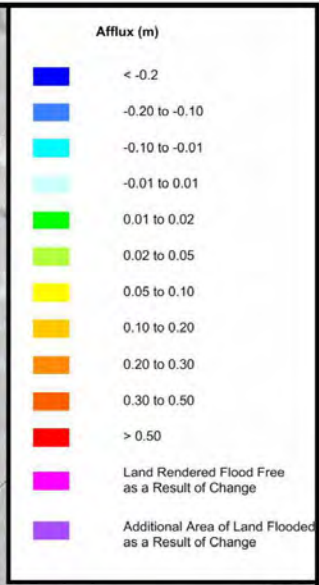
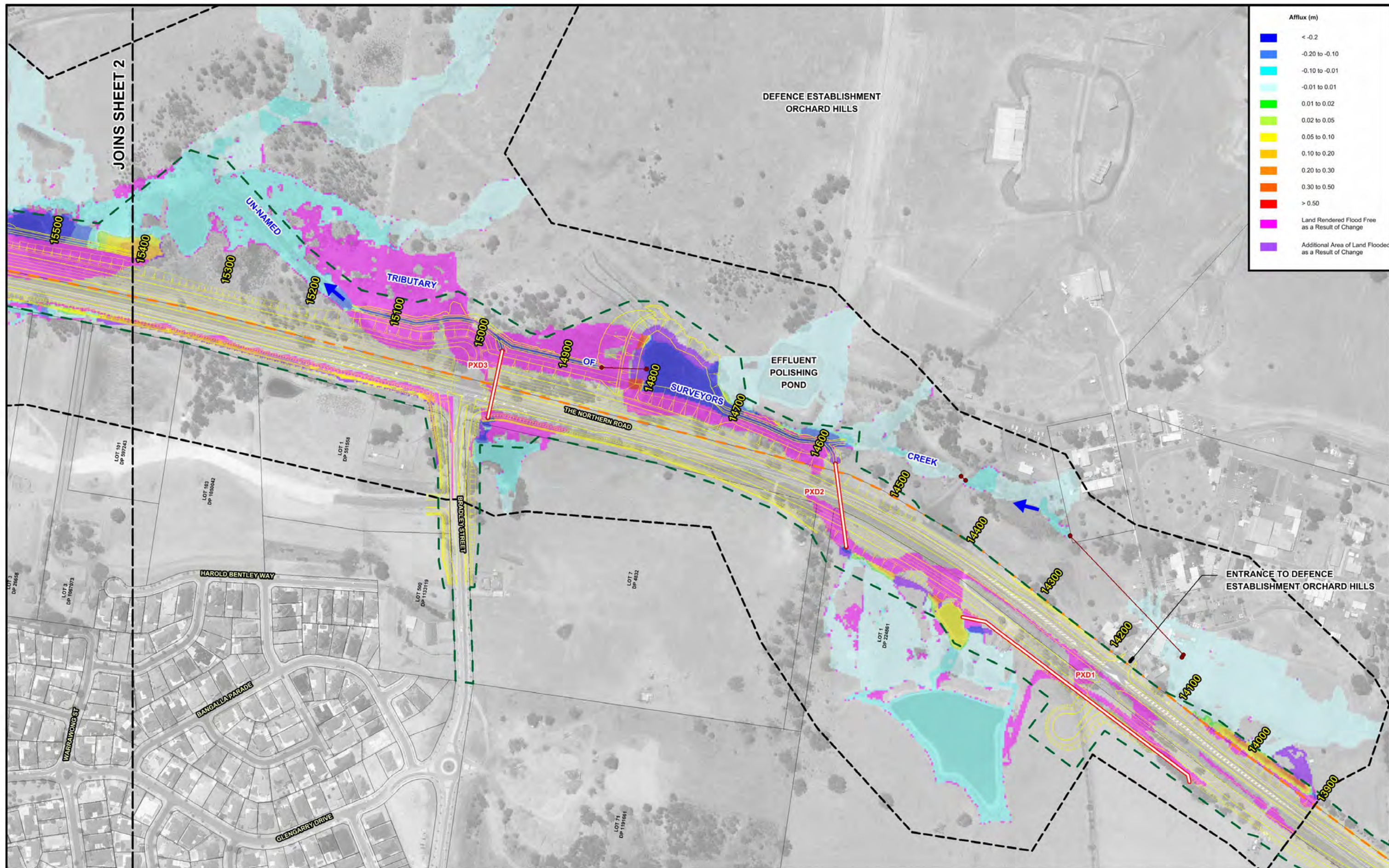












- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
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- Project Boundary

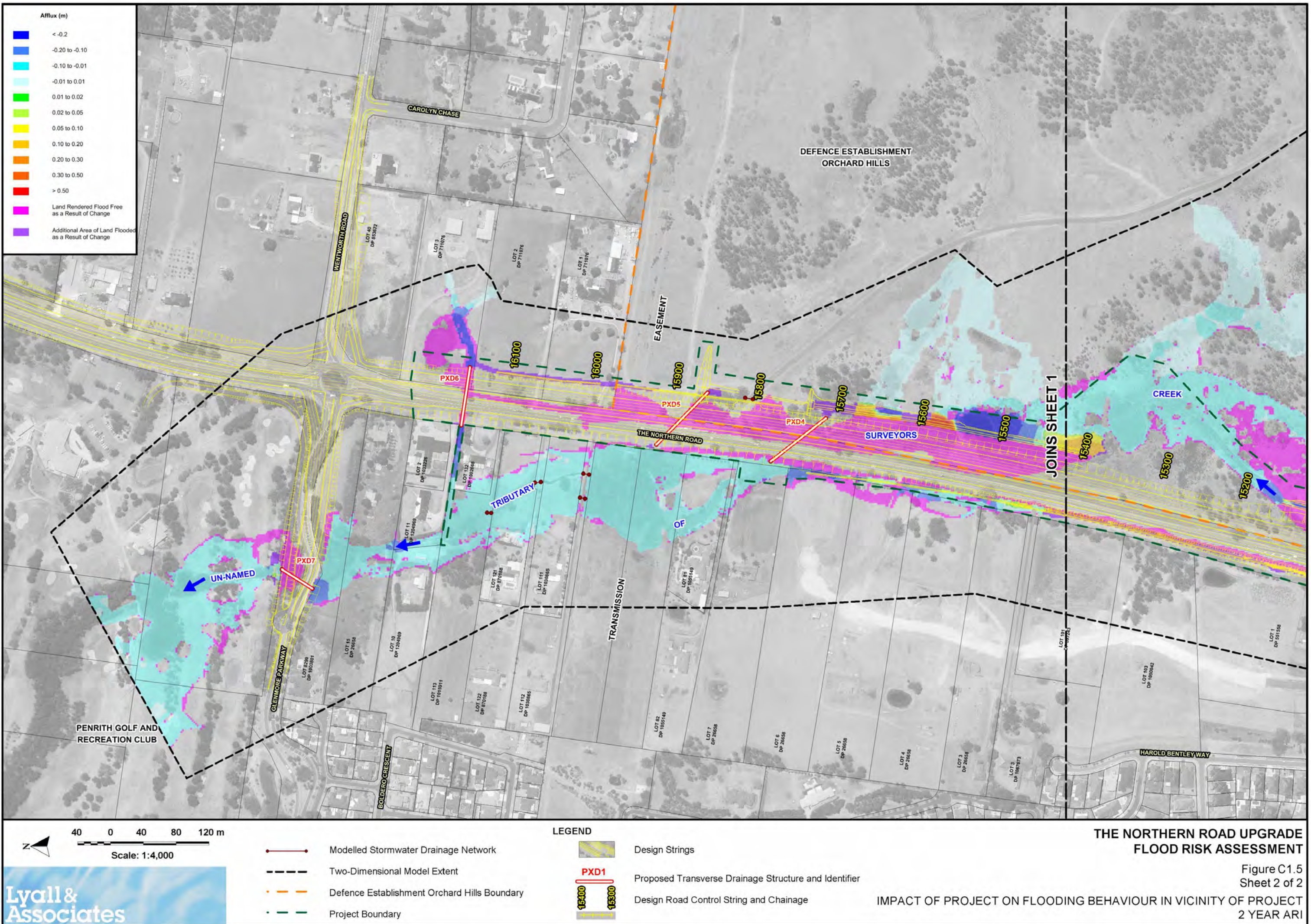
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  - Proposed Transverse Drainage Structure and Identifier
  - Design Road Control String and Chainage

## THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

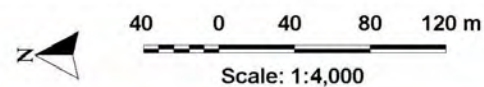
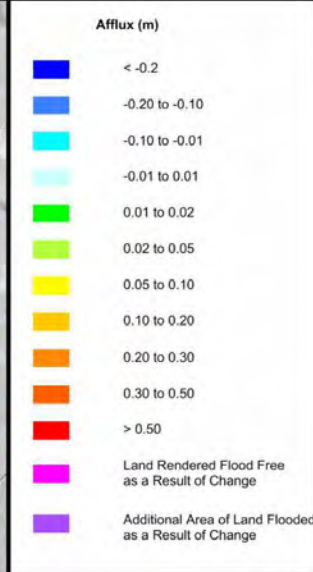
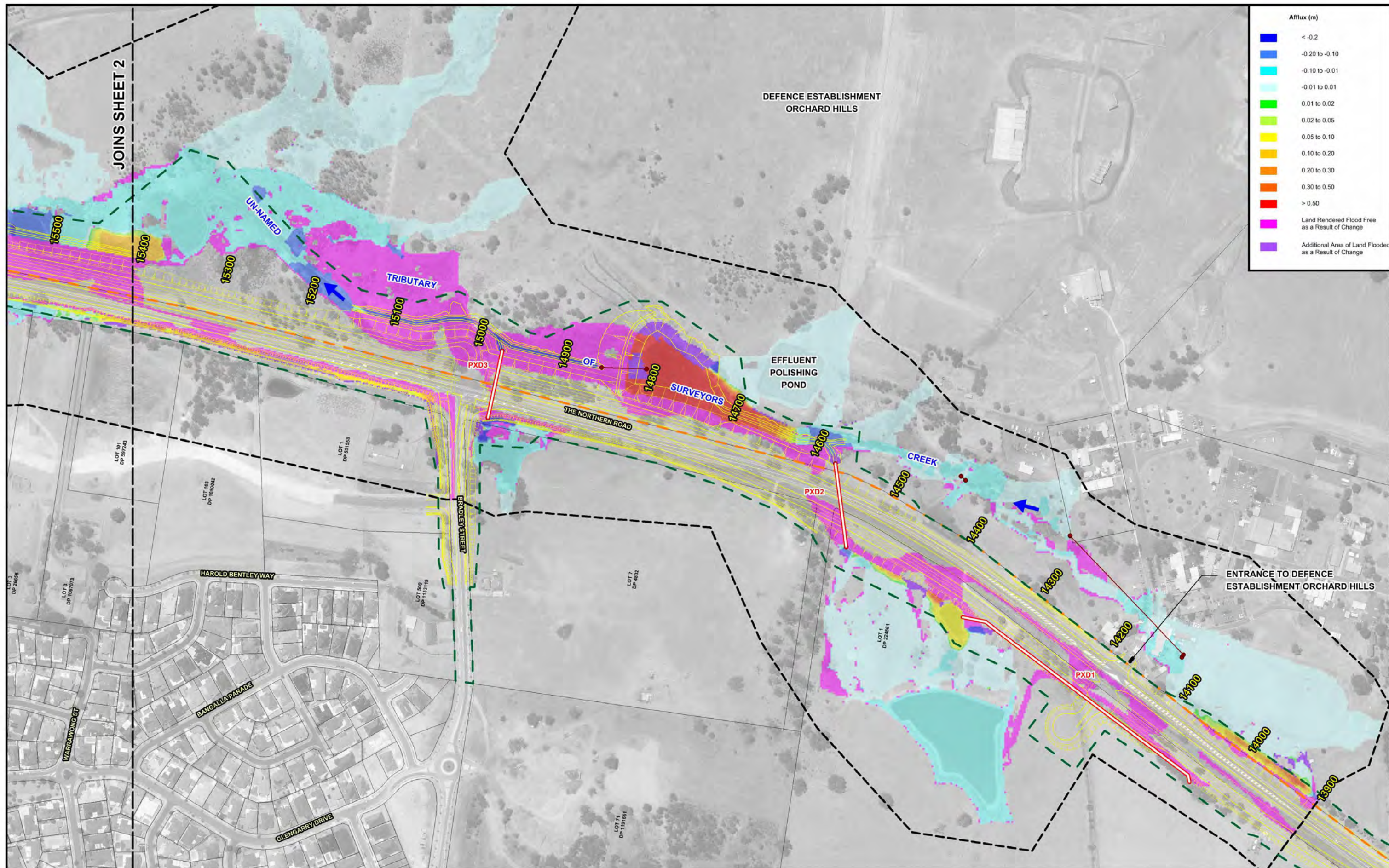
Figure C1.5  
Sheet 1 of 2

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
2 YEAR ARI









**Lycall & Associates**

- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
- Defence Establishment Orchard Hills Boundary
- Project Boundary

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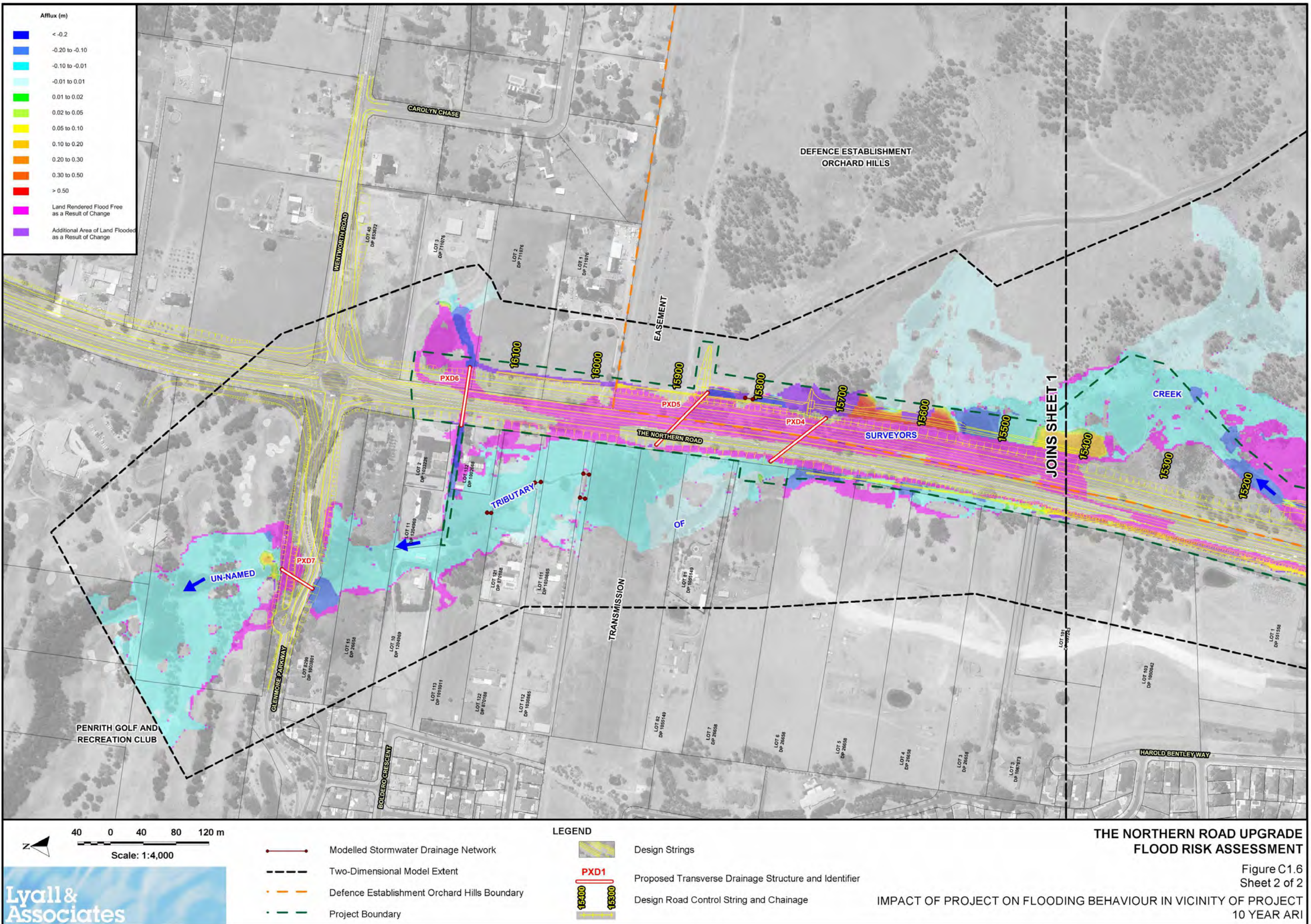
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**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

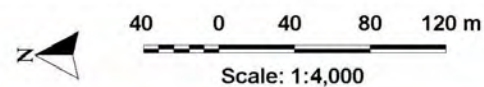
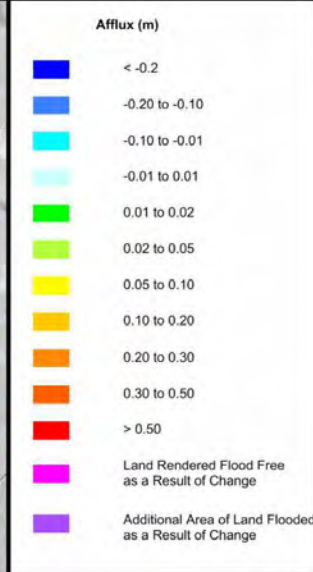
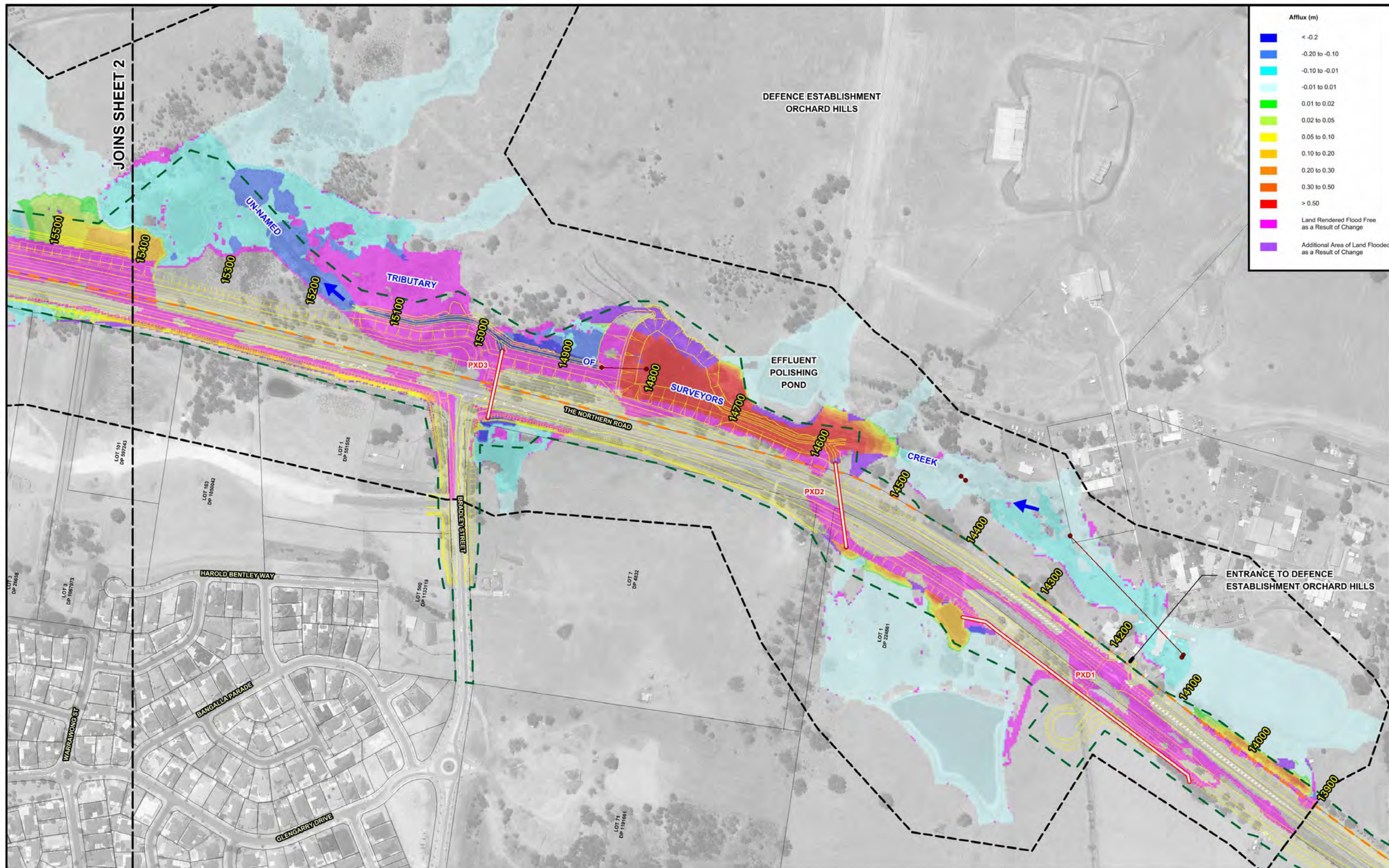
Figure C1.6  
Sheet 1 of 2

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
10 YEAR ARI









**Lycall & Associates**

- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
- Defence Establishment Orchard Hills Boundary
- Project Boundary

**LEGEND**

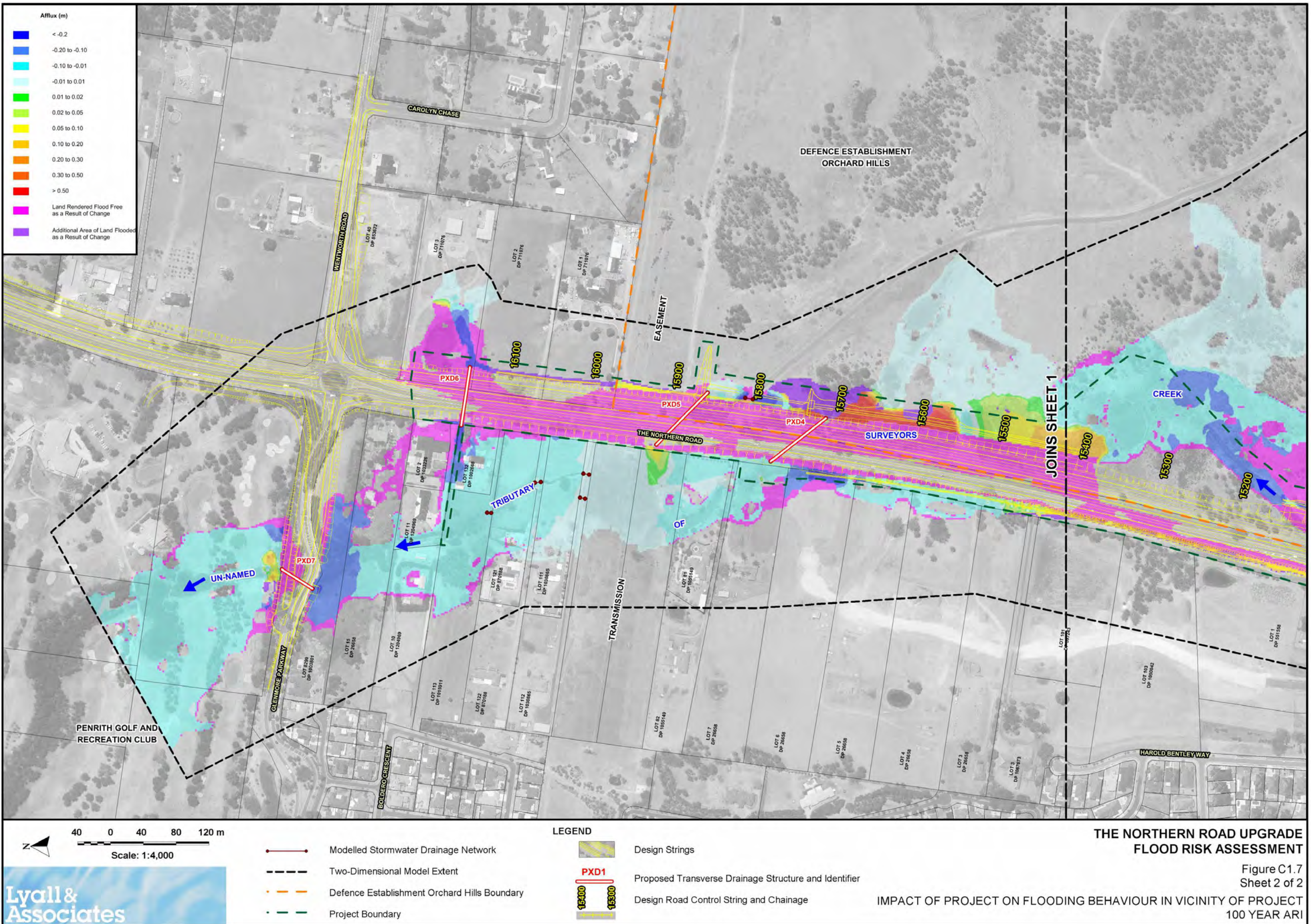
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- Proposed Transverse Drainage Structure and Identifier
- Design Road Control String and Chainage

**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

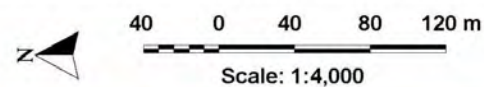
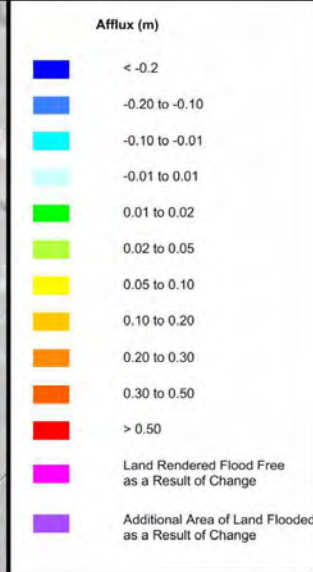
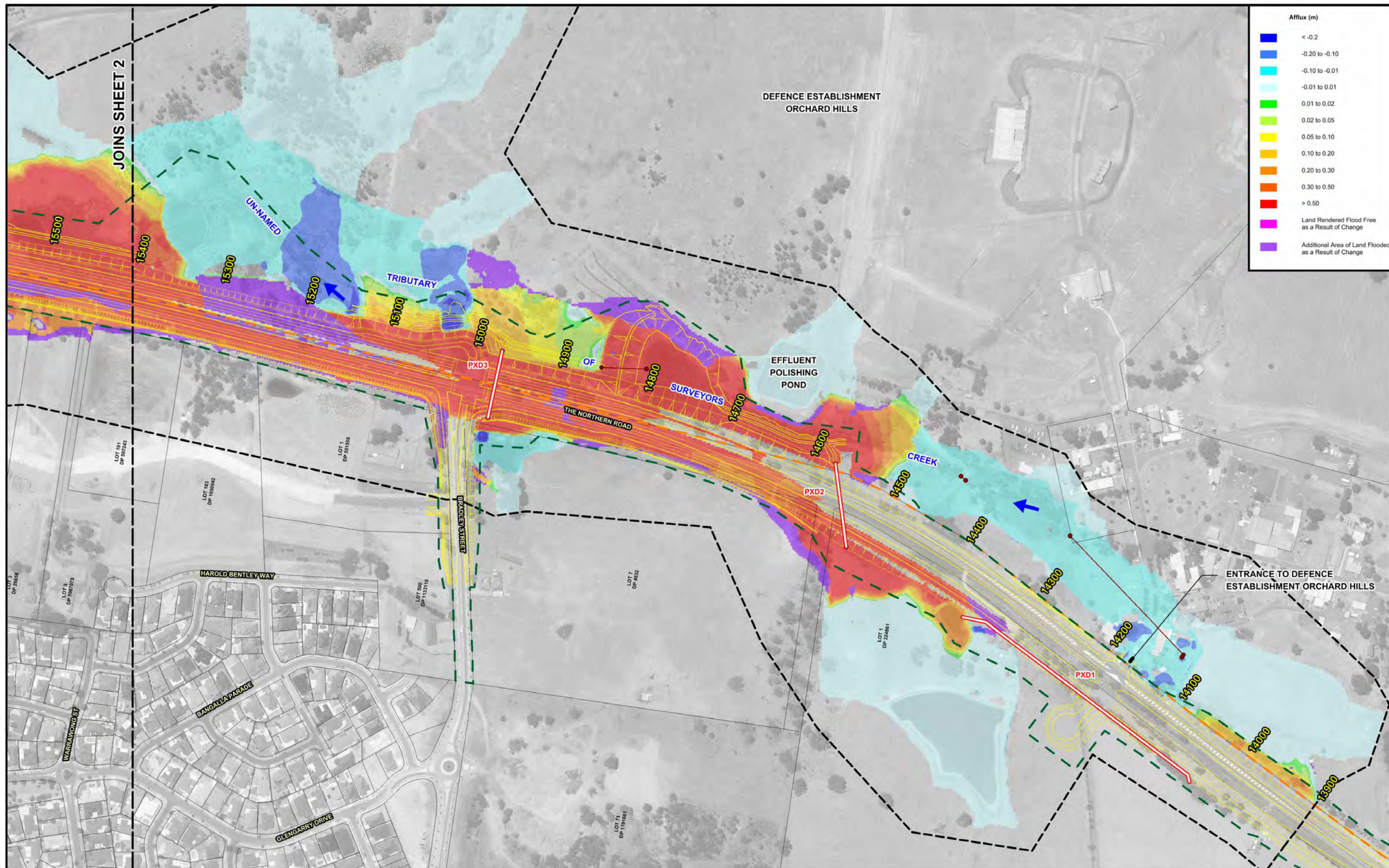
Figure C1.7  
Sheet 1 of 2

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT  
100 YEAR ARI









**Lycall & Associates**

- Modelled Stormwater Drainage Network
- Two-Dimensional Model Extent
- Defence Establishment Orchard Hills Boundary
- Project Boundary

**LEGEND**

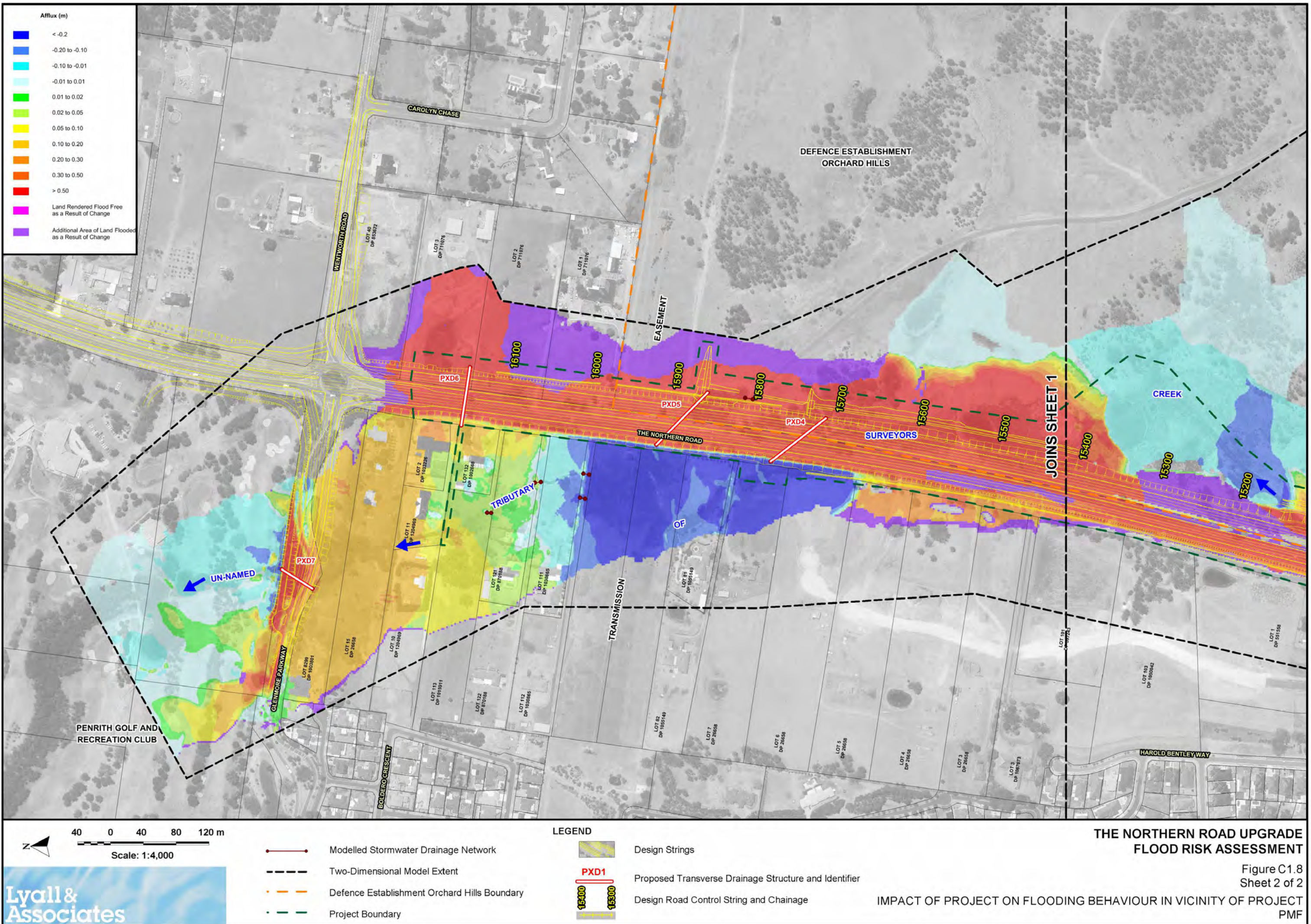
- Design Strings
- PXD1  
15400 15300  
--- Proposed Transverse Drainage Structure and Identifier
- Design Road Control String and Chainage

**THE NORTHERN ROAD UPGRADE  
FLOOD RISK ASSESSMENT**

Figure C1.8  
Sheet 1 of 2

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT PMF







**APPENDIX D**  
**SUMMARY OF PEAK FLOWS**  
**PRE- AND POST-PROJECT CONDITIONS**



**TABLE D1**  
**SUMMARY OF PEAK FLOWS**  
**PRE- AND POST-PROJECT CONDITIONS**  
(m<sup>3</sup>/s)

Peak Flow Identifier <sup>(1)</sup>	2 year ARI			10 year ARI			100 year ARI			200 year ARI			500 year ARI		
	Pre-Project Conditions	Post-Project Conditions	Difference <sup>(2)</sup>	Pre-Project Conditions	Post-Project Conditions	Difference <sup>(2)</sup>	Pre-Project Conditions	Post-Project Conditions	Difference <sup>(2)</sup>	Pre-Project Conditions	Post-Project Conditions	Difference <sup>(2)</sup>	Pre-Project Conditions	Post-Project Conditions	Difference <sup>(2)</sup>
Q01	0.8	0.7	-0.1	1.6	1.5	-0.1	3	2.4	-0.6	3.6	2.9	-0.7	4.4	3.5	-0.9
Q02	0.8	0.9	0.1	1.6	1.8	0.2	3.2	3.7	0.5	3.8	4.2	0.4	4.5	5	0.5
Q03	1.8	1.7	-0.1	3.5	3.3	-0.2	6.3	4.7	-1.6	7.1	5.4	-1.7	8.1	5.3	-2.8
Q04	2.7	1.4	-1.3	5.6	1.8	-3.8	9.7	2.3	-7.4	11.2	3.3	-7.9	13.5	5.6	-7.9
Q05	0.5	0.5	0	1	1.1	0.1	2.1	2.2	0.1	2.4	2.5	0.1	2.5	3	0.5
Q06	3.9	2.6	-1.3	7.9	4.1	-3.8	14.4	6.7	-7.7	16.8	7.7	-9.1	19.5	9.1	-10.4
Q07	6.9	5.7	-1.2	13.3	9.8	-3.5	24.7	17.2	-7.5	28.9	19.9	-9	34.4	23.5	-10.9
Q08	8.4	6.6	-1.8	13.4	10.6	-2.8	17.9	13	-4.9	25.5	14	-11.5	25.5	14.9	-10.6
Q09	0.6	0.3	-0.3	0.6	1.3	0.7	0.6	7.4	6.8	0.6	9.5	8.9	0.7	12.6	11.9
Q10	0.5	0	-0.5	3.1	1	-2.1	8.8	6.9	-1.9	11.9	9.1	-2.8	16.2	10.9	-5.3
Q11	0	0	0	0	0	0	0	0	0	0.2	0	-0.2	0.7	0	-0.7
Q12	7.9	7.7	-0.2	14.6	13.1	-1.5	21.6	17.3	-4.3	23.7	18.9	-4.8	26.4	21	-5.4
Q13	0.4	0.2	-0.2	3.1	0.4	-2.7	6.5	0.7	-5.8	8	0.8	-7.2	9.9	1	-8.9
Q14	7.9	8.1	0.2	15.7	14.4	-1.3	25.5	25.5	0	29.7	29.4	-0.3	24	34.3	10.3
Q15	2.5	2.5	0	4.8	5	0.2	7.2	9.3	2.1	7.3	10.7	3.4	7.3	12.2	4.9
Q16	0	0	0	0.8	0	-0.8	6.3	0	-6.3	10.5	0	-10.5	15.6	0	-15.6
Q17	9.6	9.4	-0.2	19.7	17.1	-2.6	35.5	30.3	-5.2	41.9	35.1	-6.8	49.7	41.3	-8.4
Q18	11.7	9.6	-2.1	20.9	17.5	-3.4	35.6	30.7	-4.9	41.6	35.4	-6.2	48.4	41.4	-7

1. Refer figures in **Appendices B** and **C** for location of Peak Flow Identifiers.
2. A positive difference indicates an increase in peak flow and conversely a negative difference indicates a reduction in peak flow when compared to pre-project conditions. Increases in peak flow are highlight in orange, while reductions in peak flow when compared to pre-project conditions are highlighted in green.



**APPENDIX E**  
**SKETCH SHOWING TYPICAL DETAILS**  
**OF PROPOSED SECURITY MEASURE**



# LYALL & ASSOCIATES CONSULTING WATER ENGINEERS

PROJECT THE NORTHERN RD UPGRADE

PAGE No. 1

JOB No. AM399

TITLE PROPOSED SECURITY MEASURE

PREPARED SAB

DATE 20/6/16

AT LOCATION OF CREEK CROSSING

CHECKED

DATE

