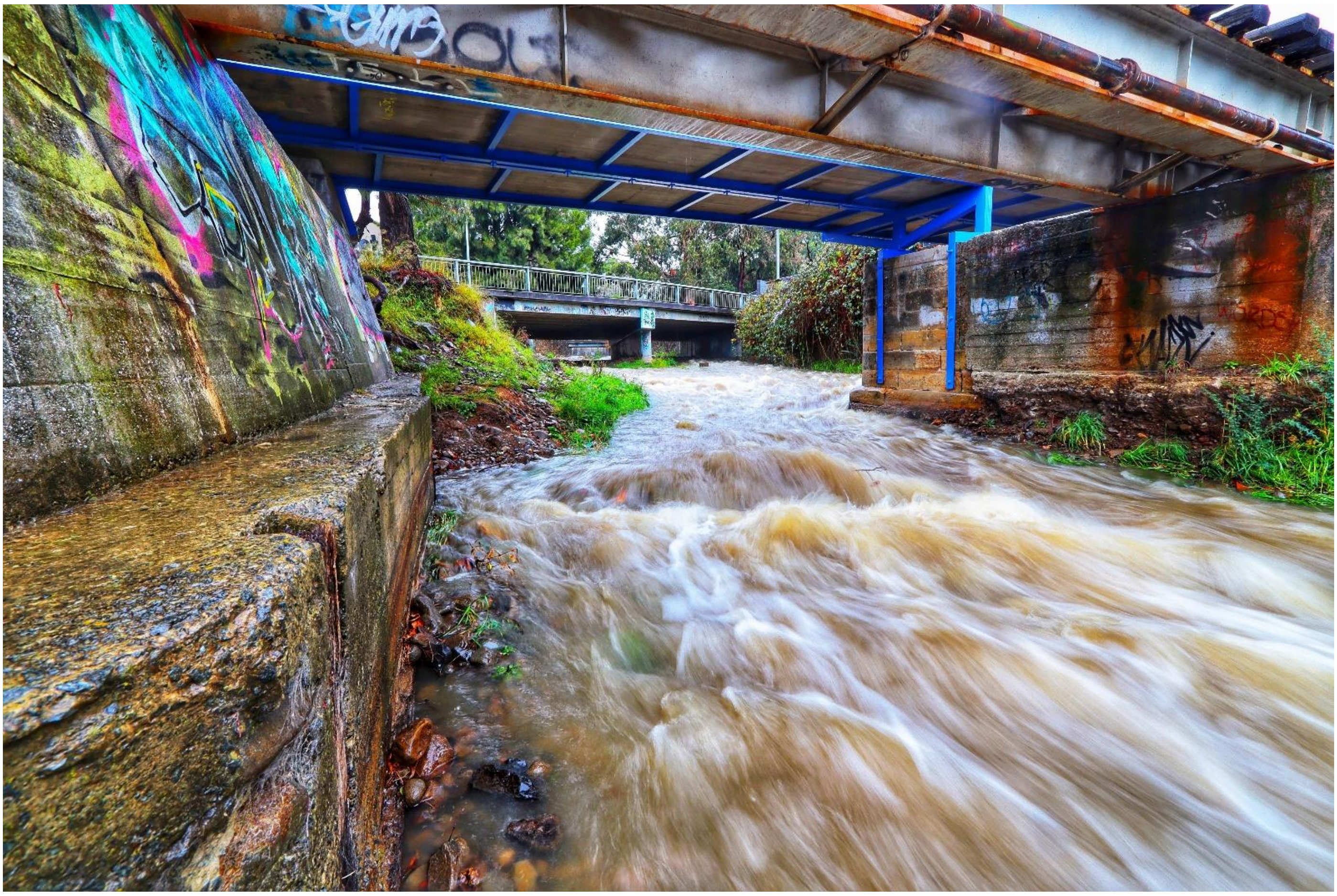


STORMWATER SYSTEM MANAGEMENT PLAN

Glenorchy City Council

Enhancing Flood Resilience: Key Recommendations for Stormwater Management

Document Control

Rev	Date	Revision Details	Author	Reviewer	Approver
0	29 April 2024	Adopted By Council	Balaji Sivakumar, Flussig Engineers	Patrick Marshall	Emilio Reale

Contents

Figures

Tables

Abbreviations

AEP – Annual Exceedance Probability

AHD – Australian Height Datum

ARI – Average Recurrence Interval

ARR – Australian Rainfall and Runoff

BOM – The Australian Bureau of Meteorology

CL – Continuing Loss (mm/hr)

DEM – Digital Elevation Model

DTM – Digital Terrain Model

GIPS – Glenorchy Interim Planning Scheme

GCC – Glenorchy City Council

HGL – Hydraulic Grade Line

IL – Initial Loss (mm)

IWL – Initial Water Level describing the first water level during a stormwater model simulation

PMP – Probable Maximum Perception

PMF – Probable maximum Flood

IFD – Intensity-Frequency-Duration

SSMP – Stormwater System Management Plans

SLR – Sea Level Rise (m)

Glossary

Annual Exceedance Probability	The probability of exceedance of a given discharge within a period of one year.
Average Recurrence Interval	The average or expected value of period between the exceedance of a given discharge.
Australian Height Datum	A common national plane of level corresponding approximately to mean sea level.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high streamflow which overtops the natural or artificial banks in any part of a stream river or surcharged from underground reticulation system due to its deficiency.
Flood hazard	Potential for damage to property or persons due to flooding.
Floodplain	The area subject to flooding during and after rainfall events.
Hydraulics	The study of water flow, in particular the valuation of flow parameters such as stage and velocity in a river or a stream.
Hydrology	The study of rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Overland Flow path	A natural or man-made path to allow surface flow passing through.
Peak Discharge	The maximum discharge occurring during a flood event.

Probable Maximum Perception	The term to define the maximum rainfall intensity that could conceivably occur at a particular location and is used to estimate the Probable Maximum Flood.
Probable Maximum Flood	The maximum flood will ever occur within the catchment area.
Probability	A statistical measure of the expected frequency or occurrence of flooding.
Runoff	The portion of rainfall which ends up as streamflow, also known as rainfall excess.
TUFLOW	TUFLOW is a suite of advanced 1D/2D/3D computer simulation software for flooding, urban drainage, coastal hydraulics, sediment transport, particle tracking and water quality.

Executive Summary

The Stormwater System Management Plan prepared by the Council's Assets, Engineering, and Design Department, aims to comprehensively address flood behaviours within the Glenorchy Municipality Area. This plan is designed to foster a deep understanding of the impact of floods in both present and future scenarios, aligning with the regulatory requisites laid out in the Urban Drainage Act of 2013.

A rainfall-runoff model has been established to provide a precise depiction of the study area. This model has been leveraged to assess inundation extents for a spectrum of design flood events, including the 1% Annual Exceedance Probability (AEP), while accounting for the influence of climate change and sea level rise. The study delivers critical information regarding flood flows, velocities, levels, and extents for the 1% AEP, thereby empowering the formulation of effective planning controls, the establishment of minimum floor levels, and the identification of flood mitigation options.

This report encapsulates a summary of the findings stemming from the analysis of fourteen catchments under the jurisdiction of the Glenorchy City Council, excluding the Humphreys Rivulet, Barossa Creek and Little John Creek catchments, which were completed separately by SMEC Holdings as part of the Glenorchy CBD Stormwater System Management Plan 2018 and attached to this report. It outlines a pragmatic and cost-effective strategy for mitigating flood-related risks to both buildings and road infrastructure. In addition to assessing structural damage to both residential and non-residential buildings, the study addresses a wide array of losses, encompassing inventory loss, loss of rental income, loss of business income, and the associated costs of fatalities.

The majority of the analysed flood mitigation options have demonstrated benefit-to-cost ratios exceeding 1.0, signifying sound investment decisions. While some exceptions exist, such as cases of dry and wet floodproofing, the utilisation of temporary barriers in high hazard zones has emerged as the most cost-effective measure.

Furthermore, the mitigation options encompass general stormwater maintenance in catchments where flood mitigation would only be feasible through land acquisition. This has been deemed unrealistic and unfeasible at this stage, warranting further investigations and internal discussions among high-level decision-makers at the Glenorchy City Council.

In this report, all urban catchments within the Glenorchy municipality were comprehensively modelled using TUFLOW to map flood extents and assess flood risks during 1% AEP rainfall events. The study has identified the critical rainfall duration for these catchments and highlighted deficiencies in the existing reticulation system, particularly during major rainfall events with a 1% AEP. To address these issues, 1D networks for pipes greater than 300mm in diameter were included in the model to enhance the accuracy of floodplain mapping. It's important to note that the Council's responsibility for providing capacity in the stormwater pipe networks only extends to minor rainfall events up to 5% AEP, and therefore, the capacity of the stormwater pipe networks for 1% AEP events were not assessed as part of this flood study, but were included to improve the flood plain model.

The floodplain maps generated in this study underscore the significant flooding risk faced by several properties during major rainfall events with a 1% AEP. Notable areas affected include Hestercombe Reserve and Playground, Gould's Lagoon, Brooker Highway, Hilton Road, Main Road, Merley Road, Weston Park, Beedhams Reserve, Claremont Oval, Newtown Rugby Park, Southern Waste Solutions, and Montrose Bay High School Playground.

While model calibration was not performed due to a lack of historic flood level data, the study underwent a rigorous validation process, which included comparing flood extents with previous models and addressing residents' complaints. Consulting engineers, Entura, conducted a peer review of the model, and model parameters were selected from the previous Glenorchy CBD Stormwater System Management Plan in 2018, prepared by SMEC Australia. Sensitivity analysis was performed in previous models by varying different parameters and scenarios.

The study also incorporates climate change scenarios, including Sea Level Rise and Storm Surge projections for the 2100s. These projections are based on assumptions of a 16% increase in rainfall and a sea level rise of 1.62 metres, as stipulated in previous flood studies and the Glenorchy Interim Planning Scheme.

To maximise the benefits derived from this study, we recommend future efforts that include integrating identified overland flow paths and flood hazard areas into the Planning Control process, exploring upgrade and flood mitigation measures, determining catchment-wide infrastructure upgrade requirements, and prioritising these upgrades. Such initiatives will aid in the achievement of a systematic, strategic, and sustainable approach to stormwater infrastructure management that aligns with the Council's commitment to safeguarding its residents from major flood risks, meeting the Level of Service promised.

1 Stormwater System Management Plan

1.1 Overview of Plan Content

This document outlines the methodology employed in crafting the Stormwater System Management Plans, adhering to the guiding principles delineated in "Stormwater System Management Planning – A Guide for Local Government in Tasmania" (LGAT, 2016).

A comprehensive Stormwater System Management Plan is expected to encompass:

- An identification of objectives and outcomes for management of stormwater in the designated urban areas
- A description of the catchment to which the plan applies, including a definition of the urban area
- A description of the existing public stormwater system, including identification of current condition and ownership of assets where known
- An identification of stormwater management problems and opportunities for achieving outcomes for public and environmental benefit in the urban areas
- An identification of strategies to meet specified management objectives for the urban areas
- Determination of capital and maintenance (including recurring) costs associated with identified management strategies
- An assessment of the benefits to be derived by implementation of proposed management strategies
- Prioritisation of the strategies and a timeframe for implementation
- Assignment of responsibilities for implementing the strategies and meeting any costs;
- A communication / consultation strategy for the Plan;

1.2 Stormwater System Management Plan Objectives

When determining the objectives of a Stormwater System Management Plan, the broader objectives of the Urban Drainage Act 2013 should be taken into account:

- to protect people and property by ensuring that stormwater services, infrastructure and planning are provided so as to minimise the risk of urban flooding due to stormwater flows; and
- to provide for the safe, environmentally responsible, efficient and sustainable provision of stormwater services in accordance with the objectives of the Resource Management and Planning System of Tasmania, as set out in Schedule 1 of the Act.

The SSMP crafted by GCC is designed to comprehensively tackle the following key aspects:

- Develop flood inundation maps for the 1% Annual Exceedance Probability (AEP) design event, illustrating flood extents, depth, flood hazard, and maximum velocities.
- Provide recommendations for modifications to the State Planning Provisions of the Tasmanian Planning Scheme, along with assessing the extent of existing planning overlays within the study area.
- Propose and prioritise mitigation solutions for recognised flood risk areas, contingent upon resource availability.

- Foster resilience and incorporate considerations for climate change impacts to proactively address future demands on the urban stormwater system.
- Cultivate community awareness and engagement, promoting effective participation in the appropriate management of stormwater.

1.3 Description of Study Catchment

20 of the 21 catchments within the Glenorchy municipality have considerable urban area, and SSMPs are required under the Urban Drainage Act 2013. All these catchments with urban areas have been modelled and analysed to identify floodplain during major events (1% AEP) and associated flood risks.

Humphreys Rivulet, Barossa Creek, Little John Creek were completed separately by SMEC Australia as part of the Glenorchy CBD Stormwater System Management Plan 2018 and are included as an attachment to this report.

Figure 1 Stormwater Catchments with Watercourse Layers

The catchments are presented in Table 1.

Table 1 List of Catchments

Order	Catchment Initial	Catchment Name	SSMP Required (Y/N)
1	BC	Barossa Creek Catchment	Not included in this SSMP
2	BB	Beedhams Bay Catchment	Y
3	BS	Black Snake Rivulet Catchment	Y
4	CB	Connewarre Bay Catchment	Y
5	DC	Dooleys Creek Catchment	Y
6	DP	Dowsing Point Catchment	Y
7	FR	Faulkners Rivulet Catchment	Y
8	GW	Goodwood Catchment	Y
9	GN	Granton Catchment - 1	Y
10	GN	Granton Catchment - 2	Y
11	GN	Granton Catchment - 3	Y
12	HR	Humphreys Rivulet Catchment	Not included in this SSMP
13	IR	Islet Rivulet Catchment	Y
14	JR	Jacques Rivulet Catchment	Y
15	LJ	Little John Creek Catchment	Not included in this SSMP
16	LB	Lowestoft Bay Catchment	Y
17	NR	New Town Catchment	Not included in this SSMP
18	RR	Roseneath Rivulet Catchment	Y
19	SC	Sorell Creek Collinsvale Catchment	N
20	SF	Springfield Catchment	Y
21	EZ	Zinc Works Catchment	Y

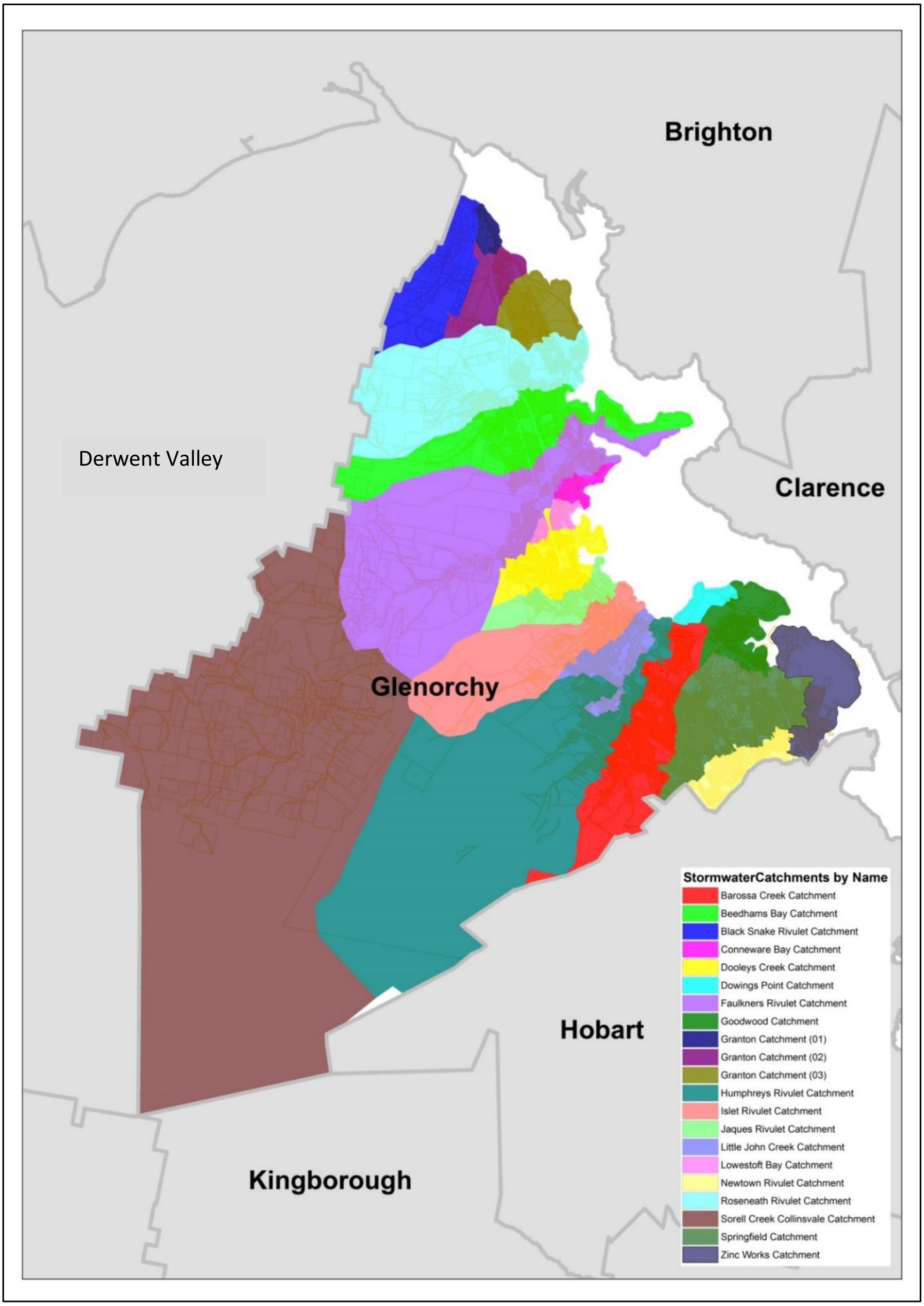


Figure 2 Stormwater Catchments by Name

Table 2 Flood Studies Catchment Size

Catchment Name	Catchment Size (ha)
Beedhams Bay Catchment	505
Black Snake Rivulet Catchment	545
Connewarre Bay Catchment	44
Dooleys Creek Catchment	210
Dowsing Point Catchment	52
Faulkners Rivulet Catchment	1280
Goodwood Catchment	184
Granton Catchment - 1	36
Granton Catchment - 2	144
Granton Catchment - 3	177
Islet Rivulet Catchment	568
Jacques Rivulet Catchment	151
Lowestoft Bay Catchment	41
Roseneath Rivulet Catchment	858
Springfield Catchment	448
Zinc Works Catchment	250
Not Included in this SSMP	
Barossa Creek Catchment	500
Humphreys Rivulet Catchment	1390
Little John Creek Catchment	270
New Town Catchment	176
Sorell Creek Collinsvale Catchment	4452

1.3.1 Beedhams Bay

Beedhams Bay Catchment is approximately 505 Ha, located in the Claremont area where most of the catchment is a natural forest positioned on a step hill. It also has a residential area situated at the lower, flatter area, adjacent to the Brooker Highway and Derwent River.

The catchment has two watercourses, namely Abbotsfield Rivulet and Hilton Creek, flowing from west to east and entering Beedhams Bay on the Derwent River.

Abbotsfield Rivulet flows from the southeast side of Mt Faulkner, through Claremont into the Bay, approximately 5 km in total length. The majority of the Abbotsfield Rivulet remains open channels expect a short section was piped in 1966.

Hilton Creek flows in parallel to Abbotsfield Rivulet at the north before joining Abbotsfield Rivulet at Main Rd. Several sections of Hilton Creek have been piped to suit the urban development needs.

The elevation changes rapidly between the upper and middle part of the catchment, dropping from 900 m (AHD) to 120 m (AHD) within only 7km horizontal distance on an average slope of 11%.

Given the close locations of these two watercourses and the potential interactions between them during large rainfall events, the two watercourses and other nearby piped stormwater drainage systems were modelled together in this Beedhams Bay Catchment Flood Study.

1.3.2 Black Snake Rivulet

Black Snake Rivulet is in the Granton area, where a large portion of the catchment remains undisturbed and undeveloped. The undisturbed and undeveloped area is mainly occupied by natural forest, positioned on steep slopes of Blacksnake.

At the lower side of the catchment in Granton, residential developments have occurred in the past few decades which only covers 15% of the total area. The remaining 85% of the catchment is a natural forest positioned on a step hill.

This catchment is approximately 545 Ha, and has a rivulet, named Blacksnake Rivulet, flowing from west to east and entering the Derwent Rive.

The rivulet channel is open, and the riparian zone remains vegetated. Along the channel, there are several culverts and bridge structures constructed over the channel to provide road and traffic crossings at multiple locations, including one major culvert underneath the Brooker Highway at Granton.

1.3.3 Dooleys Creek

Dooleys Creek Catchment is in the Chigwell and Berridale area, where approximately 30% of the catchment being a natural forest positioned on a step hill, with the balance being a residential area situated on lower, flatter land, adjacent to the Brooker Highway and Derwent River.

Dooleys Creek was flowing from west to east and entering the Derwent River before it was piped. Most of the rivulet channel within the urbanised area was piped during urban development.

The upstream piped section starts from Kilander Crescent, following Berriedale Road and ends at Main Road. Like other urban catchments in Glenorchy, the elevation changes rapidly between the upper and middle part of the catchment, dropping from 380 m (AHD) at the top of the catchment to 50 m (AHD) at the intersection of Marys Hope Road and Radcliff Crescent, on an average slope of 20%.

The lower and middle parts of the catchment are mainly occupied by residential dwellings and recreational uses.

1.3.4 Faulkners Rivulet

Faulkners Rivulet is a stream located nearby to Chigwell and Berriedale Reserve, flowing down from the Mount Faulkner Conservation area discharging into Windermere Bay.

A large portion of the Faulkners Rivulet catchment area remains undisturbed and undeveloped. The undisturbed and undeveloped area is mainly occupied by natural forest, positioned on steep slopes of Mount Faulkner.

At the lower side of the catchment in Chigwell and Berriedale, residential developments have happened over the past few decades. During the same period (1960s onwards), residential development along the southern side of the catchment also started to occur.

This catchment is approximately 1,280 Ha. The main stream, named Faulkners Rivulet, has various tributaries jointing at the upper level of the catchment. The Rivulet itself flows from west to east and enters the Derwent River at Windermere Bay.

The Rivulet channel is open, and the riparian zone remains vegetated. Along the channel, there are several culverts and bridge structures constructed over the channel to provide road and traffic crossings at multiple locations, including a major twin box culvert underneath the Brooker Highway and a bridge, made of sandstone abutment and concrete deck, at Cadbury Road, Claremont.

Elevations in the upper and middle parts of the catchment change rapidly, dropping from 600 m AHD at the top of the catchment to 100 m AHD at the Richards Road Bridge, within 3kms longitudinal distance. This change is equivalent to an average slope of 16.7%, which is moderately steep and has considerable impact on the catchment hydrology.

The middle catchment area situated at the southern side of the rivulet mainstream has been developed in the past for residential purposes, with significant growth and development potential along the northern side of the rivulet main stream.

The lower part of the catchment, between the Brooker Highway and the foreshore area, has already been developed for residential dwellings and recreational/community uses due to its relatively flat grade extending to the waterfront.

1.3.5 Goodwood and Zinc Works

Goodwood Catchment is approximately 184 Ha and Zinc Works Catchment is approximately 250 Ha, located in the Goodwood and Lutana area. Both the catchments were flowing from west to east and entering the Derwent River.

Most of the Goodwood Catchment is developed with General residential buildings where partially developed with Industrial business. Majority of the Zinc Works Catchment is developed with Industrial business and given the catchment is close proximity to the Derwent River, no pipe networks were provided. Only a small portion of the catchment at the southern side is developed with residential buildings and where stormwater network services were provided.

1.3.6 Granton

Granton Catchment is approximately 357 Ha, located in the Granton area where 50% of the catchment is general residential area and the remaining half of the catchment is a natural forest positioned on a step hill. It also has a residential area situated at the lower, flatter area, adjacent to the Brooker Highway and Derwent River.

Granton Catchment was flowing from west to east and entering the Derwent River before it was piped. Most of the rivulet channel within the urbanised area was piped during urban development.

The lower part of the catchment, after the Brooker Highway, has already been developed for residential dwellings and recreational uses due to its relatively flat grade extending to the waterfront.

1.3.7 Jacques Rivulet

Jacques Rivulet Catchment is in the Montrose area, where approximately half of the catchment being a natural forest positioned on a step hill, with the balance being a residential area situated on lower, flatter land, adjacent to the Brooker Highway and Derwent River.

Jacques Rivulet was flowing from west to east and entering the Derwent River before it was piped. Most of the rivulet channel within the urbanised area was piped during urban development.

The upstream piped section starts from Redlands Drive, following Marys Hope Road and ends at Radcliff Crescent. The open section of the rivulet flows adjacent to the rear boundary of residential properties between No. 2 and No. 22 Glenmore Street and re-enters the underground reticulation system after passing the railway embankment, close to the outlet of the Derwent River.

Like other urban catchments in Glenorchy, the elevation changes rapidly between the upper and middle part of the catchment, dropping from 410 m (AHD) at the top of the catchment to 50 m (AHD) at the intersection of Marys Hope Road and Radcliff Crescent, on an average slope of 20%.

The lower and middle parts of the catchment are mainly occupied by residential dwellings and recreational uses. The lower part, starting from the Rosetta Primary School, has a relatively flat grade extending to the river.

1.3.8 Lowestoft Bay and Connewarre Bay

Lowestoft Catchment is approximately 41 Ha and Connewarre Bay Catchment is approximately 44 Ha, located in the Berriedale and Claremont area where most of the catchment is urbanised area with residential buildings. Almost 95% of the catchment is developed with residential buildings.

Apart from the small section of rivulet channel, most of the rivulet channel within the urbanised area was piped during urban development.

1.3.9 Roseneath Rivulet

Roseneath Rivulet is in the Claremont and Austins Ferry area, where a large portion of the catchment remains undisturbed and undeveloped. The undisturbed and undeveloped area is mainly occupied by natural forest, positioned on steep slopes of Mount Faulkner.

At the lower side of the catchment in Austins Ferry, residential developments have occurred in the past few decades. During the same period (1970s onwards), residential developments along the southern side of the catchment also started to occur.

This catchment is approximately 850 Ha, and has a rivulet, named Roseneath Rivulet, flowing from west to east and entering the Derwent River at Rusts Bay.

The rivulet channel is open, and the riparian zone remains vegetated. Along the channel, there are several culverts and bridge structures constructed over the channel to provide road and traffic crossings at multiple locations, including two major culverts underneath the Brooker Highway and a sandstone bridge at Main Road, Claremont.

Elevations in the upper and middle parts of the catchment change rapidly, dropping from 900 m AHD at the top of the catchment to 130 m AHD before Toffolis Road, within 2.86kms longitudinal distance. This change is equivalent to an average slope of 26.9%, which is relatively steep and has considerable impact on the catchment hydrology.

The middle part of the catchment has a small portion of urban residential land use, with significant growth and development potential along the western side of the Brooker Highway.

The lower part of the catchment, between the Brooker Highway and the foreshore area, has already been developed for residential dwellings and recreational uses due to its relatively flat grade extending to the waterfront.

1.3.10 Springfield

Springfield Catchment is approximately 448 Ha, located in the Moonah area where 50% of the catchment is general and inner residential area and the remaining half of the catchment is a local business area. It also has a residential area situated at the lower & upper flatter area, adjacent to the Brooker Highway and Derwent River.

Springfield Catchment was flowing from west to east and entering the Derwent River. Overall, 98% of the catchment is developed and most of the rivulet channel within the catchment area was piped during the development.

1.4 Description of Existing Stormwater System

The plan delineates the infrastructure assets, as outlined in Table 3, which serve as essential components in delivering effective stormwater drainage infrastructure services to the community.

Table 3 Assets covered by this Plan

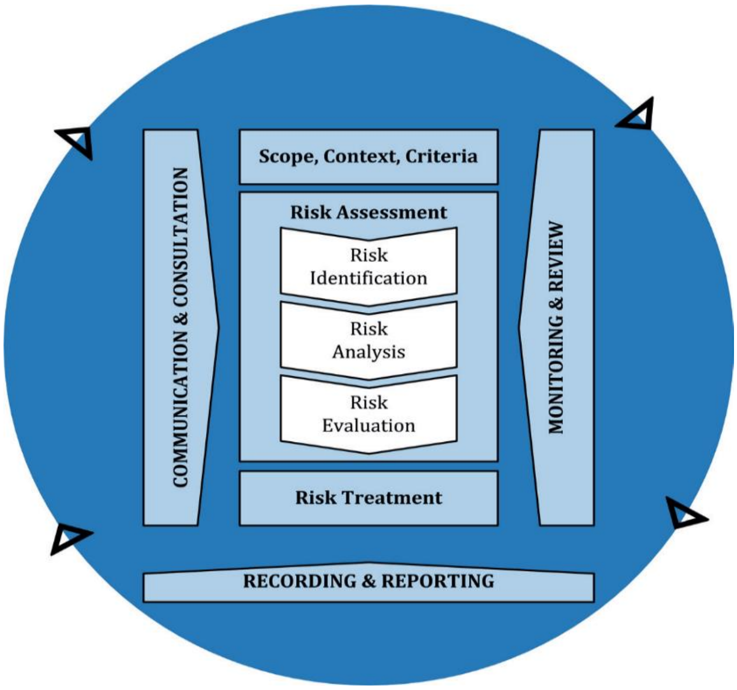
Asset Class	Asset Category	Asset Type	Dimension
Drainage	Bores & Wells	Pump Well	3 (No.)
	Irrigation	Irrigation	27 (No.)
	Lagoon	STSB (Stormwater Storage Basin)	13 (No.)
	Stormwater Drains	Box Culvert	54 (1.73 Km)
		Creek	94 (27.6 Km)
		Gravity Main	16043 (402.8 Km)
		Open Drain	442 (25.5 Km)
		Property Connection	20060 (No.)
		Sub Soil Drain	445 (26.7 Km)
	Stormwater Pits	Inlet Pit	6520 (No.)
		Maintenance Hole	7331 (No.)
		Miscellaneous	1074 (No.)
		Node Point	3903 (No.)
	Stormwater Pump	Pump	3 (No.)
	Water Nodes	Miscellaneous	3 (No.)
	Water Pumps	Water Pump	1 (No.)
	Water Plant and Equipment	Steel Plate	4 (No.)

Additional information about the Council's drainage assets is available in both the Drainage Asset Management Plan and Council's Strategic Asset Management Plan. For spatial data pertaining to the Council's current stormwater system, please refer to the online resources at:

https://maps.gcc.tas.gov.au/

1.5 Identification of Risks, Issues and Opportunities

Illustrated in Figure 3 below is the risk management process employed, serving as an analytical and problem-solving technique. Designed to offer a systematic approach, this process aids in the discernment of treatment plans and management actions, safeguarding the community against unacceptable risks. It aligns with the principles outlined in the International Standard ISO 31000:2018.



Source: ISO 31000:2018, Figure 1, p9

Figure 3 Risk Management Process – Abridged

The risk assessment process systematically identifies credible risks by assessing the likelihood and consequences of potential events. This involves the development of a risk rating, evaluation of risks, and the formulation of a treatment plan for non-acceptable risks.

In the context of service delivery, the risk assessment focuses on potential threats leading to a loss or reduction in service, personal injury, environmental impacts, financial shocks, reputational damage, or other significant consequences.

Critical risks, categorised as those with 'Very High' (requiring immediate corrective action) and 'High' (requiring corrective action) risk ratings, are pinpointed in the Infrastructure Risk Management Plan. The residual risk and associated treatment costs for the chosen treatment plan are detailed in Table 4. It is imperative to report these critical risks and costs to both management and the Council

Table 4 Risks and Treatment Plans

What can Happen	Risk Rating (VH, H)	Risk Treatment Plan	Residual Risk *
Inadequate Community Involvement - The community lacks awareness regarding the distinction between network blockages and the network's designed capacity.	M	Enhance knowledge on flood risk through additional education initiatives.	L
Insufficient Funding for Lifecycle Expenses - Falling short of meeting 100% renewal requirements.	M	Align the Long-Term Financial Management Plan (LTFMP) with the funding outlined in the Asset Management Plan (AMP) and develop a drainage predictor model.	L
Deficient Asset Data and Systems - The extensive drainage network size and the costs associated with CCTV assessments make it challenging to comprehensively assess the network's condition.	M	Employ the drainage predictor model to strategically prioritise Closed-Circuit Television (CCTV) assessments.	L
Legacy Subpar Assets - Uncertain asset quality inherited from subdivisions and ambiguous penetrations from service providers.	M	Collaborate with the planning department to guarantee thorough compliance inspections. Explore the possibility of augmenting compliance resources if needed.	L
Absence of Planning Controls - Development permitted within overland flow paths results in property flooding.	M	Foster communication between Development Engineers and civil engineers.	M
Network Capacity Issues - Inadequate stormwater network capacity to handle frequent rainfall events, leading to asset, environmental, and property damage.	M	Give precedence to network upgrades within the capital works program.	L
Impact of Climate Change - Increasingly frequent extreme weather events contributing to heightened and more regular instances of flooding.	M	Emphasise the importance of prioritising network upgrades within the capital works program.	L

1.6 Identification of Strategies and Outcomes

Section 7 documents the identification of flood risk mitigation options specific to each catchment. Within the Council, a mature understanding of stormwater asset management, design, construction, and operational management exists, supported by adequate operational resources and funding. Recent Council efforts have concentrated on comprehending the origins of various flood incidents, leading to the identification and implementation of flood mitigation works, as evidenced in this document.

However, as outlined in previous sections, additional work is needed in this domain. The discussion and risk assessments in Section 7 prompted the identification of specific actions related to works implementation, flood studies, and more strategically oriented initiatives. Matters pertaining to internal process improvements, information capture, and communication were also acknowledged, with existing administrative arrangements poised to address these gradually, as detailed in Council's Drainage Asset Management Plan.

An Action Plan has been developed to address specific tasks that require focused attention and resources. The proposed overall priorities for managing urban stormwater systems, in order of importance, are as follows:

- Develop flood inundation maps for the 1% Annual Exceedance Probability (AEP) design event, illustrating flood extents, depth, flood hazard, maximum velocities and flood heights.
- Recommend changes to provisions within the State Planning Provisions of the Tasmanian Planning Scheme and assess current planning overlays within the study area.
- Propose and prioritise mitigation solutions for identified flood risk areas as resources become available.
- Strengthen resilience and consider climate change impacts to meet future demands on the urban stormwater system.
- Enhance community awareness of and participation in the appropriate management of stormwater.

While recognising the importance of waterway environment and water quality, the Council, from a broad community perspective, prioritises the protection of people and property from flood risk. Future iterations of the Stormwater System Management Plans (SSMP) will progressively focus on waterway environment and water quality improvements.

Table 5 Action Plan

Action	Catchment	Strategy	Capital Cost	Operational Cost	Responsibility	Timeline
1	Beedhams Bay	Abbotsfield Park DN600 Replacement	$310,000	$7,750	AED	3 years
2	Humphreys Rivulet	Humphreys Rivulet Retaining Wall - Murrayfield Court	$213,000	$5,325	AED	3 years
3	Jacques Rivulet	Redlands Drive Flood Remediation Works	$540,000	$13,500	AED	3 years
4	Dooleys Creek	Chandos Drive Stormwater Diversion	$170,000	$4,250	AED	3 years
5	Zinc Works	New Town Rivulet Outlet Remediation	$415,000	$10,375	AED	3 years
6	Little John Creek	Little John Creek Flood Mitigation	$100,000	$2,500	AED	3 years
7	Springfield	Prince of Wales Bay GPT (CDS Unit) Rectification	$400,000	$1,000	AED	3 years
8	Dooleys Creek	Kilander Crescent Earth Bund – Levee Flood Detention	$120,000	$3,000	AED	5 years
9	Beedhams Bay	Dewar Place Earth Bund - Levee Flood Detention	$280,000	$7,000	AED	5 years
10	Islet Rivulet	Flood wall and culvert extension at reserve	$220,000	$5,500	AED	5 years
11	Jacques Rivulet	Vegetation – Open Drain Maintenance		$100,000	O&M	7 years
12	Faulkners Rivulet	Earth Bund - Levee Flood Detention	$200,000	$5,000	AED	7 years
13	Springfield	Flood Wall – Flow Diversion	$120,000	$3,000	AED	7 years
14	Granton	Earth Bund - Levee Flood Deviation Wall	$596,371	$14,909	AED	7 years
15	Lowestoft Bay	Earth Bund - Levee Flood Deviation Wall	$110,000	$2,750	AED	10 years
16	Black Snake Rivulet	Vegetation Management	$125,000	$3,125	AED	10 years
17	Roseneath Rivulet	Vegetation – Rivulet Maintenance		$180,000	O&M	Ongoing
18	Connewarre Bay	Underground Detention and Double Side Entry Pit	$60,000	$1,500	AED	N/A

19	Dowsing Point	Vegetation – Open Drain Maintenance		$20,000	O&M	Ongoing
20	Goodwood	General stormwater maintenance		$80,000	O&M	Ongoing
21	Zinc Works	General Stormwater Maintenance		$20,000	O&M	Ongoing

1.7 Costs, Benefits and Funding Arrangements

The cost, benefit and funding arrangement for specific flood risk mitigation options are included in Section 7.

The Action Plan has comprehensively outlined cost, benefit, and funding opportunities to tackle identified projects and strategies. This approach aids in broadly identifying priorities.

For most projects and strategies, securing funding is essential, whether through the Council's capital works program or external sources such as grants or other agencies. When pursuing such funding, a more in-depth assessment of "Cost and Benefit" is typically required to substantiate the project's viability.

This detailed assessment may encompass:

- Preliminary design and project costing.
- Cost-benefit analysis.
- Risk assessment.

This multifaceted evaluation ensures a thorough understanding of the project's financial implications, benefits, and potential risks, facilitating informed decision-making during the funding acquisition process.

1.8 Priorities and Timeframes

The action plan delineates project priorities, primarily assigned based on an assessment of risk exposure, either to the Council or more directly to the community at various levels. The prioritisation process takes into account the potential impact on both local and broader community interests. Adjustments to timeframes will be made dynamically, influenced by budget allocations, periodic reviews of project priorities, and responses to unforeseen circumstances.

1.9 Responsibilities

The Council bears the primary responsibility for urban stormwater management, while the State Government oversees the management of river environments and coastal beach strips. Any works in these areas concerning stormwater assets necessitate approval from the relevant Government Agencies. The shared responsibility for comprehending the impacts of riverine flooding involves both the State Government and the Council. However, the Council's specific role lies in understanding the extent of the risk and collaborating with stakeholders to either mitigate the risk or ensure that individuals at risk are aware of the potential for inundation.

1.10 Communication and Consultation

The purpose of this plan is to foster a comprehensive understanding of the urban stormwater system among the community and Council staff. It aims to clarify how the system is managed, highlight existing issues and potential risks, and present a prioritised plan of action for addressing them. This plan serves as a valuable tool, guiding resource allocation decisions within the Council and supporting applications for external funding to tackle identified challenges.

In addition to facilitating internal decision-making, the plan emphasises effective communication and engagement with the community. This involves:

- Providing relevant information on flood impacts, advice for flood preparedness, and outlining mitigation actions where applicable.
- Creating a dedicated page on the Council's website to disseminate information on stormwater, stormwater management, flooding, flood preparedness, and water quality issues. This page will also include a link to the State Planning Scheme hazard and flood mapping.
- Publishing the Stormwater System Management Plan on the Council's website for transparency and accessibility.
- Providing a medium to receive feedback on proposed flood mitigation strategies.

This approach ensures that the community is well-informed, engaged, and actively participating in stormwater management efforts.

2 Historical Flood Events

2.1 2005 & 2007 Flood Events

Council has recorded and mapped complaints received from residents arising from flooding on 25th October 2005 and 21st January 2007. It was noticed that during these two-events flooding occurred at various locations, due to excessive surface runoff.

Those properties affected by flooding in 2005 and 2007 are highlighted in the following map (Figure 4, Figure 5 & Figure 6. Unfortunately, due to lack of data, rainfall analysis cannot be performed for the 2005 event, but it is believed that the severity of the 2005 events was less than the 2007 event.

Rainfall data for the 2007 event was collected from three BOM owned gauges, and the analysis conducted indicates that the storm occurring on 21st January 2007 between 13:30 and 19:30 was a 6-hour storm event between 5% AEP and 1% AEP.

2.2 2018 Flood Events

Based on the complaints received from the residents, Council has recorded and mapped all the damages occurred for public infrastructure and private properties from flooding on 11th May 2018. Flooding and infrastructure damage occurred at various locations due to insufficient capacity of the stormwater infrastructure. Those properties affected by flooding in 2018 are highlighted in the following maps.

Hobart and the nearby Wellington Range, where almost all recording sites reported their highest May daily rainfall on record in the 24 hours to 9.00am on 11 May. The daily totals of 236.2 millimetres at kunanyi/Mount Wellington and 226.4 millimetres at Leslie Vale were second and third highest on the list of the top three highest May daily rainfalls ever recorded in Tasmania (behind 258 millimetres at Gray on 18 May 1986).

Much of the rain fell in about six hours on the Thursday evening, leading to flash flooding in many streams in southeast Tasmania. Hobart recorded 128 millimetres, with a third of that falling in one hour between 10.00pm and 11.00pm on the Thursday evening.

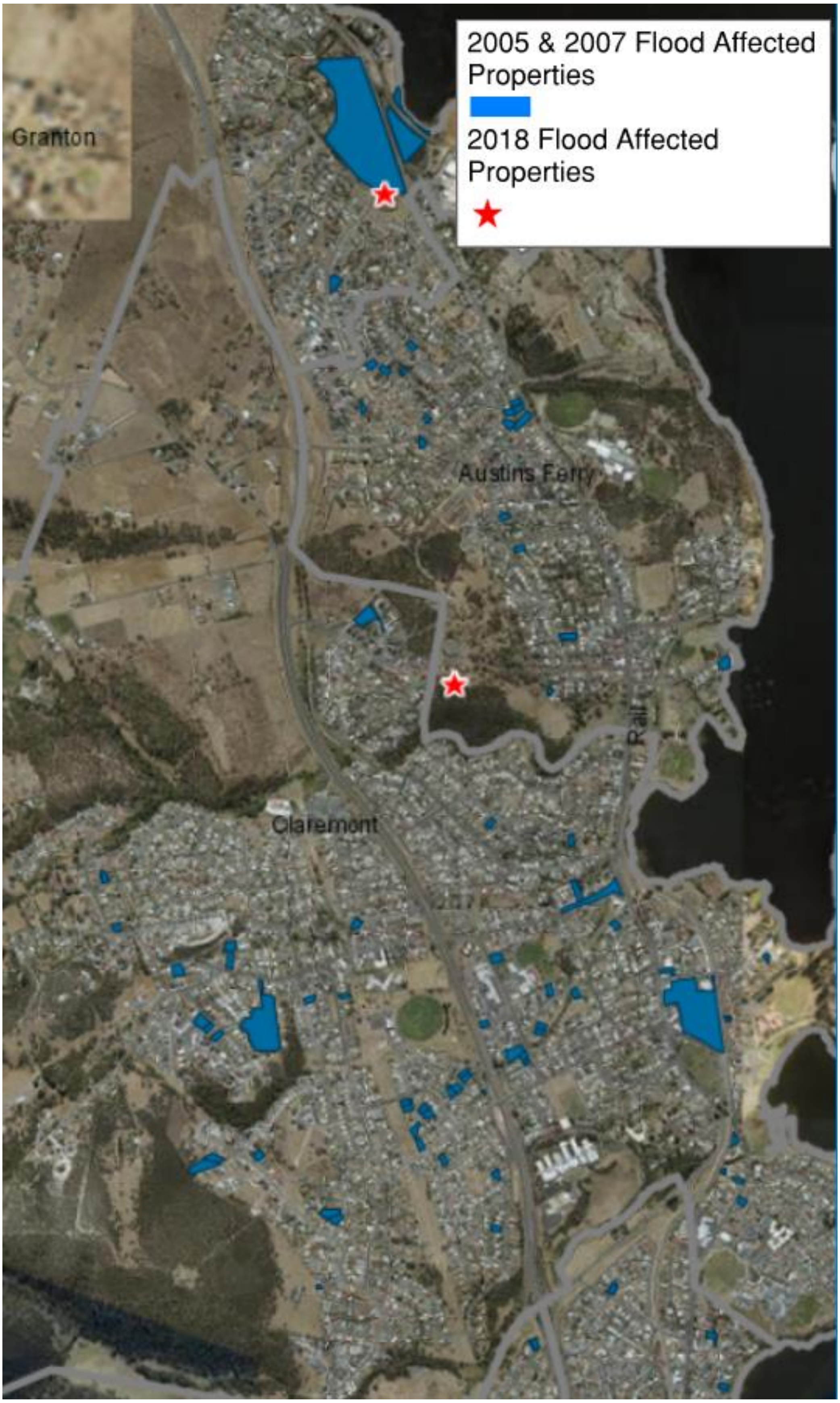


Figure 4 Properties Affected by Flood in 2005, 2007 & 2018.

Figure 5 Properties Affected by Flood in 2005, 2007 & 2018.

Figure 6 Properties Affected by Flood in 2005, 2007 & 2018.

3 Land Use Categories

As defined in the Glenorchy Interim Planning Scheme, the land use categories within the Glenorchy Municipality area include, Environmental Management, Environmental Living, Utilities, General Residential, Community Purpose, Inner Residential, Light Industrial, Local Business, Low Density Residential, Recreation and Open Space.

It was found that the Glenorchy Interim Planning Scheme has zoned over 70% to 75% of the Glenorchy Municipality area, mainly at the upper and middle elevation of the catchment, as 'Environmental Management'.

At lower elevations of the catchment where the existing urban area is, most of the land is zoned 'General Residential' with a small portion of the area is zoned 'Inner Residential'. The proportional make up of zones and zone locations are presented in Figures 6.

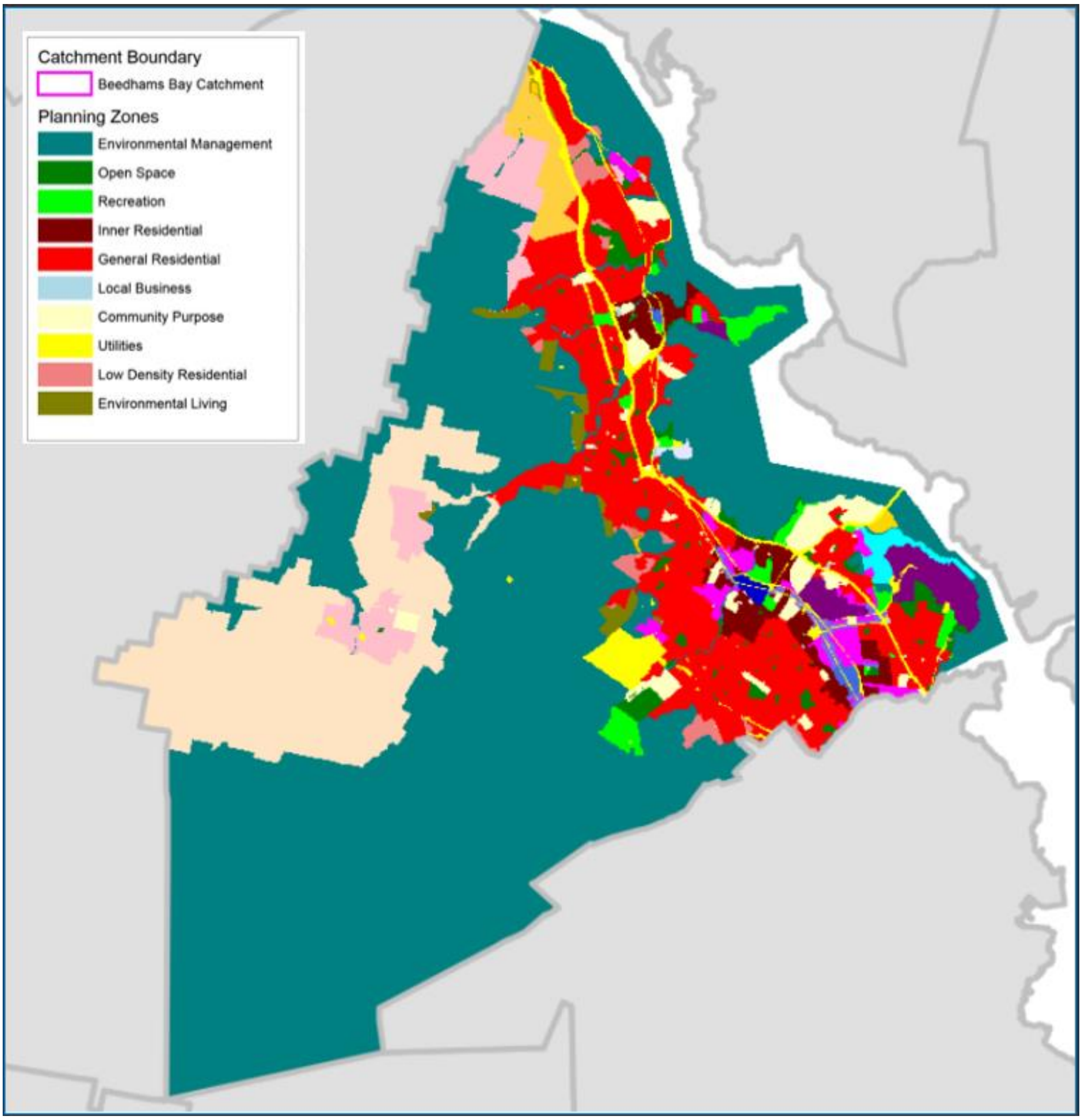


Figure 7 Glenorchy Municipality Catchment Land Use Map

4 Flood Model Development and Results

4.1 Model Setup

A rainfall-runoff model has been set up to describe the Study Area, and the layout diagram is shown as Figure 7.

The Study Area has been divided into two types, namely ‘rural’ and ‘urban’. Both urban and rural catchment was modelled using rainfall-on-grid with Tuflow HPC (Heavily Parallelised Compute), a dynamic hydraulic model which combines 1D calculation for pit and pipe flow with 2D overland flow calculations.

The Tuflow model represents both the urban and rural catchment using 2D surface terrain, surface roughness, and a 1D pit and pipe network (no less than 300mm diameter or equivalent). Tuflow version 2020-10-AA single precision has been used with HPC GPU settings. A grid size of 2x2 were used in the model to obtain more accurate results.

To balance runtime and model definition a grid size of 2x2 m was used, specifically to enhance the detail of some narrow rivulet channels modelled using the 2D grid surface. A grid size this fine for an area this large has recently become possible through the HPC version of the model.

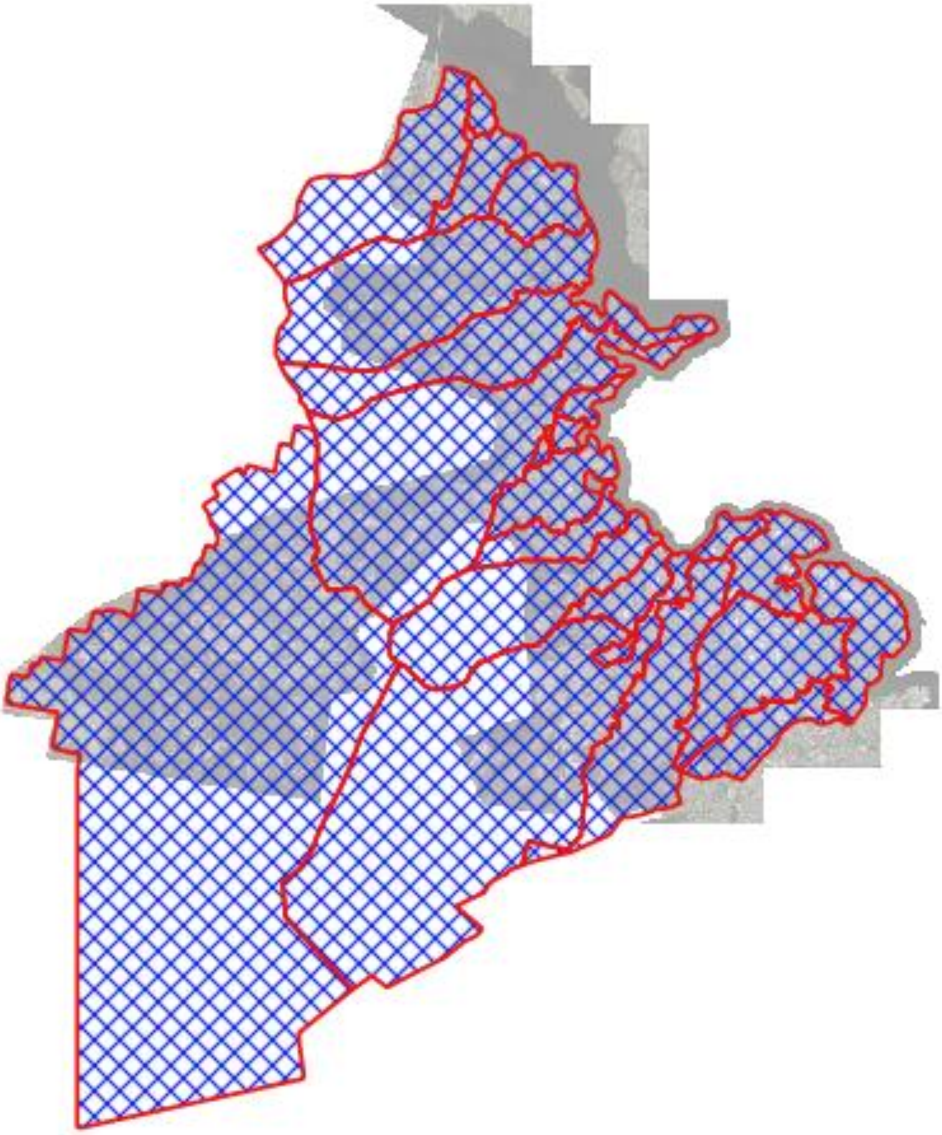


Figure 8 Hybrid Model Layout – TUFLOW Domain

(Square hatching is cosmetic only and does not represent 2D grid size or orientation)

4.2 Input Data

4.2.1 Topographic Data

In the urban catchment area, the topographic data was interpolated from the Glenorchy 0.25m contour layer derived from Mt Wellington LiDAR from 2011 and Greater Hobart LiDAR from 2013. Where the 0.25m Contour data is not available, particularly in the upper area of Mt Wellington a combination of 2m, 5m and 10m contours were used, depending on the most accurate and available contour, to determine the sub catchment, sub catchment slope and 2D terrain model used in the modelling.

The aerial image used in the model was taken in 2013 by Fugro Imagery at 0.1 m resolution (equivalent to 0.1 m per pixel). A quality assessment process of the aerial image accuracy found that it has a mean error of 0.1 m (horizontal error) with standard deviation of 0.09.

4.2.2 Rainfall Data

1% AEP design rainfalls were estimated using the online Bureau of Meteorology

(BoM) website tool located at http://www.bom.gov.au/water/designRainfalls/ifd/index.shtml. It may be noted that currently there are two IFD relationships available on this website, being 1987 and 2016 data sets. The 2016 IFD data set has been applied in this analysis.

4.2.3 Modelling Pipes and Pits

The drainage network built in the model was based on the data captured in Council's digital stormwater maps. These maps are required to be kept by Council under Section 12 of the Urban Drainage Act 2013.

This entire drainage network is formed by four types of assets, including box culverts, natural/lined creeks, gravity mains and open drains.

During the model development process, minor drainage components such as boundary boxes and pipes less than 150 mm diameter, were excluded from the model to simplify the process. It is envisaged that excluding these minor components has minimal impacts on the model integrity and modelling results.

All the 1D network (Pipes & Pits) for all the catchments were exported from XPSWMM model which was then modified to suit TUFLOW. However, for the XPSWMM models where the confidence levels for the calculated inverts were not high, site surveys were conducted by Council's Asset Survey Officer using RTK GPS handset to capture more accurate invert levels.

All the pipes and pits created in the model were represented using 1D links and nodes associating with length, inverts, surface levels, slopes and roughness assigned to individual elements. All pits were modelled as rectangular opening 'R' type as 1.5 m wide by 0.2 m opening height. All headwalls were modelled as 'Node' type.

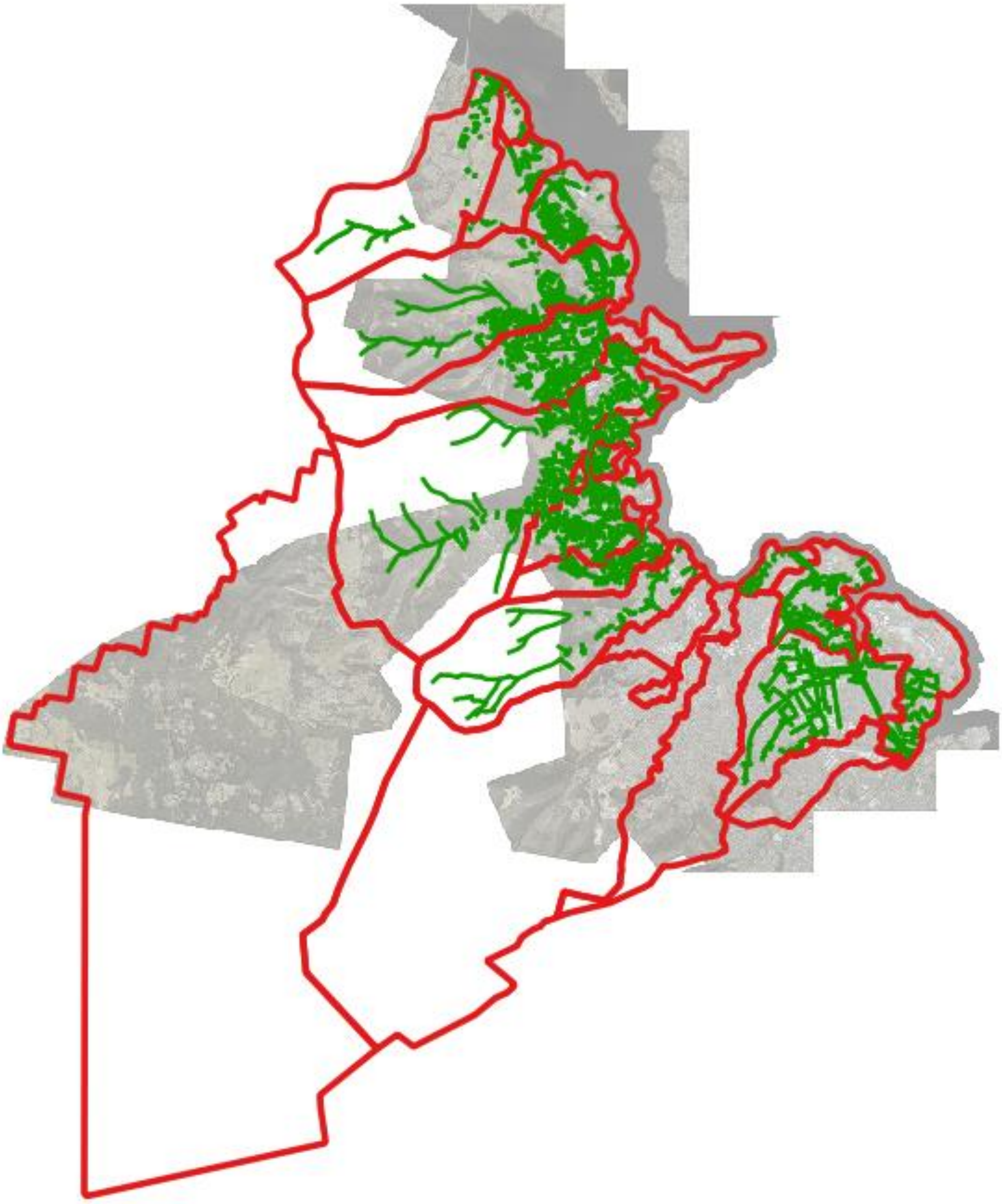


Figure 9 Glenorchy Municipality Catchment Stormwater Drainage Layout

4.2.4 Terrain Modelling

2D terrain was used to model channel flows and surface flow, and to estimate flood extents inclusive of water overflowing/ surcharging from 1D Nodes and Links.

In this study, the Digital Terrain Model is used for both rural and urban areas, was created using the topographical data mentioned in Section 3.2.1.

To achieve a balance between the level of detail and model efficiency, a 2m x 2m grid with 0.2 s timestep was selected and set in the model to calculate the extent of overland flow and its flow direction, depth, velocity, and volume.

As suggested in the *Representation of Buildings in 2D Numerical Flood Model* (Smith and Wasko, 2012) all the building footprints were given an increased elevation (e.g., 999 m AHD) and set to be above the maximum expected flood height, instead of applying a high Manning's Roughness. By elevating the level of building polygons in the 2D terrain model, this simulates the impact of the building, acting as physical obstructions, and impacting on flood direction, depth, and velocity during various flood events.

4.2.5 Fraction Impervious for Different Land Uses

As mentioned in Section 2.3, the land uses within the catchment include Environmental Management, Environmental Living, Utilities, General Residential, Community Purpose, Inner Residential, Light Industrial, Local Business, Low Density Residential, Recreation and Open space.

These land uses were applied to the estimation of the maximum impervious area percentages of individual sub catchments, and then imported into the model to calculate runoff.

Table 4.5.1 of the Queensland Urban Drainage Manual provides an estimated fraction impervious for different land uses, and was adopted for this study (Table 6).

Table 6 Estimated Fraction Impervious for Different Land Uses

Land Uses	% Of Impervious
Community Purpose	80%
Environmental Living	5%
Environmental Management	0%
General Business	90%
General Industrial	95%
General Residential	65%
Inner Residential	80%
Light Industrial	90%
Local Business	90%
Low Density Residential	40%
Open Space	0%
Recreation	0%
Utilities (TasNetworks Easement)	0%
Roads	90%

The study is aware of that, in some areas which are zoned General Residential but allowed for extensive unit developments, the impervious may exceed 65%. However, it is also expected that not all the area will reach its maximum impervious ultimately. Therefore, any underestimate of the fraction impervious rate would be offset by areas of the same catchment being assigned same impervious rate (65%) which may never to reach their maximum development potential.

It is suggested that, for future 'street-scale' flood studies and infrastructure design, a more detailed approach, including site-specific fraction impervious analysis, should be applied.

4.2.6 Rainfall Loss Parameters

The storm initial loss has been applied to Tuflow through the materials files. For impervious surfaces, the initial loss was zero. For pervious surfaces, 28 mm initial loss was applied. For each land use, a fraction impervious was selected, and the initial loss was calculated as the proportion of the two values (i.e., 0 and 28 mm).

Table 7 Losses by Land Use

Land Type/Planning Zone	Tuflow Material ID	Manning's n	Initial Loss (mm)	Continuous Loss (mm/hr)
General Business	14	0.02	1	0
Roads	11	0.02	5.6	0.3
Community Purpose	5	0.03	25.2	1.35
Recreation	7	0.045	25.2	1.35
Open Space	6	0.035	25.2	1.35
Local Business	8	0.045	2.8	0.15
Utilities	9	0.045	25.2	1.35
Inner Residential	3	0.08	11.2	0.3
General Residential	2	0.08	11.2	0.6
Waterbodies/Rivulets	12	0.04	0	0
Environmental Management	10	0.15	26.6	1.425
Environmental Living	4	0.15	22.4	1.2

The initial loss and continuing loss values used in the model are presented in Table 8 below.

Table 8 Rainfall Loss Parameters

Storm AEP	Initial Loss (mm)	Continuous Loss (mm/hr)
100	28.0	1.5

4.2.7 Roughness Coefficients

Roughness coefficient is a value to present the roughness characteristics of closed conduits or natural overflow paths. It is a critical parameter in the Manning's Equation in terms of calculating the flow velocity and depth.

For closed conduits, the roughness values adopted in the model for different conduit materials are presented in Table 9 (Chow, 1959).

Table 9 Manning's roughness for closed conduits

Material	Abbreviation	Manning's Roughness Value
Polyvinyl chloride	PVC	0.011
Steel, Cast Iron/ Ductile Iron	Steel/CI/DICL	0.012
Concrete/Reinforced Concrete	CO/RCP	0.013
Earthenware	EW	0.014

For the flood plain, the roughness for different surface conditions (Table 10) was adopted as described in the Queensland Urban Drainage Manual (QUDM, 2013).

Table 10 Manning's Roughness for Different Surface Conditions

Surface Conditions	Manning's Roughness Value
Roads	0.015
Residential Yard	0.065
Forest	0.15
Grassed Area	0.03

4.2.8 Climate Change Scenarios

The climate change scenario for this study was based on:

- Southern Slopes Tasmania Natural Resource Management Cluster
- Interest in 1% AEP places planning horizon out to the year 2090; and
- Practitioner assumption: high emissions (RCP8.5) scenario (IPCC 2013).

(Ball J, 2019) provides guidance for climate change impact on rainfall intensities at a regional level (allocating Tasmania to a region with Southern Victoria and NSW).

It is worth noting that the flood mitigation infrastructure resulting from this study will have design lives out to 100 years, and therefore adequate justification for the long-term planning horizon needs to be considered and adopted.

(T.A. Remenyi, 2020) study used a downscaling approach to create climate projections from the IPCC Special Report on Emissions Scenarios (Nebojsˇa Nakic´enovic´, 2000) at a finer grid scale over Tasmania (Antarctic Climate & Ecosystems CRC, 2010). (Antarctic Climate & Ecosystems CRC, 2010) reports the temperatures slightly lower than the (Ball J, 2019) values. (Antarctic Climate & Ecosystems CRC, 2010) reports that in the high emissions scenario the 2090 temperature rise for Tasmania is 2.6 to 3.3 degrees Celsius and rainfall depth increases 12-30% seasonally and 24% average increase annually.

(Ball J, 2019) uses the more recent (IPCC, 2013) Representative Concentration Pathways (RCPs) compared to (Antarctic Climate & Ecosystems CRC, 2010). Use of SRES, and its climate change chapter is based on coarser scale regional climate modelling by (CSIRO ansd Bureau of Meteorology, 2015).

(Ball J, 2019) allows practitioner judgement of choice between Representative Concentration Pathways (RCPs) (IPCC, 2013) of RCP4.5 and RCP8.5. RCP8.5 has been selected based on the most current CO_2 trajectories, and USA withdrawal from (UNFCCC, 2015).

Following the (Ball J, 2019) procedure based on these inputs, the (CSIRO ansd Bureau of Meteorology, 2015) estimates that on average the Tasmanian region will be more than 3 degrees Celsius hotter and a median temperature of 3.6 degrees Celsius hotter in 2090. From this temperature, the Intensity factor (FCC) calculation gives a multiplicative factor of 1.19, or a 19.2% increase in rainfall intensity (Ball J, 2019).

The results (and emissions pathways selected) between the two studies are reasonably comparable.

Table 11 below summarises the climate change parameters adopted for this study.

Table 11 Climate Change Scenarios

AEP	Rainfall Intensity (mm/hr)	Sea Level (mAHD)	Storm Surge (m)	Water level Adopted (mAHD)
1%	1% Intensity × F_{cc}^{*}	2010 HAT + SLR = 1.62	0.0	1.62

A 16% increase in rainfall depths in the year 2090 has been adopted for a climate change scenario in accordance with the ARR Data Hub.

Both Climate Change Factor and Tidal boundary level has been applied in conjunction with the SMEC Glenorchy CBD System Management Plan.

4.2.9 Tidal Boundary

A tidal boundary condition (elevation versus time) has been applied where the rivulets discharge to Elwick Bay. A historical relation has been used for the calibration model, whilst a fixed water level is applied to design model runs and varied for each scenario.

It is considered that selecting the average conditions for the Elwick Bay water level is more appropriate than the worst case. Any given design storm event has an independent probability to the tide level in Elwick Bay at the moment of maximum flow. Without conducting a joint probability assessment, the average conditions are most likely during a storm event.

Tidal gauges around Tasmania were assessed to augment understanding of tidal conditions in the Derwent River. A comparison of Hobart tidal data with Spring Bay over the same time series suggested that they share the same amplitude but differ slightly in mean (Spring Bay is higher by 0.2 m). Both gauges are somewhat sheltered from the open ocean with minimum water levels around 0.0 mAHD compared with, for example, the Burnie tidal gauge with typical -1.0 mAHD minimum tide levels.

The selected tidal boundary level of 0.16 mAHD is based on the average level of ~30 years of continuous recordings at Spring Bay of 0.36mAHD (mean and median are the same for the 2 gauges; adjusted down by 0.2m to 0.16m AHD for Hobart).

4.2.10 Peer Review

To further increase in confidence in the flood models and their results, a peer review process was undertaken by Entura. Experienced flood engineers from Entura were engaged to review the model and to provide recommendations on the following aspects, including:

- General review of model setup;

- Review of model parameters including design rainfalls, loss rates, and tailwater conditions, etc;
- Review of model validation process;
- Review of design event model results, including general assessment of model results, selected critical storm duration, and model mass balance and instabilities;
- Review of assumptions and method used to assess the impacts of Climate Change;

The review prepared by Entura stated that most model parameters were selected within reasonable ranges, and the 2D terrain and its surface roughness were correctly represented in the model, both spatially and geometrically.

5 Model Results

5.1 Critical Storm Duration

To identify the critical storm duration for the catchment area, eleven storm durations from 10 mins up to 540 mins (9 hours) were simulated in the model using the design temporal patterns.

The design rainfall patterns for 1% AEP critical storms are presented in Appendix 1 and then all the eleven storm events were modelled to determining the capacity of the reticulation system, mapping flood extents and analysing flood risks.

Refer to Appendix 1 – Critical Event Maps.

5.2 Floodplain Mapping

The flood maps presented in this section were generated using the inundation depth results from the model, as described below.

5.2.1 Post Processing Model Results

To produce fit for purpose flood level, depth, velocity and hazard maps from the model results, post processing of model results is required.

The maximum rainfall depth and velocity may vary with different rainfall intensities despite the critical duration for the catchment being identified.

The grid files from a range of rainfall durations (up to 540 mins) as tested in the model, containing depth and velocity, were post-processed by using ASC to ASC utility to find the maximum depth, velocity, and Hazard.

5.2.2 Filtering of Results

The rainfall-on-grid rainfall-runoff process applies the rainfall in a distributed manner across the entire catchment and then leaves the routing to hydraulic processes across the grid surface. This can leave behind small clusters of flooding up to a dozen grid cells within localised depressions in the model grid that are not necessarily representative of the real topography. These small water clusters, or ‘puddles’, produce a speckled effect on the inundation maps that distract from the information being presented and so require removal.

(Melbourne Water Corporation, 2012) guidelines on minimum requirements for Flood Mapping Projects provide guidance on the inundation map filtering parameters expected for projects within their jurisdiction.

"The filtering parameters were that all points with a depth greater than or equal to 50mm AND a velocity times depth product greater than 0.008 would be used for the flood extent determination.”

Similar filtering criteria were applied to this study. To account for Glenorchy’s on average steeper topography, a depth criterion of 30mm was applied in addition to the product of depth and velocity (DV) of 0.008 m2/s.

The adopted filtering parameters are:

- Remove all inundated area with water depth less than 50mm and with DV (depth times velocity) less than 0.008 m2/s

- Remove all separate 'puddles' with an area of 15 grid cells (i.e., 30 m2) or smaller.

5.2.3 1% AEP Flood Extent

A flood map was produced for 1% AEP events from the combined maximum depth and velocity results, using the post-processing and filtering parameters mentioned above. Flood Depth Maps for all the catchments are presented in Appendix 2.

Refer to Appendix 2 – Inundation Depth Maps.

5.2.4 Floodplain Hazard Mapping

To understand the risks associating with flooding, a process of flood mapping and risk assessment is critical. High stream flow velocities excessive depth of water and inundation hazards need to be mapped and understood. Flood Hazard Maps for all the catchments are presented from Appendix 3.

Refer to Appendix 3 – Inundation Hazard Maps.

5.2.5 Methodology

The flood hazards for the flood models within Glenorchy Municipality area were identified by the model following the Australian Rainfall & Runoff.

Chapter 7. Safety Design Criteria indicates that when dealing with specific floodplain management or emergency management analysis there may be a clear need to use specific thresholds as described above. However, particularly in a preliminary assessment of risks or as part of a constraints analysis such as might be applied as part of a strategic floodplain management assessment, there is also an acknowledged need for a combined set of hazard vulnerability curves, which can be used as a general classification of flood hazard on a floodplain. A suggested set of curves based on the referenced thresholds presented above is provided in Figure 10.

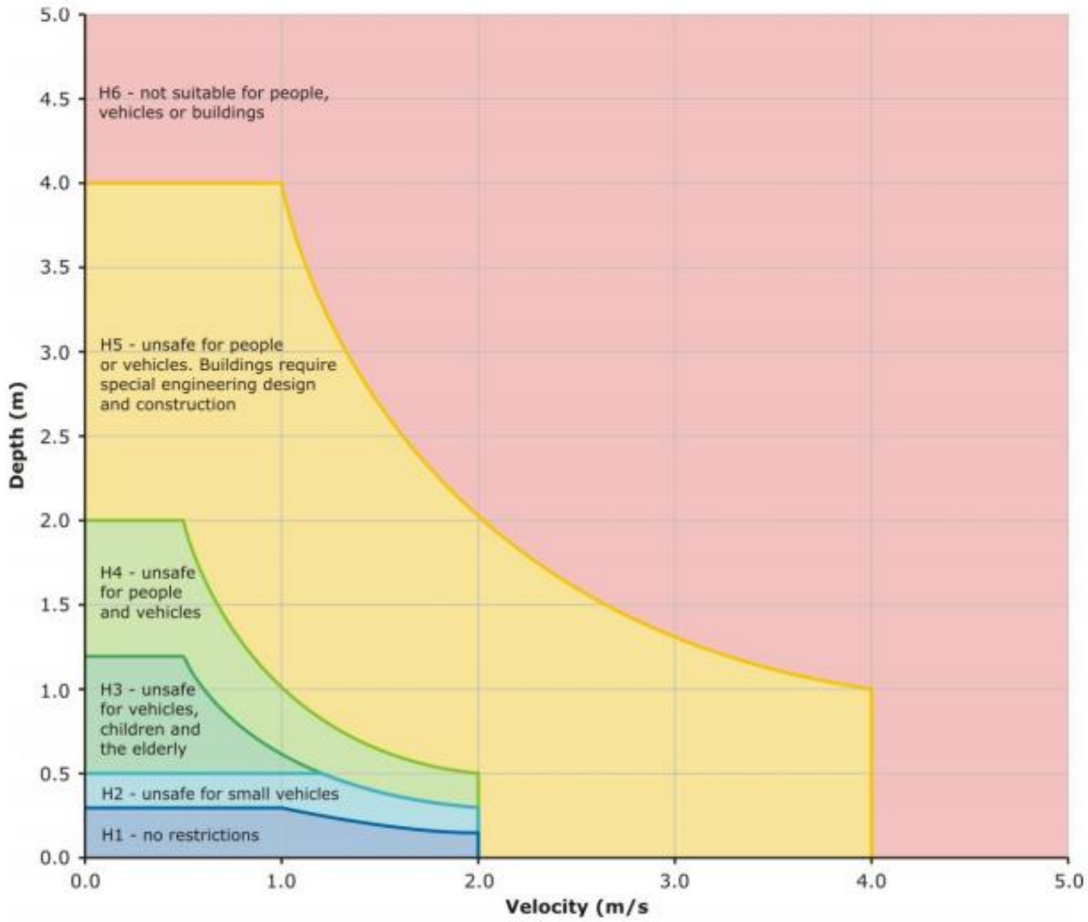


Figure 10 Depth and Velocity in term of Food Hazard (Australian Institute for Disaster Resilience , 2017)

It was defined that flood hazard rating was derived as the multiple of the water depth (m) and the flow velocity (m/s) with the hazard assessed, broadly consistent with the categories in the Australian Rainfall & Runoff. All the flood hazards can be divided into six categories based on their magnitudes (Depth x Velocity), namely Low, Moderate, Significant, High, and Extreme.

In this study flood hazards are defined as:

Table 12 Combined Hazard Curves – Vulnerability Thresholds

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 13 Combined Hazard Curves – Vulnerability Thresholds Classification Limits

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

Note that the flood hazard ratings identified in this report and the hazard maps generated from these ratings are indicative and provisional. More detail study should be conducted to look further into the relationship between hazard categories and local features such as land use, demography, and other social, environmental, and economic patterns.

5.2.6 Flood Hazard Maps

Hazard mapping was undertaken for the 1% AEP including climate change scenario.

These maps have been incorporated into the Local Provisions Schedule of the Tasmanian Planning Scheme.

Code C12.0 Flood Prone Hazard Code defines Flood-Prone Hazard Area as land:

a) shown on an overlay map in the relevant Local Provisions Schedule, as within a flood-prone hazard area; or
b) identified in a report for the purposes of C12.2.3.

The maps generated in this section highlight the land and properties which are defined as a Flood-Prone Hazard Area. It is believed that by completing the hazard maps presented in this section, Council will understand the locations of all these hazard areas, their hazard categories, and use them to manage future developments.

6 Economic Impact of Flooding

6.1 Scope

Council engaged Flüssig Engineers to conduct catchment research into possible flood mitigation measures for the 14 identified catchments in the municipal area. The goal of this inquiry is to examine the hydraulic model to better understand how the watershed and its infrastructure will behave during floods caused by storm events with 5% and 1% AEP, as well as to estimate the potential damage from such events.

The purpose of the investigation was to determine the flooding characteristics of the various catchments affecting the Glenorchy City Council to provide a dollar estimate of the likely damages to public and private property during a 1% AEP + CC storm event.

6.2 Introduction

This investigation consists of the review of the hydraulic model to better understand flood behaviour of the catchment and its infrastructure for 1% AEP storm event to determine an estimate of damages during a resultant storm.

Infoworks ICM (ICM) version 2023.1 was utilised to undertake the analysis of the supplied TUFLOW flood data model. ArcGIS was utilised for the data exploring and parameter manipulation of the results.

6.3 Assessment of Likely Damages

Damages were assessed at a high level using the ANUFLOOD criteria (NRE 2000) without onsite verification or surveys. This method determines direct damages using stage-damage curves for the level of flooding over floors for both commercial and residential premises. The residential and commercial damage curves came from a 2006 revision of Melbourne Water's NRE 2000 stage damage curves.

Indirect damages are damages that occur because of the flood occurring and are related more to temporal impacts, rather than direct contact with water, such as business disruptions, disruption to transport and costs associated with temporary housing of evacuees. These costs were estimated at 30% of direct damages to the property as per Rapid Appraisal Method (RAM), (NRE 2000) guidelines. Damage costs were indexed according to Reserve Bank of Australia inflation rise of 39% from 2006 to 2021, and all values shown in this report are shown as AUD 2021.

Residential curves as shown in Figure 11 provide total damages for structural and contents based of flooding over floor level. These were calculated for each property identified within the model as being flooded above 300 mm and summed into a total damages per event. (Due to the variability of what constitutes a ‘shed,’ these structures were not included in the damages assessment. Only residential housing and contents were estimated.)

Similarly, commercial damages Figure 12 combines structural and contents damages into a per m² quantity, so damages are assessed on the size of the commercial property.

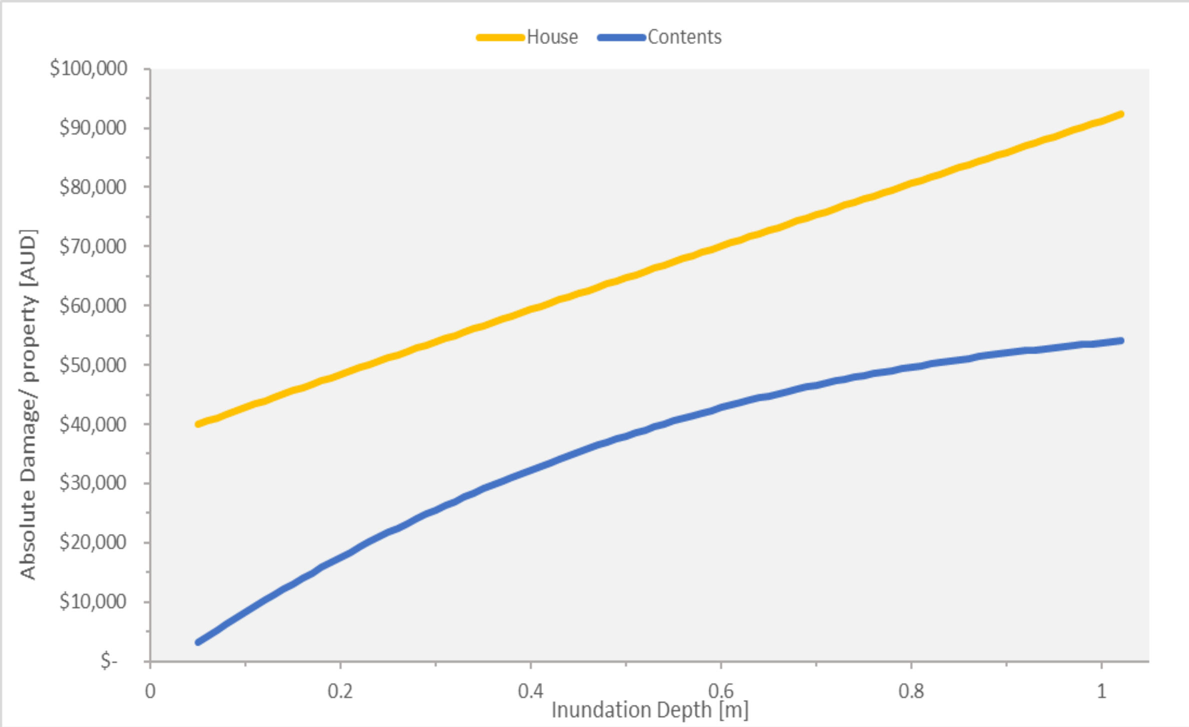


Figure 11 Residential Stage-Damage Curve (NRE, 2006)

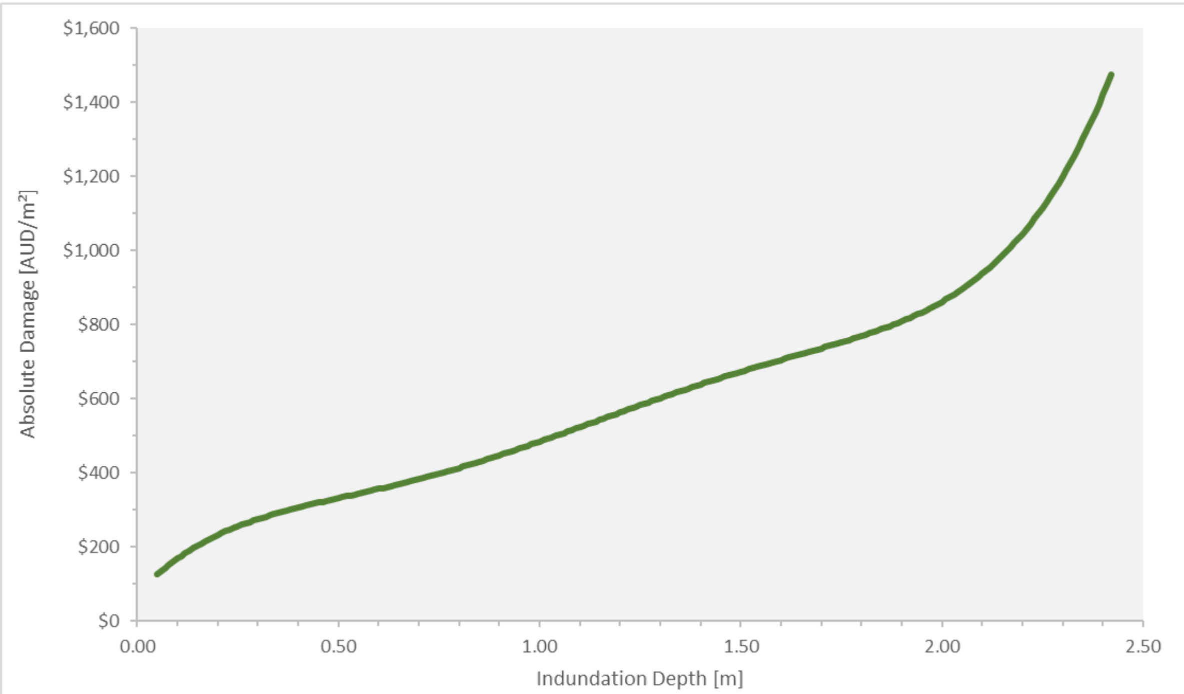


Figure 12 Commercial Stage-Damage Curve (NRE, 2006)

Additionally, the damage caused to roads assets were calculated using the RAM method where damage is assigned per km of road flooded to a depth greater than 300mm. Under the RAM method major, minor and gravel roads are assigned a value per km. Given that the lower reaches of Glenorchy City Council that are prone to flooding are mostly urban areas, gravel roads were not considered. Major roads are assigned a value of damages of $102,975 per km (2021 price) flooded, while minor roads are assigned a value of damages as $32,888 per km. As it is difficult to measure flooding linearly in GIS this figure was converted to a per m^2 value by using the average width of the road being approximately 16m. This gave a damages value of \$6.44 / m^2 and \$2.02 / m^2, respectively.

The Average Annual Damages (AAD) method, which RAM recommends, gives a cost per year by dividing the total damages per frequency against its likelihood and summing the total damages over a year. But to do this, a wide range of events — from frequent to rare — must be evaluated. Considering this limitation, the assessment was limited to the damages that could be linked to a 1% AEP +CC event.

The purpose of this assessment is to derive comparative figures based on probable costs of damages in a 1% AEP storm event. These figures are based of averages of past flooding and therefore cannot be used as an actual damage cost. To determine accurate damage costs, a survey of all premises to derive financial parameters would be required.

For the purposes of this study, the Granton catchments 1, 2 & 3 have been summarised into one catchment, and the Goodwood and Zinc Works catchments have been separated into individual catchments due to the specific nature of the Zinc Works catchment which required further in-depth analysis of the large commercial properties in this area.

6.4 Limitations

This study is limited to the availability and reliability of data, and including the following:

- The flood model is limited to a 1% AEP worst case temporal design storm.
- All parameters have been derived from best practice manuals and available relevant studies (if applicable) in the area.
- All provided data by the client or government bodies for the purpose of this study is deemed fit for purpose.
- Inflation costs are estimated to the end of the calendar year 2021. Consideration should be given to further inflation incurred after this time.
- This study is desktop only. No site visits were undertaken to determine current site conditions.

6.5 Results Summary

The image in Figure 13 shows the dollar amount in AUD (2021) of combined residential and commercial damage for properties inundated above 300 mm. There are two significant outliers in the Springfield and Zinc Works catchments. The Springfield catchment encompasses some areas in the Glenorchy City Council area just north of New Town Rivulet where 81 residential and 108 commercial properties were found to be affected by flood depths above 300mm.

The Zinc Works catchment includes the INCAT site and other industrial properties near the Prince of Wales Bay which results in a large square metre result of buildings affected which should be taken into consideration when viewing the data. The Zinc Works catchment resulted in two property ID's that were very large which, when applying the stage damage curves to such a large m^2 area of floor space, returned damage values that were probably unrealistic. These particular property IDs were separated into individual building IDs with flood damage > 300 mm being identified within the one property ID to ascertain a more realistic value of damages for these properties.

Other catchments returning significant damage values include Beedham's Bay which includes Cadbury's factory, Dooley's Creek which includes MONA museum, and Islet Rivulet that impacts 47 residential and 8 commercial properties.

Catchments that did not return any results of buildings impacted by > 300 mm flood depth include:

- New Town Catchment
- Humphreys Rivulet Catchment
- Little John Creek Catchment
- Barossa Creek Catchment
- Sorell Creek Collinsvale Catchment

The total economic damages for the Glenorchy City Council were estimated to be **$152,215,815.**

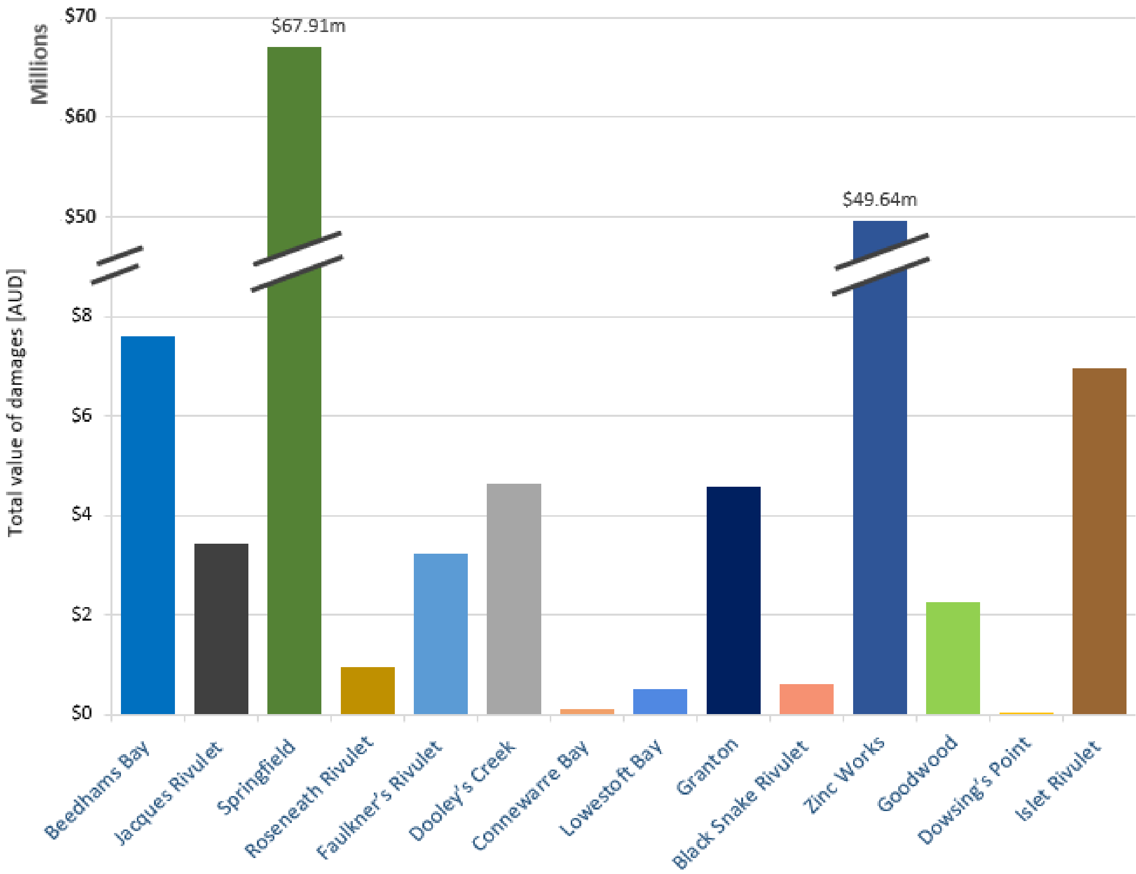


Figure 13 Total combined damages commercial and residential

6.6 Catchment Data

6.6.1 Beedhams Bay Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	28	$2,189,227
Commercial/industrial	5	$3,507,363
Roads	m²	
Public	13175	$27,378
Direct Damages		$5,723,968
Indirect Damages (30%)		$1,717,191
Total Damages		$7,441,159

6.6.2 Black Snake Rivulet Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	6	$436,063
Commercial/industrial	0	$0
Roads	m²	
Public	21873	$45,041
Direct Damages		$481,104
Indirect Damages (30%)		$144,331
Total Damages		$625,436

6.6.3 Connewarre Bay Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	1	$73,763
Commercial/industrial	0	$0
Roads	m²	
Public	629	$1,271
Direct Damages		$75,033

Indirect Damages (30%)	$22,510
Total Damages	$97,543

6.6.4 Dooleys Creek Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	18	$1,273,227
Commercial/industrial	3	$2,287,286
Roads	m²	
Public	1605	$3,490
Direct Damages		$3,564,003
Indirect Damages (30%)		$1,069,201
Total Damages		$4,633,204

6.6.5 Dowsing Point Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	0	$0
Commercial/industrial	1	$30,712
Roads	m²	
Public	1673	$3,379
Direct Damages		$34,091
Indirect Damages (30%)		$10,227
Total Damages		$44,318

6.6.6 Faulkners Rivulet Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	20	$1,656,744
Commercial/industrial	4	$751,628
Roads	m²	

Public	28272	$83,669
Direct Damages		$2,492,041
Indirect Damages (30%)		$747,612
Total Damages		$3,239,653

6.6.7 Goodwood Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	3	$208,977
Commercial/industrial	7	$1,506,674
Roads	m²	
Public	6879	$13,931
Direct Damages		$1,729,582
Indirect Damages (30%)		$518,875
Total Damages		$2,248,456

6.6.8 Granton Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	32	$2,393,729
Commercial/industrial	1	$1,130,748
Roads	m²	
Public	639	$1,291
Direct Damages		$3,525,768
Indirect Damages (30%)		$1,057,730
Total Damages		$4,583,498

6.6.9 Islet Rivulet Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		

Residential	47	$3,791,626
Commercial/industrial	8	$1,462,033
Roads	m²	
Public	7742	$18,835
Direct Damages		$5,272,494
Indirect Damages (30%)		$1,581,748
Total Damages		$6,854,242

6.6.10 Jacques Rivulet Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	35	$2,557,629
Commercial/industrial	0	$0
Roads	m²	
Public	4001	$75,383
Direct Damages		$2,633,012
Indirect Damages (30%)		$789,903
Total Damages		$3,422,915

6.6.11 Lowestoft Bay Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	6	$389,457
Commercial/industrial	0	$0
Roads	m²	
Public	125	$253
Direct Damages		$389,709
Indirect Damages (30%)		$116,913
Total Damages		$506,622

6.6.12 Roseneath Rivulet Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	9	$670,966
Commercial/industrial	0	$0
Roads	m²	
Public	24654	$71,110
Direct Damages		$742,076
Indirect Damages (30%)		$222,623
Total Damages		$964,699

6.6.13 Springfield Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	81	$6,175,105
Commercial/industrial	108	$45,807,486
Roads	m²	
Public	98653	$257,110
Direct Damages		$52,239,702
Indirect Damages (30%)		$15,671,911
Total Damages		$67,911,612

6.6.14 Zinc Works Catchment

Scenarios	1% Base	
	Quantity	Damages
Buildings		
Residential	5	$383,806
Commercial/industrial	21	$37,790,789
Roads	m²	
Public	5896	$11,910
Direct Damages		$38,186,505
Indirect Damages (30%)		$11,455,952

Total Damages	$49,642,457

6.7 Conclusion

Hydrologic and hydraulic modelling of the entire Glenorchy City Council catchments was evaluated to provide an estimate of economic impacts of a 1% AEP storm event using the Rapid Appraisal Method based on ANUFLOOD guidelines (NRE 2000).

Most catchments had an estimated total damage value of less than $8m, except for the Springfield catchment and Zinc Works catchment which were $68m and $50m, respectively. However, as this study was a desktop analysis, no onsite verification was undertaken, and site-specific conditions may provide a more accurate estimate of damages.

Damage estimates were based on applying stage damage curves from a 2006 revision by Melbourne Water of the NRE 2000 guidelines and applying the consumer price of inflation from 2006 – 2021. Consideration should be given to ongoing market conditions for inflation to specific flood remediation costs such as building materials.

The accessible data base, the used modelling approach, and the type of flooding must all be taken into consideration when determining the level of detail to be applied in estimating vulnerability to flood damage. In this study, where pluvial flooding was predominant, unit cost methodologies were shown to produce acceptable findings, such methods should only be used in conjunction with sophisticated modelling techniques, such as high resolution 1D-2D hydraulic modelling.

A summary of the total estimated damages for the Glenorchy City Council area is shown in the table below.

Table 14 Summary of the Total Estimated Damages

Compiled Catchment Data	Quantity	Damages
Buildings		
Residential	291	$22,200,319
Commercial/industrial	158	$94,274,720
Roads	m^2	
Public	215,816	$614,050
Direct Damages		$117,089,089
Indirect Damages (30%)		$35,126,727
Total Damages		$152,215,815

6.8 Recommendations

The RAM method of estimating damages by using a m^2 approach may differ significantly for buildings such as MONA art gallery compared to a storage facility for bricks and paving. As this study was conducted as a desktop analysis without onsite verification, it is recommended that areas recording flood damage for large commercial sites, undertake an on-site assessment as to the specific use of the site, considering the nature of the assets within the building and any local on-site conditions that may affect localised flood flow through the property.

Commercial properties that are returning high estimates for losses based on the building size and a flood depth impacting on some parts of that building are listed in the table below. It is recommended that further site-specific investigation be undertaken to gauge a more accurate estimate of damages.

The Zinc Works site is of particular concern in estimating damages based on a desktop analysis as the site is very large with unknown operations occurring in some of the buildings that are returning high estimated damages with one building alone (building ID 55323) recording almost $10m of damages.

Similarly, the Springfield catchment, which includes areas near the New Town Rivulet, has many properties with high damage estimates which may benefit from a more detailed economic damages assessment.

A summary of specific properties with high value of estimated damages that could benefit from more detailed investigation are shown in the table below.

Table 15 Summary of Specific Properties with High Value of Estimated Damages

Catchment	Property ID	Address	Facility	m^2	Est. losses
Springfield	7394129	10 Derwent Park Road, Derwent Park	Retail businesses	6282	$1,729,157
Springfield	7611509	20 Lampton Avenue, Derwent Park	Searoad freight company	6355	$1,867,309
Springfield	7611509	20a Lampton Avenue, Derwent Park	Disability support provider	4603	$2,003,213
Springfield	3357734 3357742	82-86 Gormanston Road & 34 Chesterman Street, Moonah	Auto Parts supplier and Tricab manufacturing	7162	$2,297,541
Springfield	5411386	5-7 Bowen Road, Moonah	Mercury Walch Printing	4968	$2,069,999
Springfield	5411394	1-3 Bowen Road, Moonah	Langford Support services	4852	$3,641,611
Springfield	5403124	95 Albert Road, Moonah	Stanley Centre (multiple tenancies)	6960	$2,890,762
Beedham's Bay	2245343	100 Cadbury Road, Claremont	Cadbury Factory	7962	$4,003,484
Dooley's Creek	2250425	651-655 Main Road, Berriedale	Moorilla Estate (MONA)	3562	$2,706,728
Zinc Works	5442043	401 Risdon Road, Lutana	Wharf, Industrial buildings Zinc Works	14837	$6,684,021
Zinc Works	7855159 (BLD_ID 55336)	300 Risdon Road, Lutana	Zinc Works	22945	$6,790,862
Zinc Works	7855159 (BLD_ID 55323)	300 Risdon Road, Lutana	Zinc Works	18867	$9,791,672
Zinc Works	3478683	18 Bender Drive, Derwent Park	INCAT	11155	$3,849,425

Zinc Works	3049264	4-8 Sunmont Street, Derwent Park	Hartz International	7042	$2,854,560

7 Flood Risk Management Options

7.1 Scope

The purpose of the investigation was to determine the flooding characteristics of the various catchments affecting the Glenorchy City Council to provide a proposed mitigation option at each catchment with an estimated value of the likely damages to public and private property during a 5% AEP and 1% AEP storm event.

7.2 Introduction

The Glenorchy City Council has undertaken catchment research into possible flood mitigation measures for the 14 identified catchments in the municipal area. The goal of this inquiry is to examine the hydraulic model in order to better understand how the watershed and its infrastructure will behave during floods caused by storm events with 5% and 1% AEP, as well as to estimate the potential damage from such events.

The fundamental cause of this level of damage and the key factor contributing to flood risk in general is the presence of vulnerable buildings constructed within floodplains due to ineffective land use inside the flood prone areas.

Retrospective analysis shows large benefits from disaster risk reduction (DRR) in the context of private and public assets. However, in spite of potentially high returns, there is limited research available on assessing the benefits of different mitigation strategies and the consequential reduction in investment made in loss reduction measures by individuals and local governments.

This report aims to identify economically optimal upgrading solutions so the finite resources available can be best used to minimise losses, decrease human suffering, improve safety, and ensure amenity for some areas of the Glenorchy City Council communities affected by flooding. This report describes the research methods, project activities, outcomes, and their potential for utilisation.

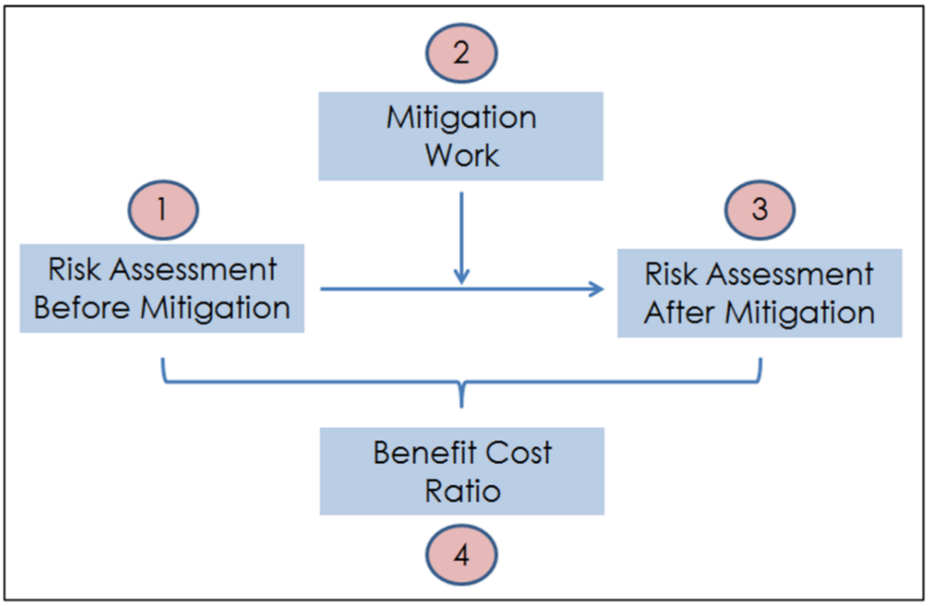


Figure 14 Cost Versus Benefit Analysis Framework (Adapted from Mechler, 2005)

The four phases that have been used in this report's methodology to determine whether each mitigation strategy is feasible and realistically implementable in the chosen catchment region are listed below.

- Risk Assessment before mitigation: at this step risk was calculated in terms of conditional loss ($) based on existing building stock (un-retrofitted).
- Mitigation work: this was the investment ($) to reduce potential impacts assessed in the first step. It was comprised of the costs of conducting the mitigation work on the relevant area.
- Risk Assessment after mitigation: at this step risk was again calculated incorporating the effects of the mitigation investment. There is typically a reduction of loss ($) compared to the pre-mitigation state. This reduction in loss ($) was considered to be the benefit arising from the investment.
- Benefit Cost Ratio: finally, economic effectiveness of the mitigation investment was evaluated by comparing benefits and costs. Costs and benefits accumulating over time needed to be discounted to make current and future effects comparable as any money spent or saved today has more value than that realised from expenditure and benefits in the future. This concept is termed Time Value of Money. Future values therefore need to be discounted by a discount rate representing the loss in value over time. A Benefit Cost Ratio of 1.0 or more suggests the mitigation investment was an economically viable decision.

The fourteen catchment mitigation options outlined in the report are below. The affected private and public assets are only included in the area of the proposed potential mitigation works and do not reflect a proposed solution for the entire Glenorchy City Council's full contributing catchment areas.

7.3 Flood Mitigation Options

7.3.1 Beedhams Bay

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Dewar Place Earth Bund - Levee Flood Detention

In order to mitigate the immediate flooding and lessen the severity of the risk and damages to some homes in the Beedhams Bay Catchment from Dewar Place to the Brooker Highway, the earth bund flood retention has been recommended. Section 1.3 has a description of the option.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in Section 1.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 16 compares the number of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels determines the actual damage cost.

Table 16 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	14	30
Commercial/industrial	0	0
Roads (m²)		
Minor	650	1270

Table 17 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 17 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$754,574	$1,617,802
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$4,225	$8,255
Damage Estimates		

Direct Damages	$758,799	$1,626,057
Indirect Damages	$227,760	$487,817
Total Damages	**$986,959**	**$2,113,874**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 18 below, shows net present value of damages determined in Table 17 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of >10 with the lowest value being the 5% AEP with a benefit-cost ratio of 4.4.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 18 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$986,959**	$280,000	$706,959	4.4	2
	1% AEP Base	**$2,113,874**	$280,000	$1,833,874	10.7	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 18 would be the 1% AEP having the highest benefit for the lowest cost. Figure 1.2 in Appendix 5 shows the relative location of the proposed earth bund flood wall described in the option.

Option 1 – Earth Bund Wall - Levee

Temporary detention with a proposed earth bund wall fitted with 5 x DN300 pipes to reduce the flood depth the existing flood impacted dwellings from >300mm to >150mm running along Dewar Place to the Brooker Highway This option provides a benefit of $1,833,874 in reduction of damages with a benefit-cost ratio (BCR) of 10.7 in the 1% AEP flood scenario, making this the most preferred option.

Further investigation of the constructability of the option shall be carried out by Council for the use of available space in the electrical corridor easement, which needs to be assessed against the TasNetwork's requirements prior to the addition of the mitigation option.

Other Mitigation Options and reason for not being Considered:

Detention pond adjacent to Abbotsfield Park – No significative benefit to the downstream catchment based in construction cost v/s reduction in damages.

Detention dam Abbotsfield Rivulet / Russell Rd – No significative benefit to the downstream catchment based in construction cost v/s reduction in damages.

7.3.2 Black Snake Rivulet

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Vegetation Management

The general Rivulet maintenance from has been recommended as it would provide a degree of relief to the immediate flooding either easing or reducing the severity of risk and damages to some of the Black Snake Rivulet Catchment properties from the Brooker Highway to the end of Black Snake Road. A description of the option can be found in section 2.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 2.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 19 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 19 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	0	3
Commercial/industrial	0	0
Roads (m²)		
Minor	300	3000

Table 20 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 20 Damages for each individual flood scenario at “do nothing” option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$0	$215,707
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$1,950	$19,500
Damage Estimates		

Direct Damages	$1,950	$235,207
Indirect Damages	$585	$70,000
Total Damages	**$2,535**	**$305,769**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 21 below, shows net present value of damages determined in Table 20 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide to be the most benefit to the overall mitigation option being the only option that results in a ratio of >1.4 with the lowest value being the 5% AEP with a benefit-cost ratio of -1.0.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 21 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$2,535**	$125,000	-$122,465	-1.0	0
	1% AEP Base	**$305,769**	$125,000	$180,769	1.4	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 21 would be the 1% AEP having the highest benefit for the lowest cost. Figure 2 in Appendix 5 shows the relative location of the proposed vegetation management described in the option.

Option 1 – Vegetation Management

The vegetation management option is to maintain adequate hydraulic conveyance capacity a natural or modified creek channel such as Black Snake Rivulet, avoiding experiencing a significant reduction in hydraulic capacity within 2% AEP to 1% AEP flood scenarios. This is because invasive species can completely block a channel in a relatively short period either directly or indirectly by creating blockages and snags. This option provides a benefit of $180,769 in reduction of damages with a benefit-cost ratio (BCR) of 1.4 in the 1% AEP flood scenario, making this the most preferred option.

Other Mitigation Options and reason for not being Considered:

Dam extension at 81 Black Snake Rd – No significative benefit to the downstream catchment based in land acquisition, construction cost v/s reduction in damages.

Detention dam at 239 Black Snake Rd boundary – Negative benefit to the downstream catchment based in land acquisition, construction cost v/s reduction in damages.

7.3.3 Connewarre Bay

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Underground Detention and Double Side Entry Pit

It has been suggested that the detention system and double-sided entrance pit be used since they would serve as a road dewatering system for flooding and shorten the amount of time that water would pool above ground along No. 1 to No. 11 Teering Road. Section 3.3 has a description of the option.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 3.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 22 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 22 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	0	1
Commercial/industrial	0	0
Roads (m²)		
Minor	480	1500

Table 23 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 23 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$0	$53,927
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$3,120	$9,750
Damage Estimates		

Direct Damages	$3,120	$63,677
Indirect Damages	$936	$19,103
Total Damages	**$4,056**	**$82,780**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 24 below, shows net present value of damages determined in Table 23 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 0.4 with the lowest value being the 5% AEP with a benefit-cost ratio of -0.9.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 24 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$4,056**	$60,000	-$55,944	-0.9	2
	1% AEP Base	**$82,780**	$60,000	$22,780	0.4	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 24would be the 1% AEP having the highest benefit for the lowest cost. Figure 3.2 in Appendix 5 shows the relative location of the proposed detention system and double side entry pit described in the option.

Option 1 – Underground Detention and Double Side Entry Pit

Reduce the flood depth and pooling along Nos. 1 to 11 Teering Road to aid in the quickest road dewatering. An underground detention system with 4 x DN450 pipes, "CorruTank" or a similar, and the construction of 2 x double side entrance pits are proposed. In the 1% AEP flood scenario, this alternative reduces damages by $22,780 with a marginal benefit and a benefit-cost ratio (BCR) of only 0.4, making it a viable choice. In order to make the best use of the available road space and avoid using subsurface services that can be inconvenient, Council must conduct additional research on the option's constructability.

Other Mitigation Option and reason for not being Considered:

Pipe upsize at 31/29 Connewarre Cr– Not enough clearance between underground services for a bigger pipe to dewater the road, adverse constructability issues.

7.3.4 Dooleys Creek

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Kilander Crescent Earth Bund – Levee Flood Detention

The earth bund flood detention has been recommended as it would provide a degree of relief to the immediate flooding either easing or reducing the severity of risk and damages to some of the Dooleys Creek Catchment properties from Chandos Drive to the Brooker Highway. A description of the option can be found in section 4.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 4.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 25 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 25 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	13	29
Commercial/industrial	0	0
Roads (m²)		
Minor	350	2000

Table 26 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 26 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$701,048	$1,563,875
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$2,275	$13,000
Damage Estimates		

Direct Damages	$703,323	$1,576,875
Indirect Damages	$210,997	$473,063
Total Damages	**$914,319**	**$2,049,938**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 27 below, shows net present value of damages determined in Table 26 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of >10 with the lowest value being the 5% AEP with a benefit-cost ratio of 4.4.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 27 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$914,319**	$120,000	$794,319	6.6	2
	1% AEP Base	**$2,049,938**	$120,000	$1,929,938	16.1	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 27 would be the 1% AEP having the highest benefit for the lowest cost. Figure 4.2 in Appendix 5 shows the relative location of the proposed earth bund flood wall described in the option.

Option 1 – Earth Bund – Levee Wall Detention

Temporary detention to minimise the flood depth along Chandos Drive to the Brooker Highway, with a proposed earth bund wall equipped with 3 x DN300 pipes. In the 1% AEP flood scenario, this alternative reduces damages by $1,929,938 and has a high benefit-cost ratio (BCR) of 16.1, making it the recommended choice. Prior to the inclusion of the mitigation option, Council shall conduct additional research into the option's constructability for the use of available space in the existing recreational green area.

Other Mitigation Options and reason for not being Considered:

Detention pond at front of 193 Marys Hope Rd – Negative benefit to the upstream catchment based in land acquisition, construction cost v/s reduction in damages.

Detention dam at the back of 13 /14 Dooleys Av – Negative benefit to the downstream catchment based in land acquisition, constructability, construction cost v/s reduction in damages.

7.3.5 Dowsing Point

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Vegetation – Open Drain Maintenance

The management and maintenance of the existing open drain has been recommended as it would provide future resilience to erosion and flooding either easing or reducing the severity of risk and damages to the stormwater system. A description of the option can be found in section 5.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 5.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 28 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 28 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	0	0
Commercial/industrial	0	0
Roads (m^2)		
Minor	0	0

Table 29 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 29 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$0	$0
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$0	$0
Damage Estimates		

Direct Damages	$0	$0
Indirect Damages	$0	$0
Total Damages	**$0**	**$0**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 30 below shows the net present value of damages determined in Table 29 against the net present capital cost of each option and the benefit by means of a reduction in damages. These costs run through the above equation and provide a ratio to compare each flood scenario option. As the mitigation option would be qualified as general maintenance for the 1% and 5% AEP flood scenarios, the table below would not provide a benefit value on this occasion.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 30 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$0**	$20,000	-$20,000	-1.0	0
	1% AEP Base	**$0**	$20,000	-$20,000	-1.0	0

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, as it would be a maintenance option only, there wouldn't be a preferred option as per Table 30. Figure 5 in Appendix 5 shows the relative location of the proposed maintenance works.

Option 1 – Vegetation – Open Drain Maintenance

Regular inspections should be undertaken to identify any erosion or sediment deposition. The inspection should identify the cause of the erosion and source of sediment and works should be undertaken to rectify the problem. Any areas where grass coverage has decreased should be revegetated. Once vegetation is established, there is no need for grading. This option provides a benefit of -$20,000 in reduction of damages with a benefit-cost ratio (BCR) of -1.0 in the 1% and 5% AEP flood scenarios, making this option an integral part of the Council's maintenance schedule.

Other Mitigation Options and reason for not being Considered:

No other option– No other mitigation options has been assessed as the few inundated areas are inside private or state government land.

7.3.6 Faulkners Rivulet

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Earth Bund - Levee Flood Detention

The earth bund flood detention has been recommended as it would provide a degree of relief to the immediate flooding either easing or reducing the severity of risk and damages to some of the Faulkners Rivulet Catchment properties from Boondar Street to Karambi Street. A description of the option can be found in section 6.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 6.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 31 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 31 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	16	27
Commercial/industrial	0	0
Roads (m^2)		
Minor	570	5500

Table 32 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 32 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$862,828	$1,456,022
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$3,705	$35,750
Damage Estimates		

Direct Damages	$866,533	$1,491,772
Indirect Damages	$259,960	$447,532
Total Damages	**$1,1126,493**	**$1,939,303**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 33 below, shows net present value of damages determined in Table 32 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 8.7 with the lowest value being the 5% AEP with a benefit-cost ratio of 4.6.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 33 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$1,126,493**	$200,000	$926,493	4.6	2
	1% AEP Base	**$1,939,303**	$200,000	$1,739,303	8.7	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, as it would be a maintenance option only, there wouldn't be a preferred option as per Table 33. Figure 6.2 in Appendix 5 shows the relative location of the proposed earth bund wall.

Option 1 – Earth Bund Wall - Levee

The proposed earth bund wall for temporary detention to lower the flood depth along Faulkner's Rivulet from Boondar Street to Karambi Street In the 1% AEP flood scenario, this solution reduces damages by $1,739,303 and has a benefit-cost ratio (BCR) of 8.7, making it the best choice. Council must do additional research into the waterway protection area for constructability for the use of the available space, which must be compared to the requirements previous to the inclusion of the mitigation option.

Other Mitigation Options and reason for not being Considered:

Detention pond at 123 Berriedale Rd – Negative benefit to the downstream catchment based in land acquisition, construction cost v/s reduction in damages.

Detention dam at the back of 35 /37 Glenlusk Rd – Negative benefit to the downstream catchment based in land acquisition, constructability, construction cost v/s reduction in damages.

7.3.7 Goodwood

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

General stormwater maintenance

General stormwater system maintenance has been recommended as it would reduce the risk of flooding of public and private property to acceptable levels for some of the Goodwood Catchment properties. As the proposed mitigation option would be classified as a past of Council's maintenance schedule and budget, a description of the option can be found in Section 7.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 7.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 34 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 34 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	0	0
Commercial/industrial	0	0
Roads (m^2)		
Minor	0	0

Table 35 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 35 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$0	$0
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$0	$0
Damage Estimates		

Direct Damages	$0	$0
Indirect Damages	$0	$0
Total Damages	**$0**	**$0**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 36 below shows the net present value of damages determined in Table 35 against the net present capital cost of each option and the benefit by means of a reduction in damages. These costs run through the above equation and provide a ratio to compare each flood scenario option. As the mitigation option would be qualified as general maintenance for the 1% and 5% AEP flood scenarios, the table below would not provide a benefit value on this occasion.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 36 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$0**	$80,000	-$80,000	-1.0	0
	1% AEP Base	**$0**	$80,000	-$80,000	-1.0	0

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, as it would be a maintenance option only, there wouldn't be a preferred option as per Table 36. Figure 7 in Appendix 5 shows the relative location of the proposed maintenance works.

Option 1 – General Stormwater Maintenance

Regular system maintenance and storm drain cleaning, remove trash, sediment, and debris from storm drains, roadways and other watershed areas to help minimise erosion and related damage and prevent flooding.

This option provides a benefit of -$80,000 in reduction of damages with a benefit-cost ratio (BCR) of -1.0 in the 1% AEP flood scenario, making this option an integral part of the Council's maintenance schedule.

Other Mitigation Options and reason for not being Considered:

No other option– No other mitigation options has been assessed as the few inundated areas are inside private or state government land.

7.3.8 Granton

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Earth Bund - Levee Flood Deviation Wall

The earth bund flood deviation wall has been recommended as it would provide a degree of relief to the immediate flooding either easing or reducing the severity of risk and damages to some of the Granton Catchment properties from the Brooker Highway to Hestercombe Road. A description of the option can be found in section 8.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 8.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 37 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 37 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	6	10
Commercial/industrial	0	0
Roads (m^2)		
Minor	210	630

Table 38 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 38 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$323,560	$539,267
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$1,365	$4,095
Damage Estimates		

Direct Damages	$324,925	$543,362
Indirect Damages	$97,478	$163,009
Total Damages	**$422,403**	**$706,371**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 39 below, shows net present value of damages determined in Table 38 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 5.4 with the lowest value being the 5% AEP with a benefit-cost ratio of 2.8.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 39 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$422,403**	$110,000	$312,403	2.8	2
	1% AEP Base	**$706,371**	$110,000	$596,371	5.4	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 39 would be the 1% AEP having the highest benefit for the lowest cost. Figure 8.2 in Appendix 5 shows the relative location of the proposed earth bund flood wall described in the option.

Option 1 – Earth Bund - Levee Flood Deviation Wall

1.8m high deviation flood earth bund wall to reduce the flood depth running along the Brooker Highway to Hestercombe Road. This option provides a benefit of $596,371 in reduction of damages with a benefit-cost ratio (BCR) of 5.4 in the 1% AEP flood scenario, making this the most preferred option. Further investigation of the constructability of the option shall be carried out by Council for the use of available space in the existing open drain corridor easement, which needs to be assessed against The Department of State Growth requirements prior to the addition of the mitigation option.

Other Mitigation Options and reason for not being Considered:

Detention dam extension at the back of 8 Gillies Rd – Negative benefit to the downstream catchment based in land acquisition from the crown, constructability, construction cost v/s reduction in damages.

Detention dam extension at the back of 32 Gillies Rd – Negative benefit to the downstream catchment based in land acquisition from the crown, constructability, construction cost v/s reduction in damages.

7.3.9 Islet Rivulet

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Flood wall and culvert extension at reserve

The earth bund flood detention and extension of the exiting DN1800 culvert has been recommended as it would provide a degree of relief to the immediate flooding either easing or reducing the severity of risk and damages to some of the Islet Rivulet Catchment properties along the channel from Philip Avenue to the Main Road. A description of the option can be found in section 9.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 9.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 40 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 40 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	22	35
Commercial/industrial	0	0
Roads (m^2)		
Minor	1200	2600

Table 41 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 41 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$1,186,388	$1,887,436
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$7,800	$16,250
Damage Estimates		

Direct Damages	$1,194,188	$1,903,686
Indirect Damages	$358,256	$571,106
Total Damages	**$1,552,445**	**$2,474,791**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 42 below, shows net present value of damages determined in Table 41 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 10.2 with the lowest value being the 5% AEP with a benefit-cost ratio of 6.1.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 42 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$1,552,445**	$220,000	$1,332,445	6.1	2
	1% AEP Base	**$2,474,791**	$220,000	$2,254,791	10.2	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 42 would be the 1% AEP having the highest benefit for the lowest cost. Figure 9.2 in Appendix 5 shows the relative location of the proposed earth bund flood wall and culvert extension described in the option.

Option 1 – Earth Bund Wall - Levee and DN1800 Culvert Extension

The proposed DN1800 culvert extension would be crossed by an earth bund wall for temporary detention in order to lessen the depth of flooding inundating some of the existing dwellings along the channel from Philip Avenue to Main Road. In the 1% AEP flood scenario, this alternative reduces damages by $2,254,791 and has a benefit-cost ratio (BCR) of 10.2, making it the recommended choice.

Prior to the inclusion of the mitigation option, Council shall conduct more research into the alternative's constructability for the use of available space on the recreational land.

Other Mitigation Options and reason for not being Considered:

Footpath and kerb rise from 96-124 Montrose Rd– Negative benefit to the affected dwelling based topographic constrains, construction cost v/s reduction in damages.

Detention pond at Montrose Rd/ Pitcairn St – Negative benefit to the downstream catchment based in constructability, construction cost v/s reduction in damages.

7.3.10 Jacques Rivulet

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Vegetation – Open Drain Maintenance

The management and maintenance of the existing open drain has been recommended as it would provide future resilience to erosion and flooding either easing or reducing the severity of risk and damages to the stormwater system. The proposed works extent from the back of the rear boundary of No12 Addison Street to the rear boundary at No54 Driscoll Street. A description of the option can be found in section 10.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 10.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 43 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 43 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	5	14
Commercial/industrial	0	0
Roads (m^2)		
Minor	0	0

Table 44 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 44 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$269,634	$754,974
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$0	$0

Damage Estimates		
Direct Damages	$269,634	$754,974
Indirect Damages	$80,890	$226,492
Total Damages	**$350,524**	**$981,467**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 45 below, shows net present value of damages determined in Table 44 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of >10 with the lowest value being the 5% AEP with a benefit-cost ratio of 4.4.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 45 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$350,524**	$100,000	$250,524	2.5	2
	1% AEP Base	**$981,467**	$100,000	$881,467	8.8	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 45 would be the 1% AEP having the highest benefit for the lowest cost. Figure 10.2 in Appendix 5 shows the relative location of the proposed open drain maintenance wall described in the option.

Option 1 – Vegetation – Open Drain Maintenance

The goal of maintaining adequate hydraulic conveyance capacity in a natural or modified stream channel, like Jacques Rivulet improving the Manning's coefficient for roughness from 0.055 to 0.025 and maintaining open drains is to prevent experiencing a major drop in hydraulic capacity during 5%

AEP to 1% AEP flood scenarios. This is due to the fact that invasive species have the potential to fully obstruct a channel in a short amount of time by causing blockages and snags. In the 1% AEP flood scenario, this alternative reduces damages by $881,467 and has a benefit-cost ratio (BCR) of 8.8, making it the recommended option.

Other Mitigation Options and reason for not being Considered:

Detention dam at Redlands Dr – Negative benefit to the downstream catchment based in constructability, construction cost v/s reduction in damages.

Footpath, kerb rise and flood walls from 54-136 Marys hope Rd– Negative benefit to the affected dwelling based topographic constrains, construction cost v/s reduction in damages.

7.3.11 Lowestoft Bay

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Earth Bund - Levee Flood Deviation Wall

The earth bund flood deviation wall has been recommended as it would provide a degree of relief to the immediate flooding either easing or reducing the severity of risk and damages to some of the Lowestoft Bay Catchment properties from Woorin St to Main Road. A description of the option can be found in section 11.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 11.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 46 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 46 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	6	10
Commercial/industrial	0	0
Roads (m^2)		
Minor	120	440

Table 47 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 47 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$323,560	$431,414
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$780	$2,860
Damage Estimates		

Direct Damages	$324,340	$434,274
Indirect Damages	$97,302	$130,282
Total Damages	**$421,643**	**$564,556**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 48 below, shows net present value of damages determined in Table 47 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 4.1 with the lowest value being the 5% AEP with a benefit-cost ratio of 2.8.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 48 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$421,643**	$110,000	$311,643	2.8	2
	1% AEP Base	**$564,556**	$110,000	$454,556	4.1	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 48 would be the 1% AEP having the highest benefit for the lowest cost. Figure 11.2 in Appendix 5 shows the relative location of the proposed earth bund flood wall described in the option.

Option 1 – Earth Bund - Levee Flood Deviation Wall

1.0m high deviation flood earth bund wall to reduce the flood depth running along the northern boundary of 680 Main Rd Berriedale to Main Road. This option provides a benefit of $454,556 in reduction of damages with a benefit-cost ratio (BCR) of 4.1 in the 1% AEP flood scenario, making this the most preferred option. Further investigation of the constructability of the option shall be carried out by Council in agreement with the property for the use of available space inside the lot boundary prior to the addition of the mitigation option.

Other Mitigation Options and reason for not being Considered:

Detention pond at the back of 9 Kanella Av – Negative benefit to the downstream catchment based in, constructability, construction cost v/s reduction in damages.

Detention pond between 41/45 Catherine St – Negative benefit to the downstream catchment based in constructability, construction cost v/s reduction in damages.

7.3.12 Roseneath Rivulet

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Vegetation – Rivulet Maintenance

The management and maintenance of the existing Roseneath Rivulet from Erskine Street to the Rusts Bay has been recommended as it would provide future resilience to erosion and flooding either easing or reducing the severity of risk and damages to the stormwater system. A description of the option can be found in section 12.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 12.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 49 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 49 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	1	5
Commercial/industrial	0	0
Roads (m²)		
Minor	250	1000

Table 50 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 50 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$53,927	$269,634
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$1,625	$6,500
Damage Estimates		

Direct Damages	$55,552	$276,134
Indirect Damages	$16,666	$82,840
Total Damages	**$72,217**	**$358,974**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 51 below, shows net present value of damages determined in Table 50 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 1.0 with the lowest value being the 5% AEP with a benefit-cost ratio of -0.6.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 51 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$72,217**	$180,000	-$107,783	-0.6	2
	1% AEP Base	**$358,974**	$180,000	$178,974	1.0	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 51 would be the 1% AEP having the highest benefit for the lowest cost. Figure 12 in Appendix 5 shows the relative location of the proposed vegetation and rivulet maintenance described in the option.

Option 1 – Vegetation – Rivulet Maintenance

It is important to conduct routine inspections to spot any erosion or silt buildup. Following the inspection, action should be made to address the issue by determining the reason for the erosion and the source of the silt. It is advisable to revegetate any locations where grass coverage has decreased. Grading is not required once vegetation has established itself. This option is a crucial component of the Council's maintenance programme to lessen the damages brought on by the Rivulet overflowing since it offers a benefit of $178,974 in damages reduction with a benefit-cost ratio (BCR) of 1.0 in the 1% AEP flood scenario.

Other Mitigation Options and reason for not being Considered:

Detention dam at 40 Cammeray Rd – Negative benefit to the downstream catchment based in land acquisition, construction cost v/s reduction in damages.

Detention dam at 22 Russell Rd – Negative benefit to the downstream catchment based in land acquisition, construction cost v/s reduction in damages.

7.3.13 Springfield

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

Flood Wall – Flow Diversion

The flood wall will achieve a grade change along the flow inundation path has been recommended as it would potentially provide a degree of relief of the immediate flooding in the private properties reducing the severity of risk and damages to some of the Springfield Catchment properties from Homer Avenue to Coleman Street intersection. A description of the option can be found in section 13.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 13.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 52 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 52 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	8	11
Commercial/industrial	0	0
Roads (m^2)		
Minor	2800	3200

Table 53 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 53 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$431,414	$593,194
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$20,800	$22,750

Damage Estimates		
Direct Damages	$452,214	$615,944
Indirect Damages	$135,664	$184,783
Total Damages	**$587,878**	**$800,727**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 54 below, shows net present value of damages determined in Table 53 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of 4.4 with the lowest value being the 5% AEP with a benefit-cost ratio of 2.8.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 54 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$587,878**	$120,000	$467,878	3.9	2
	1% AEP Base	**$800,727**	$120,000	$680,727	5.7	1

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, the preferred option as per Table 54 would be the 1% AEP having the highest benefit for the lowest cost. Figure 13.2 in Appendix 5 show the relative location of the proposed flood wall described in the option.

Option 1 – Impervious Flood Wall.

The Construction of a flood wall at the right of way of 28B Coleman St, would help to lessen the flow flood that is flooding the existing dwellings. In the 1% AEP flood scenario and would spread the overland flow path through less populated areas. this alternative reduces damages by $680,727 and has a benefit-cost ratio (BCR) of 5.7, making it the recommended choice. Prior to the inclusion of the mitigation option, Council shall conduct additional research into the constructability of the mitigation option at the existing lot boundary at 20B Coleman St for the proposed 1000mm x 500mm impervious flood wall.

Other Mitigation Options and reason for not being Considered:

Detention pond in Council's land at rear of 18 Coleman St – Negative benefit to the downstream catchment based in construction cost v/s reduction in damages.

Detention pond at 23 First Av – Negative benefit to the downstream catchment based in land acquisition, construction cost v/s reduction in damages.

7.3.14 Zinc Works

Outcomes from various flood scenarios have highlighted the following location for consideration of mitigation measure that include.

General Stormwater Maintenance

General stormwater system maintenance has been recommended as it would reduce the risk of flooding of public and private property to acceptable levels for some of the Goodwood Catchment properties. As the proposed mitigation option would be classified as a past of Council's maintenance schedule and budget, a description of the option can be found in Section 14.3.

Comparison of Damages for the upgrade scenario

Using the same appraisal method as outlined in section 14.2, damages for each upgrade scenario were calculated to view the overall effect of the upgrade.

Table 55 compares the quantity of buildings and roads affected by each option. However, as per the depth damage, the degree of flooding above floor levels provides the actual damage cost.

Table 55 Number of affected buildings and roads at pre mitigation options

Scenario	5% AEP Base	1% AEP Base
Buildings (number)		
Residential	0	0
Commercial/industrial	0	0
Roads (m²)		
Minor	0	0

Table 56 below shows the comparison of damages of each flood scenario option, when singularly compared to a do-nothing scenario.

Table 56 Damages for each individual flood scenario at "do nothing" option

Scenario	5% AEP Base	1% AEP Base
Buildings (Damage)		
Residential	$0	$0
Commercial/ industrial	$0	$0
Roads (Damage)		
Sealed Road	$0	$0
Damage Estimates		

Direct Damages	$0	$0
Indirect Damages	$0	$0
Total Damages	**$0**	**$0**

Cost Benefit Assessment

Cost benefit analysis provides a financial assessment of the capital cost of the project versus the benefits from the outcome of the project by dividing the benefit by the capital cost. The resultant ratio is than either >1 or <1, greater than one being the benefit outweighs the cost and vice versa.

$$Benefit - Cost\ Ratio = \frac{PV\ of\ Expected\ Benefits}{PV\ of\ Expected\ Costs}$$

Table 57 below, shows net present value of damages determined in Table 56 against the net present capital cost of each option and the benefit by means of reduction in damages. These costs run through the above equation provide a ratio to compare each flood scenario option. It can be seen from this table that the 1% AEP flood scenario would always provide by far the most benefit to the overall mitigation option being the only option that results in a ratio of >10 with the lowest value being the 5% AEP with a benefit-cost ratio of 4.4.

The flood mitigation option presents the most benefit for money. These ranking apply only to direct cost of an events of 5% AEP and 1% AEP magnitude occurring and do not consider the cost or benefits of social impacts on the community.

Table 57 Benefit cost table for Net Present Value (NPV) at each flood scenario mitigation option

Option	Description	NPV of Damages	NPV Cost of Option	Option Benefit Relative to Base Option	BCR	RANK
1	5% AEP Base	**$0**	$20,000	-$20,000	-1.0	0
	1% AEP Base	**$0**	$20,000	-$20,000	-1.0	0

Outcome of the option

Below is an outline of the proposed mitigation option and its benefits. If only one flood scenario was to be selected, as it would be a maintenance option only, there wouldn't be a preferred option as per Table 57. Figure 14.1 in Appendix 5 shows the relative location of the proposed maintenance works.

Option 1 – General Stormwater Maintenance

Regular system maintenance and storm drain cleaning, remove trash, sediment, and debris from storm drains, roadways and other watershed areas to help minimise erosion and related damage and prevent flooding.

This option provides a benefit of -$20,000 in reduction of damages with a benefit-cost ratio (BCR) of -1.0 in the 1% AEP flood scenario, making this option an integral part of the Council's maintenance schedule.

Other Mitigation Options and reason for not being Considered:

No other option– No other mitigation options has been assessed as the few inundated areas are inside private or state government land.

8 Recommendations

In light of the comprehensive assessment conducted in our Stormwater System Management Plan, this set of recommendations serves as a strategic roadmap to further enhance the resilience of the Glenorchy Municipality Area against potential flood events. Building upon the insights gained from the study, these recommendations are designed to refine and strengthen our approach to flood management, risk reduction, and infrastructure preparedness.

The objective of these recommendations is to fortify our stormwater system management strategies by implementing a series of targeted actions, each geared towards enhancing the accuracy of our flood models, validating our assumptions, and optimising our mitigation measures. By adopting these measures, we aim to ensure the utmost safety and well-being of our community members and the protection of their assets and infrastructure in the face of flood-related challenges.

These recommendations span various aspects of our approach, from hydraulic modelling refinements and sensitivity analyses to expanding our data sources and bolstering our understanding of flood scenarios. The ultimate goal is to foster a more resilient and adaptive stormwater management system that not only withstands the impacts of climate change but also maximises the benefits derived from our study.

By following these recommendations, we position ourselves to take a systematic and strategic approach to flood risk management while aligning with our commitment to uphold the Level of Service pledged to our residents. It is imperative that we take a forward-thinking stance in addressing these challenges, and these recommendations provide a well-defined pathway to achieving our objectives.

1. **Enhance Sensitivity Analysis for Manning's n Value:** Conduct a comprehensive sensitivity study on Manning's n value, incorporating depth-varying Manning's n coefficients. Utilise cross-validation techniques by integrating a rain-on-grid model for a catchment with well-established hydrological calibration, as demonstrated in the SMEC study of Glenorchy CBD. This will help fine-tune the accuracy of the model, improving its performance.

2. **Utilise More Historical Flood Impact Records:** Extend the scope of the study by incorporating additional historical flood impact records. Thoroughly model these events to provide more detailed data for validating the model. This will enhance the model's reliability and precision.

3. **Explore Tailwater Improvements:** Investigate potential tailwater improvements, varying the level along the River Derwent. Consider adopting a higher level than previously used, such as the 10% Annual Exceedance Probability (AEP) River Derwent flood levels for 1% AEP land-based flood scenarios. Additionally, assess a reverse case by analysing the impact of 10% AEP land-based flooding with 1% AEP River Derwent levels, incorporating wave runup considerations. This will help identify effective measures to manage river and land-based flooding.

4. **Model Additional AEP Scenarios:** Extend the range of scenarios considered by modelling different Annual Exceedance Probability (AEP) events, including 5% AEP (for pipe sizing considerations) and 2% AEP (for assessing building risks). This will provide a more comprehensive understanding of potential flood scenarios and their implications. 5% AEP flood mapping is mostly complete for all urban catchments at the time of this review.

5. **Perform Sensitivity Runs on Key Model Parameters:** Conduct sensitivity runs on the critical model parameters as described in the report. This will ensure that the model is robust and can adapt to different conditions and inputs.
6. **Verify TUFLOW Model Input Files:** Thoroughly validate the TUFLOW model input files to ensure accuracy and consistency. This step is essential for maintaining the integrity of the model.
7. **Interpret Results to Quantify and Prioritise Impacted Areas:** After modelling and analysis, interpret the results to quantify and rank the areas that are most significantly impacted by flood events. This prioritisation will aid in decision-making and resource allocation for mitigation efforts.
8. **Develop Conceptual Design and Cost Management Options:** Create conceptual designs for flood risk reduction measures and cost management options. These designs should align with the prioritised impacted areas and include cost estimates. This will provide a basis for informed decision-making and resource allocation.
9. **Enhance Stream Gauging Network:** Invest in improving the stream gauging network by expanding its coverage and capabilities. Capture more data related to flow, water level, and water quality. This enhanced network will provide valuable real-time data for monitoring and managing stormwater and flood events.

Implementing these recommendations will significantly strengthen the stormwater system management plan, ensuring its effectiveness in mitigating flood risks and safeguarding the Glenorchy Municipality Area against potential flood events.

9 References

Abelson, P. (2007). *Establishing a monetary value of lives saved: issues and controversies. Proc. Delivering better quality regulatory proposals through better cost-benefit analysis.* Canberra: Department of Finance and Deregulation.

Antarctic Climate & Ecosystems CRC. (2010). *Climate Futues for Tasmania climate modelling.* Hobart.

ARR. (2012). *Australian Rainfall and Runoff: Revision Project 15: Two Dimensional Simulations in urban Areas.* Barton: Engineers Australia.

Atkins, H., & Cassidy, R. (2014). *Flood Risk Investigation Interim Report.* Hobart: Pitty & Sherry.

Australian Building Code Board. (2012). *Construction of buildings in flood hazard areas.* Canberra.

Australian Bureau of Statistics. (2006). *Australian and New Zealand Standard Industrial Classification.* Canberra.

Australian Bureau of Statistics. (2011). *Census- counting dwellings, population, age, place of enumeration.* Canberra.

Australian Bureau of Statistics. (2014). *National Regional Profile .* Canberra.

Australian Institute for Disaster Resilience . (2017). *Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia.* Canberra.

Australian Institute for Disaster Resilience. (2014). *Australian Disaster Resilience Guideline 7-3: Technical flood risk management guideline: Flood hazard.* Canberra.

Ball J, B. M. (2019). *Australian Rainfall and Runoff: A Guide to Flood Estimation.* Canberra: Commonwealth of Australia.

Bartzis, N. (2013). *Flood insurance pricing. Proc. Floodplain Management Association National Conference.* Tweed Heads.

Blake, H. (2017). *Report of the independent review into the Tasmanian floods of June and July 2016.* Hobart: Department of Premier and Cabinet.

Bluemont. (2021, March 30). *Flood prevention*. Retrieved from Bluemont: http://www.bluemont.com.au/flood-prevention

BMT WBM. (2016). *Tamar River extreme event flood height contours.* Melbourne.

Cardno. (2021). *Hobart Rivulet Hydraulic Assessment, NW30316.* Hobart.

Chow, V. T. (1959). *Open-channel Hydraulics.* Blackburn Press.

CSIRO. (1998). *Floodplain Management in Australia – Best Practice Principles and Guidelines.* Collingwood, VIC: CSIRO.

D.I, G. M. (1993). *ANUFLOOD programmer’s guide and use Canberra: Centre for Resource and r’s manual.* Canberra: Environmental Studies, Australian National University.

Department of Natural Resources and Environment. (2000). *Rapid Appraisal Method (RAM) for Floodplain Management.* Victoria.

DIPNR. (2005). *NSW Floodplain Development Manual .* Sydney: Department of Infrastructure, Planning and Natrual Resources.

Entura. (2012). *Sandy Bay Rivulet Flood Study.* Hobart: Hyro-Electric Corporation .

Entura. (2013). *Hobart Rivulet Flood Study.* Hobart: Entura.

Entura. (2019). *New Town Rivulet – Calibration Report.* Hobart: Hydroelectric Company Pty Ltd.

Entura. (2019). *New Town Rivulet - Flood Study.* Hobart: Hydroelectric Company Pty Ltd.

GCC. (2016). *Stormwater System Management Plan, Beedhams Bay Catchment Flood Study.* Hobart.

Grose, M. R.-K. (2010). *Climate Futures for Tasmania: General Climate Impacts Technical Report.* Hobart: Climate Futures.

Handmer, J. R. (2002). *Disaster Loss Assessment: Guidelines, Assessment.* Brisbane: Department of Emergency Services.

LGAT. (2016). *Stormwater System Management Planning - A Guide for Local Government in Tasmania.* Hobart: Local Government Associassion of Tasmania.

Melbourne Water. (2006). *Melbourne Water Flood Mitigation Prioritization Tool.* Melbourne.

Melbourne Water Corporation. (2012). *Flood Mapping Projects: Guidelines and Technical Specifications.* Melbourne.

Nebojsˇa Nakic´enovic´, O. D. (2000). *IPCC Special Report Emissions Scenarios.* Intergovernmental Panel on Climate Change.

Olesen, L. L.-N. (2017). *Flood Damage Assessment.* Melbourne: Cooperative Research Centre for Water Sensitive Cities Ltd.

QUDM. (2013). *Queensland Urban Drainage Manual.* Brisbane: Department of Energy and Water Supply.

Reserve Bank of Australia. (2022). Inflation Calculator. Sydney.

SMEC. (2018). *Glenorchy CBD Stormwater System Management Plan.* Hobart.

Smith, G. D. (2014). *Flood Hazard UNSW Australia Water Research Laboratory Technical Report 2014/07.* Sydney: Water Research Laboratory, UNSW.

Southern Tasmanian Councils Authority. (2013). *Glenorchy Climate Change Adaptation Plan.* Hobart: Glenorchy City Council.

STCA. (2013). *Glenorchy Climate Change Adaptation Plan.* Glenorchy: Glenorchy City Council.

T.A. Remenyi, N. E. (2020). *Climate Change Information for Decision Making –Climate Futures Programme.* Hobart: Discipline of Geography & Spatial Sciences, University of Tasmania.

Thompson& Brett - Willing & Partners Consulting Group. (1997). *Analysis of the Humphreys Rivulet Catchment and Concept Design of Flood Protection Measures.* Hobart: Thompson& Brett - Willing & Partners Consulting Group.

10 Appendix 1 – Critical Event Maps

11 Appendix 2 – Inundation Depth Maps

12 Appendix 3 – Inundation Hazard Maps

13 Appendix 4 – Economic Impacts of Flooding Maps

14 Appendix 5 - Flood Mitigation Option Maps

15 Appendix 6 – Glenorchy CBD Stormwater System Management Plan