Colac Otway Shire Council

Colac Stormwater Development Strategy




April 2018

V2013_001

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EXECUTIVE SUMMARY

The Colac Stormwater Development Strategy (CSDS) is a vital input to Colac 2050, a long range planning project that will cater for growth in Colac's population over the next 33 years.

This strategy, through detailed hydraulic modelling of Council's drainage network has identified sustainable and economic solutions to address areas of poor drainage performance within Colac and its surrounds and to identify the surface water requirements to enable future urban growth in Colac. The impact of climate change has also been assessed and the findings will assist Council in their climate change adaptation planning.

A key input to the development of the Strategy has been the engagement of the local Colac community. The purpose of this engagement has been to gather local knowledge to influence and ensure the flood modelling is representative of what happens during flood events and to gain community support for the Strategy itself.

The following tasks have been undertaken to meet the project objectives:

- Collation of existing information on the drainage system and obtain further information to fill gaps in the existing data set
- Detailed hydraulic modelling to assess the performance of the existing drainage network
- Production of flood inundation maps for various rainfall and development scenarios
- Consultation and sharing of information with the Colac community and other key stakeholders
- Assessment of the feasibility of increasing development within Colac and identify the key stormwater infrastructure required to facilitate this development
- Provide technical information available for improved planning of future development.

The hydraulic model created as part of this study has enabled a comprehensive analysis of the drainage system as well as the production of flood inundation maps. Consultation with the Colac community and other key stakeholders and a comprehensive collation and review of drainage data have formed vital inputs to the flood modelling undertaken and subsequent study outcomes.

A series of structural and non-structural measures have been identified that aim to improve the management and performance of the drainage system within Colac. The flood model has also been used to assess the feasibility of future development in Colac and to identify works to control the impact of development within the catchment.

The key recommendations made by this study are (as summarised in the short term and long term action plan presented in Section 10):

- Consider the use of Special Building Overlays (SBO) across the catchment to manage future infill development in existing urban areas and to reduce the flood risk for new buildings. The use of SBOs is recommended as they do not have any capital cost and will result in an effective measure across the study area
- Structural mitigation works should be considered to be constructed to reduce the impacts of flooding in existing development areas
- Make provision for waterway corridors through the proposed development areas to cost effectively contain flood flows within the waterways, to improve waterway health, to allow for more development and to provide environmental and open space corridors
- Make provision for stormwater wetlands within the proposed development areas to treat stormwater to remove pollutants, thus meeting planning scheme requirements. The wetlands will also provide valuable habitat, green space and public amenity as well as peak flow attenuation.

It is important to note that the CSDS is not intended to be used as a design document, it is intended to be used a strategic document to better understand flooding for existing conditions and to assist with consultation and future planning of any proposed development. Further assessment of any works documented in the Strategy is required before construction is undertaken.

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ABBREVIATIONS AND TERMS

The following abbreviations and terms are used and referenced in the Strategy

Abbreviation / Term	Explanation
Annual Exceedance Probability (AEP)	Refers to the probability or risk of a rainfall event of a given magnitude (intensity and duration) occurring or being exceeded in any given year. A 90 % AEP event has a high probability of occurring or being exceeded; it would occur quite often and would be a relatively minor rainfall event. A 1 % AEP event has a low probability of occurrence or being exceeded; but is likely to cause extensive damage.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. For instance a 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Colac Stormwater Development Strategy (CSDS)	This document.
Development Contribution Plan (DCP)	A DCP is a levy for developments that are proposing to increase the number of dwellings on a site.
Freeboard	A factor of safety above design flood levels typically used in relation to the setting of floor levels or crest heights of flood levees. It is usually expressed as a height above the level of the design flood event.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as depth and velocity.
Flooding 'Hot Spot'	An area which has a history of repeat flooding highlighted through flood modelling, anecdotal information and / or customer complaints.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs.
Intensity Frequency Duration (IFD)	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
TUFLOW	Hydraulic modelling software used in this study to simulate the flow of flood water through the study area. The model uses numerical equations to describe the water movement.
RORB	Hydrological modelling software used in this study to calculate the runoff generated for rainfall events.

1. INTRODUCTION

The Colac Stormwater Development Strategy (CSDS) is a vital input to Colac 2050, a long range planning project that will cater for growth in Colac's population over the next 33 years. Colac 2050 will establish a plan for the expansion of Colac’s residential housing footprint, business and industry sectors. A strong understanding of the existing and future flood planning, drainage and stormwater treatment constraints and opportunities is required to facilitate appropriate future development. A copy of the layout plan highlighting development investigation areas for this Strategy, as identified in Colac 2050, is attached in **Appendix A**. The Colac 2050 plan highlights existing Farming / Low Density Residential / Rural Living land targeted for higher density levels of development to accommodate growth in Colac’s population.

Prior to the development of this stormwater, flooding and development strategy Council's knowledge of the overall performance of the existing drainage system was limited as it had never been hydraulically assessed and it was not known what frequency of storm event the drainage system was capable of handling.

A key input to the development of the Strategy has been the engagement of the local Colac community. The purpose of this engagement has been to gather local knowledge to influence and ensure the flood modelling is representative of what happens during flood events and to gain community support for the Strategy itself.

To inform the development of the Strategy detailed flood modelling of the Colac Township and surrounding suburbs, including future growth areas, has been undertaken to assess the performance of Council’s existing drainage infrastructure and to define the extent of overland flooding for a range of rainfall intensities. The 5 year Average Recurrence Interval (ARI), 10 year ARI and 100 year ARI events have been modelled to define flooding for minor and major storm events for existing catchment conditions. Climate change conditions have been assessed for the 5 year and 100 year ARIs. It is important to note that the flood model developed for the Strategy utilised previous flood models developed for the Department of Environment, Land, Water and Planning (DELWP) as part of the Deans Creek and Barongarook Creek Regional Flood Mapping Project in 2016 which was delivered in partnership with the Corangamite Catchment Management Authority (CCMA). The existing DELWP 2016 flood models for the two major creeks were used as a starting point and the remainder of the study area was input to the model.

Other key inputs to the model developed as part of the Strategy included the following:

- Aerial survey (LiDAR) data captured at the beginning of 2016 to define the existing topography
- Council drainage asset data (including pipe sizes), with confirmation of numerous assets during site visits
- Existing land use information confirmed during site visits and latest aerial photography.

At the time of preparing this report CCMA is proposing changes to the existing Land Subject to Inundation Overlay (LSIO) in response to the findings of the 2016 Regional Flood Mapping project. As part of this work it is understood that the further calibration of the flood models developed for DEWLP will be undertaken during 2017 and as a result it is possible that small differences may exist between the modelling undertaken for DELWP and the modelling undertaken to inform Council's Stormwater Development Strategy. For flooding associated with Deans Creek and Barongarook Creek the modelling undertaken for DELWP will take precedence.

In the future it is possible that the flood modelling undertaken as part of the development of the Strategy could be used to develop flood overlays (e.g. Special Building Overlay (SBO)) for other areas across Colac, areas that are located outside of the LSIO being developed by CCMA in 2017. A recommendation of the Strategy is that Council consider this further as a means of controlling development in flood prone areas of Colac.

1.1 Study Background and Objectives

The key tasks in developing the Strategy were to:

- Collate existing information on the drainage system and obtain further information, as required, to fill gaps in the existing data set
- Detailed hydraulic modelling to assess the performance of the existing drainage network
- Produce flood inundation maps for various rainfall and development scenarios
- Consult and share information with the Colac community and other key stakeholders
- Develop options to mitigate a number of existing flooding issues
- Assess the feasibility of increasing development within Colac and identify the key stormwater infrastructure required to facilitate this development
- Provide technical information available for improved planning of future development.

1.1.1 Climate Change Assessment

During the development of the Strategy Council identified the opportunity to use the flood model developed as part of the Strategy to assess the impacts of climate change with respect to flooding to help inform climate change adaptation planning. As part of this assessment the following tasks were included in the scope of the Strategy:

- Determine the likely increase in rainfall under the latest climate change predictions for the study area and to rerun the hydrology models (with consideration for latest Australian Rainfall and Runoff (ARR 2016) guidelines)

- Run the flood model for the study area for the 5 and 100 year ARI events allowing for the influence of climate change
- Create flood maps, showing the predicted climate change flood extents
- Summarise work within the CSDS to provide Council with one consolidated ‘flooding and drainage report’
- Identify locations within Colac which are most vulnerable to climate change. This task included the production of a flood depth difference plot to clearly show the changes in flooding between existing conditions and climate change conditions to quantify the impact of climate change with respect to flooding
- Assess the incremental increase in infrastructure sizing that would be needed at identified hotspots to construct a solution which also addresses the added impact of climate change.

The outcomes of the climate change assessment will assist Council in answering the following key question as part of any planning decisions for improved climate change resilience:

- What incremental increase in capital cost is required to size flood mitigation infrastructure to mitigate an area of flooding under climate change conditions compared to current climate conditions?

The answer to this question is provided within the Strategy.

1.2 Catchment Description

The study catchment covers multiple suburbs including Colac, Colac West, Colac East and Elliminyt totalling an area of approximately 131 square kilometres. The population within these suburbs was estimated at approximately 12,000 at the time of the 2016 census (Australian Bureau of Statistics).

The western side of Colac is drained by Deans Creek and the eastern side by Barongarook Creek before discharging into Lake Colac on the northern face of the township. These two major waterway catchments are divided by a well-defined ridge running north south leaving a small urban catchment which directly drains into Lake Colac. Figure 1.1 provides a layout plan showing key features of the township.

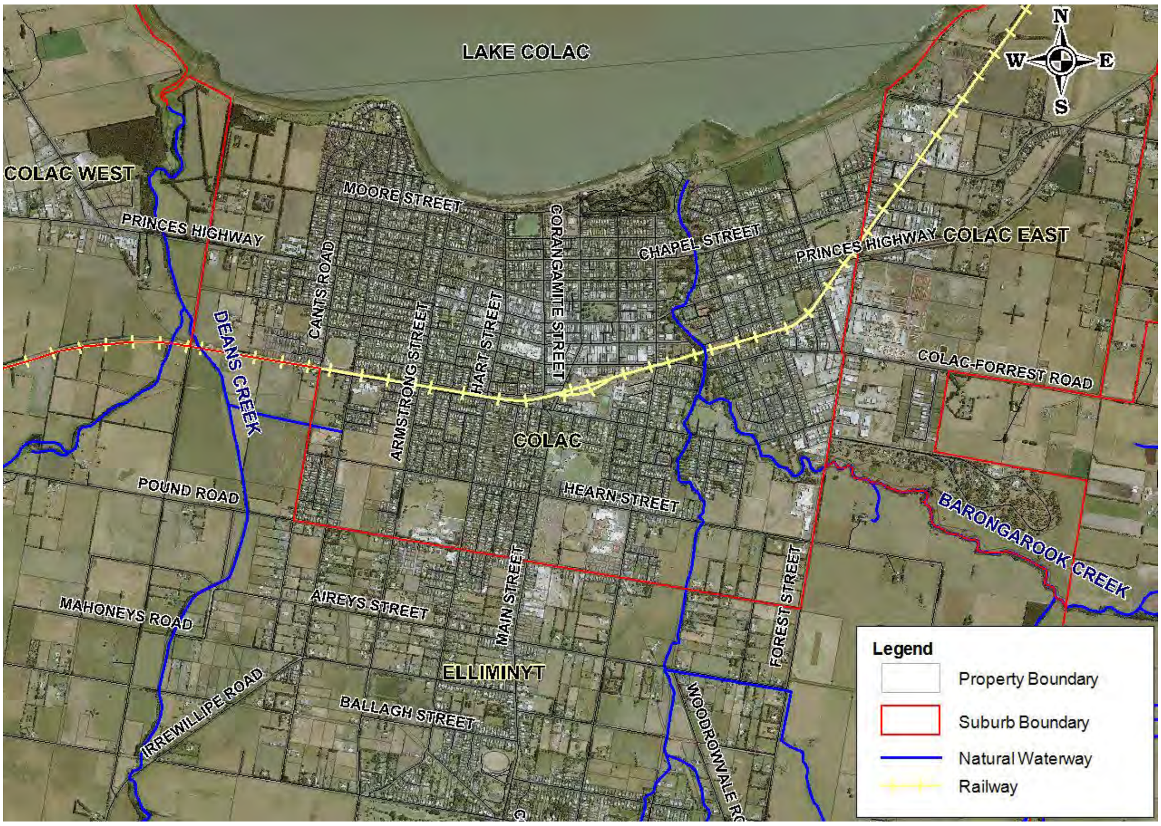


Figure 1.1 Key features of Colac and surrounds

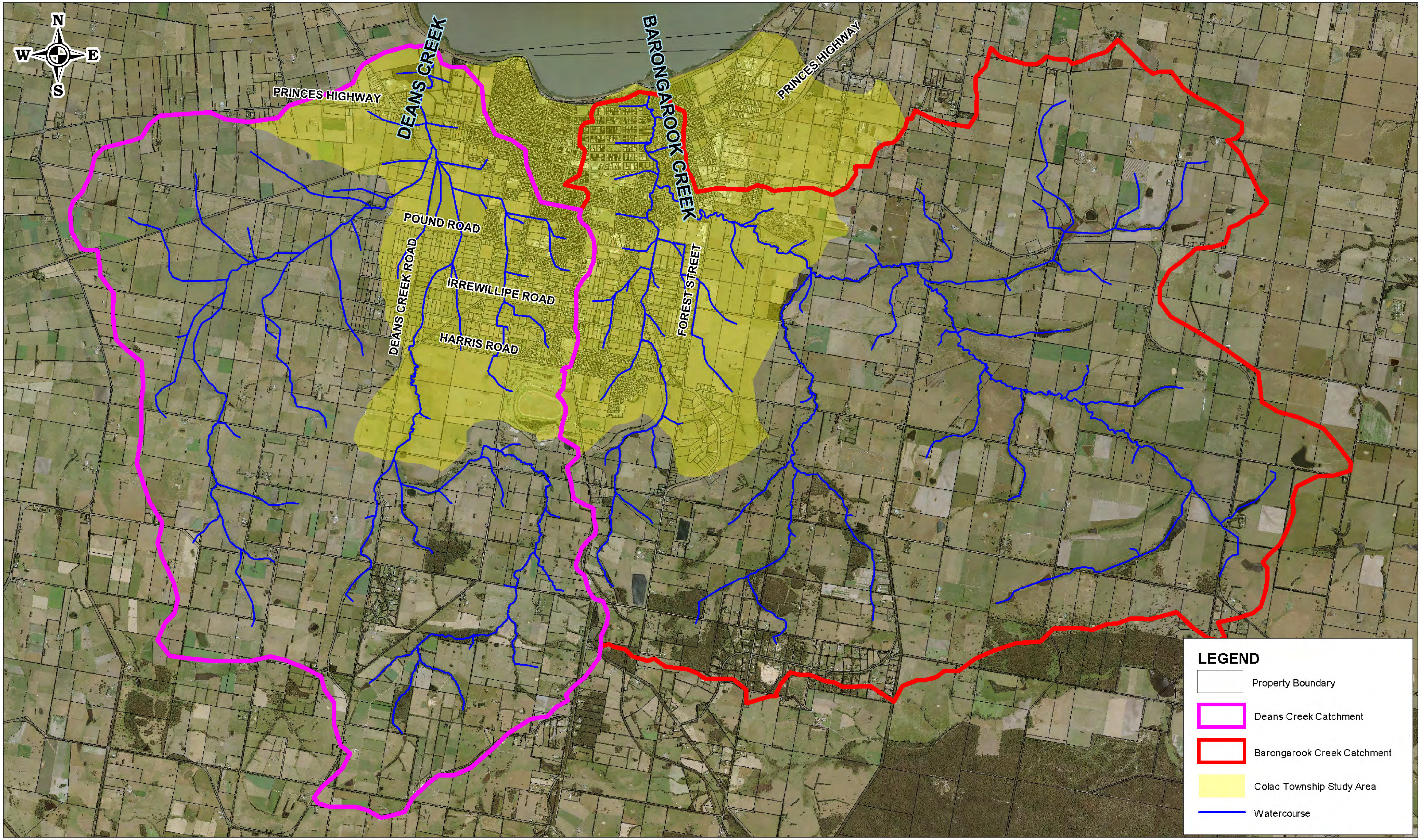
The overall catchment drains through a series of large culverts which convey flows within the waterways under the Princes Highway, the Railway line and other significant road embankments. Within the Colac Township a formal underground drainage network collects runoff from residential properties and streets and conveys flow to the waterways or Lake Colac.

With respect to existing planning zones the following zones characterise Colac:

- Large residential zone within the Township
- Extensive area of commercial zone in the Township's inner centre
- Agricultural farmland and rural living zones on the outer eastern and western boundaries
- Industrial zoned land on the eastern side of Barongarook Creek.

The Princes Highway and the railway line running east west are the major road and rail infrastructures present, enabling access to these different land use types.

The combined Deans Creek and Barongarook Creek catchment make up approximately 60 % of the overall Lake Colac catchment and therefore contribute the majority of the inflow into Lake Colac. Figure 1.2 highlights the Deans Creek and Barongarook Creek catchment boundaries.



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

0 1000 2000

Scale in metres (1:50,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

Figure 1.2

Catchment Layout PLan

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 15 Sep 2017

1.3 Drainage Stakeholders within Study Area

The following stakeholders own / manage drainage and waterway assets across Colac:

- Colac Otway Shire Council (Council);
- Corangamite Catchment Management Authority;
- VicRoads;
- VicTrack
- Property owners.

The roles and responsibilities of each of these stakeholders is summarised in the following sub-sections.

1.3.1 Colac Otway Shire Council

Councils are not flood management authorities under the Water Act. Councils are local government authorities under the Local Government Act and are Planning Authorities under the Planning and Environment Act. These Acts include roles to provide local drainage services and to provide planning advice.

Councils provide roads and drainage systems to collect and convey stormwater to creeks and rivers; they also maintain the stormwater mains owned by Council on private property. Across Colac and its surrounds Colac Otway Shire Council is the drainage authority and the responsible authority for managing stormwater drainage assets and any overland flooding resulting from the stormwater drainage network. This includes provision of advice for development in areas at risk of flooding from the stormwater drainage network. Prior to the development of this strategy knowledge of areas at risk of stormwater flooding were not as well understood or documented and the outputs generated from the development of this strategy, including the attached flood maps, will assist Council in their drainage authority role.

In 2005 the Victorian State Government recognised that the functions of Melbourne based Councils and Melbourne Water in managing drainage and flooding should be reviewed. A study was commissioned by the Victorian Auditor General's Office (VAGO). VAGO recommended that both Melbourne Water and Councils should manage flood risks associated with their systems and that this should be done on a risk based approach under two headings:

- Structural Measures
- Non-Structural Measures.

Structural Measures include physical works to reduce flooding such as retarding basins, floodways and larger drains. Non-structural measures include flood mapping, planning and building controls, public education and operational tasks.

Flood mapping of Council's drainage system, undertaken as part of the development of this strategy, is a non-structural measure and could lead to introduction of Special Building Overlay controls that could be used to set conditions on development, including the floor levels of habitable buildings.

1.3.2 Corangamite Catchment Management Authority

In Victoria the flood management authorities are the various Catchment Management Authorities. In Colac the Corangamite Catchment Management Authority (CCMA) is the flood management authority as defined in the Water Act.

Under Part 10 of the Water Act 1989, CMAs are designated with responsibility for the management of waterways and floodplains and have the lead role in developing and delivering regional programs for waterway management. The Water Act outlines their functions and powers in relation to waterway management, floodplain management and regional drainage. Within Colac and surrounds key functions of the CCMA include:

- Declaration of flood levels and flood fringe areas
- Declaration of building lines
- Controlling developments that have occurred or that may be proposed for land adjoining waterways
- Taking any action necessary to minimise flooding and flood damage
- Provision of advice about flooding and controls on development to local councils, the Secretary for Planning and Environment and the Community.

In its statutory role CCMA co-ordinates the process for permitting works on designated Corangamite waterways and on floodplains. Within Colac and surrounds this applies to Deans Creek and Barongarook Creek and their respective floodplains. CCMA no longer provides advice in relation to stormwater flooding including areas identified by any Special Building Overlay (SBO) in Councils Planning Scheme or land liable to flooding under the Building Regulations, of which none exist within Colac and surrounds.

The CCMA is currently preparing the Corangamite Regional Floodplain Management Strategy, this is discussed further in Section 2.2.4.

1.3.3 VicRoads

VicRoads is responsible for the overall management (including construction, maintenance, inspection and repair) of a network of freeways and arterial roads (the major connecting roads) throughout Victoria. VicRoads is responsible for the management of the following roads within Colac and surrounds (note these road names are as defined by VicRoads and may be referred to differently to the Colac community):

- Princes Highway
- Colac-Lavers Hill Road
- Carlisle-Colac Road
- Colac-Forrest Road.

The responsibilities of VicRoads within Colac and surrounds extends to the drainage assets, including culverts and bridges, which have been constructed as part of those roads managed by VicRoads.

1.3.4 VicTrack

VicTrack is responsible for the overall management (including construction, maintenance, inspection and repair) of a network of railway lines throughout Victoria. The responsibilities of VicTrack extend to the drainage assets, including culverts and bridges, which have been constructed as part of the railway line which traverses through Colac.

1.3.5 Property Owners

Under the Water Act 1989 (Section 16), residents and property owners:

- are liable for flow of water from their land
- have a duty of care not to interfere with the flow of water
- must not participate in negligent conduct that will interfere with the flow of water onto any land.

Property owners are required by law to maintain the stormwater pipes, gutters, downpipes, stormwater pits and any other components of their approved stormwater drainage system in good condition and in compliance with any Council requirements. Property owners are also required to accept natural overland flow from adjoining properties or public land and must not divert or redirect the flow from its natural path onto neighbouring properties.

Under the Road Management Act 2004, the responsibility for the maintenance of vehicle and culvert crossings that service private property rests with the owner of the property to which they serve. It is incumbent on the property owner to ensure that water flow through their culvert crossing is not impeded in any way.

A few examples of behaviours that may have a detrimental impact on the performance of the overall drainage system:

- Poor maintenance of private drains may result in premature blockage, reduced pipe capacity and/or prevention of stormwater runoff entering the system. This may result in localised flooding and/or increased overland flows

- Increasing the proportion of impervious surfaces within a property (such as driveways and paths) will result in increased overland flows onto adjacent properties and / or public roads, as the existing private drain may no longer have adequate capacity. When constructing hardstand (hard surfaced) areas e.g. driveways, concrete and paved areas, landscaping and any other impervious surfaces or drains owners must control the stormwater in order to prevent concentrated flows onto the adjacent property

- The erection of a physical barrier, such as a fence, across an overland flow path may divert stormwater runoff from its flow path and possibly put other properties at risk

- Easements in private backyards are generally located to minimise impact on surrounding buildings. Sheds, paths, driveway edging and other landscaping are common improvements that are sometimes placed over easements

- The planting of trees that develop large invasive root systems may lead to burst or blocked pipes.

While each property may only have a minor influence on the performance of the overall drainage network, the cumulative effects of poor maintenance and other activities may become significant.

1.4 Study Methodology

Figure 1.3 illustrates the key steps undertaken to achieve the objectives of this study.

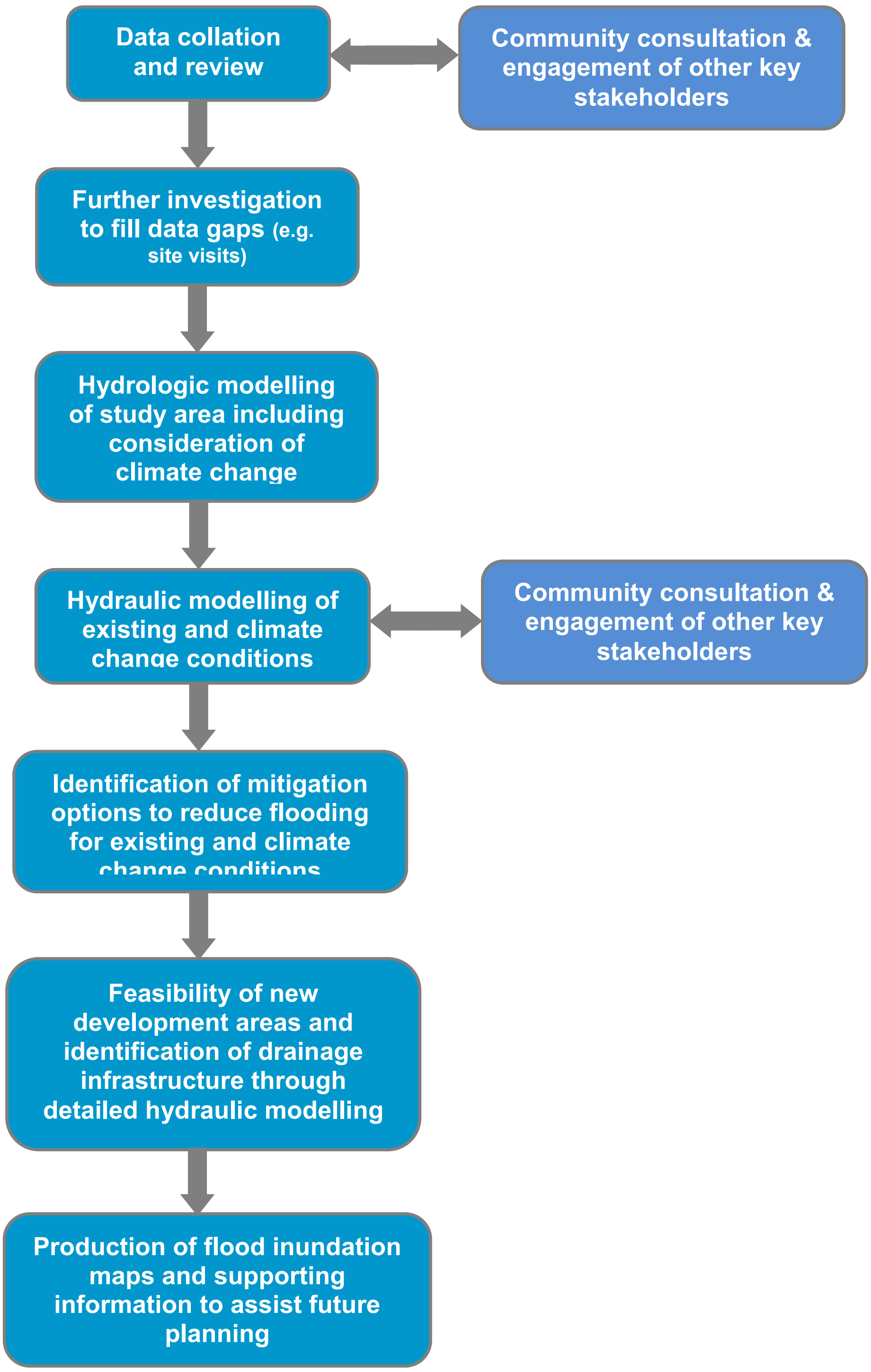


Figure 1.3 Study methodology flow chart

2. DATA COLLATION AND REVIEW

2.1 Sources of data

Council provided a combination of GIS and other technical data for the study area. This data included the following relevant information:

- Aerial photography
- Drainage (pit and pipe) asset data
- Planning schemes and overlays
- Watercourse alignments and water bodies
- Cadastral boundaries, easement boundaries and road alignments
- Colac Integrated Water Cycle Management Plan (2014).

Information provided by others for use in the study included:

- Deans Creek and Barongarook Creek Regional Flood Mapping Report and Models – provided by Department of Environment, Land, Water and Planning (DELWP, 2016).

In several instances, the above sources of data were insufficient to adequately define the drainage system to the level required for input to the flood model developed for the Strategy. For these areas, field investigations were conducted to provide the necessary information as described in Section 2.2.

2.2 Review of Data

2.2.1 Drainage Data

A thorough review of the existing pipe and culvert diameters and connectivity provided in Council's drainage asset database was undertaken. This assessment identified some areas in the study area where diameters were missing or connectivity was uncertain. Missing data was a particular issue for drainage assets crossing under roads and discharging into road side channels or swales.

To rectify this Council staff conducted site investigations to collect missing data or verify existing data. Engeny also conducted site visits to verify the connectivity and sizes of some assets.

The outcome of the drainage data collation and review is a comprehensive drainage asset database available for this study that has been utilised to conduct a detailed analysis of the existing drainage system across Colac and surrounds.

2.2.2 Aerial Photography

Aerial photography of the study area captured on the 28th of November 2014 was supplied by Council. This photography was supplemented with the latest www.nearmap.com aerial photography which highlighted some small changes across the study area. The date of the latest aerial photography on Nearmap is unknown. Whilst it is listed as being captured on the 1st of January 2005 it is clearly more recent than the 28th of November 2014. This is demonstrated by the fact that the recent development of 153 Pound Road is captured.

2.2.3 Topography

Council provided LiDAR (Light Detection And Ranging) covering the study area which was captured in 2015/16. LiDAR is an airborne surveying technology that provides a regularly spaced grid (one metre horizontal interval in this case) of ground levels. This data was used to produce a Digital Terrain Model (DTM), which allows for the waterways and other key topographical features across the study area to be defined in a flood model.

The LiDAR data was captured as part of the 2015-16 Colac-Otway and Surf Coast Towns Photography and Elevation Project (DELWP, Volume 25671A03NOB). This project captured 10cm photography and LiDAR within the shires of Colac-Otway and Surf Coast. Airborne LiDAR was acquired on the 11th and 13th of January 2016. With respect to accuracy of the LiDAR the data report shows that after processing and comparison to field survey that the following level of accuracy was achieved:

- Vertical accuracy +/- 100 mm
- Horizontal accuracy less than 300 mm.

It is important to note that there have been some small alterations to topographical features since the LiDAR was flown in early 2016. Their influence on the results of the flood modelling is expected to be minor.

Figure 2.1 shows the DTM developed for the study area with the CSDS hydraulic model extent overlaid.

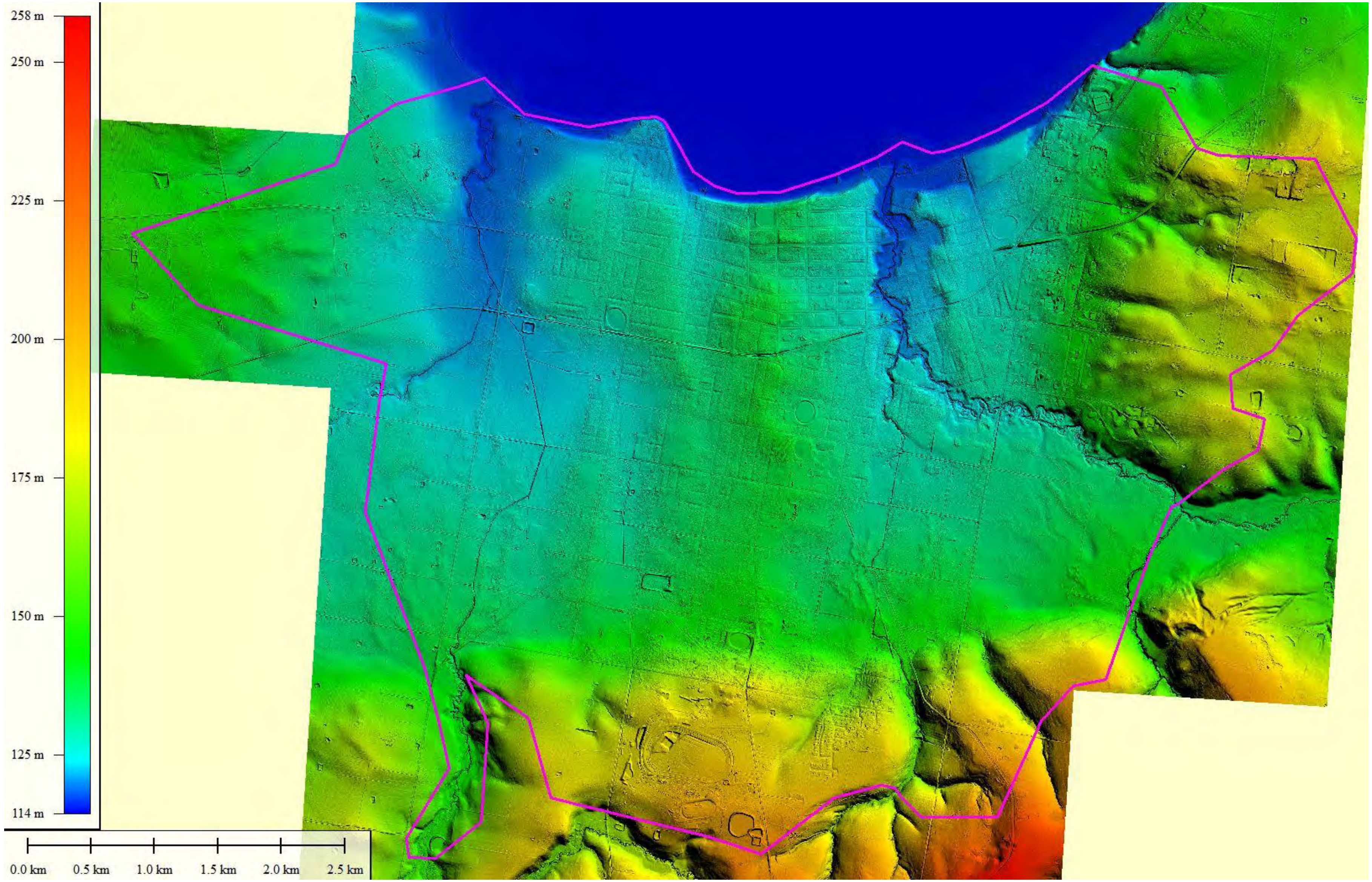


Figure 2.1 Digital Terrain Model

2.2.4 Previous / Current Studies and Reports

Summaries of previous investigations of the Colac area are provided below.

Deans Creek and Barongarook Creek Regional Flood Mapping (2016)

The scope of this study was to prepare flood mapping outputs for the Deans Creek and Barongarook Creek Catchments. The hydraulic modelling undertaken as part of this study included significant culvert crossings along Deans Creek and Barongarook Creek. Due to the objective of this project being on mapping riverine flooding, the areas of Colac draining to Lake Colac, and Council's underground drainage network draining the major waterways were not assessed or mapped.

The modelling and report produced from this study have provided valuable inputs to this project as discussed throughout this report. At the time of preparing this report CCMA is proposing changes to the existing Land Subject to Inundation Overlay (LSIO) in response to the findings of the 2016 Regional Flood Mapping project. As part of this work it is understood that the further calibration of the flood models developed for DEWLP will be undertaken and as a result it is possible that small differences may exist between the modelling undertaken for DELWP and the modelling undertaken to inform Council’s Stormwater Development Strategy. For flooding associated with Deans Creek and Barongarook Creek the modelling undertaken for DELWP will take precedence.

For flood mapping outputs produced from the Deans Creek and Barongarook Creek Regional Flood Mapping study refer to the associated study report.

Colac Integrated Water Management Plan (2014)

The Integrated Water Management Plan (IWMP) is a strategic blueprint for how the urban water cycle can make a positive contribution to Colac’s liveability. The IWMP was developed by the following four key water cycle authorities:

- Colac Otway Shire Council
- Barwon Water
- Southern Rural Water
- Corangamite Catchment Management Authority.

The IWMP recognises that the Colac Township has always had a strong connection to the water cycle through its location on the shores of Lake Colac, close urban waterways, extensive areas of green open space and wide tree-lined streets, many of which retain traditional grassed swale drains for stormwater. The IWMP recognises that the urban water cycle will continue to have an important role in shaping the characteristics of Colac as it transforms. As such the IWMP is an important consideration and input to Colac 2050.

The IWMP acknowledges that Council has a direct controlling role in the planning and operation of urban water cycle assets and services including:

- strategic, statutory and municipal planning for areas of new and infill urban development
- a strategic and operational planning role for open space, roads and streetscapes
- managing stormwater, localised flooding and driving water sensitive urban design
- regulatory role to ensure appropriate management of private septic tanks.

Council also can have an influence on the urban water cycle including:

- as a major user of drinking water and potential user of alternative water
- as a driver for best practice in urban development design and construction
- to represent and engage with its local community on community aspirations.

The most significant issues for Colac's water cycle system as identified in the IWMP which were considered important for consideration in the development of the Stormwater Development Strategy included:

- Degraded and un-connected urban waterways
- Extensive land subject to inundation that impedes development to the west of the city.

The IWMP provides a prioritised implementation plan for a range of actions and initiatives. Actions from the IWMP that have been considered in the development of the Stormwater Development Strategy include:

- Improve urban amenity through natural water assets
- Plan to use water locally including consideration of an upgrade of the Irrewillipe Road retarding basin to include a stormwater harvesting system
- Reduce the adverse impacts of stormwater on waterways
- Protect Colac's catchments and waterways.

Corangamite Waterway Strategy 2014-2022

The Corangamite Waterway Strategy (CWS) provides an evidence based framework and regional works program for the CMA to implement, in partnership with community groups, landholders, other agencies and industry, to maintain or improve the condition of priority rivers, estuaries and wetlands so they can continue to support environmental, social, cultural and economic values.

A number of threats to waterway health have been identified in the CWS and those that relate to Colac have been considered in the development of the Stormwater Development Strategy include:

- Deans Creek
  - There is an absence of large trees from the riparian zone and the riparian zone is a narrow strip
  - 25-75 % of waterway is affected by livestock access.
- Barongarook Creek
  - The riparian zone is patchy with limited large trees and areas of native vegetation with low connectivity
  - Stream flows in the catchment are affected by farm dams
  - 25-75 % of waterway is affected by livestock access.

A number of goals identified within the CWS relate to Colac and have been considered in the development of the Stormwater Development Strategy include:

- Goal ENV2 – Maintain or improve the resilience of other threatened waterway dependent species
- Goal S1 – Maintain or improve waterway conditions where it supports high social values.

Actions within the CWS Works Programs that relate to Colac that have been considered in the development of the Stormwater Development Strategy include:

- Implementation of Colac Integrated Water Cycle Management Plan
- Establishment of native indigenous vegetation.

Existing Flood Related Planning Scheme Overlays

There are existing flood overlays (Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO)) for Deans Creek and Barongarook Creek, which are part of the Colac Planning Scheme. The overlays are based on the expected area of inundation during a 100 year ARI rainfall event. The existing flood overlays are shown in Figure 2.2 and are overlaid on a layout plan of development investigation areas, highlighting areas targeted for future development as identified in Colac 2050. It can be seen that a large portion of the development investigation areas are covered by the existing FO / LSIO, particularly along Deans Creek on the western side of Colac.

The CCMA is proposing changes to the existing LSIO in response to the findings of the 2016 Regional Flood Mapping project. It is expected that these changes will be finalised in late 2017.

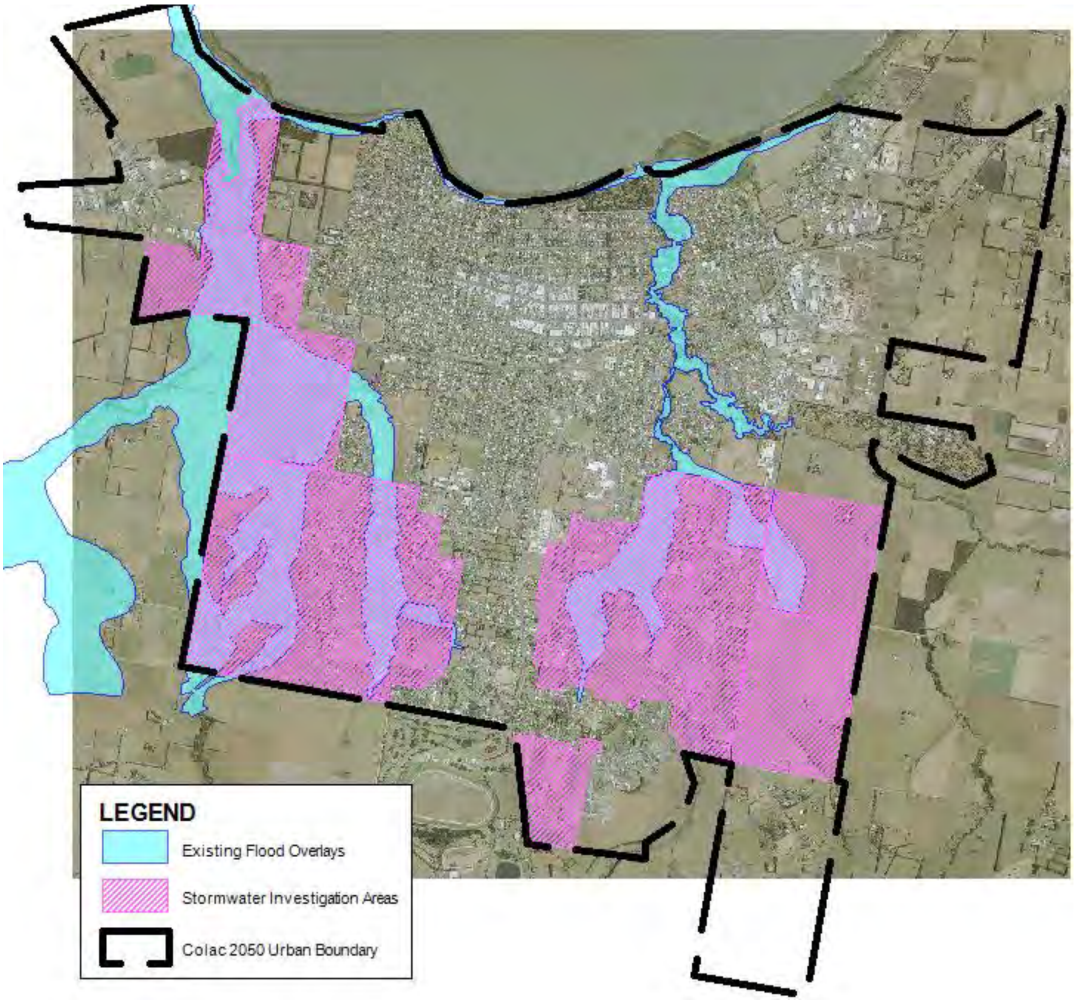


Figure 2.2 Existing Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) within study area

<u>Corangamite Regional Floodplain Management Strategy (estimated completion early 2018)</u>

In late 2016 CCMA began the first stages of preparing the Corangamite Regional Floodplain Management Strategy (RFMS). In preparing this strategy CCMA is working with the Victorian SES and the nine local governments in the Corangamite region to develop the RFMS which through community consultation will set regional and local priorities for flood management.

The Corangamite RFMS will provide a single, regional planning document for floodplain management and a high level regional work program to guide future investment priorities for the CCMA region. It will provide the starting point for councils (including Colac Otway Shire Council) and other stakeholders to identify priority flood management activities, which may include flood warning systems and flood emergency response to local needs, improving flood overlays in land use planning schemes, and dealing with riverine, coastal and urban storm water flooding issues. It aims to align the efforts of various agencies and communities to deliver the outcomes called for by the Victorian Floodplain Management Strategy.

The development of the regional strategy will ensure the following key outcomes:

- That roles and responsibilities for floodplain management are clear and that stakeholders and communities are aware of their flood risks and actively managing them appropriately
- That all agencies with flood emergency management functions have aligned priorities. This will enable agencies to align their potential to source and allocate funds towards priority actions
- That communities are empowered by being aware of their flood risks
- That local knowledge has informed the development of the strategy.

The RFMS is a high level strategic document. The strategy will not develop individual or localised projects (e.g. flood studies, planning scheme amendments, structural works), these will form actions out of the strategy. Rural drainage issues will also not be included in the regional works program, and are out of the scope of the regional strategy.

The outcomes of the RFMS will be an important consideration for the CSDS in the near future as the RFMS is expected to be finalised in early 2018.

2.2.5 History of Flooding within Colac and Surrounds

The Deans Creek and Barongarook Creek Regional Flood Mapping Project (2016) notes that "*there is little recorded information regarding flooding from Deans Creek and Barongarook Creek, resulting in an incomplete understanding of flooding within the study area. Historically, flooding has occurred in the Lake Colac region during 1951-1952, 1975, the late 1980s, the early 1990s and most recently in August 2010. This incomplete understanding of flooding within the region, combined with development pressures within the Colac Township have resulted in the study being undertaken*"

The Deans Creek and Barongarook Creek Regional Flood Mapping Project has categorised the Average Recurrence Interval (ARI) of a number of historical flood events including the following significant events:

- April 1980: Between 50 and 100 year ARI
- April 1992 / January 1991 / April 2001: Between 20 and 50 year ARI.

Figure 2.3 below presents a number of newspaper articles collated as part of the development of this Strategy documenting some historical flooding events in Colac and surrounds.

COLAC

From Our Correspondent.

Last week's heavy rain did an enormous amount of harm to crops and roadways throughout the shire. There have been three consecutive floods at the Dean's Creek crossing and a good deal of metal was washed away. In other parts of the shire, however, the metalled roads have suffered more severely. The most serious position is in regard to the crops. Some were ready to cut, but the rain beat them to the ground. Grubs are in them and as there was another flood on Monday, the majority of the crops are likely to rot. The position is serious, and as the rain appears general the people should prepare for bad times.

Mr M. O'Connor is having bad luck in his contract for making an extra basin for the Waterworks Trust. He has been flooded out time after time, and is likely to be a heavy loser on the work.

December 1916

FLOODS NEAR COLAC.

COLAC, Monday.

Four inches of rain fell between Dean's Marsh and Lorne on Friday. All the low lying ground was flooded, and crops of potatoes were washed out of the ground in some places. It is the biggest flood for 15 years at this time of the year.

April 1899

Colac flooding more serious

Colac, Sunday.

[illegible]

November 1953

Figure 2.3 **Historical newspaper articles documenting flooding in Colac and surrounds**

2.2.6 Site Visits

Throughout this study Engeny conducted multiple site visits of key areas of the catchment in order to gain an appreciation for the site conditions and verify some sections of the drainage network. Some of the photos taken during these site visits are provided in **Appendix B**.

2.3 Stakeholder and Community Engagement

2.3.1 Community Consultation

Council and Engeny facilitated two community consultations sessions during the study, which were conducted on 19 April 2016 and 2 May 2017.

The first consultation session was attended by Council's project manager, members of the Engeny project team, members of the local VICSES and approximately 13 members of the Colac community. The key objectives of the first community consultation session were to:

- Share information on the scope and objectives of the study with the community
- Obtain historical flood observations from the community to assist in the development and validation of the flood model developed to inform the Strategy.

During this session aerial maps were on display for participants to engage with and mark where they had noted previous flooding across the study area. After this session was completed VICSES took the maps and engaged further with the community in the main shopping district of Colac to gather further responses. The resultant maps are presented in **Appendix C** and were considered in the validation of the flood model which is discussed further in Section 6.3 of this report.

The second consultation session was attended by Council's project manager, members of the Engeny project team and approximately 30 members of the Colac community. The key objectives of the second community consultation session were to:

- Present draft flood modelling results and allow members of the community to view and annotate hard copy flood maps and ask questions
- Obtain any further historical flood observations from the community to assist in a final validation of the flood modelling results.

At each of the community consultation sessions a questionnaire was made available for attendees to complete. The questionnaire for the second consultation session is attached in **Appendix C** along with a Frequently Asked Questions document that was made available at the session. The questionnaire was also available for the community to complete as an online survey via Survey Monkey. The online survey generated six responses.

Responses of most significance to the Strategy that were generated from the community sessions were feedback regarding results of the draft flood modelling. A large percentage of consultation participants were in general agreement with the results of the flood modelling. Some questionnaire responses queried the modelling results and Section 6.3 of this report outlines how these responses were considered and addressed during the model validation stage.

2.3.2 Engagement of other Stakeholders

Other key stakeholders have been consulted during this study to obtain other information and ensure that the study allowed for a coordinated approach. Corangamite Catchment Management Authority (CCMA) and VicRoads have attended project meetings and provided valuable input to the study. VicTrack were invited to meetings, however were unable to attend.

3. PLANNING SCHEME

Engeny has obtained and reviewed planning scheme zone and overlay information from Planning Schemes On Line (http://planningschemes.dpcd.vic.gov.au) for consideration in the development of the Strategy.

3.1 Colac Otway Planning Scheme

There are a number of Policies within the Colac Otway Planning Scheme which relate to catchment and stormwater management and are relevant to this Strategy for Colac. These are:-

- Clause 14.02-1 (Water – Catchment Management)
  - Objective – To assist the protection and, where possible, restoration of catchments, waterways, water bodies, groundwater, and the marine environment
    - Consider the impacts of catchment management on downstream water quality and freshwater, coastal and marine environments
    - Retain natural drainage corridors with vegetated buffer zones at least 30 m wide along each side of a waterway to maintain the natural drainage function, stream habitat and wildlife corridors and landscape values, to minimise erosion of stream banks and verges and to reduce polluted surface runoff from adjacent land uses
    - Undertake measures to minimise the quantity and retard the flow of stormwater runoff from developed areas.
- Clause 14.02-2 (Water – Water Quality)
  - Objective – To protect water quality
    - Ensure that land use activities potentially discharging contaminated runoff or wastes to waterways are sited and managed to minimise such discharges and to protect the quality of surface water and groundwater resources, rivers, streams, wetlands, estuaries and marine environments
    - Discourage incompatible land use activities in areas subject to flooding, severe soil degradation, groundwater salinity or geotechnical hazards where the land cannot be sustainably managed to ensure minimum impact on downstream water quality or flow volumes.
- Clause 14.02-3 (Water – Water Conservation)
  - Objective – To ensure that water resources are managed in a sustainable way
    - Encourage the use of alternative water sources such as rainwater tanks, stormwater and recycled water by governments, developers and households.

- Clause 19.03-2 (Development Infrastructure – Water Supply, Sewerage and Drainage)
  - Objective – To plan for the provision of drainage services that efficiently and effectively meet State and community needs and protect the environment
    - Plan urban stormwater drainage systems to:
      - Coordinate with adjacent municipalities and take into account the catchment context
      - Include measures to reduce peak flows and assist screening, filtering and treatment of stormwater, to enhance flood protection and minimise impacts on water quality in receiving waters
      - Prevent, where practicable, the intrusion of litter.

- Clause 19.03-3 (Development Infrastructure – Stormwater)
  - Objective – To reduce the impact of stormwater on bays and catchments
    - Support integrated planning of stormwater quality through a mix of on-site measures and developer contributions
    - Mitigate stormwater pollution from construction sites
    - Ensure stormwater and groundwater entering wetlands do not have a detrimental effect on wetlands and estuaries
    - Incorporate water-sensitive urban design techniques into developments to:
      - Protect and enhance natural water systems
      - Integrate stormwater treatment into the landscape
      - Protect quality of water
      - Reduce run-off and peak flows
      - Minimise drainage and infrastructure costs.

- Clause 21.04-2 (Environment – Water)

  Water quality in Lake Colac has been identified as a major issue for a number of years, and this has been evident through indicators such as blue-green algal blooms and sediment build up.

  - Objectives – To protect water catchments and to retain and improve water quality and water yield
    - Ensure water quality standards and impact on water yields are considered in the assessment of planning permit applications
    - Ensure that the maintenance in natural condition of watercourses is considered in the assessment of use and development proposals
    - Encourage the use of "constructed wetlands" as a means of storing floodwater, improving water quality and adding to natural habitats.

- Clause 21.04-6 (Environment – Flooding)
  - Objective – To minimise environmental hazards.
    - Promote floodplain management policies, which minimise loss and damage, maintain the function of the floodway to convey and store floodwater and protect areas of environmental significance
    - Encourage the use of "constructed wetlands" as a means of storing floodwater, improving water quality and adding to natural habitats.
- Clause 21.06 (General Implementation)
  - Undertaking Further Strategic Work
    - Update the Land Subject to Inundation Overlay and schedule to align with revised data and mapping when available from the Corangamite Catchment Management Authority.
- Clause 56.07-2 (Integrated Water Management – Urban Runoff Management)

  This clause relates to the design management of the urban stormwater system.
  - Objectives:
    - To minimise damage to properties and inconvenience to residents from urban run-off
    - To ensure that the street operates adequately during major storm events and provides for public safety
    - To minimise increases in stormwater run-off and protect the environmental values and physical characteristics of receiving waters from degradation by urban run-off.

4. DRAINAGE DESIGN GUIDELINES

Council has adopted the Infrastructure Design Manual (IDM) to define the standards of design and construction for various types of infrastructure including drainage. The IDM is a joint initiative which recognises the benefits of municipalities working together towards consistent requirements and standards for the design and development of infrastructure.

A number of objectives / specifications within the IDM have been considered in the preparation of the Strategy, those specifications of most relevance include:

- **Urban Drainage**

  The standard objectives of urban drainage are:

  - to collect and control all stormwater generated within the subdivision or development
  - to collect and control all stormwater entering a subdivision from the water shed outside the subdivision
  - to provide an effective outlet for all collected stormwater, from the subdivision or development to a natural watercourse, relevant authority's drain or approved outfall
  - to achieve these objectives without detrimentally affecting the environment generally, surface and subsurface water quality, groundwater infiltration characteristics, the adjoining landowners and other landowners.

- **Major and Minor Drainage Systems**

  The IDM specifies that the urban drainage system must be designed to satisfy the 'major / minor' approach as outlined in Australian Rainfall and Runoff. The following definitions are provided in the Manual:

  - The minor system generally refers to a pipeline network with sufficient capacity to collect and convey the flows from a 5 year Average Recurrence Interval (ARI) storm event. These pipelines prevent stormwater damage to properties and also limit the frequency and quantity of surface water to a level that is acceptable to the community
  - A major drainage system caters for the runoff from storms of higher intensity than for which the minor drainage system has been designed. The major drainage system is designed to handle flows resulting from storms with a 100 year ARI. These flows must follow a designated overland flow path, which must be:
    - A road if the catchment area is small and / or
    - A drainage / waterway corridor reserve if it is impractical or unsafe for a road to carry the excess flows.

  The finished floor level of buildings must be at least 300 mm above the 100 year ARI flood level or in accordance with the requirements of the relevant authority and codes.

- **Stormwater Treatment**

  Section 20.1 of the IDM lists the objectives for stormwater treatment. These objectives are:

  - to ensure that all stormwater discharged to natural watercourses and other drainage authority's drains meet the requirements of the Environment Protection Act 1970 and the water quality performance objectives for individual drainage catchments as provided in the State Environment Protection Policies (SEPPs)
  - to implement the design requirements of the Council's Stormwater Management Plan
  - to ensure all designs incorporate consistent best practice WSUD measures and principles
  - to ensure treatment methods and associated structures are cost effective from a maintenance and operational perspective and that the risk to the public is minimised as far as practicable
  - protect and enhance natural water systems within urban environments
  - integrate stormwater treatment into the landscape, maximizing the visual and recreational amenity of Developments
  - improve the quality of water draining from urban Developments into receiving environments.

  The IDM objectives refer to best practice, which is currently defined in Clause 56.07 of the Victorian Planning Provisions and in the current Urban Stormwater: Best Practice Environmental Management Guide (BPEMG) produced by CSIRO. Clause 56.07 applies to new residential subdivisions. The BPEMG targets can be considered as aspirational targets when seeking to retrofit existing residential areas, with achievement of the targets subject to physical constraints, the sensitivity of receiving environments and available funding to treat stormwater.

4.1.1 Changes in Drainage Design Standards

Over time there have been a number of changes to drainage design standards, the most significant being the adoption of the "major / minor" drainage system. The "major / minor" drainage system concept, as outlined above, was first specified in Australian Rainfall and Runoff in 1987. A large portion of Council's drainage system in Colac and surrounds was designed and constructed prior to 1987 and therefore does not meet current drainage standards which is common for Councils across Victoria. There is no obligation on Council to upgrade existing infrastructure when standards alter over time. This view was confirmed by the Victorian Auditor General in the VAGO 2005 report into managing urban flood risks within Melbourne.

In areas that don't meet current drainage standards Council may choose to undertake structural flood mitigation works to achieve current flood protection standards (or at least to reduce the flood risk). To achieve the current drainage design standard for every property could represent a significantly high cost.

4.1.2 Stormwater Quality Contribution Payments

Some Councils across Victoria are giving thought to implementing an alternative arrangement for developers to meet stormwater quality management obligations.

Currently the business as usual approach if for developers to provide stormwater treatment measures on-site as part of development sites, however Councils are increasingly becoming aware that this approach is giving rise to a large number of treatment assets that ultimately become the responsibility of Council requiring increasing budgets to provide adequate maintenance regimes.

An alternative option to the business as usual approach is for the developer to pay a fixed contribution towards Council managed off-site stormwater projects with the stormwater quality contribution payment being based on the total impervious area within each development. The thought behind this approach is that the contributions will enable Council to construct larger / strategic stormwater treatment assets that have the potential to achieve BPEMG targets leading to a reduction in the number of assets. With less assets maintenance times are also reduced.

In determining the requirements for stormwater treatment as part of the future development areas consideration has been given to limiting the number of assets.

Melbourne Water administers a stormwater quality contribution system within their area.

5. HYDROLOGIC MODELLING

5.1 Purpose

The purpose of creating a hydrological model for the study area was to generate sub-catchment hydrographs for use as an input to the hydraulic model. The hydraulic model can then be used for flood mapping.

5.2 Model Development

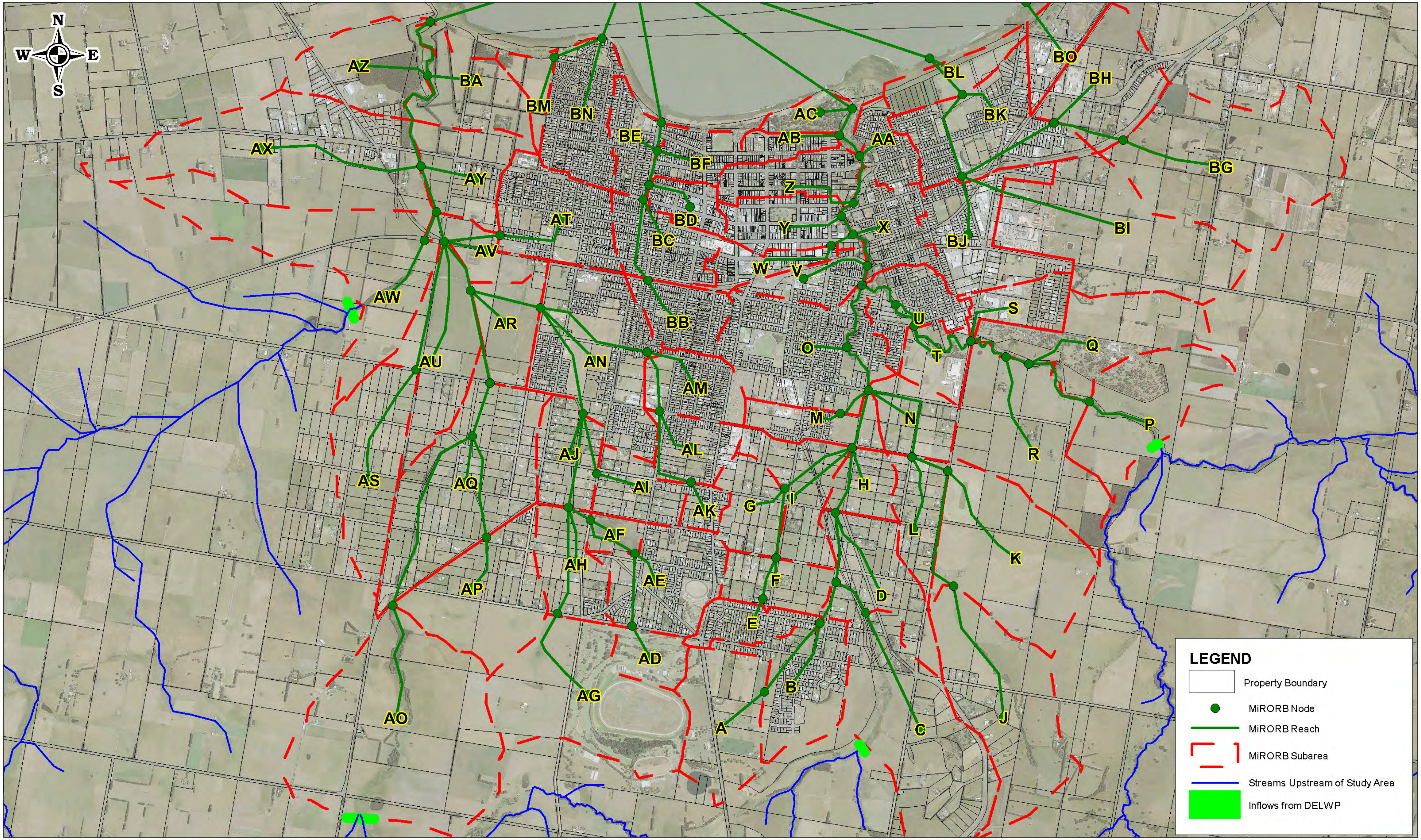
5.2.1 Methodology

Utilising the RORB model layers provided by DELWP (developed as part of the Deans Creek and Barongarook Creek Regional Flood Mapping project) as a basis, a hydrologic model was constructed covering the entire study area using RORB hydrologic modelling software. RORB is industry standard software and is one of Australia's leading flood hydrograph modelling tools.

5.2.2 Catchment Boundary

The catchment boundary for the Deans Creek and Barongarook Creek catchments was defined as part of the DELWP Regional Flood Mapping project for these waterways.

Figure 5.1 provides the overall catchment boundary and structure of the RORB model for the CSDS study area.



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

0 520 1040
Scale in metres (1:26,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

Figure 5.1

RORB Model with Inflow Locations
Layout Plan

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 15 Sep 2017

5.2.3 Sub-catchment Boundaries

The sub-catchments defined in the DELWP RORB models were largely used in the development of a RORB model for the CSDS. In the rural parts of the study area sub-catchment boundaries were unchanged whilst in the urban parts of the study area sub-catchment boundaries were refined to ensure accurate application of inflows at the drainage pit level. This is discussed further in Section 6.2.7 of this report. In some areas new sub-catchments were required to be defined to ensure that the all flows across the entire study area were appropriately defined and allowed for in the model. This was required for the central Colac area and parts of Colac East which drain directly to Lake Colac and thus were not included in the DELWP modelling.

5.2.4 Fraction Impervious

Fraction impervious is a vital component of the hydrological model as it is a key parameter in the process of converting rainfall into runoff. Engeny assigned a fraction impervious value to RORB sub-catchments based on typical fraction impervious values for the various land use types across the study area. The typical values are based on fraction impervious provided in Melbourne Water's MUSIC Modelling Guidelines (2016). Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is software that simulates rainfall, stormwater runoff and pollution.

Fraction impervious values applied for typical land uses within the catchment include:

- General Residential Zone – 60 % impervious
- Rural Living Zone – 20 % impervious
- Farming Zone – 5 % impervious
- Commercial Zone – 90 % impervious
- Industrial Zone – 90 % impervious
- Public Park and Recreation Zone – 10 % impervious
- Local roads & car parks - 60 % impervious
- Major roads - 70 % impervious
- Railway - 50 % impervious.

The fraction impervious value for a sub-catchment was obtained by calculating a weighted average of the fraction imperviousness of land types within the sub-catchment. These results were then checked using aerial photography and some adjustments made where necessary.

5.3 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for Colac was sourced from the Bureau of Meteorology. The IFD variables shown in Table 5.1 were provided in this data. The resultant IFD table that these factors produced is shown in Table 5.2.

Table 5.1 Colac IFD Parameters

Parameter	Value
Intensity - 1 hour duration, ARI = 2 years (${}^{2}I_{1}$)	16.20
Intensity - 12 hour duration, ARI = 2 years (${}^{2}I_{12}$)	3.27
Intensity - 72 hour duration, ARI = 2 years (${}^{2}I_{72}$)	0.89
Intensity - 1 hour duration, ARI = 50 years (${}^{50}I_{1}$)	33.9
Intensity - 12 hour duration, ARI = 50 years (${}^{50}I_{12}$)	5.7
Intensity - 72 hour duration, ARI = 50 years (${}^{50}I_{72}$)	1.7
Skew (G)	0.49
F2	4.29
F50	14.73

Table 5.2 IFD Table for Colac

Rainfall event duration	Average rainfall intensity for each ARI				
	2 years	5 years	10 years	20 years	100 years
10 mins	40.9	57.3	69.1	85	129
20 mins	29.3	40.5	48.4	59.2	88.6
30 mins	23.5	32.2	38.4	46.7	69.5
1 hour	15.6	21.1	24.9	30.1	44
2 hours	10.1	13.4	15.6	18.6	26.7
3 hours	7.8	10.2	11.8	13.9	19.7
6 hours	4.98	6.34	7.23	8.46	11.7
12 hours	3.17	3.97	4.49	5.22	7.09
24 hours	1.98	2.49	2.83	3.3	4.51
48 hours	1.19	1.53	1.76	2.08	2.9
72 hours	0.86	1.12	1.29	1.53	2.15

5.3.1 Consideration of ARR 2016

During the development of the Strategy Australian Rainfall and Runoff (ARR) was updated to ARR 2016. ARR 2016 represents the most significant update to ARR since 1987 and takes advantage of the significant advancements in computer technology, techniques and understanding of rainfall-runoff processes since 1987 and introduces changes to current practice. It is also based on Australian data, when previously it was partly based on USA data. Figure 5.2 below outlines some of the key changes in ARR 2016 when compared to ARR 1987. Given that this study was well underway before ARR 2016 was adopted, IFD data from ARR 1987 was used and is consistent with the IFD data used in the Deans Creek and Barongarook Creek Regional Flood Mapping project. It is also important to note that Melbourne Water and CMA's are managing flood studies in this manner also, i.e. if a flood study was undertaken prior to implementation of ARR 2016 there is no need to update it based on the new data and approaches documented in ARR 2016 as yet.

Key changes in ARR 2016

Design Input	ARR 1987	ARR 2016
Intensity Frequency Duration (IFD)	Used BoM rainfall gauges Presented as static A2 maps	Uses BoM and other agency gauges Online
Areal Reduction Factors (ARF)	Based on USA data Not available for long durations	Based on Australian data
Losses	Based on jurisdictional based advice (personal communication only)	National Advice for rural and urban catchments
Baseflow	Methods but no ungauged catchment advice	Australia wide advice
Temporal Patterns	Average Variability Method Peak Burst Patterns for less than 30 year average recurrence interval (ARI) and rarer than 30 year ARI	Temporal patterns based on historic records, multi pattern for each design quantile and complete storms, with pre burst considered.

Figure 5.2 Key Changes in ARR 2016

5.4 RORB Model Validation

A key step in the development of the hydrologic model is the validation process. This process ensures that appropriate model parameters are adopted to reflect how runoff is routed through the catchment.

The hydrologic model was jointly calibrated with the hydraulic model to ensure a good match of flood levels against the DELWP flood modelling was achieved.

Other key RORB parameters adopted in the model (based on Melbourne Water's Guidelines and Technical Specifications (November 2016)) are:

- m = 0.8
- Initial loss = 10 mm. This value was determined as part of the joint calibration process. The initial loss parameter was varied and run through the hydraulic model to

determine a value that provides a good fit with the flood levels produced by the DELWP model. Further discussion is provided in Section 6.3.1 of this report

- k_c – not applicable as excess rainfall hydrographs have been applied to the hydraulic model and therefore the RORB model has not been used to rout flows through the study area, as routing has been accounted for in the hydraulic model
- Runoff coefficients:
  - 100 year ARI runoff coefficient = 0.60
  - 10 year ARI runoff coefficient = 0.35
  - 5 year ARI runoff coefficient = 0.25

5.5 Climate Change Scenario

A review of current literature identified the latest version of Australian Rainfall and Runoff (ARR 2016) to provide the most relevant resource in determining alterations in rainfall Intensity Frequency Duration (IFD) relationships due to climate change. Chapter 6 of Book 1 of ARR 2016 highlights the large level of uncertainty in predicting climate change impacts and provides interim guidance on accounting for potential climate hazards in flood estimation. The following provides a synopsis of the methodology recommended by ARR 2016 and discusses its application within the climate change scenario modelled for Colac.

Climate change considerations utilised within ARR 2016 are based on the output of the Climate Futures web tool developed by CSIRO. The projections have focussed on 11 natural resource management (NRM) 'clusters'. Figure 5.3 provides an overview of these locations, with the Colac study area lying within the Southern Slopes Mainland NRM region.

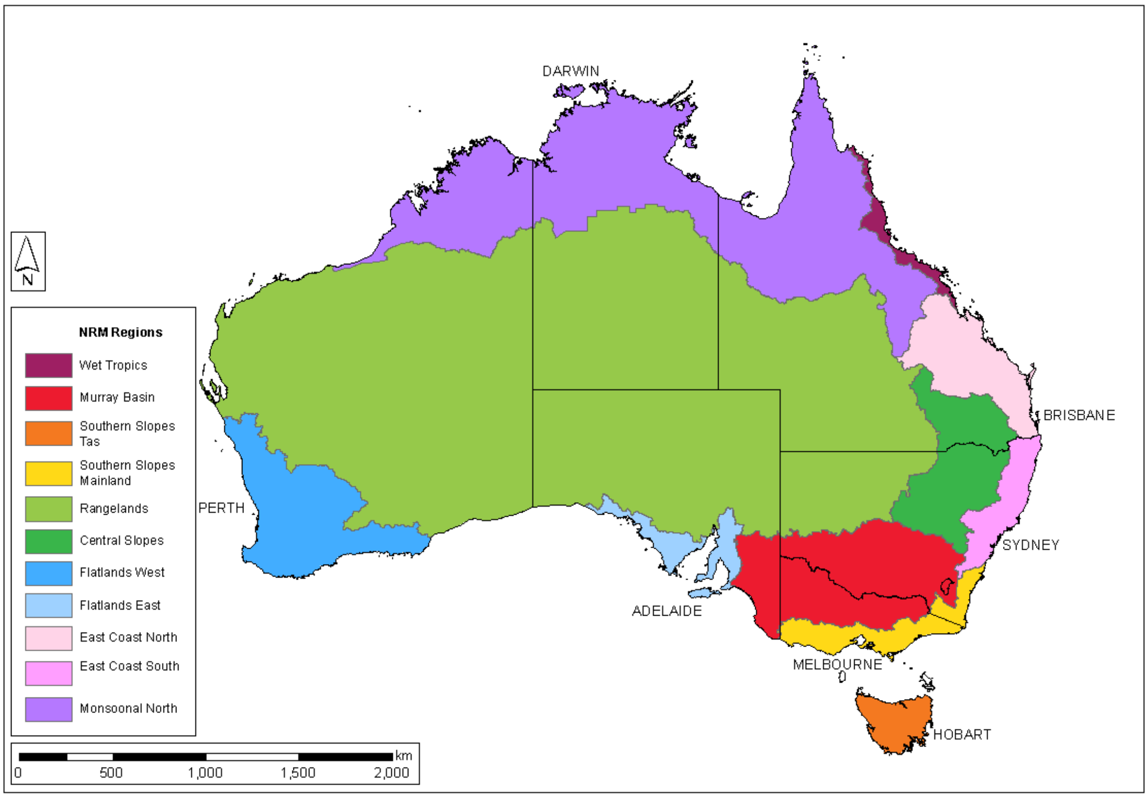


Figure 5.3 Locations of Natural Resource Management Clusters (AR&R 2016)

Climate Futures records projected changes from Global Climate Models (GCMs), for four Representative Concentration Pathways (RCPs). As discussed within the Australian Climate Futures website, the RCPs detail future pathways as based on greenhouse gas and aerosol concentration, along with land use change and are characterised by the radiative forcing (the extra heat retained by the lower atmosphere due to additional greenhouse gases in watts per square metre) produced by 2100. The four RCPs, in order of increasing severity are:

- RCP2.6 (ambitious mitigation including active removal of carbon dioxide from the atmosphere, with emissions peaking around 2020 at 440 ppm and reducing to 420 ppm by 2100)
- RCP4.5 (some mitigation employed with emission peaking around 2040 and 2100 concentration of 540 ppm)
- RCP6.0 (some mitigation employed with 660 ppm of carbon dioxide by 2100 and radiative forcing stabilising shortly after 2100)
- RCP8.5 (little mitigation employed with 940 ppm of carbon dioxide concentration by 2100).

Based on these, ARR 2016 recommends RCP4.5 and RCP8.5 are utilised as the low and high concentration scenarios for impact assessment (RCP4.5 being selected as the low emission scenario given that RCP2.6 requires the rapid implementation of ambitious, global emission reduction measures).

The Guidelines provide a six-stage process in determining the incorporation of climate change in flood design, as summarised in Figure 5.4.

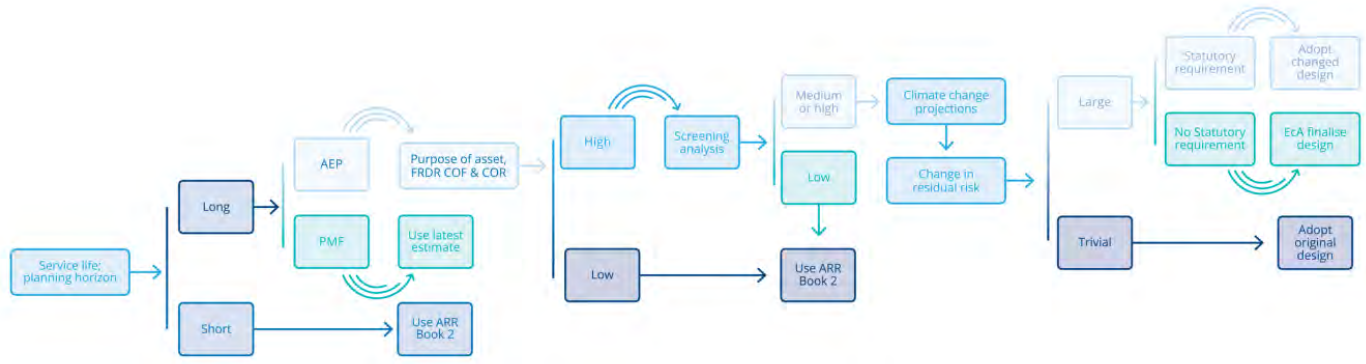


Figure 5.4 Decision Tree for Incorporating Climate Change in Flood Design (ARR 2016)

5.5.1 Rainfall Intensity Projections

Projected changes detailed within Climate Futures are divided into the two climate variables of temperature and rainfall. ARR 2016 acknowledges that for current projections of climate change impacts, there is generally more confidence in simulations of temperature than rainfall. Consequently, ARR 2016 recommends that adjustment of IFD curves is informed by temperature projections alone. In combining these temperature projections with current local and international understanding of changes to extreme rainfall intensities, the expected change in rainfall is between 2 % and 15 % per degree Celsius of warming. Given regional variability and uncertainty in rainfall projections, ARR 2016 consequently recommends a 5 % increase in rainfall per degree Celsius of local temperature warming.

Equation 5.1 denotes the method for determining projected rainfall intensity or equivalent rainfall depth (I_p) as a function of design rainfall intensity ($I_{AR\&R}$) and the midpoint or median temperature of the selected temperature class interval (T_m).

$$I_p = I_{AR\&R} \times 1.05^{T_m}$$

Equation 5.1 Projected Rainfall Intensity Equation

For use with the newly released 2016 IFDs, ARR provides interim climate change factors for RCP4.5, RCP6 and RCP8.5 in the form of temperature increase in degrees Celsius and percentage increase in rainfall. Table 5.3 summarises the interim climate change factors for the planning timeline of 2090, as sourced from the Australian Rainfall and Runoff Data Hub for Colac (longitude 143.5855 and latitude -38.3410).

Table 5.3 Interim Climate Change Factors for 2016 IFDs (AR&R 2016)

Year	Temperature increase in °C (% increase in rainfall)		
	RCP4.5	RCP6.0	RCP8.5
2090	1.527 (7.6 %)	2.009 (10.0 %)	3.21 (16.1 %)

These values are applicable to the new ARR 2016 IFDs which were released in November 2016. As discussed in Section 5.3.1 given that this study was begun prior to the adoption of ARR 2016, IFD data from ARR 1987 has been used.

As agreed with Council the most conservative value was chosen to represent the upper end of climate change predictions and thus a 16.1 % increase in rainfall intensity was selected. The existing conditions RORB model was re-run accounting for 16.1 % increase in rainfall intensity to produce hydrographs for input to the hydraulic model. Section 6.5 describes the climate change assessment undertaken as part of the development of this Strategy further and summarises the results produced by the hydraulic model.

6. HYDRAULIC MODELLING

6.1 Purpose

The purpose of creating a hydraulic model for the study area was to produce a tool that enables a comprehensive analysis of the drainage system to be undertaken. The hydraulic model uses the outputs from the hydrologic model and other inputs (as detailed in this Section) to determine the inundation due to the various rainfall events.

TUFLOW software was utilised as the hydraulic modelling software to undertake this task. TUFLOW was the model used for the DELWP Regional Flood Mapping project and is Melbourne Water's preferred 2D hydraulic modelling package. TUFLOW allows for flows in pipes to be modelled (in the 1-D domain) and overland flows to be modelled (in the 2-D domain) as part of a combined model.

The hydraulic modelling undertaken as part of this study allowed for the following tasks to be undertaken to inform the Strategy:

- Production of flood maps for a range of ARIs
- Identification of properties at risk of flooding
- Identification of opportunities to mitigate existing flood risk within the catchment for existing and future development scenarios.

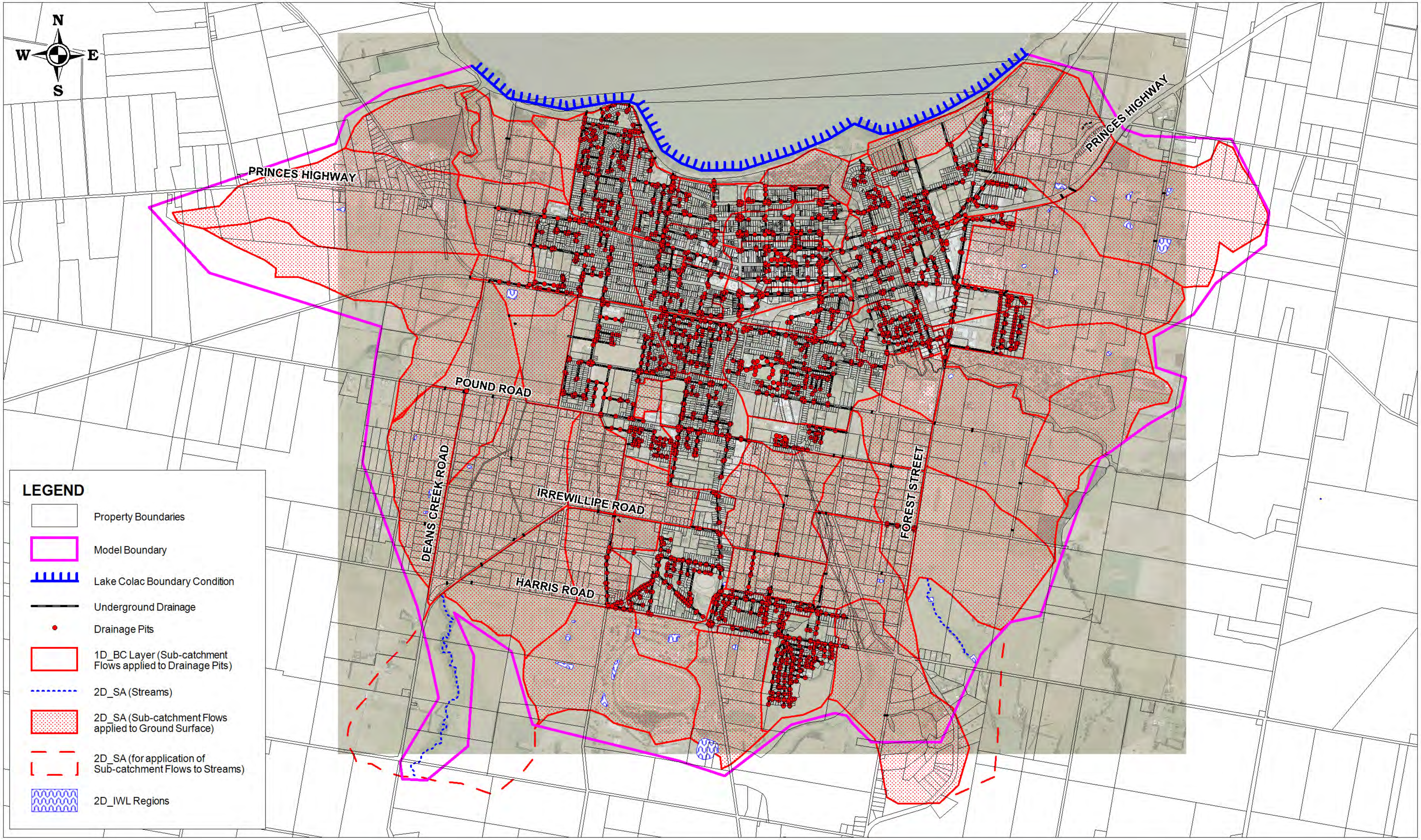
6.2 Model Development

6.2.1 Model Extent

The extent of the hydraulic model is based on enabling the key topographical features of the catchment (such as waterways and open drains) to be modelled at a high level of resolution. It was not necessary to model the entire hydrologic catchment, use of inflow boundaries from the TUFLOW flood model developed for the Deans Creek and Barongarook Creek Regional Flood Mapping project assisted to limit the required extent of the TUFLOW model used for this project.

The extent of the TUFLOW hydraulic model is sufficient to ensure that runoff through Colac and surrounds is accurately modelled, as well as being able to identify key flooding hotspots.

Figure 6.1 shows the extent of the hydraulic model and depicts some of the key inputs to the model which are described further in the following sections of this report.



Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

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Figure 6.1

Hydraulic Model Layout Plan

Job Number: V2013_001
Revision: 0
Drawn: SD
Checked: AP
Date: 1 May 2017

6.2.2 Topography

The hydraulic model uses the Digital Terrain Model (refer to Section 2.2.3) to assign elevations throughout the flood model. A model resolution (grid size) of three metres has been sued, resulting in definition of elevation every 3 horizontal metres in the model. This grid size is in accordance with recommendations in Melbourne Water's Guidelines and Technical Specifications (November 2016) and allows for key catchment features such as waterways, retarding basins, the railway line and roads to be defined in the model.

6.2.3 Drainage Assets

All assets identified in Council's Geographic Information System (GIS) database have been included in the model and considerable effort has gone into the capture of additional drainage assets missing from the GIS database so that they can be included in the model. Particular emphasis was placed on accurately modelling the drainage assets that convey significant overland flow paths under roads and the railway line, a large number of those assets being inspected and measured during site visits by Engeny and / or Council. A number of assets were extracted from the DEWLP model, largely for VicRoads and VicTrack drainage assets. The data captured as part of this study was shared with CCMA to ensure that they are used in the updated DELWP modelling (2017).

The hydraulic model requires invert levels at upstream and downstream ends of all pipes and culverts. This information is not available for most pipes within Council's GIS database (as is the case for most Councils across Victoria). Invert levels were estimated by adopting the following formula:

- Invert level = Ground level RL – 600 mm (pipe cover) – pipe diameter.

The estimated invert levels were then checked to ensure that they were connected appropriately with the inverts of upstream and downstream pipes adjusted where necessary to produce a downward grade.

6.2.4 Waterways and Open Drains

The study area includes numerous waterways and open drains that run through farmland or alongside roads. The LiDAR provides a satisfactory definition of these waterways and open drains and as such it was deemed acceptable that they can be modelled in the 2-D domain. Several culverts have been included in the model along the waterways, with the culverts modelled as pipes in the 1-D domain.

6.2.5 Retarding Basins

A large existing retarding basin is located at the intersection of Irrewillipe Road and Armstrong Road. Engeny visited the basin and gathered the required data, particularly the outlet, to ensure it is accurately represented in the hydraulic model. The outlet structure is shown in Figure 6.2 below, as well as in other photographs in **Appendix B**.

Figure 6.2 Irrewillipe Road Retarding basin outlet structure

A number of other smaller retarding basins have been appropriately represented in the hydraulic model.

6.2.6 Surface Roughness

The hydraulic model includes a land use (materials) layer that reflects the surface roughness (Manning's 'n') throughout of the catchment. The surface roughness defines how much resistance there is to runoff / overland flow passing over different land use types. For instance, high surface roughness values are found in residential properties due to the presence of buildings, fences and other structures that impede the flow of water, while flow through a paddock will have a lower surface roughness value.

Table 6.1 summarises the Manning's 'n' roughness values applied to the hydraulic model. These values are based on Melbourne Water's Guidelines and Technical Specifications (November 2016) and were verified on our site visits and from aerial photographs.

Table 6.1 Hydraulic model surface roughness values

Land Use	Manning's n
Standard density residential property (GRZ1)	0.25
Low density residential property (LDRZ, RLZ, TZ)	0.045
Remainder of parcel (Residential)	0.08
Commercial or industrial (C1Z, C2Z, IN1Z, IN3Z)	0.40
Remainder of parcel (Commercial and Industrial)	0.12
Public Use-Services, Education, Health, Community (PUZ1, PUZ2, PUZ3, PUZ7, SUZ4)	0.20
Public Use-Local Government / Cemetery (PUZ5, PUZ6)	0.045
Farm Zone (FZ)	0.04
Parks, Recreational, Public Conservation and Resource Zone (PCRZ, PPRZ, SUZ3))	0.035
Waterway / Parks – minimal / scattered vegetation	0.06
Waterway / Parks – moderate vegetation	0.09
Waterway / Parks – high density vegetation	0.12
Railway line (PUZ4)	0.035
Car parks and roads (RDZ1, RDZ2)	0.02
Concrete (for culvert modelled in 2D domain)	0.013

6.2.7 Boundary Conditions and Model Inflows

The TUFLOW model includes a series of boundary conditions to control points where flow enters or leaves the model. A HT (head versus time) boundary was drawn at the catchment outlet, Lake Colac, in order to allow water to leave the model. This boundary was based on a peak water level in Lake Colac of 117.4 m as per the DELWP flood model. As part of the development of the DELWP flood model sensitivity testing of varying lake levels found that the lake level resulted in negligible increases in flood level upstream of the foreshore.

A series of QT (flow versus time) boundaries were also placed at the upstream extents of the model in order represent the inflows from Deans Creek and Barongarook Creek in addition to some associated tributaries. These relationships were set up to reference the plot outputs of flow versus time results from the DELWP flood model and enabled the DELWP TUFLOW model extent to be reduced to focus on the study area and provide greater resolution.

Inflows to the underground drainage were input to the model in the 1-D boundary conditions layer which applies the rainfall excess hydrographs for sub-catchments across the drainage inlets within each sub-catchment. In sub-catchments where there is no drainage network the 2-D source area layer was used to apply rainfall excess hydrographs directly to the ground surface for those sub-catchments.

6.2.8 Simulation Parameters

The hydraulic model has been simulated with a 1-D time step of 0.25 seconds and 2-D time step of 1 second. Melbourne Water guidelines recommend that the 2-D time step should generally be one quarter to one half of the TUFLOW grid size. As the grid size of the model is three metres, the model satisfies this recommendation.

6.3 Model Validation

The hydraulic model has been validated by checking that flows and depths produced by the TUFLOW model are reasonable and accord with observed flooding. Any unexpectedly large or small flow results were investigated to understand whether or not they were reasonable.

Model result files were used to check that pipes are flowing full in the 5 year ARI event and if not flowing full then to confirm that the level of overland flow was minor. The pipe flows in the 100 year event were also checked to ensure that the network had been modelled correctly and that there were no ‘brick walls’ where pipes had not been correctly connected to the next pipe downstream. Results were also checked to ensure that TUFLOW was not producing high velocities or depths where they are not expected.

The TUFLOW model was reviewed internally at different stages of its development using Quality Assurance (QA) processes developed by Engeny to ensure that consistent best practice modelling has been applied and that the model is as accurate as reasonably possible.

Joint calibration of the hydraulic and hydrologic model has been undertaken to ensure a good match was achieved to the results predicted by the model developed for the Deans Creek and Barongarook Creek Regional Flood Mapping Project. Section 6.3.1 outlines the key results of this process.

Information gained from the community consultation sessions (via completed questionnaire forms) and from photos / anecdotal evidence provided by Council has also been used to validate the result of the hydraulic model. A description and visual comparison of how historical flooding at the following addresses compares to the results produced by the flood model is provided in the following sub-sections:

- 142 Hart Street
- 18 Hearn Street
- 40 - 42 Balnagowan Avenue
- 11 Lawrence Court
- 177 Aireys Street

- 24 Dowling Street.

The areas that have been considered are scattered across the study area, thus successful validation at these locations has provided high confidence in the modelling results.

Many of the photos presented were taken by local residents during the September 2016 storm event which CCMA advised was classified as a 50 year ARI storm event. The Bureau of Meteorology rainfall station at Colac (Mt Gellibrand) recorded 45.8 mm in the 24 hours to 9 am on the 14th of September. The rainfall station also indicates there were several days of wet weather leading up to this event, resulting in an already wet catchment prior to the onset of rainfall. In the 24 hours to 9 am on the 9th of September 18.6 mm of rain was recorded, whilst 14 mm was recorded in the 24 hours to 9 am on the 12th of September and 11.8 mm in the 24 hours to 9 am on the 13th of September.

6.3.1 Joint Calibration / Validation Results

It is important to consider all available information to ensure that flood modelling provides the best possible match to actual flooding behaviour. Therefore this study has considered information from actual flood events and other flood modelling in the area.

Table 6.2 below documents the results of a comparison between the flood modelling results predicted by the DELWP model and the model developed for the CSDS at Deans Creek and Barongarook Creek. Given that there are some significant differences in the model setup between the two models the results show that a close match was achieved providing confidence in the current modelling to enable decisions regarding future development to be appropriately made using the CSDS hydraulic model.

Table 6.2 Comparisons between DELWP Model and CSDS Model

Location	DELWP Model Flood Level (m AHD) (5 year ARI)	CSDS Model (5 year ARI)	DELWP Model (100 year ARI)	CSDS Model (100 year ARI)
Deans Creek Gauge located just north of railway line ~320 m	120.22	120.19	120.64	120.63
Barongarook Creek @ Princes Highway	17.35 (12hr)	17.44 (12hr)	95.07 (9hr)	92.00 (9hr)

In some areas overland flows predicted by the CSDS model were found to be lower than those predicted by the DELWP model, this is believed to include, but not limited to:

- Differences in LiDAR data used
- Differences in drainage assets used.

It is important to note that the flood extents predicted by the DELWP hydraulic model are based on the assumption that development across the study area is in line with development allowed by the respective planning zones. The result of this assumption is the use of standard density residential surface roughness values (see Section 6.2.6) in GRZ1 zoned areas even if some of the properties within that zone have not yet developed.

The objective of the validation of Engeny's modelling with the DELWP modelling was to ensure that Engeny's modelling of the riverine flooding within the floodplains of Deans and Barongarook Creeks closely matched the behaviour predicted by the DELWP model and to ensure that flooding was appropriately mapped in the residential areas of Colac and surrounds. Engeny believes this has been achieved according to the numbers produced in Table 6.2 above and consideration of noted historical flooding at locations described in the following sub-sections.

It is also important to note that calibration of the DELWP hydraulic model was undertaken to closely match the results of the hydraulic results for flooding along Deans Creek and Barongarook Creek associated with a rainfall event in August 2010. Recorded streamflow from the Deans Creek gauge and other information was used in calibration of the DELWP model.

Engeny used anecdotal evidence supported by photographs supplied by the community to ensure a close match between the results of the hydraulic model and the flooding witnessed and documented in the study area, particularly for locations associated with the local drainage system. A number of these examples are discussed on the following pages.

The flood modelling results depicted in all images below, except where noted, have been produced using the filtering criteria outlined in Section 6.4 (e.g. depth ≥ 0.05 m).

6.3.2 142 Hart Street

Engeny understands that the resident of 142 Hart Street provided Council with a range of photos to document flooding within the property that occurred during the September 2016 storm event. Figure 6.3 below presents three photos supplied by the resident;

a) taken along the southern boundary of the project

b) taken along the eastern boundary of the neighbouring property (144 Hart Street)

c) at the front of the property looking south along Hart Street.

This pattern of flooding is well represented by the flood model with Figure 6.4 highlighting the flooding that can be expected to arise from a 10 year ARI event which is less than the 50 year ARI event that the September 2016 event has been classified as being. As such Engeny believes that the flood model provides a good match to the flooding reported at this location given that the September 2016 flooding pattern is replicated in the 10 year ARI results but not as deep in terms of flood depth. The cause of this flow is breakaway flow from the Martin Street and Batson Crescent drainage system which does not have capacity for 10 year ARI flows or greater.

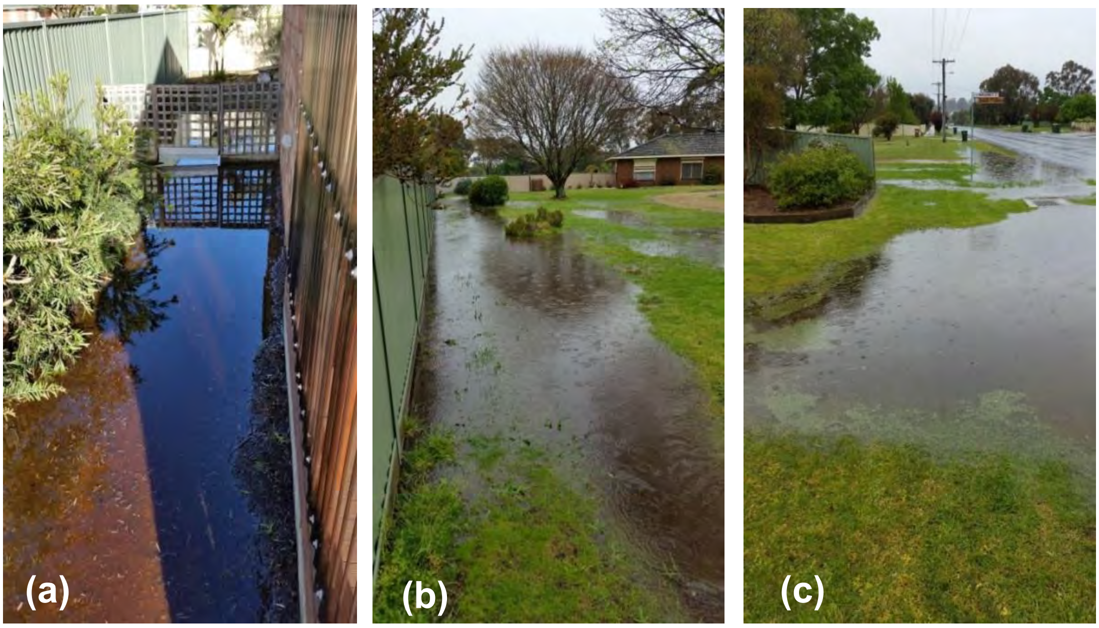


Figure 6.3 **Flooding at 142 Hart Street as captured by resident in September 2016**

Figure 6.4 **Flooding at 142 Hart Street as predicted by flood model (10 year ARI)**

6.3.3 18 Hearn Street

At the second community consultation session a member of the Colac community who had documented flooding in the vicinity of Pound Road / Egan Street / Hearn Street during the September 2016 storm event provided a range of photos. The person noted that flooding in the vicinity of 18 Hearn Street was prominent and had encroached into the property as shown in Figure 6.5 below. Figure 6.6 presents the 10 year ARI flood extent predicted by the flood model and Engeny believes this is a good fit to the flooding experienced at this property.

Figure 6.5 Flooding at 18 Hearn Street

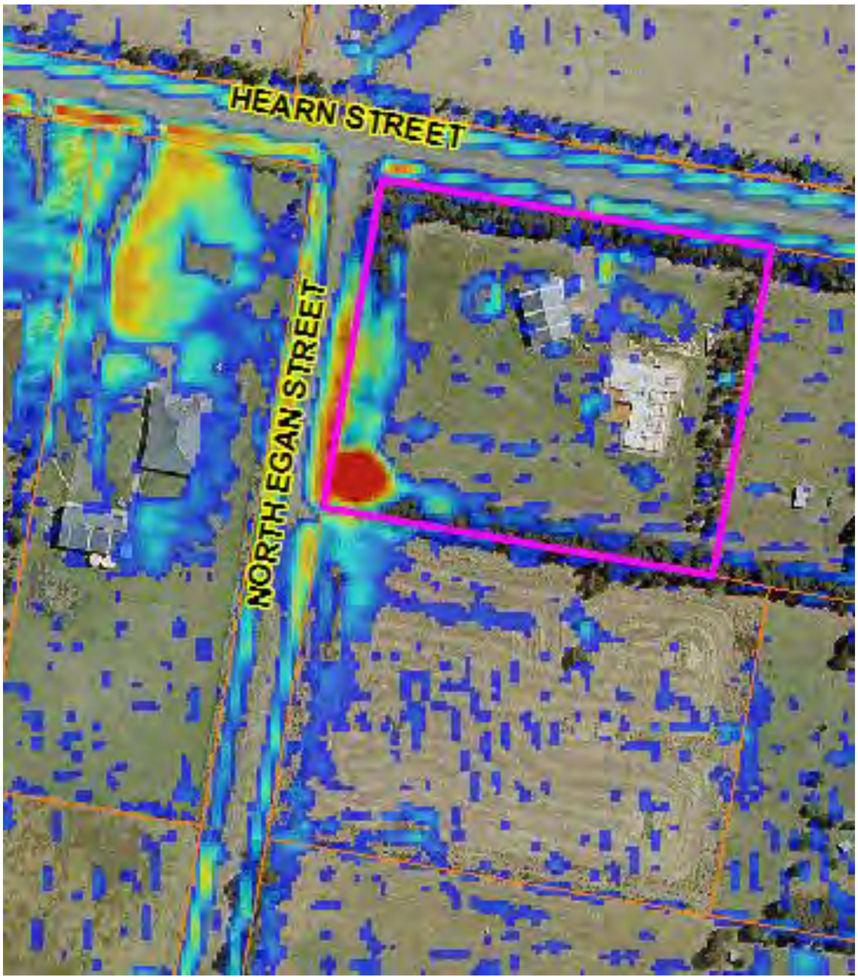


Figure 6.6 Flooding at 18 Hearn Street as predicted by flood model (10 year ARI)

6.3.4 40-42 Balnagowan Avenue

It is understood that the residents of this property highlighted previous flooding within the road in front of the property to Council. The residents noted that whilst the house has not previously been flooded above floor level they are concerned that this could happen in the future if a large storm event was to occur. The flood modelling results, shown in Figure 6.7 below, clearly depicts a low point in the road in front of the property and the results show that in a 100 year ARI event the existing underground network has insufficient capacity to prevent runoff from overtopping the kerb. Note that for the 5 and 10 year ARI events flows do not overtop the kerb if the existing drainage system is not blocked.

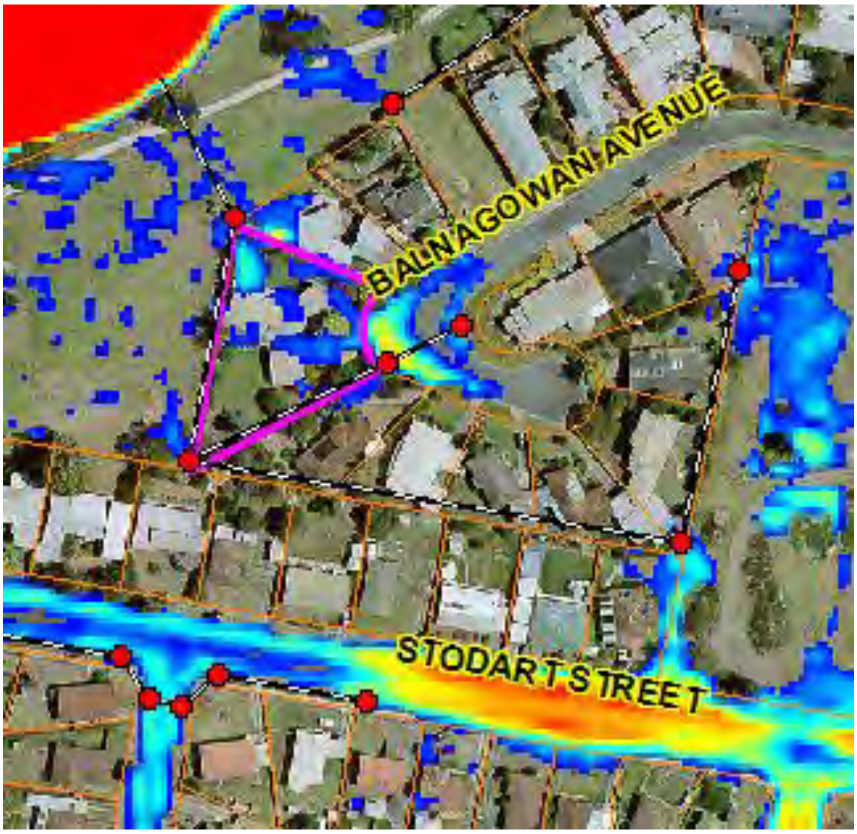


Figure 6.7 Flooding at 40-42 Balnagowan Avenue as predicted by flood model (100 year ARI)

6.3.5 11 Lawrence Court

The following is an extract from an email to Council from the resident of this property documenting that some historical storm events had caused runoff to flow through the property:

"About 20 odd years ago we had a huge downpour and although our house wasn't flooded, we were very worried that it was going to be, and around 5-10 years ago a similar thing happened to a lesser degree, with parts of our back yard being 20-25cm under water."

No photos were provided by the resident but Figure 6.8 below highlights that in a 5 year ARI event flows are sufficient to overtop the kerb and flow through the property. Whilst it is not possible to determine the ARI of the historical flooding events Engeny believes that the modelling is realistically representing what happens at this location during storm events.

Figure 6.8 Flooding at 11 Lawrence Street as predicted by flood model (5 year ARI)

6.3.6 177 Aireys Street

The resident of this property attended the second community consultation session, completed the questionnaire and provided a range of photos highlighting runoff through the front of the property associated with the September 2016 storm event. Figure 6.9 is a photo supplied by the resident and Figure 6.10 highlights flood modelling results for the 10 year ARI event (note that no filtering of flood depths is used in this figure to capture the shallow nature of flows through the driveway). The modelling results appear to highlight the pattern of flooding well noting that the September 2016 storm event was a 50 year ARI event and thus greater depths could reasonably be expected than those represented .

Figure 6.9 Flooding at 177 Aireys Street as captured by resident in September 2016

Figure 6.10 Flooding at 177 Aireys Street as predicted by flood model (10 year ARI)

6.3.7 24 Dowling Street

The resident of this property provided Council with a range of photos to highlight runoff across the property. Figure 6.11 below is a photo supplied by the resident, taken during the September 2016 storm event, and Figure 6.12 presents the results of the flood modelling for the 10 year ARI event. Based on the evidence presented in the photos Engeny believes that the flood modelling provides a good match.

Figure 6.11 Flooding at 24 Dowling Street on 14th September 2016

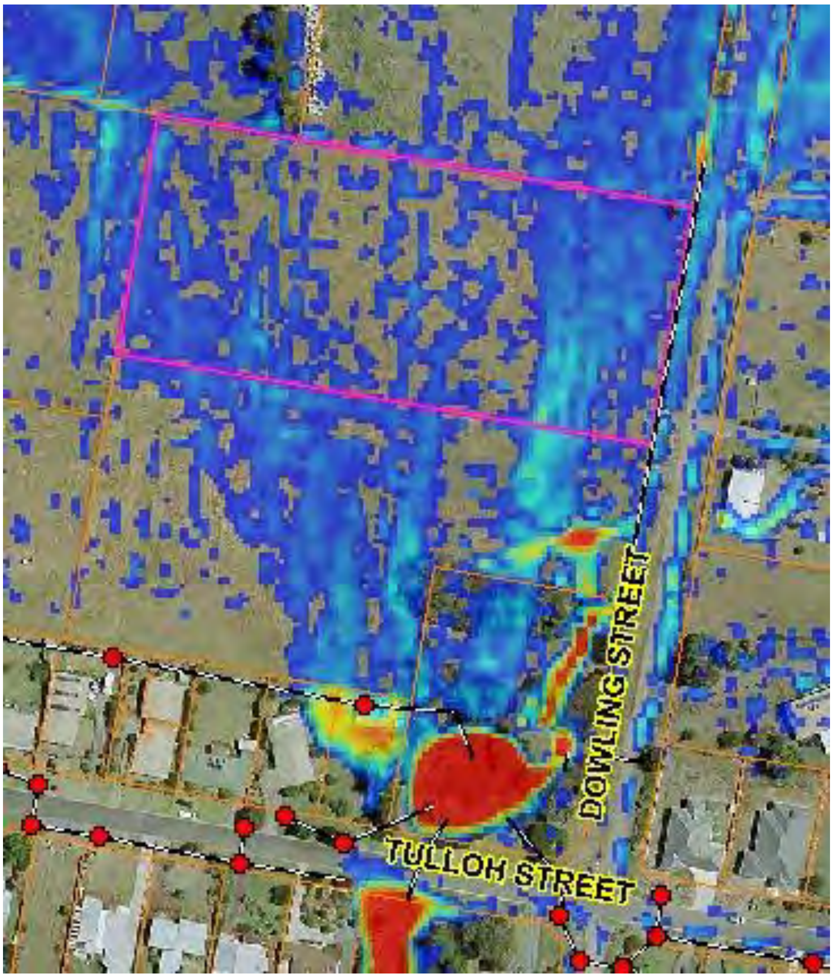


Figure 6.12 Flooding at 24 Dowling Street as predicted by flood model (10 year ARI)

6.3.8 Reported Flooding Incidences from September 2016 Storm Event

A number of flooding incidences were reported by the local community to Council during the September 2016 storm event. Council collated these reports from which Engeny made comparisons to the flood modelling results. This comparison also showed a close match between the modelling results and what really happened during the storm event for the majority of locations. In a small number of areas where blockage of drainage assets were noted the modelling results did not fully represent the flooding noted during the September 2016 storm event and that is due to the fact that the hydraulic model has not been run with the degree of blockage that may have been present at the time of the storm event. It is important to note that these locations are not identified as being located within the highest risk areas across the study area.

6.3.9 Photos supplied by Corangamite Catchment Management Authority

The CCMA provided Engeny with a range of photos captured during the September 2016 storm event including Figures 6.13 and 6.14 which highlight flooding at Wallace Street at the crossing of Barongarook Creek. The 10 year ARI event flood modelling results indicate that the event does not result in overtopping of Wallace Street whilst the 100 year

ARI event results shown in Figure 6.15 indicate that the 100 year ARI event is significant enough to cause overtopping. The photos not only provide validation that the flood modelling results are realistic, they also confirm that the September 2016 rainfall event was in the order of a 50 year ARI event.

Survey marks were also captured by CCMA and at the time of preparing this report are being used to undertake further calibration of the flood models developed for DEWLP to finalise proposed changes to the existing Land Subject to Inundation Overlay (LSIO) in response to the findings of the 2016 Regional Flood Mapping project.

Figure 6.13 Flooding across Wallace Street

Figure 6.14 Flooding between Wallace Street and the Railway Line

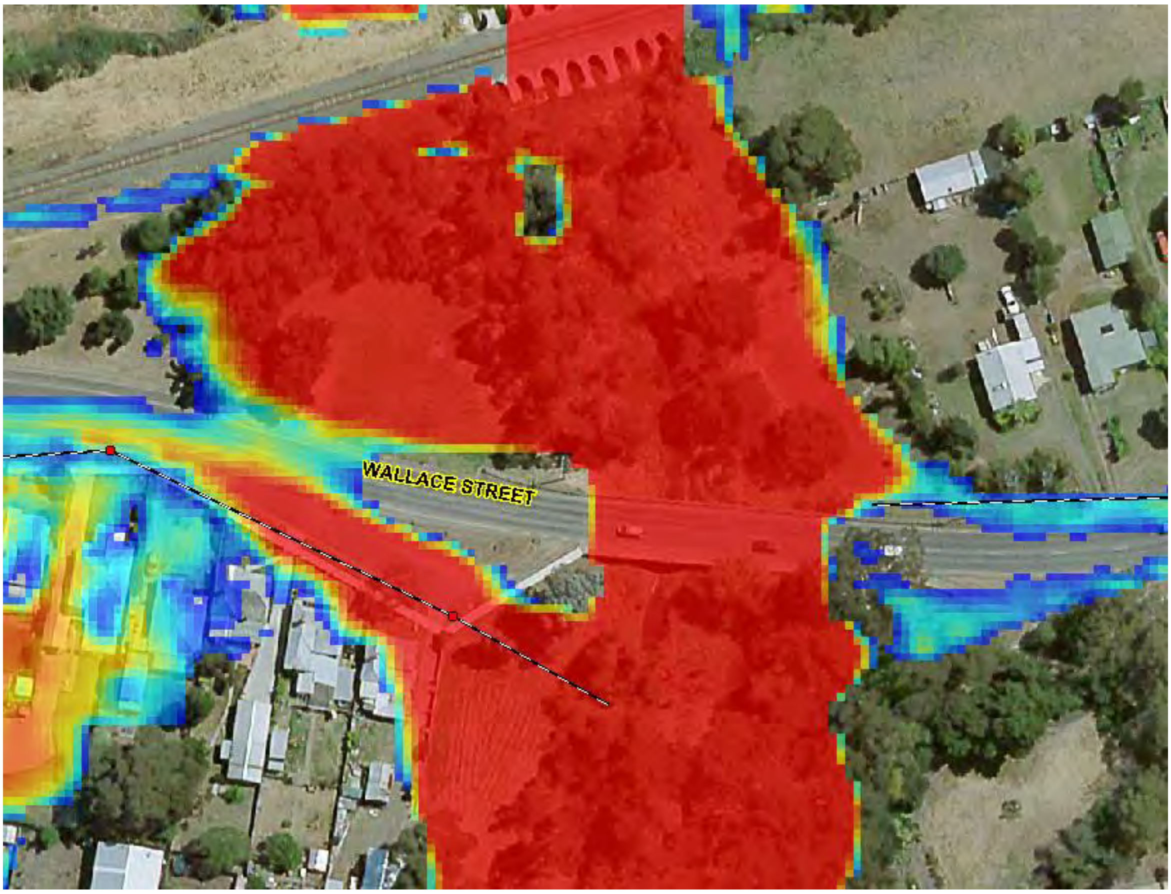


Figure 6.15 Flood modelling results at Wallace Street

6.4 Flood Mapping

For each modelled ARI a flood extent has been produced, with data included in the flood inundation map if it meets the following condition:

- Depth ≥ 0.05 m.

The flood inundation maps for each ARI are a combination of the critical results from all modelled rainfall event durations for the particular ARI.

Appendix D provides flood inundation maps for the 5,10 and 100 year ARI events for existing development conditions.

The flood inundation maps highlight the following with respect across the existing developed areas of Colac and surrounds for the minor and major storm events:

- 5 year ARI (minor event)
  - Flooding largely contained within road reserves, some overtopping of low points in road reserves noted with overland flow directed through some private properties.

- 100 year ARI (major event)
  - Higher number of private properties impacted by overland flows, largely as a result of a change in drainage design standards. As outlined in Section 4.1.1 there have been a number of changes to drainage design standards over time, the most significant being the adoption of the "major / minor" drainage system. The "major / minor" drainage system concept, as outlined above, was first specified in Australian Rainfall and Runoff in 1987. A large portion of Council's drainage system in Colac and surrounds was designed and constructed prior to 1987 and therefore does not meet current drainage standards which is common for Councils across Victoria.

6.5 Flood Warning

The Bureau of Meteorology (BoM) provides flood warning services for major waterways around Australia. In Victoria these flood warnings enable the Victorian SES to co-ordinate flood emergency responses and to assist the community. There are no major waterways in Colac that have flood warning systems provided by BoM.

Some local authorities have local flood warning systems to assist their communities. The types of local warning systems vary, depending on the resources available and the warning time that can be provided.

Outputs from the flood modelling, either undertaken as part of the development of the CSDS or as part of the Deans Creek and Barongarook Creek Regional Flood Mapping Project, could be used to develop a flood warning system and/or provide input to a Flood Emergency Response Plan for Colac and surrounds.

The Deans Creek and Barongarook Creek Regional Flood Mapping Project notes that overall catchment response is highly dependent on the antecedent conditions which is important to note for any future flood intelligence and warning systems, the design and development of which is beyond the scope of this Strategy.

6.6 Flood Impacts on Transport

The flood modelling results have been used to determine the impact of flooding on key transport infrastructure across Colac and surrounds. Table 6.3 below summarises the results of this assessment noting if the Princes Highway or the railway line are overtopped for the various ARI events.

Flooding of the main roads and / or railway line could restrict access due to closures during floods. Overtopping of road or rail embankments could also lead to damage of the embankments and significant costs and disruptions to transport.

Table 6.3 Summary of impact on key transport infrastructure

Location	5 Year ARI - overtopping?	10 Year ARI - overtopping?	100 Year ARI - overtopping?
Princes Highway @ Barongarook Creek	No	No	No
Railway Line @ Barongarook Creek	No	No	No
Princes Highway @ Deans Creek	Yes (depths up to ~ 80 mm)	Yes (depths up to ~ 200 mm, depths above 100 mm for 3.5 hrs)	Yes (depths up to 650 mm, depths above 100 mm for 9.5 hrs)
Railway Line @ Deans Creek	No	No	Yes (just overtops)

6.7 Climate Change Modelling and Results

To help inform climate change adaption planning decisions the impacts of climate changes has been assessed within the flood model developed for the CSDS.

Section 5.5 of the Strategy outlines the methodology and assumptions adopted to arrive at a prediction of 16.1 % rainfall intensity increase under climate change conditions. Having arrived at this prediction the hydraulic model was run for the 5 and 100 year ARI events including the influence of climate change. Flood inundation maps for climate change conditions are presented in **Appendix E**.

6.7.1 Impact of Climate Change

The increase in rainfall intensity predicted as a result of climate change has been shown to increase peak flood depths event throughout the study area. A flood depth difference plot is presented in **Appendix E** to clearly show the impact on flood depths across the study area when comparing existing catchment conditions with climate change conditions.

The flood depth difference plot highlights that climate change will lead to increased flooding across the study area. The increase in peak depth, however, is not uniform throughout the catchment. The increase experienced in each location depends on a number of factors including:

- Existing drainage capacity and capacity of overland flow paths
- Topography
- Position within the catchment (upstream vs downstream).

The greatest impacts on flooding across the study as a result of climate change are located along Deans Creek and Barongarook Creek as a result of those waterways carrying greater volumes of runoff generated from increased rainfall intensities. Across the existing development areas of Colac and surrounds the majority of locations where increased flood depths are noted in climate change conditions are located at low lying areas of the topography. These areas are also most are risk from a blockage of drainage assets (including pits and pipes) and are also at risk of significant flooding should an event larger than the 100 year ARI storm occur.

7. EXISTING DRAINAGE SYSTEM PERFORMANCE AND MITIGATION OPPORTUNITIES

7.1 Existing Flooding 'Hot Spot' Locations

Detailed hydraulic modelling has enabled the capacity of the drainage network within existing residential areas to be assessed in detail. In consultation with Council the following locations have been identified as flooding 'hot spots' based on the extent (number of properties impacted) and depth of flooding. Each of these locations are highlighted in Figure 7.1 and summarised in the following sub-sections.

7.1.1 Location 1 – Railway Line to the intersection of Princes Highway and Armstrong Street

Several properties are located in a well-defined valley which exists between the Princes Highway and Armstrong Street, are impacted by flooding in various ARI storm events. This is due to limits on the capacity of the existing drainage network. Flows in excess of the drainage capacity will pond in the low points of Jennings Street and Farrington Street before being directed into properties.

7.1.2 Location 2 – Gravesend Street to Hart Street

The existing drainage network running from Gravesend Street to Hart Street appears to have capacity to convey 5 year ARI flows. For rainfall events larger than the 5 year ARI event drainage capacity is exceeded with a number of adjacent properties impacted. There are a number of low points within the streets where flows in excess of the drainage capacity will pond before being directed into properties.

7.1.3 Location 3 – Hart Street to Armstrong Street

During rainfall events in excess of the 5 year ARI properties located along Deans Court, Mahoney Court, Petjuli Street and Jakaranda Street are affected by flooding mainly due to insufficient pipe of the existing drainage system.

Engeny was also commissioned to consider the feasibility of potential future development areas in Colac from a drainage perspective. This information will become available in the coming months, and should be considered alongside other background information.

Properties located on the northern face of Deans Court and Mahoney Court, are affected by flooding mainly due to insufficient pipe and pit capacity of the existing drainage system.

7.1.4 Location 4 – Lawrence Court to Wilson Street

The existing 300 mm drain at the north-eastern corner of Lawrence has capacity to convey close to the 5 year ARI flows. For rainfall events larger than the 20 % event drainage capacity is exceeded and a number of properties are impacted through to Wilson Street.

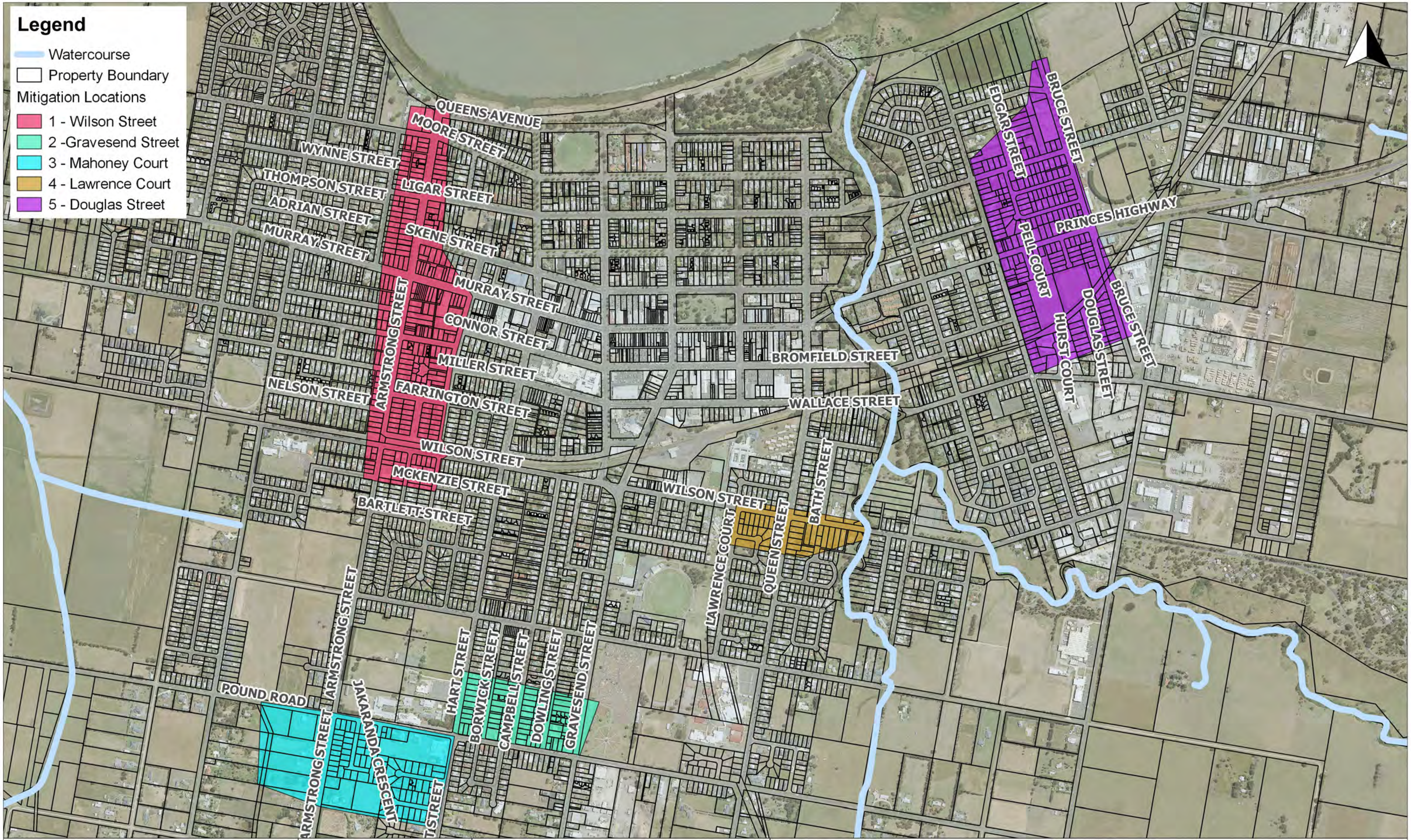
7.1.5 Location 5 – Railway Line to the intersection of Chapel Street and Bruce Street

The existing 675 mm drain located beneath the railway line between Burst Court and Douglas Street does not have capacity to cater for flows in excess of the 5 year ARI event. As a result during larger rainfall events flows in excess of the drainage capacity pond on the south side of the railway line before overtopping the railway line and impacting numerous properties through to the intersection of Chapel Street and Bruce Street. Properties north of the railway line are positioned in a well-defined valley which follows the alignment of the existing drainage network.

7.1.6 Location 6 – Hill Street to Wallace Street

The existing 375 mm diameter pipe running from Hill Street to Wallace Street does not have capacity to convey 5 year ARI flows and as a result a number of properties are impacted during minor and major storm events. The valley which follows the alignment of this 375 mm pipe conveys the overland flow through the properties where additional water is also directed into this impacted area from Queen Street also as a result of limits on drainage capacity. In larger ARI events the tailwater levels of Barongarook Creek act to reduce the capacity of the drainage system at this location.

It is difficult to address flooding up to the 100 year ARI event at this location without lowering the flood level within Barongarook Creek. Provision of underground storage would assist, however a large volume of storage, thousands of cubic metres, would be required and the available space to fit such volume of storage is limited. Due to the inherent constraints at this location a detailed mitigation assessment for this location has not been undertaken and is not described further or presented on Figure 7.1.



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

100 0 100 200 300 400 m

At A3 1:12,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

Figure 7.1

Mitigation Locations
Layout Plan

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 18/9/2017

7.2 Possible Structural Mitigation Works to Address 'Hot Spots'

7.2.1 Proposed Works

For each location summarised in Section 7.1 structural works have been identified to address flooding for up to the 100 year ARI event. The extent and sizing of works are presented in **Appendix F**. The sizing of works was undertaken utilising the results of the existing conditions flood modelling and utilising spreadsheet calculations to determine appropriate pipe sizes for the peak 100 year ARI event.

At all locations, except for Location 2, underground drainage upgrades are proposed as a result of lack of open space which could be utilised for retardation of piped flows to reduce the extent and sizing of drainage upgrades.

As part of the works identified at Location 2 a retarding basin is proposed as there is open space within the Trinity College property which could possibly be acquired. The existing conditions flood modelling results highlight that a large portion of the undeveloped area in the north eastern corner of the property is subject to flooding approximately 200-400 mm deep for the 100 year ARI event. Any future development in this area should consider the extent of flooding for existing conditions (the implementation of a Special Building Overlay (SBO) would ensure this was the case) to appropriately set floor levels and not obstruct overland flows. This could result in a more expensive development design and construction (e.g. structural footings). As such the construction of a retarding basin within a portion of the property presents an opportunity to appropriately retard catchment flows that would reduce the constraints on any future development within that part of the property.

An assessment on the sizing of proposed mitigation works as a result of predicted climate change conditions was also undertaken. This enabled the percentage increase in capital cost to address the impacts of climate change, relative to those works required to address existing conditions, to be determined. This is discussed further in Section 7.2.4. The extent and sizing of works required to address flooding for the 100 year ARI climate change condition are presented in **Appendix G**.

7.2.2 Costing

The proposed works for each location have been costed according to industry rates as defined by Melbourne Water's standard rates for Developer Services Schemes. At each location the number of properties that would likely benefit from the works has been calculated in order to compare and prioritise the works at each location based on the cost per property likely to benefit. Table 7.1 below summarises the cost (including 40 % allowance survey, design and contingencies), the number of properties likely to benefit from the proposed works and the cost per property likely to benefit from the works for both existing conditions and climate change conditions.

Table 7.1 Summary of capital costs for proposed mitigation works at all five flooding 'hot spot' locations

Mitigation Location		No. Properties likely to benefit	Existing Peak 100 year ARI Flows		Climate Change Peak 100 year ARI Flows		% Cost Increase for Climate Change Mitigation Works
			Cost (incl 40 %)	Cost Per Property	Cost (incl 40 %)	Cost Per Property	
1	Wilson Street	73	$4,854,045	$66,494	$5,325,415	$72,950.90	8.9 %
2	Gravesend Street	34	$1,323,425	$38,924	$1,441,219	$42,389	8.2 %
3	Mahoney Court	48	$3,314,339	$69,049	$3,332,305	$69,423	0.5 %
4	Lawrence Court	12	$813,949	$67,829	$839,509	$69,959	3.0 %
5	Douglas Street	90	$3,373,414	$37,482	$3,647,620	$40,529	7.5 %

7.2.3 Prioritisation

The works at all five locations have been compared based on their respective cost per property likely to benefit, summarised in Table 7.1. The result of this comparison is summarised in Table 7.2 below for both existing conditions and climate change conditions.

Table 7.2 Prioritisation of mitigation works across all five flooding 'hot spot' locations

Mitigation Location		Prioritisation Ranking for Existing Conditions	Prioritisation Ranking for Climate Change Conditions
1	Wilson Street	3	5
2	Gravesend Street	2	2
3	Mahoney Court	5	3
4	Lawrence Court	4	4
5	Douglas Street	1	1

7.2.4 Impact of Mitigation Options due to Climate Change

The assessment of mitigation works required to address flooding associated with predicted climate change has highlighted the following:

- The prioritisation of mitigation works across various locations is different when compared to the prioritisation of mitigation works for existing conditions
- The incremental increase in infrastructure sizing that is needed to address the impact of climate change across the five locations investigated as part this assessment equates to on average a 5.62 % increase in capital cost. The increase in cost varied between 0.5 and 8.9 % across the five locations.

This information will help inform Council's climate change adaptation planning.

7.2.5 Further Work / Assessment

The mitigation works presented in this Strategy are high level concepts only and a number of tasks are needed to further assess their feasibility and constructability. These tasks are likely to include the following:

- Underground service proving, as part of the concept assessment Dial Before You Dig (DBYD) information was acquired and at all locations a number of possible clashes with existing sewer and water assets were noted
- Geotechnical investigation (to confirm soil properties and / or undertake a contaminated land assessment)
- Flood modelling to confirm benefit of the works (as described in Section 7.2.1 spreadsheet calculations have been used in this concept level assessment and to confirm the benefits of the proposed works it is possible to input the works into the flood model to enable a comparison to existing conditions.

  Floor level survey of those properties predicted to be impacted by flooding would assist with this task and an Average Annual Damages (AAD) assessment could be undertaken. The objective of an AAD assessment is to determine the financial impact of flooding, in terms of the average cost of flood damages due to flooding per year. This assessment calculates the flood damage costs for a range of ARI storm events and uses this information to calculate the average cost of flood damages in any given year. It also enables the financial benefits of the proposed works to be analysed.
- Community engagement.

It is possible that these further works could change the priority order of mitigation works at the five locations. It is also possible that some works may be proven to not be feasible.

When looking to mitigate areas subject to flooding Council should consider if the cost of providing additional drainage capacity is justified for the reduction in flooding risk that it provides. In some areas it may be justified to construct infrastructure capable of conveying flow in excess of a 100 year ARI event in order to reduce the risk of flooding either as a result of climate change or in an event larger than a 100 year ARI. An example of this may be if a pipe upgrade is being planned and by increasing the pipe diameter by one or two standard sizes may significantly increase the flow capacity but may not significantly increase the cost of construction. In other areas it may only be practical to convey a certain flow rate of water away and in these areas Council (and by extension the community) may have to accept a lower level of service which would mean that flooding may occur more frequently. Other controls on development may need to apply in these areas to help manage the risk that flooding poses to the community.

7.3 Drainage Maintenance

Maintenance of urban drainage systems is important to ensure their continued efficient operation.

Blockage of drainage inlets and culverts can exacerbate flooding. On some occasions the blockage can be due to a lack of maintenance where blockages that have existed for some time have not yet been cleared. In other cases the drainage system can be free of blockage immediately before a flood event and debris can be swept down the drainage system with the flood flows and create blockages.

Typically Council drainage systems have inlets that are designed to allow for a certain blockage factor to protect the pipe capacity.

It should be noted that flooding can occur due to the occurrence of a storm event that exceeds the rainfall intensity used to design the system and that blockage or lack of maintenance in these situations may not have played a part in the flooding that occurs.

The results of the hydraulic modelling will assist Council to prioritise their periodic inspections and maintenance of drainage systems at key locations, particularly those locations documented in Section 7.1.

7.3.1 Opportunities to Improve Irrewillipe Road Retarding Basin

An action contained within Colac Integrated Water Management Plan (IWMP) is to upgrade the existing Irrewillipe Road Retarding Basin, largely to serve a stormwater treatment function from which treated water could be harvested and reused. As summarised in Colac IWMP:

"This initiative proposes to upgrade an existing but under-performing retarding basin to be a showpiece of what can be achieved through waters sensitive urban design. The Irrewillipe Road Retarding Basin is a drainage asset reserve of approximately 7.7ha. The function and management of this basin is currently not well understood (COS, pers comm.). The basin retains stormwater from a catchment of 150ha, of which approximately 45ha is residential land. However the basin is not performing its hydraulic function effectively, has become weed infested and provides no public amenity value.

Under this initiative, the basin would be transformed into a fully functional, valued urban water asset which provides drainage retardation, recreation and amenity values, conservation values and treated stormwater to service the nearby Colac Golf Course. Proposed components of the upgrade include:

- *Incorporate WSUD with a sedimentation pond and wetland*
- *Re-engineer the outlet to ensure peak flows are managed, including provision for growth and associated increased runoff*
- *Investigate utilising the storage as a stormwater harvesting and treatment system for reuse within the Golf Club precinct*
- *Extensive upgrade of the surrounding landscape to enhance the recreation and amenity value of the asset*
- *Investigate utilising the water body as a 'put-and-take' fishery.*

A number of tasks undertaken as part of the development of this Strategy have highlighted the following with respect to the Irrewillipe Road retarding basin:

- Drainage catchment to the basin is in the order of 70 hectares
- Peak inflow to basin estimated to be in the order of 5 m^3/s for the 100 year ARI event
- Provides a good level of retardation with downstream flows restricted to the capacity of the 600 mm pipe outlet, the hydraulic model predicts a peak flow of 0.45 m^3/s for the peak 100 year ARI event
- There appears to be scope, based on review of topographical data, to lower the base of the basin to include a sedimentation pond and wetland.

If the basin was to be improved / upgraded there are only likely to be small, relatively insignificant, gains that could be made with respect to flood management. Under existing conditions there is approximately 1 metre of freeboard between the peak 1% AEP flood level and the basin embankment. An upgrade to the outlet is recommended as part of any works as the outlet configuration was noted during site visits to be in poor condition.

The increase in runoff directed to the basin for future development conditions is unlikely to change the risk profile of the basin (e.g. embankment failure) due to the amount of freeboard above the 1% AEP flood level for existing conditions.

The works proposed in the IWMP for Colac will achieve significant water quality and integrated water management benefits, however the works are not strictly required from a flood management perspective. As such there is no recommendation as part of this Strategy to undertake works on the basin to either assist with flood protection of existing development areas or to reduce the extent of works to manage flooding in the future development areas.

The opportunity to improve the Irrewillipe Road retarding basin as presented in the IWMP for Colac is certainly an opportunity worth progressing further and is understood to be being considered further by Council at the time of preparing this Strategy.

7.4 Non-Structural Measures

Council could also consider the use of planning scheme overlays to control development in areas subject to flooding. In these areas minimum floor levels could be set based on a current 100 year ARI flood level and a freeboard applied to that flood level which provides for some allowance for expected future increases in flooding along with the usual uncertainties associated with flood modelling. This could involve adopting a freeboard of 500 or 600 mm above a flood level rather than a more standard 300 mm for flooding associated with a drainage network. Planning scheme controls will not stop properties from flooding but will significantly limit the financial damages when flooding occurs and also significantly reduce the risk to human safety if floors are kept above flood levels during flood events.

Non-structural measures are a cost effective way to improve drainage management. The following non-structural measures are recommended in this Strategy:

- Special Building Overlays (SBOs) are appropriate for identifying overland flow paths for 100 year ARI storms. Use of SBOs across Colac and surrounds is recommended to manage future development and to reduce the flood risk for new buildings. The use of SBOs are considered a high priority for the catchment as they do not have any capital cost and will result in an effective measure across the catchment.

A number of Melbourne based Councils have / are implementing Special Building Overlays (SBOs) to control development in existing development areas. They are noting that to undertake capital works to address flooding for up to the 100 year ARI event (the major storm event as defined by Australian Rainfall and Runoff) would be extremely costly and would take several decades to implement successfully. The use of SBOs allow Councils to prioritise and strategically implement their capital works with the understanding that the SBO will assist in providing satisfactory flooding outcomes in other areas if development is proposed.

8. STRATEGY FOR ULTIMATE DEVELOPMENT CONDITIONS

8.1 Development Areas

Council provided information detailing the areas and type of future development that may occur in Colac and surrounds as part of future rezoning. The feasibility of developing these areas from a drainage perspective has been assessed as part of this assessment the objectives of the Colac Planning Scheme, outlined in Section 3, have been considered.

A copy of the layout plan highlighting development investigation areas, as identified in Colac 2050, is attached in **Appendix A**.

8.2 Drainage Objectives

The key objective Engeny has assessed for each of the development areas is whether it is possible to develop each area without increasing flooding downstream of the development as a result of urbanisation. This objective is in line with the peak flow control requirement which is set out in Clause 56 of the Victorian Planning Provisions.

The objectives in the proposed development areas have been grouped as follows:

- Flood reduction and waterway corridor objectives to maximise development potential
- Stormwater treatment objectives to treat runoff from new development areas
- Peak flow control objectives to ensure new development areas do not increase downstream flooding.

Each of these topics are discussed in the following sub sections of this report. The overall strategy has been designed to make provision for:

- Waterway corridors through the proposed development areas to cost effectively contain flood flows within the waterways, to improve waterway health, to allow for more development and to provide environmental and open space corridors
- Stormwater treatment wetlands within the proposed development areas to treat stormwater to remove pollutants, thus meeting planning scheme requirements. The wetlands will also provide valuable habitat, green space and public amenity as well as peak flow attenuation.

This strategy has prepared layout plans and cost estimates for waterways, major culverts and wetlands within the proposed development areas. Internal sizing of drainage pipe assets has not been done, as this will occur at a later date, once the zonings and layout have been finalised and designs are required.

8.3 Waterway Corridors and Flood Management

Under existing conditions there are significant areas of the proposed development areas that are flood prone. These areas are flood prone due to one or a combination of the following reasons:

- Limited capacity of existing waterways (that are typically man-made open rural drains through the proposed development areas)
- Wide flat valleys adjacent to the existing waterways / man-made open drains
- Sheet flow across paddocks
- Flood flows from existing upstream rural catchments.

There is also the potential for urbanisation to increase peak flows and increase the total area of flooding. Urbanisation typically results in the construction of roads and underground drains that are likely to be too deep to be able to drain to the existing waterways / man-made open drains.

A solution to all of the issues described above that is commonly applied in urban development areas is to provide modified / constructed waterways. This requires the excavation of a waterway corridor. An example of a constructed waterway in an urban environment is provided in Figure 8.1 below.

Figure 8.1 Example of modified / constructed waterway (Melbourne Water Constructed Waterways Guidelines)

Melbourne Water has developed guidelines for the design of constructed waterways in urban areas. A typical constructed waterway cross section from these guidelines is provided in Figure 8.2 below.

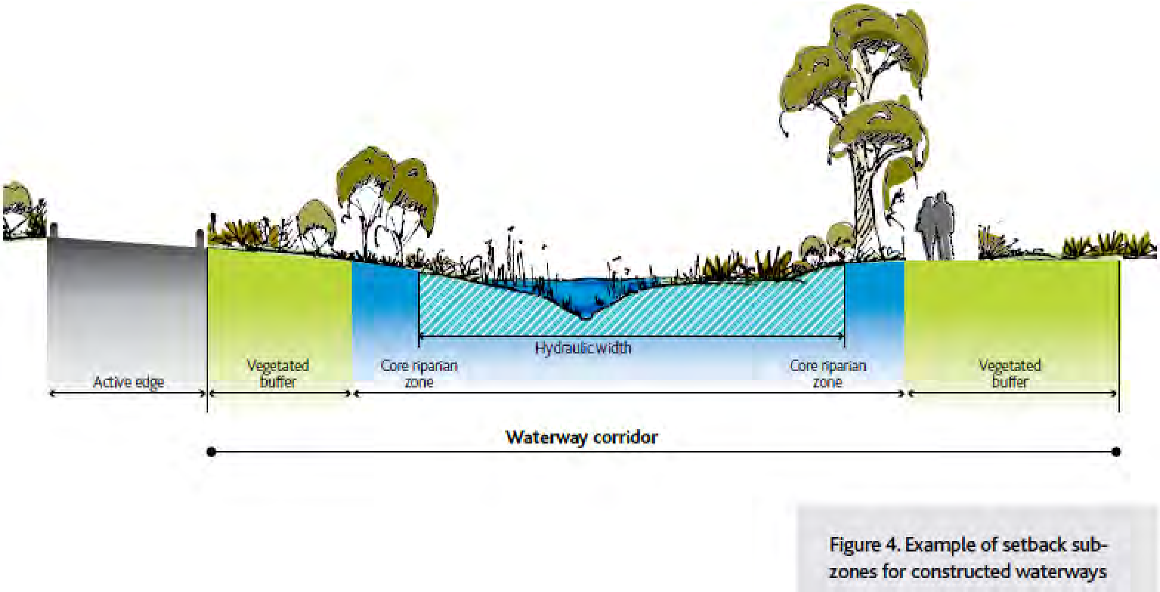

Figure 8.2 Constructed waterway corridor typical cross section

Provision of constructed waterways for the local waterways / man-made open drains for the proposed Colac development areas is expected to have the following benefits.

- The proposed waterways are designed to be excavated to cater for the 100 year ARI peak flow, with freeboard to surrounding land, enabling development and drainage of land
- The waterways will provide environmental values, habitat, riparian zones, open space corridors and visual and public amenity.

Urban development in the proposed growth areas would increase peak flows and flooding due to increased runoff from the extra impervious areas. Works can be undertaken within the development areas to offset the increased flows and mitigate the increase in flood flows. The proposed works include excavation to provide flood storage to offset the increased flows. The excavation to provide flood storage to offset the increased flows from development is proposed:

- Within the waterway corridors to increase flood conveyance and flood storage
- Within the proposed wetland sites. The proposed wetlands have been designed with an average total depth of 1.2 m to allow suitable depth for drainage pipes to discharge into the wetlands. For stormwater treatment the required storage is only 350 mm deep, leaving 300 mm for freeboard and 550 mm for flood storage.

Provision of flood storage and constructed waterways to contain 100 year ARI flows could enable the removal of flooding overlays from the Planning Scheme subject to CCMA approval and completion of planning scheme amendments.

8.4 Stormwater Treatment Objectives

Stormwater treatment is required in all new residential developments in Victoria to meet the requirements of Clause 56.07-4 of the Victorian Planning Provisions. These provisions require stormwater treatment to meet Best Practice targets for the removal of sediment, gross pollutants and nutrients.

To meet the legislated stormwater treatment targets the most common and effective method is to provide stormwater treatment wetlands. Stormwater treatment wetlands have a number of other benefits in addition to stormwater treatment, including:

- Provision of valuable habitat
- Provision of open green space
- Provision of public amenity
- Peak flow attenuation of flows from the proposed development areas.

An example of stormwater treatment wetland with combined retardation storage is shown in Figure 8.3 below.

Figure 8.3 Example of retarding basin (including permanent pond / wetland)

For the proposed Colac development areas wetlands have been proposed with consideration of the following points:

- All proposed urban areas to have their stormwater treated prior to discharge to a waterway
- Runoff from the proposed development areas must overall meet the Clause 56.07-4 pollutant removal targets prior to discharge to Deans Creek / Barongarook Creek
- Wetlands have been located at the lowest point for each catchment, often on flood prone land and / or upstream of a road embankment
- Catchment areas draining to wetlands should typically be in the range of 20 to 50 hectares
- The wetland areas include the approximate total land take for the wetlands, including provision for sediment basins, sediment drying areas, access tracks, batter slopes and the wetland
- The wetlands are proposed to be excavated to provide additional stormwater treatment and flood storage and also to remove the need for embankments and ANCOLD embankment risk assessments.

8.5 Stormwater Harvesting / Integrated Water Management Benefits

Urban development increases the volume of surface water runoff due to increases in impervious surfaces. This increased runoff provides a potential source of water for use in the local area.

The proposed development layout has wetlands to treat stormwater prior to discharge to waterways. The wetlands provide an opportunity for treated stormwater from the wetlands to be harvested. The treated stormwater is well suited for use for open space irrigation, including watering of playing fields, parkland and street trees, with stormwater typically able to supply a large portion of the demand for these uses with high reliability.

Rainwater tanks are another source of water that could be provided in Colac. Typically this could be done by providing private rainwater tanks on each urban property to collect roofwater. The water from the rainwater tanks could be plumbed to make the water available for a range of uses, including toilet flushing, washing clothes and garden watering.

Studies have shown that harvesting stormwater and reusing it in the local catchment can have a number of benefits, including:

- Reducing the adverse impact on waterways of urbanisation by removing some of the increase in flows caused by the increase in impervious areas. Harvesting of the increased flows caused by urbanisation is permitted and it has been found to be very unlikely that stormwater harvesting can reduce flows enough to make them less than the rural flows that occurred before development
- Removing some of the pollutants from water being discharged to receiving waterways

- Reducing the demand for potable water
- Greening of open spaces in the urban environment.

8.6 Recommended Works

8.6.1 Waterways

The proposed modified / constructed waterways through the development areas are shown on the plans in **Appendix H**. The waterway corridors will allow for the construction of modified / constructed waterways. The proposed waterways are proposed in the Deans Creek catchment and Barongarook Creek catchment, with plans provided in **Appendix H** for each of these catchments.

From initial site inspections, aerial images and discussions with Council and CCMA no known significant constraints would prevent the proposed modifications. The existing waterways through the development areas appear to be man-made channels constructed for rural drainage purposes. Our expectation is that there may not be any / many significant flora / fauna or heritage constraints to modifying existing local waterways through the development areas. Further study of flora and fauna and heritage issues is likely to be required before the proposed constructed waterways can be adopted as part of the development strategy some of which is understood to be undertaken as part of the development of the Colac 2050.

The waterway corridors have been designed with the following considerations:

- Modified / constructed waterways are proposed along all existing open watercourses. Where the existing open drain does not follow the lowest valley through the catchment it is proposed that the modified / constructed waterway be located to follow the lowest valley through the catchment. This particularly applies for Deans Creek between Irrewillipe Road / Harris Road and Aireys Street. The proposed waterway corridor location is along the valley, but does not follow the existing waterway. It is expected that further significant work will need to be done in relation to consultation with landowners, environmental assessments of the existing Deans Creek and consideration of options prior to adoption of the final waterway and development layout in this area

- Proposed constructed waterways were given total corridor widths based on Melbourne Water’s constructed waterway guideline using the calculated hydraulic widths (including freeboard). For the proposed constructed waterways the corridor widths have been based on waterway corridors with “active edges” as described in Melbourne Water’s Waterway Corridors guide. This means that waterway corridors are typically provided with roadways along the edges to provide maintenance access, public access and passive surveillance as well as maximising developable area

- The proposed waterways are designed to be excavated to cater for the 100 year ARI peak flow, with freeboard to surrounding land, enabling development and drainage of land

- The waterways will provide environmental values, habitat, riparian zones, open space corridors and visual and public amenity

- Culvert crossings at each location where the constructed waterways cross roads will be required with a 100 year ARI capacity.

8.6.2 Wetlands / Sediment Basins

The proposed wetlands (and sediment ponds) through the development areas are shown on the plans in **Appendix H**. The wetlands and sediment ponds will allow for stormwater treatment from proposed development to be treated to meet the requirements of Clause 56.07 of the planning scheme, in a cost effective manner and without the need for every individual property to set aside potentially inefficient areas for stormwater treatment and on-site detention.

The wetlands have been designed with the following considerations:

- Total wetland areas have been set between 4 and 4.5 % of the catchment area to be serviced by each treatment asset. This is similar to the area required in numerous Structure Plans in southern Victoria and to the areas from modelling for Melbourne Water Development Services Schemes west of Melbourne.

- Wetland areas allow for:

  - Sediment ponds at the inlet area. Sediment pond areas have been set at 5 % of the total wetland land take, with a minimum sediment pond area of 420 m^2 to meet design geometry requirements
  - Sediment drying areas, sized in accordance with Melbourne Water procedures
  - Batter slopes from existing ground level at the perimeter of the site down to Normal Water Level (NWL) of the wetland with allowance for access tracks
  - Wetland areas at Normal Water Level. Normal Water Level of the wetlands has been estimated to be 1.2 metres below natural surface to allow for pipes to drain into the wetlands with suitable cover over the pipes
  - The usual maximum Extended Detention Depth (EDD) of the wetlands for stormwater treatment is expected to be 350 mm
  - Allowing for 300 mm of freeboard from the 100 year ARI Top Water Level (TWL) in the wetland up to the surrounding ground level the typical wetland will have approximately 550 mm depth available for flood retarding (1200 mm total depth, less 350 mm ADD and 300 mm freeboard). This typically allows sufficient flood storage to retard local peak urban flows such that the overall peak flows in the waterways through the development area should not be increased by the development.

- Where the topography doesn't allow for a stormwater treatment wetland sediment basins are proposed to be constructed to protect the local constructed waterway from sediment loads and degradation. It is expected that overall the treatment will need to meet Best Practice targets (to satisfy Clause 56.07) prior to discharge to Deans or Barongarook Creek

- Cost estimates have been prepared for the proposed wetlands / sediment basins using Melbourne Water's DSS cost estimating spreadsheet using rates applicable in the Shire of Melton and City of Wyndham (municipalities considered comparable to Colac).

8.7 Preliminary Costing

The cost of the mitigation works have been estimated using Melbourne Water's standard rates for Developer Services Schemes (drainage schemes). It should be noted that land acquisition costs have not been included in this report.

Table 8.1 and 8.3 summarises the waterway corridor width and estimated construction cost of each reach of proposed constructed / modified waterway.

Tables 8.2 and 8.4 summarise the cross sectional areas and estimated costs of each road culvert along the proposed constructed / modified waterway. Where there is already a substantial width / bridge structure and the waterway is not proposed to be deepened then no additional structure is proposed. The culverts along the waterways have been designed to convey the 100 year ARI flow under the road with a velocity less than or equal to 2 m/s to provide manageable head losses and to minimise the risk of scour of the waterway.

All cost estimates presented in this section of the Strategy allow 40 % on top of the capital costs to account for the following:

- Survey

- Design

- Contingencies.

Table 8.1 Waterways works – Deans Creek catchment

Waterway Reach	Road Description	Waterway corridor width (m)	Estimated Cost (including allowance for survey, design and contingencies)
DCrk1 to DCrk2	Irrewillipe Road - Lawes Street	45	$1,025,000
DCrk2 to DCrk3	Lawes Street - No road	45	$532,000
DCrk3 to DCrk4	No road - Aireys Street	45	$459,000
DCrk4 to DCrk5	Aireys Street - Pound Road	45	$858,000
DCrk5 to DCrk6	Pound Road - No road	45	$1,519,000
DCrk6 to DCrk7	No Road - Railway	45	$833,000
DCrk8 to DCrk9	Harris Road - No road	40	$377,000
DCrk9 to Dcrk10	No road - Irrewillipe Road	40	$265,000
DCrk10 to DCrk11	Irrewillipe Road - Aireys Street	40	$204,000
DCrk11 to DCrk12	Aireys Street - Pound Road	40	$453,000
DCrk12 to DCrk13	Pound Road - Hearn Street	45	$409,000
DCrk13 to DCrk14	Hearn Street - Sinclair Street	45	$217,000
DCrk14 to DCrk15	Sinclair Street - Cants Road	45	$232,000
DCrk15 to DCrk6	Cants Road - No road	45	$670,000
		TOTAL	**$8,053,000**

Table 8.2 Waterway culverts – Deans Creek catchment

Culvert Location	Road Description	Culvert cross section area (m^2)	Estimated Cost (including allowance for survey, design and contingencies)
DCrk1	Irrewillipe Road	Existing structure	zero
DCrk2	Lawes Street	20	$1,089,000
DCrk3	No road	Not required	zero
DCrk4	Aireys Street	20	$1,089,000
DCrk5	Pound Road	20	$1,089,000
DCrk6	No road	Not required	zero
DCrk7	Railway	Existing structure	zero
DCrk8	Harris Road	2.5	$157,000
DCrk9	No road	Not required	zero
DCrk10	Irrewillipe Road	3.5	$185,000
DCrk11	Aireys Street	5	$253,000
DCrk12	Pound Road	5	$253,000
DCrk13	Hearn Street	6.5	$466,000
DCrk14	Sinclair Street	7	$466,000
DCrk15	Cants Road	7	$466,000
		TOTAL	**$5,513,000**

Table 8.3 Waterways works – Barongarook Creek catchment

Waterway Reach	Roads	Waterway corridor width (m)	Estimated Cost (including allowance for survey, design and contingencies)
BCrk1 to BCrk2	No road to Queen Street	45	$735,000
BCrk2 to BCrk3	Queen Street to Aireys Street	45	$532,000
BCrk3 to BCrk4	Aireys Street to Pound Road	45	$863,000
BCrk4 to BCrk5	Pound Road to Hearn Street	45	$722,000
BCrk5 to BCrk6	Hearn Street to No road	45	$238,000
BCrk7 to DCrk8	No road to Pound Road	40	$444,000
BCrk8 to BCrk9	Pound Road to J Barrys Road	45	$485,000
BCrk9 to Bcrk10	J Barrys Road to Barongarook Creek	45	$462,000
		TOTAL	**$4,481,000**

Table 8.4 Waterway culverts – Barongarook Creek catchment

Culvert Location	Road	Culvert cross section area (m^2)	Estimated Cost (including allowance for survey, design and contingencies)
Downstream of BCrk1	No road	Not required	zero
Upstream of BCrk2	No road	Not required	zero
BCrk3	Aireys Street	15	$786,000
BCrk4	Pound Road	15	$786,000
BCrk5	Hearn Street	16	$1,017,000
BCrk7	No road	Not required	zero
BCrk9	J Barrys Road	6	$466,000
		TOTAL	**$3,055,000**

Table 8.5 below summarises the total land area and estimated construction costs for the wetlands proposed in the Deans Creek catchment.

Table 8.5 Proposed wetlands Deans Creek catchment

Wetland number	Wetland site area (ha)	Estimated Cost (including allowance for survey, design and contingencies)
WL1	2.9	$3,110,000
WL2	1.3	$1,227,000
WL5	2.4	$2,515,000
WL6	1.7	$1,766,000
WL7	1.7	$1,679,000
WL8	1.8	$1,862,000
WL19	0.8	$743,000
WL20	1.4	$1,353,000
WL21	2.3	$2,396,000
WL22	1.6	$1,572,000
WL23	0.9	$869,000
WL24	1.8	$1,894,000
WL25	1.8	$1,868,000
WL26	1.6	$1,618,000
WL27	1.3	$1,334,000
WL28	2.1	$2,199,000
WL29	1.4	$1,353,000
	TOTAL	**$29,358,000**

There are a couple of sub-catchments in the Barongarook catchment where due to small catchment size and steep terrain it is not feasible to provide a stormwater treatment wetland. For these sub-catchments a sediment basin is proposed to protect the local receiving waterway from sediment loads. It is expected that the overall combination of sediment basins and wetlands in the Barongarook Creek catchment will be able to achieve Best Practice treatment targets prior to discharge to Barongarook Creek and Lake Colac.

Table 8.6 below summarises the total land area and estimated construction costs for the wetlands and sediment ponds proposed in the Barongarook Creek catchment.

Table 8.6 Proposed wetlands / sediment basins Barongarook Creek catchment

Wetland number	Wetland/ Sediment Basin site area (ha)	Estimated Cost (including allowance for survey, design and contingencies)
WL3	1.8	$1,865,000
WL4	2.1	$2,135,000
WL9	2.3	$2,435,000
WL10	2.4	$2,548,000
WL11	2.0	$2,067,000
WL12	1.1	$1,110,000
WL13	1.4	$1,417,000
SB14	0.4	$499,000
WL15	1.8	$1,842,000
WL16	0.5	$399,000
WL17	0.8	$752,000
WL18	0.9	$832,000
SB30	0.4	$548,000
	TOTAL	**$18,449,000**

To put the waterway and wetland costs into context the following has been considered:

- The total area of development that will be serviced by the waterways and wetlands
- The cost per hectare to the development of the proposed waterways and wetlands
- How the costs for Colac compare with the costs per hectare for Melbourne Water Development Services Schemes.

The total proposed urban areas of development that will be serviced by the waterways and wetlands are:

- Deans Creek catchment **625.3 ha**
- Barongarook catchment **414.0 ha**
- **TOTAL** **1039.3 ha**

In considering these numbers presented above it is important to note the following numbers to put them into context:

- <u>Total land within future development areas</u>: approximately 1234.6 hectares
- <u>Total land within future development areas covered by an existing flood overlay</u>: approximately 392 hectares (297 hectares of this amount, or 76 %, will become developable as a result of the proposed works)
- <u>Proposed wetlands and waterways contribute to the following land take</u>:
  - Wetlands 80.3 hectares
  - Waterway corridors 45.1 hectares
  - **TOTAL** 125.4 hectares (of which 60 % is located within existing flood prone areas designated by existing flood overlays).
- <u>The amount of land currently covered by an existing LSIO or FO that will remain unchanged</u>: approximately 59.7 hectares. It is not possible to contain all flooding in the development regions within constructed waterways and wetlands. As discussed with Council officers there are some low lying areas along Deans Creek that are currently flood prone that cannot be made flood free in a 100 year ARI event due to topographical and other physical constraints, such as the location of the railway line and highway, downstream flood levels and the expected need to retain existing environmental values in this location.

The total cost of proposed waterways, culverts and wetlands (including sediment basins and retarding effects of wetlands) are:

- Deans Creek catchment **$ 42.9 million**
- Barongarook catchment **$ 26.0 million**.

Therefore the cost in $ / ha for waterways, culverts and wetlands (including sediment basins and retarding effects of wetlands) are:

- Deans Creek catchment **$ 68,600 / ha**
- Barongarook catchment **$ 62,800 / ha**.

To put these costs into context comparisons have been made with:

- Melbourne Water Development Services Scheme (DSS) costs / contributions
- Armstrong Creek East Development Contribution Plan (DCP) costs / contributions
- Ballarat West DCP costs / contributions.

Typical Melbourne Water Development Services Schemes (DSS) in western Melbourne have contribution rates of $85,000 to $150,000 per hectare (the sample selected for comparison had an average rate of **$115,000** per hectare for normal density residential development). Melbourne Water applies factors to various zonings to adjust the contribution rate depending on impervious area. Low density residential areas pay a lower rate per hectare and industrial areas pay a higher rate. Melbourne Water DSS provide for the construction of waterways, wetlands (including retarding) and sediment basins. Melbourne Water DSS also allow for outfall pipes from each property within the DSS and land acquisition for the wetlands, which haven't been included in the above costing for Colac.

The Armstrong Creek East development area is located in the City of Greater Geelong (CoGG). The CoGG has adopted a DCP for the Armstrong Creek East development area that has been approved by the Minister and raises funds for various infrastructure needs to service the development. One of the categories of infrastructure funded by the Armstrong Creek East DCP is for drainage. The current contribution rate for drainage for the Armstrong Creek East DCP is **$70,139.28** per hectare (source http://planning-schemes.delwp.vic.gov.au/schemes/greatergeelong/ordinance/45_06s03_ggee.pdf).

The Ballarat West development area is located in the City of Ballarat. The City of Ballarat has adopted a DCP for the Ballarat West development area that has been approved by the Minister and raises funds for various infrastructure needs to service the development. One of the categories of infrastructure funded by the Ballarat West DCP is for drainage construction, including wetlands, retarding basins, constructed waterways and some drainage pipelines. The current contribution rate for drainage construction for the Ballarat West DCP is **$88,546.11** per hectare (source http://www.ballarat.vic.gov.au/pbs/city-strategy/ballarat-west/ballarat-west-development-contributions-plan.aspx).

The development investigations layout plan highlights that a range of residential zones are proposed for the growth areas of Colac. As a result a range of costs per lot are presented in Table 8.7 for varying development densities.

Table 8.7 Costs per lot for varying development densities

Catchment	5 lots / hectare	10 lots / hectare	15 lots / hectare
Deans Creek	$13,720 / lot	$6,860 / lot	$4,570 / lot
Barongarook Creek	$12,560 / lot	$6,280 / lot	$4,190 / lot

It should be noted that the final costs per lot would be lower than those presented in Table 8.7 where the development density is less than 15 lots/hectare. This would be due to the lower density of development resulting in a reduced impervious area, lower runoff and therefore a lower cost of works. For example Melbourne Water schemes are based on a standard residential rate, with adjustment factors used to calculate contribution rates for other types of development. For example in a Melbourne Water scheme a low density residential area (2,000 to 4,000 m^2 lots) would be charged 0.7 times the residential rate per hectare, whereas an industrial area would be charged 1.3 times the residential rate.

The following factors should be considered by Council with respect to the proposed scheme of waterways, culverts and wetlands:

- the amount of developable area made available by the proposed waterways and wetlands
- that the proposed waterways provide 100 year ARI flood protection to areas of proposed development
- that the stormwater treatment will meet the planning scheme requirements to treat runoff to meet Best Practice targets for pollutant removal
- the cost of the proposed works (as compared to similar schemes in Melton, Wyndham, Ballarat and Armstrong Creek (south of Geelong)
- the synergies between the proposed scheme of drainage, wetlands and waterways and the Colac 2050 plan.

8.7.1 Staging of Works

To provide infrastructure to service urban development requires the funding and timing of works to be co-ordinated with the timing of the development. This co-ordination is “business as usual” when works are funded by a Melbourne Water DSS or a Council run DCP.

In each of these types of schemes the scheme includes a map, listing and estimated costs for the infrastructure that is to be funded by the scheme. When landowners wish to develop then the infrastructure necessary to service the development is identified, including the works that are part of the approved scheme. The contribution due to be paid by the development is also determined. There is then the need to decide on how to best arrange for the design, construction and payment for the works. Often the works would be arranged by the developer and an agreement would be made between Council and the developer in relation to:

- Contribution towards the scheme to be paid by the developer to Council
- The amount that the scheme will reimburse the developer for the works that they have designed and built.

There is an aspect of offsetting contributions against the value of the works with either a net contribution or net reimbursement being paid for each stage of development. Where the works to service a development are wholly contained within the development site then the developer is usually best placed to undertake the works. Where the drainage of the site also requires works outside of the development site then the design and construction of the works should be discussed with Council to facilitate the construction of works.

Details about how this system of implementation and staging operates are provided in the Ballarat West DCP. See Sections 4 and 5 of the Ballarat West Development Contribution Plan, Version 4.2, July 2014 for more details. The Ballarat West document is incorporated into the planning scheme (from amendment C167).

8.7.2 Further Work / Input

To be able to implement the proposed development we expect that it will be necessary for:

- Council to consider the potential development and layout for waterways, wetlands and drainage for the proposed development areas
- Consultation to take place with all affected landowners
- Environmental studies be undertaken to inform the proposed waterway, wetlands and drainage layout
- Adjustments be made to the scheme as informed by the consultation and environmental studies
- Council to consider the method for funding / constructing the infrastructure required
- Council to consider the mechanism for ensuring that the land required for waterways and wetlands is provided
- Council to prepare the required Planning Scheme amendments for the rezoning and the provision of infrastructure.

This process has been followed by other Councils in Victoria to facilitate planned development to address flooding, drainage and water quality requirements.

8.8 Flood Modelling of Proposed Flood Conveyance Assets

Flood modelling of the proposed flood conveyance works (without allowance for wetlands / retarding basins) has been assessed in the hydraulic model. This was undertaken to assess the effectiveness of the proposed waterway corridors. Flood inundation maps generate from the results of this assessment are presented in **Appendix I.** The results highlight that the works are able to meet their objectives in providing sufficient flood conveyance and reducing the extent of overland flooding for the peak 100 year ARI event.

It is important to note the modelling undertaken to assess the effectiveness of the waterway corridors did not allow for any topographical changes external to the waterway corridors. No allowance was also made for the upgrade of existing drainage assets external to the waterway corridors. It is likely that future development of areas adjacent to the proposed waterway corridors will include some degree of earthworks to suit the development needs. As such it is believed that the residual ponding of flows in low lying areas represented on the maps contained in **Appendix I** will be improved as part of future development sites, via earthworks and internal drainage works. Therefore it is expected that the flooding represented on the maps will be improved upon. As development is proposed in the study area it is possible to test any proposed works within the hydraulic model to assess their impact.

9. FUNDING OPTIONS AND REVENUE SOURCES

There are various funding options and sources for projects related to stormwater drainage, flooding and stormwater quality. These options include:

- Special Charge Schemes under the Local Government Act 1989, implemented by Council. Special Charge Schemes raise funds from benefitting landowners
- Development Contributions Plans (DCPs) can be used by Councils to levy a charge on development to be used to provide infrastructure to service the development. DCPs can be implemented in accordance with provisions in the Planning and Environment Act. DCPs require a detailed scheme and cost apportionment and approval by the Planning Minister. DCPs are typically used where new development creates the need for infrastructure, rather than infrastructure being needed to service an existing developed area. Therefore DCPs are less used than Special Charge Schemes as a means to raise funds from benefitting landowners for drainage upgrades in existing urban areas, but are well suited for providing infrastructure in substantial development areas, as shown by their use in areas such as Armstrong Creek and Ballarat West
- Council can use General Revenue to fund capital works through Council's Capital Works Program. This method of funding is typically used by Councils for projects that have wide benefits across significant areas of the municipality such as libraries or civic centres. Funding of local road and drainage construction works is not usually funded from General Revenue for equity and “user pays” reasons
- Funding via Regional Development Victoria (RDV). RDV aims to assist the growth of rural Victoria by providing grants for infrastructure projects that have the potential to stimulate economic activity in rural towns and their surrounding areas. There is potential for some works identified in this strategy to be funded by RDV. Council would need to prepare an application for funding to RDV to obtain any funds
- The Victorian Government can provide grants to local Government for flooding related works where the works contribute to meeting the objectives of the Government’s Floodplain Management Strategy. Where areas in Victoria are subject to flooding the State Government would typically contribute up to 50 % of the capital cost of flood mitigation initiatives, including studies and capital works. The Victorian Government, through the Department of Environment, Land, Water and Planning (DELWP) has produced a Floodplain Management Strategy in 2016. The strategy includes examples where flood mitigation works in towns have been funded 50 % by the Victorian Government and 50 % by the Commonwealth Government (NDRGS funding, see below), with the local Council agreeing to take over maintenance responsibility for the work. Further details of the Floodplain Management Strategy can be found online at: https://www.water.vic.gov.au/__data/assets/pdf_file/0017/53711/Victorian-Floodplain-Management-Strategy-Introduction-Section-1.pdf
- The Commonwealth Government provides grants for projects that respond to flooding risks. The funding is provided through the Natural Disaster Resilience Grants Scheme

(NDRGS). Funding can be sought by applying to the Commonwealth Government. Funding is provided for projects that study flooding (including flood mapping), improve community flood resilience or provide capital works for flood mitigation. Funding is typically provide for amounts in the range of $10,000 to $250,000 and requires matching local funding. Further information is provided online at: http://www.emv.vic.gov.au/our-work/current-projects/natural-disaster-resiliencegrants-scheme.

Engeny recommends that Council consider the possible funding arrangements listed above for the drainage works proposed in Colac.

10. ACTION PLAN

The tasks completed as part of the development of the CSDS have identified a number of short terms actions that are recommended for further consideration by Council. These actions once considered further are expected to lead to longer term actions which would involve the implementation of those actions.

10.1 Short Term Actions

A number of actions have been identified that could be implemented in the short term, within say a 5 year timeframe. Some of these action items have little associated cost and could begin immediately. These works have been prioritised and are outlined in Table 10.1 below. The benefit and cost rating system used to determine the priority of actions is summarised as follows and has been used subjectively to compare the inherent benefits and costs of all actions identified:

- Benefits
  - Low (L) – Unlikely to result in immediate noticeable benefits, may lead to longer term benefits
  - Medium (M) – May lead to small immediate benefits with greater influence likely in longer term
  - High (H) – Ability to result in immediate, noticeable, benefits that continue to be noted over the longer term.
- Costs
  - Low (L) – Low cost to responsible stakeholder / authority
  - Medium (M) – Medium cost to responsible stakeholder / authority
  - High (H) – Higher Little cost to responsible stakeholder / authority.

Final prioritisation and adoption of any of these actions would be subject to consideration by Council and other stakeholders / authorities in consultation with the community.

Table 10.1 Summary of short term actions in priority order

Priority	Action	Comments	Benefit	Cost	Responsibility
1	Consider implementing flooding overlays in existing development areas	Council to consider a planning scheme amendment to include a Special Building Overlay (SBO) to control development in existing flood prone development areas.	H	L	Council
2	Consider implications of climate change assessment	Results of climate change assessment to be assessed and considered as part of Council's climate change adaptation planning.	H	L	Council
3	Consider Development Plan for waterways, drainage and stormwater treatment in proposed development areas	Undertake necessary work / consultation to confirm if the drainage works presented in this Strategy are viable for Colac. Council to consider adoption of a DCP for future development areas.	H	M	Council
4	Consider implementation of flood warning system	Flood warning system has the ability to assist the community in planning for and responding to predicted storm events that could result in flooding across Colac and surrounds	H	M	CCMA / DELWP
5	Consider flood mitigation options	Consider the concept level flood mitigation options presented in this Strategy to address flooding 'hot spots' in existing urban areas. Further work to progress the design would include but not limed to survey and underground asset proving. Targeted floor level survey could also be undertaken (See Action 5) to inform an AAD assessment.	H	M	Council
6	Use flood modelling results to assist programming of maintenance activities	All drainage asset owners within study area to assess the flood modelling results presented in this Strategy to help create proactive maintenance regimes.	M	L	All drainage asset owners (Council, VicRoads, VicTrack)

Priority	Action	Comments	Benefit	Cost	Responsibility
7	Survey / condition audit of existing drainage assets	Survey / condition audit of existing assets will assist in asset renewal planning. This data can also be used to update the hydraulic model in the future. The flood modelling results also have the ability to assist in managing drainage assets. An understanding of drainage capacity can assist asset renewal planning and for incorporation into forward estimates.	H	H	Council
8	Floor level survey	Undertake floor level survey of properties shown to impacted by the 100 year ARI event by the flood modelling	M	H	Council

10.2 Long Term Actions

A number of those actions presented in Table 10.1 are expected to result in agreement upon longer term actions between stakeholders. For instance Actions 1-5 in Table 10.1 are short term actions for Council and other stakeholders to firstly consider the merits of progressing those actions further. The implementation of those actions is expected to occur over a longer period of time, especially the implementation of any flood mitigation works given their respective costs and the work required to arrive at designs ready for construction.

As such the longer term actions are expected to be defined upon further consideration of the short term actions.

11. CONCLUSIONS AND RECOMMENDATIONS

The Colac Stormwater Development Strategy (CSDS) is a vital input to Colac 2050, a long range planning project that will cater for growth in Colac's population over the next 33 years. Colac 2050 will establish a plan for the expansion of Colac's residential housing footprint, business and industry sectors.

This strategy, through detailed hydraulic modelling of Council's drainage network has identified opportunities to address areas of poor drainage performance within Colac and its surrounds and to identify the surface water requirements to enable future urban growth. Climate change considerations have also been assessed, the findings of which will assist Council as part of their climate change adaptation planning.

A key input to the development of the Strategy has been the engagement of the local Colac community. The purpose of this engagement has been to gather local knowledge to influence and ensure the flood modelling is representative of what happens during flood events and to gain community support for the Strategy itself.

The flood modelling results highlight that a significant number of existing properties across Colac and surrounds are at risk of overland flooding as a result of a lack of capacity in the underground drainage network for the major (100 year ARI) storm event. It is important to note that over time there have been a number of changes to drainage design standards, the most significant being the adoption of the "major / minor" drainage system. The "major / minor" drainage system concept was first specified in Australian Rainfall and Runoff in 1987. A large portion of Council's drainage system in Colac and surrounds was designed and constructed prior to 1987 and therefore does not meet current drainage standards which is common for Councils across Victoria. There is no obligation on Council to upgrade existing infrastructure when standards alter over time. This view was confirmed by the Victorian Auditor General in the VAGO 2005 report into managing urban flood risks within Melbourne.

Section 7 of this report summarises an assessment of structural mitigation options to potentially address flooding at five of the most significant flooding 'hot spots' across Colac and surrounds. The capital costs and benefits of those works have been calculated and prioritised, the benefits determined by calculating the number of properties likely to benefit from the proposed works. The structural mitigation assessment also included an assessment of the works required to address the impacts of climate change predictions. Key findings from this assessment which will help inform Council's climate change adaptation planning include:

- The prioritisation of mitigation works across various locations is different when compared to the prioritisation of mitigation works for existing conditions
- The incremental increase in infrastructure sizing that is needed to address the impact of climate change across the five locations investigated as part this assessment equates to on average a 5.62 % increase in capital cost. The increase in cost varied between 0.5 and 8.9 % across the five locations.

Section 9 details the recommended stormwater drainage and treatment works to enable the appropriate development of the future development areas. These works have been costed and compared to a number of similar DCPs. The objectives of the works recommended in the future development areas include:

- Flood reduction and waterway corridor objectives to maximise development potential
- Stormwater treatment objectives to treat runoff from new development areas
- Peak flow control objectives to ensure new development areas do not increase downstream flooding.

Flood modelling of the proposed flood conveyance works (without allowance for wetlands / retarding basins) was assessed in the hydraulic model. The results highlight that the works are able to meet their objectives in providing sufficient flood conveyance and reducing the extent of overland flooding for the peak 100 year ARI event.

Section 10 outlines a prioritised action plan for consideration and implementation of various actions to improve flood management across existing and future development areas. The highest priority of this Strategy is for Council to consider implementing flooding overlays within existing development areas across Colac and surrounds. Special Building Overlays (SBOs) are appropriate for identifying overland flow paths for 100 year ARI storms. Use of SBOs is recommended to manage future development and to reduce the flood risk for new buildings. The use of SBOs do not have any capital cost and will result in an effective measure across the catchment given it could take many decades to construct structural works to address flooding across the study area. For many areas across Colac and surrounds it is also not possible to construct mitigation works to address flooding for the major (100 year ARI) storm event highlighting the need for an alternative measure, such as an overlay, to control future development in those areas.

It is recommended that Council consider the findings of the Strategy and determine if the action plan is appropriate and realistic.

12. REFERENCES

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13. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

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   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

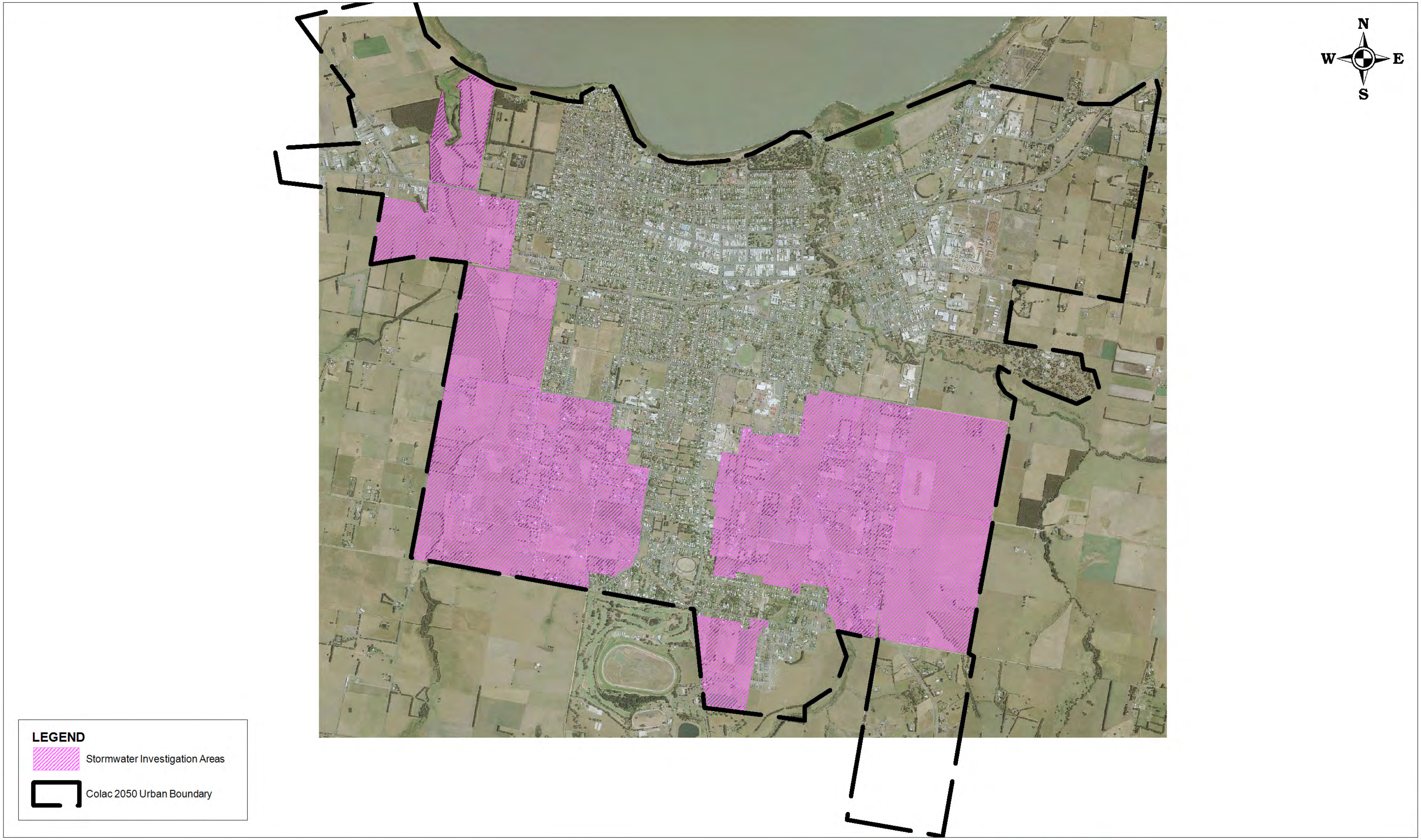
d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

APPENDIX A

Development Investigation Areas Layout Plan



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

0 600 1200

Scale in metres (1:30,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Colac Stormwater Development Strategy

Extent of Investigation Areas

Job Number: V2013_001
Revision: 0
Drawn: SD
Checked: AP
Date: 22 April 2018

APPENDIX B

Site Visit Photos

Photo 1 – Stormwater outlet to Lake Colac (near intersection of Queens Ave and Armstrong Street)

Photo 2 – Drainage outlet structure (near intersection of Queens Ave and Armstrong Street)

Photo 3 – Low flow diversion to GPT within drainage outlet structure (near intersection of Queens Ave and Armstrong Street)

Photo 4 – Educational signage within Barongarook Creek Reserve

Photo 5 – Barongarook Creek Reserve

Photo 6 – Barongarook Creek post September 2016 flood event

Photo 7 – Stormwater pit lid indicating Lake Colac as outlet to drainage network

Photo 8 – Drainage inlet structure near intersection of Harris Rd and Scanlan Drive

Photo 9 – Drainage swale alongside Ballagh Street

Photo 10- Flow path from Ballagh Street through to Irrewillipe Road retarding basin

Photo 11 – Outlet from Irrewillipe Road retarding basin

Photo 12 – Outlet structure within Irrewillipe Road retarding basin

Photo 13 – Drainage outlet from Irrewillipe Road retarding basin

Photo 14 – Drainage culvert at intersection of Irrewillipe Road and Armstrong Street

Photo 15 – Lake near intersection of Main Street and Tulloh Street

Photo 16 – Drainage inlet to lake near intersection of Main Street and Tulloh Street

Photo 17 – Overflow path from lake near intersection of Main Street and Tulloh Street

Photo 18 – Drainage outlet at the northern end of Dowling Street

Photo 19 – Drainage along western side of Dowling Street

Photo 20 –Basin near intersection of Tulloh Street and Dowling Street

Photo 21 – Drainage outlet from lake near intersection of Tulloh Street and Dowling Street

Photo 22 – Drainage outlet from Calco Timbers to Colac-Forrest Road

Photo 23 – Looking westwards along Colac-Forrest Road from Calco Timbers drainage outlet

Photo 24 – Deans Creek at Pound Road

Photo 25 – Deans Creek at Princes Highway

Photo 26 – Railway culvert located near Armstrong Street / Railway Street intersection

Photo 27 – Typical roadside channel in Sinclair Street South

APPENDIX C

Community Consultation Questionnaire and Maps

Colac Stormwater Development Strategy FAQs

Q: How were the maps developed?

A: The flood maps have been developed from flood modelling outputs. The flood model developed for the study area utilised previous flood models developed for DELWP as part of the Deans Creek and Barongarook Creek Regional Flood Mapping Project in 2016 which was delivered in partnership with the Corangamite Catchment Management Authority (CCMA). The existing DELWP 2016 flood models for the two major creeks were used as a starting point and the remaining areas of the study area were input to the model including the following:

- Aerial survey (LiDAR) data captured at the beginning of 2016 to define the topography
- Council drainage asset data (including pipe sizes), with confirmation of numerous assets undertaken via site visits during the project.
- Existing land use information confirmed during site visits and latest aerial photography

Q: What are you going to do with this data?

A: The data will be used to identify localised problem areas and therefore assist in identifying possible improvements to the drainage network

Q: Will this affect my land values?

A: There is no evidence to suggest land values would be impacted. Property values are determined by a multitude of factors and are subject to a wide variety of influences. These include:

- Economic considerations (i.e. interest rates, employment levels, income growth, finance availability, consumer confidence, supply and demand);
- Population and demographic trends;
- Suburb, location and street desirability; and
- Dwelling characteristics and features (lot size, style/age of property, internal space, renovation potential, quality of finishes.

In strong housing markets these factors are all considered to be stronger determinants of price than flood notification, which tends to be obscured against these considerations.

Q: Will this affect my insurance premiums?

A: The flood levy incorporated in insurance premiums is based on ‘Land Subject to Inundation overlay’. Your premium will only be affected if there is a change to the existing overlay.

Q: Will this result in an overlay over my property?

A: A Land Subject to Inundation (LSIO) overlay already applies in flood prone areas of Colac and Elliminyt associated with flooding from Deans Creek and Barongarook Creek. Corangamite Catchment Management Authority (CCMA) is currently proposing changes to the LSIO in response to the findings of the 2016 Regional Flood Mapping project. Some properties may be removed and some may be added, this is to be finalised later in 2017. In the future it is possible that the flood modelling undertaken as part of the current study could be used to develop overlays for other areas across Colac, this is to be considered further upon completion of this study.

Q: Will this restrict what I can do with my property?

A: If an overlay is placed on your property in the future it may have an impact on what you can do on your property. Flooding behaviour (including depth) within you property as calculated by the modelling will govern the extent to which future development of your property can be undertaken.

Q: Does this mean Council is going to upgrade its drainage network? What happens if you don’t?

A: Localised problem areas will be identified to assist in identifying possible improvement measures to the drainage network. Each measure will be assessed on its merits including the consideration of its costs and its relative benefits.

Q: How does climate change fit into this modelling?

A: Currently the modelling is based on existing rainfall data from the Bureau of Meteorology. Modelling of a climate change scenario is being considered currently by Council.

Q: I don’t think those maps are right – how can I ensure they’re changed?

A: Council will be pleased to hear potential changes. You can e-mail John Furleo from Council (john.furleo@colacotway.vic.gov.au) or Council’s flood modelling consultant Scott Dunn (scott.dunn@engeny.com.au)


DEANS CREEK
BARONGAROOK CREEK

DEANS CREEK
MURRAY STREET
BROMFIELD STREET
WILSON STREET
COLAC-FORREST ROAD
BARONGAROOK CREEK

APPENDIX D

Flood Inundation Maps for Existing Conditions

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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Colac Stormwater Development Strategy

5 Year ARI Flood Extent
Catchment Wide

Job Number: V2013_001
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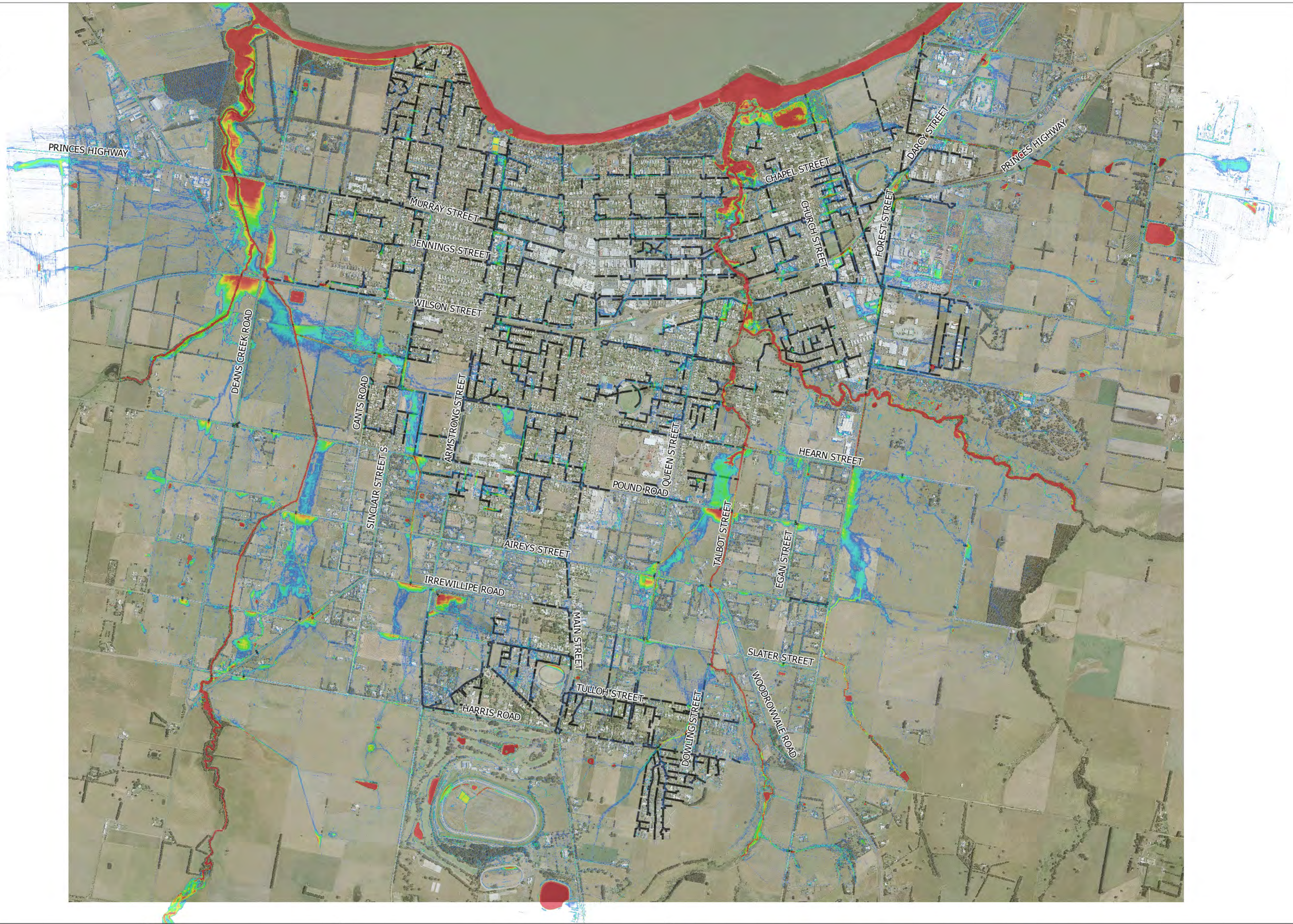
Checked: AP
Date: 5/1/2017

Legend

10 year ARI Max Depth

- 0.05-0.10m
- 0.10-0.20m
- 0.20-0.30m
- 0.30-0.40m
- 0.40-0.50m
- >0.50m
- Pipes



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Colac Stormwater Development Strategy

10 Year ARI Flood Extent Catchment Wide

Job Number: V2013_001
Revision: 0
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E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Colac Stormwater Development Strategy

100 Year ARI Flood Extent Catchment Wide

Job Number: V2013_001
Revision: 0
Drawn: SD
Checked: AP
Date: 5/1/2017

APPENDIX E

Flood Inundation Maps for Climate Change Conditions

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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

5 Year ARI Flood Extent
Catchment Wide
Climate Change Scenario
with no development

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 11/4/2018

Legend

Difference (m)

- <-0.03
- -0.03 to -0.01
- 0.01 to 0.03
- 0.03 to 0.05
- >0.05

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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

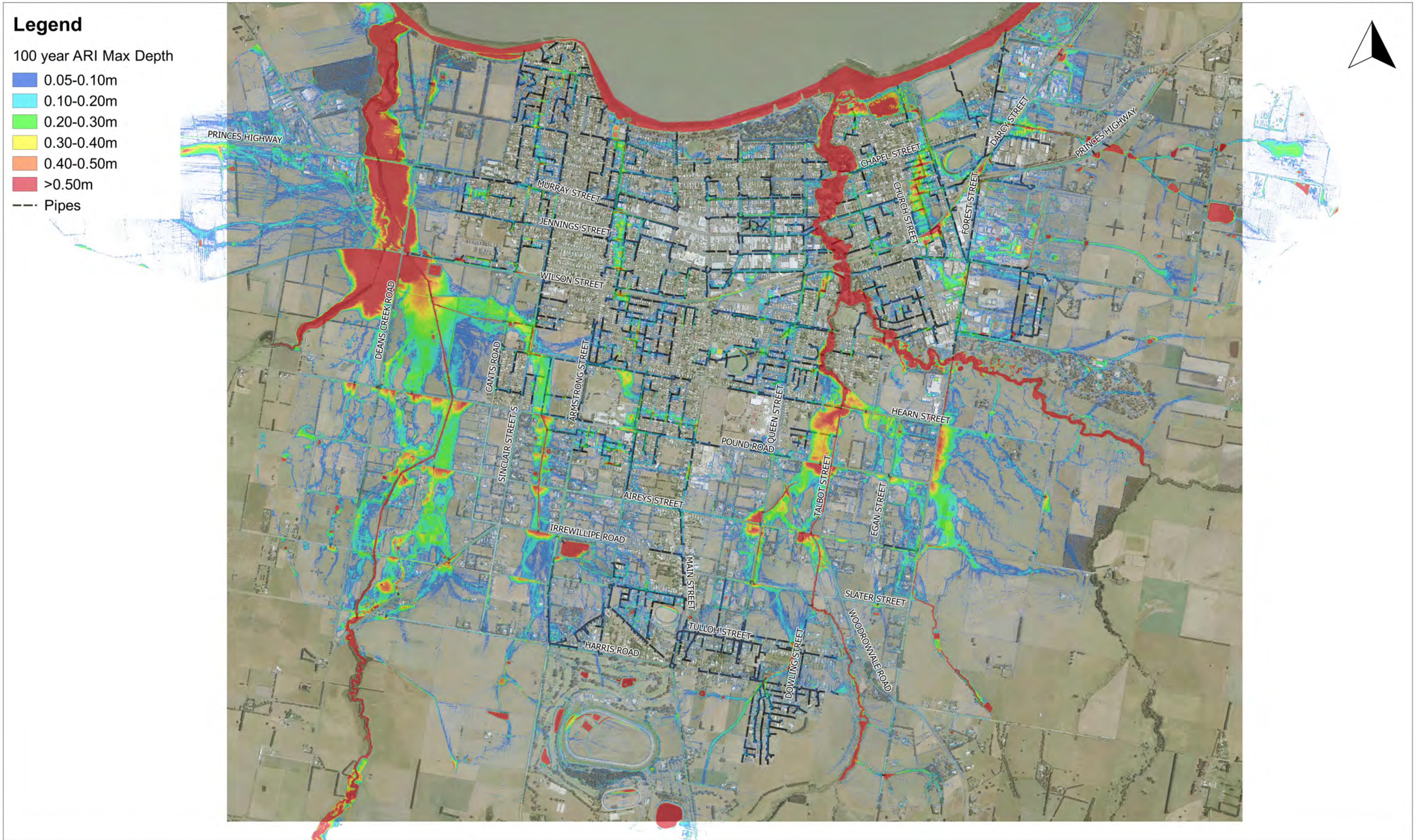
At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

5 Year ARI Flood Depth Difference Plot
Catchment Wide
Climate Change Scenario
(with no development)

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 22/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

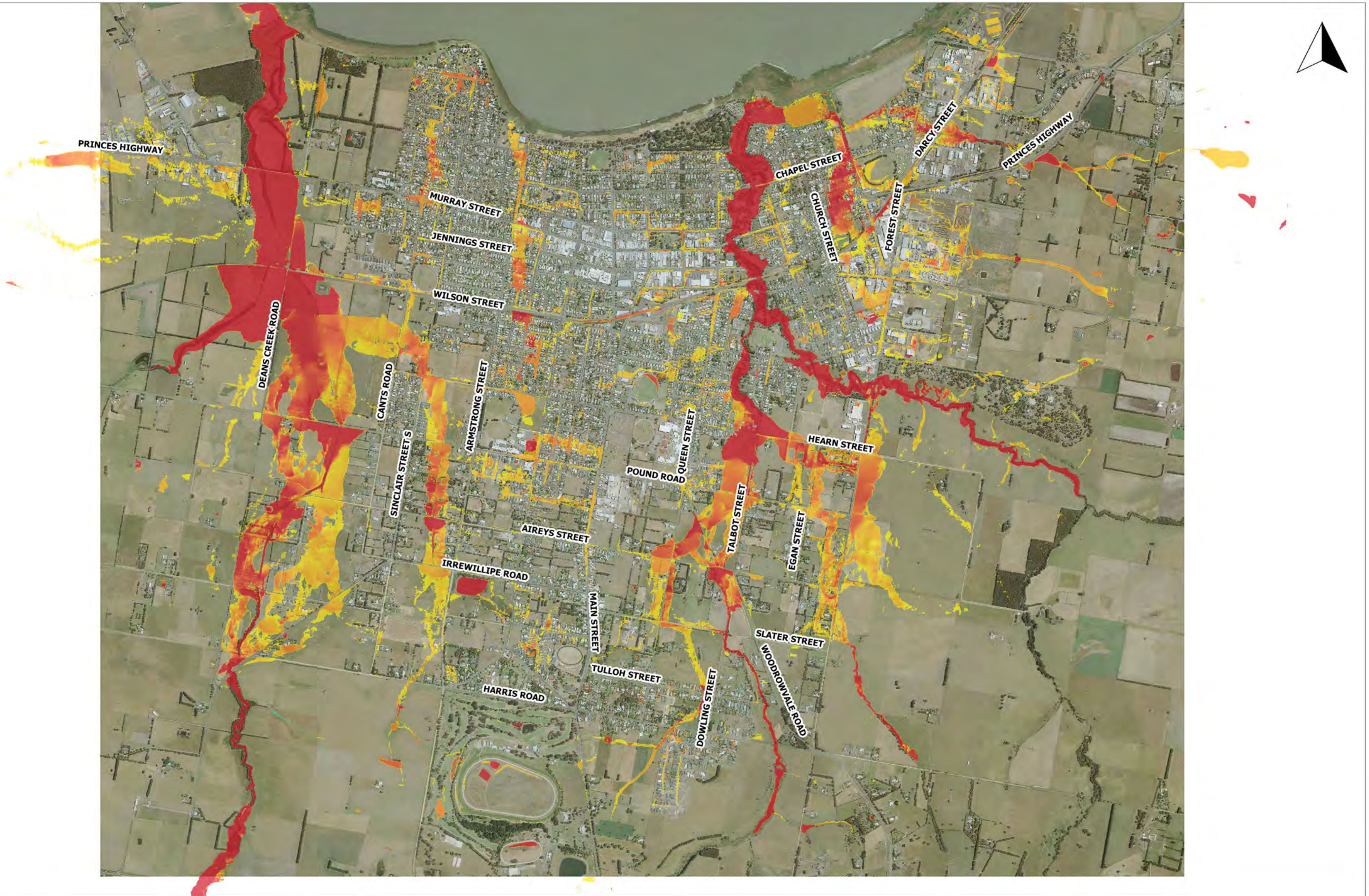
100 Year ARI Flood Extent
Catchment Wide
Climate Change Scenario
with no development

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 11/4/2018

Legend

Difference (m)

- <-0.03
- -0.03 to -0.01
- 0.01 to 0.03
- 0.03 to 0.05
- >0.05



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

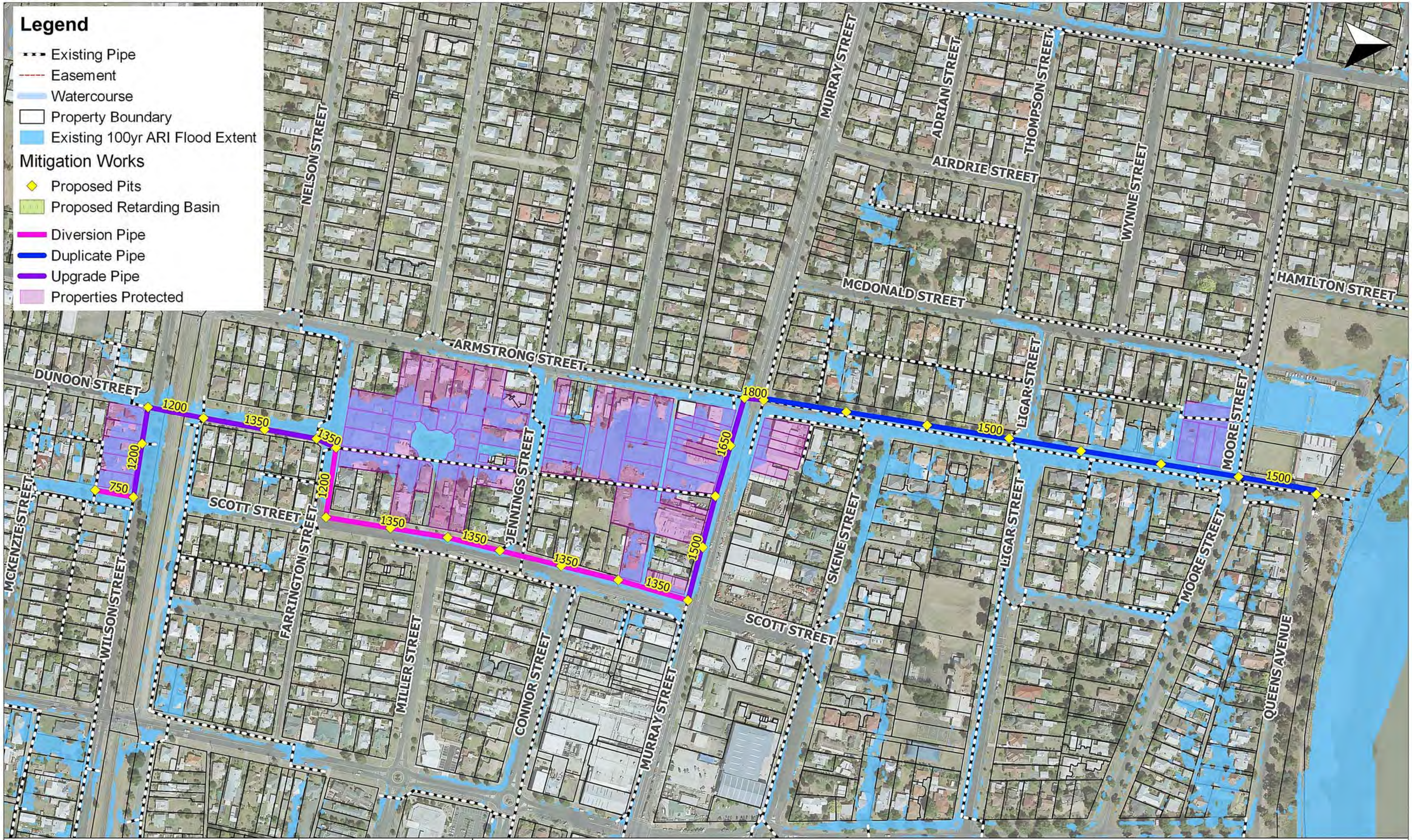
Colac Stormwater Development Strategy

100 Year ARI Flood Depth Difference Plot
Catchment Wide
Climate Change Scenario
(with no development)

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 22/9/2017

APPENDIX F

Possible Flood Mitigation Works for Existing Urban Area (Existing Conditions) Possible



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ENGENY WATER MANAGEMENT

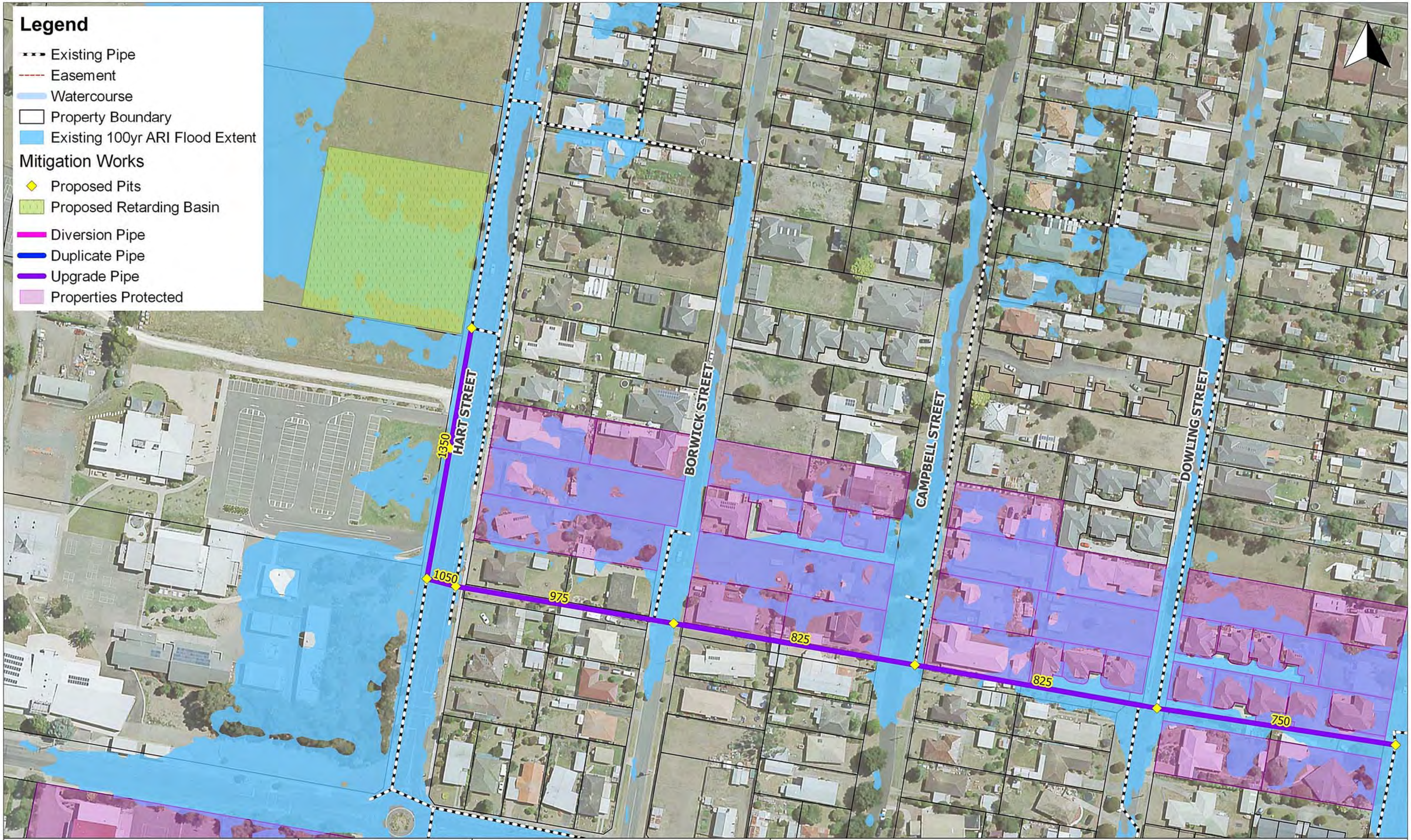
Colac Otway SHIRE

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Existing Conditions
Mitigation Location 1
Wilson Street

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

10 0 10 20 30 40 m

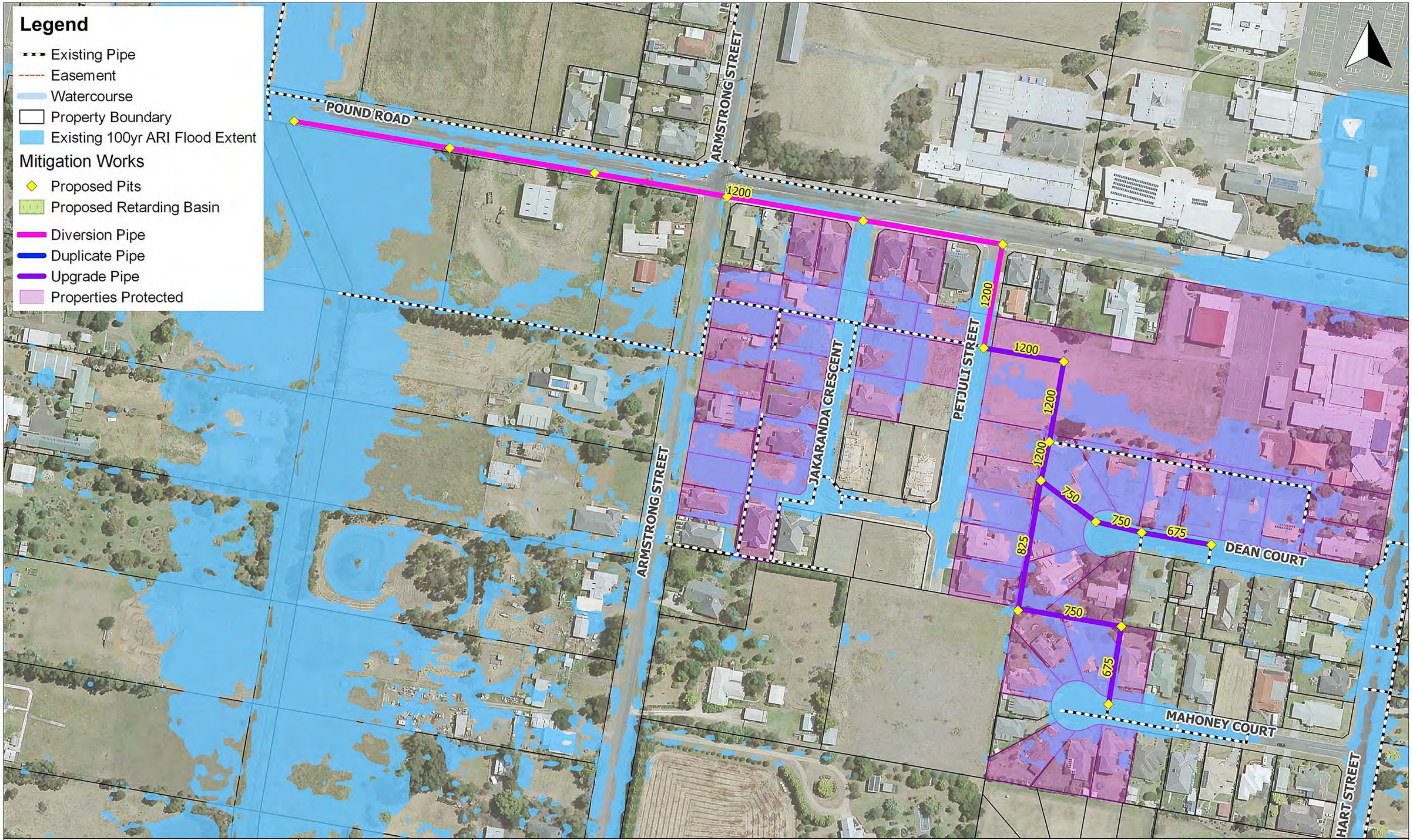
At A3 1:1,500

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Existing Conditions
Mitigation Location 2
Gravesend Street

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

19 0 19 38 57 76 m

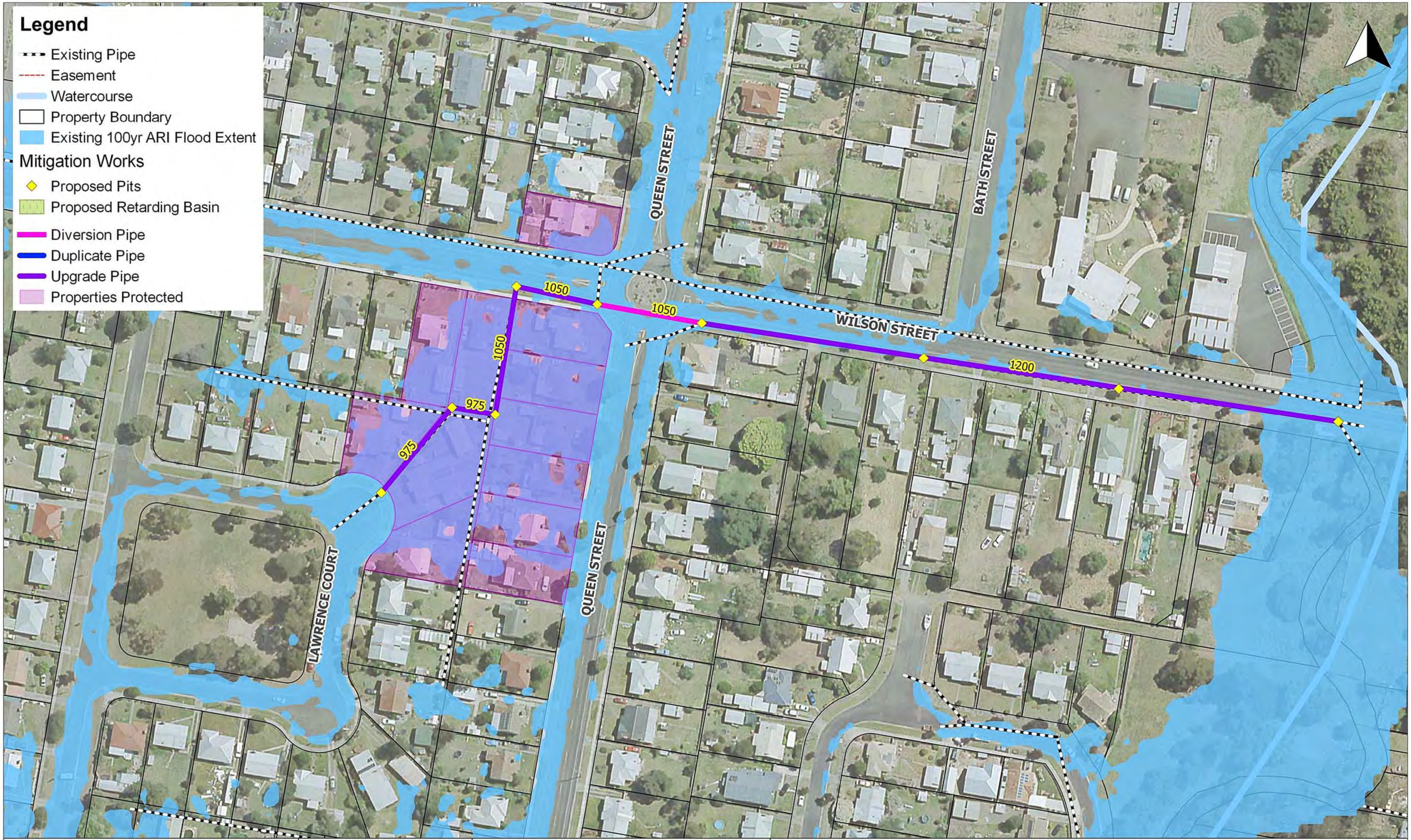
At A3 1:2,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Existing Conditions
Mitigation Location 3
Mahoney Court

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

10 0 10 20 30 40 m

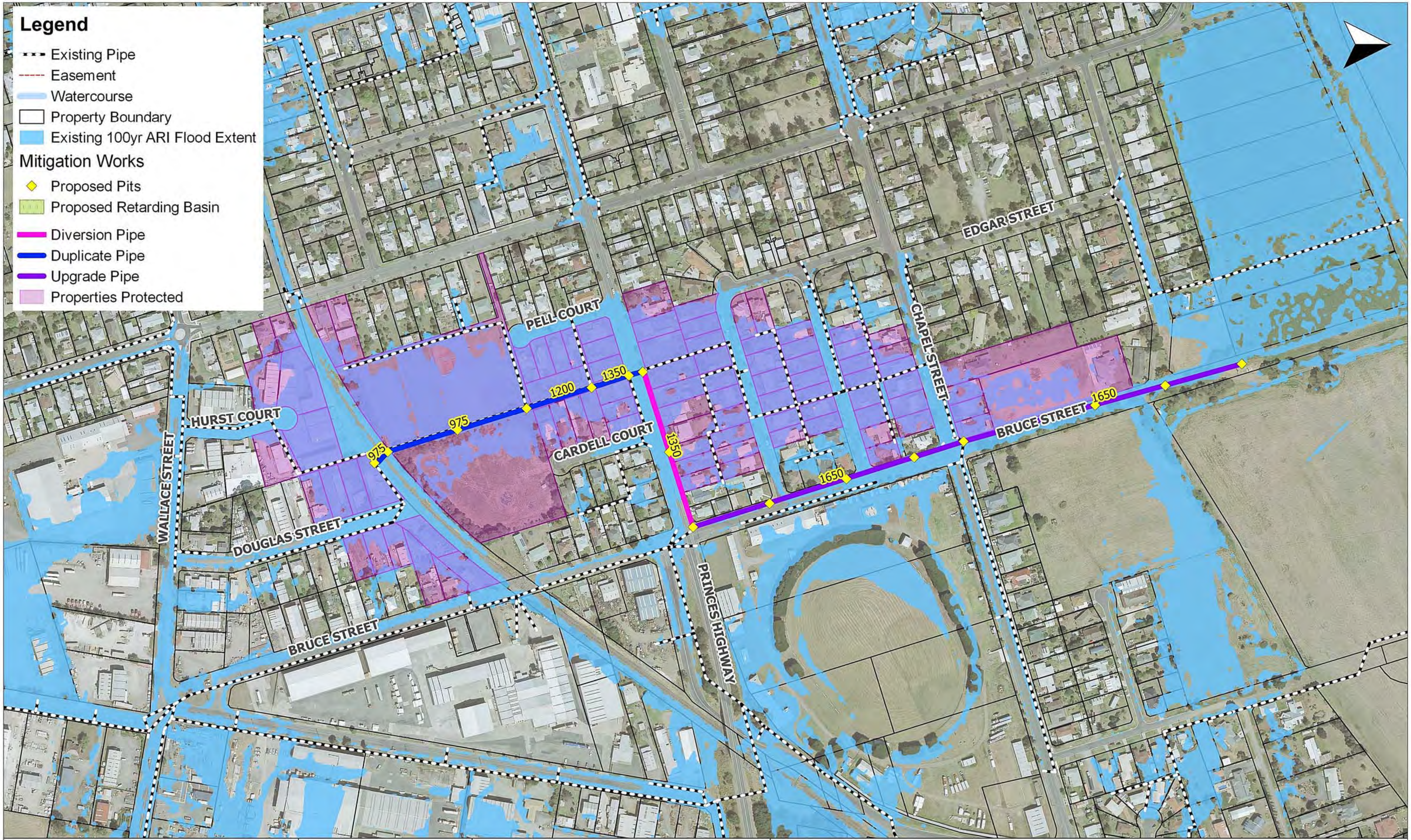
At A3 1:1,250

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Existing Conditions
Mitigation Location 4
Lawrence Court

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

30 0 30 60 90 120 m

At A3 1:3,500

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

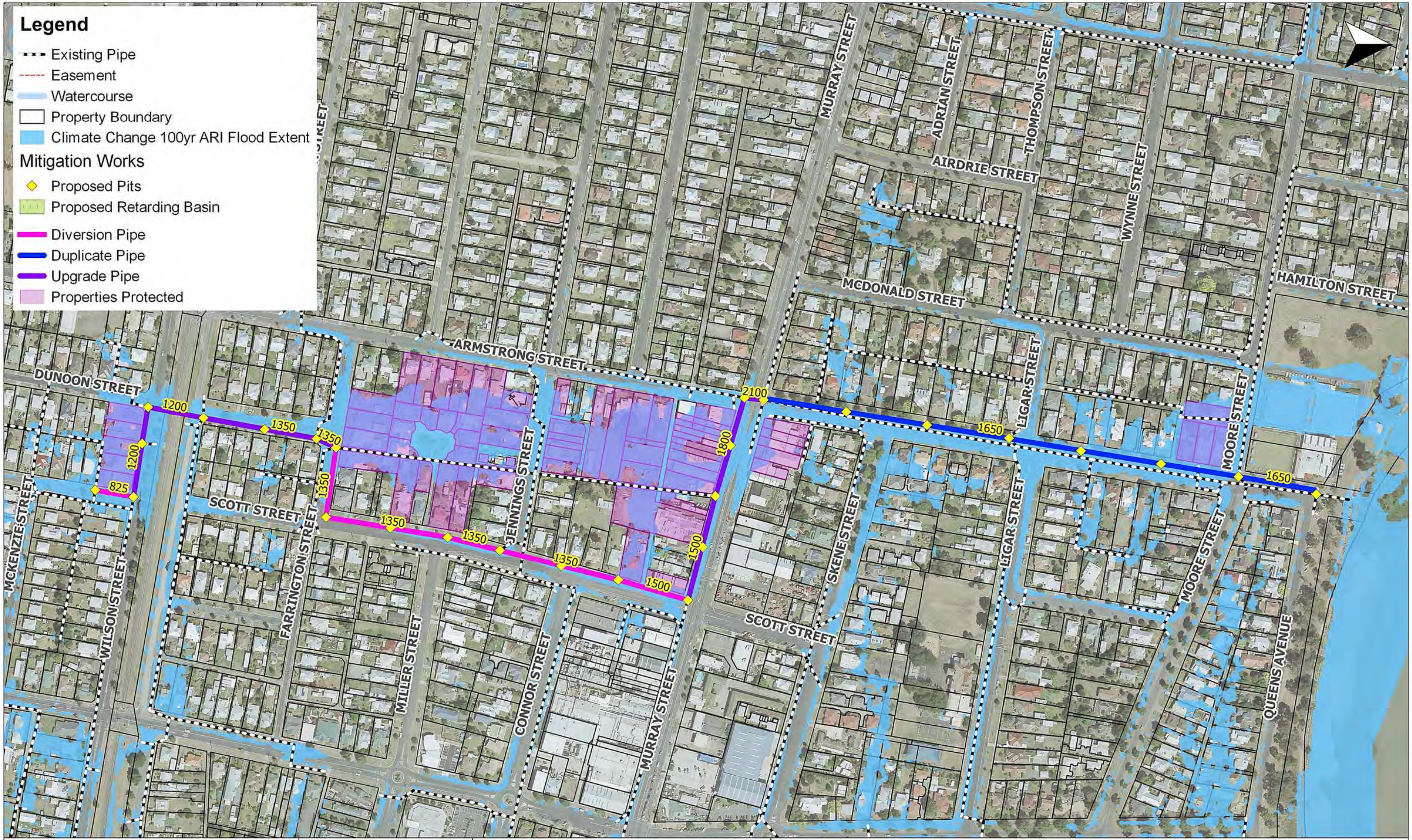
Colac Stormwater Development Strategy

100yr ARI Existing Conditions
Mitigation Location 5
Douglas Street

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017

APPENDIX G

Flood Mitigation Works for Existing Urban Area (Climate Change Conditions)



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

30 0 30 60 90 120 m

At A3 1:3,500

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Climate Change Conditions
Mitigation Location 1
Wilson Street

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017

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ENGENY WATER MANAGEMENT

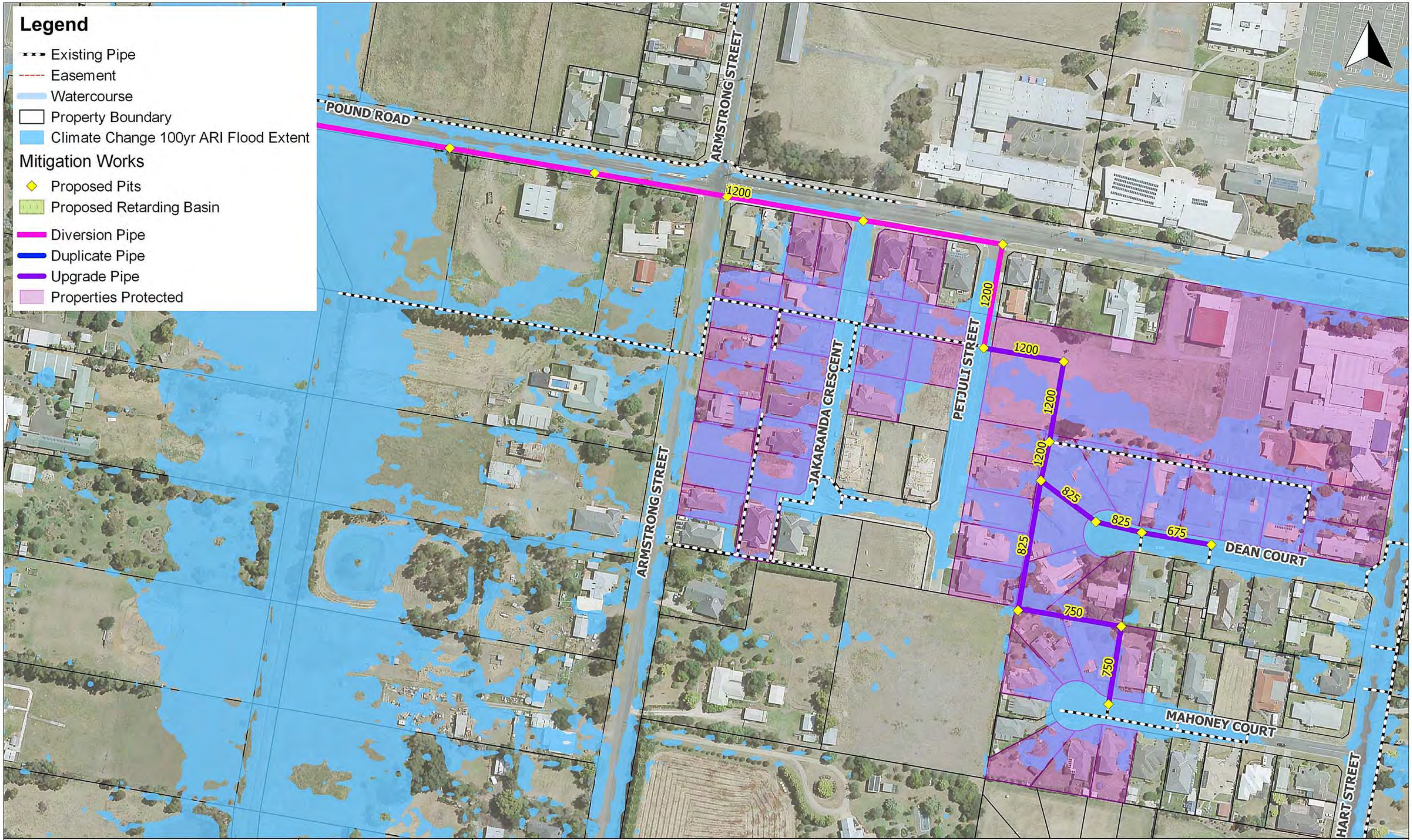
Colac Otway SHIRE

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Climate Change Conditions
Mitigation Location 2
Gravesend Street

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

19 0 19 38 57 76 m

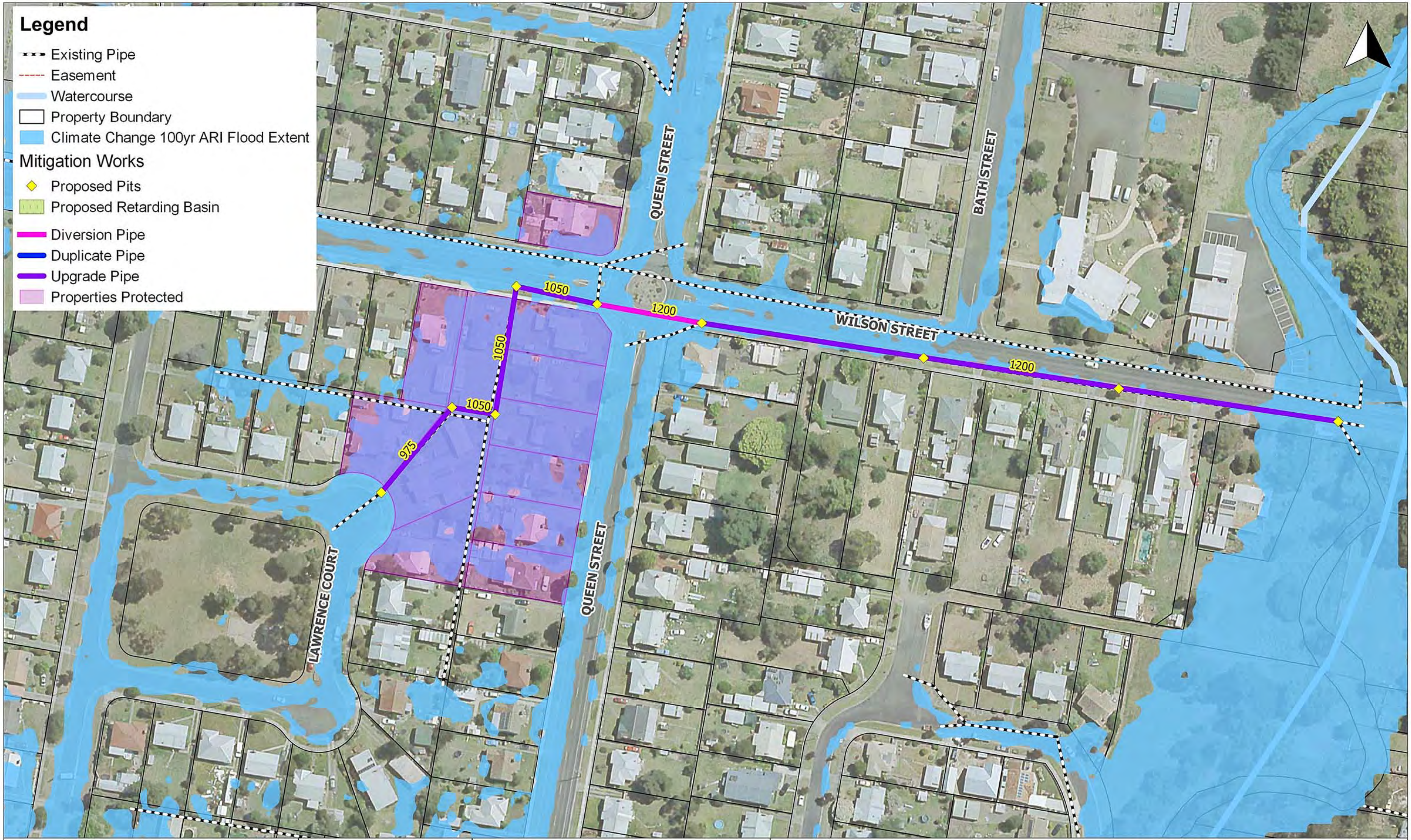
At A3 1:2,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Climate Change Conditions
Mitigation Location 3
Mahoney Court

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

10 0 10 20 30 40 m

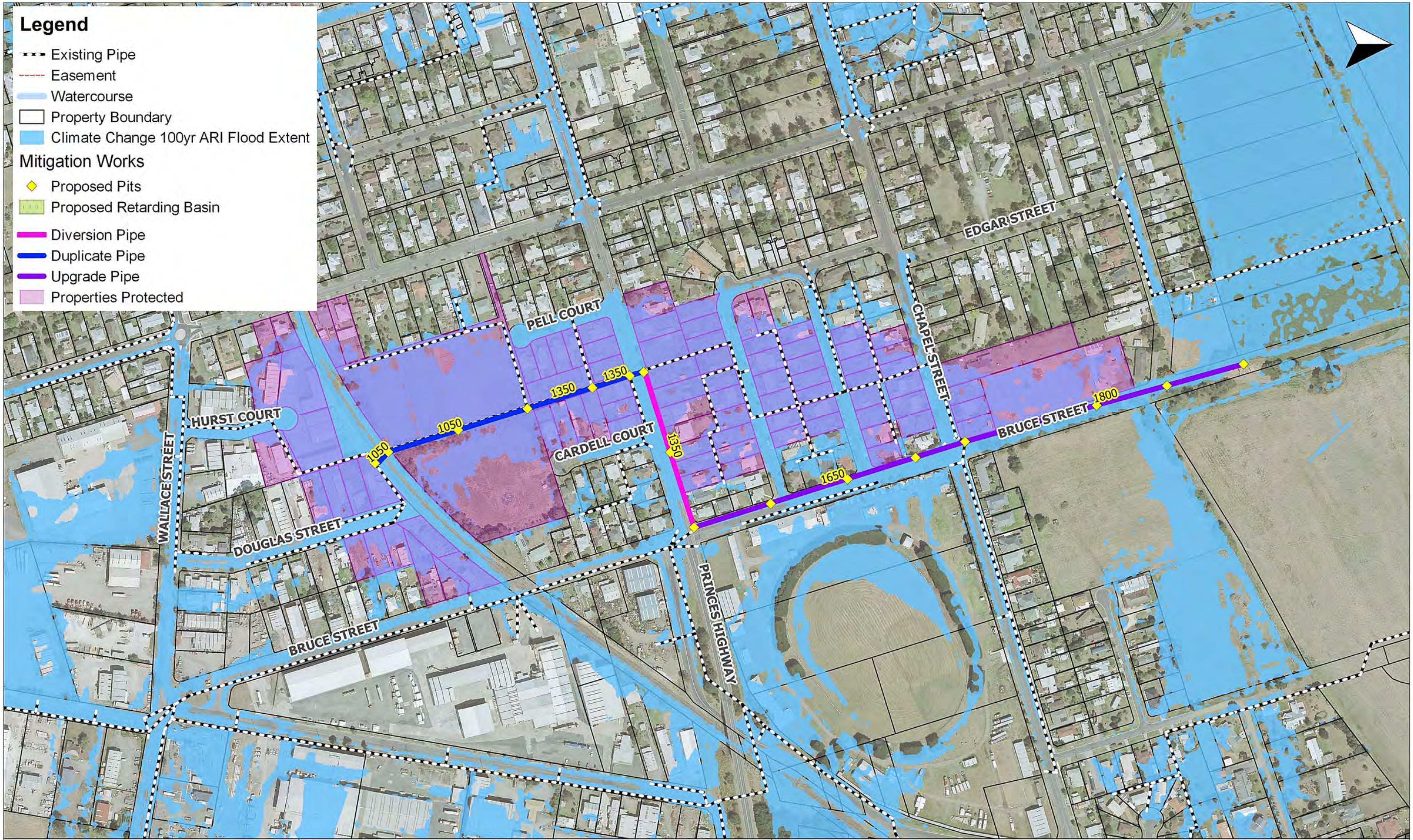
At A3 1:1,250

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100yr ARI Climate Change Conditions
Mitigation Location 4
Lawrence Court

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

30 0 30 60 90 120 m

At A3 1:3,500

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

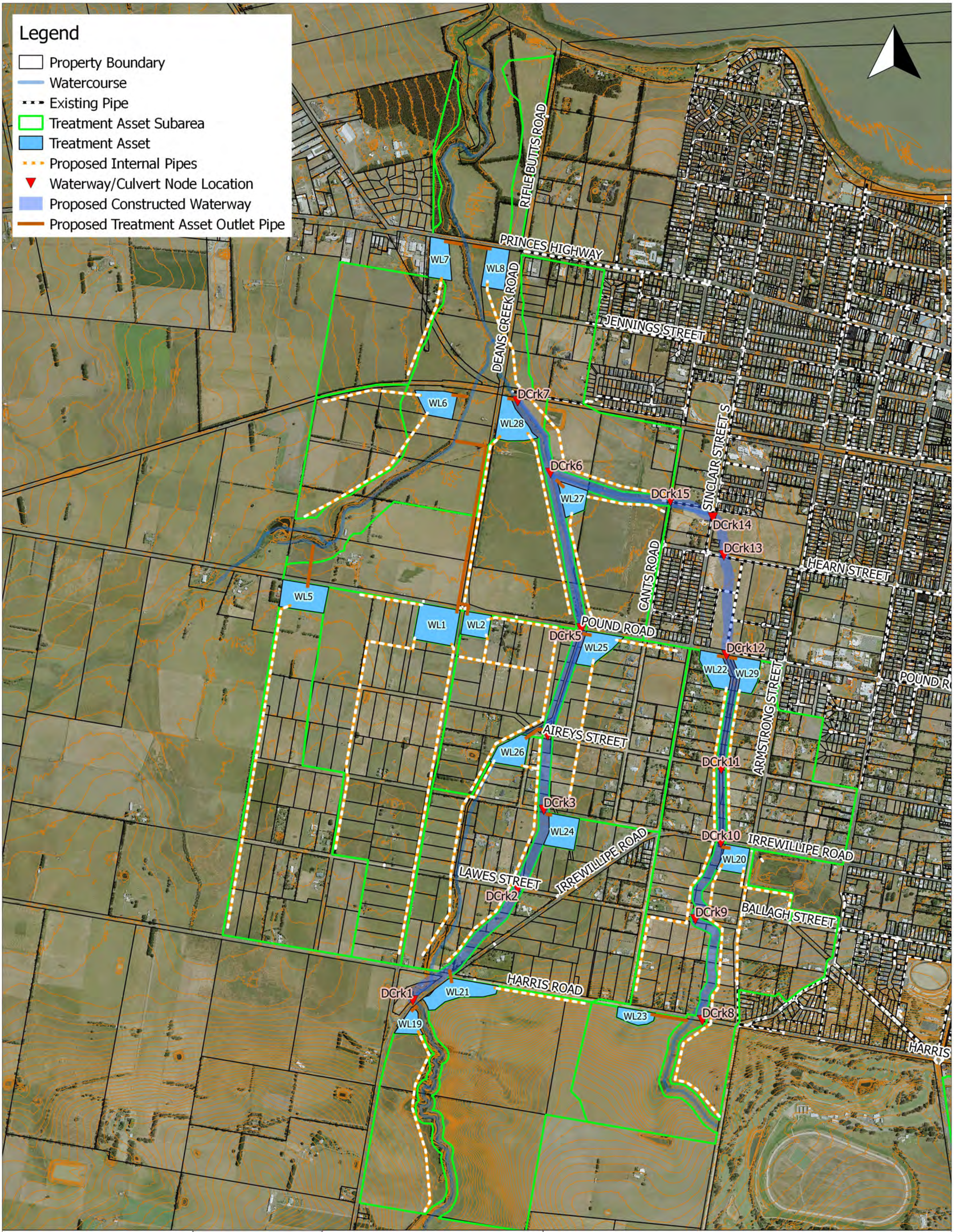
Colac Stormwater Development Strategy

100yr ARI Climate Change Conditions
Mitigation Location 5
Douglas Street

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 21/9/2017

APPENDIX H

Proposed Waterways and Wetlands Plans



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

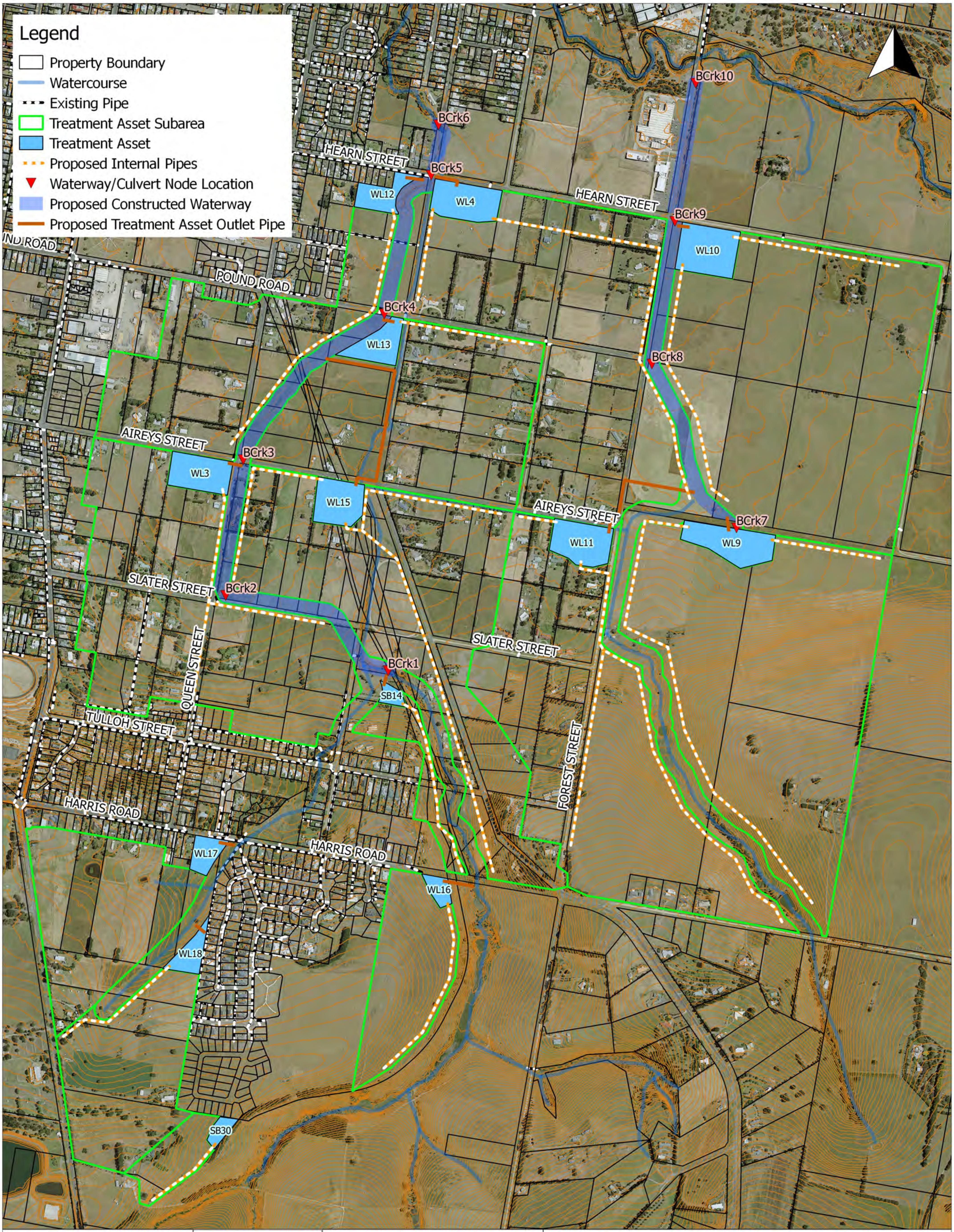
298 0 298 m

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy
Waterway and Wetland Layout Plan

Deans Creek

Drawn: MM
Checked: SD
Date: 15/9/2017



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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

198 0 198 m

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy
Waterway and Wetland Layout Plan

Barongarook Creek

Drawn: MM
Checked: SD
Date: 15/9/2017

APPENDIX I

Flood Inundation Maps for Development Conditions

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ENGENY WATER MANAGEMENT

Colac Otway SHIRE

200 0 200 400 600 800 m

At A3 1:25,000

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Colac Stormwater Development Strategy

100 Year ARI Flood Extent
Catchment Wide

Proposed Developed Scenario

Job Number: V2013_001
Revision: 0
Drawn: MM
Checked: SD
Date: 15/9/2017