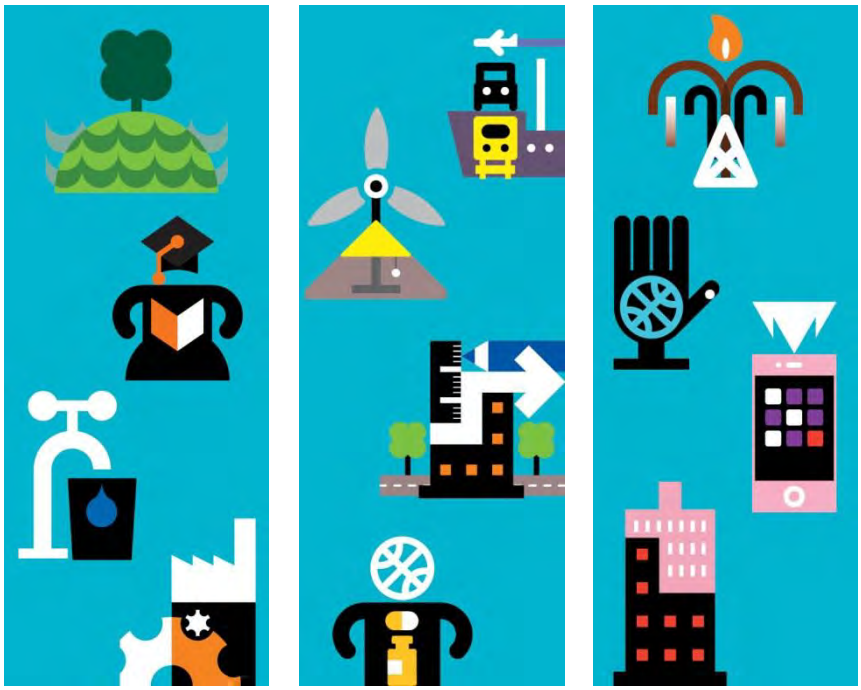

# Arncliffe Priority Precinct

Desktop Literature Review
Flooding and Drainage

October 2016

NSW Department of Planning and Environment

Mott MacDonald

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# Issue and revision record

| Revision | Date | Originator | Checker | Approver | Description |
|---|---|---|---|---|---|
| A | 21.08.2015 | N. Franklin, J. Taylor | G. Lee | C. Avis | Draft |
| B | 27.08.2015 | N. Franklin, J. Taylor | G. Lee | C. Avis | Final |
| C | 01.09.2015 | N. Franklin, J. Taylor | G. Lee | C. Avis | Final |
| D | 02.10.2015 | N. Franklin, J. Taylor | G. Lee | C. Avis | Final |
| E | 13.10.2015 | N. Franklin, J. Taylor | G. Lee | C. Avis | Final |
| F | 13.10.2016 | N. Franklin, J. Taylor | G. Lee | C. Avis | Minor Amendments |
| F | 28.10.2016 | G.Lee | G. Lee | C. Avis | Minor Updates |

Information class: Standard

# Contents

## Figures

# 1 Introduction

## 1.1 Purpose of This Document

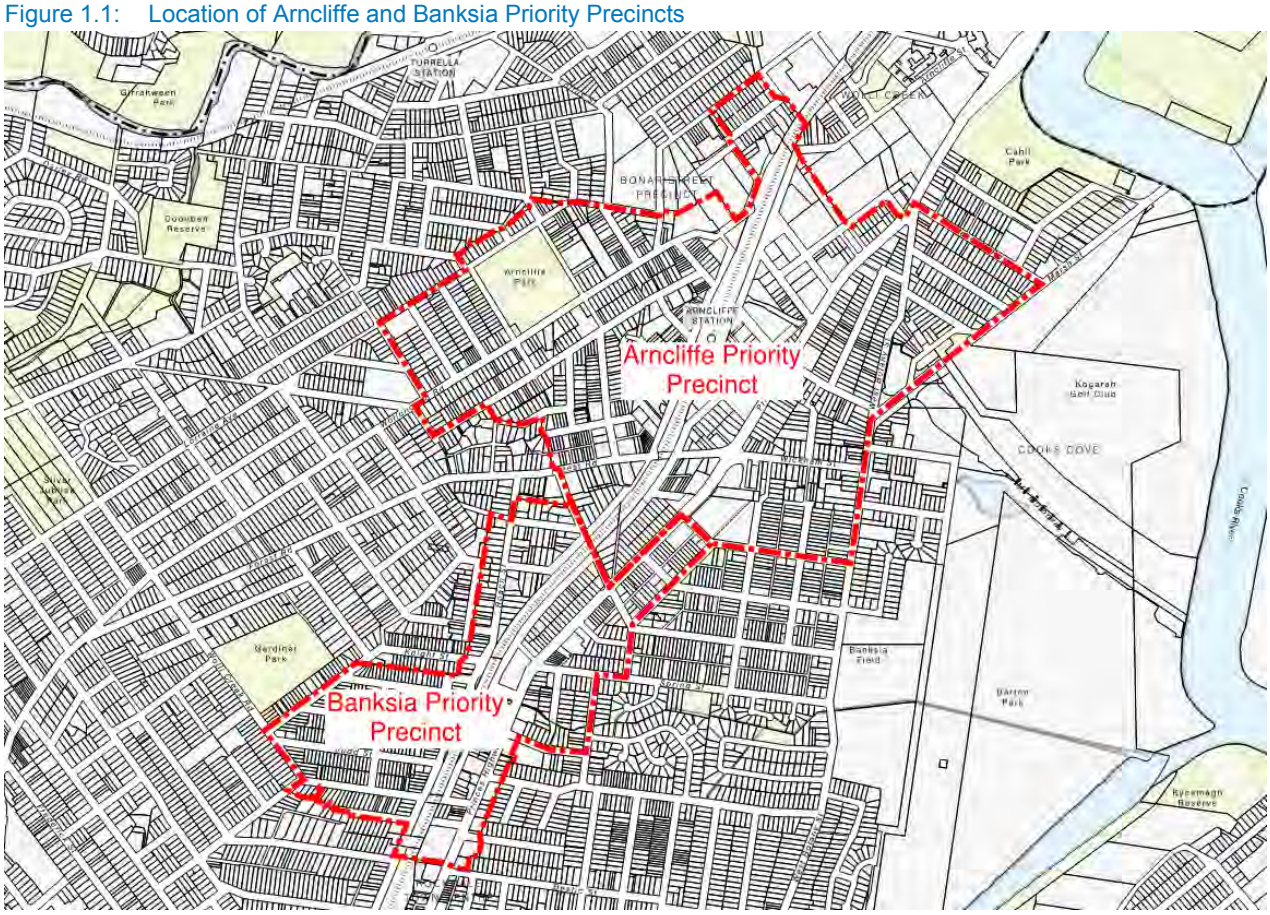
Mott MacDonald has undertaken an assessment for the New South Wales Department of Planning and Environment on the existing flooding and stormwater drainage conditions in and around the Arncliffe and Banksia Priority Precincts.

This document focuses on the Arncliffe Priority Precinct and is an interim report which describes the existing flood studies, opportunities and constraints pertaining to drainage, and initial recommendations for the precinct proposal.

## 1.2 Precinct Location

The Arncliffe and Banksia Priority Precincts are located in Sydney's south, approximately 10-12km from the Sydney CBD. They occupy an area along the Princes Highway Corridor extending from Wolli Creek to Rockdale Town Centre and Banksia and Arncliffe Train Stations. The Precincts are located within the Rockdale City Council Local Government Area. See Figure 1.1 for the precinct location.

Figure 1.1: Location of Arncliffe and Banksia Priority Precincts





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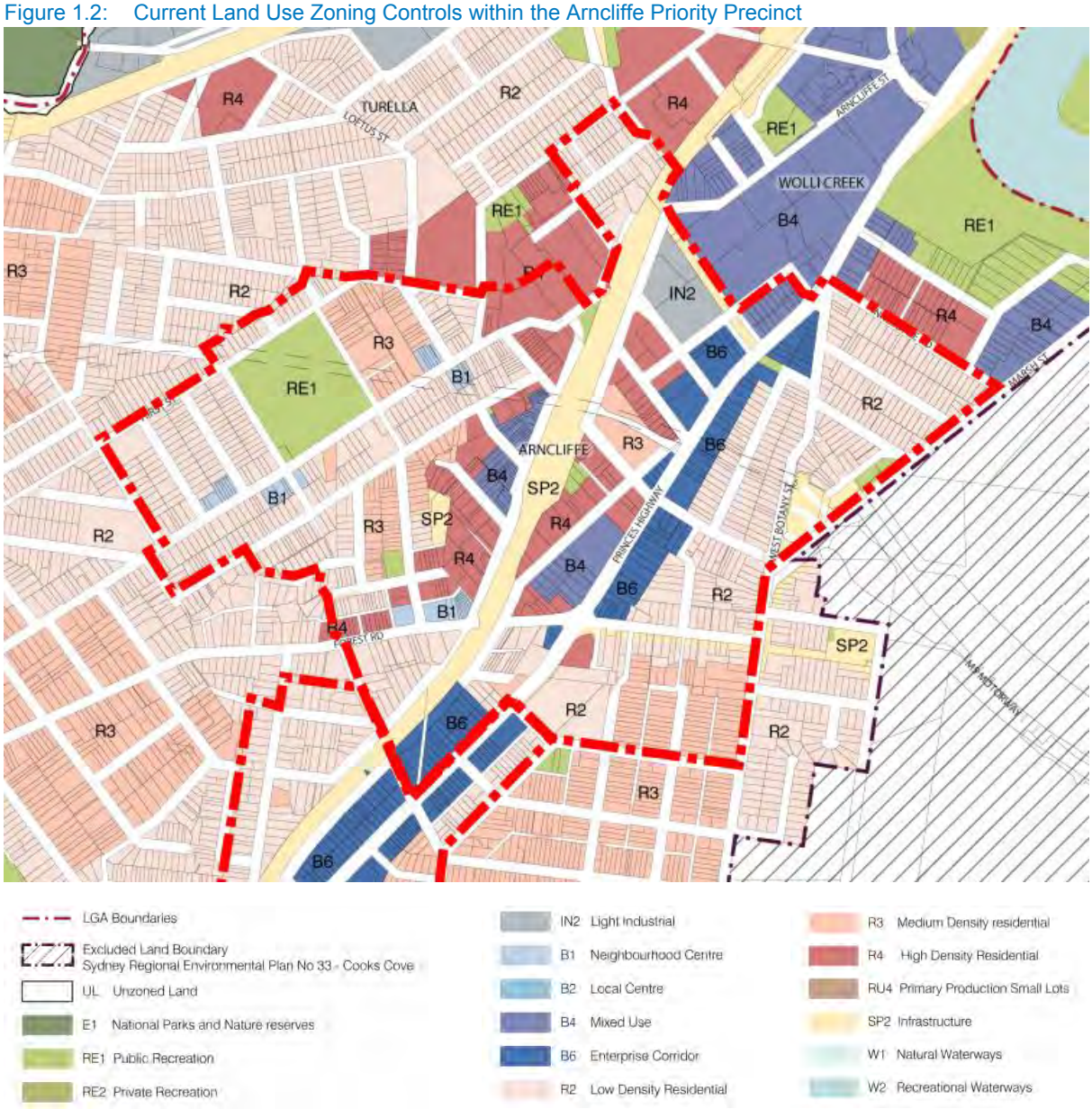
The location of the Arncliffe and Banksia Priority Precincts along the Princes Highway defines them as a key gateway along the main north / southern route through Sydney. The Precincts are well serviced by public transport, being centrally located around Arncliffe and Banksia Train Stations. From these stations, ready access to Central Station and the wider Sydney Train network can be achieved. The Arncliffe Priority Precinct forms the northern portion of the overall Precincts and encompasses Arncliffe Park, Arncliffe Station and surrounding residential and mixed use property.

## 1.3 Precinct Description

The Arncliffe and Banksia Priority Precincts have been identified by NSW Government in conjunction with Rockdale City Council as key precincts for development. The precincts comprise a total area of approximately 200ha.

The current land use zoning controls in the Arncliffe Priority Precinct is shown in Figure 1.2. From the figure it can be seen that the majority of land use zoning within the precinct is low, medium and high density residential. Moderate areas of mixed use zoning around Arncliffe Station and a small zoning of Neighbourhood Centre adjacent Banksia Station are present.

Figure 1.2: Current Land Use Zoning Controls within the Arncliffe Priority Precinct

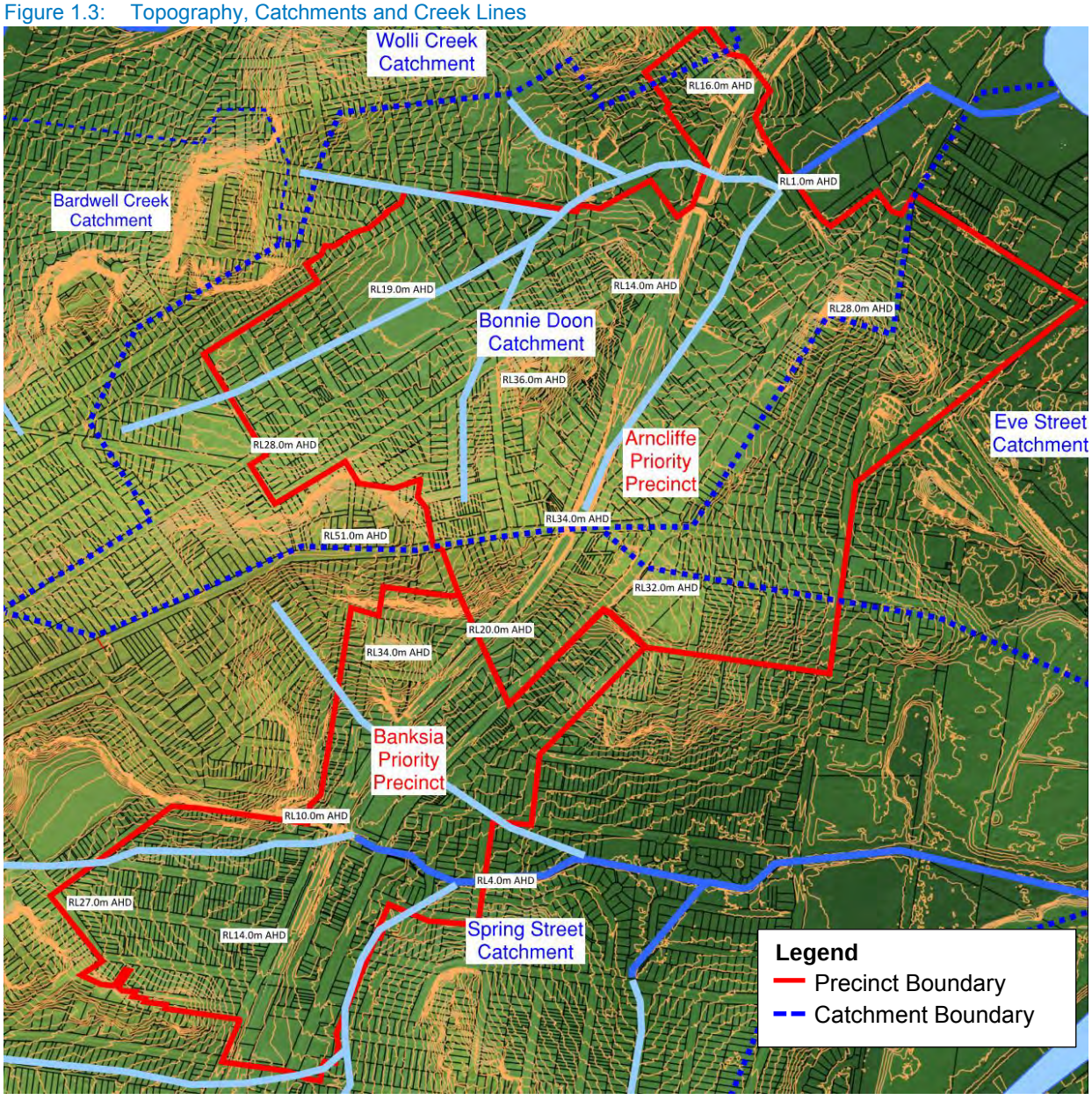



Source: *Arncliffe and Banksia Urban Activation Precinct Background and Initial analysis, Architectus Group/ Gallagher Studio*

The topography of the combined precincts and surrounding areas is generally undulating in a north-south direction, with some fall towards the east and the Cooks River. A crest, generally along Forest Road, west of the rail line forms a ridge line, and defines the two dominant catchments housing the precincts; being the Bonnie Doon Catchment, which holds the majority of the Arncliffe Priority Precinct, and the Spring Street Catchment which holds all of the Banksia Priority Precinct, as well as a small portion of the Arncliffe Priority Precinct. The Arncliffe Priority Precinct touches on the Wolli Creek Catchment boundary to the north. A fourth catchment to the east, the Eve Street Catchment holds the remaining portion of the Arncliffe Priority Precinct. Figure 1.3 shows the precinct locations in relation to these catchments.

The Bonnie Doon Catchment has two main flow paths. The northern flow path starts at the vicinity of the intersection of Lorraine Avenue and East Street which is external to the Arncliffe Priority Precinct boundary. From here it traverses Arncliffe Park with a number of flows contributing along the way. It then runs beneath the rail line at the Wollongong Rd/ Allen St underpass. The southern tributary generally starts at Arncliffe station, on the eastern side of the rail line and runs largely parallel to it, deviating to the east and converging with the northern tributary around the location of the existing Rockdale Mazda and Ford Service Centres (the intersection of Allen and Argyle Streets) to form the Bonnie Doon Channel. The channel then continues along the alignment of the Princes Hwy, traverses the northern section of Cahill Park and joins the Cooks River.

Figure 1.3: Topography, Catchments and Creek Lines




*Source:*
- *Catchment Boundaries: Rockdale Technical Specification, Stormwater Management*
- *Topography and Cadastre: Rockdale Council GIS data*
- *Creek Lines: Gallagher Studios/Architectus Group*

The Spring St Catchment covers a larger area than the Bonnie Doon Catchment, though a number of sub-catchments do not impact the precincts directly. There are two main tributaries through the Banksia Priority Precinct. The northern tributary, which also accommodates the small portion of the Arncliffe Priority Precinct, starts generally along Mount St, external the Banksia Priority Precinct boundary, crossing Roach Street and passing beneath the rail line where it deviates south, to join the Spring Canal, around the intersection of Chestnut Dr and Short St. The southern tributary generally starts at Oswell St, again outside of the Banksia Priority Precinct boundary, crosses the southernmost tip of Gardiner Park, continuing to Subway Road where it passes beneath the rail line and becomes the Spring Canal at confluence with the northern tributary. A small sub-catchment in the south of the Banksia Priority Precinct collects flows from generally Judd and Kimpton Streets and conveys them beneath the rail line at Kimpton St and again converging at the start of the Spring Canal. The Spring Canal joins Muddy Creek which then joins The Cook River.

The Eve Street Catchment is relatively low lying along the Cooks River consisting primarily of the Eve Street Wetland, Kogarah Golf Course and Cahill Park and has capacity issues with the drainage network. There are no clearly defined drainage channels, though the area of the Arncliffe Priority Precinct lying within the Eve Street Catchment is generally split around the intersection of West Botany Street and Marsh Street and falls north to Cahill Park and south to the Eve Street Wetland.

## 1.4 Proposed Works

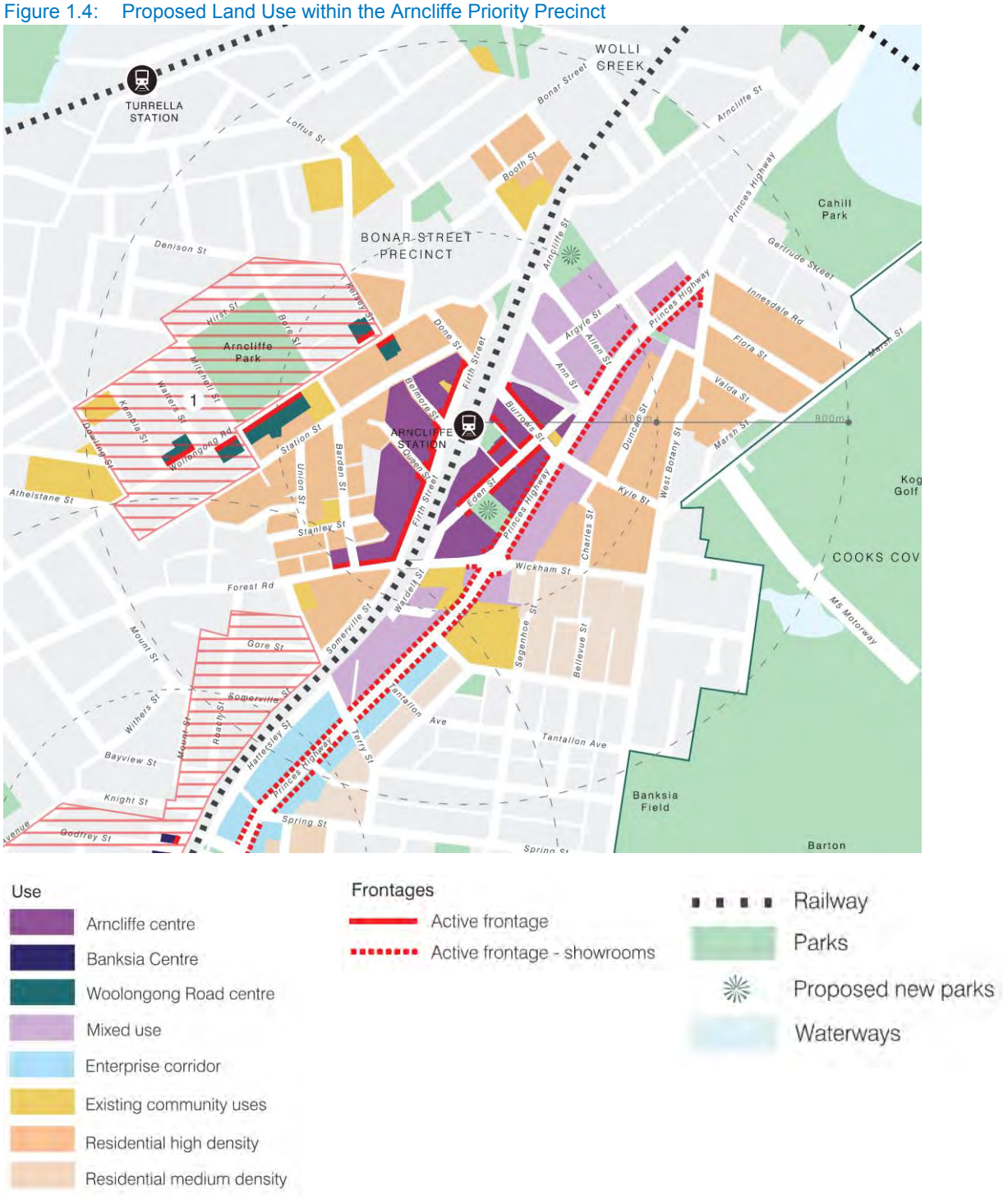
The Arncliffe and Banksia Priority Precincts will be a vibrant and well planned town centre around Arncliffe and Banksia train stations. The new centre will include more restaurants and cafes, open spaces and parks, and more residencies.

The existing retail areas of Banksia and Arncliffe will extend east across the railway. There will be a greater local centre focus around Arncliffe Park, joining the existing areas of shops and the potential for new local facilities around Gardiner Park providing an improved focus and entry to the park.

The Princes Highway corridor will continue to focus on large-format commercial uses at ground floor with the potential for some residential uses above and set back from the street.

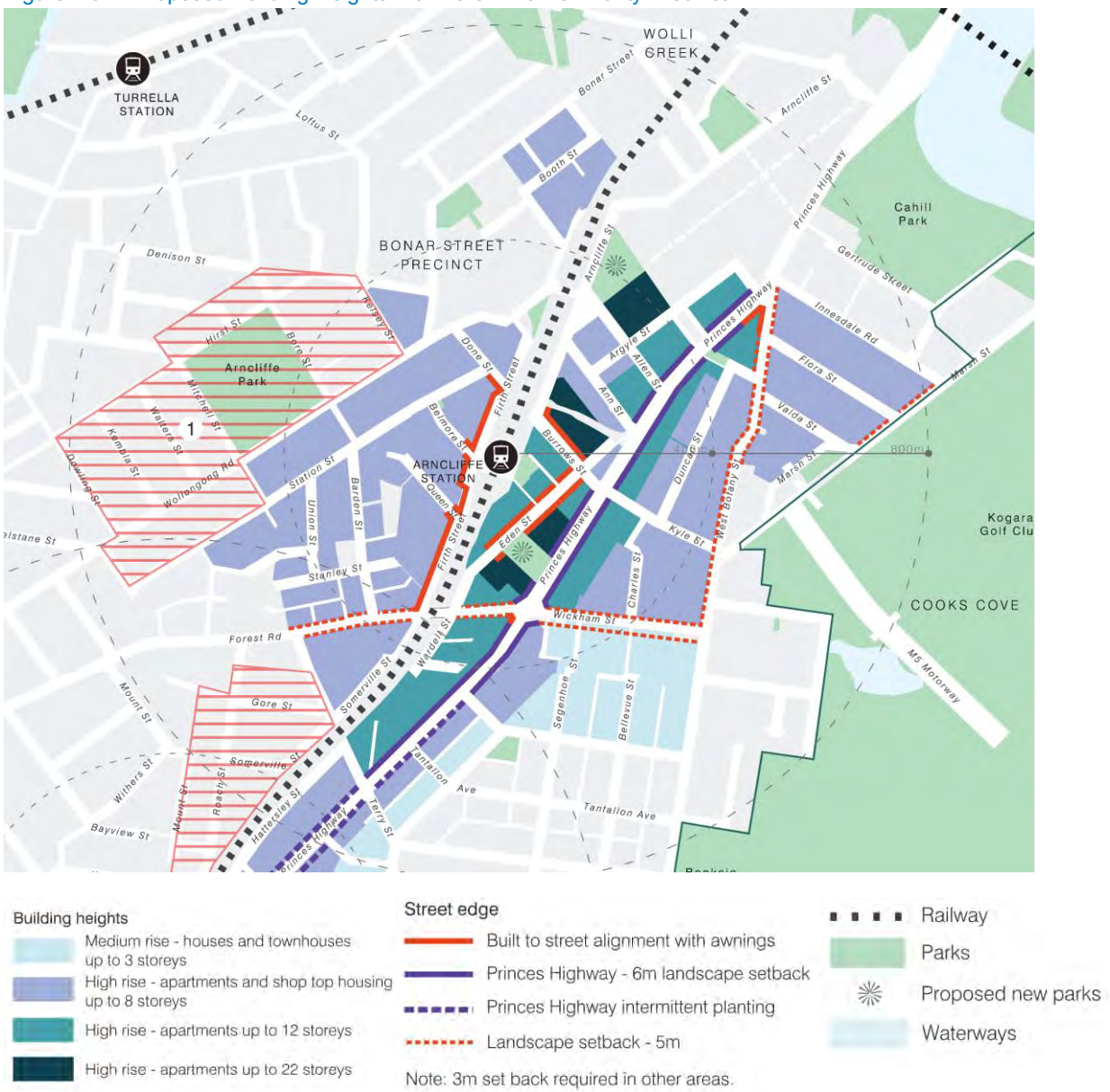
Proposed development will include an increased building height and potential site consolidation. Increasing building height will provide opportunities for offices and residential units. The greatest increase in building density will be to the east of Arncliffe Station.

Figure 1.4: Proposed Land Use within the Arncliffe Priority Precinct




Source: *APP Corporation*

Figure 1.5: Proposed Building Heights within the Arncliffe Priority Precinct




Source: *APP Corporation*

## 1.5 Applicable Standards and Guidelines

Local Government Area (LGA) controls:

- Rockdale City Council's *Rockdale Technical Specification, Stormwater Management*, adopted 4 May 2011, effective 5 December 2011;
- Rockdale City Council's *Rockdale Development Control Plan 2011*, Amendment number 2 dated 5/6/2013, effective 20/6/2013;
- *Rockdale Local Environmental Plan 2011*, version 8 January 2015;

State-wide (NSW) controls:

- *Environmental Planning and Assessment Act 1979 No 203*, version 5 March 2015;

# 2 Historical Studies

## 2.1 List of Studies

- *Bonnie Doon Pipe & Overland 2D Flood Study*, WMA Water, December 2011;
- *Cooks River Flood Study*, Sydney Water Corporation Engineering & Planning Services MWH+PB Joint Venture, Ref. 24203-040, February 2009;
- *Spring Street Drain - Piped Drainage and Overland Flow Analysis*, Brown Consulting, Ref. X04184-01E, October 2007;
  - *Spring Street Drain - Piped Drainage and Overland Flow Analysis - Supplementary Report*, Brown Consulting, Ref. X04184-02C, October 2007;
- *Water Sensitive Urban Design Implementation Strategy for Bonar Street Rezoning Application, Amended June 2005*, Webb, McKeown & Associates, June 2005 (for Brewster Murray Pty Ltd)
- *Bonnie Doon Catchment Upper Catchment Diversion Preliminary Assessment*, Webb McKeown and Associates, June 2001;
- *Arncliffe Park Detention Basin Concept Design, Draft Report*, Webb McKeown and Associates, December 1998;
- *Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study*, Webb, McKeown & Associates, November 1996;
  - *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Study*, March 1998;
  - *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Plan*, March 1998;
- *Bonnie Doon Drainage Catchment Flood Study*, Version 4 Revised Final, Lawson and Treloar, Ref. J1464/R1692, May 1997;
- *Eve Street - Cahill Park, Flood and Drainage Study,* Webb, McKeown & Associates, July 1996;

## 2.2 Supplementary Data

- In-progress TUFLOW model for Bonnie Doon and Eve Street/Cahill Park provided by WMA Water;
- GIS Data provided by Rockdale City Council;
- Analysis of drainage works in Bonar Street:
  - *Bonar Street Upgrade Project – Design Options Assessment*, Cardno NSW/ACT Jan 2014;
  - *Bonar Street Upgrade Drainage Design*, Cardno NSW/ACT July 2014;
- *Bonar Street Redevelopment Precinct Drainage Study*, Rockdale City Council, July 2014;

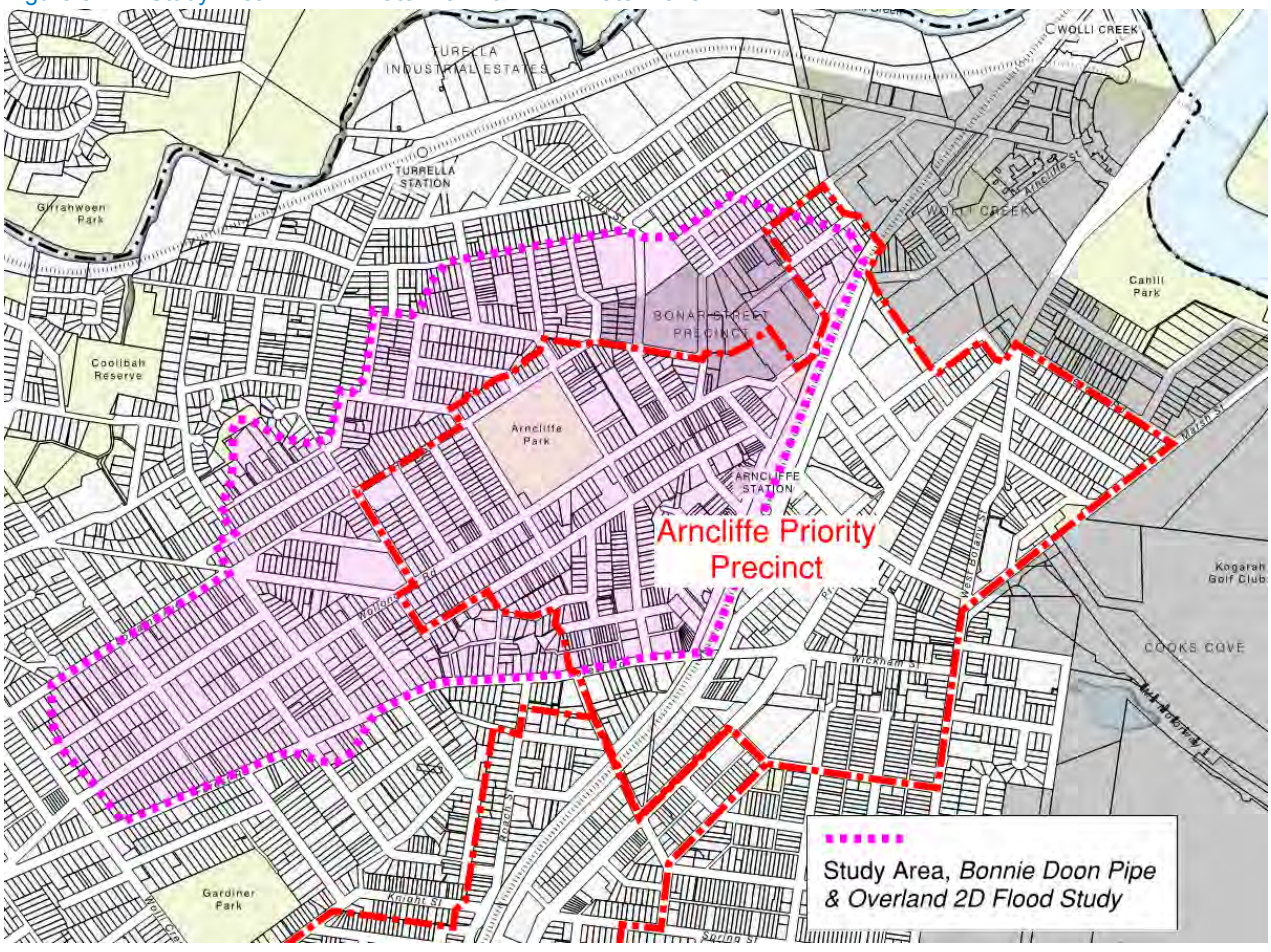
# 3 Arncliffe Priority Precinct

## 3.1 Summary of Historical Studies

### 3.1.1 Bonnie Doon Pipe & Overland 2D Flood Study (WMA Water 2011)

The *Bonnie Doon Pipe & Overland 2D Flood Study* assesses existing flood behaviour in the Bonnie Doon Catchment as part of the first stage of the NSW Government's Flood Policy process. It covers the portion of the proposed Arncliffe Priority Precinct that lies to the west of the Illawarra Railway Line (refer Figure 3.1).

Figure 3.1: Study Area – WMA Water 2011 & WMA Water 2015




Source: *Bonnie Doon Pipe & Overland 2D Flood Study* (WMA Water 2011)

The study consists of a combination of DRAINS runoff routing software and TUFLOW two-dimensional hydraulic modelling software to determine peak flow extents, levels, depths and velocities for the 20% (1 in 5), 5% (1 in 20) and 1% (1 in 100) annual exceedance probability (AEP) and the Probable Maximum Flood (PMF) event.

Existing pit and pipe data was obtained from Rockdale City Council. DRAINS was used to determine inflow hydrographs at each of the sub-catchments, which were then input into TUFLOW to model flood extents along the overland flow paths.

#### 3.1.1.1 Piped and Overland Flows

The study indicates that runoff from the catchment generally flows in a north-easterly direction, along a sag which runs generally from Dowling Street, through Arncliffe Park, and towards the Wollongong Road/Allen Street road underpass (under the Illawarra railway line). The piped drainage network within the catchment also generally flows in a north-easterly direction, with the confluence of several piped drainage systems at (a) a box culvert at the underpass beneath the railway line; and (b) a single 1500mm diameter pipe just north of the underpass. An additional 750mm diameter pipe carries piped flows from the southernmost area of the catchment to the downstream side of the Illawarra rail line. Piped flows in the western-most part of the catchment drain to the adjoining Bardwell Creek catchment, however flows in excess of the pipe system capacity remain within the Bonnie Doon catchment.

The study results indicate that the existing pit and pipe drainage system does not have adequate capacity for frequent design rainfall events in several locations across the catchment. Surcharging of pits predominantly occurs in locations where the drainage from trapped low points has insufficient piped capacity. Key surcharge locations identified by the report are as follows:

- Along the sag either side of Arncliffe Park, from Dowling Street to Bonar Avenue, significant overland flows occur in events greater than the 20% (1 in 5) AEP.
- Wollongong Road/Allen Street road underpass – the sag at the western side of the Illawarra railway line coincides with the confluence of several piped drainage systems to the aforementioned box culvert and 1500mm diameter pipe. The study indicates that after flood waters reach an approximate depth of 0.8m at the intersection of Wollongong Road and Martin Avenue, an overland flow path occurs through the underpass. Flood depths up to approximately 2m are predicted in Martin Ave for the 1% AEP event. Historically flood waters through the underpass have been significant enough to move vehicles.

#### 3.1.1.2 Obstructions to Overland Flow

The Illawarra railway line is raised above the surrounding ground level and restricts surface flows from west to east.

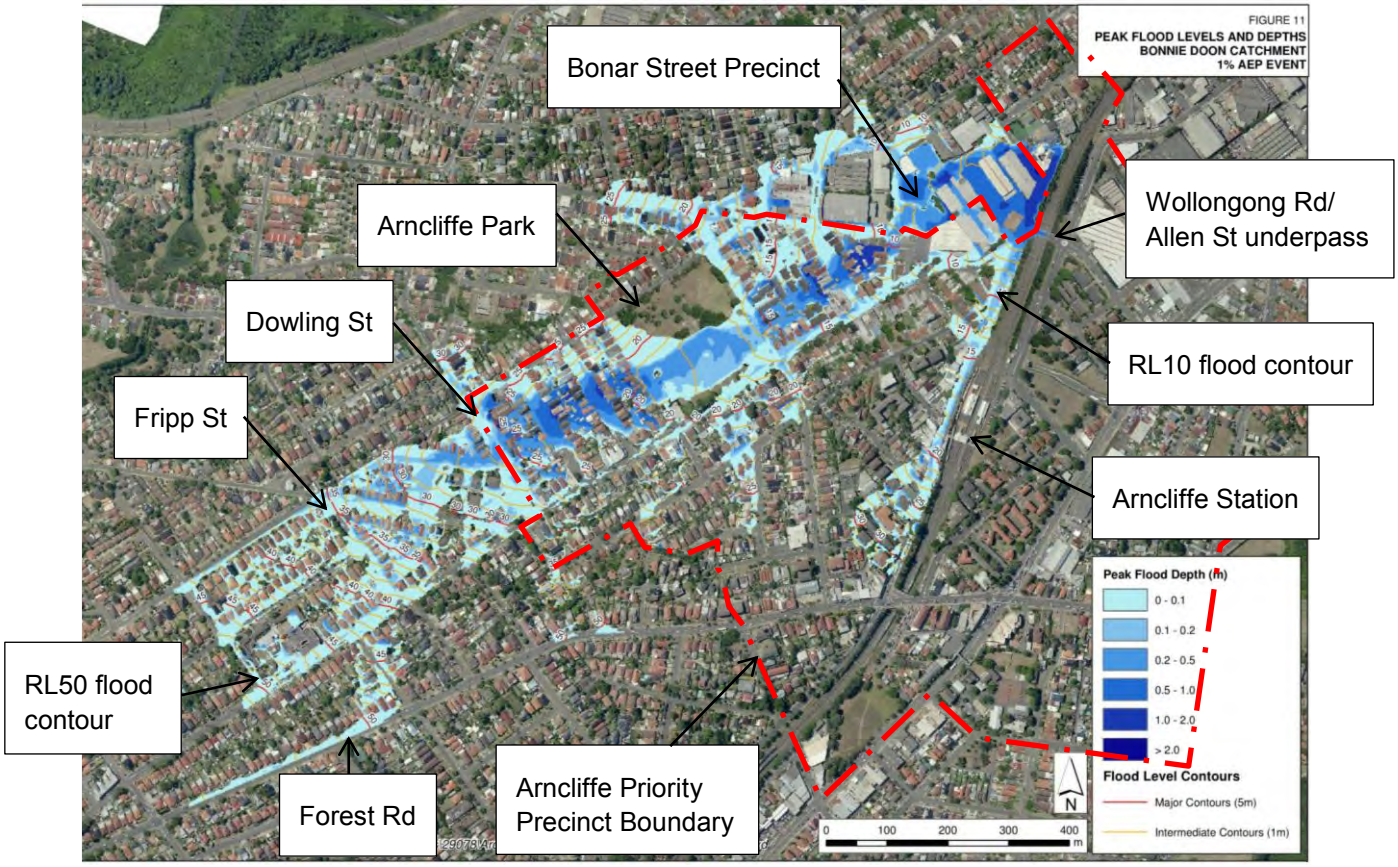
The Southern and Western Suburbs Ocean Outfall Sewer (SWSOOS) is a heritage listed Sydney Water aqueduct that runs generally from Thompson Street (north of Arncliffe Railway Station), under the Illawarra Railway Line, in a south-easterly direction towards the general alignment of the M5 Motorway. The aqueduct is a combination of above ground and tunnelled structure. The Bonnie Doon study indicates that the SWSOOS is a “major obstacle to overland flow downstream of the Illawarra railway line”. For the purpose of modelling the study utilises an assumed tailwater level at the SWSOOS to simulate a charged downstream system.

The Princes Highway is also downstream of the Illawarra railway line, and the study indicates that the highway also provides a major obstruction to overland flow as “flows in excess of the culverts must cross the highway”.

#### 3.1.1.3 Key Results

The study indicates 1% AEP peak flood depths of between 0.24m to 1.73m at key locations along the sag from Fripp Street through Arncliffe Park and towards the road underpass (refer Figure 3.2). Flood depths appear deepest between Dowling Street, Arncliffe Park, and in the vicinity of the Bonar Street Precinct/ rail underpass. Flood levels vary from approximately RL6mAHD at the underpass to RL50mAHD at the top of the catchment, generally following the topography of the land, for the 1% AEP. Additional localised flooding less than 100mm deep for the 1% AEP is identified near Forest Road as well as along the western edge of the railway line adjacent Arncliffe Station.

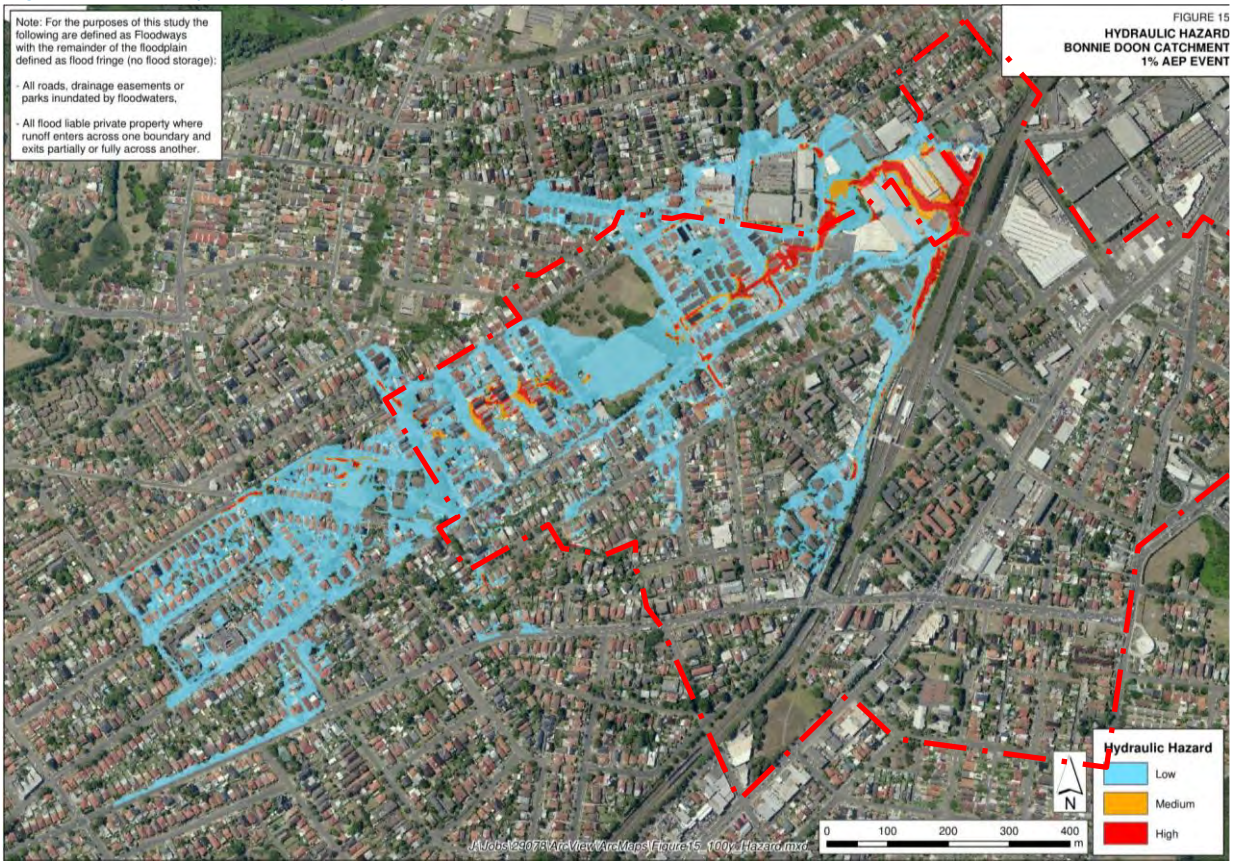
Figure 3.2: Study Results – Peak Flood Depths and Levels, 1% AEP Event




Source: *Bonnie Doon Pipe & Overland 2D Flood Study* (WMA Water 2011)

Results indicate that medium to high hazard areas (as classified by the NSW Floodplain Development Manual) generally occur downstream of Dowling Street, and between Arncliffe Park and the Illawarra railway line, at the sag where the depth and/or velocity are greatest. Areas such as the park are expected to carry relatively wide shallow overland flows and as such the resultant hydraulic hazard is generally lower in these areas.

Figure 3.3: Study Results – Hydraulic Hazard, 1% AEP Event




Source: *Bonnie Doon Pipe & Overland 2D Flood Study* (WMA Water 2011)

The study also assesses the effect of the following design scenarios greater than the 1% AEP:

- PMF – results in depths from 0.45m at Fripp Street to 3.92m just upstream of the road underpass.
- 1% AEP + climate change – results in an average increase in flood depth of 0.02 to 0.05m for a 10% rainfall increase scenario to a 30% rainfall increase scenario respectively. Localised areas such as the underpass experience an increase in flood depth of approximately 0.16m to 0.56m for a 10% rainfall increase scenario to a 30% rainfall increase scenario respectively.

#### 3.1.1.4 Study Limitations

As the study utilises an assumed tailwater level downstream of the Illawarra line, at a distance which it deems sufficient to have no impact on the study area, the results from the study are only applicable for the area upstream (west) of the Illawarra railway line.

It is understood that the study is currently being extended by WMA water to include the wider Arncliffe area including east of the Illawarra railway line. The in-progress TUFLOW model has been supplied to Mott MacDonald in order to provide a general indication of the wider precinct flooding behaviour. The interim results of this model are discussed in further detail in section 3.1.2.

#### 3.1.1.5 Study Recommendations

- The report identifies that Historical flood data is very limited and that comprehensive data collection should be implemented for all future flood events.
- The report notes that when establishing Flood Planning Levels, the scenario where fast flowing water "recovers" to a higher level due to flows slowing downstream should be considered, or Flood Planning Levels should be determined by taking the highest peak flood level within a property grid.
- The report provides provisional Hydraulic Hazard categorisation, however recommends that this should be refined at a later date to take into account other factors that influence hydraulic hazard such as warning time, flood readiness, rate of rise, duration of flooding, evacuation problems, effective flood access and type of development.

### 3.1.2 In-progress TUFLOW model for Bonnie Doon and Eve Street/Cahill Park (WMA Water 2015)

As the 2011 *Bonnie Doon Pipe & Overland 2D Flood Study* by WMA Water is bounded by the Illawarra railway line, it is understood that WMA are currently extending the study to include the area to the east of the railway line to Cooks River. This area was also partly covered in the *Eve Street - Cahill Park, Flood and Drainage Study* (section 3.1.10) however this study was undertaken in 1996, so the model would presumably incorporate more recent data and modelling software.

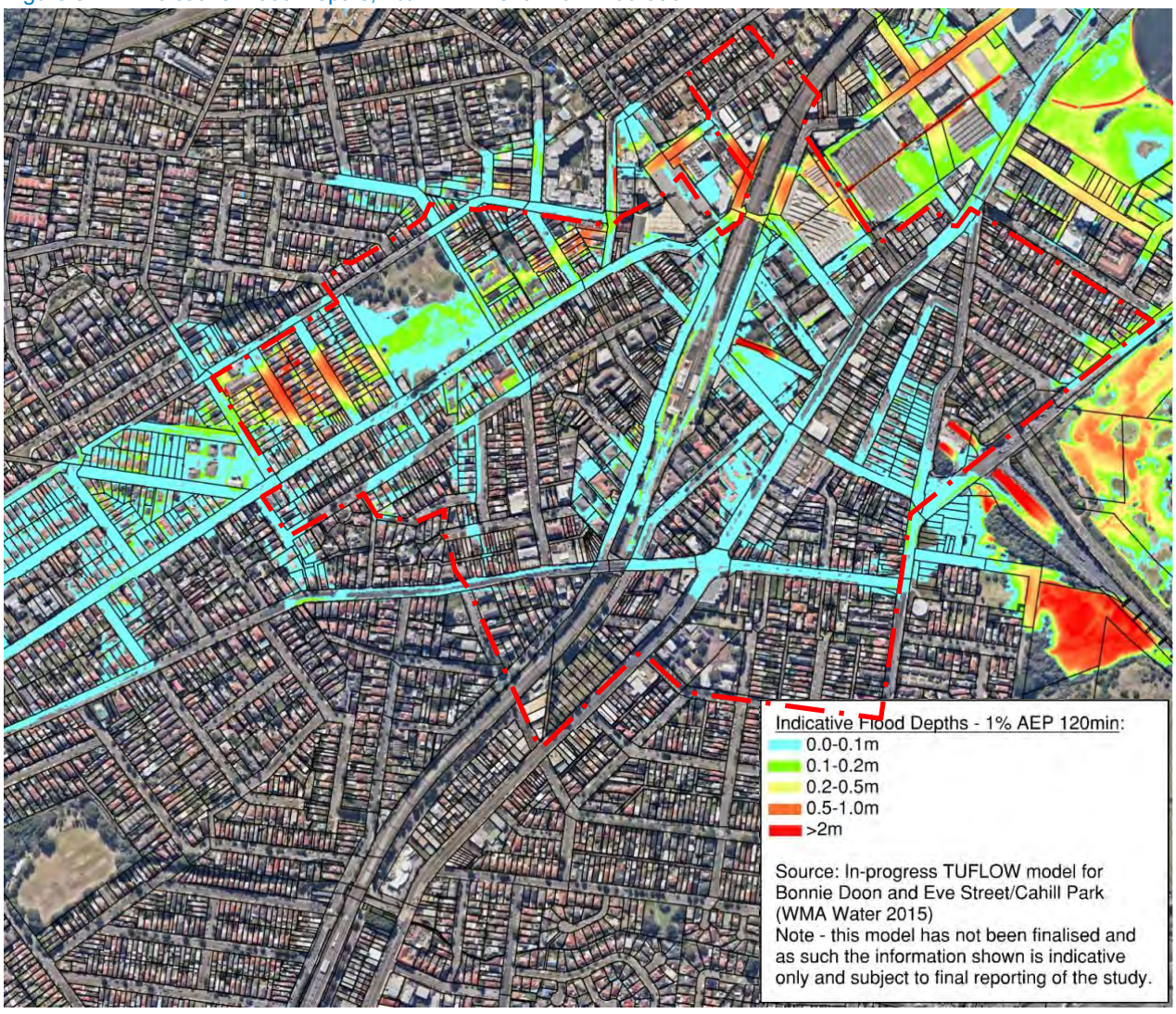
The new extended study utilities TUFLOW two-dimensional modelling software, and the in-progress model has been provide to Mott MacDonald by WMA Water, with the study and modelling scheduled for completion in late 2015.

The model provides the following indicative information in addition to the 2011 study:

- The existing box culvert under the Wollongong Road/ Allen Street underpass is defined in the model as 1.2m high by 1.37m wide. A flow estimate of approximately 3.4 $m^3$/sec is anticipated through the box culvert during the 1% AEP, 120 minute duration storm.
- Within the existing 1500mm diameter pipe just north of the underpass, flow is estimated to be approximately 6.66 $m^3$/sec during the 1% AEP, 120 minute duration storm
- The underpass is modelled as a gap in the raised rail line and flows for the 1% AEP, 120 minute duration storm are estimated to be approximately 0.5m deep with a velocity in the order of 1.6-1.7m/s.

- Indicative flood extents and depths for the 1% AEP, including the area downstream of the Illawarra railway line, are indicated in Figure 3.4 which was output from the in-progress model and overlaid on an aerial photo.

Figure 3.4: Indicative Flood Depths, 1% AEP Event 120min duration



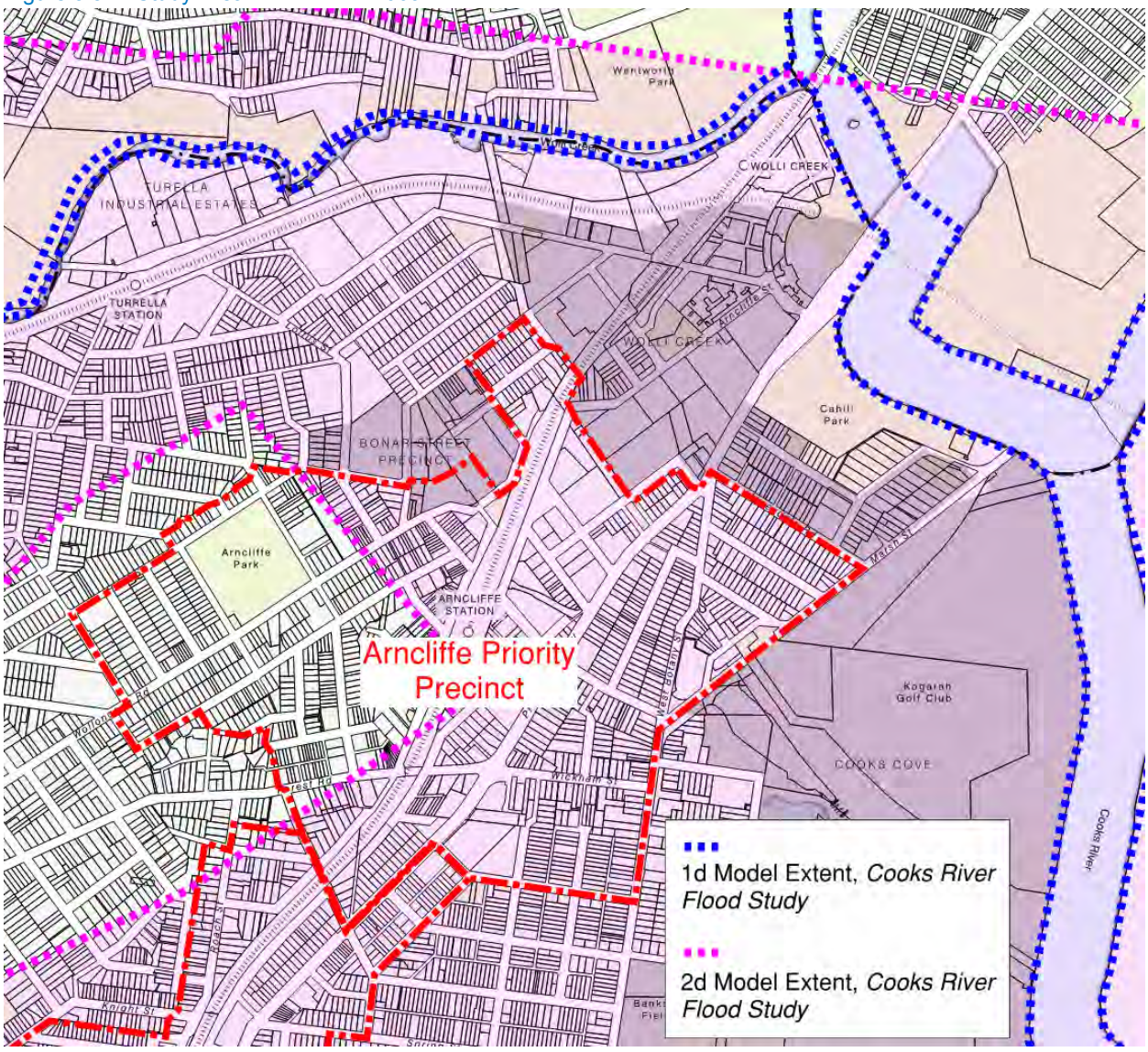

Source: In-progress TUFLOW model for Bonnie Doon and Eve Street/Cahill Park (WMA Water 2015)
Note: this model has not been finalised and as such the information shown is indicative only and is subject to final reporting of the study by WMA.

The model and associated reporting are ongoing and are expected to be completed around late 2015. This will provide further guidance around flood levels downstream of the railway line.

### 3.1.3 Cooks River Flood Study (MWH+PB 2009)

The *Cooks River Flood Study* assesses existing flood behaviour in the Cooks River Catchment (spanning portions of 13 LGAs) as part of Sydney Water and the Cooks River Foreshore Working Group's (CRFWG) investigation on the feasibility of naturalising sections of the river. The study covers areas to the north and east of the proposed Arncliffe Priority Precinct and touches on the north-eastern corner of the precinct (refer Figure 3.5). It is noted that the study assesses mainstream flows of the Cooks River only and as such contains limited information on flooding within the precinct boundaries.

Figure 3.5: Study Area – MWH+PB 2009




Source: *Cooks River Flood Study* (MWH+PB 2009)

The study utilises a combination of an existing one-dimensional RUBICON software model and TUFLOW two-dimensional modelling software, as well as a WBNM rainfall hydrology model, to estimate flow behaviours in the Cooks River for the 2 year, 20 year, 100 year Average Recurrence Interval (ARI) and the Probable Maximum Precipitation (PMP) event. LiDAR survey, bathymetric survey, tidal data, historical flood and rainfall data, and select detailed survey were obtained to prepare the model.

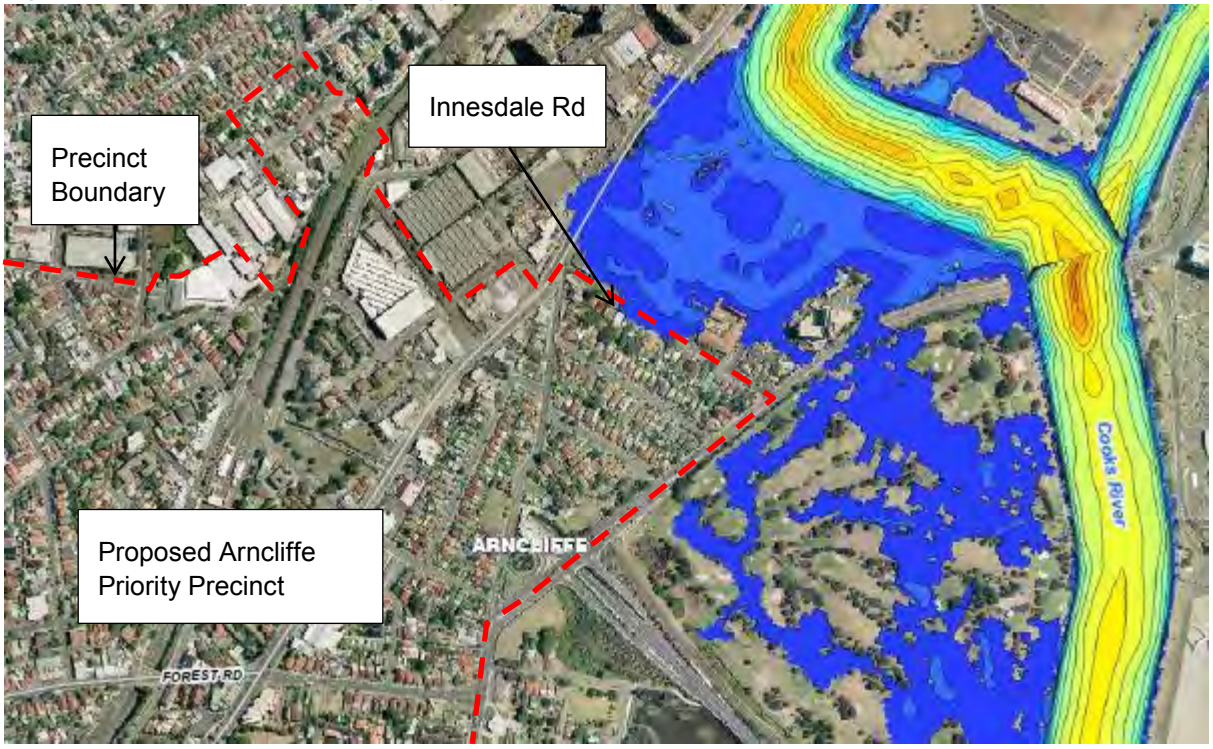
#### 3.1.3.1 Study Limitations

The focus of the study is to assess flood behaviour within the Cooks River, Wolli Creek and Alexandra Canal. As such, flood information within minor tributaries of the Cooks River (all waterways outside of the extent of the one-dimensional (1D) component of the hydraulic modelling shown in Figure 3.5) are not accurately defined in the study. This includes the Arncliffe Priority Precinct which forms part of the runoff catchment however is not within the immediate extent of the Cooks River flow modelling.

#### 3.1.3.2 Study Results

The study mapping indicates the presence of low velocity (0.0-0.5m/s), shallow depth (0.0-0.5m) flooding occurring during the 100 year ARI in the vicinity of Innesdale Road at the north-eastern corner of the Arncliffe Priority Precinct.

Figure 3.6: Flood Depth Mapping: 100 year ARI



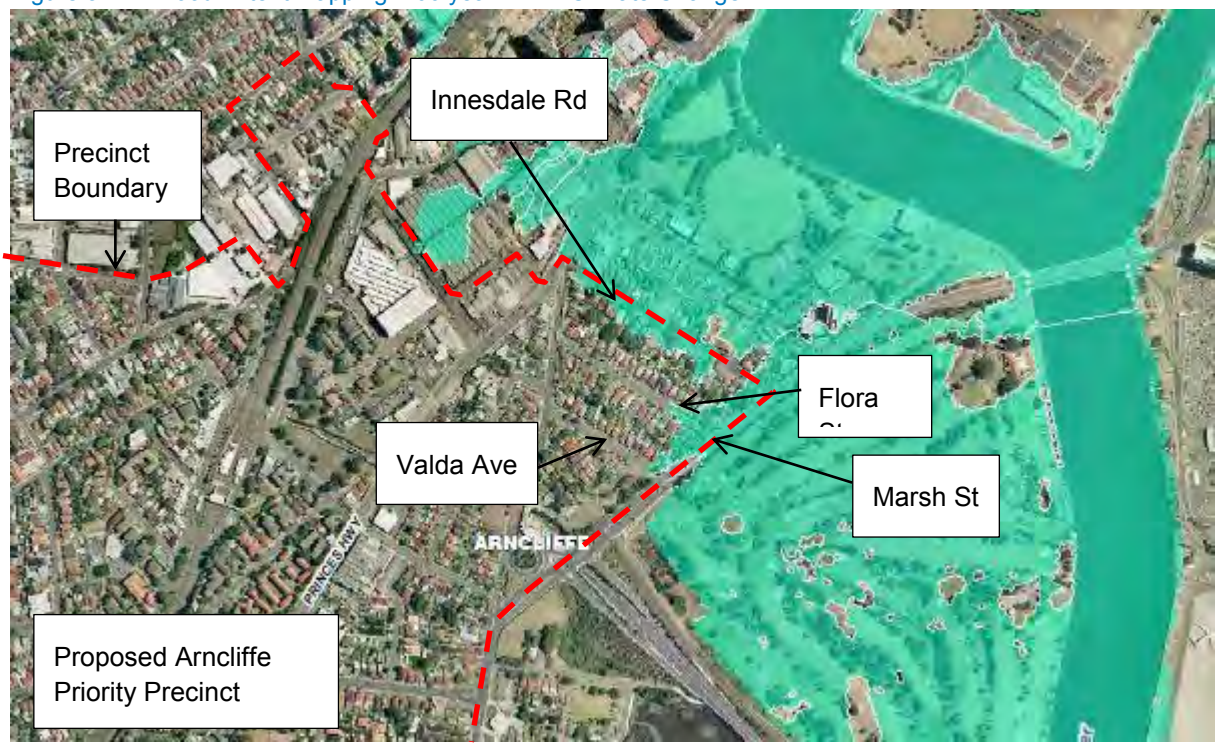

Source: *Cooks River Flood Study* (MWH+PB 2009)

The study also assesses the impact of the following design scenarios greater than the 1% AEP:

- 100 year ARI + climate change (Figure 3.7) – results in an increased flood extent from the 100 year ARI, potentially affecting land in the vicinity of Marsh Street along Innesdale Road, Flora Street and Valda Avenue.
- PMF (Figure 3.8) – resultant flood extent affects land in the vicinity of Marsh Street along Innesdale Road, Flora Street and Valda Avenue, as well as land to the north-west of Princes Highway

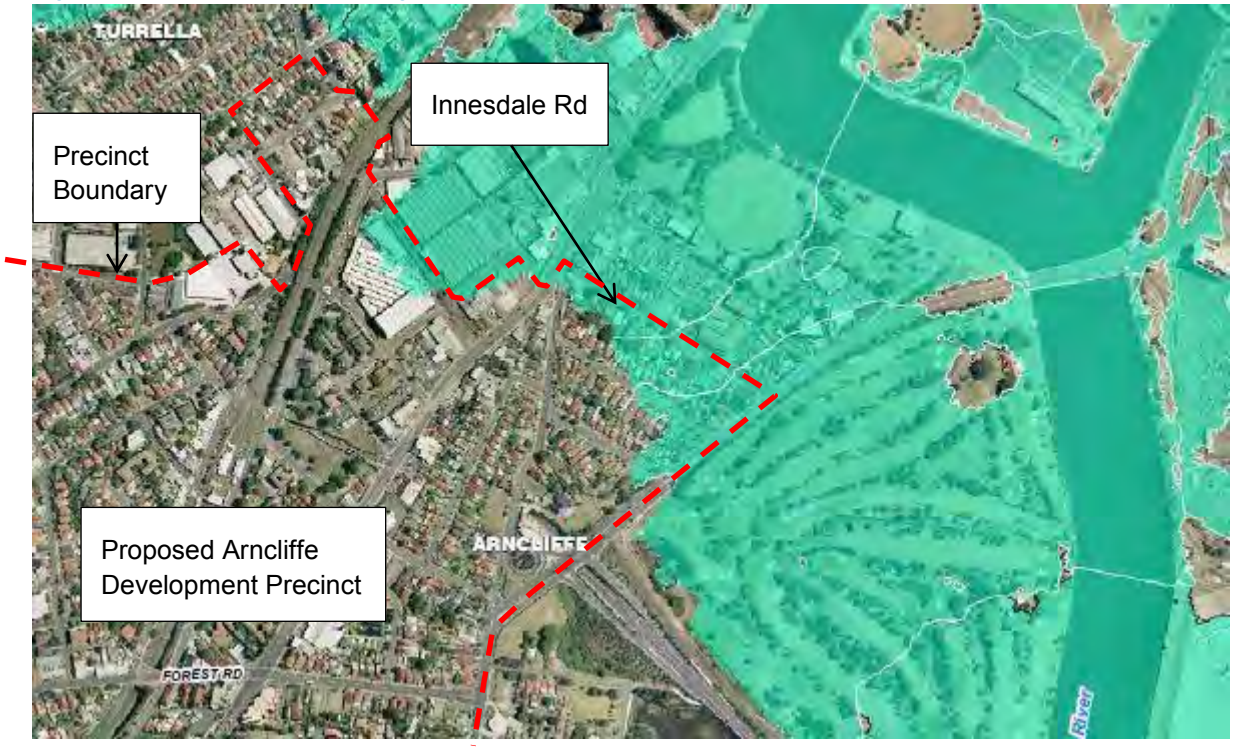
As noted in Section 3.1.3.1, the subject site is outside of the immediate modelling area of the Cooks River study. As such the results should be interpreted as indicative only, as a means of highlighting areas in which more detailed investigations should be undertaken.

Figure 3.7: Flood Extent Mapping: 100 year ARI + Climate Change




Source: *Cooks River Flood Study* (MWH+PB 2009)

Figure 3.8: Flood Extent Mapping: PMF




Source: *Cooks River Flood Study* (MWH+PB 2009)

#### 3.1.3.3 Study Recommendations

- The study notes that the models developed will be used to provide an assessment of the hydraulic impacts of the bank naturalisation options along the Cooks River proposed by the CRFWG, to assist in ensuring that flood levels at properties within the catchment are not adversely affected.

### 3.1.4 Spring Street Drain – Pipe Drainage and Overland Flow Analysis (Brown Consulting, October 2007)

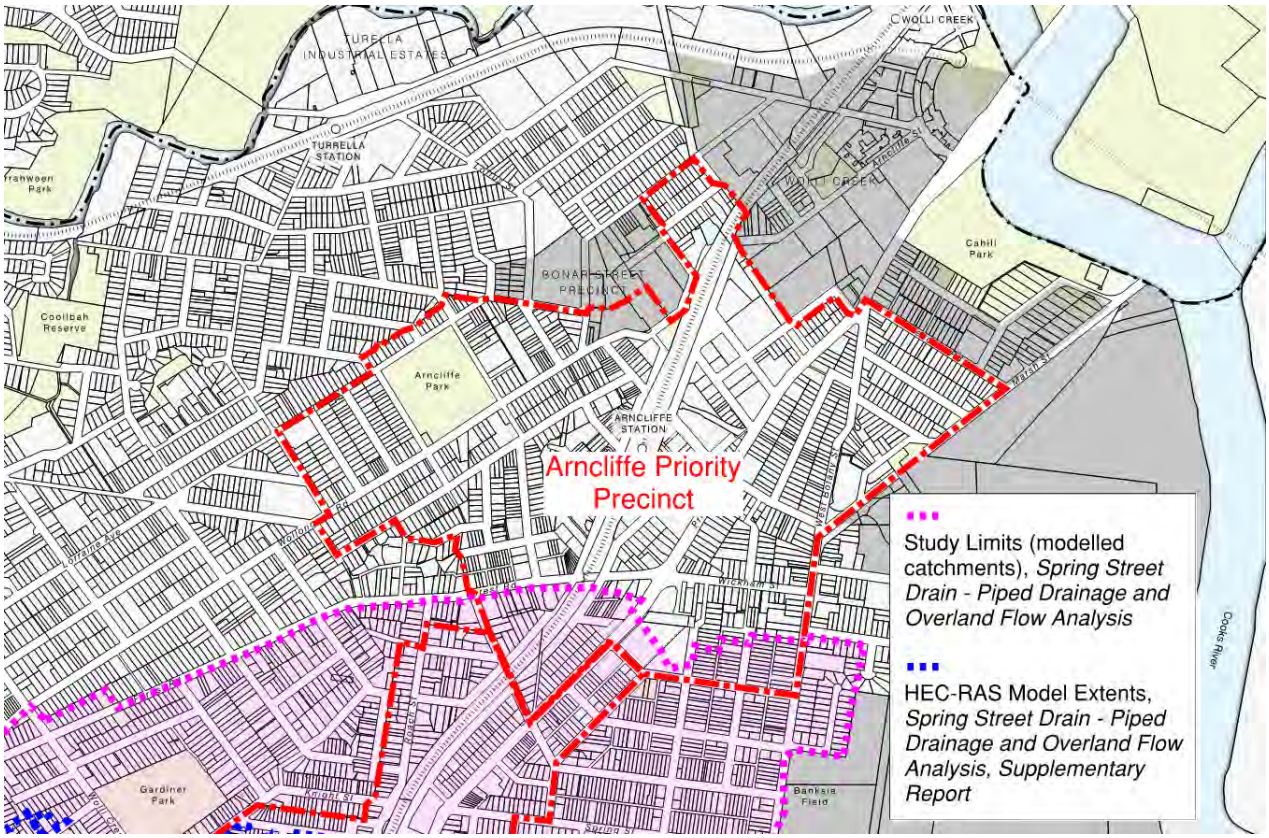
The *Spring Street Drain – Piped Drainage and Overland Flow Analysis* was undertaken as part of the first stage of the floodplain management process for the Spring Street Catchment area. Extensive information for the study was sourced from Rockdale City Council including GIS data records.

The Spring Street Drainage Catchment covers an area of 224 hectares draining eastwards to an outlet at West Botany Street, within the suburbs of Rockdale, Banksia, Arncliffe and Bexley. Stormwater ultimately drains to Botany Bay via Muddy Creek.

The aim of the study was to identify and assess the properties affected by overland flows within the catchment using the DRAINS and HEC-RAS computer models. The study investigated the sub-catchments draining to the channel and not the channel itself.

Only a small area of the Arncliffe Priority Precinct area to be analysed as part of this Mott MacDonald Literature lies within the study area of the Spring Street Drain – Pipe Drainage and Overland Flow Analysis report; see Figure 3.9.

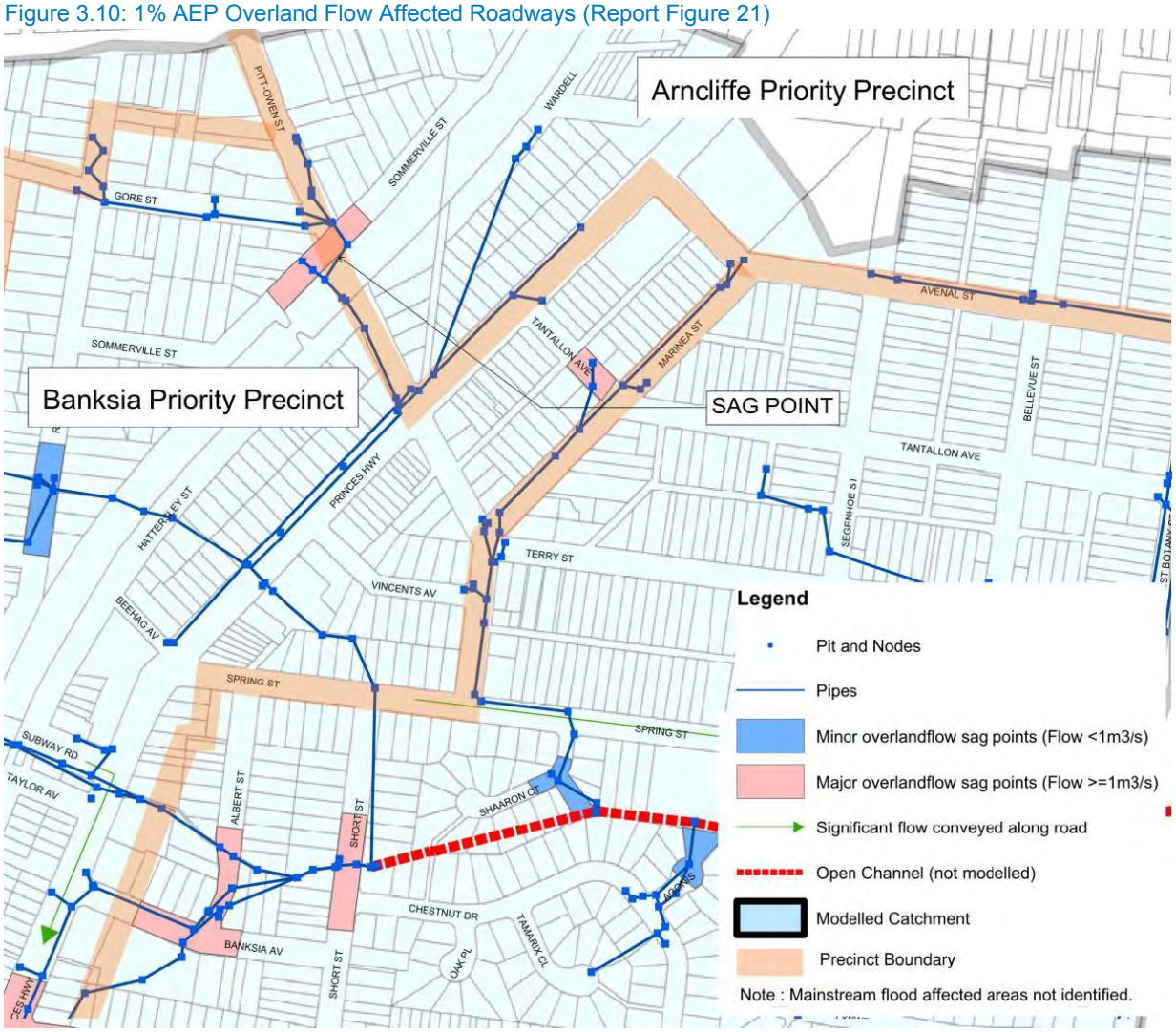
Figure 3.9: Study Area – Spring Street Drain – Pipe Drainage and Overland Flow Analysis, Brown Consulting, October 2007




Source: *Spring Street Drain – Pipe Drainage and Overland Flow Analysis*, Brown Consulting, October 2007

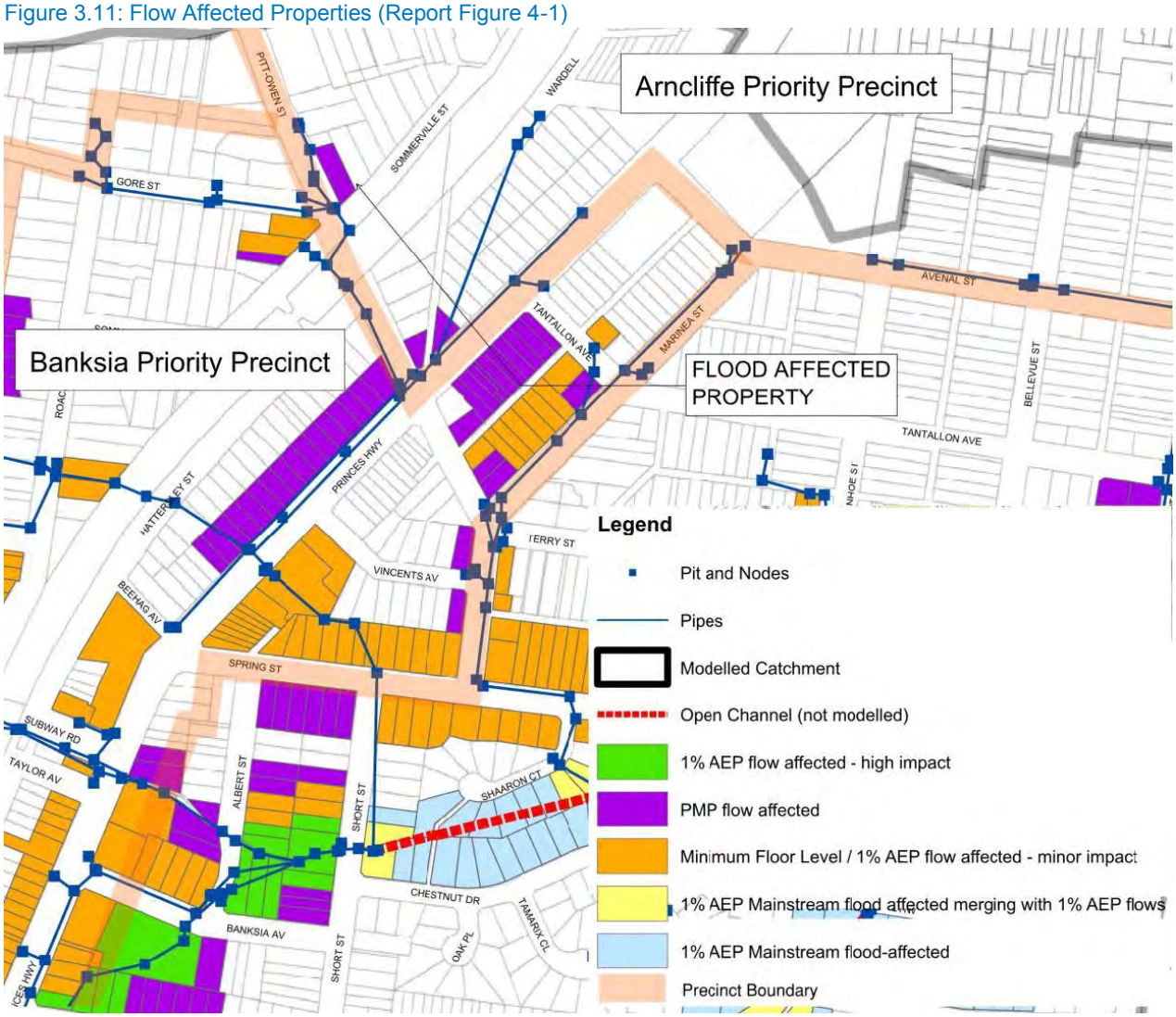
The area of the Spring Street Catchment relating to the Arncliffe Priority Precinct is in its upper reaches, meaning relatively minor flows have been observed. A major overland sag was identified at the intersection of Sommerville St and Pitt-Owen St where the drainage network for this sub-catchment crosses the rail line. As a result of this sag, some properties in the immediate area are impacted by ponding water, noting only one falls with the Arncliffe Priority Precinct, and is only impacted by the PMP. The following figures show the sag and affected properties respectively.

Figure 3.10: 1% AEP Overland Flow Affected Roadways (Report Figure 21)




Source: *Spring Street Drain – Pipe Drainage and Overland Flow Analysis*, Brown Consulting, October 2007

Figure 3.11: Flow Affected Properties (Report Figure 4-1)




Source: *Spring Street Drain – Pipe Drainage and Overland Flow Analysis – Supplementary Report*, Brown Consulting, October 2007

### 3.1.5 Water Sensitive Urban Design Implementation Strategy for Bonar Street Rezoning Application, Amended June 2005 (Webb, McKeown & Associates, June 2005, for Brewster Murray Pty Ltd)

Although this study is focused on the Bonar Street Redevelopment Precinct (outside of the Arncliffe Priority Precinct boundary), it considers floodplain management/ drainage augmentation issues outside of the Bonar Street Redevelopment Precinct relating to overland flow paths, blockages and flood risk in the zone between Wollongong Road and the Southern and Western Suburbs Ocean Outfall Sewer (refer 3.1.1.2).

The report discusses the preparation of a concept stormwater design for the Bonar Street rezoning, including staging, design concept elements and hydraulic analysis. Preliminary hydraulic modelling results indicate that the concept design would perform satisfactorily for floods up to the 100y ARI event. However, the report notes that a number of design issues will need to be further addressed at the detailed design stage, requiring further hydrologic and hydraulic modelling to be undertaken.

### 3.1.6 Bonnie Doon Catchment Upper Catchment Diversion Preliminary Assessment (Webb, McKeown & Associates, June 2001)

This study assesses the feasibility of diverting flows from the upper catchment of Bonnie Doon catchment into the Bardwell Creek catchment. Results indicate that the proposed diversion would reduce peak 100 year ARI flowrates at critical locations upstream of Arncliffe Park by between 40% and 50%, while the effect of the diversion on peak flood levels in Bardwell Creek is considered to be negligible.

The study indicates that further studies would be required into the hydraulic operation of a diversion system, the technical feasibility of capturing and diverting the water, interactions with buried services, detailed design, final project costing and a Review of Environmental Factors, recommending that a concept level design be carried out based on “topographic survey of the route/s, geotechnical assessment of ground conditions, consideration of all service constraints, design of surface re-grading, and hydraulic and civil design of the pipe system."

### 3.1.7 Arncliffe Park Detention Basin Concept Design, Draft Report (Webb, McKeown & Associates, December 1998)

This report assesses the feasibility and concept design for provision of a detention basin at Arncliffe Park, as one proposed flood management solution identified in their earlier study discussed in Section 3.1.8.2. The report describes the development and assessment of several alternative basin arrangements, with the objectives of obtaining reasonable flood mitigation benefit, cost effectiveness, enhancement of the park utilisation and embankment safety. The assessment utilises ILSAX modelling to evaluate various basin storage options for a range of storm events. Benefit/cost analysis was then undertaken for the various options.

#### 3.1.7.1 Study Limitations

The modelling excludes the drainage system downstream of Arncliffe Park and as such does not allow direct estimation of flood levels and damages at downstream properties. Estimation of flood levels at downstream properties was therefore based on information from Webb, McKeown & Associates' earlier study discussed in Section 3.1.8.2.

#### 3.1.7.2 Study Results

A range of initial options were assessed, summarised as follows:

- Embankment downstream of trees, close to Broe Avenue;
- Wall downstream of trees, close to Broe Avenue;
- Embankment on the sports field, upstream of the trees, with reduced storage volume;
- Other combinations of the above options with additional excavation to increase the storage volume;
- An additional cascading basin north of the main basin to retard flows from Hirst Street.

Assessment was undertaken for various storage volumes in the order of 5,100m$^3$ to 10,500m$^3$ for each of the options, with results indicating that the smaller volume basins would only provide attenuation for small (5 year ARI) storms, and the larger volume options potentially providing attenuation up to 100 year ARI inflows. Three embankment options were selected, further developed and their costs, impacts and hydraulic performance assessed.

The findings note that none of the options provides a completely satisfactory flood reduction solution, due to the difficulty in providing adequate storage without significant impact on the park. The relatively high cost, impact and limited benefit of the various solutions are cited as barriers to implementing most of the options put forward. The option which is identified to offer the most benefit (although still limited) with the least adverse impacts is as follows:

- Construction of an embankment upstream of the trees and path, with up to 1.7m excavation over the playing field (5,600m$^3$) and adjustment of the existing twin 600mm stormwater pipes beneath the playing field to achieve a total storage volume of 10,600m$^3$, with a 1 in 10 year overtopping frequency.

### 3.1.8 Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998)

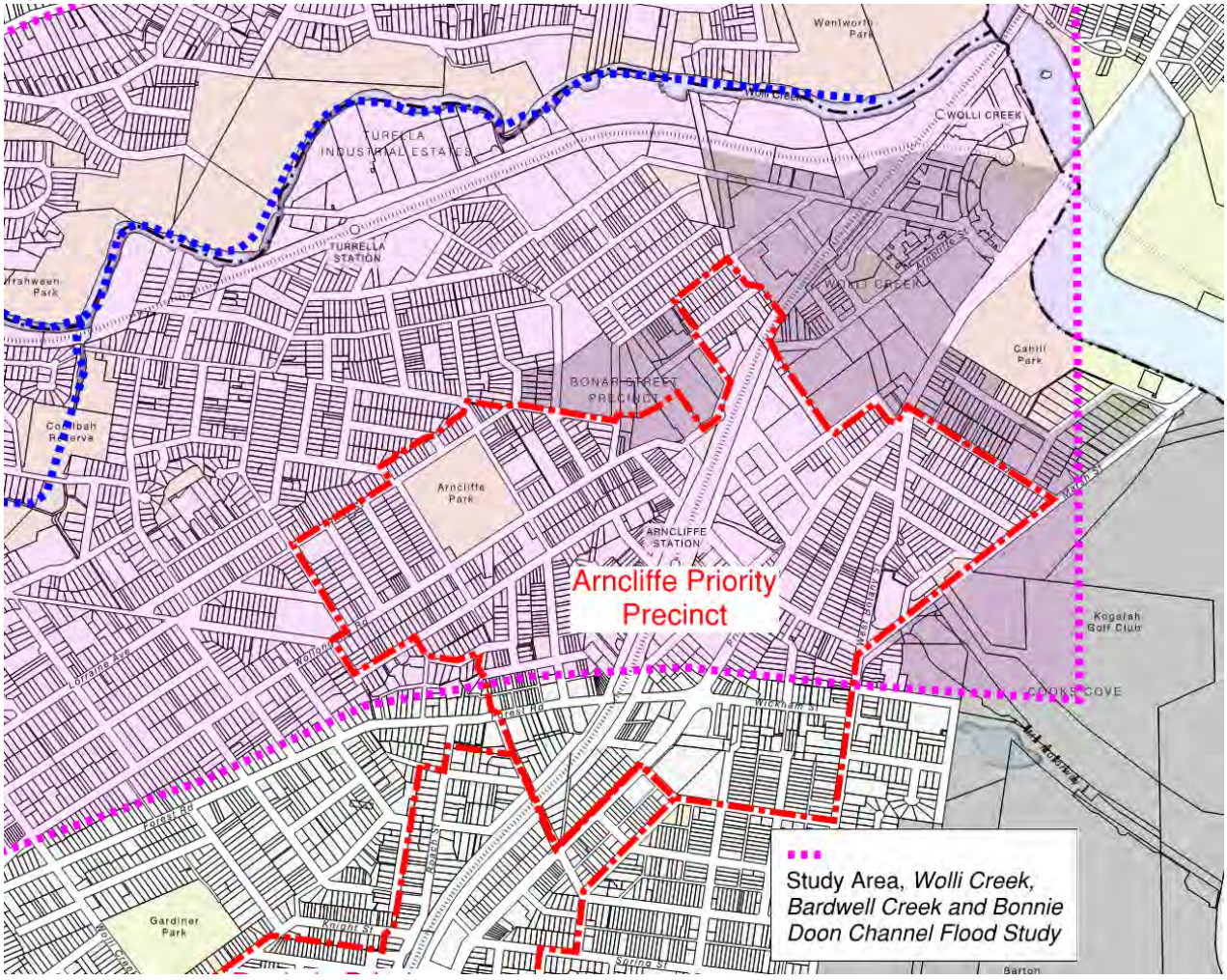
As part of the first three stages of the NSW Government's Flood Policy process, the following reports were prepared for the Wolli Creek, Bardwell Creek and Bonnie Doon Catchments:

- Flood Study:
  - *Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study*, Webb, McKeown & Associates, November 1996;
- Floodplain Management Study:
  - *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Study*, March 1998;
- Floodplain Management Plan:
  - *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Plan*, March 1998;

The reports assess existing flood behaviour in the catchments, evaluate management options for the floodplain for existing and proposed development, and then present a plan for adoption by Council. Council have advised that any adopted Floodplain Risk Management Plan (FRMP) is considered to be a policy of Council, and that the *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Plan* is one of three FRMPs that have been adopted by Council and are considered as "policy".

The study area partially covers the proposed Arncliffe Priority Precinct (refer Figure 3.12), with the upstream limit of the study at Wollongong Road on the Bonnie Doon Channel.

Figure 3.12: Study Area – Webb, McKeown & Associates 1996, 1998 & 1998




Source: *Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study* (WMA1996)

### 3.1.8.1 Flood Study

The study utilises a combination of a RUBICON hydraulic model and a WBNM hydrologic model, to estimate flow behaviours within the mainstream drainage lines within the catchments.

The study describes the Bonnie Doon catchment and channel in agreeance with the Bonnie Doon Study discussed in Section 3.1.1, along with some additional downstream information:

- The majority of runoff passes under the Illawarra Railway Line at Wollongong Road;
- Immediately downstream of Wollongong Road the sewer line forms a major restriction to flow;
- There is little open space (apart from small parks and reserves) in the area, with most of the ground surface being covered by impervious materials

- A lined open channel constructed during the 1940s starts north of the sewer line near Allen Street and runs between Arncliffe Street and the Princes Highway, crossing under the Highway north of Gertrude Street. East of the Highway the lined channel runs through Cahill Park to the Cooks River;
- Buildings along Arncliffe Street prevent floodwaters reaching the Bonnie Doon channel via overland flows. In cases where drains are blocked or undersized, ponding needs to rise to a depth greater than 0.5m before floodwaters can flow from Arncliffe Street through the factories to the Bonnie Doon Channel;

The study notes that blockage by debris carried by flood waters may have a significant impact on capacity of culverts within the catchment. The report notes that blockage of the culvert under the sewer line near Allen Street would cause a significant increase in flood levels, while blockage in other areas may cause less impact due to the piped/culvert system being already at capacity in minor floods.

It is noted that while the 1996 study results give a broad overview for the Bonnie Doon catchment and mainstream flows, the results in the 2011 *Bonnie Doon Pipe & Overland 2D Flood Study* as well as the Bonnie Doon and Eve Street/Cahill Park TUFLOW model that is currently in progress (both by WMA Water) are considered more relevant to the subject area due to the currency as well as the level of detailed assessment.

#### 3.1.8.2 Floodplain Management Study

The Floodplain Management Study aims to define the nature and extent of flood hazard, as well as identify and assess strategies and measures aimed at reducing the impact of flooding on both existing and future development. The study utilities results from the three Flood Studies discussed in sections 3.1.8.1, 3.1.8.3 and 3.1.10.

The study identifies small retarding basins located in areas of open space such as parks or golf courses as a potentially viable structural measure to reduce flooding. Within the Bonnie Doon catchment, Arncliffe Park was assessed as the only possible site due to the level of existing development within the catchment. The study notes that in the existing situation, approximately 40% of the 4 hectare park is inundated by up to 0.3m depth during the 1% AEP event. The report suggests that a detention basin of approximately 20,000m$^3$ (approx. 1.9 hectare footprint x 1.3m depth) would sufficiently attenuate the peak flood such that the outflow would be contained within the existing pipes under the park, and subsequently reduce flood levels in Broe Avenue, Kelsey Street, Bonar Street and Wollongong Road.

The study discusses potential upgrading of the existing piped drainage system from Dowling Street to Bonar Street. As the existing pipe alignment is through residential lots, the study suggests implementing a parallel line under Wollongong Road or Hirst Street, or diverting flows from the central pipeline to the north or south pipeline. It also notes the option of diverting additional runoff to East Street (where the existing pipe discharges to the Bardwell Park catchment) however rejects it due to existing problems in East Street. Options to upgrade to either 5% or 20% AEP capacity are considered, and the study notes that upgrading to the 5% AEP capacity would eliminate above floor inundation in localised properties in a 1% AEP flood.

The study identifies the Martin Avenue/Wollongong Road intersection (just upstream of the underpass to the Illawarra railway line) as a significant choke point for overland flows, with ponding occurring at the intersection before runoff enters the underpass. The option to upgrade the piped network with say twin 1800mm diameter pipes under the railway line is discussed but is considered cost-prohibitive. Alternatively it is suggested that part of Wollongong Road at the underpass be lowered so that runoff can escape through the underpass, eliminating the low point in Martin Avenue. However it is noted that this solution could potentially increasing the traffic hazard at the underpass, and that it would have no effect in 20% AEP floods and greater. Use of a 600mm diameter pipe to reduce the incidence of ponding in the railway underpass is suggested but not discussed.

The raised sewer carrier downstream of Allen Street is also identified as a significant hydraulic restriction. The study identifies that the only existing openings under the carrier are a channel and a series of brick arch openings, a number of which have been blocked. It is suggested that unblocking some of these arches under the sewer will reduce flood levels upstream and is unlikely to cause a significant increase in downstream flood levels because of the wide floodplain, noting that clearing all of the openings would reduce the 1% flood level upstream by up to 0.5m. Discussion with the landowners is suggested.

The study also notes several other potential measures to contribute to flood management in the area:

- Remedial Measures:
  - Voluntary purchase of houses to create an open-space overland flow path;
  - House raising or flood proofing of non-residential buildings – the study notes that 26 buildings in the study area are inundated above flood level in the 1% AEP flood, six of which may be suitable for house raising and five of which may be suitable for flood proofing;
  - Lowering of driveways, moving sheds, replacing paling fences to reduce the problem for small events;
  - Flora – removal of exotic vegetation in waterways and replacement with less-choking native vegetation (catchment wide);
- Policy Measures:
  - Review of Council's On Site Detention policy;
  - Developer contributions towards the basin and/or pipe upgrade options in lieu of site based detention;
  - Additional building and development controls to maintain flowpaths clear of filling/ fences/ garages/ driveways, force new developments to build on stilts and/or stagger building layout to maintain a flowpath through the site, and prescribing minimum flood level control of 0.3m above natural ground surface (in the absence of a Design Flood Level policy);
  - Public information and education – recommends that the community needs to be continually informed an updated on the current state of knowledge in order for appropriate reaction to flood warnings or advice regarding flooding in future;
  - Emergency Services – recommends that Local Emergency Management Committees should review their procedures in light of flood studies;
  - Road Crossings – use of warning signs and education about hazard levels;

The study concludes that clearing the openings under the sewer and undertaking road and drainage works in Wollongong Road to reduce upstream ponding would be most viable on a cost basis. Due to significant

cost the other options require additional investigations (for example the basin option may provide additional benefits or draw developer funding to justify the cost). The study recommends a detailed services search along Wollongong Road to confirm whether a drainage upgrade along this alignment is feasible.

The study further discusses development strategies including continuing review of Council's flood policies and the following key issues for consideration:

- Flood Planning Level – adopting a freeboard of 0.5m above the 1% AEP flood level in setting the Minimum Design Floor Level;
- Review of Section 149 Certificates in the context of Council's flood policy – advice on individual property flood affectation;
- Flexible Design Floor Level policy for non-residential buildings and consideration of alternative protection methods;
- Review of policy details with regards to Flood Evacuation Plans, minimum ground levels for car parking and non-residential development, and below-ground garages;
- Increased rainfall considerations due to climate change;
- On-site detention and retention described in Council's design code, and alternative solutions such as a Section 94 contribution to upgrade regional drainage;
- Limiting of filling in the floodplain;
- Using major redevelopment as an opportunity to address flood hazard;
- Modifications to the Bonnie Doon channel;
- Redevelopment of north Arncliffe west of the Illawarra railway line;
- In summary, ensuring that any future development does not adversely impact on the existing flooding regime.

#### 3.1.8.3 Floodplain Management Plan

The *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Plan* is one of three FRMPs that have been adopted by Council as policy. The plan covers the floodplain of Wolli Creek from Kingsgrove Road to the junction with the Cooks River; the floodplain of Bardwell Creek from Croydon Road to the junction with Wolli Creek; the Bonnie Doon Channel catchment; the Eve Street/Cahill Park catchment; and, the area of North Amcliffe between the East Hills and Illawarra Railway Lines. The plan works on the basis of providing the maximum degree of flood mitigation possible within the constraints of practicability and cost, noting that it is not feasible to provide protection to all buildings inundated in the 1% AEP event.

Key controls presented by the plan are as follows:

- Continued adoption of the 1% AEP flood as the Flood Standard;
- Establishment of Design Floor Level for residential buildings as 0.5m above the 1% AEP flood level;
- Definition of the 1% flood extent and identification of properties subject to Design Floor Level requirements;

In addition, the plan presents strategies for flood management:

- Strategies applying to the whole study area including amending the Section 149 database with the latest information, information and education, updating of warning and evacuation procedures.

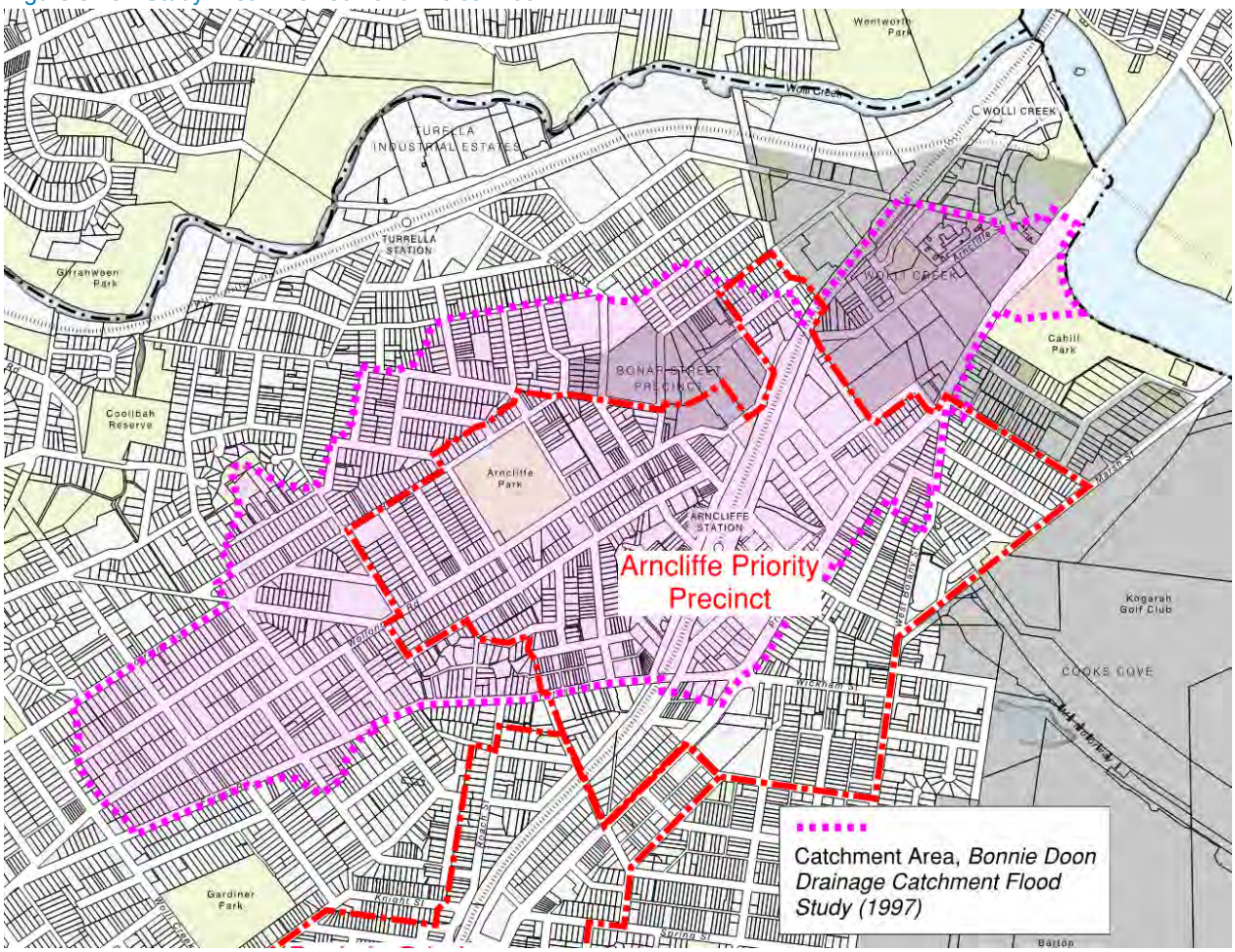
Revision of flood policy, removal of noxious vegetation, collection of data, controlling alterations to the floodplain during the development approval process, land use planning process, climate change, OSD/ Section 94 contributions, impacts, maintenance and hazard reduction at road crossings;

- Strategies which apply to North Arncliffe between the East Hills and Illawarra railway lines including flap gating to reduce inundation from Wolli Creek, and modifications to the drainage system to improve the routing of upstream runoff.
- Strategies which apply to the Bonnie Doon channel from Princes highway/ Illawarra railway line to the sewer carrier including not allowing future development to proceed unless it can be shown that it will reduce the existing flood problem, investigation of a levee option to reduce inundation from Cooks River, and modifications to the drainage system to improve the routing of upstream runoff.
- Strategies which apply to the Bonnie Doon channel upstream of the sewer carrier including:
  - Upgrade of existing drainage system along existing alignment / realignment along Wollongong Road subject to services search
  - Investigating construction of a retarding basin in Arncliffe Park
  - Undertaking drainage works to reduce ponding at Wollongong Road and the underpass
  - Maintaining free flow of water through the openings under the sewer carrier
- Strategies which apply to Eve Street/ Cahill Park from Gertrude Street through Innesdale Street to Valda Avenue including improved maintenance of the pit and pipe system, pipe upgrades, investigation of a levee option to reduce inundation from Cooks River, and monitoring upgrades to the M5.
- Future development within the catchment and in the floodplain to be monitored to ensure that it does not exacerbate the flood problem or water quality/sedimentation problems.
- Measures by Public Authorities to increase the length of flood warning time available to the residents or the efficiency of emergency services.

### 3.1.9 Bonnie Doon Drainage Catchment Flood Study (Lawson and Treloar 1997)

The *Bonnie Doon Drainage Catchment Flood Study* assesses existing flood behaviour in the Bonnie Doon drainage catchment as part of the first stage of the NSW Government's Flood Policy process. It covers a portion of the proposed Arncliffe Priority Precinct (refer Figure 3.13).

Figure 3.13: Study Area – Lawson and Treloar 1997




Source: *Bonnie Doon Drainage Catchment Flood Study* (Lawson and Treloar 1997)

The study utilises a combination of a hydrologic/pipe hydraulic model (MOUSE software) and hydraulic model (MIKE-11 software) to model the piped and overland flow drainage systems for the 20%, 10%, 5%, 2% and 1% AEP and an extreme event. The hydraulic model results indicate that parts of the existing piped stormwater drainage system do not adequately cater for runoff generated from frequent design rainfall events. Significant overland flows are predicated to occur at all modelled design events through Dowling, Kembla, Walters and Mitchell Streets, Arncliffe Park, and Broe, Kelysey and Bonar Streets.

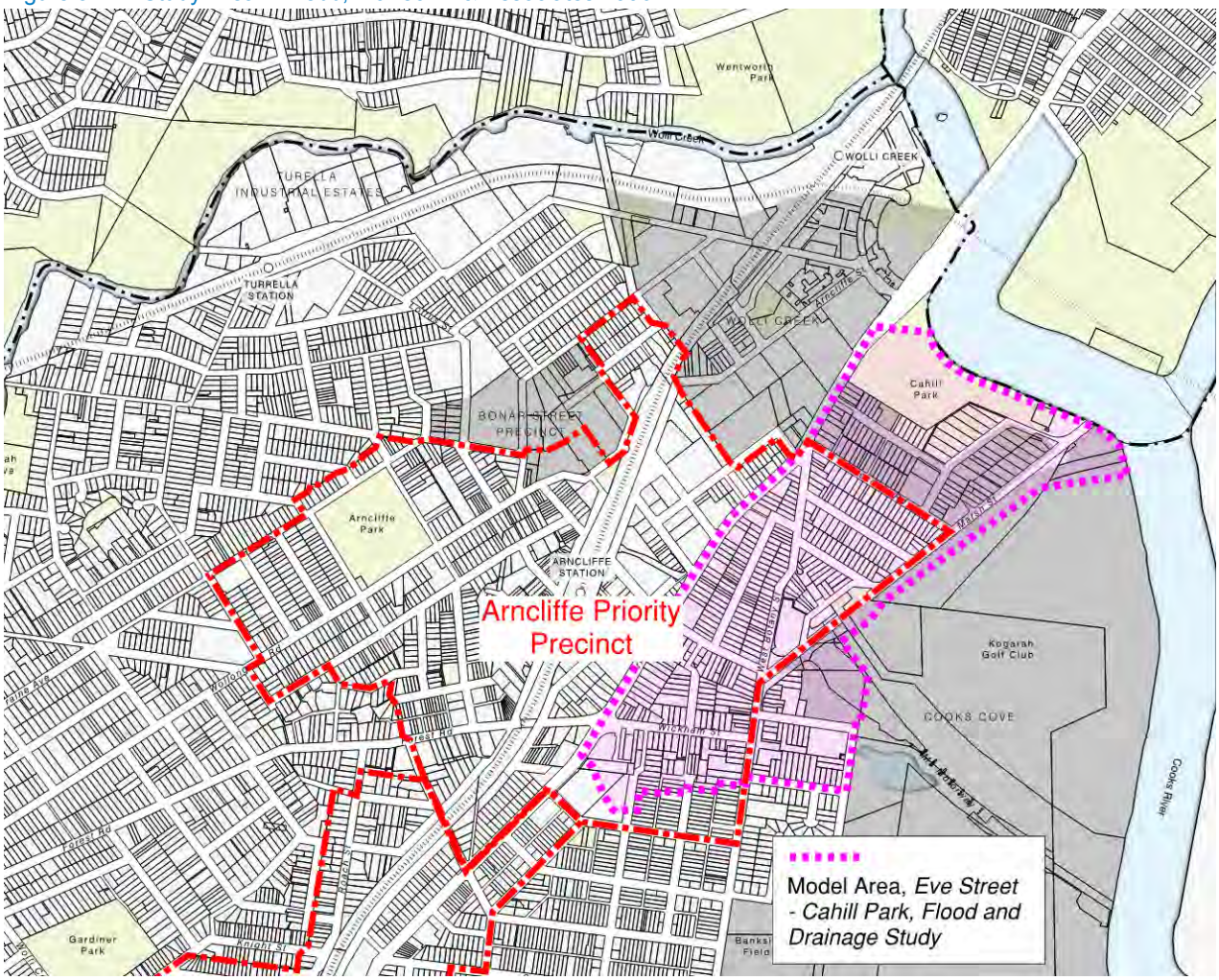
Flooding depths up to approximately 1.2m for the 1% AEP design event are predicted to occur adjacent to the intersection of Wollongong Road and Martin Avenue just upstream of the underpass.

The study was considered in the undertaking of future studies such as the *Bonnie Doon Pipe & Overland 2D Flood Study* discussed in section 3.1.1 and the *Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study* discussed in section 3.1.4. It is understood that the *Bonnie Doon Pipe & Overland 2D Flood Study* as well as the currently in-progress TUFLOW modelling for Bonnie Doon and Eve Street/Cahill Park (section 3.1.2) expand upon and supersede the results from the 1997 study.

### 3.1.10 Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996)

The *Eve Street - Cahill Park, Flood and Drainage Study* assesses existing flood behaviour in the Eve Street-Cahill Park drainage catchment at Arncliffe as part of the first stage of the NSW Government's Flood Policy process. It covers the easternmost portion of the proposed Arncliffe Priority Precinct (refer Figure 3.14).

Figure 3.14: Study Area – Webb, McKeown & Associates 1996




Source: *Eve Street - Cahill Park, Flood and Drainage Study* (Webb, McKeown & Associates 1996)

An ILSAX hydrologic/hydraulic model was used to determine the capacity of the existing drainage system, and results were compared with a Hydraulic Grade Line (HGL) analysis, which showed that downstream reaches with backwater conditions were more accurately reflected by HGL analysis. The study also evaluated the effects of future catchment urbanisation and proposed pit/pipe upgrade schedules.

The report recommends that flood data should be collected, surveyed, photographed and recorded immediately following all future flood events, as well as recommending that Council install several maximum height recorders in the catchment.

#### 3.1.10.1 Piped and Overland Flows

The study indicates that the piped drainage systems in the area all drain in a northerly or easterly direction to the Cooks River, which is tidal in the vicinity of the catchment. Once the capacity of the pit/pipe drainage system is exceeded, runoff travels by overland flow through properties and road reserves to the lower reaches of the catchment, ponding in the flatter areas of the Eve Street Wetland, Kogarah Golf Course and Cahill Park until the depth exceeds and overtops the river bank.

The study identifies properties within Charles Street, Wickham Street, West Botany Street, Eve Street, Valda Avenue, Marsh Street, Flora Street, Innesdale Road and Gertrude Street as properties requiring further investigation, with the results indicating them as being either potential overland flow paths if the drainage system capacity is exceeded/blocked, or as low lying areas with inadequate surface drainage.

#### 3.1.10.2 Problem Areas and Drainage Improvements

The study identifies the following key drainage issues and provides recommendations for drainage improvements:

- Localised drainage problems
  - Inundation across Kogarah Golf Course – not investigated further due to unlikely use during inclement weather and due to flat low lying topography making it difficult to drain.
  - Ponding at 1-5 Gertrude Street due to insufficient pipe capacity downstream. Report recommends that amplification of the drainage system would improve the situation.
  - Ponding in Eve Street – contributing factors include blockage, overflow from the major catchment outlet pipes and inadequate inlet at Brennans Road. Report recommends maintenance works, minor road works, and pipe upgrades.
  - Overland flow between Charles Street and West Botany Street due to inadequate pipe capacity draining the low point in Charles Street. Report notes that even if upgraded capacity is still limited by the drainage line in Wickham Street.
  - Low point in Valda Avenue causing ponding, exacerbated by under-capacity pipe draining the area. Report recommends provision of additional inlets and supplementary (parallel) downstream pipe drainage.
- Mainstream trunk drainage problems
  - Existing drainage system is under-capacity, with the report suggesting amplification using either additional/parallel pipes or replacing existing pipes with larger ones, subject to cost viability.
  - Inlets with inadequate capacity or poor positioning at various locations.

  - The provision of overland flow paths is suggested, however due to the dense nature of development in Arncliffe the opportunity is noted to be limited.
  - Flood storage and basins are suggested, however no practical sites were identified in the upper catchment, and detention in the lower catchment would provide no benefit. OSD is mentioned as a means of mitigating future increase however with no benefit to reducing current flooding.
  - Minor measures such as pipe maintenance are recommended to ensure the hydraulic efficiency of the existing system.
- Inundation from the Cooks River
  - This is identified as the major risk contributor to Gertrude Street and Levey Street. Suggestions include raising the river bank (levee), providing additional internal drainage capacity, and flap gating incoming drainage lines.

#### 3.1.10.3 Council Policy Discussion

The study notes that Council's existing (at the time of the study) Stormwater Drainage Code bases the need for OSD upon a percentage increase in impervious area, and recommends instead that it may be more appropriate to establish an overall permissible percentage applicable to individual lots dependant on zoning.

The study also notes that in the past, Section 149 planning certificates only noted mainstream flood affected properties, while moving forward localised flooding should also be considered.

#### 3.1.10.4 Report Recommendations

The study recommends a combination of monitoring future storms and overland flow paths, undertaking drainage and flood mitigation measures, continuing OSD policy for non-residential or multi-unit residential developments where OSD is more cost effective, removing OSD requirements for additions or improvements to single site residential developments, and designing a standardised detention/retention system for new single site residential developments.

### 3.1.11 Bonar Street Upgrade Project – Design Options Assessment, Cardno NSW/ACT Jan 2014; and Bonar Street Upgrade Drainage Design, Cardno NSW/ACT July 2014

Cardno was engaged by Rockdale City Council to analyse and design drainage works in Bonar Street. The two reports prepared as a result document the analysis and design phases for the detailed design of culverts under Bonar Street and at the rear of no 13-15 Wollongong Road. Whilst the reports focus on the Bonar Street Redevelopment Precinct (which technically is outside of the Arncliffe Priority Precinct), the study area for analysis includes the area around Wollongong Road.

### 3.1.12 Bonar Street Redevelopment Precinct Drainage Study (Rockdale City Council, July 2014)

Rockdale City Council has commenced review of the Floodplain Risk Management Plan for the Wolli Creek, Bardwell Creek, Bonnie Doon Channel and Eve Street / Cahill Park Catchments, which is currently ongoing. The Bonar Street Redevelopment Precinct Drainage Study has been undertaken prior to completion of the full review, as part of interim reviews required to manage the planning of trunk drainage augmentation works for development within the high density zoning. The study identifies potential stormwater drainage works with prioritisation and floodplain risk management within the Bonnie Doon Channel catchment, with focus on the area of the Bonar Street development precinct.

Hydrologic and hydraulic modelling was utilised to investigate existing flood behaviour within the Bonar Street Development Precinct. Results indicate that the existing trunk stormwater drain through the Bonar Street Precinct does not cater for the 1% AEP flow. Overflows spill through properties and roadways from Kelsey Street through to Wollongong Road. Restrictions of overland flow cause elevated water level profiles at Bidjigal Street (behind 9-11 Wollongong Road) and Wollongong Road (behind the Illawarra Railway corridor, potentially resulting in inundation of properties.

The study recommends both planning and physical works to address the temporary and final situation. Although focused on the Bonar Street Precinct, it recommends strategies outside of the precinct including further review of Arncliffe Park detention basin, and the area between Wollongong Road to the SWSOOS, as well as issues for property between Kelsey Street to Bonar Street. Rockdale City Council has undertaken a review of the recommendations of the study and a summary of priorities is presented in Table 3.1.

Table 3.1: Bonar Street Drainage Study July 2014 – Draft Evaluation of Priorities (Rockdale City Council 2014)

| Number | Strategy | Outcomes | Action By | Timing | Cost |
|---|---|---|---|---|---|
| *Planning* | | | | | |
| P1 | Planning – Site Controls and OSD | Ensure site controls for impervious area and OSD meet RDCP2011 | Development Assessment | Ongoing | Nil – normal operations |

| Number | Strategy | Outcomes | Action By | Timing | Cost |
|---|---|---|---|---|---|
| P2 | Planning – FPL | Ensure FPL responds to highest flood level from Stage 1 or Stage 2 | Development Assessment/ City Infrastructure | Ongoing | Nil – normal operations |
| P3 | Planning – Acquisition of 13-15 Wollongong Road | Identify land for acquisition, amend the RLEP 2011 Land Reservation and Acquisition Map accordingly and expedite drainage augmentation | Urban Strategy / Property Services | ASAP | Nil – normal operations<br>(Acquisition costs TBC) |
| P4 | Planning – Rezoning/planning proposal for block bounded by Bonar Street, Kelsey Street and Hirst Street | Provide for higher density development with reserved lands for drainage purposes to improve system inlet capacity and overall hydraulic efficiency | Urban Strategy/ City Infrastructure | ASAP | Planning: Nil – normal operations<br>Study: See W8 |
| P5 | Planning – Instigate action against PCA for 9-11 Wollongong Road | Redacted | | | Planning: Nil – normal operations<br>Study: See W1 |
| P6 | Planning – Review planning strategies for 12 Arncliffe Street | Identify the current flood risk and review modelling options. Review planning strategies in light of flood risk (current and future). | City Infrastructure/ Urban Strategy | Short Term (prerequisite is the completion of the Bonnie Doon and Eve Street/Cahill Park flood study) | Nil - normal operations |
| P7 | Planning – Review Flood Protection at 45 Bonar Street | Identify impacts to driveway levels and identify flood action plan for the developer to implement | City Infrastructure/<br>Development Services | ASAP | TBC |
| *Works* | | | | | |
| W1 | Works – Augmentation alignment between 9-11 Wollongong Road to Arncliffe Street | Confirm the augmentation alignment between 9-11 Wollongong Road to Arncliffe Street, through 7 Wollongong Road and the railway corridor | City Infrastructure | ASAP | Design Study: Cost $150k<br>Funds: S94 |

| Number | Strategy | Outcomes | Action By | Timing | Cost |
|---|---|---|---|---|---|
| W2 | Works – Arncliffe Park Detention Basin | Complete investigation on the feasibility of the detention basin at Arncliffe Park | City Infrastructure | ASAP | Cost $120k<br>Funds: SW Levy (part OEH) |
| W3 | Works – Overland flow improvements to Wollongong Road | Complete investigation on the feasibility of overland flow improvements to Wollongong Road | City Infrastructure | ASAP | Cost $90k<br>Funds: SW Levy (part OEH TBC) |
| W4 | Works – Augmentation Bonar Street to 13-15 Wollongong Road | Implement augmentation through New Street West (including temporary surcharge structure at 13-15 Wollongong Road boundary) | City Infrastructure/Urban Strategy & Design/Developer (Works-In-Kind) | ASAP | Cost $3.9M<br>Funds: S94 |
| W5 | Works – Augmentation Bonar Street, between Hirst Street and New Street West | Implement augmentation in Bonar Street, between Hirst Street and New Street West | City Infrastructure | ASAP | Cost $4.1M<br>Funds: S94 |
| W6 | Works – Augmentation Bonar Street to 13-15 Wollongong Road | Implement augmentation through 45 Bonar Street (southern boundary), subject to investigation of concept design, | City Infrastructure | Short Term (prerequisite is P5) | Cost $2.8M |
| W7 | Works – Augmentation 45 Bonar Street to 9-11 Wollongong Road | Implement augmentation through 13-15 Wollongong Road, subject to investigation of concept design, hydraulic capacity assessment and detailed design | City Infrastructure | Short Term (prerequisite is P3 and P5) | Cost $1.8M<br>Funds: S94 |
| W8 | Works – Inlet capacity at Bonar Street, at Hirst Street intersection (including 43 Bonar Street) | Implement inlet capacity improvements at Bonar Street, at Hirst Street intersection, (including 43 Bonar Street) subject to investigation of concept design, hydraulic capacity assessment and detailed design, and resolution of drainage easements | City Infrastructure | Medium Term (prerequisite is P4, and W1-W7) | Cost $810k<br>Funds: S94 |

| Number | Strategy | Outcomes | Action By | Timing | Cost |
|---|---|---|---|---|---|
| W9 | Works –Augmentation 9 - 11 Wollongong Road to Martin Avenue | Implement augmentation between 9 - 11 Wollongong Road to Martin Avenue, subject to:<br>□ resolution of the augmentation alignment between 9-11 Wollongong Road to Arncliffe Street ; and<br>□ investigation of concept design, hydraulic capacity assessment and detailed design | City Infrastructure | Subject to Developer time frame | Cost $1.4M<br>Funds: S94 |
| W10 | Works – Augmentation Martin Avenue to Arncliffe Street | Implement augmentation between Martin Avenue to Arncliffe Street, but restrict inlet capacity | City Infrastructure | Long Term (prerequisite W8 and W9) | Cost $14M<br>Funds: TBC |
| W11 | Works – SWSOOS capacity restrictions | Complete an investigation on the feasibility of the capacity restriction removal at the SWSOOS | City Infrastructure | Long Term (prerequisite is W10 and P6) | Cost $100k<br>Funds: S94 |
| W12 | Works – Remove capacity restrictions | Remove capacity restrictions between Martin Avenue to Arncliffe Street, and through SWSOOS | City Infrastructure | Long Term (prerequisite is W11 and Bonnie Doon upgrades in Wolli Creek precinct) | Cost $100k<br>Funds: S94<br>(Offset mitigation costs have been excluded, presumed to be transferred to the Wolli Creek S94) |
| *Education and Emergency Response* | | | | | |
| E1 | Education – Flood Education | Flood education strategies integrated into development consents by conditions | Development Assessment | Ongoing | Nil – normal operations |
| E2 | Emergency Response – Local Flood Plan | Target know risk areas, and incorporate into the Rockdale Local Flood Plan | SES | Ongoing | Nil – normal operations |
| E3 | Depth markers | Placement of depth markers at various locations | City Infrastructure | ASAP | Cost $50k<br>Funds: SW Levy |

## 3.2 Key Issues to be Addressed in Planning for the Arncliffe Priority Precinct

### 3.2.1 Existing Flood Affected Land within the Proposed Precinct

The key flood affected areas in the Arncliffe Priority Precinct are:

- Dowling Street through Arncliffe Park to Bonar Street
- Railway underpass at the intersection of Wollongong Road and Allen Street
- Firth Street along the western face of the Illawarra railway line

These areas outlined above generally coincide with land areas of medium hydraulic hazard and road areas of high hydraulic hazard (refer Appendix A). Areas of medium hydraulic hazard are primarily through proposed high density residential zoned areas and some mixed use areas. Council currently use the *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Study* (WMA 1998) to assess flood risk within the Precinct. As the areas are already developed, future planning controls should be implemented to minimise flood hazard category as new developments take place. These controls are outlined in Section 3.3.4.

Additional widespread areas of the precinct are affected by shallow or low hazard flooding. Refer to Appendix A flood extents and the locations of the below identified flow restrictions.

### 3.2.2 Existing Flow Restrictions

#### 3.2.2.1 Piped/ Formed

- Box culvert and 1500mm diameter pipe that pass under the Illawarra railway line, which is at the confluence of several piped drainage systems within the catchment.
- 750mm diameter pipe that passes under the Illawarra railway line; once the capacity has been exceeded the flows are directed overland towards the aforementioned confluence area.
- Pit and pipe drainage system from Dowling Street through Arncliffe Park to Bonar Avenue which in various areas is undersized for frequent rainfall events, resulting in surcharge during events great than 5 year ARI.
- Open channel from Allen Street through Cahill Park to the Cooks River;
- Culvert/openings under the sewer aqueduct east of the railway line;

#### 3.2.2.2 Overland

- Illawarra railway line which is raised above the surrounding surface levels;
- Road underpass at Allen Street;
- Sewer aqueduct east of the railway line;
- Blockages due to dwellings in the zones from Dowling Street to Mitchell Street, and Broe Avenue to Bonar Street;

## 3.3 Recommendations and Opportunities

### 3.3.1 Further Studies and/or Modelling

The following is suggested for further investigation on the basis of the historical reports:

- Flood data collection – the reports generally appear to identify a lack of flood data records and recommend that comprehensive data be collected for all future events.
  - It should be noted that historical flood record for the purpose of model calibration is generally not available (i.e. 1993 flood), however the work currently being undertaken by WMA Water is seeking to obtain useful flood information related to recent events in March 2012, November 2014 and April 2015 for the purposes of model calibration.
- Further detailed modelling of flows from the eastern side of the railway line, including:
  - Innesdale Road, Flora Street and Valda Avenue, near Marsh Street, including localised flooding as well as any mainstream flooding effects from the Cooks River. In particular the Cooks River flood study suggests that the effect of Climate Change may have a significant impact on the containment of mainstream flooding effects. Progression of the TUFLOW modelling and associated reporting currently being undertaken by WMA is anticipated to provide the majority of this information.

### 3.3.2 Remedial Works/Design Recommendations

It is noted that flooding within the precinct is relatively widespread; however, results from the historical studies generally indicate that a large proportion of flooding is less than 100mm deep or classified as being low hazard for the 1% AEP event. Areas of medium to high hazard are generally identified as localised along the sag from Dowling Street to Bonar Street, mixed use areas towards Bonar St, and along the western face of the Illawarra railway line, where depths are generally increased as a result of concentration of flows or ponding.

#### 3.3.2.1 Pipe Upgrades

Flows through other areas in the precinct are relatively wide and difficult to contain within a single controlled flow path. Opportunities have been identified in the reports to upgrade the pit and pipe network; however, these are generally aimed at reducing the occurrence of localised drainage flooding during frequent design events. While they may have an on-flow effect of reducing flood levels during the 1% AEP event, it should be noted that this solution would not eliminate flooding during events larger than the design event.

#### 3.3.2.2 Detention Basin

Ideally, upgrading of the pipe network would be complemented with the provision of detention basin(s) to assist in attenuating flows from the upper half of the catchment. The FMS by Webb, McKeown & Associates (1998) indicates that a detention basin with footprint covering approximately half the park area at 1.3m deep would be required to contain the 1% runoff and reduce flooding levels in the streets downstream. While further concept design was undertaken in 1998 (refer Section 3.1.7) there has been no

agreement at this stage to proceed to detailed design. With the constraints of the heritage listing applied to Arncliffe Park outlined in the Rockdale Council LEP, there is limited opportunity to provide regional detention within the park. It is understood that a feasibility review is currently being prepared by Rockdale City Council for the provision of regional detention in the area.

#### 3.3.2.3 Overland Flow Upgrades

Opportunities to provide clearer flow paths are suggested in the historical reports as a part of new development, however due to the nature of the precinct there is limited opportunity to provide dedicated overland flow paths through sites which have already been highly developed. Any minor works to improve piped/overland flows would be assessed within individual Development Approval (DA) applications, with the DA required to prove that flooding is not being worsened elsewhere by the works.

#### 3.3.2.4 Upgrades in Adjacent Catchments

The reports also identify that some of the flooding within the catchment may be partly attributed to flooding within adjacent catchments. As such opportunities may exist for upgrades outside of the precinct to potentially improve flooding within Arncliffe. It is noted however that this would need to form part of a separate exercise on a regional scale, also noting that as this would be situated outside of the proposed precinct the issue of sourcing funding would need to be considered. Conversely, Council's policies should ensure that development within adjacent catchments does not adversely affect flooding within the precinct.

#### 3.3.2.5 Cooks River

The *Cooks River Flood Study* (MWH+PB 2009) notes that the feasibility of naturalisation of sections of the Cooks River is being investigated. Capacity should be considered in any potential future modifications to the river, in collaboration with the CRFWG, as any loss in capacity may have significant impact, in particular upon the multi-storey residential development proposed by the precinct plan at the northern end of the precinct.

Remedial works would need to be considered on a cost-benefit basis, with the historical reports generally suggesting that many of the proposed solutions would be cost prohibitive while only benefitting a small proportion of the precinct. Additional sources of funding such as Section 94 contributions for upgrades in lieu of site-based detention are suggested.

### 3.3.3 Council Actions to Date

It is noted that Rockdale City Council have undertaken further assessment of a number of the management options presented within the studies, in particular the feasibility and concept design outcomes for the Arncliffe Park detention basin, upper Bonnie Doon diversion, and Bonar Street Redevelopment Precinct works and mitigation strategies (including strategies between Wollongong Road to the SWSOOS). Known actions to date as advised through discussions with Rockdale City Council are summarised in Table 3.2.

Table 3.2: Summary of Remedial Options Presented in the Studies

| Source of Option | Key Remedial Options | Comments from Studies where applicable | Estimated Construction Cost noted within Study | Status as Confirmed by Rockdale City Council |
|---|---|---|---|---|
| Suggested Priority (on basis of significance of impact upon existing flooding of properties)<br>1 = High impact, 2 = Moderate impact, 3 = Limited impact | | | | |
| **Priority 1 Items** | | | | |
| Arncliffe Park Detention Basin Concept Design, Draft Report (Webb, McKeown & Associates, December 1998) | Construct detention basin in Arncliffe Park, Option 5.3 embankment near playing field, 10 year basin capacity | Embankment, excavation and diversion of existing stormwater pipes. | Estimated cost of $1.04m* | Concept design undertaken in 1998, however no agreement to proceed to detailed design; feasibility review currently being prepared by Council. |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Construct detention basin in Arncliffe Park | Detention basin of approximately 20,000m$^3$ (approx. 1.9 hectare footprint x 1.3m depth). Varying degrees of benefit to approximately 12 buildings. | Assumed cost of $730,000* | Additional study undertaken as above. |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Parallel upgrade of the existing piped drainage system along Wollongong Rd from Dowling Street to Bonar Street. | Upgrading to 20% capacity reduces number of buildings inundated in 1% flood by 17.<br>Upgrading to 5% capacity eliminates floor inundation in 1% flood. | $6.56m*<br>$8.93m*<br>Costs do not include relocation of services or complicated constructions. | Not an adopted option in Council's Floodplain Risk Management Plan; feasibility review currently under review by Council. |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Pipe Upgrade | Upgrade the piped network with say twin 1800mm diameter pipes under the railway line | Cost up to $1.83m* | Adopted action in Council's Floodplain Risk Management Plan; incorporated into Bonar Street S94 Plan but costs under review, with current cost estimates >$8M; iPart to assess revised plan due to exceeding the cap; feasibility review currently being prepared by Council. |

| Source of Option | Key Remedial Options | Comments from Studies where applicable | Estimated Construction Cost noted within Study | Status as Confirmed by Rockdale City Council |
|---|---|---|---|---|
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Investigation of a levee option to reduce inundation from Cooks River | | | Adopted action in Council's Floodplain Risk Management Plan; initial review and concept design undertaken in 1998; costs incorporated into the S94 plan for Wolli Creek but under review; feasibility review currently being prepared by Council in conjunction with Cahill Park masterplanning; requires further review related to Cooks Cove and RMS/ Westconnex work at Marsh Street (projects not controlled by Council). |
| Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996) | Raising the river bank (levee), providing additional internal drainage capacity, and flap gating incoming drainage lines to reduce inundation from the Cooks River | | | As per levee item above. |
| **Priority 2 Items** | | | | |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Voluntary purchase of houses to create an open-space overland flow path | Voluntary purchase of 11 houses between Dowling and Bonar St. Notes purchase must be done all at once, not piecemeal. | Exceeding $5.47m* | Flood related development controls in place for overland flow; no voluntary purchase program in place; Bonar Street development area zoning and DCP enabled to (a) augment stormwater system and (b) implement development controls. |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | House raising or flood proofing of non-residential buildings | Indicates that 6 buildings may be suitable for house raising.<br><br>5 non-residential buildings may be suitable for flood proofing. | $73,000* each<br><br>$19,000* each | Not an adopted action in Council's Floodplain Risk Management Plan; flood related development controls in place for overland flow |

| Source of Option | Key Remedial Options | Comments from Studies where applicable | Estimated Construction Cost noted within Study | Status as Confirmed by Rockdale City Council |
|---|---|---|---|---|
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Part of Wollongong Road at the underpass be lowered so that runoff can escape through the underpass, eliminating the low point in Martin Avenue | Eliminate ponding in Martin Ave in small events, however no benefit to floods 20% and greater and would increase traffic hazard at the underpass.<br>Alternatively, small say 600mm pipe to reduce incidence of ponding in the underpass. | Cost approx. $146,000*<br>$92,000* | The road has not been lowered; however 600mm pipe has been laid but is blocked with tree roots & not flowing to capacity. |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Unblocking of brick arch openings under the sewer carrier | Reduce 1% flood level upstream by up to 0.5m however discussion with downstream and upstream landowners required. | | Not an adopted action in Council's Floodplain Risk Management Plan; incorporated into Bonar Street S94 Plan; staging issue - cannot be completed without works downstream to mitigate flooding of properties alongside the Bonnie Doon channel, feasibility review currently being prepared by Council. |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Modifications to the Bonnie Doon channel | | | Adopted action in Council's Floodplain Risk Management Plan; zonings in place to require reservation for road purposes; feasibility review currently underway by Council. |
| **Priority 3 Items** | | | | |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Lowering of driveways, moving sheds, replacing paling fences to reduce the problem for small events | | | Not an adopted action in Council's Floodplain Risk Management Plan. |

| Source of Option | Key Remedial Options | Comments from Studies where applicable | Estimated Construction Cost noted within Study | Status as Confirmed by Rockdale City Council |
|---|---|---|---|---|
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Flora – removal of exotic vegetation in waterways and replacement with less-choking native vegetation (catchment wide) | | | Action has been taken in a small section of Wolli Ck & Bardwell Ck but follow up action is required as vegetation has re-grown |
| Wolli Creek, Bardwell Creek and Bonnie Doon Channel Flood Study (Webb, McKeown & Associates 1996) and associated FMS and FMP (1998) | Amplification of the drainage system at 1-5 Gertrude Street | | | Drainage works were undertaken in Gertrude St to enable the removal of the open drain that runs along the backs of 3-19 Gertrude St |
| Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996) | Maintenance works, minor road works, and pipe upgrades at Eve Street | | | Only maintenance work is an adopted strategy in Council's Floodplain Risk Management Plan; maintenance improvements are outlined through the Council Asset Management Strategy. |
| Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996) | Additional inlets and supplementary (parallel) downstream pipe drainage in Valda Avenue | | | Not an adopted action in Council's Floodplain Risk Management Plan. |
| Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996) | (General) Upgrade trunk drainage across catchment | | | Not an adopted action in Council's Floodplain Risk Management Plan; works identified in the Wolli Creek S94 plan, costs subject to review; feasibility review currently being prepared by Council. |
| Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996) | Provide dedicated overland flowpaths | | | Assessed as a part of DA approvals; flood related development controls |

| Source of Option | Key Remedial Options | Comments from Studies where applicable | Estimated Construction Cost noted within Study | Status as Confirmed by Rockdale City Council |
|---|---|---|---|---|
| Eve Street - Cahill Park, Flood and Drainage Study (Webb, McKeown & Associates 1996) | Flood storage and detention basins as a measure to mitigate future increase flooding (note no reduction to current flooding) | | | On-site detention as a part of DA process. OSD excluded for Wolli Creek precinct (ref Council's Technical Specification for stormwater) due to proximity to discharge point. |

*All costs have been adjusted to the latest 2014 data on Building Price Index (BPI) figures given in the Australian Construction Handbook, Rawlinsons 2015 (Prices rounded up to nearest $10,000 where appropriate). BPI is based on historical data and is intended as a guide to the effect on building costs brought about by periodic variations in the rates of labour and materials as well as reflecting the cost effect of building activity and resource availability (i.e. market competition) at any time.

It is noted that the remainder of the studies discussed are generally part of the first stage of the NSW Government's Flood Policy process and as such only assess the existing situation and do not provide recommendations.

### 3.3.4 Planning Controls

Rockdale City Council currently adopts flood hazard categories for development and roads based on information from the *Wolli Creek, Bardwell Creek and Bonnie Doon Channel and Eve Street/Cahill Park Catchments Floodplain Management Study* (WMA 1998), which classifies the catchment into Flood Management Areas. These areas are traced on Figure A02 in Appendix A for information and will need to be applied to the future land use strategy for the Arncliffe Priority Precinct. There may be opportunities for improvement and reduction of flood hazard category with the implementation of works listed in Table 3.2.

Lands are classified as either Low, Medium or High hazard for a flood equivalent to the Flood Standard (in this case the 1% flood). The classification is a qualitative assessment based on several factors including (but not limited to) depth and velocity of floodwaters, rate of rise, and evacuation difficulties.

**Low Hazard** is typically within the floodplain (i.e. the extent of the probable maximum flood) but generally above the 100 year flood and suitable for most land uses. Although a risk of flood damages exists, appropriate planning and building controls can minimise the risk to an acceptable level.
**Medium Hazard** generally indicates land below the 100 year flood where a significant risk of flood damage exists and where there may be some evacuation difficulties, but these damages can be minimised by applying appropriate development controls.
**High Hazard** areas indicate potential high flood damages, risk to life, evacuation issues or where development would significantly and adversely affect flood behaviour in the catchment. Development is usually restricted in areas classified as High Hazard.

Rockdale City Council is currently in the process of consolidating planning controls for the Local Government Area through the preparation of a City Wide Floodplain Risk Management Study and Plan

which is currently in draft format. Council's draft policy is yet to be finalised and will supersede any land hazard categories or planning controls presented within this report.

Preliminary planning controls are suggested in Section 4, on the basis of Council's existing flood management policies as well as the draft Floodplain Risk Management Study/Plan that is currently being developed by Rockdale City Council. It should be noted that the draft policy has not yet been publically exhibited, however it collates Council's existing policies that are in effect and was deemed useful in understanding appropriate controls.

In addition the following site specific controls are suggested for further assessment on the basis of the historical studies:

- Recommend that freeboard and/or flood storage requirements for development in the area bounded by Innesdale Road and Valda Avenue should take into account potential increases in the extent of mainstream flooding from the Cooks River due to climate change. Thought should also be given to evacuation access/procedures during PMF event.

# 4 Recommendations

## 4.1 Summary of Planning Controls **in accordance with Rockdale City Council's** Draft Floodplain Risk Management Study and Plan

The following presents a summary of some of the key appropriate planning controls for various hazard classifications. Rockdale City Council's draft policy is yet to be finalised and will supersede any planning controls presented within this report.

### 4.1.1 Development on Land with Flood Depths >100mm or Medium to High Hydraulic Hazard

Suggested planning controls for proposed future development for areas of the proposed priority precinct identified as being affected by the existing 1% AEP flood extents (illustrated in Appendix A), with depths greater than 100mm and/or which are classified by the existing flood reports as medium to high hydraulic hazard, are as follows:

- Minimum Planning Level for non-habitable floors at 100 year ARI flood level.
- Minimum Planning Level for habitable floors at 100 year flood level plus 500mm freeboard.
- All structures to have flood compatible building components and methods below the Planning Level or the 100 year ARI, whichever is greater.
- Engineer to certify that the structure can withstand forces of floodwater, debris and buoyancy up to and including the 100 year ARI plus 500mm freeboard.
- Engineer to certify that the development will not have adverse flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood conveyance; and (iii) the cumulative impact of multiple potential developments in the floodplain.
- Minimum surface level of open car parking spaces, garages or carports shall no lower than the 100 year ARI. Notwithstanding, where enclosed car parking is provided all openings to the car parking area shall be protected from inundation from floods up to the 100 year ARI plus 500mm freeboard.
- Residential:
  - A flood evacuation strategy for the development that provides reliable access for pedestrians or vehicles is required from within the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF. Such a refuge may comprise a minimum of 20% of the gross floor area of the development or such other area which is demonstrated as capable of accommodating the likely occupants of the development for the period of the flood. An engineer's report may be required.
  - The flood evacuation strategy for the development must be consistent with any flood evacuation plan, or local plan or similar strategy if adopted by Council.
  - Provide a Site Flood Management Plan that demonstrates how the required flood evacuation strategy will be implemented, including initiation of procedures and on-going emergency management procedures during and after the flood event. The Plan should include procedures to maintain flood emergency procedure awareness as owners, residents or occupants change through time.
  - Provide a *Site Flood Management Plan* that demonstrates the procedures for the management of contents such as valuable articles and equipment or potentially hazardous materials stored below

the prescribed floor level. The Plan should include procedures to maintain flood emergency procedure awareness as owners, residents or occupants change through time.

- Commercial and Industrial:
  - A *Business FloodSafe Plan* is required that demonstrates the required evacuation provisions including the evacuation facilities, initiation of evacuation procedures, and on-going emergency management procedures during and after the flood event. The Plan should include procedures to maintain flood emergency procedure awareness as owners, residents or occupants change through time.
  - The flood evacuation strategy for the development must be consistent with any flood evacuation plan, or local plan or similar strategy if adopted by Council.
  - Provide a *Business FloodSafe Plan* that demonstrates the procedures for the management of contents such as valuable articles and equipment or potentially hazardous materials stored below the prescribed floor level. The Plan must include procedures to maintain flood emergency procedure awareness as owners, residents or occupants change through time.

### 4.1.2 Development on Land with Low Hydraulic Hazard

For additional areas within the precinct affected by 1% AEP flood extents where the hydraulic hazard is classified as low, preliminary suggested flood controls are as follows:

- Minimum Planning Level for non-habitable floors at 100 year ARI flood level.
- Minimum Planning Level for habitable floors at 100 year flood level plus 500mm freeboard.
- All structures to have flood compatible building components and methods below the Planning Level or the 100 year ARI, whichever is greater.
- Engineer to certify that the structure can withstand forces of floodwater, debris and buoyancy up to and including the 100 year ARI plus 500mm freeboard.
- Commercial and Industrial:
  - Engineer to certify that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood conveyance; and (iii) the cumulative impact of multiple potential developments in the floodplain.
- Minimum surface level of open car parking spaces, garages or carports shall no lower than the 100 year ARI. Notwithstanding, where enclosed car parking is provided all openings to the car parking area shall be protected from inundation from floods up to the 100 year ARI plus 500mm freeboard.
- Commercial and Industrial:
  - A Business FloodSafe Plan is required that demonstrates the required evacuation provisions including the evacuation facilities, initiation of evacuation procedures, and on-going emergency management procedures during and after the flood event. The Plan should include procedures to maintain flood emergency procedure awareness as owners, residents or occupants change through time.
  - The flood evacuation strategy for the development must be consistent with any flood evacuation plan, or local plan or similar strategy if adopted by Council.
  - Provide a *Business FloodSafe Plan* that demonstrates the procedures for the management of contents such as valuable articles and equipment or potentially hazardous materials stored below

the prescribed floor level. The Plan must include procedures to maintain flood emergency procedure awareness as owners, residents or occupants change through time.

### 4.1.3 Development on Land with Flood Depths <100mm and Low Hydraulic Hazard

It is noted that some areas affected by 1% AEP flood extents are classified as low hydraulic hazard and depths are less than 100mm, generally within the roads. These would generally be considered gutter flows and as such a Minimum Floor Planning level of 200mm above surrounding ground level would be considered more appropriate than a freeboard above "flood level".

### 4.1.4 **Land shown as "Flood Planning Area" in the Rockdale LEP 2011**

Controls applied by the LEP which specifies a 500mm freeboard to "flood planning level" for properties identified by the flood affected land map, as well as *"other land at or below the flood planning level"*, would still apply as legislatively required.

### 4.1.5 General Controls

The following additional controls would be applicable to development within the Arncliffe and Banksia Priority Precincts on the basis of Rockdale City Council's existing policies:

- Stormwater Management
  - Filling of land up to the 100 year ARI flood level (or flood storage area) is not permitted.
  - Filling of land between the 100 year ARI flood level and the PMF level (or in flood fringe) is discouraged however will be considered if proven it does not adversely impact flood behaviour.
  - Pipes shall be designed to convey the 5 minute, 20 year ARI design rainfall of 204mm/hr.
- Overland Flow
  - The water level of surface flow routes and ponding sag pits designed to cater for the 100 year ARI flow shall be at least 100mm below the floor level of any adjacent building.
  - Maximum ponding depths permitted are 200mm for parking and driveways; 600mm for courtyards, grass and landscape.
  - Adjacent floor levels are to have 300mm freeboard to overland flow level. In cases where the 100 year flow can be contained within the piped system, habitable floor levels are to be a minimum of 200mm above finished ground level.
  - Design standard is the 100 year ARI although a viable escape route is required to PMF.
- On Site Detention
  - Permissible site discharge (PSD) and OSD volume rates for the 50 year ARI event are specified in Section 6.2 of Council's *Rockdale Technical Specification, Stormwater Management* (2011).
  - Permissible site discharge (PSD) and OSD volume rates for the 2 year ARI event are specified in Section 6.3 of Council's *Rockdale Technical Specification, Stormwater Management* (2011).
- Groundwater
  - Areas identified by Map B.1 of Council's *Rockdale Technical Specification, Stormwater Management* (2011) are situation in a Groundwater Protection Zone, refer Figure 4.1.

Figure 4.1: *Groundwater Protection Zone (Indicative Location of Absorption Areas and Low Absorption Areas)*


Source: Appendix B Map B.1, *Rockdale Technical Specification, Stormwater Management* (Rockdale City Council 2011)

- Flooding Freeboard – refer sections 4.1.1 to 4.1.4 inclusive.
- Low Level Properties
  - Appendix D of Council's *Rockdale Technical Specification, Stormwater Management* (2011) outlines the drainage policy for properties which fall away from the street which cannot be gravity drained to Council's stormwater pit and pipe network in the street.
- Climate Change
  - Council have indicated that for the Banksia and Arncliffe area, the projected increase in average daily rainfall due to climate change is as follows:
    - +11.36% by years 2060-79
    - +1.40% by years 2020-39
  - Increase in rainfall due to climate change will need to be considered as part of the DA application for future developments on a site by site basis.
  - The *Bonnie Doon Pipe & Overland 2D Flood Study* (WMA Water 2011) indicates that for a 10% to 30% rainfall increase scenario, the average increase in flood depth is approximately 20-50mm

respectively. As such it is generally not expected that there will be significant impact for the majority of sites in the precinct as this increase is easily contained within freeboard.
  - However, according to the report, localised areas such as the railway underpass at Wollongong/Allen Streets are expected to experience larger increases in the order of 160-560mm for a 10% to 30% rainfall increase scenario respectively. Sites near this area may need to be given more in-depth consideration.
  - In addition, development sites in the area bounded by Innesdale Road and Valda Avenue should take into account potential increases in flood levels as a result of combined rainfall increase and mainstream tidal effects on the Cooks River due to sea level rise resulting from climate change. The *Cooks River Flood Study* (MWH+PB 2009) indicates that the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (DECC, 2007) recommends sensitivity analysis looking at low, mid and high sea level rises (0.18, 0.55 and 0.91m by the year 2100) in combination with low, mid and high level rainfall intensity increases to asses changes in flood behaviour.
- Wolli Creek
  - For the Wolli Creek catchment, it is noted that Council requires the design flood to be increased to the 0.5% AEP flood with 500mm freeboard.
  - Water retention and re-use is suggested, while on-site detention is not encouraged as being located at the lower end of the regional catchments detention may exacerbate the peak flood.
  - It is noted that some properties at the northernmost point of the Arncliffe Priority Precinct may lie within the Wolli Creek catchment according to Map B.2 of the *Rockdale Technical Specification, Stormwater Management* (refer Figure 1.3). Noting that Council's catchment map is large-scale, controls for these properties should be confirmed with Council and documented on the individual S149 certificates.

# Appendices

# Appendix A. Plans

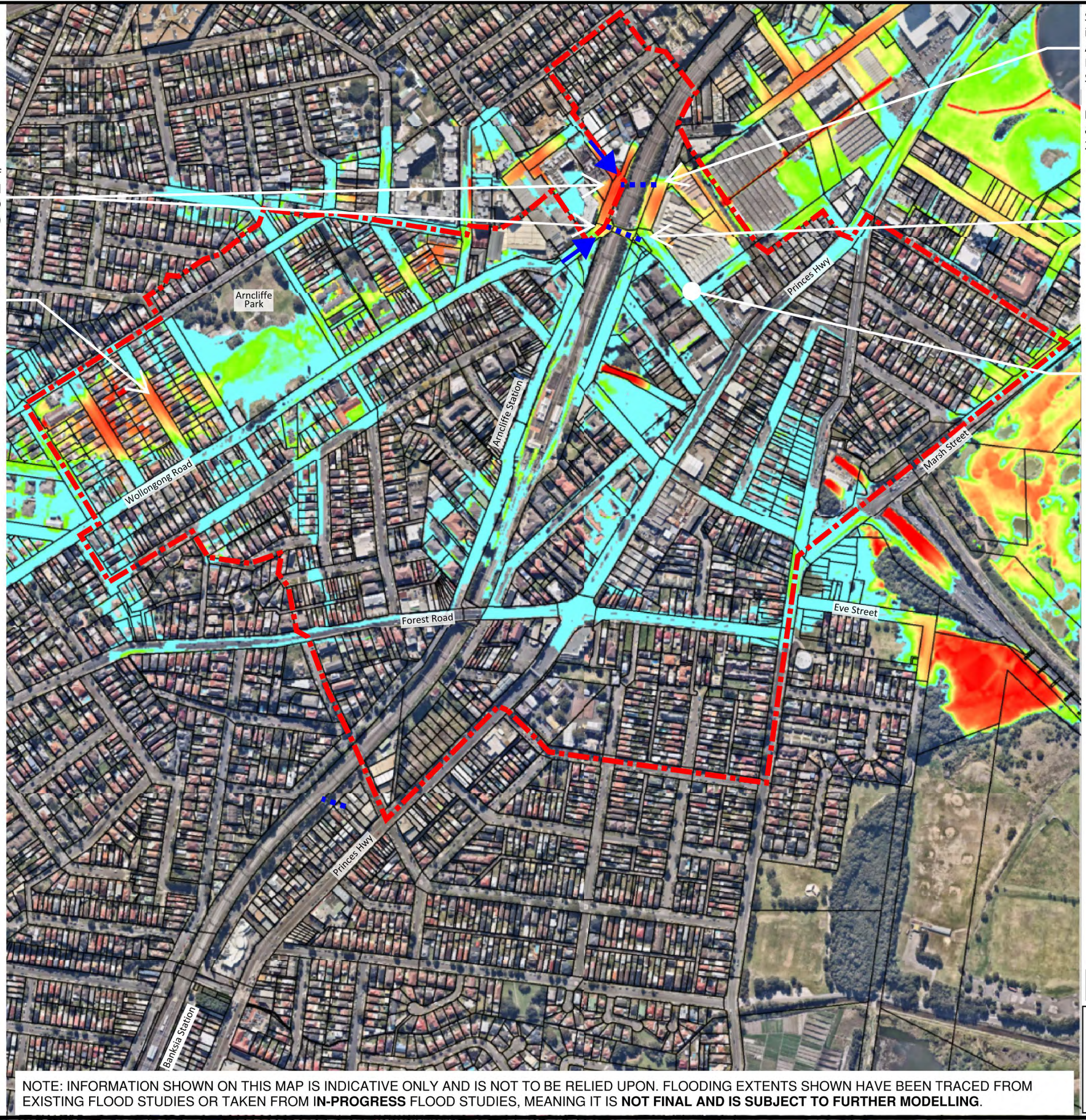
Legend

Indicative Flood Depths - 1% AEP 120min

- 0.0-0.1m
- 0.1-0.2m
- 0.2-0.5m
- 0.5-1.0m
- >2m

Key surcharge location - Confluence of several piped drainage systems to pipe and culvert Bonnie Doon Pipe & Overland 2D Flood Study (WMA Water 2011)

Indicative 100yr ARI Flood Extent based on In-progress TUFLOW model for Bonnie Doon and Eve Street/Cahill Park (WMA Water 2015)




Single 1500 mm diameter pipe from the intersection of Wollongong Road and Martin Avenue draining to Arncliffe Street, Bonnie Doon Pipe & Overland 2D Flood Study (WMA Water 2011)

Box culvert at underpass, Bonnie Doon Pipe & Overland 2D Flood Study (WMA Water 2011)

Indicative 100yr ARI Flood Extent based on In-progress TUFLOW model for Bonnie Doon and Eve Street/Cahill Park (WMA Water 2015)

Map is Not to Scale

Arncliffe Priority Precinct
Desktop Literature Review
Flooding and Drainage

Figure A01
Existing Indicative Flood Extents

NOTE: INFORMATION SHOWN ON THIS MAP IS INDICATIVE ONLY AND IS NOT TO BE RELIED UPON. FLOODING EXTENTS SHOWN HAVE BEEN TRACED FROM EXISTING FLOOD STUDIES OR TAKEN FROM I**N-PROGRESS** FLOOD STUDIES, MEANING IT IS **NOT FINAL AND IS SUBJECT TO FURTHER MODELLING**.

Mott MacDonald

Legend

Hazard Classification Areas (WMA, 1998)

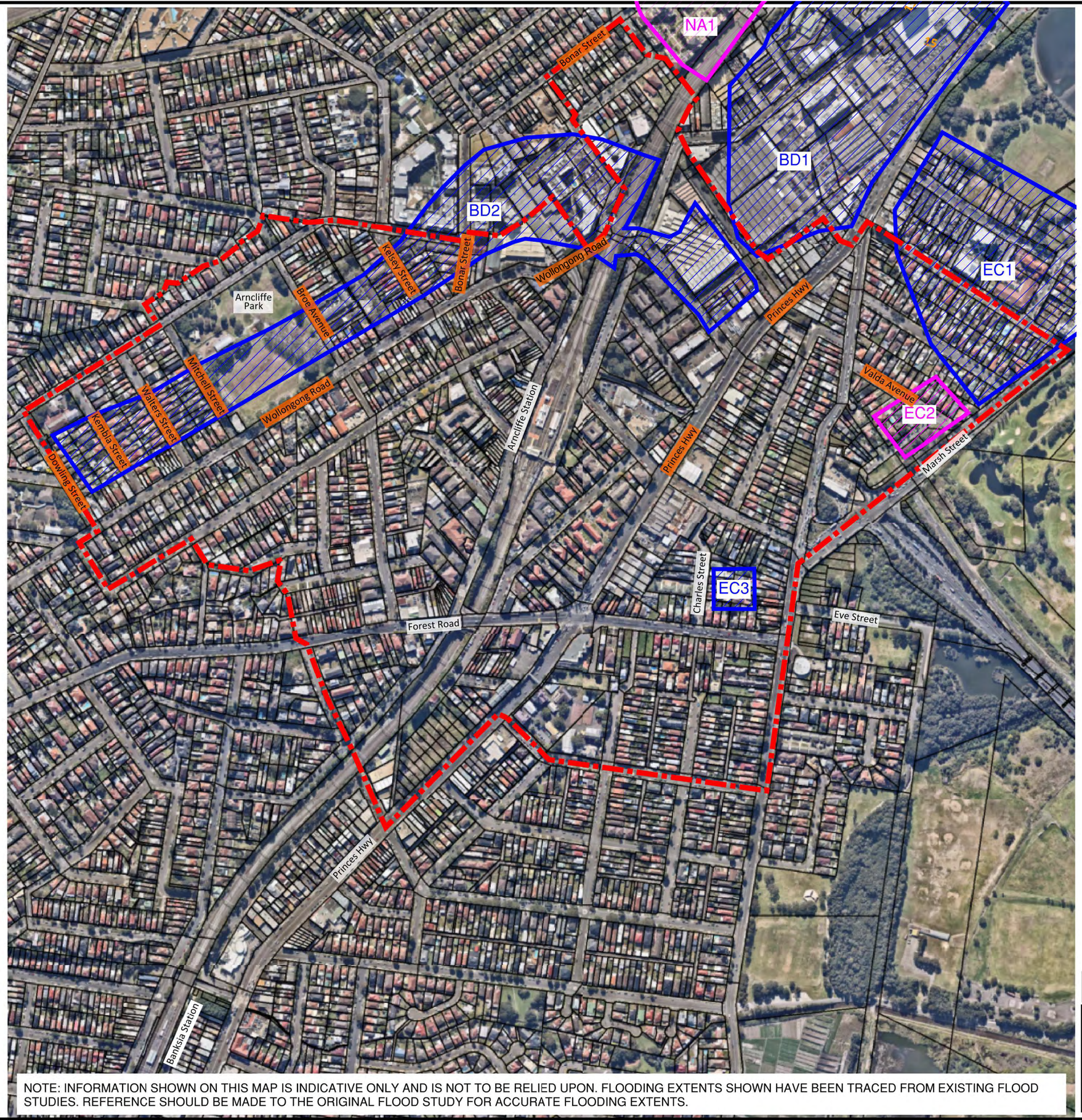
Medium Hazard

Low Hazard

BD2 Floodplain Management Area reference per Table 3 of the WMA Study (1998)

Hazard Classification Roadways (WMA, 1998)

Princes Hwy High Hazard




Note:
Hazard data sourced from Wolli Creek Floodplain Management Study (WMA 1998).
Rockdale City Council currently use this document to asses flooding in the area.

Hazard classification shown is for the 1% flood level as per Table 3 of the above study. In an Extreme flood some areas may become an Extremely Hazardous Floodway.

Mott MacDonald

NOTE: INFORMATION SHOWN ON THIS MAP IS INDICATIVE ONLY AND IS NOT TO BE RELIED UPON. FLOODING EXTENTS SHOWN HAVE BEEN TRACED FROM EXISTING FLOOD STUDIES. REFERENCE SHOULD BE MADE TO THE ORIGINAL FLOOD STUDY FOR ACCURATE FLOODING EXTENTS.

Map is Not to Scale

Arncliffe Priority Precinct
Desktop Literature Review
Flooding and Drainage

Figure A02
Existing Indicative Flood Hazard