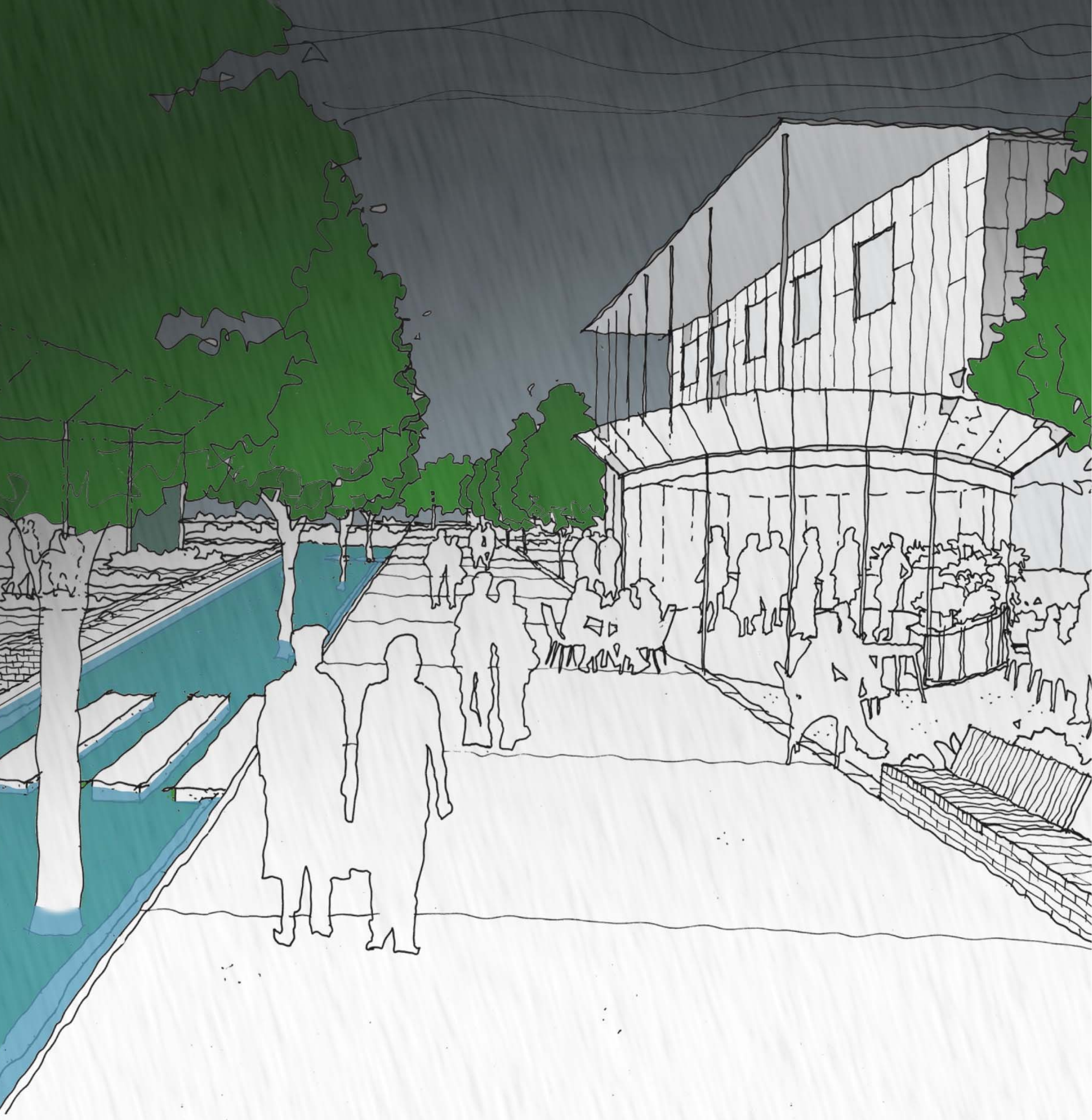

Melbourne Water

Fishermans Bend Water Sensitive Drainage and Flood Strategy

Final Report

July 2019

Purpose of this report

The purpose of this report is to present the outcomes of GHD's work on the Fishermans Bend Water Sensitive Drainage and Flood Management Strategy. This presents the high level strategy for the management of flooding within Fishermans Bend Urban Renewal Area endorsed by the Fishermans Bend Drainage Steering Group on 7th December 2018. It also identifies the further work and decisions that will be needed to confirm the precise infrastructure, design and management approaches ultimately adopted in specific locations. It builds on the body of work undertaken to date, including the Baseline Drainage Plan (GHD for Melbourne Water, 2018), rather than superseding it.

Scope and limitations

This report: has been prepared by GHD for Melbourne Water Corporation and may only be used and relied on by Melbourne Water Corporation for the purpose agreed between GHD and the Melbourne Water Corporation as set out in section 1.3 of this report. GHD otherwise disclaims responsibility to any person other than Melbourne Water Corporation arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to the questions and issues explored through GHD's work on the Fishermans Bend Water Sensitive Drainage and Flood Management Strategy between September 2018 and December 2018, as specifically detailed in the report. These are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer throughout this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Melbourne Water Corporation and others who provided information to GHD (including City of Port Phillip, City of Melbourne, South East Water, The Fishermans Bend Taskforce (DELWP) and other Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

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GHD prepared preliminary cost estimates as referenced in different sections of this report ("Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD. This includes reliance on cost estimates provided by Melbourne Water. This version of the report, dated 16th October 2020, has removed the cost estimates as they are subject to refinement and will be released separately by the Fishermans Bend Taskforce.

Executive Summary

Introduction

The purpose of the *Water Sensitive Drainage and Flood Strategy* project was for the Fishermans Bend Water Sensitive City Working Group to collaboratively explore the potential to use distributed flood storages in streetscapes and open spaces as an alternative to the 'baseline' drainage infrastructure (i.e. pipelines and pump stations). The stakeholders' aim was to optimise Water Sensitive Urban Design (WSUD) as a drainage solution to support and enhance streetscape and public open space landscape and resilience.

The 'baseline' scenario was defined to be the *Baseline Drainage Infrastructure Plan* (GHD for Melbourne Water, 2018), which comprised a levee, pump stations, new pipes to transfer stormwater to the pump stations, upgrades and duplications of existing drainage pipes, and rainwater tanks for all buildings. The 'hybrid' scenario or solution refers to the use of distributed flood storages in the public realm (streets, linear reserves, tree pits, raingardens and public open spaces) primarily to avoid or reduce the extent of pipes and pumps. In essence, the purpose of this project was to develop a 'hybrid' approach that integrated the use of these distributed storages with the baseline drainage plan.

It is also important to note that this *Water Sensitive Drainage and Flood Strategy* is part of a wider Water Sensitive City Strategy for Fishermans Bend, with this report being one of the key technical inputs the broader strategy. The strategy presented in this report focussed on examining drainage and flood management options from a flood performance perspective. The level of greening and WSUD in the public realm (e.g. quantity and location of street trees, tree pits/raingardens, linear parks & open spaces), and a range of other assumptions, were held constant when comparing the 'baseline' and the 'hybrid' solutions. However it should be noted that the broader Water Sensitive City Strategy may consider these other aspects, and their interaction with this strategy, in the future.

Purpose of this Report

This report captures much of the work completed across various drainage studies over the past four years, as well as the key focus of this most recent project: the use of distributed flood storages in streetscapes and open spaces (also referred to in the report as a 'hybrid' approach), an approach endorsed on 7th December 2018 by the Fishermans Bend Water Sensitive City Steering Group which comprises executives from Melbourne Water, the City of Port Phillip, the City of Melbourne, the Fishermans Bend Taskforce South East Water and the Cooperative Research Centre for Water Sensitive Cities (the Steering Group).

This report is primarily focussed on the management of stormwater (pluvial) flooding. It also explores broader coastal and riverine flooding issues, but does not explore the solutions (e.g. a levee) in detail. This report also discusses various related topics, including alternative flood risk mitigation approaches (e.g. permissible/compatible uses) and WSUD, which will be subject to further consideration and work by stakeholders.

Process

The project was funded by Melbourne Water and undertaken collaboratively with all members of the Steering Group. The working group met weekly throughout the project, which was overseen by the Fishermans Bend Taskforce Sub-Committee, who convened three times during the project.

In addition, the co-development of the functional designs of street cross-sections and plans that incorporated flood storage was an iterative design process requiring much collaboration between a range of disciplines/areas at GHD, CoPP, CoM and the Taskforce. This required an integration of the drainage strategy development process with the precinct planning and streetscape and open space design process at different levels of planning.

Structure of the Report

Section 1 establishes the context and purpose of the project, and describes the collaborative process.

Section 2 presents some important background information on preceding studies, the Fishermans Bend Framework, flooding performance objectives and the role of flood modelling.

Section 3 describes the challenges for managing the three sources of flooding (stormwater, coastal/tidal and riverine) at Fishermans Bend over time, including challenging site conditions, existing flood risk, and climate change resulting in rising sea levels and groundwater levels and higher intensity rainfall events.

Section 4 presents the Water Sensitive Drainage and Flood Strategy. For coastal flooding, riverine flooding and then stormwater flooding, the challenge is first established and then the solutions are described. This includes more detail on the use of distributed storages, than on other elements (which are comprehensively covered in appendices and preceding studies).

Section 5 discusses a broad range of implementation risks, issues and possible responses.

Section 6 presents the capital cost estimates for the strategy.

Section 7 provides a conclusion, and Section 8 summarises some key recommendations for stakeholders to consider.

There are a number of comprehensive appendices which explore different aspects of the strategy in detail. This includes documentation of the development of the "hybrid" approach (Appendices A-D), discussions on groundwater issues, coastal, riverine & climate change modelling assumptions, rainwater tanks, the levee, pump stations and Westgate Lakes (Appendices E-H & K-L), cost information (Appendices I & J), and comprehensive strategy information (Appendix M).

The Challenge

Fishermans Bend has a number of challenges that need to be addressed in developing a drainage and flood management strategy. It is an area that already floods today, it is low-lying, with contaminated soils and groundwater, there is uncertainty around development timing and sequencing, and in the future, climate change is predicted to increase rainfall intensities and lead to a rise in the level in Port Phillip Bay.

Flooding may arise from three separate sources in Fishermans Bend: **Coastal** (or tidal) flooding from Port Phillip Bay and extending into the Lower Yarra River, **Riverine** (or fluvial) flooding from flows in the Yarra River, and **Stormwater** (or pluvial or surface) flooding from local rainfall events overwhelming the underground drainage network. Upstream of Wurundjeri Way the Yarra River levels are flow-dominated during flood events and may be higher than peak Port Phillip Bay levels. This means that in the Montague Precinct riverine flooding needs to be considered, not just coastal flooding.

Strategy

The water sensitive drainage and flood strategy includes the following solutions:

- **90 ML of rainwater tanks**, to store and detain roofwater runoff from all buildings;
- **25 ML of distributed storages designed into streetscapes and open spaces** to store and detain stormwater runoff in six sub-catchments (rather than existing pipe upgrades);
- **Upgrading existing underground pipes** in two sub-catchments, to relieve bottle-necks in the drainage network;
- **7 new pump-stations, and new pipes**, in seven sub-catchments, to collect the stormwater flows at the end of the catchments and pump to the Yarra River.
- **Non-return valves** on the existing drainage outlets to prevent back-watering of the drainage system.
- A **levee** that will be adapted over time to manage coastal and riverine flooding.

Discussion

This strategy provides a preliminary high level approach for managing flooding at Fishermans Bend that aligns with and supports the vision and goals of the *Fishermans Bend Framework*.

A levee is required along the edge of the Yarra River in the future to protect against coastal flooding as many areas of Fishermans Bend will be below the predicted tidal water levels in Port Phillip Bay. This should be implemented using an Adaptive Pathways Planning approach –a flexible approach with defined trigger points so that options are available and can be implemented over time, if needed, to future proof for potentially higher/faster levels of sea level rise than 0.8m by 2100. The first step however will be to implement non-return valves on the existing drainage pipes to prevent backwatering of the drainage network. It is important to note that levee concept will require further work following this study. This is critical to achieving the vision and *Goal 4 - A Climate Resilient Community* in the *Fishermans Bend Framework*, which articulates the need to be resilient to extreme weather events including flooding and storm surges associated with sea level rise.

Ongoing work being undertaken outside of this study, investigating areas vulnerable to riverine flooding from the lower Yarra River, will need to be monitored. Revision of Yarra River flood levels has implications for the timing and height of the levee, the timing and operational requirements of one and possibly two of the pump stations, and also has implications for planning controls.

With just a levee in place and without additional mitigation measures, large areas within Fishermans Bend would still be subject to stormwater flooding from local rainfall runoff overwhelming the underground drainage network.

The *Fishermans Bend Framework* already contained a requirement for rainwater tanks in all buildings providing a flood storage function. This reduces the runoff entering the drainage network.

Seven pumps are required along the Yarra River to provide the appropriate hydraulic conditions to quickly drain all of the catchments flowing to the Yarra in high intensity rain events. The pumps are required regardless of whether distributed storages or pipe upgrades are used within the catchment, although the use of storages reduces the required capacities (peak pumping rates) to some extent.

New pipes are also required along the Yarra River to transfer the flow from the existing drainage outlets to the new pump stations.

Distributed storages in the streets and open spaces have been compared as an alternative to upgrading (i.e. upsizing or duplicating) existing drainage pipes in twelve drainage catchments within Fishermans Bend. The analysis undertaken in this study indicates that the distributed storages approach is favoured in six catchments, upgrades of existing pipes are required in two catchments (due to low lying conditions and the influence of an external catchment), and no augmentations are needed in the four remaining catchments (noting that flood attenuation is already being provided in these catchments by the rainwater tanks).

The linear parks, tree pits and open spaces will be multi-functional green infrastructure. In addition to provide green infrastructure and open spaces for the community, they will be provide a flood management function and can also be designed to make water visible in the landscape. From a flood management perspective, the green infrastructure may only need to store water in infrequent events (e.g. once every 10 years), however these assets can be designed to feature water regularly. This approach strongly supports Goal 5 of the Fishermans Bend Framework which states *"… landscapes will be designed to incorporate water sensitive urban design principles to improve water quality and manage flooding"* and will help to deliver the strategic action to "*design the public realm to make water visible"*. As suggested by the Working Group, this may also contribute to social resilience as visibility of water may raise awareness of flooding among the community.

The strategy has been developed over a large urban area, using detailed location specific case studies with City of Port Phillip and City of Melbourne to inform general assumptions about the ability to implement distributed storage that were extrapolated/scaled across the whole of Fishermans Bend.

It is recommended that further work is undertaken as part of precinct planning to determine how the storage targets are specifically proposed to be accommodated in each of the sub-catchments where this has been determined to be feasible.'

GHD acknowledges that this work was an entirely collaborative effort by the Fishermans Bend Taskforce Drainage Working Group, with much intellectual and technical contribution from the various stakeholders.

Further iterations of this strategy are likely to follow before a final strategy is agreed to by partner organisations. This will include, but is not limited to, making decisions on ownership, operation and implementation of infrastructure, as well as more detailed design, refinement and optimisation on particular aspects of the strategy. It is also important to note that implementation of the strategy will require continual tracking of progress and iterative review of the drainage strategy. It will need to be a “living” strategy.

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1. Introduction

This report presents the *Water Sensitive Drainage and Flood Management Strategy* for Fishermans Bend, collaboratively developed by the Fishermans Bend Water Sensitive City Working Group in late 2018.

1.1 Introduction

Fishermans Bend is the largest urban renewal area in Australia, at approximately 480 hectares and more than twice the size of the Melbourne's CBD, it is expected to be home to 80,000 residents and 80,000 jobs by 2050. There are five defined precincts, shown in Figure 1 below. It is an area that has many challenges for development, including managing an existing flood risk that will increase over time due to climate change.

Figure 1 Fishermans Bend Precincts

The *Fishermans Bend Framework*, released in October 2018, will guide development and investment through to 2050. The Vision for Fishermans Bend is *"a thriving place that is a leading example for environmental sustainability, liveability, connectivity, diversity and innovation"*. The framework includes goals relating to climate resilience and water sensitive communities. This includes an action to "*prepare a strategy to holistically manage drainage and mitigate the impacts of storms and sea-level rise"*.

1.2 Purpose of the Project

The purpose of the *Water Sensitive Drainage and Flood Strategy* project was for the Fishermans Bend Water Sensitive City Working Group to collaboratively explore the potential to use distributed flood storages in streetscapes and open spaces as an alternative to the 'baseline' drainage infrastructure (i.e. pipelines and pump stations). The stakeholders' aim was to optimise WSUD as a drainage solution to support and enhance streetscape and public open space landscape and resilience.

This needed to be underpinned by a rigorous assessment of this 'hybrid' solution from a flooding perspective, as well as benefits and costs and feasibility, appropriately informed by an overarching understanding of risk and uncertainty in the context of climate change.

Note that the 'baseline' scenario refers to the *Baseline Drainage Infrastructure Plan* (GHD for Melbourne Water, 2018). This comprises a levee, pump stations, new pipes to transfer stormwater to the pump stations, upgrades and duplications of existing drainage pipes, and rainwater tanks for all buildings. The 'hybrid' scenario or solution refers to the use of distributed flood storages in the public realm (in streetscapes and open spaces) primarily to avoid or reduce the extent of pipes and pumps. In essence, the purpose of this project was to develop a ‘hybrid’ approach that integrated the use of these distributed storages with the baseline drainage plan.

It is also important to note that this *Water Sensitive Drainage and Flood Strategy* is part of a wider Water Sensitive City Strategy for Fishermans Bend. This strategy focussed on examining drainage and flood management options from a flood performance perspective, for a defined urban development scenario. That is, the level of greening and water sensitive urban design (WSUD) in the public realm (e.g. quantity and location of street trees, tree pits/raingardens, linear parks & open spaces), the extent of renewal of existing streets, and other liveability and sustainability objectives were held constant when comparing the ‘baseline’ and the ‘hybrid’ solutions. The broader Water Sensitive City Strategy may however consider these other aspects, and their interaction with this strategy, in the future.

1.3 Purpose of this Report

This report captures much of the work completed across various drainage studies over the past four years, as well as the key focus of this most recent project: the use of distributed flood storages in streetscapes and open spaces (also referred to in the report as a ‘hybrid’ approach), an approach endorsed by the *Drainage Steering Group* on 7th December 2018. This is primarily focussed on stormwater (pluvial) flooding.

This report also explores broader coastal and riverine flooding issues, but does not explore the solutions (e.g. a levee) in detail. This report also discusses various related topics, including alternative flood risk mitigation approaches (e.g. permissible/compatible uses) and water sensitive urban design, which will be subject to further consideration and work by stakeholders.

1.4 Process

The project was undertaken collaboratively with all members of the Drainage Working Group: Melbourne Water, Fishermans Bend Taskforce (DELWP), City of Melbourne (CoM), City of Port Phillip (CoPP), South East Water (SEW) and Cooperative Research Centre for Water Sensitive Cities (CRCWSC). The working group met weekly throughout the project, which was overseen by the Fishermans Bend Taskforce Sub-Committee, who convened three times during the project.

In addition, the co-development of street cross-sections and plans that incorporated flood storage was an iterative design process requiring much collaboration between a range of disciplines/areas at GHD, CoPP, CoM and the Taskforce. This required an integration of the drainage strategy development process with the precinct planning and streetscape and open space design process at different levels of planning. This was a novel innovative process, undertaken in a short timeframe.

1.5 Next Steps

It is important to note that following this report there will be various elements of the *Fishermans Bend Water Sensitive Drainage and Flood Strategy* that are explored and planned in greater detail (including but not limited to confirming arrangements for ownership, operation and implementation of infrastructure), and these elements will require formal agreement from partner organisations. Further iterations of this strategy are likely to follow before a final strategy is agreed to by partner organisations.

1.6 Acknowledgements

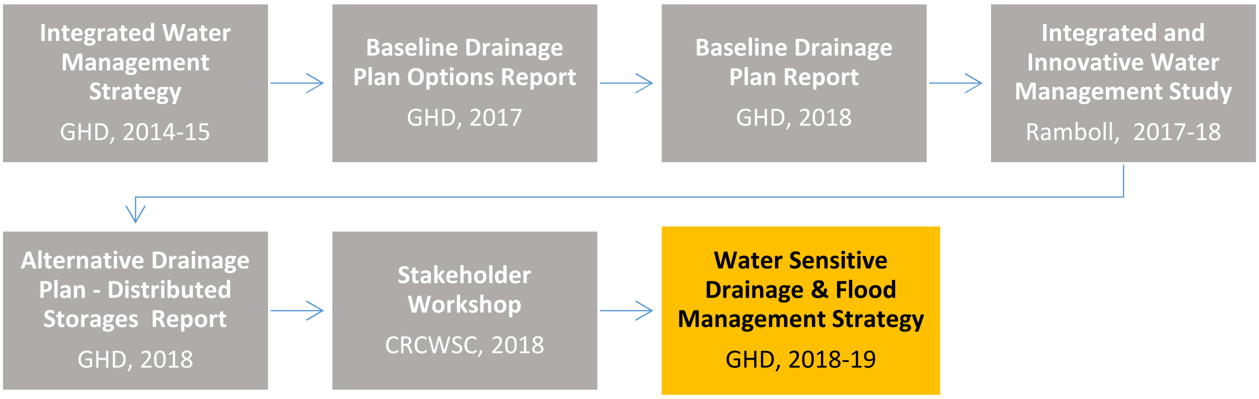
GHD would like to acknowledge the contribution of all members of the working group to the development of this strategy.

2. Background

This section provides contextual information for the strategy, including a summary of past studies, the Fishermans Bend Framework and agreed flood performance objectives.

2.1 Previous Studies

The diagram below summarises the key drainage and flood management studies for Fishermans Bend undertaken in the past 5 years. At the commencement of this strategy in September 2018 a large body of work had already been undertaken. This work had explored and resolved fundamental issues around climate change assumptions and level of service objectives, identified and resolved large knowledge gaps, significantly improved flood models, provided a solid understanding of how drainage and flooding functions under a range of existing and future conditions, established a baseline drainage plan and explored various innovative alternative approaches.



2.2 Fishermans Bend Framework

Fishermans Bend Framework guides development within Fishermans Bend and is supported by a comprehensive set of planning controls in the Melbourne and Port Phillip Planning Schemes. The Framework is structured around eight sustainability goals which include:


4 A climate resilient community

Fishermans Bend will need to be resilient to extreme weather events – including flooding, drought, heat waves and storm surges associated with sea level rise. A high degree of social cohesion exists, creating an environment that enhances community resilience. In the future in Fishermans Bend, the urban heat island effect will be lower than in other areas of Melbourne.

5 A water sensitive community

Stormwater and recycled water will be utilised as a substitute for potable water to conserve water resources. An integrated water recycling facility will be developed to supply a new third-pipe network. Stormwater detention and retention will be provided within buildings. Landscapes will be designed to incorporate water sensitive urban design principles to improve water. quality and manage flooding.

These goals specifically identify the need to be resilient to extreme weather events including flooding and storm surges associated with sea level rise.

The strategies that were proposed in the *Fishermans Bend Framework* include:

- design the public realm to make water visible

- retain design controls to raise habitable floor levels to avoid flooding where other mitigation measures are not possible
- stormwater harvesting and reuse (via building scale rain tanks at all buildings) to minimise flooding
- smart grid technology to maximise the capture of rainwater in buildings, while maintaining enhanced flood mitigation

Over the coming months, it is anticipated that these strategies will be supplemented by an Infrastructure Contribution Plan, a detailed implementation plan for each precinct and an overarching Water Sensitive City Strategy. This report is an input to this further program of work.

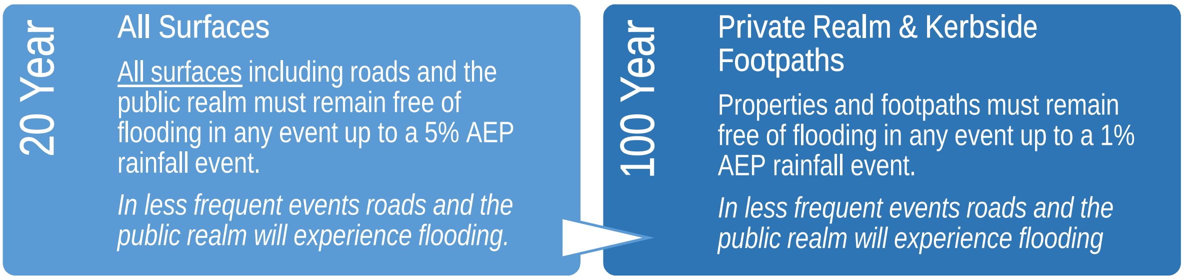
2.3 Flooding Performance Objectives

The performance objectives for flood protection are summarised in ***Figure 2*** below.

Flooding is defined as a water level greater than 50 mm depth.

Level of service (LoS) objectives for managing flooding are as follows:

Figure 2 Level of Service Objectives



Safety Risk Criteria

- Up to the 1% AEP rainfall event, designated overland flow paths (inclusive of minor and/or major thoroughfares) should meet a low safety risk in roads category where practical. A low safety risk in roads is defined as having a Velocity x Depth ≤ 0.40 m^3/s with a depth ≤ 0.40 m (Flood Mapping Projects, Guidelines and Technical Specifications (Melbourne Water, 2014).
- Due to its flat nature, flood flow velocities through the renewal area are generally low and therefore depth is the critical component in the safety risk factor. The results presented in this report therefore focus on Depth plots rather than Velocity or Velocity-Depth plots.

Note:

- It is important to note the use of open spaces and linear parks to function as a flood storage will, upon a strict interpretation, directly conflict with the above LoS definitions and safety risk criteria. This is because the public realm would intentionally contain water in the 5% AEP event, and water depth may be higher than 0.40 m in the storages within linear parks. This is an issue that was explored in the project and is discussed in subsequent sections.
- The *Baseline Drainage Plan Options* report (GHD for Melbourne Water, 2017) explored in detail the augmentation requirements and associated costs of achieving a 5 year versus a 20 year LoS for stormwater (pluvial) flooding. It should be highlighted that whilst CoM has adopted a 20 year LoS across their municipality, CoPP has a 5 year LoS.
- LoS relating to coastal/riverine flooding will be addressed by the levee (although levee design is out of scope for this study).

Average Recurrence Interval vs. Annual Exceedance Probability

This report describes the frequency of rainfall events as an Annual Exceedance Probability (AEP) for consistency with current standards. Earlier reports used the description of an Average Recurrence Interval (ARI) which people are generally more familiar with.

To explain the difference, a 100 year ARI is an event predicted to occur once every hundred years. This is the same as 1% AEP, which is an event that has a 1% probability of occurring in any given year. A 20 year ARI is an event predicted to occur once every twenty years. This is the same as 5% AEP, which is an event that has a 5% probability of occurring in any given year.

2.4 Flood Modelling

The modelling presented in this report is based on the TUFLOW and RORB models used in GHD's previous drainage studies, and the details on the setup of those models are presented within those reports.

Two key model updates that were made for this project that need to be highlighted are that (i) the distributed storages have been configured into the TUFLOW model (rather than the RORB model), enabling the location and sizing of the storages to be optimised, and (ii) the new street layout provided during the project has also been configured into the models.

Optimisation of Storages

RORB has been used on past Fishermans Bend studies just to generate stormwater runoff volumes, as an input to the TUFLOW model (which simulates the performance of the drainage network). Prior to this project, the distributed storages were modelled in RORB as source control storages (effectively in the same way that rainwater tanks were modelled), capturing stormwater before it enters the underground drainage network. Mid-way through this project, the working group decided to modify the operating philosophy to allow stormwater to enter the drainage network and where certain pipes are at capacity, having storages to capture the 'spill' volume. This was considered likely to require smaller storage volumes. Using the storages in such a way needed to be done in TUFLOW.

Design Storm

Different design storms were used for different purposes in this project. The model runs did not include all possible durations, but rather were selected based on an understanding developed from previous flood modelling assessments for Fishermans Bend which have identified the critical duration storms. This enabled a smaller number of event simulations to be run in this study, to optimise the run times and explore a large number of scenarios.

Shorter rain event durations with higher intensities are more critical to estimating pump station capacities. As a result, a 1-hour duration rain event was used to estimate the peak flows at the pump stations.

To estimate flood levels and depths, a larger range of storm durations were modelled to capture the peak flood depths and levels for different critical durations in various parts of the catchment. The resulting flood depth plots are therefore not generated from a single model run, but rather capture the peak flooding across the model runs. The event durations modelled were:

- 1, 2, 3, 4.5, 6, 9 and 12 hour duration events for the distributes storages assessment
- 6, 9, 12 and 18 hour duration events for the existing conditions and baseline infrastructure assessments

Note that the longer durations were generally more critical in the "no mitigation" scenarios when water is ponding for longer and unable to drain within the catchment.

What type of flooding has been modelled and is represented in the maps?

The flood modelling integrates both stormwater (or pluvial or surface) flooding from local rainfall events and coastal (tidal) flooding from Port Phillip Bay and extending into the Lower Yarra River. It does not include riverine (or fluvial) flooding from flows in the Yarra River. This is discussed more in Section 3.5 below.

3. The Challenge

This section describes the context and the challenge for flood management at Fishermans Bend.

3.1 Site Context

Fishermans Bend is currently predominantly privately owned light industrial and warehousing. Four precincts totalling 250 hectares were rezoned to Capital City Zone (Montague, Wirraway, Lorimer and Sandridge) enabling high density development. The 230 hectare Employment Precinct has industrial zoning and is one of Melbourne's seven National Economic and Innovation Clusters (NEIC). Fishermans Bend presents some relatively unusual challenges for planning drainage and flood management works, particularly when compared to a greenfield development or redevelopment of a single land parcel.

Existing Flood Risk

Some areas in Fishermans Bend are already subject to flooding today, and this may be a constraint for development in those areas without the provision of significant flood mitigation infrastructure in the short term. This is discussed more in sections below.

Imperviousness

Fishermans Bend is currently highly developed and impervious, with close to the maximum possible stormwater runoff being generated from rainfall today. The imperviousness of the area, for the purposes of flood modelling, was assumed to be same for both current conditions and 2100 (full development) modelling scenarios.

Generation of increased stormwater runoff due to conversion of vegetated areas to hard surfaces, as would be the case in a Greenfield development or some renewal areas, is not an issue at Fishermans Bend. Conversely, the renewal of the area will gradually increase the area of public open space and greening in the public and private realms, and therefore increase the perviousness of the area. However this has not been modelled, and so modelled runoff volumes may be conservative for the full development scenario.

Development Timing and Sequencing

The timing and sequencing of development and renewal of roads is uncertain, and has not been taken into account in this study. It is important to note that some of the proposed flood management solutions would necessarily be delivered through development and renewal (e.g. rain tanks in buildings and distributed storages in new/renewed roads and open spaces), and that the desired level of service is likely to be achieved gradually over time until full development is reached. This is also the case for the infrastructure solutions (e.g. pipes, pumps, levees). Also, it is worth noting that the area is already subject to flooding and the implementation of the flood strategy is expected to progressively improve flooding as development occurs.

It is therefore likely that development will be sequenced in a way that is not ideal from a flood management perspective. For example, a downstream area could develop before an upstream area develops.

Elevation

Fishermans Bend is low lying, with ground levels as low as 0.6m AHD, as shown on Figure 3 over page. This means that some areas are currently exposed to coastal flooding, which will increase over time due to sea level rise. Approximately 25 ha (or 5%) of Fishermans Bend is below the current 1% AEP flood level (1.6 m AHD), and 166 ha (or 35%) of Fishermans Bend is below the predicted 2100 1% AEP flood level (2.4m AHD).[1] Noting both these numbers exclude the Westgate Lakes area.

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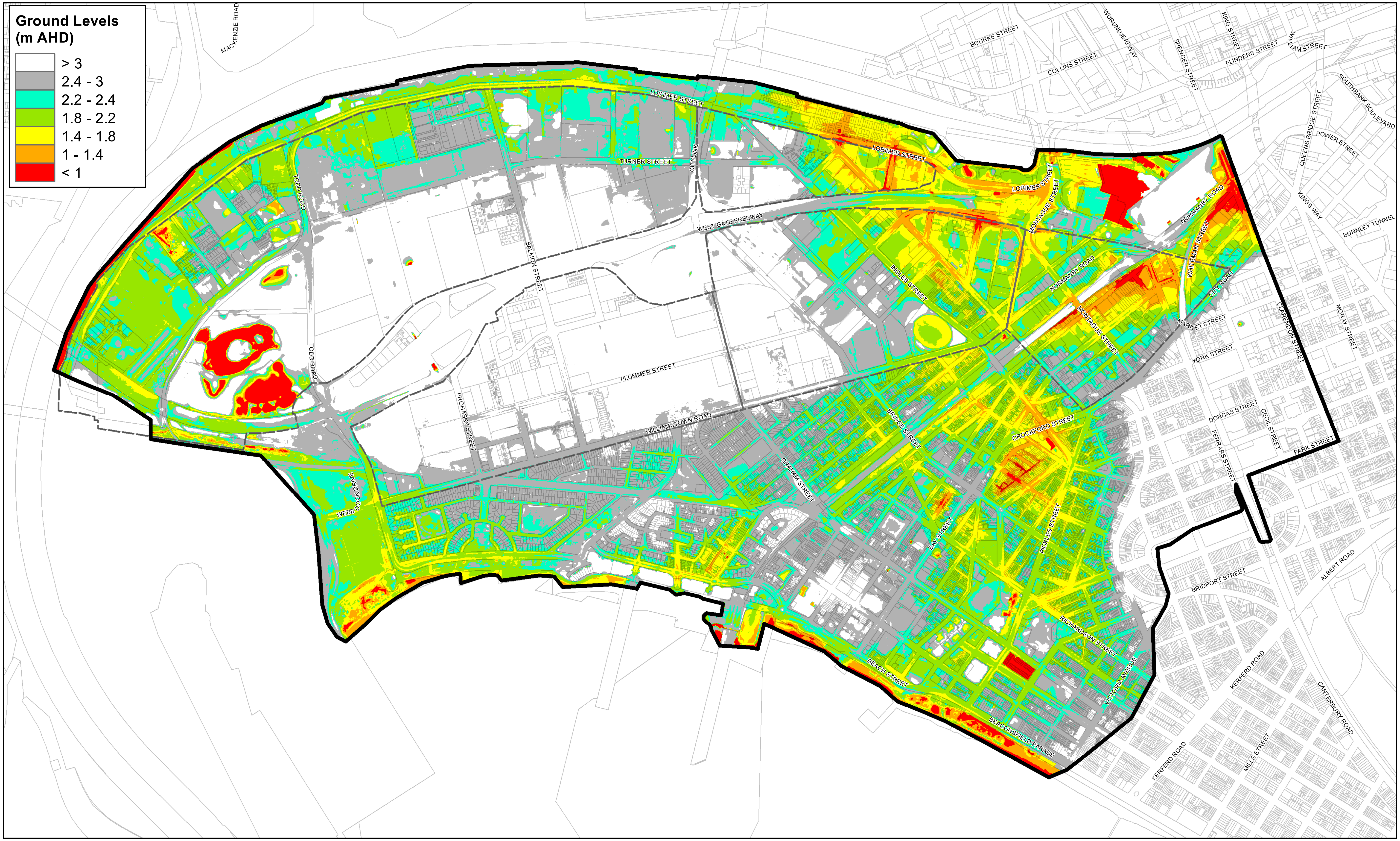
[1] Melbourne Water has adopted 1.6m AHD as the current 1% AEP flood level, and 2.4m AHD as the 2100 1% AEP flood level, for Port Phillip Bay (Planning for Sea level Rise Guidelines, Melbourne Water 2017). Noting that these levels make some allowance for wave action, and the 2100 level makes allowance for 0.8m sea level rise.



Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

Model Boundary

Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Ground levels

Job Number	31-36555
Revision	A
Date	04/04/2019

Figure 3

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Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: sng

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Soil contamination

Contaminated soils occur across much of Fishermans Bend. Often this is a result from past use of contaminated imported materials for broad scale filling which can be 1-2 m thick, and from the past industrial uses of the land. However, the degree of contamination is highly variable between different locations and the exact category or type of contamination requires site investigations to confirm the issues. Excavation and offsite disposal and remediation of the soils is expected to be required across the whole areas. This has the potential to add significant costs to any works requiring underground assets or excavation of soils (Golder, 2018).

Groundwater

Groundwater is contaminated at a regional scale, is highly saline, and with groundwater levels at a depth of approximately 1.0–3.5m below ground level, is relatively shallow. The depth varies due to the presence of former landfills/quarries, extensive underground sewer networks, former wetland areas, proximity to the river and the bay, and local surface elevation. Close to the Yarra River and the bay, the groundwater level is roughly mean sea level (about 0m AHD).

Groundwater levels, close to the Yarra and the bay are expected to increase over time at a rate comparable to sea level rise. This would result in groundwater levels of about 0.8m AHD, which is at ground level in some small areas and just below ground level in large areas in the North-Eastern part of Fishermans Bend.

If groundwater levels are not actively managed (e.g. through de-watering), then any excavated storages in low-lying areas would be exposed to contaminated and saline groundwater. It is not desirable to have (untreated contaminated) groundwater in open water bodies where there is a risk of community contact. There would therefore need to be a management response, including avoiding storage at low-lying areas, sealing/lining of storages, or for example, use of dense plantings and riparian furniture to prevent community contact.

Refer the Groundwater Issues Memorandum in Appendix E for more information.

3.2 Climate Change

Rainfall Intensity

Climate change is predicted to increase the intensity of rainfall events (against a background of hotter and drier climate with fewer overall rainfall days). This will result in increased stormwater flooding over time. All future condition modelling has allowed for an increase in rainfall intensity of 15.5%.[2]

Sea Level Rise

Global sea level rise (SLR) will increase the risk of coastal flooding at Fishermans Bend and result in higher tail-water levels for the underground drainage network. Current planning requirements and practice are to plan for a sea level rise of 0.8m by 2100.[3] This is however only one scenario, and it is important to acknowledge that (i) 0.8m may be reached some time before or after 2100, and (ii) 0.8m is not an end point – that sea levels will continue to rise beyond this. As discussed in Appendix G (Levee Discussion Memorandum), the latest science indicates 0.8m SLR could be reached as early as 2070 and that by 2100 SLR could be as high 1.8m. The timing of sea level rise is important for infrastructure planning as the requirement for a levee and any pump stations is significantly driven by SLR.

Best practice planning should consider a range of scenarios acknowledging the uncertainty in level and timing of sea level rise, and use an adaptive pathways planning approach in response to this uncertainty (e.g. a levee that can be adapted as needed over time).

[2] Following guidance in *Melbourne Water Corporation's Flood Mapping Projects Guidelines and Technical Specifications* for use with ARR1987 (noting that current guidance for use with ARR2016 has a marginally higher increase of 18.3%).

[3] http://planningschemes.dpcd.vic.gov.au/schemes/vpps/13_01-2S.pdf

For the purpose of setting a tail-water level for future conditions flood modelling, a time varying tail-water level peaking at 2.25m AHD (from Water Technology 2017) was used, which combines a 1% AEP extreme water level event in Port Phillip Bay of 1.45m AHD with 0.8m sea level rise.

Note that for the purpose of setting flood levels for development, Melbourne Water has adopted a 2100 1% AEP flood level of 2.4m AHD for Port Phillip Bay, as discussed in the previous section. Refer to the Modelling Review Memorandum in Appendix K for a detailed explanation of climate change, sea level rise and modelling assumptions.

3.3 Three Sources of Flooding

Flooding may arise from three separate sources as shown in Figure 4: **Coastal** (or tidal) flooding from Port Phillip Bay and extending into the Lower Yarra River, **Riverine** (or fluvial) flooding from flows in the Yarra River, and **Stormwater** (or pluvial or surface) flooding from local rainfall events overwhelming the underground drainage network.

Upstream of Wurundjeri Way the Yarra River levels are flow-dominated during flood events and may be higher than peak Port Phillip Bay levels. This means that in the Montague Precinct riverine flooding needs to be considered, not just coastal flooding.

Coastal and riverine flooding can increase the effect of stormwater flooding. This is because the ability of the stormwater drainage network to free drain under gravity is constrained if there is a high water level at the outlet of the network (e.g. in Port Phillip Bay or the Yarra River).

Catchment Context

Fishermans Bend's precinct boundaries do not align with stormwater catchment boundaries, meaning there are interdependencies between development conditions and management of stormwater outside of Fishermans Bend. The stormwater catchments are shown and described in Figure 4:

In particular:

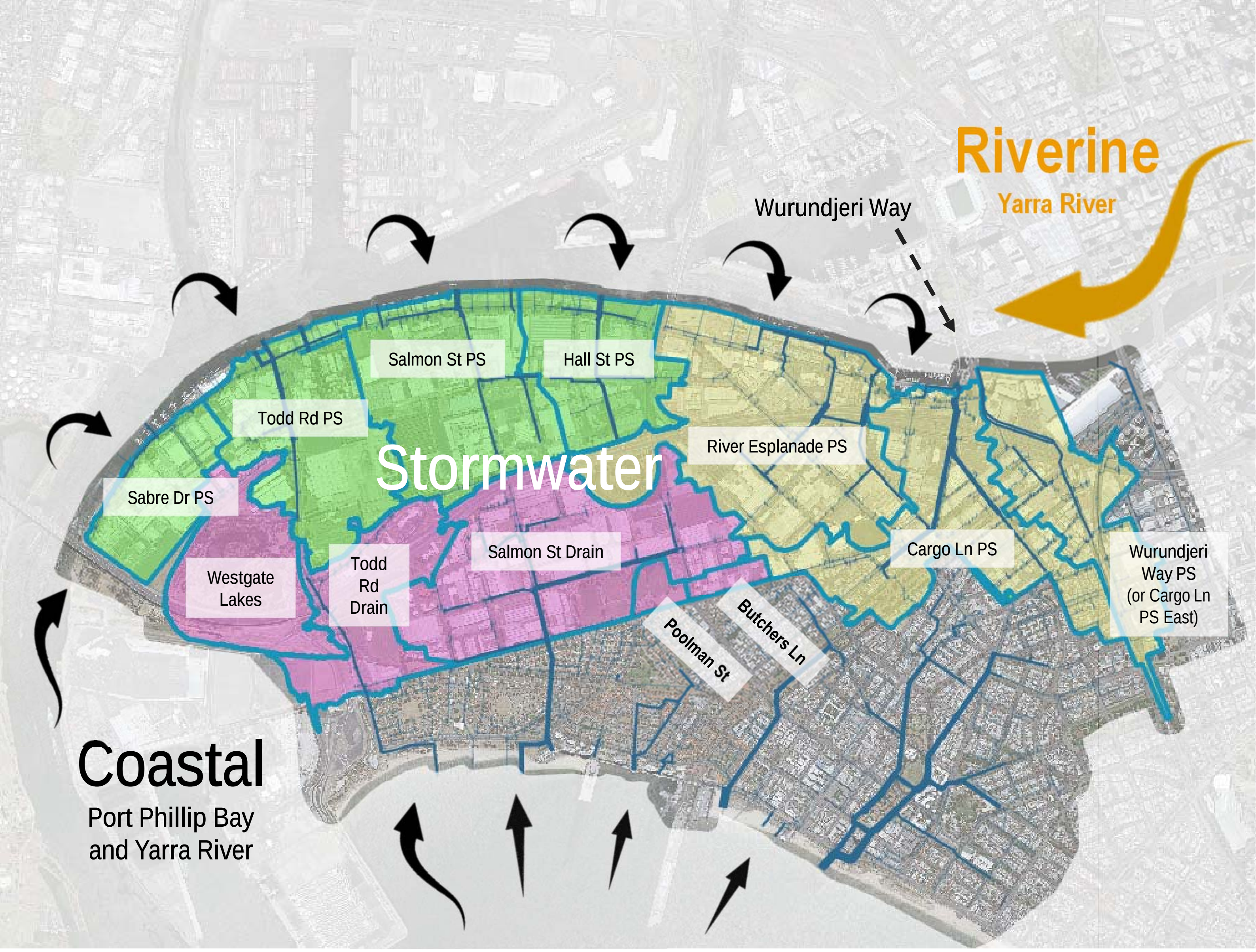
- Flooding in the Montague Precinct (and Wurundjeri Way PS catchment) is hydraulically connected to the adjacent Hannah St Main Drain catchment in South Melbourne. Flooding in that catchment impacts Fishermans Bend.
- Downstream of Wirraway Precinct, in Port Melbourne, the capacity of the stormwater network is constrained. This affects the ability of the network within Fishermans Bend to drain efficiently, particularly when the tide is high. This also means that flood attenuation measures within Wirraway Precinct (e.g. rainwater tanks and distributed storages) will provide a downstream benefit in Port Melbourne.

3.4 Drainage Infrastructure

The existing drainage network is also represented in Figure 4, with the drainage pipes shown in dark blue and the twelve drainage sub-catchment boundaries in light blue. The sub-catchments characteristics are described below the figure.

Additionally, there is the Westgate Lakes sub-catchment. This contains the Westgate Park including two large existing waterbodies.

Figure 4 Drainage Infrastructure and Sources of Flooding



Sub-Catchment	Area (ha)	Catchment Description
Wurundjeri Way PS	35	• Drains north to the Yarra. • Covers most of Lorimer, Montague & Sandridge precincts. • Lower lying areas, with high proportion of existing streets and heritage areas.
Cargo Ln PS	78	
River Esplanade PS	108	
Hall St PS	49	• Drains north to the Yarra. • Covers most of the employment precinct. • Higher elevation areas, with larger land parcel sizes resulting in less existing public drainage infrastructure.
Salmon St PS	66	
Todd Rd PS	64	
Sabre Dr PS	29	
Todd Rd Drain	42	• Drains south to the bay, via Port Melbourne. • Covers all of Wirraway and a small part of Sandridge. • Higher elevation, but are impacted by downstream constraints in Port Melbourne.
Salmon St Drain	95	
Poolman St Drain	5	
Butchers Ln Drain	5	

3.5 Flood Maps

This section contains a series of maps representing flooding at Fishermans Bend under current conditions (i.e. today) and future conditions (i.e. full redevelopment at the year 2100), both without any additional flood mitigation measures (i.e. just the existing underground drainage infrastructure).

Existing Flooding

Flood depth maps for existing conditions without mitigation for the 5% AEP and 1% AEP rainfall events are shown in Figure 5 and Figure 6 below.

This demonstrates if a 5% AEP or 1% AEP rainfall event occurred today, there would be flooding that does not meet the level of service in several areas.

Future Flooding

A flood depth map for conditions in 2100 (fully redeveloped, with the potential effects of climate change) without mitigation for the 5% AEP and 1% AEP rainfall events are shown in Figure 7 and Figure 8 below.

This demonstrates that if a 1% AEP rainfall event occurred in the year 2100, there would be flooding that does not meet the level of service across a much larger area, as compared to existing conditions.

This is principally because of higher tidal levels (from sea level rise), resulting in higher tail-water levels for drainage catchments discharging to the Yarra and the Bay, and some direct inundation from the Yarra. This is also exacerbated by a higher intensity rainfall event resulting from climate change.

Note the previous Baseline Drainage Options Report (GHD for Melbourne Water, 2017) and Baseline Drainage Plan Report (GHD for Melbourne Water, 2018) contain flood maps for other frequency events.

Flood Mitigation

The flood maps show that the Fishermans Bend area has an existing flood risk that will increase over time. This encumbers substantial areas of high value land, and therefore requires an effective drainage and flood management strategy to enable development of the area

What type of flooding has been modelled and is represented in the maps?

The flood modelling integrates both stormwater (or pluvial or surface) flooding from local rainfall events and coastal (tidal) flooding from Port Phillip Bay and extending into the Lower Yarra River. It does not include riverine (or fluvial) flooding from flows in the Yarra River, for reasons discussed briefly in Section 4.3 and in detail in Appendix K (modelling review memorandum). In the model, the Yarra River has the same tidal cycle boundary condition as the bay.

<u>Flood Depth Maps</u>

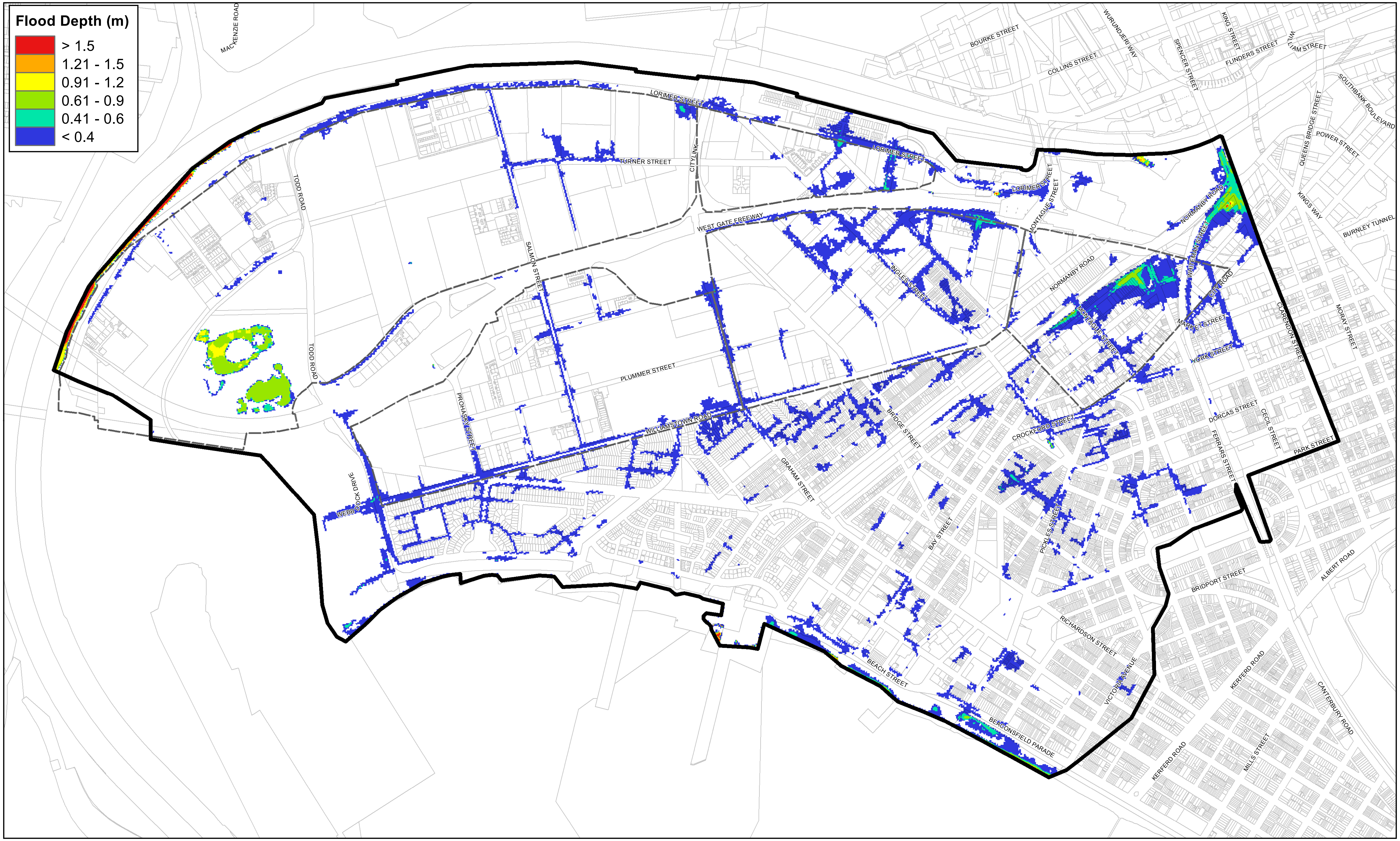
Flood depth maps show the extent and depth of flooding under different conditions.

It is important to highlight, for the purpose of interpreting these maps, that Melbourne Water's safety risk criteria for the 1% AEP rainfall event is that flooding on roads must be less than 0.4m depth.

This means that any flooding on roads greater than 0.4m, or any flooding at all on footpaths or private property, does not meet the required 100 year level of service (LOS).

On the flood depth maps shown below, flooding less 0.4m is shown as a dark blue colour.

For scenarios where there is no levee, the flood maps will show a combination of stormwater and coastal flooding. For scenarios where there is a levee in place, the levee is assumed to be effective and protect against coastal flooding, and so the flood maps will be showing stormwater flooding.



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary

Precinct Boundaries

GHD

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	31-36555
Revision	A
Date	04/04/2019

Current conditions: no mitigation

5% AEP

Figure 5

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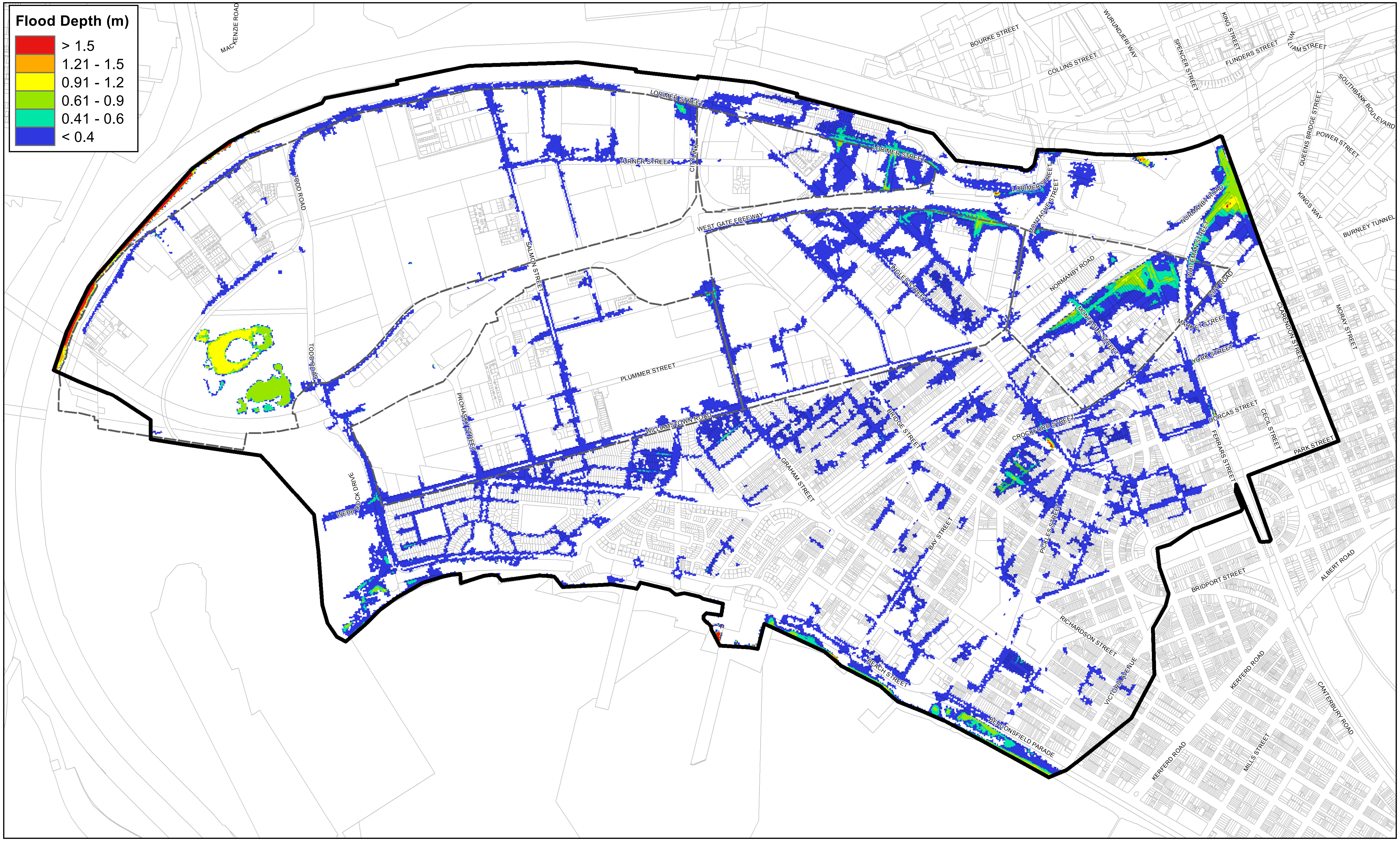
Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: sng



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary

Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number 31-36555
Revision A
Date 04/04/2019

Current conditions: no mitigation

1% AEP

Figure 6

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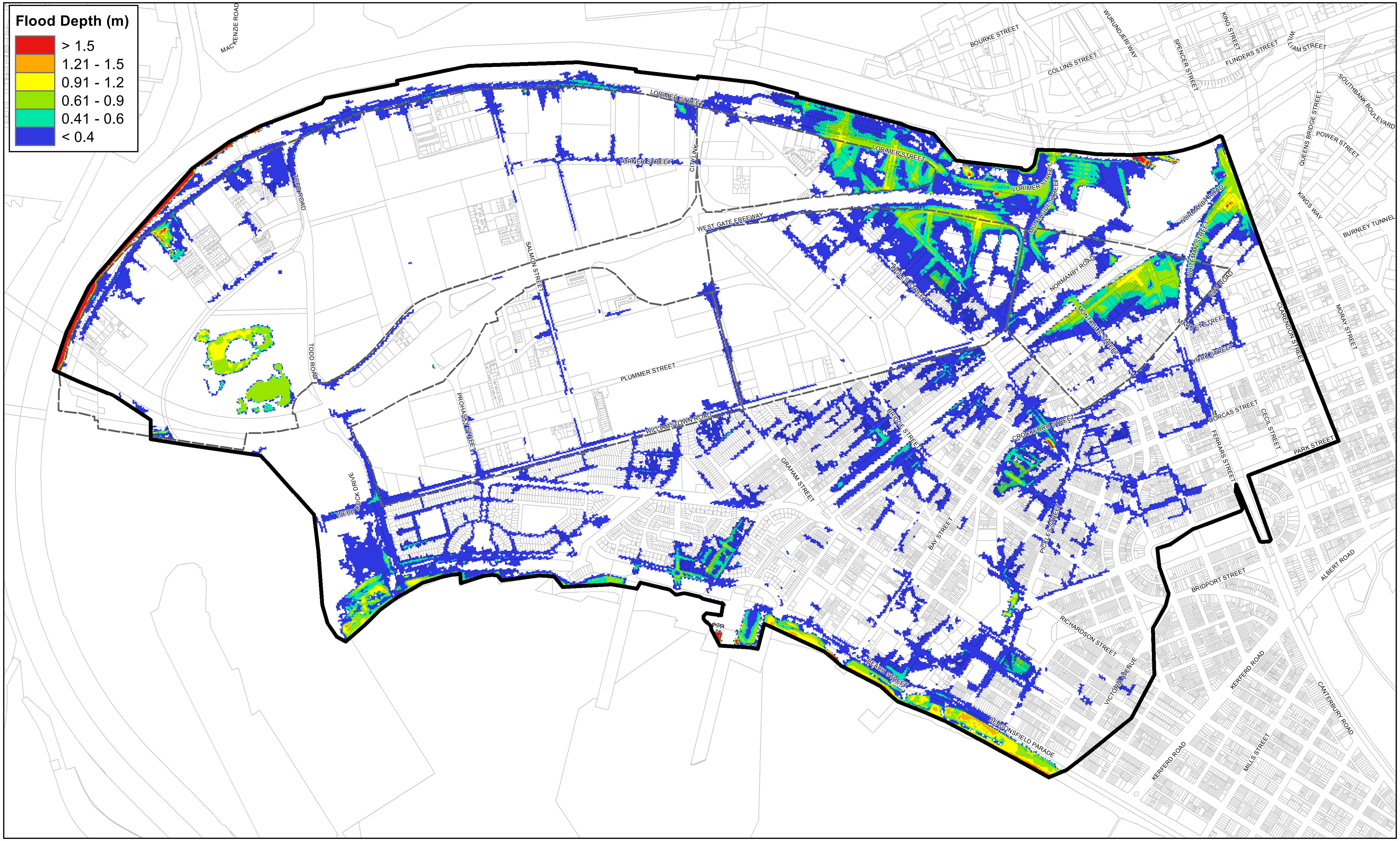

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Model Boundary

Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	31-36555
Revision	A
Date	04/04/2019

2100 conditions: no mitigation

5% AEP

Figure 7

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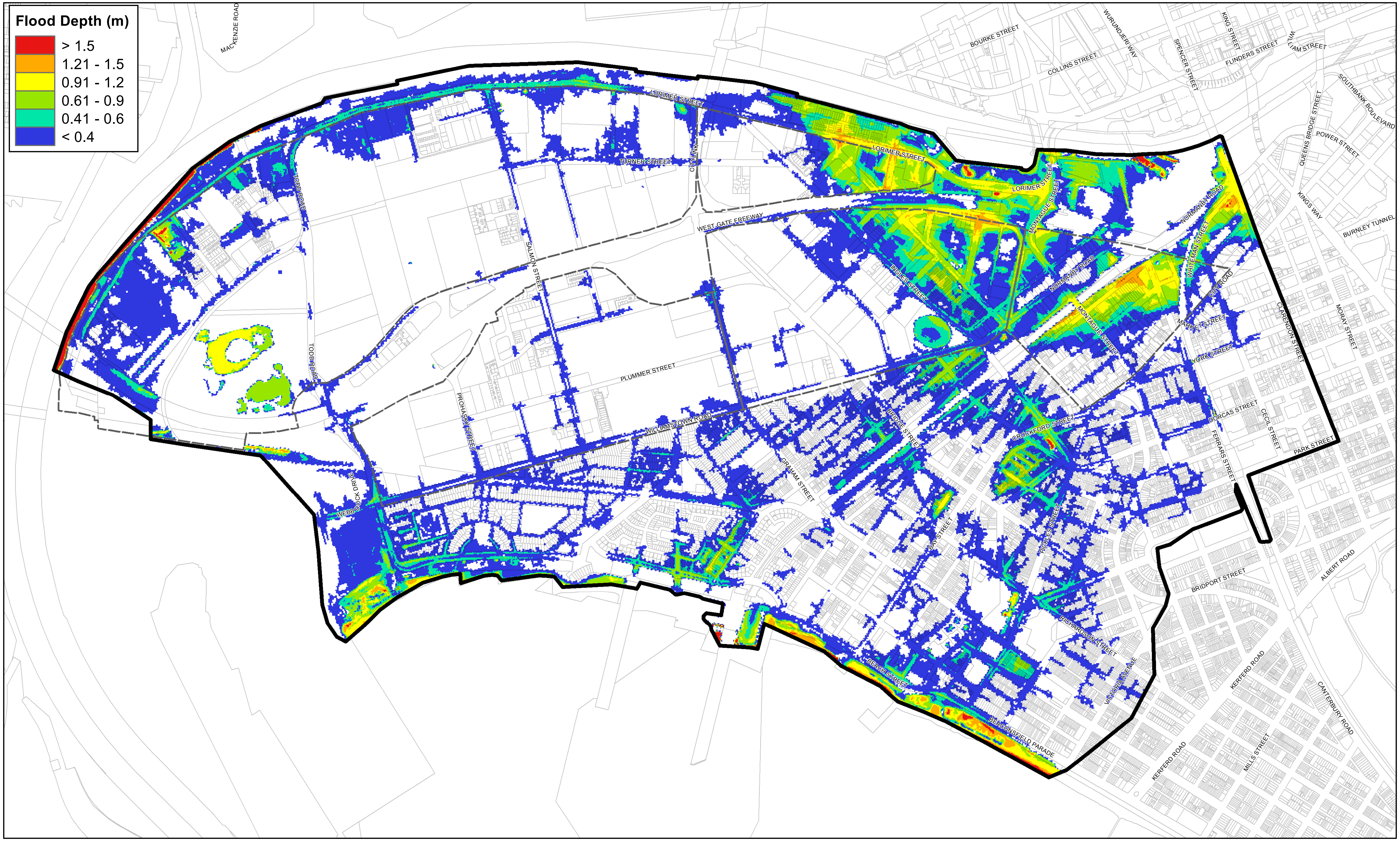

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Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 55

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LEGEND

Model Boundary

Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	31-36555
Revision	A
Date	04/04/2019

2100 conditions: no mitigation

1% AEP

Figure 8

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4. Strategy

This section presents the *Water Sensitive Drainage and Flood Management Strategy* for Fishermans Bend, collaboratively developed by the Fishermans Bend Taskforce Drainage Working Group. This builds on the work completed across various drainage studies over the past four years, including the baseline drainage plan and exploration of various innovative alternative approaches, and provides an agreed high level strategy for managing flooding into the future.

4.1 Summary

The 'water sensitive' (or 'hybrid') strategy aims to manage coastal, riverine and stormwater flooding through to the year 2100, including allowing for the effects of climate change. This strategy has been designed to support the vision and the sustainability goals expressed in the *Fishermans Bend Framework*, particularly *Goal 4 - A Climate Resilient Community* and *Goal 5 - A Water Sensitive Community*. As discussed in section 2.2, this includes the need to be resilient to extreme weather events including flooding and storm surges associated with sea level rise, design of the public realm to make water visible and manage flooding, and building scale rain tanks at all buildings to minimise flooding.

The water sensitive drainage and flood strategy, which is shown in Figure 11 further below in this document, includes the following solutions to manage stormwater flooding:

- **90 ML of rainwater tanks**, to store and detain roofwater runoff from all buildings;[4]
- **25 ML of distributed storages designed into streetscapes and open spaces** to store and detain stormwater runoff in six sub-catchments (rather than pipe upgrades);
- **Upgrading existing underground pipes** in two sub-catchments;
- **7 new pump-stations, and new pipes**, in seven sub-catchments, to collect the stormwater flows at the end of the catchments and pump to the Yarra River.

Additionally, the strategy includes **a levee that will be adapted over time** to manage coastal and riverine flooding.

The following sections outline the mitigation solutions for the three sources of flooding. This includes a high level discussion for coastal and riverine flooding (which will be further explored in the broader Water Sensitive Cities strategy), and a detailed discussion for stormwater flooding, which was the primary focus of this project.

4.2 Coastal Flooding

Challenge

Fishermans Bend is relatively low lying and is exposed to coastal flooding on its northern edge along the Yarra River, at locations where the tidal water level exceeds the height of the existing ground surface.

Along or near the water's edge, only a small segment is lower than Melbourne Water's adopted current 1% AEP Port Phillip Bay flood level of 1.6m AHD. This means that there is negligible coastal inundation (and the drainage network can free drain once the peak tide has receded).

In the future due to sea level rise there are large segments of Fishermans Bend that are lower than Melbourne Water's adopted 2100 1% AEP Port Phillip Bay flood level of 2.4m AHD (taking into account the current 1% AEP flood level resulting from low air pressure and wind/wave effects, plus 0.8m sea level rise). *As discussed in section 3.1, these requirements are from Melbourne Water's Planning for Sea Level Rise Guidelines (2017).* This means that in many areas there would be many areas exposed to coastal flooding

[4] For context, over 300 ML of rain falls onto Fishermans Bend in a 5% AEP event and over 420 ML of rain in a 1% AEP event (noting the exact numbers vary depending on event duration and climate change factors adopted)

by 2100. In addition to traditional flood risk considerations, coastal inundation could result in salt water flooding the urban forest.

As sea levels rise, the risk of coastal flooding will increase. It is important to recognise that sea levels may rise faster than 0.8m by 2100, and sea levels will continue to rise past 0.8m and beyond 2100.

Solution

A levee with a minimum 3.0m AHD crest, around the entire edge of the Yarra River, is required as part of the overall drainage solution, to mitigate the effects of coastal flooding which will increase over time due to sea level rise. This is because water levels will be higher than the ground surface levels during tidal events in Port Phillip Bay.

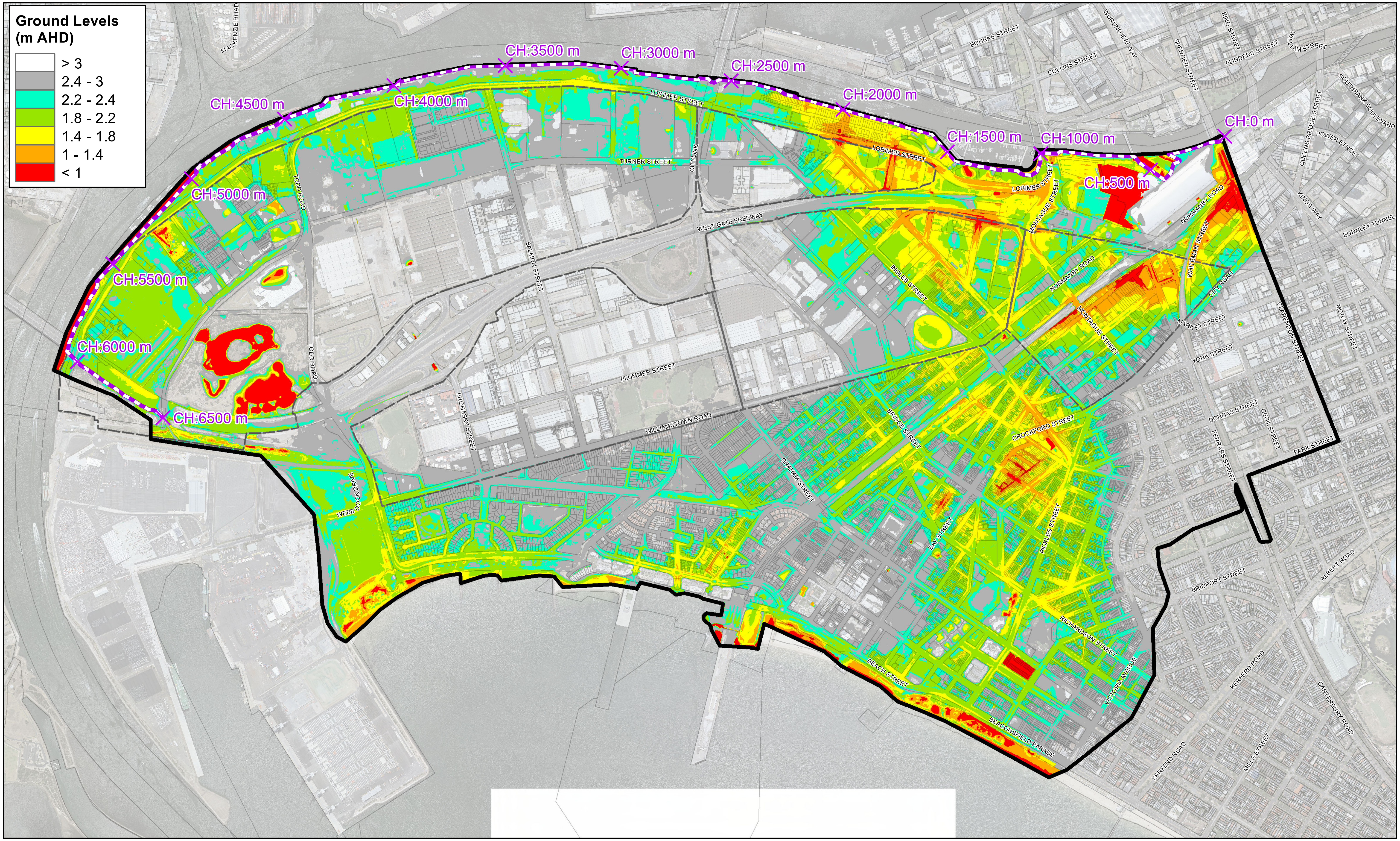
Due to the uncertainty of the timing and extent of sea level rise, an adaptive strategy for implementing the levee and potentially responding to higher than expected sea level rise will be necessary and is discussed below.

The term “levee” is used in the general sense to describe a continuous physical barrier against coastal (and riverine) flooding which may comprise the existing ground surface, earthen levees, concrete barriers, flood walls, raised roads, raised shared paths/cycling paths, etc.

Figure 9 over page shows the *modelled* levee alignment, along the northern boundary of Fishermans Bend extending up through to Southbank, along the water’s edge. This map also shows ground levels, and so provides an indication of where a levee would be needed for a certain peak water level.

Figure 10 shows the 2100 1% AEP flood map with the levee in place, but no other additional mitigation measures.[5] The levee can be seen to alleviate the flooding from coastal inundation to the East of Ingles St in Lorimer, Sandridge and Montague precincts, and to the West of Todd Rd in the Employment Precinct.

[5] The 2100 5% AEP scenario is not shown as it was not modelled



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

- Model Boundary
- Precinct Boundaries
- Levee Chainage (CH)
- Proposed Levee

GHD

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Ground levels & proposed levee

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Figure 9

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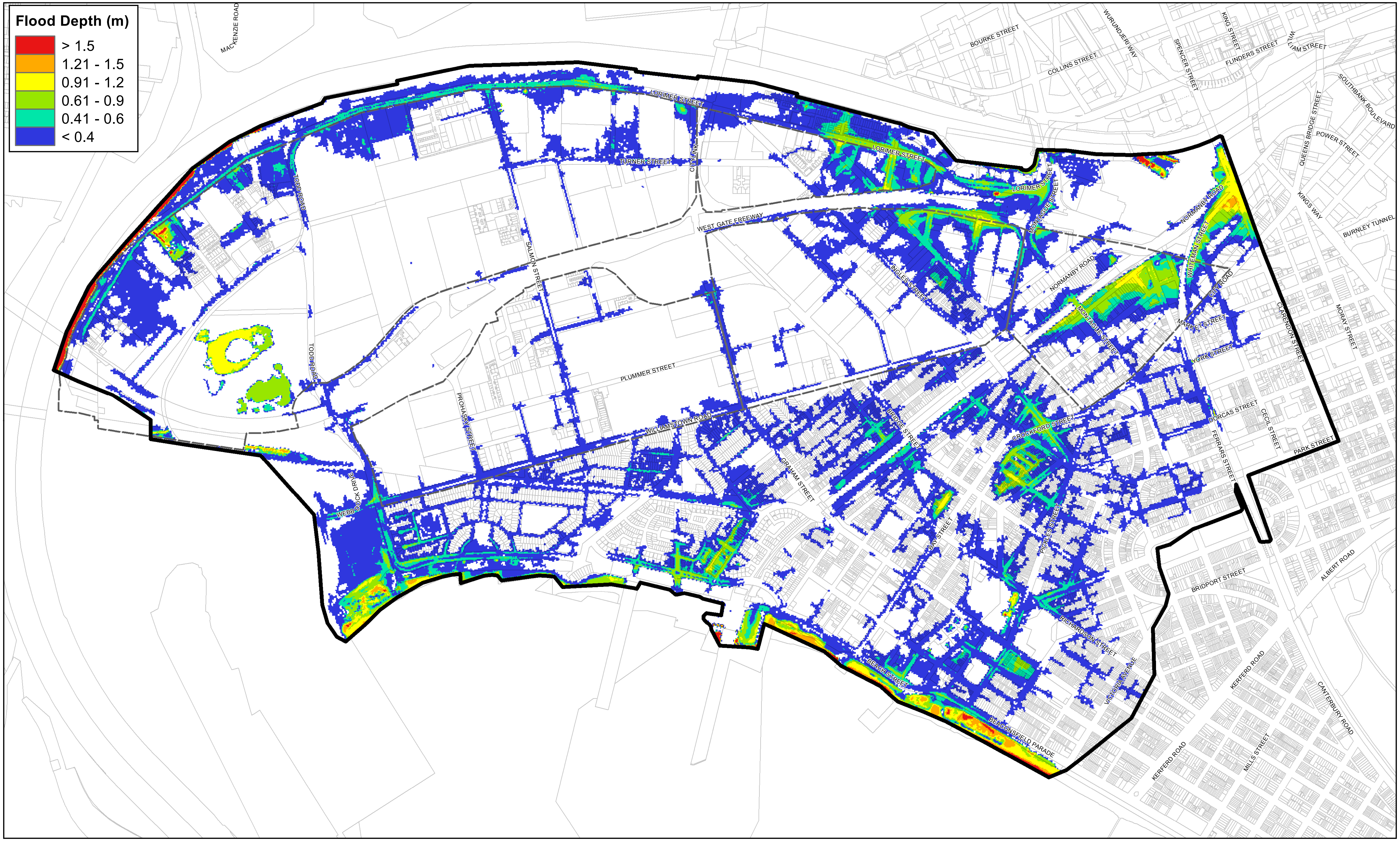

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LEGEND

Model Boundary

Precinct Boundaries

GHD

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	31-36555
Revision	A
Date	04/04/2019

2100 conditions: levee as only mitigation

1% AEP

Figure 10

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Non-Return Valves

The placement of non-return valves on existing drains is necessary to provide protection using the existing river edge in the short term. This will prevent back-watering of the existing drainage system. In the longer term however, a levee will need to be constructed.

Levee Form

The “levee” could take many forms, including the concept of a ‘liveable levee’ or incorporation into the urban form (roads or buildings). This is a design choice that depends strongly on the height, extent and alignment of the levee.

Levee Route

Further work is needed to optimise the levee route, taking into account constructability, integration with the urban form and future developments, ground surface elevation, land ownership, etc. Considerations include:

- The modelled levee alignment is along the water’s edge. This alignment was chosen in the Baseline Drainage Plan (GHD for Melbourne Water, 2018) as it reflected stakeholders’ views that this alignment was optimal, albeit subject to agreement with key landholders such as Port of Melbourne.
- From an elevation perspective, there are instances where, set back from the water, the ground level or existing built form have higher elevations than at the water’s edge.
- Levees also need to be continuous, and so the continuity of the levee between different sections is important.
- The levee route requires careful consideration of how it passes through different areas of public and private land ownership, existing uses and the existing built form to identify the way(s) the levee can be delivered and identify what limitations/constraints exist.

Levee Height

The crest of the levee (m AHD) would need to be at least 3.0m AHD by 2100, in order to meet Melbourne Water’s adopted 2100 1% AEP flood level of 2.4m AHD (*Planning for Sea level Rise Guidelines*, Melbourne Water 2017) plus an allowance for a minimum 0.6m freeboard (*Levee Management Guidelines*, DELWP 2015).[6]

This will need to be higher if sea level rise occurs faster than predicted.

To provide an indication of the extent of such a levee, a levee with a route along the waters’ edge, with a crest height of 3.0m AHD, would effectively extend along the entirety of the western and northern boundary of Fishermans Bend as shown previously in Figure 9. This would be approximately 6.4km long, with a maximum height of 2.1m and average height of 0.8m.

Timing and Adaptation

To account for the uncertainty around the extent and timing of sea level rise, an adaptive pathways approach will be necessary for the levee. This commits to providing protection for 0.8m sea level rise by year 2100, as per planning requirements, with the works potentially staged over time. Additionally though, options to construct an even higher levee to protect against levels above 0.8m sea level rise should be kept open (e.g. contingency/flexible options to be actively considered) and actively monitored over time. Whilst not committing to a higher levee, this might require preparatory actions to be taken now and incorporated into designs (e.g. setting aside land, flexibility in design such as stronger foundations, and modifiable urban design) to ensure the option can be taken in the future if needed.

[6] "General engineering practice is to provide a minimum freeboard allowance in urban areas of 600 mm" (DELWP, 2015)

It is important to note that the setting of the levee requirements, including the design flood level and freeboard requirement, is outside the scope of this report and will be subject to further consideration by relevant stakeholders.

Refer to the Levee Memorandum in Appendix G for more information.

4.3 Riverine Flooding

Challenge

Fishermans Bend is subject to riverine flooding from the Yarra River upstream of Wurundjeri Way, as existing 1% AEP flood flows in the Yarra may produce higher water levels than the existing ground surface.

It is important to note that the peak level in the Yarra River at this location is largely independent of the coastal (tidal) water level, as discussed in detail in Appendix K (modelling review memorandum). This means that for the purposes of a high level strategy, it is appropriate to consider the riverine flood risk independently from the coastal flood risk.

There is however uncertainty around the appropriate 1% AEP flood level to use for the lower Yarra River. This is currently subject to review in Melbourne Water's *Lower Yarra Flood Modelling Project*, from which initial results demonstrate that the flood level may be higher than what the current datasets show, and may be higher than future bay tidal water levels.

Note:

Given the uncertainty, all drainage modelling for Fishermans Bend has used a consistent tidal cycle water level (i.e. the tidal level in Port Phillip Bay) as the boundary condition for both downstream and upstream of Wurundjeri Way in any given modelling run. This will need updating in the future.

Solution

The proposed levee (see previous section) should also be designed to protect against flood flows in the Yarra River. Once the Yarra River flood level has been determined, an agreed approach to manage the levee design (and planning controls) will be required.

Unlike sea level rise, the riverine flood risk is a present one and so the levee in this section may also need to be constructed sooner.

Levee Height

If flood flows in the Lower Yarra River are higher than Melbourne Water's adopted 2100 1% AEP flood level for Port Phillip Bay of 2.4m AHD, then it is possible that the levee will need to be higher upstream of Wurundjeri Way and may need to extend further upstream than shown in Figure 9.

Levee Timing

Refer to the Levee Memorandum in Appendix G for more information on the levee, and the Modelling Review Memorandum in Appendix K for a detailed review of modelling assumptions.

4.4 Stormwater Flooding

Fishermans Bend is currently highly impervious which leads to stormwater (or pluvial or surface) flooding in significant rain events, resulting in stormwater runoff overwhelming the underground pipe network and spilling from the pits.

Figure 10 above shows the residual stormwater flooding in year 2100 with a levee in place to protect against coastal and riverine flood events. This shows there would still be flooding in many areas that does not meet the level of service.

Stormwater flooding occurs for two main reasons. Firstly, there are capacity constraints in the existing network, and secondly, high tailwater levels prevent free draining under gravity when the tide is high. For the catchments that drain south to the bay via Port Melbourne, the constraints exist downstream outside of Fishermans Bend. Both these reasons will be exacerbated by climate change. Increasing rainfall intensity will result in larger runoff volumes that need to be drained, and sea level rise will increase the tailwater levels.

The two factors are discussed separately below.

4.4.1 Tailwater levels

Challenge

The water levels in the Yarra River are higher than the ground surface levels during (1) tidal events in Port Phillip Bay (coastal flooding) and potentially (2) flood events in the Yarra River (riverine flooding) upstream of Wurundjeri Way. Whilst a levee can protect against inundation directly from the Yarra River, a high water level behind a levee (the 'tailwater level' for the underground drainage network) means that the stormwater can't free drain under gravity.

Solution: Pump Stations

Pump stations along the Yarra River at low points are required as part of the overall drainage solution, because regardless of the within catchment response (e.g. pipe upgrades or distributed storages) the stormwater is unable to drain adequately under gravity to the Yarra River within the 24 hour period following peak events.

This is discussed in greater detail in Appendix H (Pump Station Memorandum), which draws on the analysis and conclusions from the Alternative Drainage Plan - Distributed Storages Report (GHD for Melbourne Water, 2018).

Pump station locations

Indicative locations for the seven stormwater pump stations are shown in the *Proposed Water Sensitive Drainage Infrastructure Map* in Figure 11 below.

Pump station footprints

Land take and site location requirements still need to be confirmed. Allowance for driveway access, parking and superstructure (the overall building structure) will need to considered. An indicative estimate for land take is in the order of 70 m^2 for a 1 m^3/s pump station, and 190 m^2 for a 5 m3/s pump station (see *Appendix H* for the discussion on this). In practice, the land take will be very dependent on a range of factors including both site conditions (e.g. connection to existing infrastructure and services) and design choices (e.g. integration with the urban form).

Pump station capacity

Pump station capacities will likely range from around 2-7 m3/s (sized based on the 1 hr critical duration event). It is important to note that the larger pump stations will be handling substantial flows, and will be large structures with large diameter pipes and multiple pumps.

For catchments using distributed surface storages, modelling shows that the pump station capacities will reduce by around 15% (as compared to the Baseline Drainage Plan).

It is important to note that:

- Both the Baseline Drainage Plan and the Distributed Storages Approach include the same quantity of rainwater tanks, which already reduces the pump station capacities.
- The further reduction in pump station capacities *due to the addition of distributed surface storages* is not greater in magnitude because the operating philosophy adopted for the storages was not designed to attenuate the peak flow rates in the stormwater network. Rather, the philosophy for the functioning of the storages was to optimise them (i.e. minimise their size) by capturing the spill volumes from the stormwater network, rather than using the storages as source control storages (capturing the stormwater before it enters the drainage network). Further work would be required

to understand to what extent source control storages would be in effective in certain locations at further reducing the peak flow rates experienced at the pump stations.

- Similarly, further work would be required to understand whether additional storage volume would be in effective in certain locations at further reducing the peak flow rates experienced at the pump stations.

Pump station timing

The timing of the pump stations will be triggered by a combination of the extent of flooding and the timing of development. Further work to understand the flood depths and extents for interim time slices (e.g. 2040 and 2060) would be a first step to assist understanding the staging better. This can inform discussions with stakeholders about when, and under what conditions, the implementation of pump stations would be triggered.

Under existing conditions for the 1% AEP rainfall event, there are small areas of all the catchments draining North to the Yarra River that do not technically meet the level of service criteria. Specifically:

- The flood extents, depths and durations are more extensive in the catchments for the following three proposed pump stations: Wurundjeri Way, Cargo Lane and River Esplanade. Pump stations are likely to be required at these locations first.
- Flooding is less extensive for the Hall Street and Salmon St sub-catchments, and there is only a small amount of flooding in the Todd Road and Sabre Drive sub-catchments.

For 2100 conditions for the 1% AEP rainfall event, pump stations will be needed in all catchments.

Additionally, note that when the Lower Yarra Flood Modelling Study (GHD for Melbourne Water, current) is completed the timing of the Wurundjeri Way and Cargo Lane pump stations will need to be reassessed, as this may be driven by riverine flooding rather than tidal flooding.

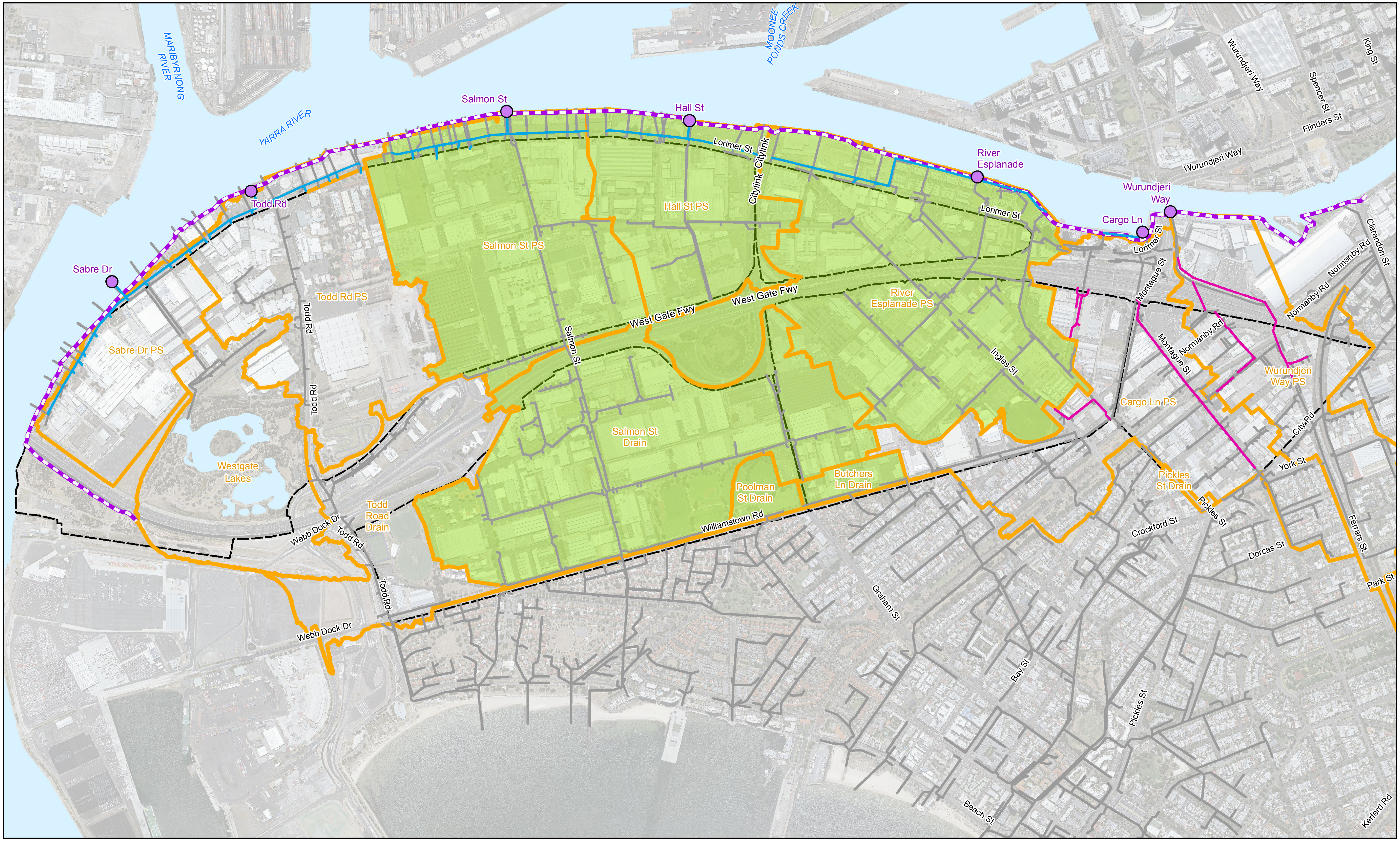
For more information on the pump stations refer to the Pump Stations Memorandum in Appendix H.

Solution: New Pipes

In addition to the pump stations, new pipes are required to transfer the stormwater flows at the end of each sub-catchment to the new pump stations. This has not changed from the Baseline Drainage Plan (GHD for Melbourne Water, 2018). These pipes are shown in light blue in the *Proposed Water Sensitive Drainage Infrastructure Map* in Figure 11 below.

Solution: Non-return valves

Non-return valves (e.g. flap gate) would be required at the outlets of all stormwater pipe outlets to prevent tidal waters backwatering the underground drainage network in Fishermans Bend when tide levels are sufficiently high. This is an important aspect of making the river edge an effective levee for current storm surge. Note that when looking at this in detail in the future, monitoring technology should be considered to detect performance and failures.



Paper Size A3

0 62.5 125 250 375 500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

- Proposed Pump Stations
- Proposed Levee
- Existing Pipes
- Precinct Boundaries

Proposed Pipes

- Duplicate / Upgrade
- New

Proposed Catchment Approach

- Baseline
- Distributed Storage

GHD

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

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Proposed Drainage Infrastructure

Figure 11

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Data source: DELWP, VicMap, CIP Imagery (Jan 2017), Precinct Boundaries, 2018; CoPP/CoM/MWC, Existing Drainage Network, 2018; Created by: splaird

4.4.2 Rainfall runoff

Challenge

With a levee protecting against coastal and riverine floods, and pumps allowing the area to drain under high tide conditions, there are still capacity constraints in the existing drainage network that will cause stormwater flooding.

There are three proposed solutions: **rainwater tanks**, **distributed storages** and **pipe upgrades**.

In the private realm, there are rainwater tanks for all buildings. In the public realm, either distributed storages designed into the streetscapes (e.g. linear parks, tree pits/raingardens) and open spaces, or upgrading of existing underground pipes, will be used. Noting in some catchments neither are required as no augmentations are needed.

The three proposed solutions are discussed separately below.

Solution: Rainwater tanks

Rainwater tanks are required at all buildings to store and detain roofwater runoff, as outlined in the *Fishermans Bend Framework*. This requires a capacity of 0.5 kL active flood storage per $10m^2$ of contributing catchment area, which across Fishermans Bend results in 90 ML of storage connected to 178 ha of catchment area *(noting this assumes 100% of roof area and 70% of podium areas are connected to the tanks, as per the IWM Strategy assumptions in 2015)*. Note that for the purpose of modelling this full volume of storage is assumed to be available at the start of a rainfall event.

The general rainwater tank operating philosophy, originally documented in the Fishermans Bend IWM Strategy (GHD, 2015) and updated based on latest advice from SEW, is shown in Figure 12.

The tanks provide harvested rainwater to the building scale third pipe network, but have the ability to release water in advance of high intensity rainfall events to maximise their flood storage function if they are fitted with smart grid technology.

The rainwater tanks are critical to flood protection across Fishermans Bend, and reduce the amount of pipe upgrades or surface storages required. It is important to note that the extent of other mitigation infrastructure required at Fishermans Bend assumes that the rainwater tanks are fully effective as flood storages. Additionally, it is important to note that the rainwater tanks in the precincts that drain south will also mitigate flooding outside the precinct.

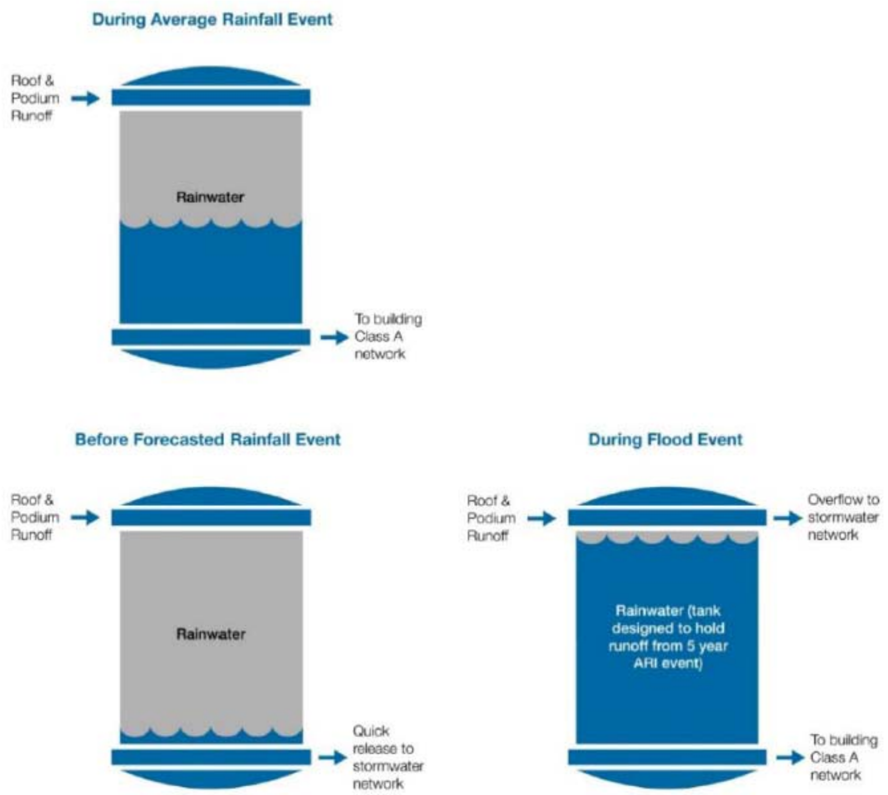
A sensitivity analysis of the risk of not achieving the required rainwater tank flood storage volumes was undertaken as part of this study,[7] which showed that if only 50% of the rainwater tank flood storage volumes were implemented (or effective during an event), for any given reason, then this would approximately double the required surface storage volumes from around 24 ML to 47 ML within the sub-catchments for which distributed storage is proposed.

Given the strategy relies heavily on storage in the private realm, there needs to be a strong focus in further planning and implementation on ensuring that the operating philosophy, planning basis and key assumptions, use of technology, planning controls, compliance and monitoring approach, are all understood and agreed by stakeholders.

The details, and the other benefits from the multi-functional rainwater tanks (e.g. water supply, stormwater quality) are discussed in the *Rainwater Tank Benefits Memorandum* in Appendix F.

[7] For 2100 conditions for the 5% AEP rainfall event, two model scenarios were run, each with the levee, pumps and rainwater tanks included in the model, but without any within-catchment pipe upgrades or distributed storages. For these scenarios the ‘spill’ volumes that result are a measure of the required volume of distributed storage that would be needed to alleviate the flooding. The baseline scenario assumes 100% of rainwater tank flood storage volume is available (i.e. that they are implemented and are effective). The sensitivity case assumes only 50% of the storage is available, uniformly across the whole area.

Figure 12 Smart Multi-Functional Tank Concept

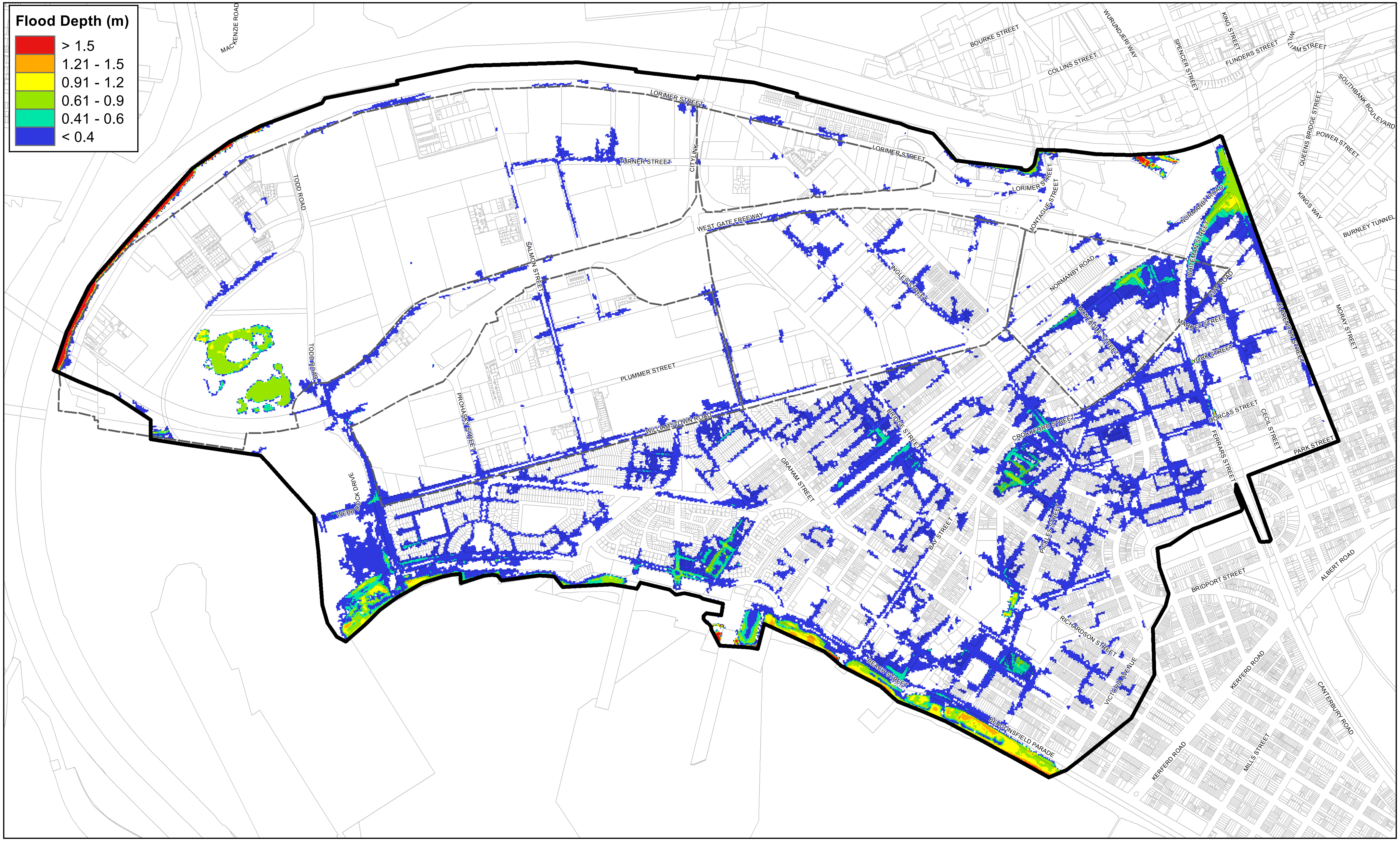


Residual flooding

The residual stormwater flooding, with a levee, pumps and rainwater tanks all in place (but no pipe upgrades or distributed storages), is shown in Figure 13 and Figure 14 below for the 5% AEP and 1% AEP rainfall events respectively.

The required level of service for the 5% AEP rainfall event is that there is no flooding. The flooding shown on Figure 13 therefore does not meet the required level of service, and needs to be managed by either capacity upgrades of existing drainage pipes to increase conveyance, or the use of distributed storages to detain stormwater at the surface. Note that the flooding shown in the map effectively represents the “spill volume” that would need be captured in the distributed storages.

To meet the required level of service for the 1% AEP rainfall event (Figure 14), flooding should be limited to the roads and be no greater than 0.4m.



Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

Model Boundary

Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

2100 conditions: levee, pumps & rain tanks

5% AEP

Job Number	31-36555
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Date	04/04/2019

Figure 13

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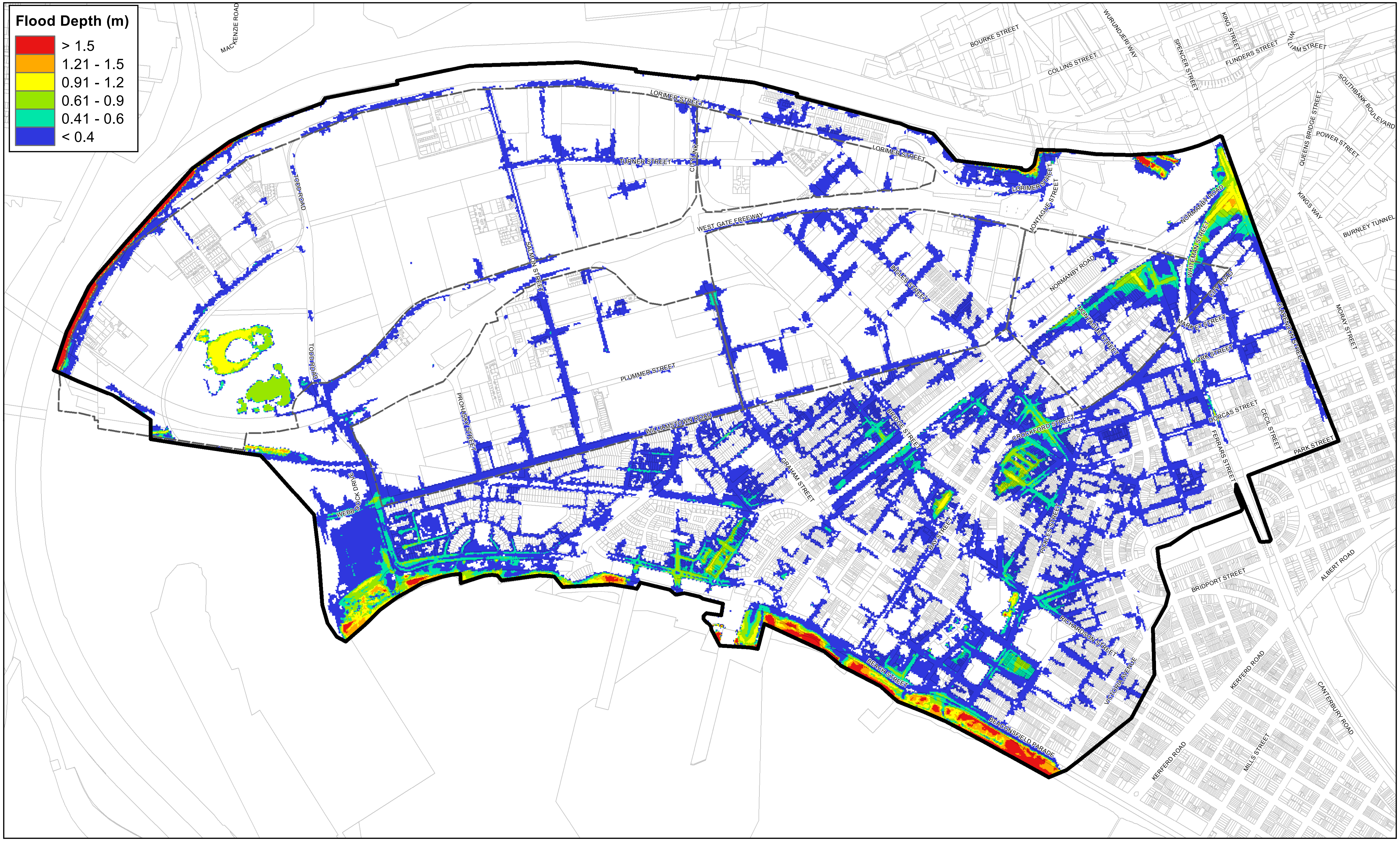
Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: sng



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary

Precinct Boundaries

MELBOURNE WATER

FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

2100 conditions: levee, pumps & rain tanks

1% AEP

Job Number	31-36555
Revision	A
Date	04/04/2019

Figure 14

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Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: sng

Solution: Distributed Storages in Streetscapes and Open Spaces

A total of 25 ML of distributed storages are proposed to be designed into streetscapes (and where needed open spaces) to store and detain stormwater runoff from six catchments, shown in Figure 11, as an alternative to pipe upgrades. The decision process for selecting storages rather than pipe upgrades is shown in Figure 20 below and discussed in further below in subsequent sections. In summary, storages were found to be lower capital cost whilst still providing an equivalent level of service in six of the catchments.

A range of surface and underground storage options were explored, with the preferred concept from the Fishermans Bend Taskforce, City of Melbourne and City of Port Phillip comprising a combination of surface storages within linear parks and tree pits (and raingardens)[8] in the streetscape, and in lowered open spaces (if required).

It is important to note that the operational philosophy developed during the project was for the storages to be used to capture the stormwater "spilling" from pits at locations where the drainage network is at capacity. This is a different approach to source control storages. The 25 ML of storage was determined by calculating the residual stormwater spill volumes with the levee, pumps and rainwater tanks in place (as shown in Figure 13).

Surface storages were preferred to underground storage options for a number of reasons, but particularly because it is lower cost and it meets the broader objectives and goals outlined in the *Fishermans Bend Framework* relating to designing the public realm to make water visible, and managing water in the landscape.[9] Underground storage options by contrast were originally considered because they complied with the level of service and safety risk criteria presented in Section 2.3. Importantly, stakeholders challenged the necessity of strict compliance with these standards, which is discussed further in the section below.

Note that this work was done to a high degree of detail and with significant collaboration using case study areas and street cross-sections for both council areas. Both a low-lying area and a higher elevation area were chosen to test the extremes in Fishermans Bend, so that the results/learnings were transferable to all precincts. Note that the collaborative process is presented in Appendix A, the various iterations of the case study plans and street cross-sections are all documented in Appendix B, and the final outputs captured in Appendix C.

Figure 16 shows conceptually how the different storage elements interact. Note that some elements, such as the overflow from the rainwater tank, are just represented conceptually and may be configured in other ways.

Distributed Storage in Streetscapes

Each of the proposed street typologies (numbering 13 in total for CoPP and 10 in total for CoM) was assessed to determine the storage volume that could be achieved in the linear parks and tree pits. This took into account a range of constraints such as spacing of tree pits, breaks at intersections, the width of the linear parks, interaction of different street scape elements, functionality of the space for their primary purposes, etc. This was a result of an iterative design process with the Fishermans Bend Taskforce and the Councils and so embeds engineering/hydraulic considerations and site constraints as well as Councils' urban design considerations.

Figure 15 over page shows the street typologies which have *potential* for distributed flood storage in linear parks and tree pits (as well as open space areas that could potentially be used for flood storage). Based on analysis of proposed street elements (cross sections and plan view sections), it has been determined a

[8] For the remainder of the document "tree pits" can be considered to also potentially include raingardens, depending on street typology. For simplicity, the term "tree pits" is just used.

[9] Although the level of urban greening and WSUD is assumed constant between the baseline and distributed storages scenarios, stakeholders articulated the following rationale for how storages meet these broader goals. This was because by lowering the elevation of linear parks (and potential open space areas), it is logical to direct minor stormwater catchments towards those storage areas. This presents an opportunity to design features into the storages to make water visible in frequent rainfall events, and also maximise the passive irrigation of parks and street trees.

street could be designed to accommodate up to ~1.3 cubic metres of storage per linear meter if the street has tree pits and raingardens, and up to ~6.5 cubic metres per linear metre if the street contained a linear reserve. The variance between street typologies is documented in Appendix C.

This results in potential flood storage volumes (expressed as m^3 per linear m of street or laneway) of between 0.12 – 1.26 m^3/m if the street typology has tree pits only, and up to 6.46 m^3/m if the street typology also has a wide linear park. This is represented by colour banding on the map. The calculation of these potential storage volumes for each street typology is documented in Appendix C.

The actual locations of the storages, and the balance between streetscape and open space, will need to be tailored within each catchment at a later stage. The work done in this project demonstrated there is sufficient storage potential within each catchment within just the streetscapes (with the exception of Poolman St Drain Catchment requiring some storage in J L Murphy Reserve), meaning storage in open space may not be necessary.

However, the work comparing the storage potential at the sub-catchment level, indicates there a number of location specific variances between the "spill" volume that needs to be captured and the storage potential in the streetscapes. This can be resolved by having storage in public open space, or having more storage added up-stream (i.e. source control) which would reduce the spill volume downstream. The optimisation/design of this needs father detailed planning and will need to be tailored by catchment at a later stage.

Distributed Storage in Open Spaces

In a given catchment or sub-catchment, if the required storage volumes to avoid spills in the 1 in 20 year event can't be met solely in the streetscape storages, then allowance will need to be made for additional storage in public open spaces or a lower level of service provided. The location of the potential storages is shown in Figure 15. Whether or not storage is designed into any of these open spaces will be part of the optimisation/design process that will need to occur at a later stage.

Storage Concepts

The difference between a street that does not have distributed storage design into it, and one that does, is shown in Figure 17 and Figure 18 respectively.

Figure 18 shows 300mm high distributed surface storages above the four lines of tree pits and within the linear park. For a 5% AEP event, these storages will fill with water and cycle paths and roads will remain free of water (achieving a 20 year LoS). For a 1% AEP event, the roads and cycle paths will be covered in water, but the footpaths adjacent to buildings will remain free of water to enable egress.

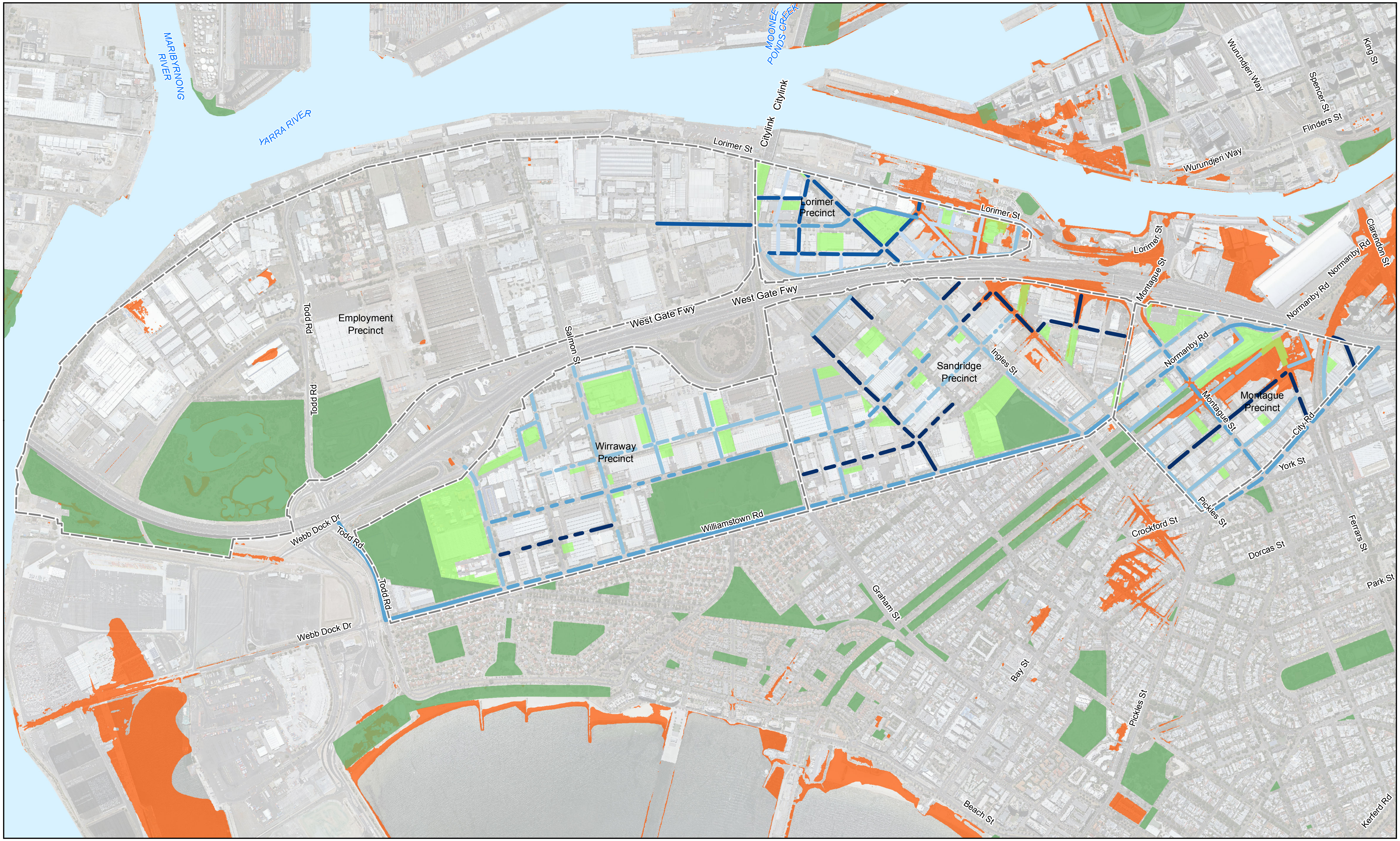
Figure 19 then shows for a street with storage designed into the linear park and tree pits, where water will be during different frequency rainfall events. This shows that open spaces are only encumbered in very infrequent events (e.g. ~10% AEP rainfall event).

These figures show that fundamentally there is no difference in the level of service provided between the two approaches. Although it should be noted that the linear parks with distributed storages will feature water in less than 5% AEP events and have water depth greater than 0.4m in 1% AEP events ,which under a strict definition would not satisfy the LoS and safety risk criteria presented in Section 2.3. For this project, it was agreed that where open spaces/linear parks are designed as flood storages then this is acceptable, as represented in the cross-sections. Beyond this project, it may be necessary to categorise linear parks and open spaces that act as a flood storage differently, with potentially new LoS and safety risk criteria definitions applied. This is an important discussion and is interlinked with the community's understanding of and resilience to flood risk.

Note that these Figures presented were developed using a specific cross-section from Graham Street, but for the purpose of the report they have been generalised. As part of the case study work in the project, a range of other cross sections within both Council areas were also considered and evaluated for their storage potential (refer Appendix B for a detailed record of this work, and Appendix C for the final outputs, including *the storage calculations for each street typology. This includes assumed tree spacings, storage area per tree pit/raingarden, number of tree lines, width of linear park, etc.).*

Discussion

The linear parks, tree pits and open spaces will not only provide open spaces and green infrastructure for the community, they will also have a flood management function and make water visible in the landscape. This approach strongly supports Goal 5 of the Fishermans Bend Framework which states *"… landscapes will be designed to incorporate water sensitive urban design principles to improve water quality and manage flooding*" and will help to deliver the strategic action to *"design the public realm to make water visible"*. As suggested by the Working Group, this may also contribute to social resilience as visibility of water may raise awareness of flooding among the community.



Paper Size A3

0 62.5 125 250 375 500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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LEGEND

Precinct Boundaries

Proposed Open Space

Existing Open Space Areas

Surface Elevation

<1.4m AHD

>1.4m AHD

Storage Potential (m3/m)

0.09 - 0.50

0.51 - 1.00

1.01 - 1.50

1.51 - 3.00

3.01 - 4.00

4.01 - 6.35

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Streetscape and Open Space Storage Potential

Figure 15

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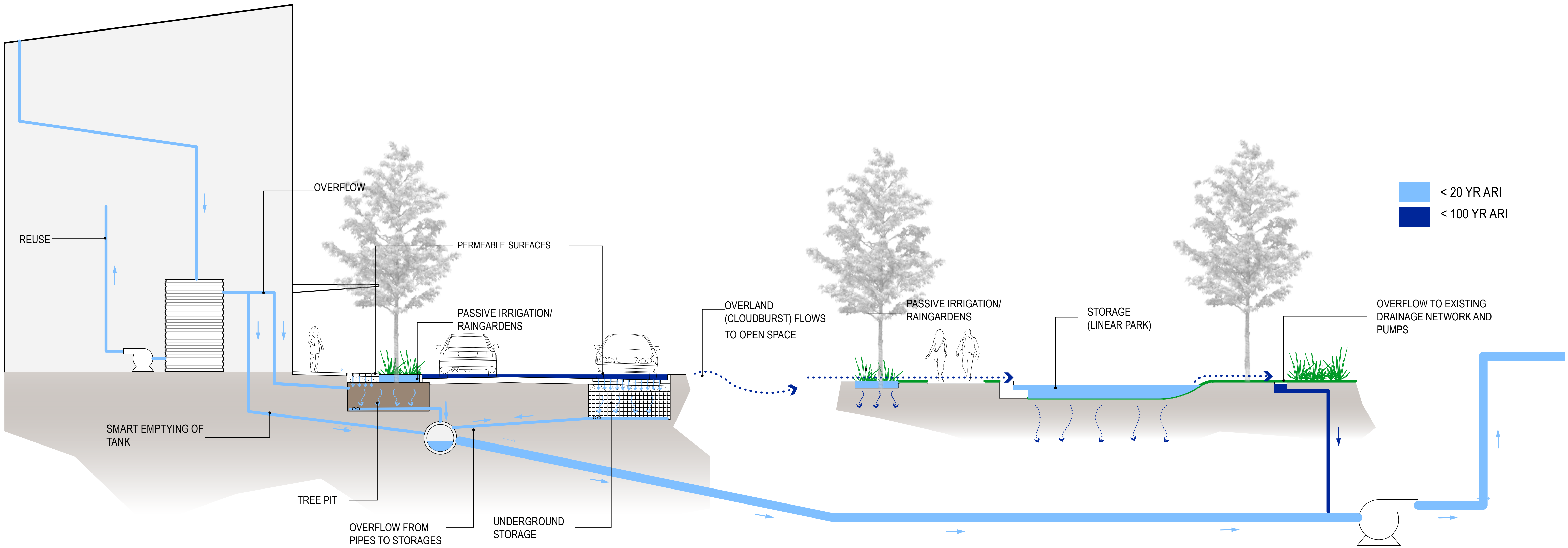


PRIVATE REALM

RAIN TANKS

REUSE

ONSITE PERMEATION

PUBLIC STREET

STORAGE

PERMEABLE PAVING

RAINGARDENS

PASSIVE IRRIGATION

PUBLIC OPEN SPACE

STORAGE

PERMEABLE PAVING

RAINGARDENS

PASSIVE IRRIGATION

DRAINAGE INFRASTRUCTURE

PITS

PIPES

PUMPS

FIGURE 16 DIAGRAMMATIC CONCEPT FOR HOW DIFFERENT STORAGE ELEMENTS MAY BE CONFIGURED IN A TYPICAL GREEN STREET

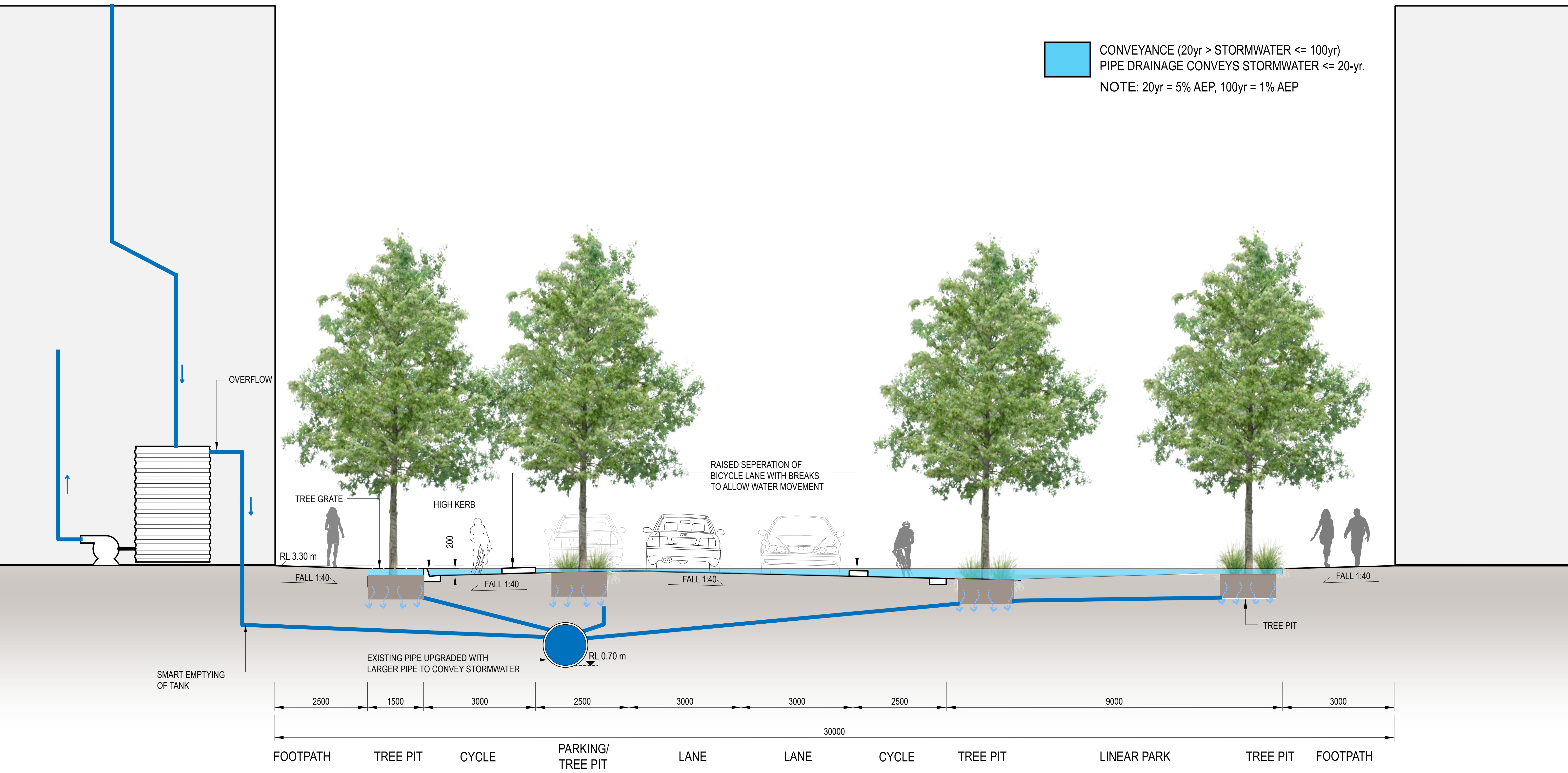


FIGURE 17 TYPICAL STREET SECTION WITH NO STORAGE

SCALE 1:100 @A3 0 1 2 5 m

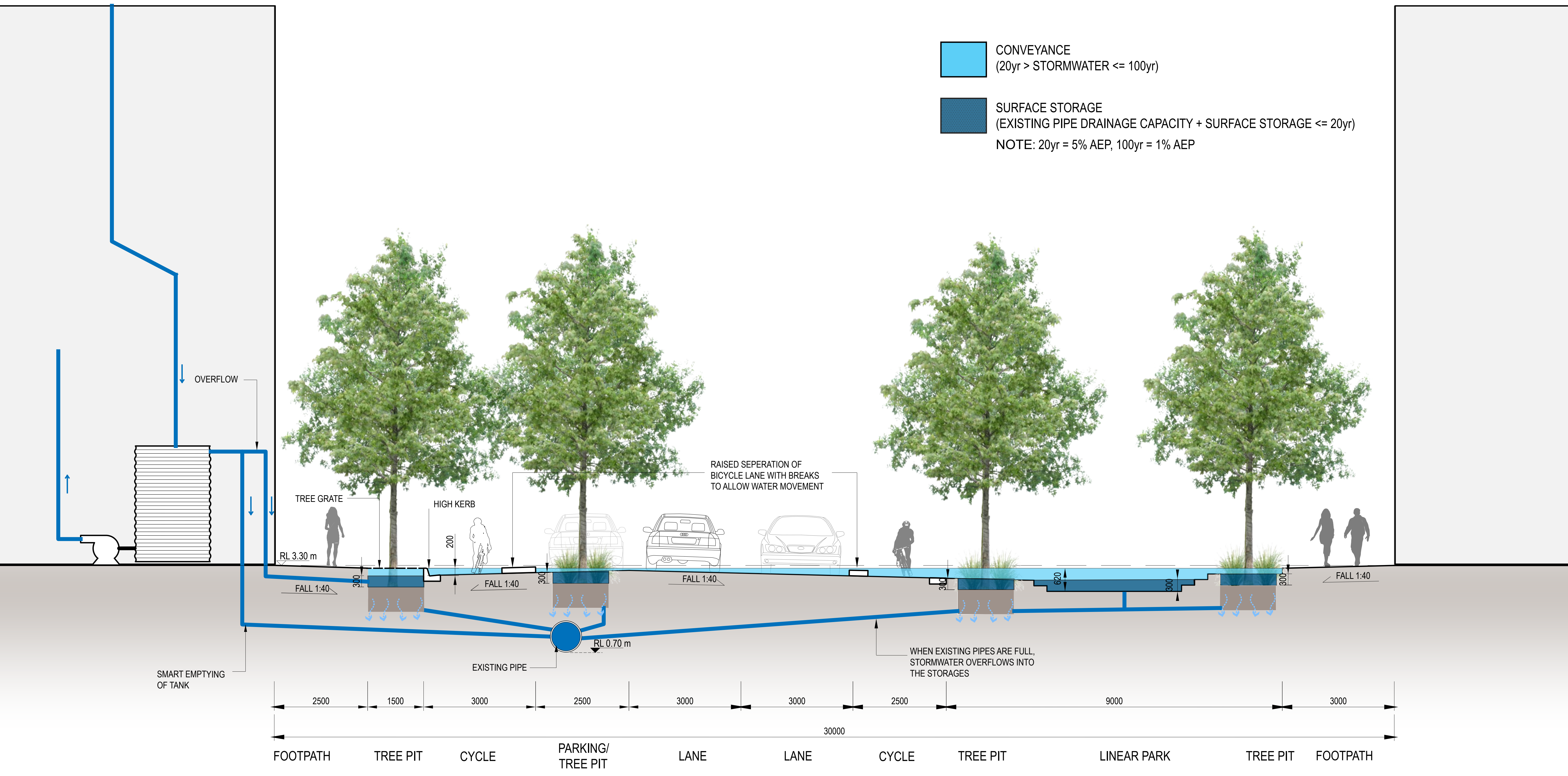
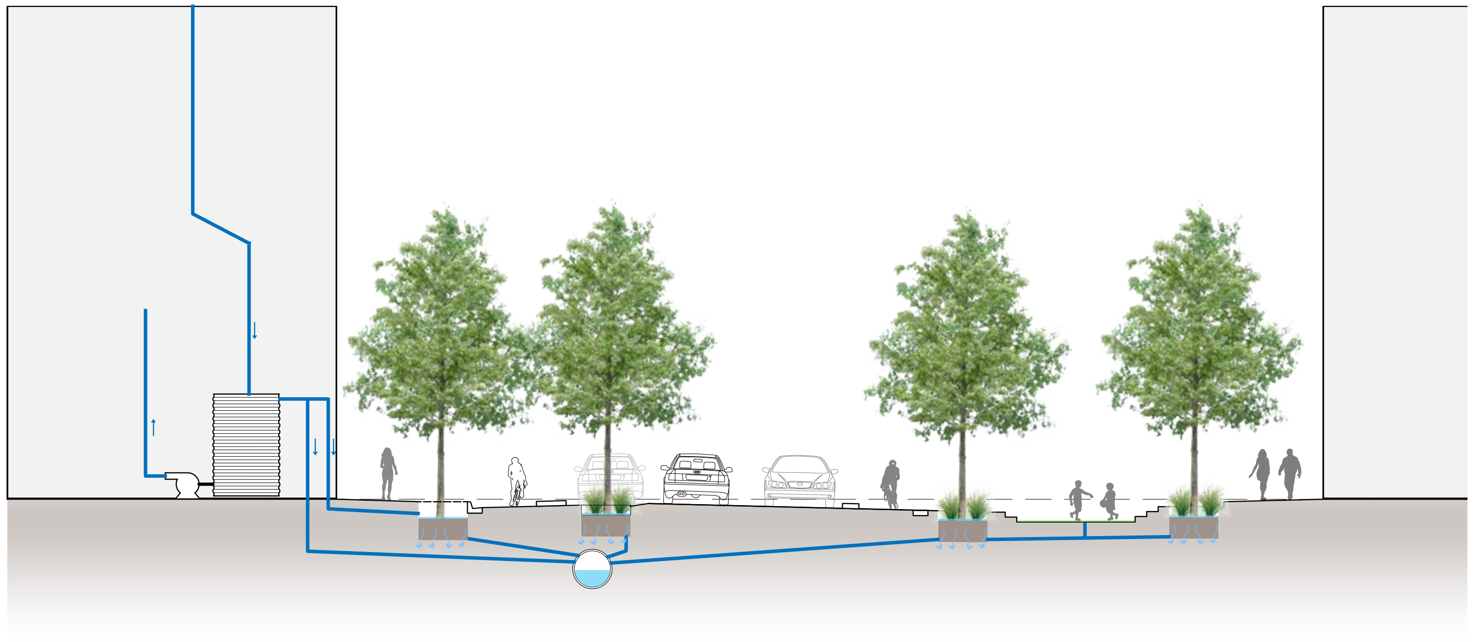
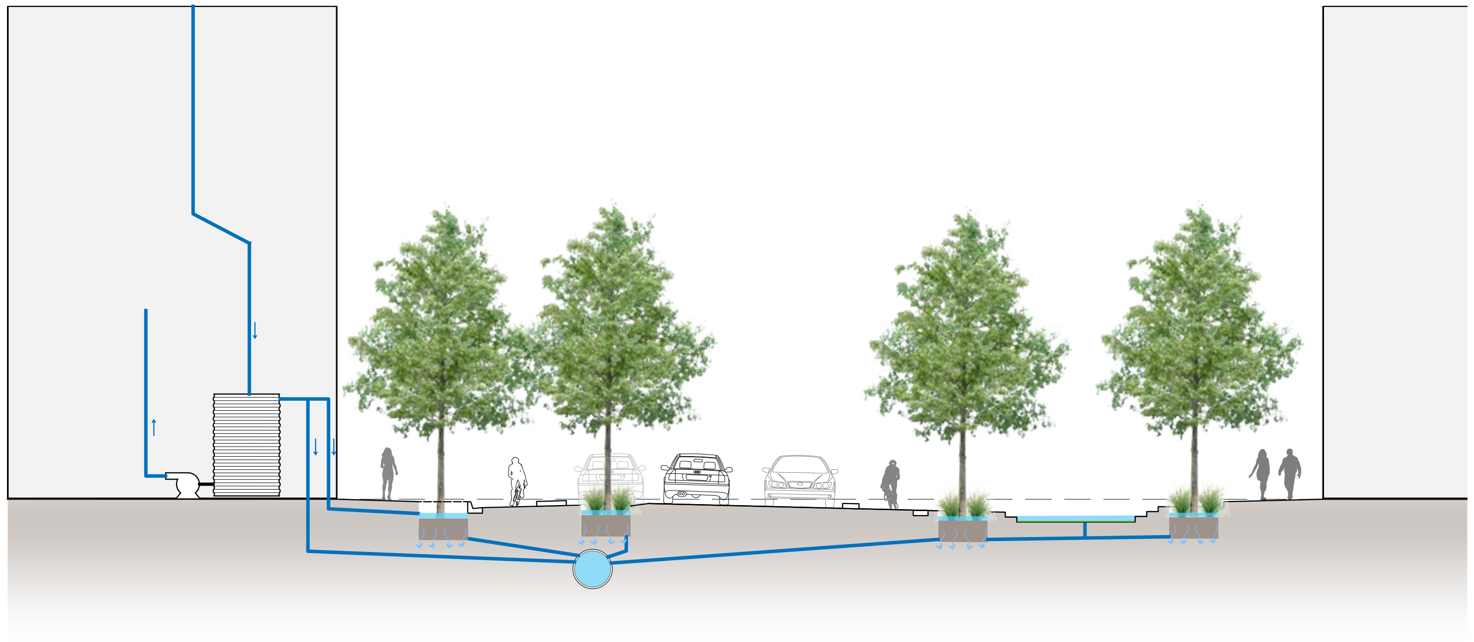


FIGURE 18 TYPICAL STREET SECTION WITH STORAGE

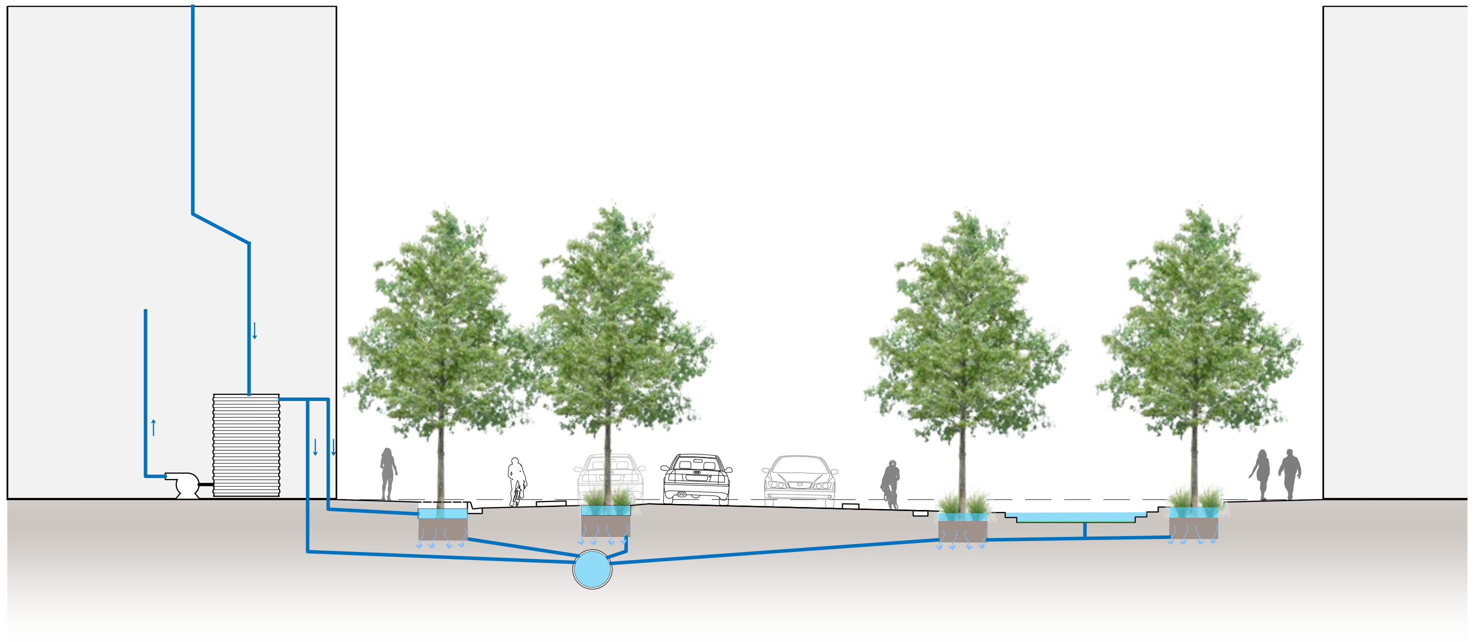
SCALE 1:100 @A3 0 1 2 5 m



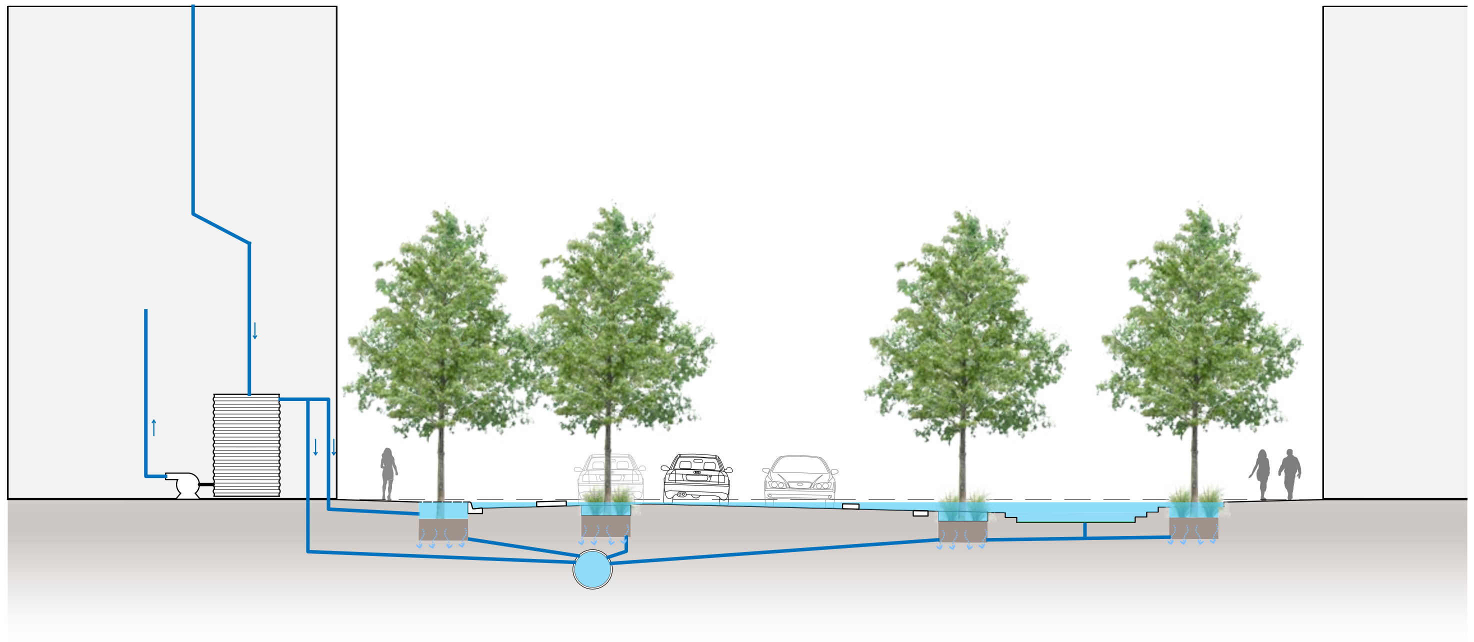
TYPICAL STREET SECTION WITH STORAGE
5 - YR ARI EVENT (20% AEP)



TYPICAL STREET SECTION WITH STORAGE
10 - YR ARI EVENT (10% AEP)



TYPICAL STREET SECTION WITH STORAGE
20 - YR ARI EVENT (5% AEP)



TYPICAL STREET SECTION WITH STORAGE
100 - YR ARI EVENT (1% AEP)

FIGURE 19 TYPICAL STREET SECTION WITH STORAGE, DURING DIFFERENT RAINFALL EVENTS

Solution: Upgrading Underground Pipes

Upgrading existing underground drainage pipes is required in two sub-catchments (the Wurundjeri Way PS and Cargo Ln PS catchments, which cover much of the Montague precinct), as shown previously in Figure 11. These sub-catchments are both low-lying and are to some extent influenced by conditions outside of Fishermans Bend, and so distributed storages were not effective in achieving the required level of service.

The upgrading of existing drainage pipes was considered in detail in past studies, and most recently in the Baseline Drainage Plan (GHD, 2018). In this study, the distributed storage requirements were tested against the infrastructure requirements from the Baseline Drainage Plan. Note that Figure 20 shows the process used for deciding between use of distributed storages versus pipe upgrades.

In the Wurundjeri Way PS catchment, storage could theoretically be used to meet the 20 and 100 year LoS requirements, however it was not considered feasible to design that quantity of storage into streetscapes and public open space. Additionally, storage would likely be higher capital cost than the pipe upgrades.

In the Cargo Ln PS catchment, although sufficient storage could potentially be designed into the streetscapes and public open space, and it would likely be lower capital cost, the use of storages was not effective in meeting either the 20 or 100 year LoS requirements.

Flood Maps

The flood depth maps for the overall water sensitive cities drainage infrastructure (or hybrid) solution are not shown here as they simply demonstrate that the flooding has been mitigated. It should be highlighted that these are contained in two separate sets of modelling results, one using pipe upgrades only and the other using distributed storages only. For the purpose of developing this strategy there was no need to then develop a model that integrated the two approaches, although this is a suggested next step. For the flood depth maps for the distributed storages scenario refer Appendix M.

Catchment Based Decision Making

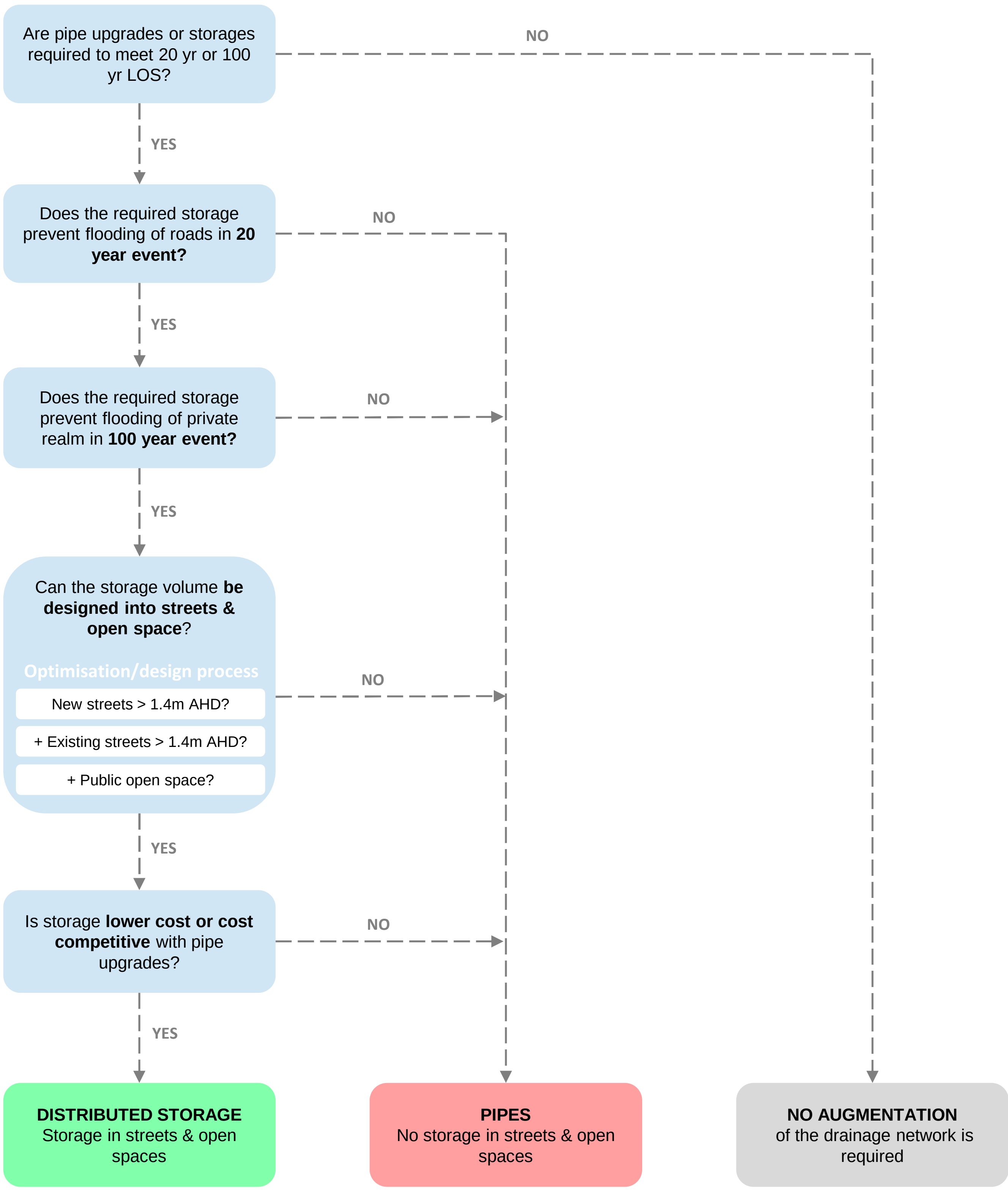
A catchment based decision framework, shown in Figure 20, was developed and then used to determine whether or not to use distributed storages to manage stormwater flooding for each of the twelve sub-catchments in Fishermans Bend.

Note that:

- This decision framework only includes physical, or technical, feasibility criteria and preliminary capital cost estimates.
- There are further considerations that will need to be worked through before committing to the distributed storages approach, including addressing risks and other implementation issues and more detailed planning.
- The cost comparison between pipe upgrades and storages does not factor in potential reductions in pump station capacities, which are a further benefit of the distributed storages approach.[10]
- This decision framework doesn’t cover optimisation of storages and pumps (e.g. increasing storages to reduce pump station capacities). This is an investigation that should be considered in greater detail in future work.
- In practice, there may be situations where an optimised combination of pipe upgrades and storage is used.
- The “required storage” refers to the storage volume identified by modelling needed in a given sub-catchment to avoid triggering a pipe upgrade.
- The issue of implementing storages in locations that may have high groundwater levels in the future was discussed in detail and this is captured in Appendix E.

[10] This does not impact the results.

Figure 20 Catchment based decision framework



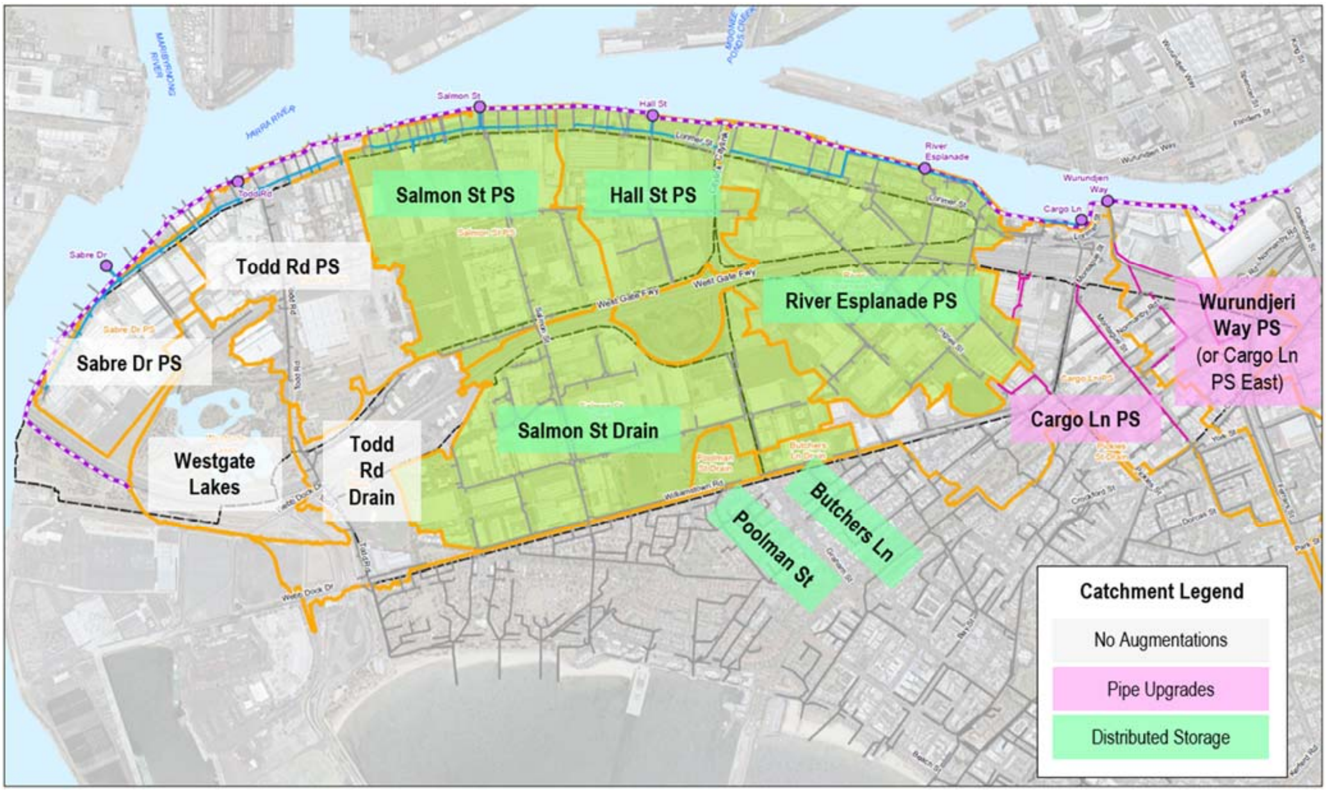
Stormwater Flooding Strategy Summary: Distributed Storage vs. Pipe Upgrades

The residual stormwater flooding (with levee, pump stations and rainwater tanks in place), as shown in Figure 13 and Figure 14 above, can be mitigated in all areas by capacity upgrades of existing drainage pipes to increase conveyance, and in most areas by using distributed surface storages to capture spilling/backwatering from the existing drainage network.

The proposed strategy is shown in Figure 21. This shows for each catchment where distributed storages are proposed and where pipe upgrades are proposed, and those catchments where neither is required as there is negligible residual flooding to manage.

The details of the strategy development for this hybrid approach are outlined in Appendix D.

Figure 21 Strategy: Distributed Storage vs. Pipe Upgrades



4.5 Westgate Lakes

Westgate Park contains two large waterbodies, called the Westgate Lakes. Community groups have for a number of years been advocating for additional flows to be diverted to the Westgate Lakes to achieve environmental benefits. It is also understood this is a concept being considered at the GMH site. In the Ramboll work, the Westgate Lakes were identified as a cloudburst storage, and GHD then modelled this in the distributed storages modelling investigation work in 2018.

As part of the Water Sensitive Drainage Strategy work, GHD has considered at a high level the potential for diversion of additional stormwater to the Westlake Park waterbodies ("Westgate Lakes"), for flood mitigation benefits. This could be either from the catchments draining north towards the Yarra (it wasn't clear that there was a flood mitigation benefit from doing this), or from the Todd Rd Drain catchment which is draining South to the bay (which would primarily benefit downstream flooding outside of Fishermans Bend).

These concepts require further discussions and work before any recommendations can be made.

Refer Appendix L for a more detailed consideration of the potential to supply additional stormwater to these lakes and a discussion of the various issues and suggested next steps.

4.6 Other Flood Management Responses

This strategy largely focussed on the infrastructure solutions to manage stormwater flooding and to a lesser extent to manage riverine/coastal flooding.

Ongoing flood management planning will need to also focus on the technological solutions (i.e. smart technology), disaster preparedness (including community/social flood resilience), planning controls (e.g. compatible uses), building scale flood resilience, and other considerations. These broader issues were not part of the scope of this study and will be considered in ongoing work as part of the broader Water Sensitive City Strategy for Fishermans Bend.

5. Implementation Risks and Issues

This section summarises some of the issues and risks identified for the implementation of this strategy, categorised into: Coastal and Riverine Flooding, Stormwater Flooding, Rainwater Tanks, Surface Storages, Costs, Regional Interfaces and Governance.

These implementation risks and issues consider staging/timing of development and infrastructure provision, responding to uncertainty and change, risk management, identification of regional interfaces, and considering what happens at the end of the planning horizon, governance arrangements, amongst other things.

The risks were identified from a combination of sources. Many have been identified in past strategies, some have been identified based on insights and understanding emerging from this study, and many have been put forward by different stakeholders. This list is not intended to be exhaustive, but rather is intended to identify key issues that should be considered and inform next steps for the working group.

Table 1 Coastal and Riverine Flooding Risks

Risk or Issue	Description	Response
Levee Height Uncertainty	The levee height is related to a number of unknowns such as the future rate of sea level rise, time horizon related to that objective, and the need for freeboard to counter various factors. This also relates to the discussion of risk at Fishermans Bend and the overall standard of protection.	As per DELWP's Levee Management Guidelines relating to public urban levees, a 600 mm freeboard should initially be allowed for the levee at Fishermans, until Melbourne Water (the relevant authority) provide clear guidance as to why freeboard should be reduced and this agreed with relevant stakeholders. Additionally, actions may need to be taken in the short term to preserve the ability to construct a levee in the future (such as preserving a conservative area of land or planning controls), and further adapt the levee in the future to cope with faster/higher rates of SLR. In the longer term, as an example raised by stakeholders, consideration of operational strategy where there is a designated preferential overtopping section along the level could be considered (e.g. located such that the Westgate Lakes to be inundated first). The levee height and standard of protection should be considered in the context of a broader risk assessment at Fishermans Bend.

Risk or Issue	Description	Response
Levee Design, Extent and Cost Uncertainty	In the context of the above uncertainty, the height, location/route, form/type, cross section, land take requirement and cost of levee are not yet determined. The need for some more significant landscaping is a key risk, as is the potential need for freeboard or a higher level in certain locations due to existing flood risk from Lower Yarra Flooding. The extent and therefore cost of the Levee is difficult to estimate.	Detailed discussions with all related parties are required to develop levee concept(s) to enable these issues to be worked through. Although the construction of a levee may be deferred to the future, it is important to develop the long term plan early so that appropriate future proofing arrangements and triggers for action can be established. Further work will be required following this strategy relating to the planning of the levee, including concept development of an optimal route, height and form, with consideration of urban design and landscaping and existing land ownership and use. This will need to be embedded in a wider landscape/urban design treatment of the interface areas between Fishermans Bend and the river. It is also important to allow for a flexible process to adjust the scope, budget and funding (or recover additional costs) if needed in the future. If the levee is going to be developed when river edge is upgraded, then levee requirements will need to be embedded into the planning system.
Sea level rise is higher than predicted	Sea level rise increases beyond 0.8m by 2100. A levee designed for 3.0m AHD may result in a levee failure (by over-topping) from more regular events. Velocities would be relatively low, but may be high in some areas if this results in a levee breach.	An adaptive pathways approach should be used in the design of the levee. This approach, for example, would commit to providing protection up to 0.8m sea level rise by year 2100. However, the initial works could be delayed or staged over time. Additionally, options to construct an even higher levee to protect against levels above 0.8 sea level rise should be kept open (e.g. contingency/flexible options are actively considered). Whilst not committing to a levee of this height, this might require preparatory actions to be taken now and incorporated into designs (e.g. setting aside land, flexibility in design such as stronger foundations, and modifiable urban design) to ensure the option can be taken in the future if needed. This requires further planning now.
Tidal events are higher than levee	Peak tidal water level is higher than the predicted 1:100 level, e.g. through storm surge. This can result in the levee over-topping.	An allowance for freeboard can mitigate this risk to an extent.
1:100 Flood Flows event in Lower Yarra is higher than the current designated flood level	Melbourne Water's designated flood level may change in the near term for the Lower Yarra River (above Wurundjeri Way), dependant on the outcomes of a MW flood study for that system that is currently underway. This could result in a risk that that part of the levee is too low and is overtopped. This has implications for Fishermans Bend (and other areas), including the extent and height of the levee, and updating planning controls (e.g. LSIO).	An agreed approach to manage the levee design and planning controls once the final Yarra River flood level is determined in 2019 is required. Therefore there will be a need to allow for flexibility to accommodate the outcomes of this future work.
Maintenance	The levee is not maintained to a sufficiently high integrity	Could have active monitoring to detect system performance and potential modes of failure.

Table 2 Stormwater Flooding Risks

Risk or Issue	Description	Response
Higher than expected rainfall event (> 1% AEP)	A greater than 1% AEP rainfall event occurs. This could result in significant flooding across all low lying areas of Fishermans Bend. ***Refer to 0.2% AEP flood map over page.***	Further consideration is required of flood risk, including under higher than 1:100 events. This has implications for flood preparedness planning and planning control
Location, Type, Design and Cost of Pump Stations Uncertain	Low-lift high-capacity stormwater pumping stations of the size required at Fishermans Bend (e.g. up to 7 m^3/s) are not common in Australia. Additionally, there are challenges relating to appropriate location of the pump stations and incorporating these into the urban form. There is a large uncertainty around the land take requirement and therefore the location and urban design of the pump stations, and so too the cost.	A concept design of one of the pump stations is recommended to enable all of the necessary issues to be worked through with the various parties. Whilst some of the pump stations may be deferred to the future, it is important to identify the actions that may need to be taken in the short term to preserve the ability to locate the pump stations optimally in the future (e.g. securing land).
Failure of Mechanical Devices	There is a need for mechanical devices, in particular pumps and flap valves, as ground level in many areas is below future peak water levels (and in some cases current peak water levels).	Further work is needed to ensure the design concepts and costing for these assets is appropriate for the risk protection needed, including allowance for ongoing maintenance and testing to ensure they function when needed. This may be associated with significantly higher initial and ongoing costs than the preliminary estimates, due to the need to provide sufficient risk protection. Requires active monitoring, maintenance and contingency response planning for critical infrastructure. Monitoring on non-return outlets for blockages
Power Failure	The pump stations will need secure high voltage power supplies.	Further work is needed to consider the power supply requirements for the pump stations. However it is understand that power failure will be a reducing issue as the area will have the reliability of a CBD area, and backed up by critical power users such as data centres setting up in the area which will require high power reliability.

Risk of higher storm events

The map over-page shows the flooding associated with a 1 in 500 year event (future conditions at 2100), with all proposed drainage mitigation infrastructure in place.

Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary

Precinct Boundaries

GHD

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

2100 conditions: baseline infrastructure

0.2% AEP (9 hour event)

Job Number	31-36555
Revision	A
Date	04/04/2019

Figure 22

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_TUFLOW_A3L.mxd

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Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: sng

Table 3 Rainwater Tank Risks

Risk or Issue	Description	Response
Required storage volumes not achieved	Rain tanks do not achieve the active volume of flood storage expected/modelled *(noting that design requirements are for 0.5m^3 storage per 10m^2 catchment area, which has been modelled as a total of 90 ML of storage with a contributing catchment area of 178 ha)*. This could be for a variety of reasons, including: (i) because tanks are partially full or full at the start of a storm event due to governance or technology failure (ii) design requirements of storage per roof area aren't being met (iii) contributing roof/podium catchment sizes are smaller than modelled (noting the planning controls refer only to "100% of suitable roof area") resulting in more stormwater runoff to the drainage network than expected. A sensitivity analysis of the risk of not achieving the required rainwater tank flood storage volumes was undertaken. This found that if only 50% of the rainwater tank volumes were achieved (for any given reason) then this would approximately double the required surface storage volumes from around 24 ML to 47 ML (in the five sub-catchments for which distributed storage is proposed).	Monitor compliance with planning requirements. Contingency actions should be considered including changes to planning controls, or additional public flood mitigation measures. Regularly test remotely controlled rapid discharge valve for tanks (coinciding with forecast upcoming storm event). Additional storage is created in the public realm to address the deficit. Storage targets for catchments. Review modelling assumptions against the planning controls to identify any inconsistencies.
Implementation and Compliance	Non-compliance may lead to less flood storage volume available overall.	Penalties applied for non-compliance to fund additional storages that may be required in the street and in open space (to achieve the overall required storage volume in the catchment/precinct).

Table 4 Surface Storages Risks

Risk or Issue	Description	Response
Poor coordination of infrastructure servicing and reconstruction	Poor coordination of street infrastructure and reconstruction, resulting in service authorities digging up water sensitive city infrastructure or laying in areas which impede the strategy.	Responses will need to be developed as part of on-going governance arrangements.
Planned surface storage volumes not achieved	Storage volumes required to meet the 20 yr LOS are not achieved in streetscapes/open spaces	Contingency actions should be allowed for, including a mechanism for addressing storage deficits (from both rain tanks and surface storages), e.g. by investing in storage in other streets/open spaces, or alternatively, increased pipe or pump capacities. Precinct plans should be checked once complete, to ensure sufficient storage has been allowed for. Design guidelines and storage targets for designers / engineers delivering streets.
Streets renewed & developed over time	The distributed storage solution may not be fully effective until full development, as streetscape and open space storage & street conveyance will be delivered through the renewal of existing roads and development of new roads. This may take time (decades) to occur. In the meantime, storages are not effective if not yet built and therefore flood risk may increase over time. The reason is that the solution is dependent on road grades and the specific location of storage in the streetscapes and open spaces. The distribution of stormwater flows to provide even runoff along various streets might not work in practice until most of the development is complete. The quantity of storage required may not be achievable until all existing roads are redeveloped, noting that approximately 50% of roads are existing. Additionally, sequencing of development is uncertain. If downstream areas develop before upstream areas, then this would result in increasing flood risk until such time that storage is built in the upstream catchment.	This issue needs to be considered holistically through the precinct planning implementation strategy and ICP process. In some cases, it may be acceptable that the level of service provided will be gradually improved over time from a current ~ 5 year LoS towards the 20 year LoS at full development. However, in other cases this may not be acceptable, and the strategy might need to revert back to pipe upgrades. This is because, technically, it is possible to upgrade existing underground drainage pipes when required and is not necessary to wait for development.
Site specific requirements	The work to-date is at a catchment scale, informed by detailed case studies looking at individual streets and open spaces. However the specific local infrastructure works may not be optimised.	Further more detailed, or location specific/context specific design is required in each local area. This may partly be a design exercise led by Councils at the precinct planning stage, but will also need to be considered at the development scale taking into actual conditions (e.g. contaminated land, infrastructure constraints, etc.).

Risk or Issue	Description	Response
		Allow for a process to recover additional costs if they arise.
Rising groundwater level	At low lying areas close to the Yarra River the groundwater level is expected to correlate with mean sea level, which is currently about 0m AHD. It is expected that groundwater levels will increase at a comparable rate to the sea level rise in proximity to the Yarra River, resulting in a level of approximately 0.8m AHD by 2100. This means there would be large areas of Fishermans bend with groundwater at or less than 500mm below ground level. In these areas, groundwater would be at the same level as the bottom of any storages, meaning storages would need to isolated/lined adding additional costs. This assumes that future groundwater levels are not being actively managed (e.g. suppressed through pumping).	This is a known and managed issue in many other places in the world, so solutions are available. However it is recommended given the uncertainty that, as a general rule (for strategy development purposes), storages are not pursued in low lying areas. Although, this is a general rule for the purpose of this strategy, and at the point at which detailed planning is undertaken, local conditions should be considered and opportunities for storage evaluated.
Renewal of drainage assets due to age/condition	It is unknown whether/when drainage assets may need to be renewed over time due to age and condition. There is a risk that that the existing pipe upgrades that are being “avoided”, may need replacement anyway in the future. There is also an opportunity to piggyback on asset renewals and upsize pipes at the time of replacement to increase capacity strategically in the network.	Further work is needed to understand the characteristics of the existing underground drainage network. An asset management investigation may be warranted as this has implications for the overall strategy.

Table 5 Cost Risks

Risk or Issue	Description	Response
Costs underestimated	The costs of works are underestimated. This is most likely to impact the storages, the pump stations, new pipelines, and the levee.	Further detailed planning and onsite investigation will be required. Given this is a novel situation, establishing a process to recover any additional costs, could mitigate this risk. Note that this issue will apply to all construction works in the precinct and therefore is a shared risk.

Table 6 Regional Interface Issues

Risk or Issue	Description	Response
Lack of a catchment perspective: Port Melbourne	Stormwater runoff from a large portion of the site drains south to Port Phillip Bay via Port Melbourne. It utilises the capacity in the downstream network to convey water to the bay, but is also constrained by bottle-necks in the network and high tailwater levels (which will increase over time). The use of rainwater tanks and surface storages has downstream benefits that, whilst modelled, have not been quantified or monetised (in terms of the avoided downstream pipe/pump augmentations). Conversely, it may be that pipe upgrades and pumps downstream are more optimal from a catchment basis (by reducing bottlenecks downstream and therefore relieving flooding at Fishermans Bend).	Undertake a whole of catchment study based on achieving an optimal response with agreed levels of service for the different areas, and with an agreed cost sharing approach.
Lack of a catchment perspective: Hannah St Main Drain	Flooding is shown to occur within the Montague precinct where flood waters back up from the Hannah Street Main Drain to the east (outside of Fishermans Bend, in South Melbourne). Mitigation of this flooding would likely require the capacity of the Hannah Street Main Drain to be improved.	Undertake a whole of catchment study based on achieving an optimal response with agreed levels of service for the different areas, and with an agreed cost sharing approach.

The following table presents governance risks. This was not specifically focussed on in the current project, however a range of issues relating to governance emerged from discussions and workshops throughout the project. It should be noted however that given the innovation and novel solutions being pursued at Fishermans Bend as part of the Water Sensitive Cities Strategy, governance is critically important and deserves further consideration beyond this study.

Table 7 Governance Risks

Risk or Issue	Description	Response
Ownership maintenance and operation responsibilities undefined	The ownership, maintenance and operation responsibilities of key infrastructure including the pumps, levee and hybrid storages are yet to be defined. This is a significant risk in terms of cost and flooding/drainage outcomes.	Further work on detailed planning is required to set up roles and responsibilities to sufficient detail. This will enable cost-risk management allocation to take place. It is understood that the working group is developing a governance strategy for implementation of the Hybrid Option.
Novel solutions conflict with traditional design standards and LoS/criteria, inhibiting innovation	The strategies being pursued at Fishermans Bend are unique in Australia. The relevant authorities and responsible organisations are proposing new solutions that require new methods of assessment and evaluation. There is a risk that strict adherence to traditional design standards and performance/assessment criteria prevents innovation.	There must be a willingness to challenge design standards and traditional flood management methods. The continued efforts of members of the working group to drive the strategy within each organisation are critically important.
Creating a living strategy	At the heart of the water sensitive drainage and flood strategy is the concept of adaptation to uncertain and changing circumstances. Organisation and individual commitment in perpetuity is critical to its success.	The WSC strategy will continue in perpetuity and there needs to be a process for educating new staff and the broader businesses on the fundamental basis of and philosophy of the strategy. This is critical to defining and embedding the boundaries of ownership and operation, coordination of planning, asset and service delivery and works operations, and funding and finance clarity and commitment

6. Costs

Preliminary capital cost estimates were developed for the Fishermans Bend Water Sensitive Drainage and Flood Strategy to inform the options evaluation and to provide initial inputs to the Infrastructure Contributions Plan. These are subject to ongoing refinement, and full cost details will be released seperately by the Fishermans Bend Taskforce.

7. Conclusions

This strategy provides a preliminary high level approach for managing flooding at Fishermans Bend that aligns with and supports the vision and goals of the *Fishermans Bend Framework*.

A levee is required along the edge of the Yarra River in the future to protect against coastal flooding as many areas of Fishermans Bend will be below the predicted tidal water levels in Port Phillip Bay. This should be implemented using an adaptive pathways approach to future proof for potentially higher/faster levels of sea level rise.

The levee concept requires significant further work to identify a suitable and optimal route and design, given the diverse land ownership and the need for it to be integrated with existing land uses and future desired urban form. The first step however will be to implement non-return valves on the existing drainage pipes to prevent backwatering of the drainage network.

The areas vulnerable to riverine flooding from the lower Yarra River require a watching brief, as ongoing revision of flood levels has implications for the timing and height of the levee, the timing and operational requirements of one and possibly two of the pump stations, and also has implications for planning controls.

With just a levee in place, without additional mitigation measures, large areas within Fishermans Bend would still be subject to stormwater flooding from local rainfall runoff overwhelming the underground drainage network. The proposed responses include (i) rainwater tanks in all buildings *(which are already embedded in the Fishermans Bend Framework)*, (ii) distributed storages in streets and open spaces, (iii) new pumps (and associated pipes), and (iv) upgrading of some existing pipes in two of the twelve catchments.

Rain tanks across the whole of Fishermans Bend (sized at $0.5m^3$ flood storage volume per $10m^2$ of roof catchment, and totalling 90 ML across the development) have been assumed in the modelling. The implementation of raintanks requires ongoing monitoring to confirm the effective/actual catchment areas and storage volumes being achieved.

Seven pumps are required along the Yarra River to provide the appropriate hydraulic conditions to quickly drain all of the catchments flowing to the Yarra in high intensity rain events. The pumps are required regardless of whether distributed storages or pipe upgrades are used within the catchment, although the use of storages reduces the required capacities (peak pumping rates) to some extent. These will likely be staged over time, although some will likely be required in the short term. Further work is needed to clarify costs and land take, and determine the optimal timing/staging.

New pipes are also required along the Yarra River to transfer the flow from the existing drainage outlets to the new pump stations.

Distributed storages in the streets and open spaces have been compared as an alternative to upgrading (i.e. upsizing or duplicating) existing drainage pipes in twelve drainage catchments within Fishermans Bend. The analysis undertaken in this study indicates that the distributed storages approach is favoured in six catchments (as shown in Figure 11), upgrades of existing pipes are required in two catchments (due to low lying conditions and the influence of an external catchment), and no augmentations are needed in the four remaining catchments (noting that flood attenuation is already being provided in these catchments by the rainwater tanks).

This comparison kept everything constant between the two approaches, including fundamental streetscape design, urban greening (e.g. linear parks, trees, open spaces, etc.) and water sensitive urban design features to meet stormwater quality objectives (e.g. tree pits and raingardens). This enabled the assessment to be undertaken primarily on flood mitigation effectiveness and cost (with a qualitative discussion on the broader benefits).

The strategy has been developed over a large urban area, using detailed location specific case studies with City of Port Phillip and City of Melbourne to inform general assumptions about the ability to implement distributed storage that were extrapolated/scaled across the whole of Fishermans Bend. It is important that further planning occurs to determine within each catchment where distributed storages will be utilised (e.g. maximised in streets, utilising parks more, etc.). This optimisation of the design solution will need to continue to integrate the urban design/planning process and drainage planning. The level of detail required will depend largely on what specificity is required for precinct and open space planning in the short term, or what can be worked through in detail as the redevelopment occurs over time. There will also be local context specific design solutions that can be explored for specific locations that haven't been considered in the overarching strategy.

Because the distributed storages component of the stormwater (pluvial) flooding solution has been integrated into streetscapes and open spaces, and will therefore be delivered incrementally over time, it is critical that this is a 'living' strategy that is subject to ongoing review and adjustment.

There are also other aspects of the strategy that would benefit from further consideration, including the interdependency of the strategy on the regional interfaces with South Melbourne and the Hannah St Main Drain (which impacts on the effectiveness of distributed storages) and Port Melbourne, diversion of water from the Todd Rd Drain catchment to the Westgate Lakes, and optimisation of the pumping stations, including potentially through additional distributed storage to defer implementation and reduce capacities.

GHD acknowledges that this work was an entirely collaborative effort by the Fishermans Bend Taskforce Drainage Working Group, with much intellectual and technical contribution from the various stakeholders.

It is our understanding that the strategy outlined in this report is supported by each of the stakeholders represented on the Working Group and Steering Group. This is important, as there are areas of ambiguity and uncertainty that have been worked through by consensus, for example, challenging strict definitions of level of service requirements, and design considerations for street cross-sections.

Further iterations of this strategy are likely to follow before a final strategy is agreed to by partner organisations. This will include, but is not limited to, making decisions on ownership, operation and implementation of infrastructure, as well as further more detailed on particular aspects of the strategy.

Finally, it is important to recognise that implementation of the strategy will require continual tracking of progress and iterative review and adjustment.

8. Recommendations

This section, drawing on the conclusions in Section 7 and the possible responses to implementation risks and issues in Section 5, provides a set of recommendations to assist the working group prioritise and pursue next steps.

Managing Coastal and Riverine Flooding with a Levee:

1. The levee height and standard of protection should be considered in the context of a broader risk assessment, encompassing together all risks to flooding, undertaken for Fishermans Bend.

2. The levee concept should be developed, considering an optimal route, height and form, with consideration of urban design and landscaping and existing land ownership and use, and using an adaptive pathways planning approach so that appropriate future proofing arrangements and triggers for action can be established. This would also consider how planning controls could be used to embed the development of the levee into the redevelopment of the river edge.

3. Following completion of the Lower Yarra River Flood Study (GHD for Melbourne Water), reassess the levee requirements upstream of Wurundjeri Way to manage riverine flooding (noting also has implications for other drainage infrastructure and areas outside of Fishermans Bend).

Pump Stations:

4. A concept design of one of the pump stations is recommended to enable all of the necessary issues to be worked through with the various parties. This would identify with greater confidence the type(s) of pump station, integration in the urban form, associated cost and land take, etc. This will provide better information to enable a decision whether to investigate optimisation of the pump stations, potentially through additional storage (i.e. beyond what is required to prevent flooding in the 5% AEP event).

5. Better understand the likely timing of implementation of the pump stations. Initially this can be supported by flood modelling of interim time slices (e.g. 2040, 2060) to understand flood extent, depth and duration. This can input to a risk assessment [potentially also if pump stations can be used to avoid pipe upgrades]

Rainwater Tanks:

6. Undertake sensitivity analysis to determine the importance/criticality of the tanks on the overall drainage solution, spatially, and potentially also in terms of staging of development (e.g. if one area develops first).

7 Undertake a review of the modelling assumptions (e.g. assumed catchment areas and active flood storage volumes available at the start of an event) against the planning controls to identify any inconsistencies or potential implementation risks.

Storages:

8. Further more detailed, or location specific/context specific strategy development (or solution design) is required in each local area. This may partly be a design exercise led by the Fishermans Bend Taskforce in collaboration with the Councils at the precinct planning stage, but will also need to be considered at the development scale taking into account actual conditions (e.g. contaminated land, infrastructure constraints, etc.). This may be iterative, if the operating philosophy of the strategy evolves over time.

9. Define a process by which distributed storage volumes (and potentially rainwater tank storage volumes) can be tracked against a set target over time, to ensure sufficient storage has been allowed for, and define a process to recover additional costs if they arise.

Regional Interfaces:

10. Expand the analysis to a whole of catchment study based on achieving an optimal response with agreed levels of service for the different areas, and with an agreed cost sharing approach. This would consider the

downstream mitigation options available in Port Melbourne, and the influence of the Hannah St Main Drain catchment in South Melbourne.

Governance:

11. Further ongoing work will be required to define roles and responsibilities to sufficient detail. This will enable cost-risk management allocation to take place.

12. The importance of setting up a “living” strategy - The WSC strategy will continue in perpetuity and there needs to be a process for educating new staff and the broader businesses on the fundamental basis of and philosophy of the strategy. This is critical to defining and embedding the boundaries of ownership and operation, coordination of planning, asset and service delivery and works operations, and funding and finance clarity and commitment.

13 The strategy has considered novel solutions that conflict with traditional design standards and Level of Service definitions and performance criteria. This was debated and worked through collaboratively within this project, but going forward there is a risk that this will stifle innovation. There must be a willingness to challenge design standards and traditional flood management methods, and it may be appropriate to consider developing new levels of service definitions for this unique context.

Renewals of Pipes:

14. Further work is needed to understand the characteristics of the existing underground drainage network. It is understood a condition assessment is being undertaken in the near future. The strategy should be reviewed once this information is available.

Implementation Planning:

15. There are a number of areas of this strategy that require more work and agreement between stakeholders before an agreed implementable drainage plan, can be delivered. This project delivered a strategy, and has provided information to enable implementation planning, but is not a comprehensive drainage plan. Further work is required to deliver this.

16. Prepare a more detailed staged infrastructure plan with NPVs incorporating operating and maintenance costs.

Flood Modelling:

17. Melbourne Water to consider refining the TUFLOW model with a greater spatial resolution (this may involve splitting the model up),, and going through the standard QA process to enable the flood modelling to be used beyond the scope of the strategy.

18. Consider updating the flood models to ARR2016.

Water Sensitive City Strategy:

19. Further explore and define the interlinkages between the drainage strategy and other elements of the Water Sensitive City strategy (e.g. water sensitive urban design, and urban forest), in order to better articulate benefits and any potential risks.

9. References

Past drainage, flood management and water management strategies:

GHD, *Fishermans Bend Integrated Water Management Options Evaluation: Final Report*, report issued to South East Water and Melbourne Water, September 2015, GHD ref 3132191

GHD, *Fishermans Bend Baseline Drainage Plan Options: Final Report*, report issued to Melbourne Water, March 2017, GHD ref 3134157

Ramboll, *Fishermans Bend Integrated and Innovative Water Management: Final Report - Draft*, report issued to Melbourne Water, February 2018

GHD, *Fishermans Bend Baseline Drainage Plan: Draft Report*, report issued to Melbourne Water, August 2018, GHD ref 3135713

GHD, *Fishermans Bend Alternative Drainage Plan – Distributed Storages: Draft Report*, report issued to Melbourne Water, August 2018, GHD ref 3135713

Guidance and Reference Documents:

Levee Management Guidelines (Department of Environment, Land, Water and Planning, 2015)

Planning for Sea Level Rise Guidelines (Melbourne Water, 2017)

Australian Rainfall and Runoff 1987

Memorandum to Todd Berry, DELWP, Contamination Cost Information to Support Infrastructure Contribution Plan, Fishermans Bend Redevelopment (Golder, 2018).

Yarra River Flood Mapping Project (Unpublished Draft) (GHD, 2018)

Victorian Coastal Strategy (VCS) (Victorian Coastal Council (VCC), 2014)

The Effect of Climate Change on Extreme Sea Levels in Port Phillip Bay (CSIRO, 2009)

Derivation of Victorian Sea Level Planning Allowances (Hunter, 2013)

Information for Australian Impact and Adaptation Planning in response to Sea-level Rise (McInnes et al, 2015)

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Appendices

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