# WARRNAMBOOL FLOODPLAIN MANAGEMENT PLAN 2018-2023

WARRNAMBOOL
CITY COUNCIL

**Prepared For**
Warrnambool City Council
November 2018

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| Project Details | Warrnambool Floodplain Management Plan |
| Client | Warrnambool City Council (Rohan McKinnon -Project Manager) |
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| Job Number | 292018 |

| Document | | | | |
|---|---|---|---|---|
| Version | Type | Review | Release | Date |
| 1 | Draft | Brad Henderson | Utilis | 25/05/2018 |
| 2 | Draft | Brad Henderson | Utilis | 7/09/2018 |
| 3 | Final | Brad Henderson | Utilis | 14/11/2018 |

## Acknowledgement of Warrnambool's Aboriginal Communities

The Warrnambool City Council proudly acknowledges the region's Aboriginal communities and their rich culture; and pays its respects to their Elders past and present. The Council also recognises the intrinsic connection of Traditional Owners to Country and acknowledges their contribution in the management of land, water and resources. We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

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Front Cover Image: Allansford and Hopkins River in flood 17 January 2011 (Credit: Glenelg Hopkins CMA)

## Executive Summary

The Warrnambool Floodplain Management Plan (2018-2023) follows on from extensive flood investigations and works across the Warrnambool City. The Plan has been developed in the context of the Victorian Floodplain Management Strategy (2016) and Draft Regional Floodplain Management Strategy (2017) in particular, but also in the context of a range of other strategic and technical documents.

The Warrnambool region has a long history of flooding across three main sources – rivers, stormwater systems and storm tides. The historical reference point for flooding in the region is the March 1946 flood that caused extensive damage across the region. This and numerous other flood events have yielded a significant body of knowledge that has been further built upon through specific flood investigations. These investigations have created justification for a major investment in flood mitigation works in the North Warrnambool area. The information derived from these investigations has been reviewed along with the current status of floodplain management for the region. Land use and current flood planning controls have also been described as part of this review.

This Plan has been developed under the direction of a Project Control Group (PCG) and Technical Working Group (TWG) made up of key stakeholders including:

- Warrnambool City Council
- Glenelg Hopkins CMA
- VicSES
- Department of Land, Water, Environment and Planning (DELWP)

Other stakeholders were engaged under the direction of a Stakeholder Engagement Plan, including:

- Wannon Water
- VicRoads
- Eastern Marr Aboriginal Coropragtion

Both have contributed to the identification and assessment of a vision, objectives and desired outcomes also developed as part of the Plan process.

The vision and objectives identified for the Plan are:

**A flood resilient city community**

**Adapting to climate change**

**Strategically manage flood risk**

**An integrated design approach to development**

A range of floodplain management options that seek to respond to this vision and objectives have been guided by the following principles:

- Protecting life, assets, the natural environment and social amenity as a priority
- Sharing responsibility for floodplain management between local agencies, communities, business and individuals
- A proactive risk management approach
- A consultative and informed approach
- Recognition that all flood risk cannot be eliminated
- Recognition of individual responsibility

With the guidance of the PCG and TWG – 18 floodplain management options were identified for further assessment. The options were grouped into three general categories:

- Flood mitigation measures
- Planning measures
- Response measures.

These options were assessed using a multi-criteria analysis which considered a range of criteria across a broad spectrum of considerations. A workshop was conducted with the TWG to confirm the assessment but also provide an opportunity for stakeholders to 'weight' options in order of importance. These weighted scores are included in Table 1.

Likewise engagement with the community has influenced the development of the Plan and ranking of options. Through a community drop in day on 31 July, 17 community members participated in weighting the options based on level of importance and a further 25 residents contributed to a survey. Again these results produced the scoring for 'community acceptance' in Table 1.

Throughout the Plan development, a range of recommendations have been identified that should be considered alongside the implementation of the management options. In summary, it is recommended that:

1. Sea level rise (SLR) planning (benchmarks are reviewed and updated. AR6 is due out in 2021 and will be a key reference point for a benchmark review.
2. Consistency is sought in the approaches to modelling flooding under climate change scenarios for all future investigations. Current State policy adopts a SLR of not less than 0.8m to be used for planning purposes.
3. Measures to maintain and enhance remnant EVC values and ecological opportunities are considered within the delivery of this Plan.
4. The Special Building Overlay (SBO) is considered as a planning control for stormwater flooding in urban areas. Further exploration in consultation with DELWP and Glenelg Hopkins CMA to explore its application for stormwater and/or riverine flooding behind the North Warrnambool flood levees.

The Plan represents a baseline for further revision of subsequent plans beyond 2023. It also provides a basis for sourcing funding and support for delivering on the options and recommendations identified.

**Table 1. Top ten priority plan options**

| Ref | Option | Economic Merits | Financial Feasibility | Environmental Cultural | Impact on vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win | TWG Loading | Est. Cost $000 | Weighted TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mitigation Measures | | | | | | | | | | | | | | | |
| F4 | Establish an operating procedure for North Warrnambool flood levees | 3 | 3 | 0 | 3 | 3 | 2 | 1 | 3 | 0 | 3 | 3 | 2 | 2.5 | 26 |
| P1 | Undertake Warrnambool coastal flood investigation | -1 | 1 | 1 | 2 | -1 | 2 | 2 | -1 | 2 | 2 | 0 | 5 | 200 | 14 |
| R1 | Develop a flood response plan template for residents | 1 | 1 | 0 | 3 | -1 | 0 | 2 | -1 | 2 | 3 | -1 | 4 | 20 | 13 |
| P3 | Undertake Woodford flood investigation | 2 | -1 | 1 | 3 | 1 | 3 | -2 | 1 | 1 | 3 | 0 | 0 | 100 | 12 |
| R3 | Implement a TFFWS for Russells Creek | 0 | 2 | 0 | 3 | 0 | 0 | -2 | 1 | 3 | 3 | 0 | 2 | 250 | 12 |
| P2 | Undertake Allansford flood investigation | 1 | -1 | 2 | 3 | 1 | 3 | -1 | -1 | 1 | 1 | 0 | 3 | 150 | 12 |
| F2 | Install a backflow prevention for Tooram Lane outfall | 1 | -1 | 0 | 3 | 2 | 1 | -1 | 3 | -1 | 0 | 1 | 1 | 10 | 9 |
| R5 | Undertake community flood education engagement activities | 1 | -1 | 1 | 2 | 0 | 1 | 3 | -1 | 1 | 2 | -1 | 1 | 35 | 9 |
| P4 | Undertake Russells Creek crossing assessment | -1 | 1 | 0 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 2 | -3 | 30 | 9 |
| P5 | Warrnambool flood models integration | -1 | 1 | 0 | 0 | 1 | 3 | 0 | -1 | 1 | 1 | 1 | 2 | 30 | 8 |

Table 1 is further summarised overleaf as a 'plan on a page'

WARRNAMBOOL
CITY COUNCIL

# FLOODPLAIN MANAGEMENT PLAN

2018-2023

## TOP 10 OPTIONS

1. Establish an operating procedure for North Warrnambool flood levees (F1)
2. Undertake Warrnambool coastal flood investigation (P1)
3. Develop a flood response plan template for residents (R1)
4. Undertake Woodford flood investigation (P3)
5. Implement a TFFWS for Russells Creek (R3)
6. Undertake Allansford flood investigation (P2)
7. Install a backflow prevention for Tooram Lane outfall (F2)
8. Undertake community flood education engagement activities (R5)
9. Undertake Russells Creek crossing assessment (P4)
10. Warrnambool flood models integration (P5)

## Glossary of Terms

**Annual Exceedance Probability (AEP)** Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude.

**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. A 10 year ARI flood is expected to be exceeded on average once every 10 years. 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.

**Catchment** The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.

**Coastal flooding** Flooding of low-lying areas by ocean waters, caused by higher than normal sea level, due to tidal or storm-driven coastal events, including storm surges in lower coastal waterways

**Design flood** A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.

**Flash flooding** Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.

**Flood** Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.

**Flood damage** The tangible and intangible costs of flooding.

**Flood hazard** Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.

**Flood mitigation** A series of works to prevent or reduce the impact of flooding. This includes structural options such as levees and non-structural options such as planning schemes and flood warning systems.

**Flood risk** The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types – existing, future and residual. Existing flood risk refers to the risk a community is exposed to as a result of its location on the floodplain. Future flood risk refers to the risk that new development within a community is exposed to as a result of developing on the floodplain. Residual flood risk refers to the risk a community is exposed to after treatment measures have been implemented.

| | |
|---|---|
| **Floodplain** | Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land. |
| **Geographical information systems (GIS)** | A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data. |
| **Mitigation** | Permanent or temporary measures (structural and non-structural) taken in advance of a flood aimed at reducing its impacts. |
| **Municipal Flood Emergency Plan** | A sub-plan of a flood-prone municipality's Municipal Emergency Management Plan. It is a step-by-step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies |
| **Planning Scheme zones and overlays** | Planning Schemes set out the planning rules – the State and local policies, zones, overlays and provisions about specific land uses that inform planning decisions. Land use zones specify what type of development is allowed in an area (e.g. urban (residential, commercial, industrial), rural, environmental protection). Overlays specify extra conditions for developments that are allowed in a zone. For example, flooding overlays specify that developments must not affect flood flow and storage capacity of a site, must adhere to freeboard requirements, and not compromise site safety and access. |
| **Project Control Group (PCG)** | A working group established to provide governance oversight for the development of the Warrnambool Floodplain Management Plan. |
| **Riverine flooding** | Inundation of normally dry land when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels. |
| **Storm surge** | The increases in coastal water levels above the predicted tide level resulting from a range of location dependent factors such as wind and waves, together with any other factors that increase tidal water level. |
| **Stormwater flooding** | The inundation by local runoff caused by heavier than usual rainfall. It can be caused by local runoff exceeding the capacity of an urban stormwater drainage systems, flow overland on the way to waterways or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (see also local overland flooding). |
| **Total Flash Flood Warning System (TFFWS)** | A Total Flood Warning System (TFWS) encompasses all the elements necessary to maximise the effectiveness of the response to floods. These are data collection and prediction, interpretation, message construction, communication and response. Effective warning time refers to the time available to a flood-prone community between the communication of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. |
| **Technical Working Group (TWG)** | A working group established to guide the development of the Warrnambool Floodplain Management Plan |

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# 1 Introduction

Warrnambool City Council (WCC) requires a Floodplain Management Plan (the Plan) to guide community, Council and its partners in managing flood risk into the future (2018-2023).

Warrnambool is Victoria's largest coastal City outside Port Phillip Bay, and is one of Victoria's fastest growing regional cities. The Warrnambool City population forecast for 2018 is 35,377 and is forecast to grow to 46,210 by 2036.

Approximately 465 hectares of land is available for future housing (Warrnambool City-Wide Housing Strategy, 2013). Warrnambool is considered the economic, cultural and social capital of south western Victoria, as well as being a popular tourist and retirement destination. WCC attributes the significant growth of Warrnambool to the strength of its diverse regional economy and the liveability of the City and its region.

Two significant river systems flank the present edges of urban development within the City of Warrnambool. The Hopkins River passes the eastern and southern edge of the City, while the Merri River wraps around the northern and western extent of development. Russells Creek is a major tributary of the Merri River which flows through the north-east portion of town. The land surrounding the urban area is cleared and agriculture is the predominant land-use. In recent years there has been significant urban expansion, particularly to the north, which is expected to continue into the future.

The flood risk in the built environment of the WCC region needs to be managed. The issues stemming from changing climate and expanding urban environments cannot be avoided. It is important to have a clear direction for interventions aimed at maintaining and enhancing the natural and flood conveyance function of the region's floodplains. These interventions represent investments that are focused on the most benefit for the majority of Warrnambool's population now and into the future.

Much has been done already to identify and respond to the flood risk across the WCC region. In particular, the North Warrnambool Flood Mitigation works were completed in 2017 and represent the largest single investment in flood mitigation in Warrnambool's history.

The Plan establishes the strategic and historic context for WCC's floodplain management agenda. It explores the current situation in relation to available information, emerging issues and future actions. This background, along with stakeholder engagement, community consultation and use of a multi-criteria assessment all combine to establish priority actions for WCC and its partners to address over the planning horizon (2018-23).

The Plan fits within the broader State context of the Victorian Floodplain Management Strategy (2016) and regional strategic framework and over-arching (draft) Glenelg Hopkins Regional Floodplain Management Strategy (2017). It establishes a clear way forward for floodplain management in the Warrnambool City region. It guides the work required based on the history, context and emerging issues related to flooding.

# 2 Strategic Context

The Victorian Floodplain Management Strategy (VFMS) sets the direction for floodplain management in Victoria. The Strategy aligns with the Victorian Government's responses to the Victorian Floods Review and the parliamentary inquiry into flood mitigation infrastructure. It also aligns with the broader emergency management framework set out in the Emergency Management Act 2013. Importantly, it helps integrate floodplain management with the Victorian Waterway Management Strategy 2013 and the Victorian Coastal Strategy 2014.

The Glenelg Hopkins Regional Floodplain Management Strategy (RFMS) builds on the extensive work that has been undertaken over the past decade to improve management and reduce flood risks across the region. Glenelg Hopkins Catchment Management Authority (GHCMA) led the development of the strategy in collaboration with Local Government Authorities (LGAs), the Victoria State Emergency Service (VICSES), Traditional Owners, other agency partners and the community.

This strategy interprets and applies the policies, actions and accountabilities of the VFMS in managing flood risks at the regional and local level.

It provides a single regional planning document for floodplain management and a high-level list of regional priorities to guide future investment. The primary role of the RFMS is to assist agencies that have floodplain management and flood emergency management functions to align their priorities and maximise community benefits with available funding. Regional strategies represent future business cases for investment by government in floodplain management.

The regional strategies are at a larger scale and typically involve more than one agency either in funding or delivering projects. At a local level, detailed risk evaluations, in the form of flood investigations, fill gaps in knowledge and help communities consider flood management options. Warrnambool City's role in the flood investigation process is described in Figure 1 below.

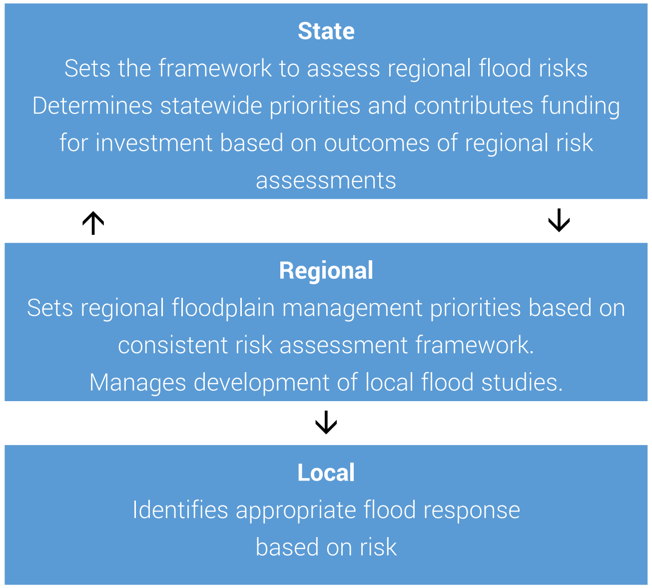



Figure 1: The role of different levels of Government in flood investigations[1]

Chapter three of the Plan details the range of floodplain management projects that WCC has contributed to in recent years. Prior to the VRMS and RFMS, there was limited direction in the form of a strategic approach to floodplain management for the WCC. Both Strategies provide for clear high level roles and responsibilities as described in Figure 2. This Plan is a response to the current strategic direction and status of floodplain management for the Council region.

| | Minister for Environment, Climate Change and Water | | | Minister for Planning | Minister for Emergency Services | Minister for Local Government |
|---|---|---|---|---|---|---|
| STATE | Victorian Coastal Council | DELWP | DELWP | DELWP | VICSES | |
| STATE | Coastal Strategy | Victorian Waterway Management Strategy | Victorian Floodplain Management Strategy | Policy and Victoria Planning Provisions (State Policy Planning Framework) | State Flood Emergency Plan | |
| REGIONAL | Coastal Boards | CMAs | CMAs & DELWP | Regional Growth Plans | Regional Flood Emergency Plans | |
| REGIONAL | Regional Coastal Plans | Regional Waterway Strategies | Regional Floodplain Management Strategies | Regional Growth Plans | Regional Flood Emergency Plans | |
| LOCAL | Local Councils | CMAs | CMAs and/or local councils | Local Councils | Local Councils | |
| LOCAL | Coastal Management Plans | Works on Waterways permits | Local flood studies | Local Planning Policy Framework and local planning scheme controls | Municipal Emergency Management Plans | |

Figure 2. Relationship between State, regional and local roles and responsibilities[1].

A key objective of the Plan is to ensure it aligns with State and regional strategic direction. It provides WCC with an enhanced strategic position in relation to establishing a basis for future investment. Some of the advantages to both councils and the community in having a properly considered management plan include:

- A consolidation of emerging flood issues into one document through stakeholder engagement and community consultation
- A greater understanding of the major challenges relating to flood risk
- Clear direction for investment in floodplain management actions.

# 3 Warrnambool Floodplain Management in Review

There is a substantial body of flood information for the rivers and creeks within the Warrnambool City region. There is a long history of floodplain management for Warrnambool that dates back to 1857 when the Merri River was diverted from its original course (along the sand dunes) through Lake Pertobe ('the Cutting"). Along with the construction of the breakwater (circa 1890) these represent major historic coastal and riverine investments in flood mitigation and hydraulic controls. The most recent investment in flood mitigation was the North Warrnambool Flood Mitigation Project (2015-18) which included a range of works including a major upgrade to the Mortlake Road culvert. This area of Russells Creek has a long history of flooding causing problems for municipal administrations as early as 1917 (Figure 3).

Figure 3. Road making Mortlake Road circa 18662 (Russells Creek in background).

Flooding occurs regularly in Warrnambool. While the severity varies, the Merri River and Russells Creek typically deliver a 'nuisance' flood every few years. The scale of flood magnitude is wide and while flooding is not an irregular visitor to the Warrnambool region – it was the 1946 flood that stands out as a catastrophic event in Warrnambool's flood history. More recently, the 2010/11 Hopkins River and 2014 Merri River storm surge flooding have been notable events – both creating scenes not experienced before by many. Appendix 1 summarises the flooding history of the WCC region.

## 3.1 Sources of Flooding

When we think of flooding in the Warrnambool region context – we typically think of the three sources – Russells Creek, Merri and Hopkins Rivers – refer Figure 4. Traditionally, floodplain management has focused on riverine flooding as there is a long history of such floods in Australia, causing enormous loss and damage. Increasingly however, as towns and cities grow, as infrastructure and transport changes, as demographics change, as climate changes – flooding is becoming an increasingly more complex issue. As climate drives a variety of rainfall, tidal, wave and wind conditions, any resulting flooding is never the same as a previous event. Estimating rainfall, runoff, storm tides and flow paths requires complex computer modelling reliant on data with a high degree of accuracy and fidelity to achieve reliable results. Flooding from rivers, stormwater and the ocean can occur independently or in combination and models attempt to simulate this. To communities who experience flooding – the source of flooding is not as important especially to those who may be at risk of experiencing loss or damage. This is an important consideration in communicating and consulting with local communities about flooding.

Flooding occurs when:

- Heavy rain falls in a catchment that breaks the banks of a river or creek and spreads across the floodplain.
- Heavy rain falls on a developed area where there is housing, roads and other hard surface. The drains and pipes (known as the stormwater system) that

receive the flow of water cannot cope with the runoff and water spreads out across land.

- Ocean tides affect water levels and flooding along the lower tidal reaches of coastal rivers and/or drainage systems.

Stormwater and river flooding have traditionally been treated separately. However, stormwater and river flows interact and can increase flooding. Rivers can cause a "backwater" effect on a stormwater system causing it to "surcharge" out onto land. Thus, the interaction between stormwater and river flooding needs to be evaluated and accounted for when undertaking flood investigations.

Floodplain managers must address the complexity across three phases of floodplain management – planning, response and recovery. Within these phases are three distinct flood risks:

- Existing flood risk refers to existing buildings and developments on flood-prone land. These buildings and developments because of their presence and location, are exposed to an "existing" risk of flooding
- Future flood risk refers to buildings and developments that may be built on flood-prone land. These buildings and developments will be exposed to a "future" flood risk (i.e. a risk that does not materialise until the developments occur).
- Residual flood risk refers to the risk associated with floods generally and with those, floods that exceed management measures already in place (i.e. unless a floodplain management measure is designed to withstand the probable maximum flood (PMF), it will be exceeded by a sufficiently large flood at some time in the future (it is not a matter of if, but when).

A recent example of residual flood risk is that associated with the North Warrnambool Flood Mitigation Project (completed 2017). The works that were installed to reduce the impact of flooding will not contain all floods.

Floodplain management measures to reduce flood risk can be grouped into two principal categories:

- Structural mitigation; physical works that decrease the risk of flooding (e.g. North Warrnambool Project).
- Non structural mitigation; land use planning controls; development and building controls; flood emergency response measures, and community education/awareness activities.

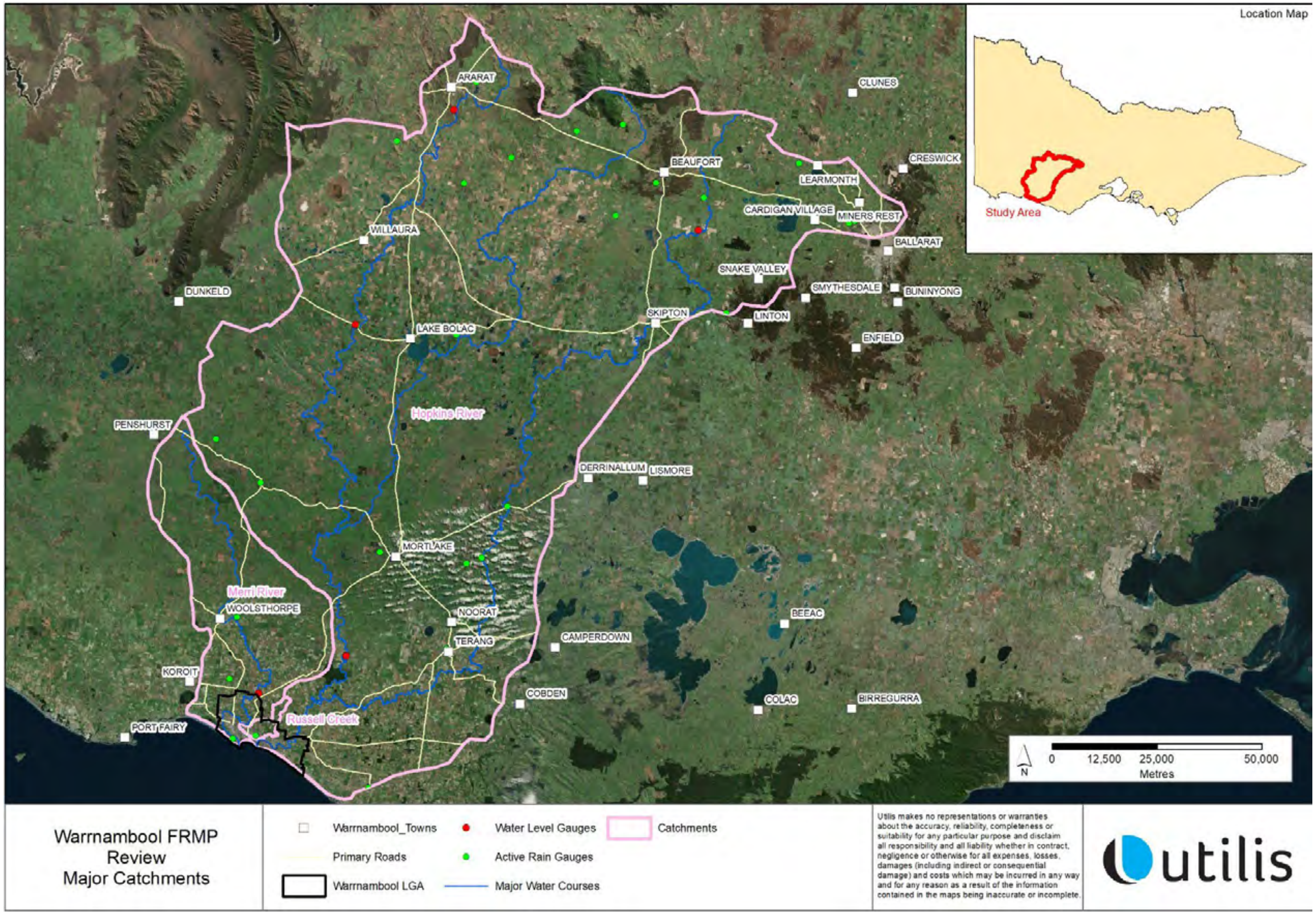



Figure 4. Key sources of riverine flooding for Warrnambool Region

## 3.2 Knowledge of Flooding

For several decades, the primary responsibility for floodplain management in non-metropolitan Victoria resided with the Rural Water Corporation (and its predecessors like the State Rivers and Water Supply Commission). As a result of the decision by the Victorian Government to disband the RWC, these responsibilities were transferred to the Department of Conservation and Natural Resources (NRE) in 1994, and a review of floodplain management policy in Victoria was initiated.

A culmination of that review was the formation of the nine non-metropolitan Catchment Management Authorities (CMAs). Their new responsibilities came into effect on July 1, 1997, and included waterway management, floodplain management and rural drainage service delivery[4].

CMAs have carried the floodplain management function from circa 1998 to the present. However, there has been a shift in policy direction in recent years towards a greater responsibility in this and the rural drainage function to Local Government. In 2013, CMAs status under the Planning and Environment Act (1987) changed from a 'determining' referral authority to a 'recommending referral authority'. While it varies across the State, some Councils are taking more responsibility in the delivery of flood investigations in both the riverine and coastal contexts.

Establishing the current status of floodplain management in Warrnambool begins with a strategic review of the studies undertaken to consider their currency and consistency. The following review focusses on where there are potential gaps in the study coverage. The coverage of investigations has been mapped to determine the spatial coverage of the data derived (shown in Figure 5).

## 3.3 Studies Undertaken

There have been a range of flood investigations undertaken for Warrnambool City Council. These investigations vary in spatial location (i.e. which area of the region they cover), time of completion and the purpose of the study.

While there have been a range of studies undertaken for varied purposes, this Plan focuses primarily on those investigations where modelling has been undertaken.

The flood investigations that have been undertaken are outlined in Table 2.
Other significant flooding related studies that have been undertaken include:

- State Rivers and Water Supply Commission: Report on the Western District Floods of March 1946
- The DNRE Flood Data Transfer Project (2001) which compiled all available data at the time.
- The 2010 – 11 Victorian Floods Rainfall and Streamflow Assessment Project (2012) which outlines flooding that occurred during 2010 and 2011.
- A scoping study for a Russell Creek Flood Warning System (2013), which examines the viability of a flood warning system for Russell Creek floods.
- Barwon South West Regional Local Coastal Hazard Scoping Project (DELWP, 2016 - )

**Table 2. Completed Flood Investigations**

| Study | Year Complete | Consultant | Modelling Software |
|---|---|---|---|
| North Warrnambool Flood Study | 2003 | GHD | RORB, HEC-RAS |
| Russell Creek Flood Mitigation Options | 2003 | GHD | RORB, HEC-RAS |
| North Warrnambool Floodplain Risk Management Plan | 2006 | GHD | RORB, HEC-RAS |
| South Warrnambool Flood Study | 2006 | Water Technology | RORB, MIKE FLOOD |
| Dennington Flood Study | 2007 | Water Technology | RORB, MIKE FLOOD |
| Russell Creek Flood Modelling – Internal Memo | 2007 | Cardno | RORB, SOBEK |
| South Warrnambool Sea Level Rise | 2008 | Water Technology | RORB, MIKE FLOOD |
| North Warrnambool Design of Implementation Works | 2010 | Cardno | RORB, SOBEK |
| South Warrnambool Flood Study – Addendum | 2011 | Water Technology | RORB, MIKE FLOOD |
| North Warrnambool Design of Implementation Works – Phase 2 | 2012 | Cardno | RORB, SOBEK |
| South Warrnambool Sea Level Rise Modelling Project | 2013 | Water Technology | RORB, MIKE FLOOD |
| North Warrnambool Design of Flood Mitigation Works | 2015 | Water Technology | RORB, SOBEK |
| Urban Drainage Strategy | 2015 | Water Technology | NA |
| Logans Beach Strategic Framework Plan Flood Modelling | 2017 | Water Technology | Rain on Grid, TUFLOW |
| Russell Creek Flood Mitigation Works – As Constructed modelling | 2017 | Water Technology | RORB, TUFLOW |
| Warrnambool City Council Drainage Study | 2017 | Engeny | TUFLOW |

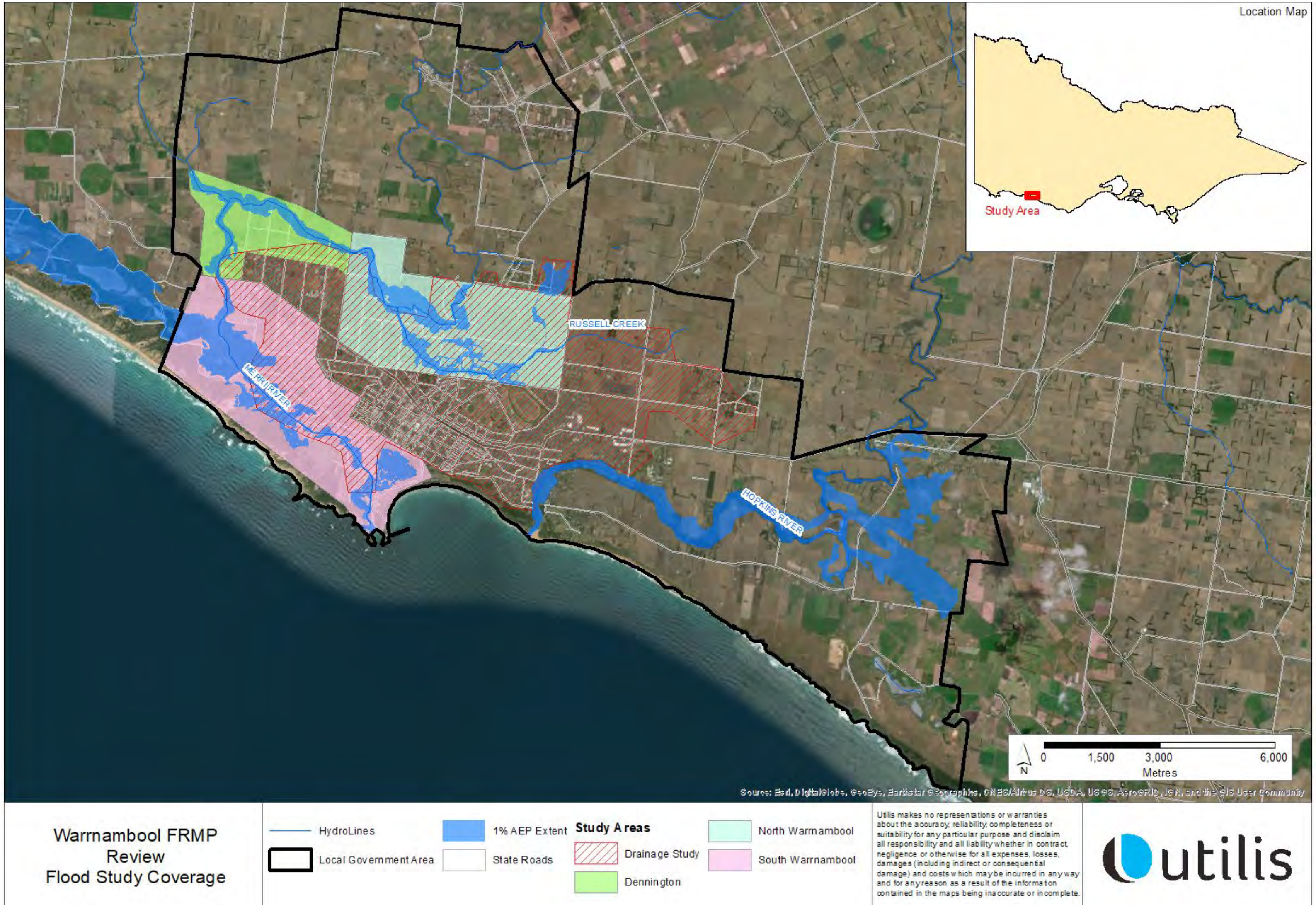



Figure 5. Coverage of Flood Investigations

## 3.4 Currency

As Table 2 shows, a number of the studies are relatively old and therefore utilise old data and techniques. This may be a particular issue for Dennington and South Warrnambool where no follow up studies have been undertaken. Apart from the modelling techniques, a potential issue with these studies is the accuracy of the photogrammetry derived Digital Elevation Model (DEM). Newer LiDAR derived DEMs are available for these study areas.

For North Warrnambool and Russells Creek progressive updating of modelling has occurred and therefore the flood information is relatively current. However, the North Warrnambool studies continue to utilise design flows from 1987 Australian Rainfall and Runoff (AR&R), rather than the newer 2016 version. This may be appropriate as a number of mitigation works have been constructed based on these flows and as stated below, this is likely to have resulted in a more conservative final design.

It is our understanding that for some of the studies modelling files may not be available to either the CMA or WCC. This may create inefficiencies in future investigations that are required to develop models 'from scratch'.

The studies also rely on Flood Frequency Analysis (FFA) of the Merri River (at the Woodford Gauge). This flood frequency is likely to have changed as additional data for at least 10 years is available and therefore an update to the FFA will be an important component of future studies. However, this should be considered in concert with maintaining consistency between studies. Similarly, the impacts of the latest AR&R (2016) rainfall approaches could be investigated on the North Warrnambool model. Note that the latest Russell Creek model uses the new AR&R 2016 approaches.

## 3.5 Consistency

There are three aspects to consistency that were examined as part of this review, they are:

- Consistency in Approach; are the approaches (i.e. modelling techniques) consistent between the different studies?
- Consistency in Flows; are the flows that have been used in the different studies been consistent?
- Consistency in Software: has the software used between the different studies been consistent?

Consistency in Approach

The models developed for the different studies generally have a consistent approach of applying a hydrological model to rout catchment flow to the study boundary, and then a combined one and two-dimensional hydraulic model to describe the flood conditions within the study area. Some of the older studies tend to rely more on one dimensional channels to describe floodplain flow, however this is likely due to data limitations or computer power limitations that were significant at the time. Should these models be updated, the floodplain should be modelled using a two dimensional grid and the one dimensional areas should be limited to channels and structures.

The latest Drainage Study model (Engeny, 2017) applies a "rainfall on grid" approach rather than a hydrological model to rout flows. However, this inconsistency is appropriate as the area of interest (i.e. the city) is actually within the catchment for this study. In this instance a rainfall on grid approach is appropriate.

### 3.5.1 Consistency in Flows

The adopted 1% AEP design flows for each of the riverine floodplains have been extracted and are shown in Table 3 for the Merri River and Table 4 for Russell Creek. The flows adopted for the Merri River for the relevant studies have been largely consistent with the exception of the 2010 Design of Implementation Works (Cardno, 2010). However, these flows are significantly higher and therefore more conservative than the previous studies undertaken.

For the Russell Creek flows, there has been significant variation in the flow applied between the different studies, with a range of 56 – 79 m3/s at the Merri River Confluence. Interestingly, the earlier studies, such as the North Warrnambool Flood study (GHD, 2003), are similar to the more recent studies, such as the Russell Creek

Flood Mitigation Works (Water Technology 2017). Note that the Russell Creek Flood Mitigation Works (Water Technology 2017) utilises the AR&R 2016 rainfall. Given that the interim studies tend to have higher flows, the structures have likely been designed in a conservative fashion.

### 3.5.2 Consistency with Software

Table 3 shows the modelling software used for the various studies. The hydrological model RORB has been applied relatively consistently in all studies. However there has been a range of hydraulic models used. Currently the industry standard hydraulic software is TUFLOW and it appears to be the model of choice for new model builds for flood investigations. Whereas MIKE FLOOD and SOBEK are more rarely used and most consultants have limited experience and access to licenses for the software.

**Table 3. Merri River 1% AEP Flows**

| Study | Report Reference | Flows ($m^3/s$) | |
|---|---|---|---|
| | | Upstream of Russell Creek | Downstream of Russell Creek |
| 2003 Flood Study | Table 5.1 | 347 | 409 |
| 2006 Floodplain Management Plan | Section 3.1 Table 1 | 347 | 409 |
| 2007 South Warrnambool Flood Study | Table 6.7 | N/A | 410 |
| 2008 Dennington Flood Study | Table 4-1 | N/A | 410 |
| 2010 Design of Implementation Works | Table 3.8 | 423 | N/A |

**Table 4. Russell Creek 1% AEP Flows**

| Study | Report Reference | Flows (m3/s) | | | | |
|---|---|---|---|---|---|---|
| | | Aberline Rd | Wangoom Rd | Mortlake Rd | Queens Road | Merri River Confluence |
| 2003 Flood Study | Table 6.2 | 34.7 | N/A | 59 | 62.5 | 62.5 |
| 2006 Floodplain Management Plan | Table 2 | 38 | 18 | 62 | 63 | Not Available |
| 2007 Russell Creek Flood Modelling | Table 2.5 | 34 | N/A | 51 | N/A | 56 |
| 2010 Design of Implementation Works | Table 3.19 | 45 | 18.6 | 69.5 | N/A | 76.9 |
| 2015 Design of Flood Mitigation Works | App B Table 3 | 45 | 18.6 | 69.5 | N/A | 76.9 |
| 2017 Russell Creek Flood Mitigation Works - As Constructed Modelling | Table 2-11 | 32.01 | 17.34 | 59.83 | N/A | 64.94 |

## 3.6 Spatial Coverage

The spatial coverage of the studies is shown in Figure 5. It can be seen from the figure that the urban areas with riverine flooding are largely covered by the North and South Warrnambool and Dennington Flood Studies. The remaining urban areas are covered by the Drainage Study which would include overland flow.

The main urban areas that do not have flood study coverage are the Woodford and Bushfield urban area and the eastern area of the city that is potentially flood affected by the Hopkins River. Anecdotally, the Hopkins River floodplain in this area may have a less significant risk profile than other areas of the region. (with the exception of the Allansford township)

The other major area with potential flood risk, and potential flood impacts, is the rural area to the north of the city. While the area within the LGA is a relatively small proportion of the Merri River catchment, there may be future development pressure in this area that may ultimately affect flooding downstream in the city.

# 4 Warrnambool Region Floodplain Management

Most floods fall into one of three major categories:

- Riverine flooding
- Coastal flooding
- Stormwater flooding

## 4.1 Riverine Flooding

### 4.1.1 Merri River

The Merri River has a total catchment area of approximately 1,050 km2 and is formed by two main tributaries. The principle tributary that forms Merri River is Spring Creek, which rises in the Southern Grampians near Penshurst. The other tributary is Drysdale Creek, which rises near the Woolsthorpe–Hexham Road approximately 15km northwest of Woolsthorpe. (refer Figure 4).

The March 1946 event is the largest flood on record for the Merri River (estimated to be in the order of a 0.2% AEP or larger event). The weather system associated with this event caused widespread flooding in south-west Victoria with the highest rainfall total of 327 mm at Macarthur over 3 days). Significant damages occurred, particularly to bridges at Woodford and Warrnambool (refer Figure 6).

Figure 6. Woodford bridge washed away March 1946

The Merri River floodplain through Warrnambool is well defined particularly to the Dennington bridge. From there the river breaks out to the east and inundates the Kelly Swamp are along with areas adjacent to the Merri River cutting. Numerous flood events have occurred in recent decades (refer Figure 7) from which good data has been sourced to improve flood modelling over time. Accurate data provides an opportunity to test response plans and grow the communities experience with flooding. The challenge for the Plan is to build the resilience of the community to large and hazardous floods.

Figure 7. Merri River looking southeast from Manuka Drive 12 August 2010[3]

#### 4.1.2 Russells Creek

Russells Creek is a relatively small tributary of the Merri River, with a total catchment area of 32.7 $km^2$. The Creek passes through the north Warrnambool urban area to its confluence with the Merri River near Daltons Road (refer Figure 8). The catchment is primarily urbanised with some agricultural land in the upper sections. The predominant land use in the urban part of the catchment is residential.

Russells Creek has a long history of flooding (refer Appendix 1: Flood History Timeline). Newspaper reports refer to flooding banking upstream behind the Mortlake Road, north of Moore Street . The legacy of this long flood history is that while there has been development encroachment on the floodplain over the decades – a significant portion of the floodplain area has been maintained for the free passage of floods (refer Figure 8)..

Figure 8. Russells Creek and Merri River Confluence – 12 September 2016[8]

Flooding of Russells Creek causes inundation of a number of streets and roads particularly between Garden Street and Daltons Road. While for minor floods the depth over the road is typically shallow, the response requirement is for the roads to be closed while the flood passes through. Typically flood waters recede within hours to enable roads to become trafficable again. However, there is clearly a behavioural concern with many commuters ignoring road closures (refer Figure 9 and Figure 10). This behaviour may arise from complacency due to the frequency of minor flooding, the inconvenience of road closures, and/or a learned behaviour from witnessing 'everyone else doing it'. Regardless, this behaviour creates an increased risk situation as the likelihood and/or consequence of driving through floodwaters at creek crossings is increased. This issue is addressed further in management options identified in section 5.

Figure 9. Ardlie Street (from Daltons Road intersection) looking southeast 12 August 2010[3]


Figure 10. Daltons Road bridge 12 August 2010[3]

#### 4.1.2.1 Review of the North Warrnambool Flood Mitigation Works (2017)

The recently installed flood mitigation works included high flow culverts through Mortlake Road and a series of concrete levee banks in the Garden Street/Mortlake Road area. Previous flood investigations had demonstrated that the original culvert under Mortlake Road (Figure 11) was too small to pass significant floods causing flows to back up and break out to the north potentially flooding numerous properties. The original culvert also provided the pedestrian crossing for Mortlake Road which exacerbated the capacity issue and created a potential safety hazard. The upgraded high flow bypass culverts (Figure 12) now provide for the pedestrian access.

Figure 11. Russells Creek Mortlake Road original culvert 12 August 2010[3]

Figure 12. New high flow culverts to right of image 19 July 2018

The installation of the infrastructure has been modelled to confirm their effectiveness in reducing flood depths and extents in the Mortlake Road area (in particular). The Average Annual Damages (AAD) is an estimate of the damage cost per year over an extended period. The AAD calculated for the mitigation works is $69,571. The previous existing conditions modelling determined an AAD of $491,783, demonstrating a reduction of $422,212. This significant reduction is also reflected in the number of above floor flooded buildings. During the 1% AEP flood event the number of buildings expected to be flooded above floor has reduced from 146 to 14[40].

This is a significant benefit to the community and response agencies. The flood mitigation infrastructure performing as designed will provide protection for many properties and buildings up to and including the 1% AEP flood. The benefit is illustrated by Figure 13.

However, floods larger than the design 1% AEP flood will not be contained by this infrastructure. This needs to be understood and incorporated into planning work.

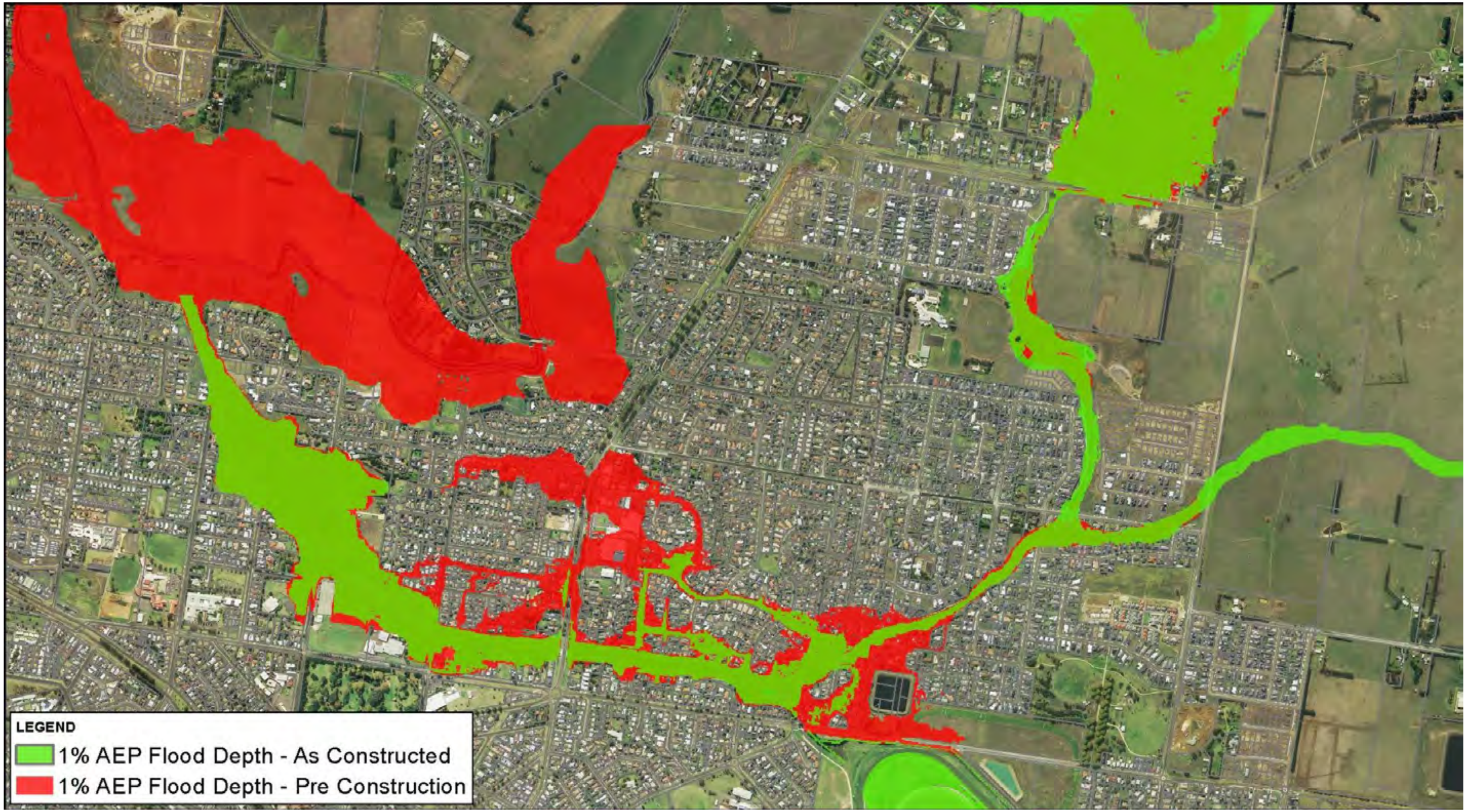



Figure 13. Flood extent reductions due to flood mitigation works (Water Technology 2017)

### 4.1.3 Hopkins River

The Hopkins River rises in The Grampians in the vicinity of Ararat and flows approximately south-west to the confluence with Salt Creek, just downstream of Hexham. The Hopkins then flows south to the confluence with Mount Emu Creek, just upstream of Cudgee. Mount Emu Creek is a major tributary and has a catchment area at Cudgee of 3150km$^2$. The total Hopkins catchment is in the order of 8,700 km2, hence Mount Emu Creek commands approximately 35 percent of the catchment contributing flow to the river system (refer Figure 4).

Up until the 2010/11 floods there was minimal flood information available for the Hopkins River system. Flows within the City are generally contained within the narrow floodplains, with some effluent streams diverging from the river through low-lying agricultural land. This is well understood by the lead agencies in flood planning and response – however much of the publicly available flood information is of unknown reliability. For example – the flood extent shown on Figure 5 depicts a flood flow path through the Allansford township - something not seen during the 2010/11 floods (refer Figure 35). This mapping is deemed to be 'low reliability' by the FDTP. Flood modelling as part of a full flood investigation for the Hopkins River will establish the best available flood information to be used in strategic planning and response.

Figure 14. Hopkins River at Allansford 19 January 2011[3]

### 4.2 Coastal Flooding

Coastal inundation is mostly caused by storm surges combined with high tides (Figure 16) and can be exacerbated in estuaries by rainfall in coastal catchments and river mouth closures. Warrnambool's most recent experience with coastal flooding occurred (most notably) in the South Warrnambool area on 24 and 25 June 2014 (Figure 15).

Figure 15. Storm-tide flooding Merri River mouth – Viaduct Road 24 June 2014[3]

The Victorian Coastal Strategy 2014 establishes the long term framework for the planning and management of the Victorian coastline. It sets out the State's policies on coastal hazards and benchmark for planning for sea level rise. The Victorian Coastal Hazard Guide (2012) says coastal flooding "... may occur during extreme weather, when higher water levels cause seawater to flood land that is normally dry.

The primary causes of inundation are storm surges combining with high tides (storm tides) and extreme wave events. Flooding can be worsened in estuaries by rainfall in coastal catchments." The Guide goes on to say: "Additionally, the effects of climate change are contributing to a progressive permanent increase in sea level that will increase the extent and duration of storm-induced coastal inundation." The mix of factors influencing a storm tide flood is conceptualised in Figure 16.

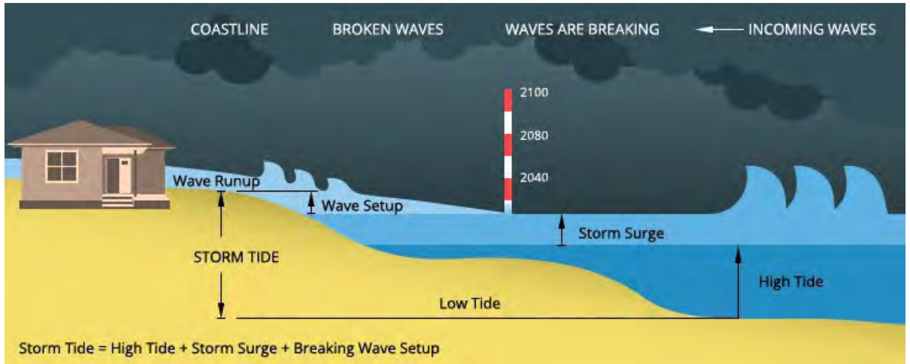



Figure 16. The mix of parameters making up storm tide

Figure 16 provides an illustration of the coastal elements which together result in "storm tide" (coastal) inundation. The timeline indicator conveys the effect of rising mean sea level on storm tide inundation over time.

A significant amount of investigation has been delivered in relation to WCC's coastline, including:

- South Warrnambool Sea Level Rise Investigation 2013
- Warrnambool Coastal Management Plan 2013
- Logans Beach Strategic Framework Plan – Flood Modelling 2017
- Scoping Paper – Local Coastal Hazard Assessment (LCHA) Stage 1

The LCHA aims to build a detailed picture of the region's existing and future coastal hazards and enable prioritisation and focus of current and future coastal planning and management.

Stage 1 is the first in a three stage process for undertaking a coastal hazard assessment. Stage 2 will involve modelling and mapping which may be used by WCC for further planning of its coastline – particularly in the Merri and Hopkins River estuary areas. It may also be important for the risk associated with potential coastal erosion of the dune system and subsequent inundation along the Belfast Coastal Reserve.

The framework for coastal management is described in Figure 17. A clear next step beyond the Local Coastal Hazard Assessment Project is a coastal flood investigation and risk assessment which is further discussed in section 6.5.

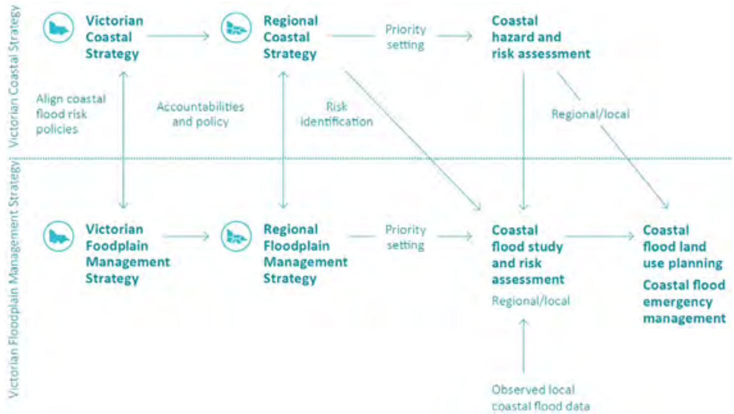



Figure 17. Victoria's coastal flood management framework [26]

Sea level rise (SLR) is an important consideration in relation to coastal flood investigations. The Victorian Coastal Strategy 2014 identifies that Victoria should plan for a SLR of not less than 0.8 metres by 2100 and that 0.9m is currently considered a more conservative option. The VFMS also directs that:

> Accountability 15b - LGAs are accountable for ensuring that their Planning Schemes correctly identify the areas at risk of coastal flooding, and contain the appropriate objectives and strategies to guide decisions in exercising land use controls relating to flooding.
>
> Policy 15e - Planning scheme controls must be applied to all priority coastal

areas, identified through Regional Floodplain Management Strategies, expected to be at risk of inundation by the 1% AEP flood level, taking into account a rise in mean sea level of at least 0.8 metres.

These projections have been derived from (among other sources) the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5). This is consistent with the projections for Warrnambool provided by CoastAdapt (refer Figure 18). Sea level rise is likely to continue beyond the 2100 horizon. As the science continues to emerge, it is **recommended** that sea level rise planning benchmarks are reviewed and updated. AR6 is due out in 2021 and will be a key reference point for a benchmark review.

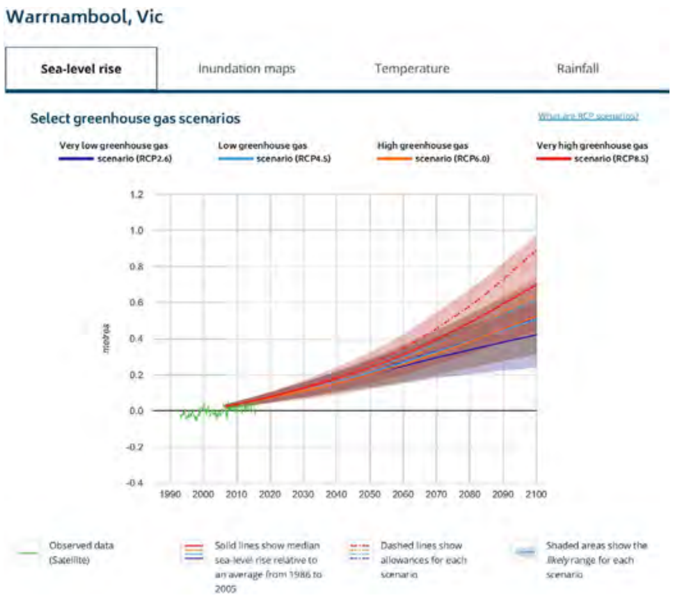



Figure 18. Sea Level Rise Projections for Warrnambool Coastline[c]

## 4.3 Stormwater Flooding

Urban stormwater flooding impacts a number of areas particularly within the Warrnambool and Allansford townships. The causes of the flooding are varied, but in built up areas flooding typically occurs when the capacity of the underground drainage network is exceeded and there is either no, or limited alternative overland flow path available. Local Government Authorities are accountable for managing urban stormwater. Improved management of urban stormwater flooding represents an integrated approach to the management of all forms of flooding, and results in resilient urban water systems which address the impacts of climate change, population growth and new development. The VFMS includes policy (14a) that:

> LGAs, in exercising their urban stormwater flood risk accountabilities, will consider integrated water management options in developing and evaluating measures to manage the urban stormwater flood risks.

WCC has completed recent investigations into stormwater flooding for Warrnambool. Engeny Water Management recently completed modelling for a range of locations across the City that identified 1% AEP flood extents (refer Figure 19). It also considered climate change scenarios and adopted an increase of 12% in intensity for rainfall. The results show a substantial increase in flooding depths and extents for the climate change scenario compared to the 1% AEP baseline (refer Figure 20).

Accountability 14b - LGAs are accountable for applying the planning requirements of Clause 56 of the Victoria Planning Provisions' Practice Note 39 to ensure that new developments do not have significant third party impacts as a result of increased runoff from impervious surfaces.

This Plan identifies areas with a history of stormwater flooding in Section XX and recommends the further exploration of options to avoid increasing community exposure to stormwater flooding.

These options include the revision of Development Plan Overlay requirements to encourage local rainwater harvesting, achieving minimum impervious surface areas to be achieved and investigation of local retardation of flood flows.

The completion of a stormwater infrastructure and asset survey, and identification of possible upgrades is a consideration under Council's infrastructure design and maintenance responsibilities. This has not been further considered by this Plan.

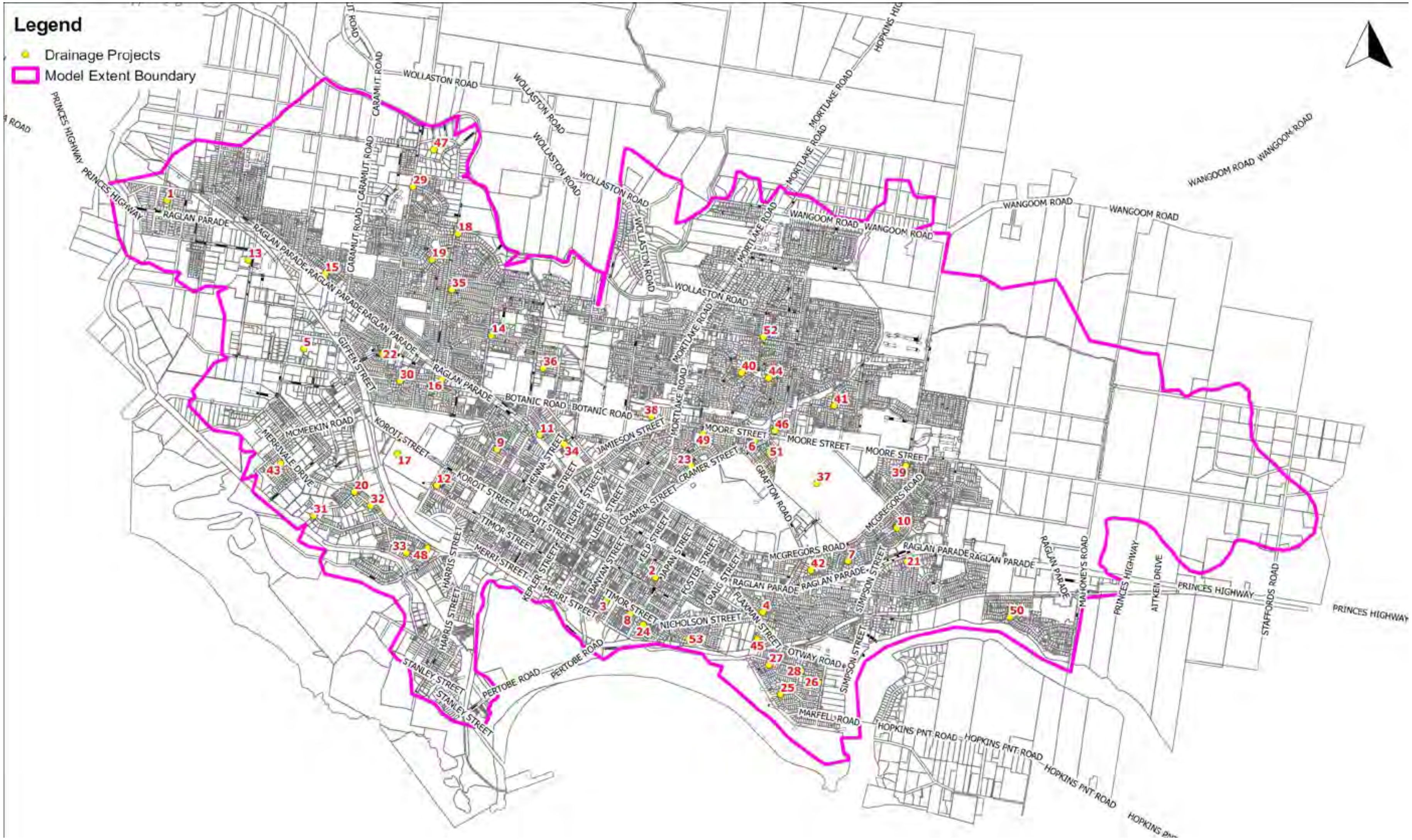



Figure 19. Locations of stormwater modelling across Warrnambool City (Engeny, 2016)


Figure 20.  1% AEP flood extents/depths under climate change scenario (Engeny, 2016)

The Warrnambool City Council Climate Change Action Plan acknowledges the need to "adapt to the physical impacts of climate change". Physical impacts of climate change are typically related to damage to infrastructure such as roads due to temperature variations increasing rainfall intensity (among other factors). The increases in flooding modelled under climate change scenarios demonstrate the likelihood of increase in risk The likelihood and consequence of damage and hazard to life and safety is increased along with flood depth, velocity and extent.

Climate change scenarios vary depending on the projected global temperature and consequently there are typically low, medium or high ranges to consider. There is no consensus on the most appropriate scenario to adopt for a given location or type of investigation. The Engeny report for example adopts a 0.46m sea level rise (by 2090) while other contemporary investigations adopt 0.8m SLR (by 2100) consistent with State policy. Further discussion of the approaches to modelling climate change scenarios is provided in Appendix 2. It is recommended that consistency is sought in the approaches to modelling flooding under climate change scenarios for all future investigations. Current State policy adopts a SLR of not less than 0.8m to be used for planning purposes.

The existing body of knowledge into stormwater flooding has been substantially increased due to the recent investigations. The mapping available shows flood extents and depths for both a baseline (1% AEP) and climate change scenarios. This is valuable information that can now be used to inform flood mitigation, planning and response. Mitigation may involve upgraded stormwater infrastructure where a positive benefit cost ration (BCR) is demonstrated. Planning may involve an adjustment to the planning scheme to include controls that decrease the risk or increase the resilience of development to flooding.

Planning controls may include requiring a floor level freeboard of up to 600mm for new or extended infill development. Over time, this can reduce the burden on emergency services called out to provide real time flood defence installations (e.g. Figure 22). This relates closely to new development in growth areas for which Local Government is:

> Accountable for applying the planning requirements of Clause 56 of the Victoria Planning Provisions' Practice Note 39 to ensure that new developments do not have significant third party impacts as a result of increased runoff from impervious surfaces[26]

The interaction between riverine and stormwater flooding is a significant factor in planning. Indeed interactions between all sources of flooding must be considered, as far as is practicable, in flood estimation and management. Allansford has known issues with its stormwater system and likewise the interaction between stormwater and riverine flooding. As Figure 21 shows, there are situations where a river flood can exacerbate flooding by surcharging stormwater systems. The Tooram Road outfall is a known location for this to occur and emergency efforts were made in the 2010/11 and 2016 floods to prevent this.

Figure 21.  Tooram Road drainage outlet Allansford

Likewise, recent intense storm events have underscored the need for planning and response actions at both a municipal and household level.  Figure 22 and Figure 23 illustrate the results of short, intense rainfall events that overwhelm the local stormwater system.  Whilst planning controls can be put in place to benefit future development – there remains a residual flood risk that requires response planning by both agencies and individuals.


Figure 22.  Sandbagging door of residence on Moore Street 11 October 2017 circa 10am[3]

Figure 23. Stomwater flooding on Wanstead Street 11 October 2017[3]

### 4.4 Flood Warning

Flood warning systems are designed to provide communities and emergency management agencies with information about when flooding may occur, the likely severity and what to do to reduce flood impacts. The Total Flood Warning System (TFWS) concept contains five elements as shown in Figure 24.


Figure 24. Elements of a TFWS[7]

Each element typically consists of:

- Data – a streamflow gauge that indicates the rise of floodwater in the river. Bureau of Meteorology (BoM) weather stations also provide rainfall data
- Forecast – the BoM provide a prediction (forecast) of how high flood waters may rise on the streamflow gauge.
- Modelling – based on the prediction from BoM an estimation of how wide the floodwaters may extend is modelled. The modelling seeks to provide an understanding of what the impacts may be.
- Alert – Notifications to affected communities are issued by the BoM through emergency broadcasters such as the ABC and other media outlets. The alerts are also issued to relevant agencies.
- Response – agencies with a response function enact their flood emergency plans. VicSES is the control agency for flood and responds to emergency calls from the community.

The 2010-11 floods across Victoria exposed deficiencies in the management of TFWS services as no one agency had overall accountability for the co-ordination. Consequently the Victorian Government has made DELWP accountable for the co-ordination of TFWS services at the state level. This will be outlined in a State-level service development plan that is informed by the RFMS.The development of the RFMS included an assessment of the TFWS services provided to the flood-prone communities of the Warrnambool region.

There is no formal TFWS in operation within the Warrnambool City region. However, the BoM issues warnings such as Flood Watches and Severe Weather Warnings that advise on weather conditions that have the potential for flooding. For example – a Flood Watch was issued by the BoM on 4 October 2016. This warning was issued for the southwest region of Victoria. Typically, these warnings are for a larger region where there is no formal TFWS in place.

As is the case with all interventions in floodplain management there needs to be an assessment of the cost, benefit and community value. For each of the three waterways there are range of factors to consider before committing to the implementation of a flood warning system. Within the components of the TFWS (Figure 24) any system must be practically feasible meet the needs of the Warrnambool community – including:

- Levels of flooding at which warnings are required
- The impacts at different levels of flooding
- The warning time available, and the warning time required by the community
- What warning messages should be disseminated
- Frequency of message updates

Consideration must also be given to the local emergency management arrangements and the roles of the emergency agencies must be clearly defined for each component of the system.

### 4.4.1 Russells Creek

A draft Russells Creek Flash Flood Emergency Plan is currently being developed. The Plan describes the Russells Creek catchment as responding rapidly to rainfall events. If the catchment is already wet prior to a significant storm event – this can also increase the response of the catchment. The time it takes for runoff to travel along Russells Creek through Warrnambool varies between 1 and 6 hours. For short and intense rainfall in localised areas the travel time can be less than 1 hour.

A scoping study was completed in 2013 for a Russells Creek TFWS. It highlights the challenges with Russells Creek, in particular:

- The time it takes for rainfall to turn into a flood can be very short (i.e. <6 hours)
- There is no permanent stream gauge
- There are no formal fall gauges in the catchment

Following this study, a discussion paper was delivered for the implementation of a Total Flash Flood Warning System (TFFWS) for Russells Creek. This paper identified that 'while not the cheapest solution, the favoured (and proven) approach is an Event Reporting Radio Telemetry System (ERTS) based data collection network reporting to Enviromon software residing in the WCC office in Warrnambool. A distinct advantage of this approach, (provided that BoM adjust web based tables and maps) is that real-time data from the catchment will be publicly available via the BoM website. The need for a system Administrator within WCC is noted'. This proposed solution has been costed and the technical feasibility tested by the Bureau of Meteorology (BoM) in November 2016 (Figure 25). This work points to a technically feasible solution for which an implementation plan could be considered as a next step (refer section 6.16).


Figure 25. TFFWS base station testing on Aquazone Roof November 2016 (BoM, 2016)

### 4.4.2 Merri River

Unlike Russells Creek there has not been a specific investigation into flood warning for the Merri River. Previous flood investigations suggest there is a delay of approximately 12-18 hours between rainfall in the upper catchment and flood peaks reaching the south Warrnambool area. There is a flow and level gauge at Woodford from which records indicate there is approximately 4 hours travel time for a flood to reach south Warrnambool. In order for formal flood warning activities to be pursued it is considered necessary to introduce telemetered rain gauges through the catchment and install new flow gauges further upstream on Spring Creek and Drysdale Creek.

### 4.4.3 Hopkins River

Without a dedicated flood investigation for the Hopkins River through the Warrnambool area, there is limited information available on flood warning. Travel times from Allansford to the Hopkins River mouth have not been estimated. There are flow and height gauges at Hopkins Falls and Framlingham which would become important components of any bespoke flood warning system. These gauges could be linked to water level monitoring boards at key locations (e.g. Allansford bridge and Mahony's Road). These in turn could be linked to the existing water level monitoring board at the Simpson Street boat ramp (refer Figure 26).


Figure 26. Simpson Street boat ramp water level monitoring board


Figure 27. Simpson Street water level monitoring board during 24 June 2014 flood[3]

### 4.5 Floodplain Ecological and Cultural Values

Local indigenous people are thought to have given the area its name. Warrnambool may be an anglicised version of Warrnimmble, phonetically spelt according to the pronunciation of indigenous people circa 1830. It is thought it was the name of a local chief from the area . The Eastern Maar are Traditional Owners of south-western Victoria. Eastern Maar is a name adopted by the people who identify as Maar, Eastern Gunditjmara, Tjap Wurrung, Peek Whurrong, Kirrae Whurrung, Kuurn Kopan Noot and/or Yarro weatch (Tooram Tribe) . Eastern Maar land extends from Ararat in the north and encompasses the Warrnambool City Council area.

> ...works must consider significant places, sites and landscapes through consultation with Traditional Owners.

There is a limited amount of formal knowledge of Indigenous cultural values associated with Warrnambool region floodplains. We know more generally that Indigenous people frequently used the coast and waterways for gathering food, shelter and navigation. The Moyjil Aboriginal Place Point Richie Management Plan is a good example of cultural heritage management that is directly related to Warrnambool's floodplains (refer Figure 28).

The focus area is the mouth of the Hopkins River but the plan acknowledges that the whole river is significant to the Easter Maar people.

Consequently, all floodplain management activities both structural and non-structural may have impacts on Indigenous cultural heritage. Regional flood assessments, local flood studies and flood mitigation works must consider significant places, sites and landscapes through consultation with Traditional Owners. The Aboriginal Heritage Register is a valuable resource; however, Traditional Owners have a much broader information base about Aboriginal cultural heritage than is currently available to government. Therefore, it is essential to consult with Traditional Owners in assessing and mapping flood risks.

Figure 28. Moyjil Point Richie area 12 August 2010[3]

European and Chinese cultural heritage may also play a role in the future of floodplain management for the region. The construction of the Merri Cutting and Bromfield Weir represent significant projects in the historic narrative for the Warrnambool region. Further, Chinese gardens are referred to frequently in newspaper reports of Merri River flooding during the 19th century. Any future structural projects may need to consider this further in the planning phase.

Warrnambool's Open Space Strategy (2014) suggests less than 10% of native vegetation remain within the Warrnambool City area. This strategy also highlights the important role Warrnambool's open spaces will have in returning beneficial habitat and creating wildlife corridors. As much of this open space is located within floodplain areas, this presents an opportunity to build ecological benefits into both structural and non-structural projects. WCC is currently reviewing its Environmental Significance Overlay for the Hopkins and Merri Rivers and will consider this opportunity.

A key source of environmental information is the Ecological Vegetation Class (EVC) mapping for the region. Four key EVCs are mapped within Warrnambool's floodplains refer Table 5 and Figure 30. Their bioregional conservation status is either endangered or depleted. Again, this points to the opportunity to build ecological opportunities into floodplain management for Warrnambool. It is **recommended** that measures to maintain and enhance remnant EVC values and ecological opportunities are considered within the delivery of this Plan.

**Table 5. Key EVCs for the Warrnambool region**

| Ecological Vegetation Class | Number | Bioregional Conservation Status |
|---|---|---|
| Plains Grassy Woodland | 55 | Endangered |
| Damp Sands Herb-Rich Woodland | 3 | Endangered |
| Coastal Dune Scrub | 160 | Depleted |
| Swamp Scrub/Aquatic Herbland Mosaic | 720 | Endangered |

The Kelly's Swamp area extends to the west of the Merri River downstream of the Dennington bridge. A series of wetlands extend west from the Merri River behind the Belfast Coastal Reserve. During significant flood events, flows from the Merri River push westward and drain through Rutledges Cutting into the sea (Figure 29). The storage and flood attenuation function of this area is not well known. Further the ecological value of the intermittent flooding of the area is similarly not well documented.

Figure 29. Kelly's Swamp area looking north (Dennington in background)[3]

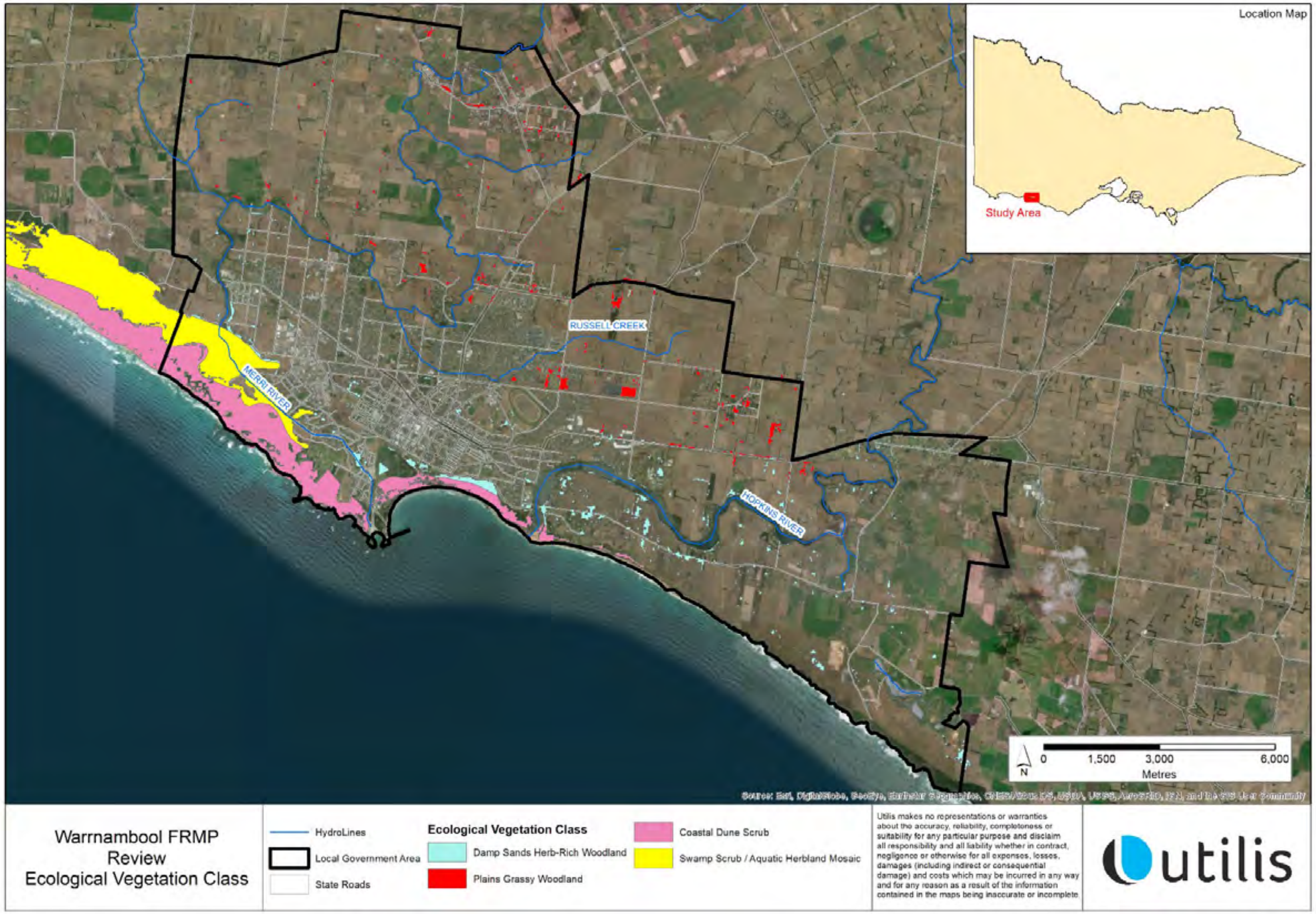



Figure 30. Warrnambool region's EVCs

## 4.6 Land Use Planning and Development

The use and development of land can both influence and be impacted by flooding. Planning policy and provisions enabled under the Planning and Environment Act 1987 (the Act), and implemented by municipal Planning Schemes, are an essential component to management of land use and development occurring on floodplain areas and reducing the exposure of new development in Warrnambool to flood risk.

It is widely recognised that land use planning and building controls are generally more cost effective than other flood mitigation options including flood mitigation infrastructure. Effective land use planning therefore directs development to appropriate locations where the degree of flood risk is compatible with urban development, and away from areas where the level of flood risk is incompatible with development..

Section 62(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous'.

State planning policy for floodplain management requires, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions. The statutory authorities responsible for the collection of flood information and for land use planning in flood-affected areas are councils and floodplain management authorities.

As described in the VFMS, the Victorian Planning Provisions (VPP) (refer Figure 31) set out a framework from which all Victorian Planning Schemes are constructed. Flood controls in Planning Schemes include local policies addressing flood risks within a municipality, a zone and overlays with associated schedules. These are detailed in Planning Practice Note 12: Applying the Flood Provisions in Planning Schemes (Victoria State Government, 2015).


Figure 31. The legislative context of planning schemes in Victoria[6]

### 4.6.1 Warrnambool Planning Scheme:

An assessment of the flood related planning provisions considered relevant to dealing with flood risk exposure in Warrnambool is outlined below. Discussion of possible amendments to the Planning Scheme is included and options are listed for further consideration in section 6.

It has been acknowledged that the significant resources required to facilitate the Planning Scheme Amendment process is a barrier to updating planning schemes. A particular example of this is planning for coastal flooding which requires particular expertise and resourcing. Funding to assist Council's to update their Planning Schemes has been announced as part of the VFMS.

This Plan identifies a range of options related to land use planning policy and processes. In the course of actioning these options, it is likely that amendment to the Local Planning Policy Framwork (LPPF) would be undertaken accordingly.

The LPPF may also include references to elements of flood risk less adequately represented by suitable zone and overlay provisions, and in doing so provide additional guidance to statutory and strategic planning decision making. Opportunities relevant to Warrnambool City may include the identification of policy objectives and strategies which recognise the:

- Importance of cross municipal boundary coordination of upper catchment areas.
- Locations prone to flood risk during events larger than a 1% AEP flood.
- Degree of protection afforded by a levee or other structure
- Coastal flood risk and a description of places likely or known to be at risk.

Further discussion of the application of the State Planning Policy Framework (SPPF) and LPPF is provided in Appendix 4: Floodplain Planning Policy.

NOTE: The Victorian Planning Provisions (VPP) and structure of all Victorian Planning Schemes are soon to be altered by combining the SPPF and LPPF. It is understood that local policy considerations will be appropriately represented under this new structure. This report has been prepared on the basis of the current Planning Scheme as at July 2018.

Amendment C78

Amendment C78 Part 1 was gazetted on 21 January 2016. The amendment applies to land within the Merri River and Russell Creek floodplains as identified as being liable to flooding and inundation during a severe storm of 1 in 100 year intensity. Following exhibition, Amendment C78 was split into two parts. Amendment C78 Part 1 generally consists of:

- Russell Creek floodplain (downstream of Bromfield Street)
- Merri River floodplain in South Warrnambool (upstream of Block Street)
- Merri River floodplain in North Warrnambool (except for areas adjoining Membery Way, 123 Queens Road, and 2-18 Daltons Road).

Part 2 of the amendment applies to land downstream of Block Street and other sites where submissions of objection were received. The mitigation works and subsequent remodelling of flood levels for Russells Creek have been completed allowing progress with C78 Part 2 to commence.

This Plan includes a number of recommendations that are intended to inform the progression of Part 2, in particular the calibration of available flood data.

### Flood Zone and Overlay Controls:

Flood zone and overlay controls are based on the extent of flooding resulting from 1% AEP flood. This relates to a flood event which has a one per cent chance of occurring in any given year. The VPPs and associated practice notes currently describe a flood of this magnitude as a 100 year ARI flood. This information assists in the consideration of the development and redevelopment of land, determination of appropriate uses and assists in the design of stormwater drainage systems.

Discussion of available Zone and Overlay controls and their application within the Warrnambool Planning Scheme is provided below:

### Urban Floodway Zone (UFZ):

The UFZ has typically been applied to mainstream flooding in urban areas where the primary function of the land is to convey active flood flows. It applies to urban floodway areas where the potential flood risk is high due to the presence of existing development or to pressures for new or more intensive development. The UFZ restricts the use of such land, as the risk associated with flooding renders it unsuitable for any further intensification of use or development. Unlike the overlay controls, the UFZ controls land use as well as development.

The UFZ is applied extensively within Warrnambool, extending along urban areas adjoining the Merri River and Russell Creek (refer Figure 32 and Figure 33).

As an alternative, a flood overlay can be used in conjunction with an appropriate zone (such as the Floodway Overlay and the Public Park and Recreation Zone) to enable the primary use of the land to be recognised at the same time as acknowledging its flooding characteristics (Planning Practice Note 12, June 2015).

This approach may be suited to Warrnambool, as it aligns with Council's aspirations that all floodplain locations form part of open space networks as directed by strategies included within Clause 21 of the Planning Scheme.

### Floodway Overlays (FO):

The FO applies to land that's identified as carrying active flood flows associated with waterways and open drainage systems and can applied in urban and rural settings. This overlay is generally categorised by flood depths in excess of 0.5m and/or where the product of depth and velocity is 0.4m2/s or more. The FO is suitable for areas where focus is more on control of development.

The FO is applied extensively within Warrnambool, extending along urban areas adjoining the Merri River and Russell Creek.

### Land Subject to Inundation Overlays (LSIO):

The LSIO applies to mainstream flooding in both rural and urban areas. In general, areas covered by the LSIO have a lower flood risk than UFZ or FO, generally with lower flood depths and velocity.

Within Warrnambool, the LSIO covers the balance of land subject to inundation, except the floodway area where the UFZ and FO have been applied.

### Special Building Overlays (SBO):

The SBO is a control that identifies areas prone to overland or stormwater flooding. The purpose of these overlays is to set appropriate conditions and floor levels to address any flood risk to developments. These overlays require a planning permit for buildings and works. The application of an SBO is not presently utilised within the Warrnambool Planning Scheme.

While it is recognised that the SBO commonly applies to stormwater flooding in urban areas only; further exploration in consultation with DELWP is recommended to explore its application for stormwater and/or riverine flooding behind the North Warrnambool flood levees.

### Local Floodplain Development Plans (LFDP):

Each of the flood controls identify the opportunity to prepare precinct specific FDMP's, for either existing developed areas and forecast urban growth areas affected by flooding. Future land use and development must consider the FDMP under the various flood overlay controls available.

A local floodplain development plan should include:

- Flood history
- Information sources
- Flood impacts
- Climate change
- Cultural values
- Flora, fauna and other environmental values and constraints
- Development guidelines for permissible subdivisions, buildings and works, including earthworks.

It is recognised that the application of a FDMP commonly coincides with a flood related zone or overlay control, however such a plan may be prepared and applied to locations where conventional flood control is not able to be applied. Its application within the planning scheme occurs through incorporation at clause 81, and strengthened in Local Policy (with an appropriate location map assisting in community awareness).

### Environmental Significance Overlay - Schedule 2 (ESO2):

Whilst not a flood related planning control, the application of ESO2 within the Warrnambool Planning Scheme for the protection from inappropriate development, states that:

> "the Hopkins and Merri River environs should be retained as natural drainage corridors with vegetated buffer areas wherever possible in order to perform their long term function as drainage areas, stream habitat and landscape areas. Erosion and polluted surface runoff from adjacent land uses should be minimised. Emphasis needs to be placed on the restoration and revegetation

of degraded streamsides. The Hopkins River has a significant tidal estuary, and both rivers contain important fish stocks and provide a habitat for rare and threatened species."

The application of the ESO2 provides an extremely valuable addition to floodplain management within Warrnambool.

### Design and Development Overlay (DDO):

The Warrnambool Planning Scheme includes 17 DDOs to guide various design outcomes for development and redevelopment. The purpose of the DDO is "to identify areas which are affected by specific requirements relating to the design and built form of new development."

The DDO also requires a planning permit for further subdivision of land in accordance with the requirements of the schedule.

These provisions may provide reference to appropriate building design requirements for the retention of permeable space, or which consider possible or predicted long term flood exposure where other flood overlay controls are not appropriate or warranted (i.e. land that is unencumbered by a 1%AEP flood event as the result of structural flood mitigation infrastructure).

### Building Regulations:

A building permit is required for the construction or significant alteration of most buildings in Victoria. This process is independent of the land use planning process and is regulated under the Building Act 1993 and the Building Regulations 2006. The VFMS directs DELWP and the Victorian Building Authority to work together to improve the effectiveness of the flooding provisions of the Building Code of Australia.

> Policy 13a – The 1% Annual Exceedance Probability flood will remain the design flood event for the land use planning and building systems in Victoria

Building Regulations 2018, Division 2 (Definitions and interpretations) provides that:

> For the purposes of subregulation (1), land is in an area liable to flooding if—
>
> (a) by or under the Water Act 1989 it is determined as being liable to flooding (however expressed); or
>
> (b) it is identified in a planning scheme under the Planning and Environment Act 1987 as being in an area liable to flooding (however expressed); or
>
> (d) it is designated by the relevant council as likely to be flooded by waters from—
>
> > (i) a waterway, as defined in section 3(1) of the Water Act 1989; or
> >
> > (ii) any land upon which water concentrates or upon or over which surface water usually or occasionally flows (whether in a defined channel or otherwise) including land affected by flow from a drainage system.

Section 153 of the Building Regulations (report and consent for building in areas liable to flooding) provides that:

> (2) The report and consent of the relevant council must be attached to an application for a building permit if the site is on an allotment that is in an area liable to flooding.
>
> (5)(2) the relevant council may specify a level for the surface of the lowest floor of a building on the site.

Considering the provisions listed above, further exploration in consultation with the GHCMA regarding the designation of either a **special area** or an area **liable** to flooding under the Building Regulations may be considered appropriate for locations where standard flood controls provided by the Planning Scheme do not suitably apply.

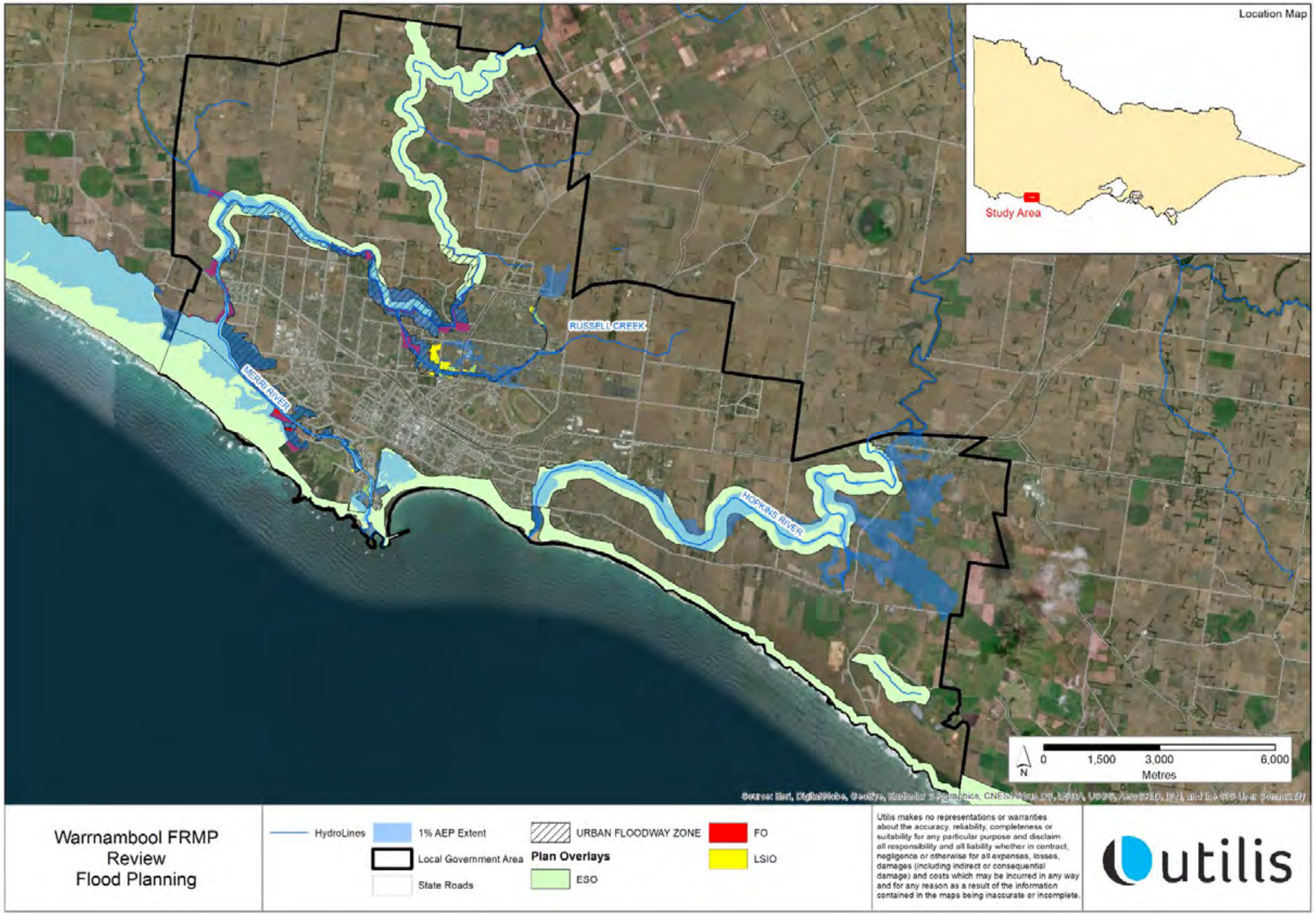



Figure 32. Existing flood and environmental controls for the WCC region

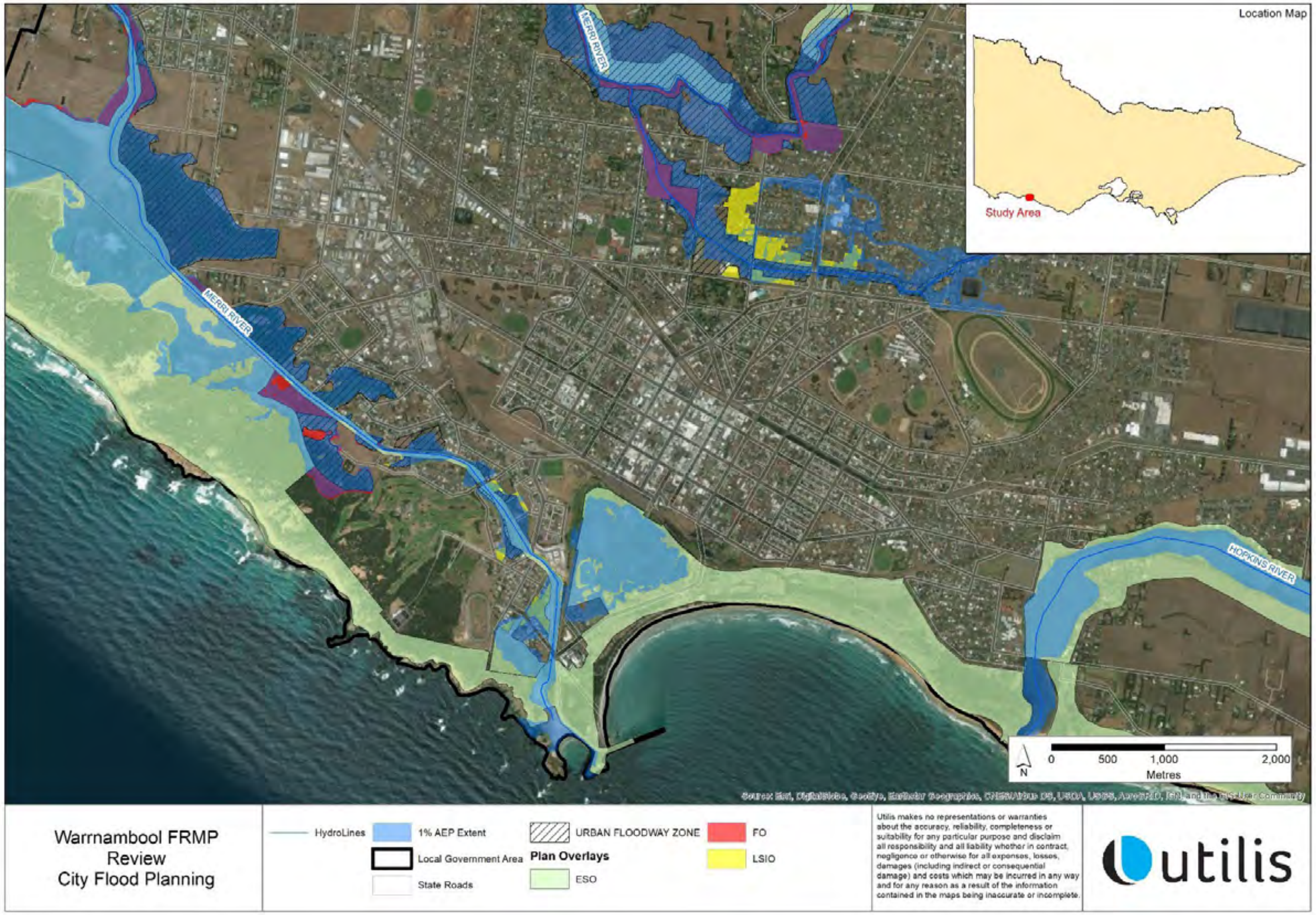



Figure 33. Existing flood and environmental controls for Warrnambool City

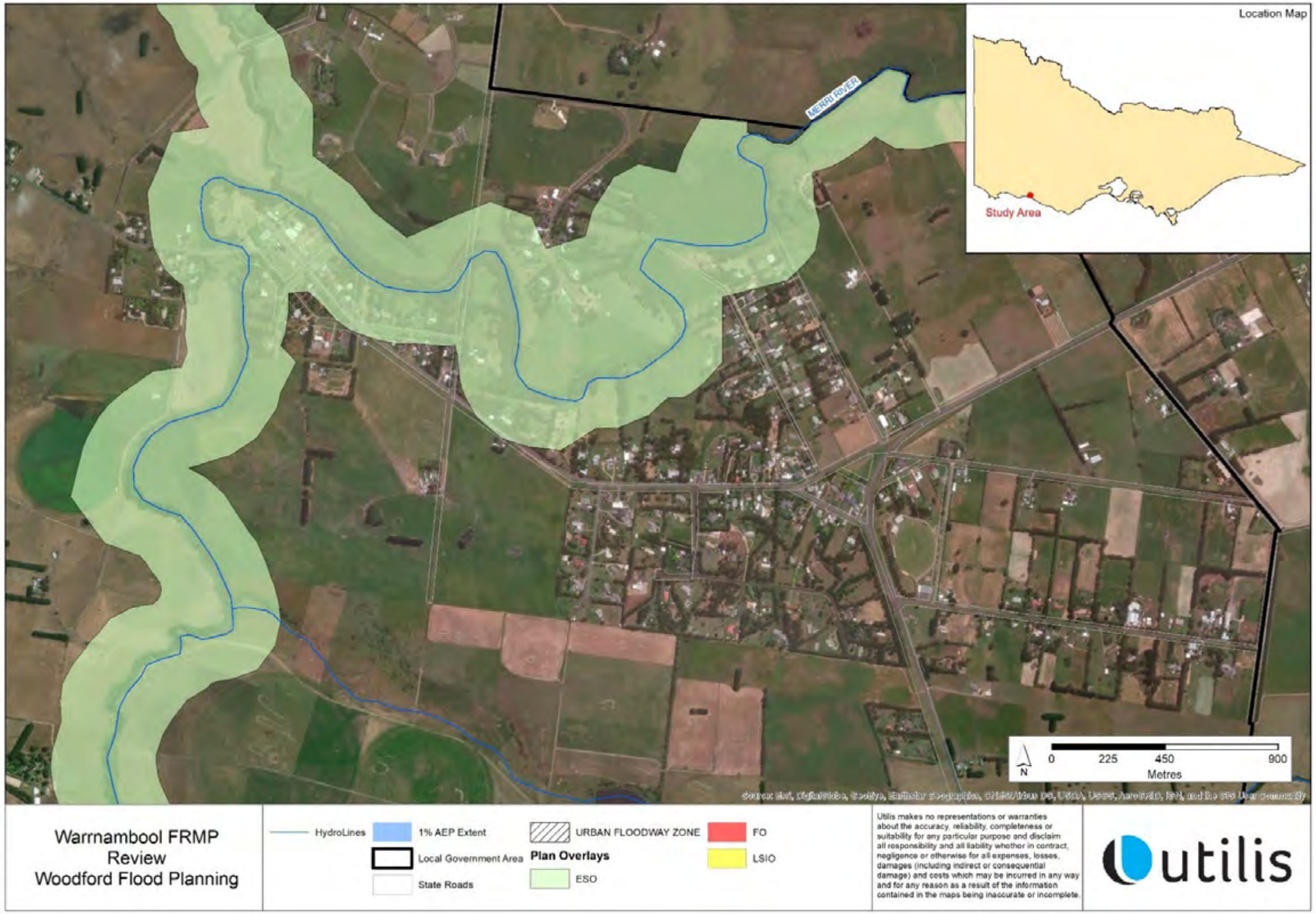



Figure 34. Existing flood and environmental controls for Woodford (no flood controls at present)

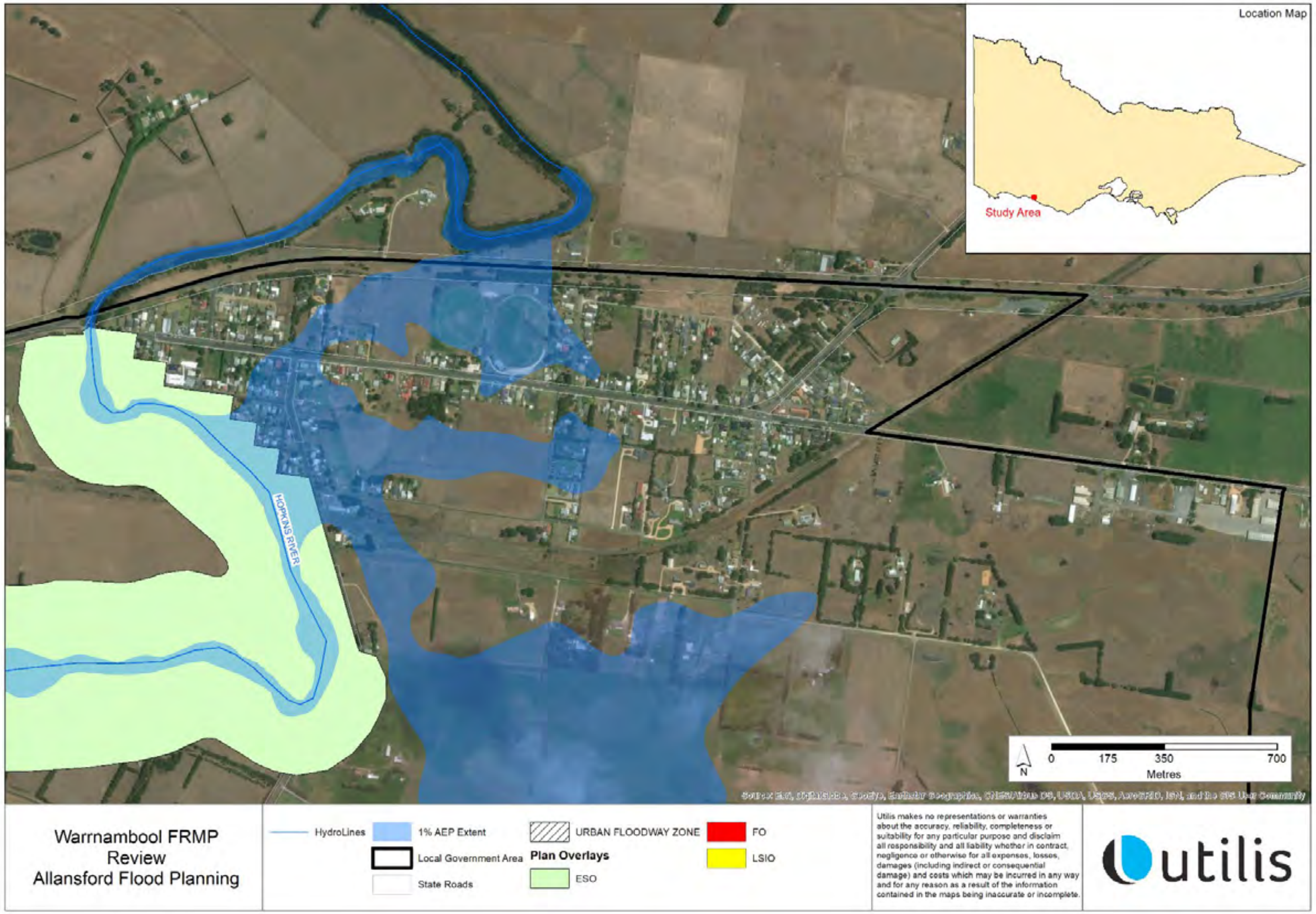



Figure 35. Exising flood and environmental planning controls for Allansford

# 5 Management Plan

This management plan identifies and compares options to manage flood related challenges, together with opportunities to enhance floodplain and cultural environments. A successful floodplain management plan requires a comprehensive multidisciplinary approach and active community consultation. Selection of the optimum mix of management measures is challenging as it requires compromises, professional judgment and local knowledge. The Plan identifies constraints and opportunities for managing flood risk to Warrnambool communities.

The Plan responds to the overarching Council Plan (2017-21) objectives - specifically:

- Sustain and enhance the natural environment
    - Protected waterways, coast and land
    - Preparedness for climate change
- Foster a healthy city that is socially and culturally rich
    - Resilience in emergencies
- Maintain and improve the physical fabric of the city
    - More fit-for-purpose infrastructure
    - Greater amenity and ease of movement

## 5.1 Stakeholder Engagement

Consultation with key stakeholders is an essential element in the floodplain management plan development process. Engagement with key stakeholders has been primarily delivered through the Project Control Group (PCG) and Technical Working Group (TWG). The TWG met formally over four sessions to guide the development of the Plan. In between this, consultation included phone conversations, emails and one-on-one meetings with the relevant agencies and individuals.. Some of the key feedback of the stakeholder engagement process included:

- Ensuring that the Plan incorporates cultural heritage considerations and the need to ensure future projects provide for these values.
- The importance of pursuing both flood warning and coastal flooding projects. Flood warning for Russells Creek and Merri River were considered important future considerations particularly by response organisations. Coastal flooding (storm surge) has not had the scrutiny of other detailed flood investigations and is considered an important future consideration for South Warrnambool in particular.
- Raising the awareness of the community to the risk of flooding is also considered important among the stakeholder group. Giving residents the tools and information to understand their level of flood risk along with measures they can take to respond to it, is considered important.

## 5.2 Community Engagement

Community engagement was an important component in the development of the Plan. A significant portion of Warrnambool's population either live or work on or near the floodplain of Russells Creek and the Merri and Hopkins Rivers. Others live and work in low lying areas that may be subject to stormwater flooding. Many more experience flooding by being inconvenienced due to road or bridge closures. Therefore, WCC's response to floodplain management through this Plan has the potential to impact a significant population directly or indirectly. Floodplain management has a positive impact on communities by seeking to minimise their exposure to flood risk over time. A good example is the North Warrnambool Flood Mitigation project which has significantly reduced flood risk for a large number of people. However, not all flood risk can be removed completely, and not all issues and challenges can be addressed at once. There are other social, economic and environmental factors important to communities that need to be addressed as well. Hence the need for a five year Plan that prioritises what needs to be done and when.

Communities help with the prioritisation process by identifying what is important to them in relation to flooding. It may relate to flood mitigation (ways to reduce flooding), planning (ways to live with flooding) or response (what to do when it floods). The level of importance to a community will vary depending on what their experience is with flooding, where they live or work and what their values are.

The Plan incorporates community feedback and places a value on community acceptance in the prioritisation of floodplain management options (refer section 5.4). This feedback has been sourced by making the draft Plan available to the public website, social media and a drop in day on 31 July 2018. In particular – community feedback provided for the 'community acceptance' scores for each of the management options.

### 5.3 Vision, Objectives and Guiding Principles

Warrnambool City seeks to ensure that the high risk component of the floodplain – the 'floodway' is managed for the most appropriate use. These areas are typically close to the river or creek itself – it is where flood water is deep and/or flows fast. But when it is not in flood – these areas draw people for walks, fishing, boating, picnics and many other forms of recreation and relaxation. This is considered the best use of floodway land – there is room for water when it floods – and for the rest of the time - room for people and activities.

Warrnambool City's overarching vision is to be "a cosmopolitan city by the sea". The Plan, whilst having its own vision and objectives needs to contribute to this. It also needs to fit within the broader context of State and regional vision for floodplain management illustrated in Figure 36.

Both the VFMS And RFMS have very similar objectives for floodplain management:

1. **Encourage communities to act responsibly to manage their own risks**
2. **Flood risks are reduced through improved flood intelligence and mitigation**
3. **Not making things worse**
4. **Emergency agencies are provided with the support to manage flooding.**

The Warrnambool Floodplain Management Plan has been developed to complement the vision, objectives and expected outcomes of the VFMS and RFMS. At the municipal level, there is no merit in adopting these directly given the differences in scale. Recognising this, the Plan seeks to 'localise' a vision and set of objectives and outcomes. The vision developed for the Plan acknowledges that there is constant and increasing change both in societal, economic and environmental aspects of community life. In particular, climate change, demographic and technological change will continue to create challenges and opportunities for floodplain management. Key to living with change is resilience which is foundational to the vision for the Plan (Figure 36).


Figure 36. Vision for the Plan within the broader City, State and Regional vision

The focus on resilience is derived from the long history and substantial body of knowledge of flooding across the Warrnambool region. While there is much more to plan for and understand – much is already known through experience and modelling about where it floods and to what extent. While there will always be a need to update flood mapping and response intelligence – in parallel is the need to raise community resilience in relation to residual and future (through climate change) flood risk.

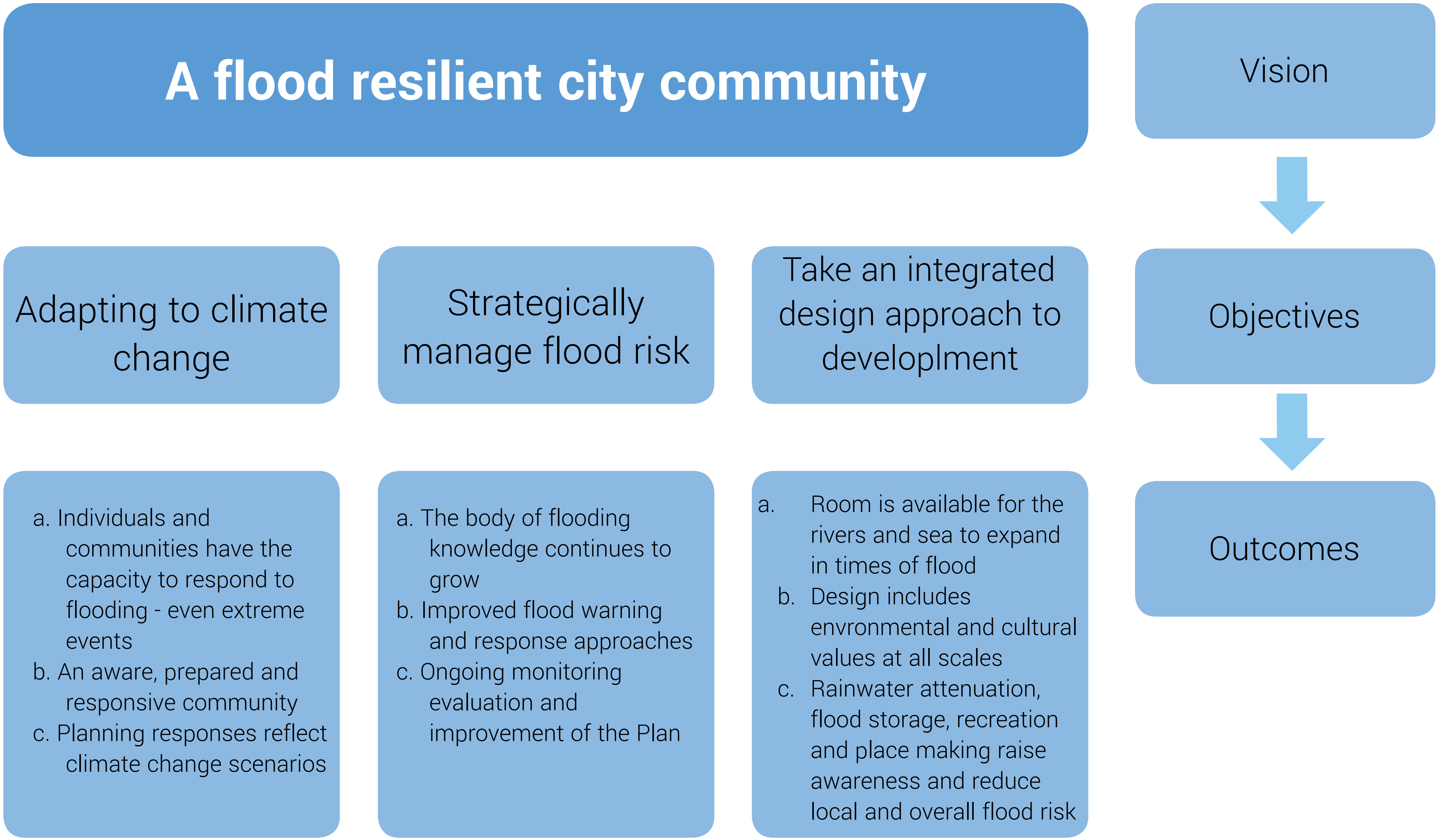



Figure 37. Vision, objectives and expected outcomes for the Plan

The guiding principles to support the vision, objectives and expected outcomes include:

- Protecting life, assets, the nature environment and social amenity as a priority
- Sharing responsibility for floodplain management between local agencies, communities, business and individuals
- A proactive risk management approach
- A consultative and informed approach
- Recognition that all flood risk cannot be eliminated
- Recognition of individual responsibility

## 5.4 Multi-Criteria Assessment

There are a number of factors to be considered when assessing options to progress floodplain management. Cost-benefit ratios (BCRs) do not reflect the range of factors to be considered (e.g. wellbeing, environmental, technical), and therefore do not provide a full picture of an option's merit. BCR analysis should be considered on a project by project basis however any subsequent decisions made that are based on BCR need to understand that the true cost of floods is far higher than the economic damages alone. These intangible costs have the effect of increasing the BCR, strengthening the argument for completing further flood mitigation, planning and response actions.

To provide a basis for comparing options a multi-criteria matrix has been developed, assigning scores to each of the listed criteria. An option that has a negative score would not be considered to have merit, while positive scores indicate that there are more pros than cons, and that the option should be considered further. The scoring system for the selected criteria is provided in Table 6.

Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further.

The TWG had the role of guiding the development of the plan to ensure it responds appropriately to the challenges and context of the Warrnambool City. As professionals in their own floodplain management discipline, they have expertise and experience to bring to bear upon the assessment of the options. Consequently, their assessment has been incorporated through a workshop exercise in applying an individual loading to options considered more important and/or urgent. The scores from the TWG were collated and this loading applies a score which either increases or decreases the overall priority of a management option.

**Table 6. Multi Criteria Assessment Matrix**

| Measure/Score | -3 | -2 | -1 | 0 | 1 | 2 | 3 | Explanation |
|---|---|---|---|---|---|---|---|---|
| Economic Merits | major disbenefit | moderate disbenefit | minor disbenefit | neutral/ unknown | minor benefit | moderate benefit | major benefit | An estimate of capital and recurring costs versus reduction in flood risk/damages or overall benefits |
| Financial Feasibility | high unlikelihood | medium unlikelihood | minor unlikelihood | neutral/ unknown | low likelihood | medium likelihood | high likelihood | Sourcing funding can be challenging. This criteria gives a consideration for obtaining local, state and/or federal funding for the option. |
| Environmental and Cultural benefits | major disbenefit | moderate disbenefit | minor disbenefit | neutral/ unknown | minor benefit | moderate benefit | major benefit | This provides a consideration for the impact on environmental/cultural values. |
| Impacts on VicSES | major disbenefit | moderate disbenefit | minor disbenefit | neutral/ unknown | minor benefit | moderate benefit | major benefit | All floodplain management measures can have an impact on response agencies. |
| Regulatory/ Administrative Issues | major negative | moderate negative | minor negative | neutral/ unknown | minor positive | moderate positive | major positive | This relates to reputational, legal or institutional challenges associated with an option |
| Impact on Flood Behaviour | major negative | moderate negative | minor negative | neutral/ unknown | minor positive | moderate positive | major positive | Projects may have a direct or indirect impact on flood behaviour e.g. planning schemes have a long term positive impact. |
| Community Acceptance | major disapproval | minor disapproval | minor disapproval | neutral/ unknown | minor approval | moderate approval | major approval | The level of comfort the community has with a particular option |
| Technical Complexity | major negative | moderate negative | minor negative | neutral/ unknown | minor positive | moderate positive | major positive | This relates to the level of complexity that comes with the option. It can be technically difficult to model a flood. It can be technically difficult communicating flood risk. |
| Innovation | major negative | moderate negative | minor negative | neutral/ unknown | minor positive | moderate positive | major positive | This refers to the level of innovation that a particular project incorporates. A high level of innovation will be considered better practice. |
| Scale of Impact | major disbenefit | moderate disbenefit | minor disbenefit | neutral/ unknown | minor benefit | moderate benefit | major benefit | This refers to the size of impact on relevant area, residents or infrastructure. |
| Quick Win | Beyond five years | within five years | within three years | neutral/ unknown | within one year | within six months | start immediately | This refers to the speed with which the project can be implemented and completed, thus allowing a 'quick win' to be achieved by undertaking the project. |

# 6 Floodplain Management Options

The Floodplain Management Plan development process under the direction of the Technical Working Group has identified and assessed a range of management options for WCC's floodplains. The options are assessed using the multi-criteria analysis. These options are summarised in a prioritised plan of action for the management of flood risk in the WCC region.

The options identified are broken down into three broad categories. These categories reflect those identified by the NSW Government Floodplain Development Manual.

**Flood mitigation measures** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered where practical.

**Planning/property measures** modify the existing land use and development controls for future development. This is generally accomplished through such means as undertaking flooding investigations, strategic planning such as land use zoning, building regulations such as flood-related development controls, flood proofing, house raising or sealing entrances, or voluntary purchase/voluntary house raising.

**Response measures** modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

**Table 7. Summary of MCA Outcomes**

| Ref | Option | Economic Merits | Financial Feasibility | Environmental Cultural | Impact on vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win | TWG Loading | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | Develop a vegetation management plan and MoU for Russells Creek | 1 | -1 | 1 | 1 | -2 | 1 | 2 | 1 | 2 | 1 | -1 | -5 | -1 |
| F2 | Install a backflow prevention for Tooram Lane outfall | 1 | -1 | 0 | 3 | 2 | 1 | -1 | 3 | -1 | 0 | 1 | 1 | 9 |
| F3 | Develop a concept design for channel and floodplain improvements | -1 | -1 | 3 | 1 | -1 | 1 | 3 | -1 | 3 | 1 | -2 | 2 | 8 |
| F4 | Establish an operating procedure for North Warrnambool flood levees | 3 | 3 | 0 | 3 | 3 | 2 | 1 | 3 | 0 | 3 | 3 | 2 | 26 |
| Planning Measures | | | | | | | | | | | | | | |
| P1 | Undertake Warrnambool coastal flood investigation | -1 | 1 | 1 | 2 | -1 | 2 | 2 | -1 | 2 | 2 | 0 | 5 | 14 |
| P2 | Undertake Allansford flood investigation | 1 | -1 | 2 | 3 | 1 | 3 | -1 | -2 | 1 | 1 | 0 | 3 | 12 |
| P3 | Undertake Woodford flood investigation | 2 | -1 | 1 | 3 | 1 | 3 | -2 | 2 | 1 | 3 | 0 | 0 | 12 |
| P4 | Undertake Russells Creek crossings assessment | -1 | 1 | 0 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 2 | -3 | 9 |
| P5 | Warrnambool flood models integration | -1 | 1 | 0 | 0 | 1 | 3 | 0 | -1 | 1 | 1 | 1 | 2 | 8 |

| Ref | Option | Economic Merits | Financial Feasibility | Environmental Cultural | Impact on vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win | TWG Loading | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P6 | Develop guidelines for cost sharing for stormwater flood mitigation infrastructure | 2 | -1 | 0 | 0 | -2 | 0 | -3 | 2 | 1 | 1 | -2 | 1 | -1 |
| P7 | Investigate the introduction of Special Building Overlays or Design Development overlays | 2 | 2 | 0 | 2 | -3 | 0 | 3 | -1 | 2 | 3 | -2 | -1 | 7 |
| P8 | Introduce a local Floodplain Development Plan | 1 | -1 | 2 | 2 | -2 | 0 | 2 | -1 | 1 | 2 | -2 | 0 | 4 |
| P9 | Investigate the replacement of the UFZ for public land | -2 | 0 | 3 | 1 | -2 | 0 | 0 | -1 | 3 | 3 | -1 | -7 | -3 |
| Response Measures | | | | | | | | | | | | | | |
| R1 | Develop a flood response plan template for residents | 1 | 1 | 0 | 3 | -1 | 0 | 2 | -1 | 2 | 3 | -1 | 4 | 13 |
| R2 | Undertake rapid assessment of WCC's rural roads | 1 | 1 | 0 | 2 | 0 | 0 | -3 | 1 | 2 | 3 | 0 | -3 | 4 |
| R3 | Implementation a TFFWS for Russells Creek | 0 | 2 | 0 | 3 | 0 | 0 | -2 | 1 | 3 | 3 | 0 | 2 | 12 |
| R4 | Engage with St Josephs Primary school on flood response and access arrangements | 2 | 2 | 0 | 2 | 1 | 0 | -1 | 2 | 1 | 0 | 0 | -3 | 6 |
| R5 | Undertake community flood education engagement activities | 1 | -1 | 1 | 2 | 0 | 1 | 3 | -1 | 1 | 2 | -1 | 1 | 9 |

The description of the option, MCA assessment and a further description of the estimated outputs and outcomes for each option is provided below.

### 6.1 Option F1 – Develop a vegetation management plan for Russells Creek

The Russells Creek Engineering Assessment (2011) identified particular instream species of vegetation that may exacerbate local flooding during small events. This vegetation both native and exotic was also suggested to increase the risk of blockage at a number of crossing locations.

This option seeks to develop a management plan to maintain instream and riparian vegetation in a way that minimises flooding impacts while not being detrimental to environmental and cultural values. One of the contributors to the weed growth and spread is garden waste being dumped in the creek. The Plan should consider ways (e.g. signage) to discourage this behaviour. This option is considered to have positive overall return on investment through overall reduced flood damages where the plan can deliver flood risk benefits over the long term. Funding for the plan may be difficult to obtain through typical external funding sources and may need to be included in recurrent budgets.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1 | 1 | 1 | -2 | 1 | 2 | 1 | 2 | 1 | -1 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | GHCMA¬ | $20k<br><br>2018 | F3 | Take an integrated design approach to development. |

| Outcomes |
|---|
| It is expected that a Management Plan will be accompanied by a MoU between WCC, GHCMA and other Authorities to enable works to occur as scheduled and to an agreed standard.<br>A comprehensive Management Plan will enable works that will reduce the risk of structure blockage and the exacerbation of localised flooding. A well designed plan may result in positive environmental and aesthetic externalities. |

### 6.2 Option F2 – Install backflow prevention at Tooram Lane outfall

The 2010/11 flooding on the Hopkins River put areas of Allansford at risk both in the September 2010 and January 2011 events. Coupled with drainage issues in the town, part of the response effort focussed on preventing floodwaters backing up the stormwater system and flooding properties in the Tooram Lane area. Figure 21 shows sandbagging the outlet to prevent backflow into the township. Whilst there has not been a detailed flood or drainage investigation in Allansford – experience with flooding in the Tooram Lane has demonstrated that a backflow prevention device would provide a benefit to upstream properties. This benefit could be quantified through any future flood/drainage investigation.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1 | 0 | 3 | 3 | 2 | -1 | 3 | -1 | 1 | 3 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | VicSES | $10k<br><br>2019 | P2 – stormwater modelling should be included in a flood investigation for Allansford | To strategically manage flood risk |

| Outcomes |
|---|
| The installation of a backflow prevention device at the Tooram Lane outfall will reduce the risk of flooding to upstream properties. |

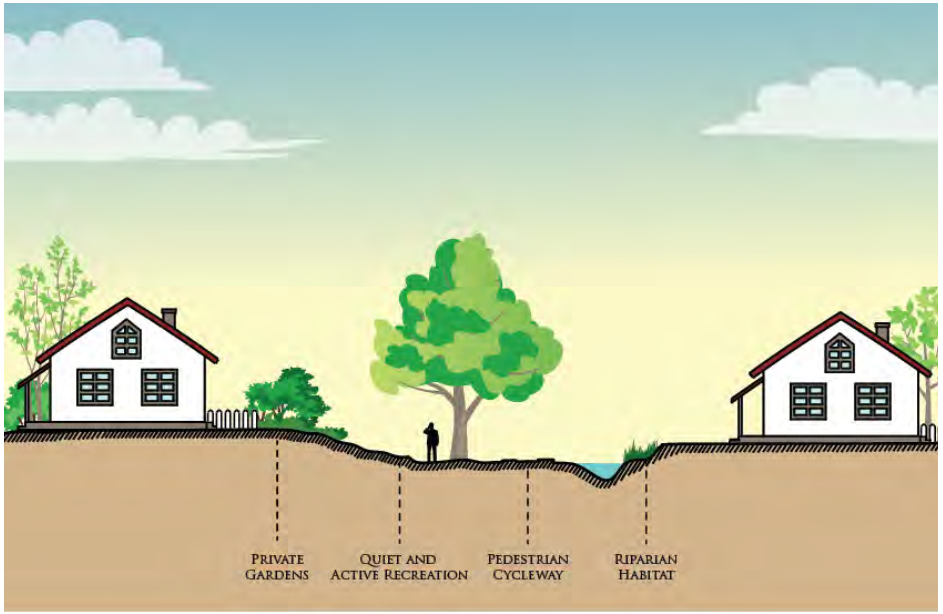
### 6.3 Option F3 – Develop a concept design for channel and floodplain improvements

There is a significant area of Public Park and Recreation Zone land along the Russells Creek floodplain between Ardlie and Bromfield Street. This is an important area from a floodplain, connectivity and recreation perspective. Along the creek, stream edges and standing water bodies of water, reed beds and marginal vegetation could be established. Areas of grass could be subject to varied mowing regimes to create a mosaic of habitat for birds and invertebrates. A wet swale with wetland planting and attenuation ponds could provide an attractive feature and an important drainage corridor (e.g. Figure 38). There may be long term economic benefits from flood attenuation and amenity. These benefits could be modelled as part of the design.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| -1 | -1 | 3 | 1 | -1 | 1 | 3 | -1 | 3 | 1 | -2 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | DELWP | $30k<br><br>2020 | F1 | Take an integrated design approach to development |

| Outcomes |
|---|
| This project will determine the overall benefits associated with a new approach to using Council owned public land. An example of a design which represents an alternative approach to floodplain development is illustrated at Figure 38. This incorporates a range of features including quiet and active recreation, habitat and flood attenuation areas. |




Section Through A Stream Corridor

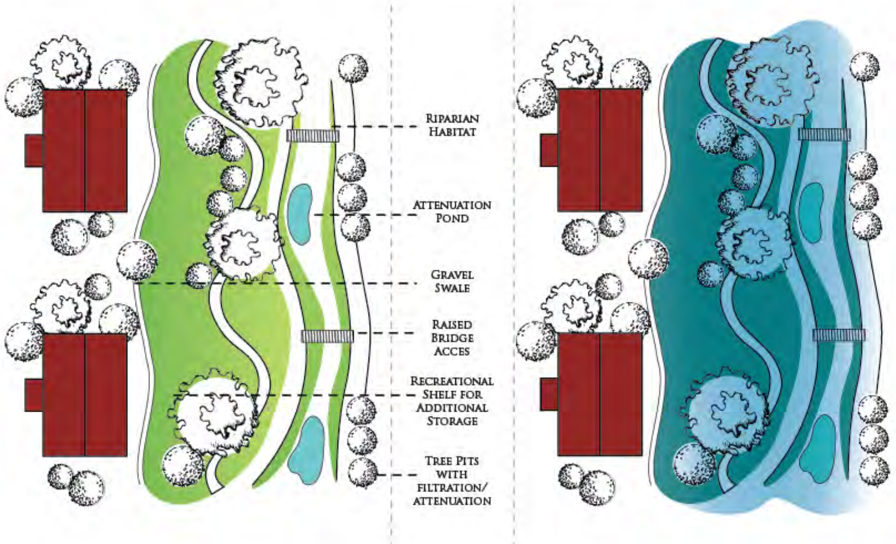



Figure 38.  Concept plan of stream corridor and flood storage area (Utilis 2018)

### 6.4 Option F4 - Establish an operating procedure for North Warrnambool flood levees

The North Warrnambool Flood Mitigation project has provided a major reduction in flood risk for many properties along Russells Creek. The concrete levees require board inserts to be installed to fulfil the design protection level (up to the 1% AEP flood level). Whilst this is a relatively straightforward procedure – it is important that an operating procedure is developed and staff trained and tested at least annually. This operating procedure will form part of the MFEP and is a crucial to ensure the performance of the levees.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 0 | 3 | 3 | 2 | 1 | 3 | 0 | 3 | 3 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | VicSES | $2.5k<br><br>2018 | | R3 – the procedure must be linked to any flood warning system implemented | | | To strategically manage flood risk | | | |
| Outcomes | | | | | | | | | | |
| The procedure and training in place will provide confidence in the mitigation assets and ensure WCC meets its flood response responsibilities. | | | | | | | | | | |

Figure 39.  Board insert housing requires an accompanying procedure

## 6.5 Option P1 - Undertake Warrnambool coastal flood investigation

The Barwon South West Region Local Coastal Hazard Assessment – Stage 1 was completed in June 2017 and identified the Merri River and Hopkins River entrances as areas where flood investigations require updating. The Merri River estuary has been extensively investigated – however there is now new information from the experience with the 2014 storm tide flooding. There is also additional data and key modelling inputs such as the Warrnambool LIDAR dataset that will improve the accuracy and confidence of the information supplied.

Stage 2 of the Coastal Hazard Assessment will include modelling and mapping of the coastline. This information may provide a baseline for a more detailed investigation into how storm tide flooding will affect areas of both South Warrnambool, Moyjil (Point Danger) and the Hopkins estuary. There is a significant body of flooding knowledge associated with the Merri River in South Warrnambool. However, not so extensive is the understanding of storm tide flooding. The interrelationship between storm tide and riverine flooding also needs further investigation to arrive at an appropriate scenario for planning purposes

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 1 | 1 | 2 | -1 | 2 | 2 | -1 | 2 | 2 | -2 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| GHCMA | WCC<br>VicSES<br>DELWP | $200k<br><br>Yr.2020 | Integration into other flood models (P5) should be considered. R5 | To strategically manage flood risk.<br><br>To adapt to climate change. |

| Outcomes |
|---|
| This investigation will provide planning and response agencies with the information necessary to update the Planning Scheme and Municipal Flood Emergency Plan. |

### 6.6 Option P2 - Undertake Allansford flood investigation

The 2010/11 floods had a significant impact on Allansford township predominantly through stormwater flooding influenced by a backwater effect from the Hopkins River. The highway was inundated for a period and the VicSES co-ordinated a number of callouts and sandbagging efforts. There is no flood warning system in place for Allansford and the lower Hopkins – however there are a number of stream and rainfall gauges within the catchment upstream that may be incorporated into a formal or informal system.

The current flood information for Allansford is based on the FDTP and is of low reliability. The available mapping shows a breakout point on the north side of the town that suggests an overland flow through the main part of the town (refer Figure 35).

While the 2010/11 flood provided valueable information and experience with Hopkins River flooding – there remain significant unknowns about the overall risk associated with both river and stormwater flooding and their interaction. Establishing the benchmarks for Allansford (e.g. 1% AEP flood) and the lower Hopkins is considered an important goal for the Plan.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1 | 2 | 3 | 1 | 3 | -1 | -1 | 1 | 1 | -2 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| GHCMA | WCC<br>VicSES<br>DELWP | $150k<br><br>Yr 202 | F2, R5 | To strategically manage flood risk |

| Outcomes |
|---|
| The flood investigation builds the body of knowledge. The overall risk will be more fully understood along with the interrelationship between stormwater and riverine flooding. Flood warning options are another key opportunity within this option. |

### 6.7 Option P3 - Undertake Woodford flood investigation

Like Allansford, Woodford is increasingly becoming an option for new residents due to land prices and proximity to Warrnambool. Similarly, the Merri River is a feature that adds to the attraction. In September 2016 flooding destroyed the footbridge and significant areas of the local school grounds were impacted.

Again, like Allansford, the extent of the floodplain is relatively well defined and so flood extent mapping, while important, is perhaps subordinate to the strategic importance of the location of the Woodford gauge and its role in flood warning (refer Figure 40). A flood investigation for Woodford should include a detailed assessment of the current gauge and the options and benefits for its upgrade from a flood warning perspective. It should also include consideration of rainfall monitoring options higher in the catchment (e.g. around Woolsthorpe) as part of a broader flood warning network for both Woodford and Warrnambool.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -1 | 1 | 3 | 1 | 3 | -2 | 1 | 0 | 3 | -2 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| | WCC<br>VicSES<br>DELWP | $100k<br><br>Yr.2021 | | P1, R5 | | | To strategically manage flood risk | | | |
| Outcomes | | | | | | | | | | |
| The flood investigation builds the body of knowledge and generates a way forward for key elements of floodplain management for Warrnambool e.g. flood warning for the Merri River. | | | | | | | | | | |

Figure 40.  Merri River gauge at Woodford

### 6.8 Option P4 - Undertake Russells Creek crossings assessment

Russells Creek has a long history of frequent flooding. Its flood record is predominantly furnished with minor (nuisance) events which typically create transport and connectivity disruptions. Noticeably, community behaviour in response to road closures and traversing flooded areas is of concern. Complacency may lead to incidents and often the behaviour behind this is either impatience - the inconvenience of road closures and the curiosity and novelty of a flooded area. Typically, this happens on or near road crossings.

This option seeks to provide for an assessment of these crossings in terms of their safety risk to pedestrians or vehicular access. It also includes development of novel ways to curb potentially risky behaviour for example – an automated flood camera that captures transgressors ignoring signage. The assessment would seek to build efficiency into WCC's response approach to road closures – for example the consideration of automated closures.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 1 | 0 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 2 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | VicSES | $30k<br><br>Yr 2019 | | This option is closely linked to a flood warning system – R3. | | | To adapt to climate change<br><br>To strategically manage flood risk | | | |
| Outcomes | | | | | | | | | | |
| This option will lead to improved efficiency in response actions for Russells Creek road crossings. Recommendations from the project could lead to an overall reduction in flood risk to commuters and pedestrians. | | | | | | | | | | |

Figure 41. Queens Road crossing in flood[1]

## 6.9 Option P5 - Warrnambool flood models integration

There are at least 11 computer flood models that simulate flooding across Warrnambool. These models utilise three separate and incompatible software packages; SOBEK, Mike FLOOD and TUFLOW. As a result, there are inconsistencies at the interfaces between the models. These interfaces represent the various study areas along the Merri River and Russells Creek. Differences in flood levels and extents at these interfaces creates an element of uncertainty. Creating one complete model for Warrnambool is considered achievable and will become an asset to all agencies involved in flood planning and response. Particularly when emergency response mapping is required – or scenarios need to be modelled real time – a single model represents a single point of truth.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 1 | 0 | 0 | 1 | 3 | 0 | -1 | 1 | 1 | 1 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | GHCMA | $30k<br>2019 | | P3, P4 | | | To strategically manage flood risk | | | |
| Outcomes | | | | | | | | | | |
| This option will create a greater degree of certainty in a 'single point of truth' for estimating flood scenarios. This model will enable developments and planning scenarios to be tested | | | | | | | | | | |

### 6.10 Option P6 - Develop guidelines for cost sharing for stormwater flood mitigation infrastructure

While there are clear funding arrangements between levels of Government for flood related infrastructure and investigations – often at a local level there can be varied circumstances which can influence investment responses. The 'PESTLE' categories of risk assessment can often influence where investments are made – potentially in inequitable ways. Political – Economic – Societal – Technological – Legal and Environmental factors are often all in play when considering planned or unplanned investments in structural or non-structural flood mitigation. Typically complexities in cost sharing arise within new developments that need to integrate into existing infrastructure. Often direct and indirect costs and values can be difficult to determine and guidelines may help to provide a way forward.

When looking to mitigate areas subject to stormwater 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 flows exceeding minimum design standards in order to reduce the risk of flooding as a result of climate change.

For some areas it may only be practical to convey a certain flow rate of water away (such as areas drained by pump systems). In these areas WCC (and the community) may have to accept a lower level of service which may mean that flooding may occur more frequently.

The guidelines should consider shared contribution arrangements towards existing and new flood mitigation infrastructure for both existing and new urban areas where a 'beneficiary pays' model may apply. Such options may be implemented via Development Contribution Plan Overlays, Special Charge Schemes or caveats applied to property titles.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | -1 | 0 | 0 | -2 | 0 | -3 | 2 | 1 | 1 | -2 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | DELWP | $10k<br>2022 | P7, P8 | To strategically manage flood risk<br>To adapt to climate change |

| Outcomes |
|---|
| The pressure on assets and infrastructure may be increased overtime due to a changing climate. The establishment of guidelines for the investments of flood mitigation funds will lead to more efficient application of scarce resources. |

### 6.11 Option P7 - Investigate the introduction of Special Building Overlays and/or Design and Development Overlays

As the flooding body of knowledge grows across the three source categories (riverine, coastal, stormwater) this does not automatically give rise to straight forward planning responses. On the contrary, interactions between the sources in a range of scenarios can be complex. Turning complex engineering concepts into strategic and statutory planning can be equally as challenging. There are no standards for strategic and statutory planning that deal specifically with climate change, coastal inundation and flooding that may occur if a levee system fails or is overtopped by a flood larger than the infrastructures' design. The introduction of the Special Building Overlay (SBO) or Design and Development Overlay (DDO) are worthy of consideration for applying controls across infill and developed to which application of the existing flood related planning controls may not be straight.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 0 | 2 | -3 | 0 | 3 | -1 | 2 | 3 | -2 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | GHCMA<br>DELWP | $20k<br><br>2021 | | P8 | | | Take an integrated design approach to development | | | |
| Outcomes | | | | | | | | | | |
| The application of these overlays provides opportunity to build resilience into existing and infill development. This will lead to reduced flood exposure over time for re-developed or extensions to existing buildings | | | | | | | | | | |

### 6.12 Option P8 – Introduce a Local Floodplain Development Plan

Local floodplain development plans (LFDP) can be prepared to provide a performance-based approach for development decisions that reflects local issues and best practice and can respond directly to the objectives set for floodplain development. The performance criteria established within a LFDP can direct minimum standards and opportunities for integrated design.

A LFDP should also include:

- Flood history
- Information sources
- Flood impacts
- Climate change
- Cultural values
- Flora, fauna and other environmental values and constraints

The application of a LFDP commonly coincides with a flood related zone or overlay control, however such a plan may be prepared and applied to locations where conventional flood control is not able to be applied. Conversely, precinct specific LFDP's can be developed for either existing or forecast urban growth areas that may be affected by flooding.

The LFDP's application within the planning scheme may be included as an incorporated document, or included in Local Policy (with an appropriate location map assisting in community awareness).

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1 | 2 | 2 | -2 | 0 | 2 | -1 | 1 | 2 | -2 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | GHCMA<br>DELWP | $20k<br><br>2020 | P6, P7, P9 | Take an integrated design approach to development<br><br>To adapt to climate change<br><br>To strategically manage flood risk |

| Outcomes |
|---|
| This option is considered to provide long term benefits both for infill and greenfill development proposals. A well designed LFDP can incorporate the relevant features of the overall structure plan and apply design and performance based principles for the local flood risk. This will lead to improved spaces for both floodplain functioning, place and play. |

### 6.13 Option P9 - Investigate the replacement of the UFZ for public land

Significant portions of the Warrnambool floodplain is within the Urban Floodway Zone. The UFZ is a strong and effective control to maintain the floodplain for its purpose. Often however, less desirable uses of this land from an amenity, place and neighbourhood values perspective occur. This option seeks to convert where appropriate, UFZ into Public Open Space that can cater for both the floodplain and amenity function. This may require land purchase and re-development of land with integrated design features. A scoping study into the cost and benefits of this option is a first step.

However, there are already significant areas of WCC land within the UFZ (e.g. South Warrnambool) for which the application of FO in lieu of UFZ may align with the broader open space networks while allowing broader uses and developments to be considered (as appropriate).

Considerations for this option include:

- FO considers buildings and works only, whereas UFZ considers both use and buildings and works.
- This approach may become more relevant following introduction of a single Planning Policy Framework (PPF) to be introduced by the State Government Smart Planning initiatives whereby the zone will become increasingly relied upon to articulate the preferred land use outcome.
- This option would only apply to land in public ownership (as a stage 1 approach)
- Clauses 21.01-2: Strategy – Access to open space. Open space is not evenly distributed throughout the City and some areas have poor access to open space. Improved access to our waterways will continue to provide important recreational opportunities.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| -2 | 0 | 3 | 1 | -2 | 0 | 0 | -1 | 3 | 3 | -1 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | GHCMA | $20k<br>Yr. 2021 | | P8, P7 | | | Take an integrated design approach to development | | | |
| Outcomes | | | | | | | | | | |
| Open space values may be enhanced while retaining the purpose of the floodplain. | | | | | | | | | | |

### 6.14 Option R1 - Develop a flood response plan template for residents

The growing body of knowledge of flooding for the Warrnambool region includes an understanding of the properties at risk. Without effective flood warning, residents (along with response agencies) can be caught by surprise. While flood response agencies are trained and well planned in flood response, often residents rely on the support of these agencies (e.g. VicSES) to provide flood defence support at a household level. This can place a burden on the resources of responders and is symptomatic of a community unprepared for their level of risk. This option is designed to provide residents with a first step in making their own response arrangements at a household level. Stay and defend in place or evacuate are two of the options available to residents. The template and support in individualising it will empower residents to take personal responsibility for flood response.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 3 | -1 | 0 | 2 | -1 | 2 | 3 | -1 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | GHCMA<br><br>VicSES | $20k<br><br>Yr. 2019 | | R2, R3, R4, R5 | | | To strategically manage flood risk<br><br>To adapt to climate change | | | |
| Outcomes | | | | | | | | | | |
| This option is squarely focussed on building resilience and understanding of flood risk across the City – and increasing individual responsibility. | | | | | | | | | | |

### 6.15 Option R2 – Undertake rapid assessment of WCC's rural roads

Recent research into flood fatalities and accidents has identified a number of factors common to the incidents that have occurred in recent decades. Common factors include unsealed and narrow roads, deep table drains and commuter behaviour. This research provides an opportunity to assess where these factors may be present within the road network of the City. Having identified the locations of risk and level of hazard, planning and response measures can be considered further to reduce this risk. Some of the risk factors identified in the research include:

- Small catchment size (rate of rise)
- Lack of side barriers at point of entry
- Deep water adjacent to roadway
- Downstream vegetation or obstacle
- Local road
- Limited turning area
- No curb and gutter
- Sealed road
- Low traffic volume

Knowing the areas with these characteristics can significantly improve the planning and response approach. Signage, barriers and road closures can all be further considered.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 2 | 0 | 0 | -3 | 1 | 2 | 3 | 0 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | GHCMA<br>VicSES | $20k<br><br>2020 | R5 | To strategically manage flood risk<br><br>To adapt to climate change |

| Outcomes |
|---|
| This option builds the body of knowledge into flooding for the City. As the rural road network is relatively small compared to other shires, this project could have a positive long term benefit to life and safety risk reduction. |

### 6.16 Option R3 – Implement a TFFWS for Russells Creek

With the completion of the North Warrnambool Flood Mitigation Works and growth corridors toward the Creek headwaters – this underscores the need for a system that supports both agency and communities to take action in a timely manner. There are many challenges with the development of such a system – the short response time of the catchment being primary. However, the development of a system that provides a level of notification for residents is considered worthwhile critical to the response effort. An implementation plan is proposed to ensure costs, administration and construction of the system are detailed. This will provide the linkages with the related response measures that depend upon a warning trigger to be put into action. The implementation plan may be strengthened by an MoU between the relevant partners.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2 | 0 | 3 | 0 | 0 | -2 | 1 | 3 | 3 | -2 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | BoM<br>GHCMA<br>VicSES | $40k<br><br>2019 | | R1, R4, R5, F4, P4 | | | To strategically manage flood risk<br><br>To adapt to climate change | | | |
| Outcomes | | | | | | | | | | |
| Having the design of a flood warning system in place will provide Warrnambool with a significant non-structure flood mitigation tool from which many other initiatives can be linked too. | | | | | | | | | | |

### 6.17 Option R4 – Engage with St Josephs Primary School on flood response and access arrangements

The location of the St Josephs Primary School is central to the Russells Creek floodplain. As a landholder of much of the land between Bromfield Street and Queens Road – there is a significant area of land within a high hazard portion of the floodplain. During flood events in school hours there can be significant traffic movements of parents picking up their children. If Queens Road and Bromfield Street are closed due to the flood – this can concentrate these movements on Botanic Road. This amount of activity in close proximity to an area in flood increases the risk of accident or injury due to traffic and/or the flooding itself.

Anecdotally, the School has response arrangements in place for flooding – however, there is an opportunity to engage on this to seek opportunities for collaboration with the broader response planning efforts. This option also includes the discussion about integrated design and development for the land owned by the school.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 0 | 2 | 1 | 0 | -1 | 2 | 1 | 0 | 0 |
| Owner | Partner | Cost / Time | | Related Options | | | Objective | | | |
| WCC | GHCMA<br>VicSES | $5k<br>2020 | | P9, R5. A predecessor for this option is R3. | | | To strategically manage flood risk. | | | |
| Outcomes | | | | | | | | | | |
| This option impacts a significant portion of the business and school community that operate in an area with a high risk of flooding. Putting response measures in place will lead to increased flood awareness and response behaviours. | | | | | | | | | | |

### 6.18 Option R5 – Undertake community flood education engagement activities

The Draft GHCMA FMS identifies flood education and engagement activities as a priority for Warrnambool City. Section 4 of this plan describes the myriad of issues surrounding the 'types' of flooding across the Warrnambool region. This represents not only a management but communication challenge for all agencies involved in planning and responding to flooding. To a community – by and large – flooding is flooding (especially in the middle of an event). So it is important to help a community understand its flood risk – where and how the flooding occurs so households can take measures to respond to that risk.

Like with fire management, there needs to be a continual effort to keep communities aware of the risk associated with flooding. While a complacency can grow through both long absences in flooding – and frequent nuisance flooding – regularly pushing the key messages associated with flooding can result in positive externalities such as increased resilience. A flood resilient community is one which is aware of the risks and what it needs to do both in planning and responding to that risk. Key messages (e.g. don't drive through floodwaters) need to be reinforced along with the reasons behind floodplain management measures. This can be done in a number of ways:

- S.198 planning certificate notifications. Flood planning controls where applied can be flagged through the issuing of this notification process. Council may also provide additional information in the form of a flyer (e.g. floodsafe guide)
- Council's C2C publication and website are great mediums for providing project related information. The website in particular may be a place to furnish more detailed information on flooding that could be specific to town/suburb.
- Historical flood markers like that already in place at the Mortlake road crossing are a good way of reinforcing to the community and visitors of the flood risk in the particular location.
- The recently completed North Warrnambool Flood Mitigation Works consist of concrete levees and high flow culverts. This new infrastructure could be used to provide flood information to the community. Key messages, flood heights and facts could be incorporated into the infrastructure (e.g. "A levee does not keep out all floods, and one day a bigger flood will come") – refer Figure 42.
- Each of the above options may be considered further as a package option. However, the FloodSafe guide is considered a lead tool from which further tools can be built upon. It is considered to be a low cost option that could become a bi-annual recurring task.

| Economic Merits | Financial Feasibility | Environmental Cultural | Impact on Vicses | Regulatory Issues | Flood Behaviour | Community Acceptance | Technical Complexity | Innovation | Scale of Impact | Quick Win |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1 | 1 | 2 | 0 | 1 | 3 | -1 | 1 | 2 | 3 |

| Owner | Partner | Cost / Time | Related Options | Objective |
|---|---|---|---|---|
| WCC | GHCMA<br>VicSES<br>DELWP | $35k<br>Yrs. 2019-23 | R1, R4, P8, F3 | To strategically manage flood risk<br><br>To adapt to climate change |

| Outcomes |
|---|
| The investment in education and awareness is considered a mandatory aspect of floodplain management. Building resilience within a community is a key objective of floodplain management. An aware and resilient community reduces the burden on emergency services during times of flooding. It also takes responsibility for safety and response actions. |

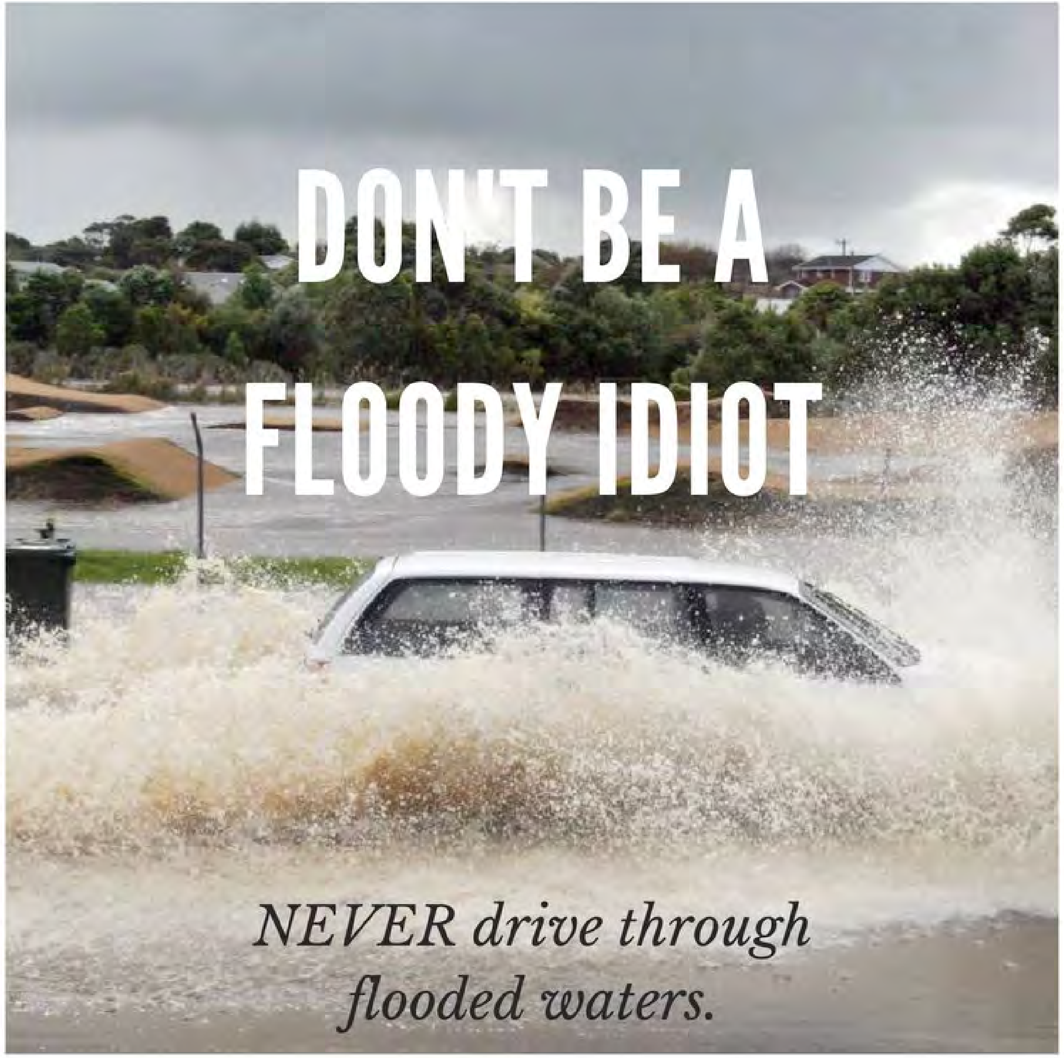



Figure 42. Example key flood message poster (Utilis, 2018)

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## Appendix 1: Brief Flood History Timeline

| Year | Description / Location |
|---|---|
| | |
| 1908 | The Camperdown Chronicle on Saturday 5 September 1908 (p1) reports "The heavy rain of Tuesday last caused a flood in the Warrnambool district…On Wednesday morning the flood was at its height. It was the largest experienced there since 1894. |
| 1909 | The Age Thursday 24 June 1909 (p6) reports that "At Cassady's-bridge the Chinese gardens are flooded out." |
| 1913 | The Age Saturday 20 September 1913 (p16) reports "No damage has yet been reported, except to the Chinese gardens, where considerable losses have been caused by the flood waters in the Merri. The flood is only 1 foot 6 inches below the 1893 record". |
| 1932 | The Age Monday 27 November 1932 (p6) reports that "The rain coming on country already saturated quickly caused the Merri River to rise to flood level, submerging all the low-lying lands along the coast and near Dennington destroying a considerable area of crops and pasturage". |
| 1946 | Largest flood on record. Height of floodwater estimated as it was before gauge installed. Seven deaths, thousands homeless, and livestock and crop losses experienced by farmers plus at least two bridges, Cassidy's and Woodford were washed away. Reached a height of 8.55m on the gauge at Woodford. |
| 1984 | A gauge level of 7.10m was recorded by the gauge at Woodford in September. |
| 1995 | A gauge level of 6.67m was recorded by the gauge at Woodford. |
| 2001 | A gauge level of 7.75m was recorded by the gauge at Woodford in August. |
| 2010 | A gauge level of 7.80m was recorded by the gauge at Woodford in August. |
| Note. The VicSES Warrnambool Flood Guide refers to other floods occurring in 1960 and 1978. | |
| Russells Creek | |
| 1908 | The Camperdown Chronicle on Saturday 5 September 1908 (p1) reports "Within 100 years of the north boundary of the Warrnambool Botanic Gardens a lake was formed a mile long and early a mile wide. The water stretched from Russell's Creek to Spring Gardens and flooded numerous grazing paddocks and gardens. |
| 1909 | The Age Thursday 24 June 1909 (p6) reports that "Russell's Creek is running over the Woodford-road to a depth of about 4 feet." |
| 1913 | The Age Saturday 20 September 1913 (p16) reports "Heavy rain fell in the district during Thursday night and to-day….Russell's Creek is running over all the low lying land north of the botanical gardens and this afternoon the Hopkins River commenced to rise, and by 7pm it was up 3 feet and level with the decking of the boatshed jetties. |
| 1917 | The Warrnambool Standard Wednesday 23 May 1917 reports "Cr. Anderson directed attention to water flooding gardens on the north side of Moore-street, at Russell's Creek, and he asked that the engineer see if something could be done to divert the flow of water coming down from Banyan-street. The engineer said it would be necessary to put in a new culvert."<br><br>The Warrnambool Standard Monday 24 September 1917 reports that "Russell's Crek was running a banker yesterday, and all the paddocks at the back of the Botanical Gardens and along the creek at Spring Gardens were inundated…" |
| 1918 | The Warrnambool Standard Monday 15 July 1918 (p2) reports that "Russell's Creek was running at flood level, and all the low land at the back of the Botanical Gardens was under water." |
| 1931 | The Age Thursday 30 July 1931 (p5) reports that "Large volumes of flood water are coming down the Hopkins and Merri rivers, ad the Hopkins Falls present a fine spectacle. A repetition of the floods of over 20 years ago is feared at Russell's Creek." |
| 1932 | The Age Monday 27 November 1932 (p6) reports that "Russell's Creek also overflowed its banks to a considerable extent, inundating the Chinese gardens to some extent…" |
| 1946 | Largest flood on record. Flood levels from 1946 were recorded along Russells Creek. |
| 2013 | A YouTube video shows minor flooding Russells Creek in the Bromfield Street / Daltons Road area (dated August 23). |
| Note. Additional flood records between 1946 and 2013 are likely available via the Warrnambool history centre and/or public library. | |
| | |

**Hopkins River**

| | |
|---|---|
| 1903 | The Age Saturday 18 July 1903 (p10) reports that "The Hopkins River is higher that it has been for very many years, and vast volumes of flood waters are coming down. The backwash at Allansford has submerged the culvert on the main road, and temporarily cut off all traffic to Warrnambool…" |
| 1908 | The Age on Thursday 3 September 1908 (p9) reports "The Hopkins river started to rise about midday, and at about 6pm it was 2 feet 6 inches above normal level. It is expected that the flood waters from inland will reach here about midnight. Preparations are being made to prevent damage." |
| 1933 | The Camperdown Chronicle Saturday 9 December 1933 (p2) refers to flood waters cutting through the sand bar at the river mouth. |
| 1946 | The SRWSC Western District Flood Report 1946 describes the Hopkins River as being in flood but not to unduly high levels. |
| 1953 | The Argus Tuesday 10 November 1953 (pg9) refers to "the heaviest volume of water for years pouring over the Hopkins Falls". |
| 2010 | September 7 the Hopkins experienced significant flooding which is detailed in the 2010-11 Victorian Floods – Rainfall and Streamflow Assessment Project |
| 2011 | January 17 the Hopkins experienced significant flooding which is detailed in the 2010-11 Victorian Floods – Rainfall and Streamflow Assessment Project. |
| 2016 | September 18 the Hopkins experienced significant flooding. A YouTube video provides footage of the Hopkins Falls. |
| Note. Additional flood records between 1953 and 2010 are likely available via the Warrnambool history centre and/or public library. | |
| Coastal Flooding | |
| 2014 | Significant flooding occurred in the south Warranmbool area as a result of a high storm tide. June 23 was the worst of a number of days of high tide and strong southwesterly winds. A YouTube video captures good footage of the event. |

# Appendix 2: Climate Change and Flood Estimation Review

Australian Rainfall and Runoff (2016)

Australian Rainfall and Runoff (2016) (ARR2016) has led to a number of significant changes to the way that flood modelling is undertaken in Australia. The main practical changes are briefly outlined below.

Most of the data required to undertaken the work in ARR2016, such as rainfall patterns, pre-burst rainfall, areal reduction factors etc is available from the AR&R Datahub.

Temporal Rainfall Patterns

Previously a single temporal pattern for each storm duration was modelled e.g. 12 hour 1% AEP. ARR2016 now presents three options; a simple event, an ensemble event and Monte Carlo analysis.

- The simple event is a similar approach to ARR1987, where a single storm is run. This is recommended for simple design, such as single lot drainage or small road culverts.
- The Ensemble Event uses 10 pre-defined temporal patterns to distribute the rainfall and the modeller then chooses a representative temporal pattern for each AEP (typically the pattern that produces flows that are just above the median flow). This is recommended for studies up to medium sized flood studies (e.g. a town or small city)
- The Monte Carlo will typically use thousands of storms with varying parameters patterns to produce a cloud of results of varying AEPs, the modeller then picks a representative sample of those results to include in the hydraulic model. This is recommended for large studies.

The net result is that we are now running hundreds of additional scenarios and where previously there may be 2 or 3 critical durations (and associated storms) per AEP there is now likely to be many times this number, as different temporal patterns are critical in different locations. Modellers typically try to reduce the number of critical temporal patterns and durations by mapping where each run is critical and then choosing a sub-sample of representative events i.e. the ones that are most critical in most locations.

Revised IFDS

As part of the ARR revision process, the Intensity-Frequency-Duration data were revised based on the additional stations and rainfall data that is now available. This means that the rainfall depths for the design flows vary from ARR1987. In our experience the rainfall depths can be either higher or lower in ARR2016 and it is spatially dependent.

Pre-Burst Rainfall

ARR2016 now accounts for “pre-burst rainfall” which is the expected rainfall that occurs prior the storm. It varies between location and for different AEPs. The data is expressed as a depth or ratio of the event rainfall depth. For example, if the 1% AEP depth is 100 mm and a pre-burst rainfall ratio is supplied of 0.1, then 10 mm of pre-burst rainfall is applied. This value is then subtracted from the Initial Loss in the hydrologic model.

It is unclear what should be done in cases where the pre-burst rainfall exceeds the initial loss, however most practitioners seem to be setting the initial loss to 0 mm. It could be argued that the additional pre-burst rainfall should be applied to the model, however no guidance is provided on how this should be undertaken.

Areal Reduction Factors

Areal reduction factors (ARF) were applied in ARR1987, however this was generally based on overseas research. These have been updated as part of ARR2016. Care needs to be undertaken when applying the ARF as it applies to the total catchment size (i.e. as the catchment gets bigger, then the ARF increases as the likelihood of a storm covering the whole catchment decreases). This is an issue where there are areas of interest within a study area that are upstream (i.e. have a smaller catchment) and downstream (have a larger catchment), such as Russells Creek. A conservative assumption in this case would be to assume there is no ARF.

Rainfall Losses

The AR&R datahub provides Initial and Continuing Loss rates based on a spatially variable map, with the disclaimer advising that the loss rates provided are not applicable to urban areas. The loss rates are based on the location of nearby gauges and soil mapping. In our experience these loss rates drastically over-estimate the losses compared to calibrated modelling. The current advice from the AR&R editors is to uses loss as a "last resort" and to instead rely on calibration data, or parameters from nearby calibrated catchments in the first instance.

## Riverine Modelling

### Hydrological Modelling

Hydrological modelling is generally undertaken using a hydrological modelling package such as RORB, RAFTS and WBNM with sub-catchments delineated as per the user guides for the models. Most models have to some extent built in functionality for ARR2016, other software, such as the Catchment Simulation Solutions "Storm Injector" will automate a number of the ARR2016 procedures.

### Hydraulic Modelling

Riverine modelling is typically undertaken using an integrated one dimensional (1D) and two dimensional (2D) TUFLOW model, with the major watercourses modelled as an embedded 1D feature connected to the 2D floodplain area. One dimensional channel modelling is typically undertaken to maintain the assumptions of the shallow water equations (Saint-Venant equations) or otherwise to ensure that the detailed bathymetry of the channel is not smoothed out by the coarse 2D grid.

The shallow water equation's assumptions typically break down when the depth is greater than the spatial dimensions of the 2D computational grid (i.e. in a 2 m grid cell model, depths shouldn't exceed 2 m).

Purely one dimensional modelling is generally not undertaken unless there is no Digital Elevation Model (DEM) and the hydraulic system and project objectives are relatively simple e.g. determining the impact of a work that will encroach on an existing floodway.

Other modelling software, such as MIKE FLOOD and SOBEK typically have the same functionality as TUFLOW, however these are not widely used in the industry and if a consultant uses this software, it may limit future competition for model upgrades or uses. Similarly, it may potentially result in inconsistencies where consultants for property owners employ the more widely used software instead.

## Overland Flow / Stormwater Modelling

Overland Flow and Stormwater modelling is generally undertaken using similar procedures to those used in Riverine modelling, however to a finer resolution (i.e. smaller sub-catchment areas, smaller grid cell size etc.) to account for the smaller size of influencing factors/controls (such as the gaps between buildings limiting the flow area through these areas).

TUFLOW can include the underground stormwater assets as a 1D network that operates underneath the 2D floodplain area. The stormwater assets modelled are usually limited to those owned by organisations such as Council or various water authorities and do not include private connections from properties into the stormwater network.

Hydrological model outputs are generally applied either using sub-catchment inflows (over a point or area) or by using a direct rainfall, which is commonly referred to as "rain on grid".

Rain on Grid has the advantage of modelling the behaviour right up to the catchment boundary. Which is useful for small urbanised catchments. However, Rain on Grid is often criticised as it tends to produce a lower peak flow at a slower rate than the more proven combined hydrological and hydraulic model. Often there is limited calibration data available and so it is difficult to determine the veracity of a rain on grid model. Typically Rain on Grid model results can be improved by:

- Using pre-burst rainfall to provide an initial "wetting up" of the model domain, this fills depression storage and more closely mimics a hydrological model approach.
- Using open building types (i.e. not blocking them out of the model) but applying a depth varying roughness; where flow is of very low depths the roughness is relatively low (to represent rain running off the roof) and for higher depths (e.g. greater than 0.1 m) the roughness is relatively high value, in the order of 0.1 to 0.5

Whether using the hydrologic model outputs or the Rain on Grid method, Overland Flow modelling tends to be less directionally controlled than Riverine Flow modelling. As such, Overland Flow modelling will typically require that the critical duration and pattern from ARR2016 be determined through the hydraulic model (as opposed to the hydrologic model as per Riverine Flow modelling).

### Climate Change Modelling

As part of the AR&R Data Hub output, recommended Interim Climate Change factors are included. The Interim Climate change factors include the estimated temperature increases and percentage rainfall increase for the years 2030 through to 2090 in ten year intervals. Results for RCP 4.5, RCP6 and RCP8.5 are included and RCP 4.5 and RCP 8.5 are typically recommended.

Standard practice is to estimate the increased flooding at a range of dates, typically 2050 and 2090 for a selected number of AEPs. The floodplain sensitivity to the increased rainfall can be determined by afflux mapping.

### Coastal Modelling

Coastal modelling is usually considered in relation to the coincidence between a rainfall event and a sea level event, and how the two mechanisms interact where they overlap. Similar to how the amount of rainfall to occur during a probabilistic rainfall event (i.e. the 1% AEP rainfall depth) is specified by industry authorities such as the Bureau of Meteorology and not derived from first principles for every flood study.

Typically, TUFLOW is used to model the coincident rainfall and sea level events as rainfall inflows and sea level boundary conditions. TUFLOW can also model the sea level boundary conditions individually.

A key consideration is the coincidence of flooding between the riverine flood and the coastal inundation. ARR2016 offers some guidance on this as well as a tool (currently in beta stage development) for determining the degree of independence. However, in our experience the coincidence is typically determined based on overlaying historic sea level and hydrograph data if possible, or otherwise by consensus between the relevant stakeholders. For example, in studies whee the coincident flooding is determined by consensus studies it is typical to use an envelope of a 1% AEP riverine flood with a 5% AEP coastal inundation and a 1% coastal inundation with a 5% AEP riverine flood as the design flood.

If it is necessary to obtain an exact measure of the various components within the sea level estimate (i.e. wave setup, wind setup, storm surge etc.) then a coastal expert would need to be engaged.

In NSW the sea level to occur during a probabilistic sea event (i.e. the 1% AEP sea level) is specified by NSW OEH Department through the following guideline where the parameters are dependent on the coastal morphology as well as the level of detail in the study. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiPvZbN5oTcAhVBC6YKHUdmD-8QFggzMAE&url=http%3A%2F%2Fwww.environment.nsw.gov.au%2F~%2Fmedia%2FB6CE9A5D9B8043BCAC62D97486FF1B6C.ashx&usg=AOvVaw0lLivS_IaaTOP-FlV7gdFm ).

# Appendix 3: Warrnambool Demographic Trends

Warrnambool City is located along the Great South Coast in Victoria's South-West, about 260 kilometres from Melbourne. Warrnambool is the largest urban centre in the Region and is the main service centre for retailing, business services, health and education. About 25% of the City's workforce is employed in wholesale and retail trade, with a further 30% employed in education, health, community and business services. Tourism is also a notable employer in Warrnambool, with the City attracting many people to its beaches during the warmer months, as well as whale spotting during the winter months.

Manufacturing was formerly the largest employer in Warrnambool, with clothing production highly significant due to the Fletcher Jones company. However, like many areas in Victoria, major decreases in manufacturing jobs were recorded since the mid-1970s, especially in the clothing, textiles and footwear industry. In recent years, manufacturing jobs have been on the increase again, with large investments to dairying plants in and around the City (Dennington, Allansford and Koroit) which have resulted in overall gains in employment. The City is the major source of employment for its residents, as well as other areas in the South-West of Victoria, most notably Moyne Shire. As a consequence future changes to population in the City, as well as neighbouring areas, will be associated with employment growth or decrease.

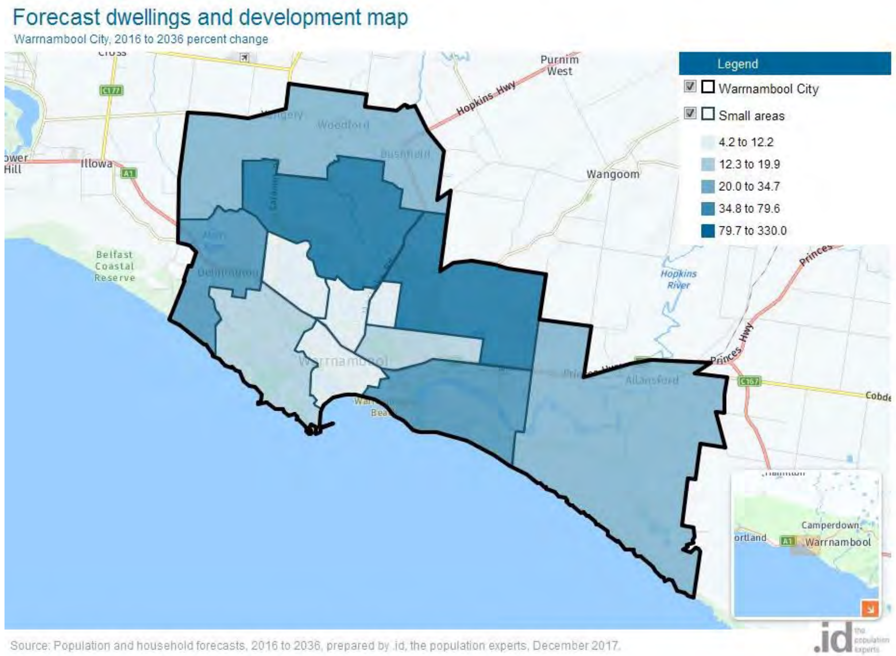


Figure 43. Forecast dwellings and development map

# Appendix 4: Floodplain Management Planning Policy

State Planning Policy Framework (SPPF):

The State planning policy for floodplains (Clause 13.02) provides the broad framework for the integration of flood policy and provisions into planning schemes. It brings together various strands of policy and strategic planning from all areas of government that have a bearing of floodplain management (refer Figure 43). It also aims to provide consistency in planning controls for flood affected areas.

The overall objectives of floodplain management included at Clause 13.02-1, is to assist the protection of:

- Life, property and community infrastructure from flood hazard;
- The natural flood carrying capacity of rivers, streams and floodways;
- The flood storage function of floodplains and waterways; and
- Floodplain areas of environmental significant or of importance to river health'.

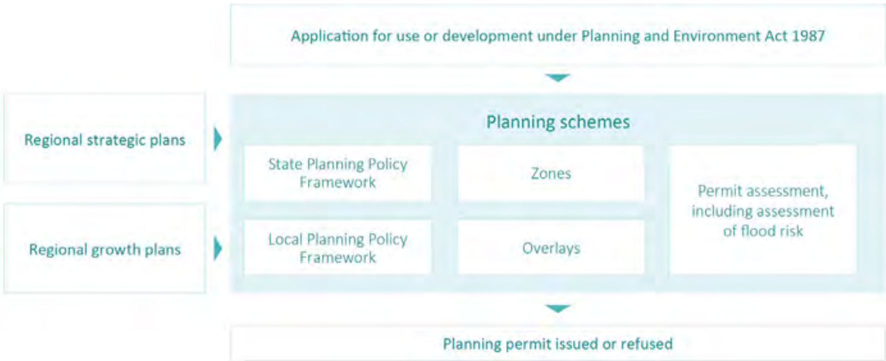


Figure 44. Minimising flood risk through the planning system

Provided below is an overview of the SPPF components considered as part of the preparation of this Plan and corresponding actions.

Clause 11.11 – Great South Coast

Specific policy directions applicable to Warrnambool are provided at Clause 11.11 – Great South Coast and further outlined by the Great South Coast Regional Growth Plan (Victorian Government, 2014), as follows:

Clause 11.11-4 Networked Settlements

- Plan for a network of settlements based around Warrnambool, Hamilton, Portland and district towns drawing on proximity to services, affordable living and a variety of lifestyle opportunities.
- Support the role of Warrnambool as the key population and employment centre for the region with key links to Geelong and Melbourne and facilitate major development in designated growth areas.
- Support rural residential development in locations that: Avoid unmanageable exposure to natural hazards, especially bushfire, flood and coastal hazards.

Clause 11.11-6 Environmental Assets:

- Protect waterways from the effects of urban and rural land use change and facilitate growth
- at established settlements where water and wastewater can be managed.
- Support the sustainable management of growth around coastal, estuary and marine assets to protect environmental values, and to achieve regional economic and community benefits.

11.11-7 Infrastructure

- Plan open space areas for multiple uses, such as community gardens, sports and recreation, active transport routes, wildlife corridors, and flood storage basins.

Clause 11.11-10 includes the Great South Coast Regional Growth Plan (see below). Importantly this plan identifies Warrnambool as the Regional City and centre for Major Growth.

Clause 12.02 Coastal Areas

Relevant strategies included at Clause 12.02-1 to this Plan area as follows:

Coordinated land use and planning with the requirements of the Coastal Management Act

1995 to:

- Provide clear direction for the future sustainable use of the coast, including the marine environment, for recreation, conservation, tourism, commerce and similar uses in appropriate areas.
- Protect and maintain areas of environmental significance.
- Identify suitable areas and opportunities for improved facilities.
- Apply the hierarchy of principles for coastal planning and management as set out in the Victorian Coastal Strategy 2014, which are:

Principle 1: Ensure the protection of significant environmental and cultural values.

Principle 2: Undertake integrated planning and provide clear direction for the future.

Principle 3: Ensure the sustainable use of natural coastal resources.

Principle 4: Ensure development on the coast is located within existing modified and resilient environments where the demand for development is evident and any impacts can be managed sustainably.

Relevant strategies included at Clause 12.02-2 to this Plan area as follows:

- Maintain the natural drainage patterns, water quality and biodiversity within and adjacent to coastal estuaries, wetlands and waterways.
- Protect cultural heritage places, including Aboriginal places, archaeological sites and historic shipwrecks.

Clause 13.01 Climate Change Impacts

Relevant strategies to this Plan included at Clause 13.01-1 (Coastal inundation and erosion) are as follows:

- Plan for possible sea level rise of 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change.
- Consider the risks associated with climate change in planning and management decision making processes.
- For new greenfield development outside of town boundaries, plan for not less than 0.8 metre sea level rise by 2100.
- Ensure that land subject to coastal hazards are identified and appropriately managed to ensure that future development is not at risk.
- Ensure that development or protective works seeking to respond to coastal hazard risks avoids detrimental impacts on coastal processes.
- Avoid development in identified coastal hazard areas susceptible to inundation (both river and coastal), erosion, landslip/landslide, acid sulfate soils, bushfire and geotechnical risk.
- Planning must consider as relevant:
    - The Victorian Coastal Strategy (Victorian Coastal Council, 2014).
    - Any relevant coastal action plan or management plan approved under the Coastal Management Act 1995 or National Parks Act 1975.

o Any relevant Land Conservation Council recommendations.

Clause 13.02 Floodplains

Relevant strategies to this Plan included at Clause 13.02-1 are as follows:

- Identify land affected by flooding, including floodway areas, as verified by the relevant floodplain management authority, in planning scheme maps. Land affected by flooding is land inundate by the 1 in 100 year flood event or as determined by the floodplain management authority.
- Avoid intensifying the impacts of flooding through inappropriately located uses and developments.
- Locate emergency and community facilities (including hospitals, ambulance stations, police stations, fire stations, residential aged care facilities, communication facilities, transport facilities, community shelters and schools) outside the 1 in 100 year floodplain and, where possible, at levels above the height of the probable maximum flood.
- Planning must cosider as relevant:

- State Environment Protection Policy (Waters of Victoria).

- Regional catchment strategies and special area plans approved by the Minister for Environment and Climate Change.

- Any floodplain management manual of policy and practice, or catchment management, river health, wetland or floodplain management strategy adopted by the relevant responsible floodplain management authority.

- Any best practice environmental management guidelines for stormwater adopted by the Environment Protection Authority.

- Victoria Floodplain Management Strategy (Department of Environment, Land, Water and Planning 2016).

Local Planning Policy Framework (LPPF):

The LPPF sets out the local policy context for a municipality and is made of the Municipal Strategic Statement and Local Planning Policies. The LPPF provides a comprehensive range of objectives and strategies which aid in land use and development decision making.

Provided below is an overview of the LPPF components relevant to the preparation of this Plan and corresponding actions.

Clause 21.01-2:

Strategies

- Access to open space – open space is not evenly distributed throughout the City and some areas have poor access to open space. Improved access to our waterways will continue to provide important recreational opportunities.
- Climate change – Climate change presents a threat to the natural and built coastal environment, to the community and to economic activity. It is important that the effects of climate change are mitigated now and into the future.
- Growth areas for housing within the municipality include:

o North East Warrnambool Growth Area

o Coastal Hopkins Growth Area

o North Dennington Growth Area

o North of the Merri River Growth Area

o East of Aberline Road Future Urban Growth Corridor

o South Dennington Growth Area.

Clause 21.02-3 Open Space

- Ensure development does not compromise the ecological integrity of the Merri

River, Hopkins River and Russell's Creek corridors, and the coastal reserves.

- Incorporate and protect sites with high environmental or cultural values in the open space network as the opportunity arises.
- Identify and address key connectivity gaps including those mentioned in the Warrnambool Open Space Strategy (2014) with priority given to providing continuous open space corridors along Russell's Creek and the Merri River.

The following Policy Guideline is also included:

- Require land along urban waterways to be vested in Council to provide a drainage corridor (with secondary passive open space functions).

Clause 21.03-1 Biodiversity

Key issues include:

- Recognising, protecting and enhancing biodiversity conservation areas.
- Managing urban and rural pressures on coastal areas, waterways and sensitive ecosystems.

Strategies:

- Require development to be directed away from wetlands and rehabilitate urban waterways to protect and enhance sensitive ecosystems.
- Improve natural habitats on public land and encourage revegetation on private land and in aquatic systems within the city.
- Facilitate the creation of wildlife corridors through the provision of a network of open space.

Clause 21.03-1 also provides the following direction to the application of land zoning:

- Applying the Public Conservation and Resource Zone to publicly owned river corridors, wetlands, floodplains, and coastal reserves. (This direction is also repeated at Clause 21.03-2 and 21.03-4)
- Applying the Environmental Significance Overlay over the coastal reserve, rivers, land adjacent to river corridors and wetlands and other significant habitats.

Clause 21.03-2 Native vegetation management

Strategies:

- Protect remnant vegetation, especially in habitat corridors, associated with drainage lines, stream frontages and on roadsides and protect, in particular, those Ecological Vegetation Classes rated as having either high or very high conservation significance, and habitat corridors or areas identified as habitat for rare and threatened flora and fauna species.
- Require revegetation along waterways and floodplains using original Ecological Vegetation Class species, with the inclusion of understorey species.
- Contain the spread of noxious and pest weeds and progressively reduce the areas affected.

21.03-3 Coastal areas

Key issues

- Warrnambool's coastal reserves provide important wildlife habitat and corridors for vulnerable and threatened flora and fauna species.
- The Foreshore and Breakwater Activity Nodes provide important tourism and recreational opportunities.

Strategies:

- Support opportunities for sustainable use and development along the coast (within identified settlement boundaries).

Clause 21.03-4 Significant environments and landscapes:

Key issue:

- The management of urban impacts such as erosion, surface runoff and protection and restoration of indigenous vegetation on significant river and estuarine environments.

Strategies:

- To ensure that all new use and development proposals sustain and enhance estuary, river and lake water quality, nutrient and sediment load conditions. This is to maintain the capacity for scientific research and the operation of ecological systems, together with appropriate agricultural and recreational uses.
- To ensure that all new use and development proposals mitigate against any potential environmental or visual impact to the estuary or rivers and their environs and where possible achieve net environmental gain.

Clause 21.04-1 Climate change impacts

Strategies:

- Ensure that use and development proposals take into account and respond adequately to possible sea level rise and storm surge.
- Avoid development in identified coastal hazard areas susceptible to sea level rise and storm surge.

Application of Zones and Overlays states:

- Applying the Land Subject to Inundation Overlay to areas affected by possible sea level rise and storm surge.

Clause 21.04-2 Floodplains

Key issues:

- The protection of floodplains from inappropriate development.
- The protection of life, property and community infrastructure from flood events.

Strategies:

- Minimise development on flood prone land to avoid impeding or redirecting floodwaters.
- Ensure that areas identified as being subject to inundation are planned and managed to reduce flooding and risks to life, property and community infrastructure.
- Ensure that when drainage and flood protection works are constricted, that existing habitable buildings are protected from flooding in major storms.

Objective 2: To maintain the integrity of the Merri River and Russells Creek floodplains.

- Require floodplains to be incorporated into open spaces.
- Discourage the filling of land that is subject to flooding.
- Encourage the use of constructed wetlands as a means of storing floodwater, to improve water quality and contribute to natural habitats. Ensure that new developments will not have an adverse impact on downstream properties and environments in terms of flooding and water quality.

Further Actions:

- Prepare floodplain management plans for the Merri River and Russells Creek floodplains.

Clause 21.05-2 Water

Strategies

- Require adequate buffers and reserves between waterways and new development.
- Support the restoration of degraded land, particularly stream frontages, floodplains and riparian areas.
- Improve stormwater quality and minimise stormwater run-off in urban and rural areas
- Require new development to include water sensitive urban design techniques.
- Establish artificial wetlands, retention basins and stormwater pollution traps and other water sensitive urban design features as a means of controlling the quality and quantity of stormwater run-off from urban areas.
- Encourage the re-use of wastewater and stormwater run-off within greenfield growth areas.
- Defer growth within Bushfield and Woodford pending resolution of sewerage and effluent management options.
- 1.5 Ensure further growth within the Allansford township considers the
- availability of stormwater drainage infrastructure.

Clause 21.10-3 Development Infrastructure (Water supply, sewerage and drainage) Strategies:

- Require new development to include water sensitive urban design techniques.
- Establish artificial wetlands, retention basins and stormwater pollution traps and other water sensitive urban design features as a means of controlling the quality and quantity of stormwater run-off from urban areas.
- Encourage the re-use of wastewater and stormwater run-off within greenfield growth areas.

Clause 21.11 Local Areas

Discussion of Local Areas and future growth areas, relevant to this Plan is provided in relations to current and future flood studies required to inform urban growth fronts. These include:

- North Merri Growth Area
- Coastal Hopkins Growth Area
- North Dennington Growth Area.