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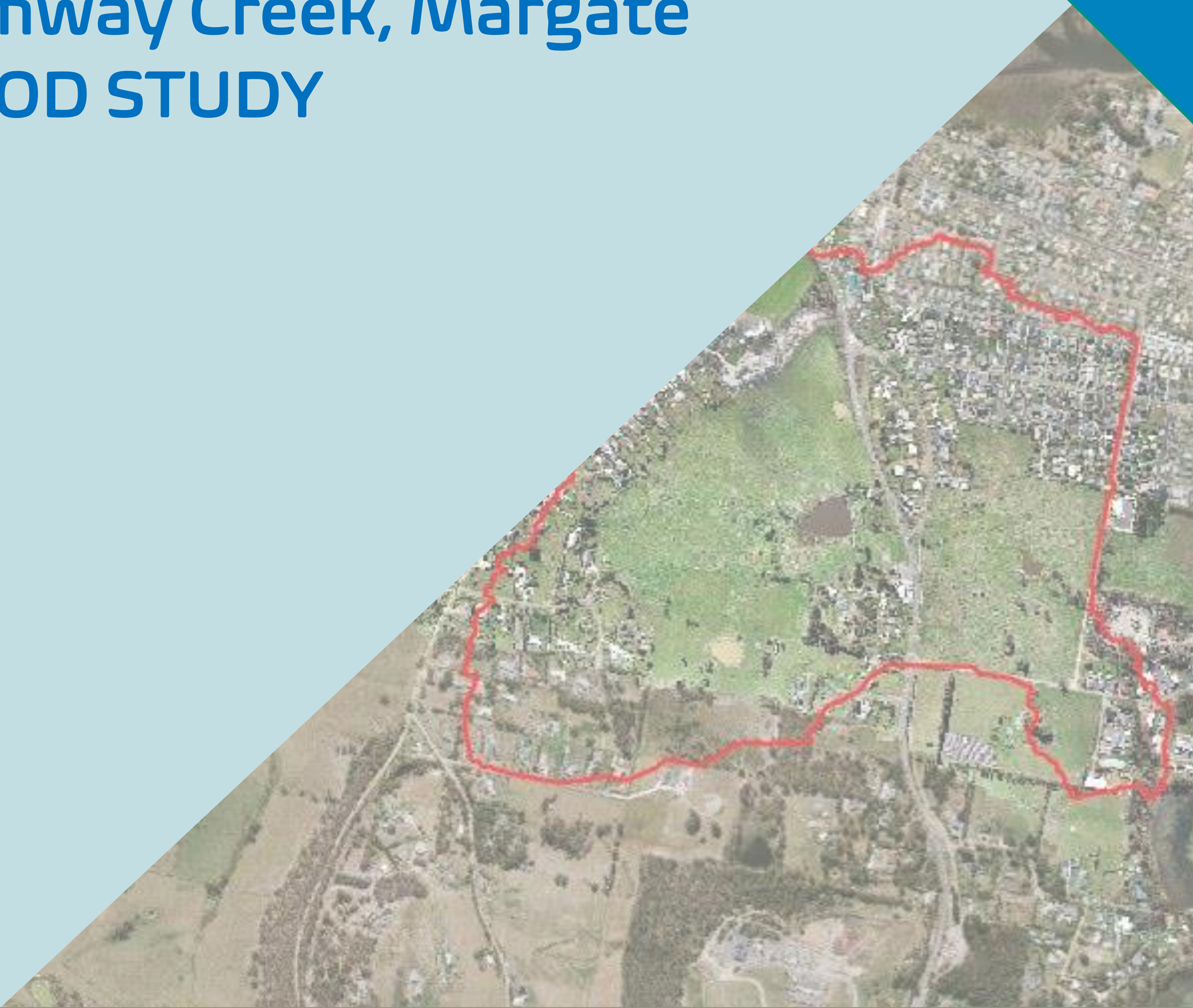
Tramway Creek, Margate
FLOOD STUDY



Prepared for: Kingborough Council

flüssig ENGINEERS

Level 4 - 116 Bathurst Street
HOBART TASMANIA 7000

ABN 16 639 276 181

Document Information

Title	Client	Document Number	Project Manager
Tramway Creek, Margate Flood Study	**Kingborough Council – Alan Walker**		**Max W. Möller** *BEng,FIEAust,EngExec,CPEng,NER,APEC Engineer, IntPE(Aus)* Managing Director/ Principal Hydraulic Engineer

Document Initial Revision

REVISION 00	Staff Name	Signature	Date
Prepared by	Max W. Moller ***Principal Hydraulic Engineer***		08/12/2021
Prepared by	Mark Smith ***Senior Water Resources Specialist***		08/12/2021
Prepared by	Christine Keane ***Senior Water Resources Analyst***		08/12/2021
GIS Mapping	Damon Heather ***GIS Specialist***		08/12/2021
Reviewed by	John Holmes ***Senior Engineer***		10/12/2021
Reviewed by	Max W. Möller ***Principal Hydraulic Engineer***		10/12/2021
Authorised by	Max W. Moller ***Principal Hydraulic Engineer***		14/12/2021

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00	Tramway Creek, Margate Flood Study	Mark Smith	Max W. Möller	14/12/2021
01	Client's feedback and changes	Max W. Möller	Max W. Möller	10/01/2023

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Executive Summary

Flüssig Engineers were engaged by Kingborough Council to undertake a catchment investigation into flood risks for the Tramway Creek catchment. This investigation consists of the creation of a hydrological and hydraulic model to better understand flood behaviour of the creek and its tributaries for the 5%, 1% and 0.5% AEP. This included the development of 2100 climate change, storm surge, fully developed and modified creek scenarios.

Infoworks ICM (ICM) version 2021.8 was utilised to undertake both the hydrologic and hydraulic model. ICM is an integrated software capable of interfacing the hydrologic and hydraulic modelling into one package.

The hydrologic model comprised of splitting the Tramway Creek catchment into 35 sub-catchments which convert rainfall to runoff through the Laurenson routing procedure. To reduce computational time, this model used a 1D channel to link catchments to run all design temporal patterns for all durations through the model to derive the respective critical design storms for each frequency. Peak flows were compared to scaled flood frequency analysis of nearby catchments to verify total outflow. Each catchment was then connected at the centroid of the catchment to the 2D hydraulic model for the analysis of design storm flood behaviour.

The model was used to create flood maps for the 5%, 1% and 0.5% storm events including analysis of possible future alterations to the catchment including, climate change at 2100, fully developed catchment, storm surge coincident model, and a dam removed scenario. A sensitivity analysis was conducted on the hydraulic model to better understand the model sensitivity to surface roughness, blockage, and soil losses. This analysis determined the model was relatively insensitive to all parameters measured.

This study did not extend to the investigation of mitigation measures or policy creation. However, several locations were identified as sources of further review, most notably the culvert crossings at Bundalla and Gemalla Roads, which show overtopping in more frequent events which can lead to premature asset renewals. Similarly flood maps show possible flooding to several houses in the lower section of Tramway Creek.

1. Introduction

Flüssig Engineers have been engaged by **Kingborough Council (council)** to undertake a catchment investigation of the Tramway Creek catchment, located just outside the township of Margate within the **Kingborough Council** municipality. The creek has a small catchment (approximately 1km^2) made mostly of Rural Resource that outlets into Northwest Bay.

The purpose of the investigation is to determine the flooding characteristics of the Tramway Creek and its tributaries. With increased development in Margate over the past several years it is likely continued growth will extend development on the outskirts of the township. Tramway Creek has been identified by council as a possible location for increased residential development in the future. As such, this study investigates the current and future flood characteristics of the catchment to better inform planning and mitigation strategies for the future use and planning, including, but is not limited to, current and future flood scenarios as well as a fully developed scenario.

The resultant report will aid council in understanding risks associated with flooding to land, buildings and infrastructure and provide the background required to adequately inform planning and catchment management decisions.

Tasks undertaken by this study include:

- Data collection and review of existing information and past studies relevant to the analysis of the Tramway Catchment.
- Preparation of a hydrologic model of the area looking at peak design hydrographs for inclusion in the hydraulic model
- Hydraulic model for the determination of flood characteristic through Tramway Creek and analysis of current and future risks from flooding.
- Validation and Sensitivity analysis providing confidence of derived outputs.
- Analysis of Results and preparation of flood maps

1.1 Study Area

The Tramway Creek catchment is located between the Margate township and Barretta, approximately 8.7km south of Kingston. The catchment, which covers approximately 1.1km^2, is bound between Van Morey Road to the west and Bundalla Road and Northwest Bay to the east.

The catchment can be split into predominantly three land uses; Low Density Residential on the upper, western sections of the catchment running through mostly Rural Resource land use, then passes through a Light Industrial zone just upstream of the outlet. The main creek runs through a series of farm dams and outlets into a small bay which makes up part of the Northwest Bay coastline. The topography in the area sees a steeper grade through the upper sections from Van Morey Road between 5%-10% with a flatter section once the creek passes the Channel Highway with between 1%-4%.

Figure 1 Below shows the study area extent for the Tramway Creek catchment.

Figure 1. Tramway Creek Study Area

1.2 Past Flooding

Major flood events, such as May 2018 and January 2015 have recorded anecdotal evidence in neighbouring catchments such as Margate (Cardno 2021). These events were likely to have had an effect on the Tramway Creek catchment given their proximity to these other catchments. Unfortunately, no anecdotal evidence was able to be found for the Tramway Creek catchment, and therefore, validation to historic events was unable to be undertaken for this investigation.

1.3 Past Studies

No past studies into Tramway Creek were provided or known to have been undertaken in the area. The following studies of surrounding catchments were utilised for references:

- Margate Rivulet Hydraulic Study – Cardno 2021
- Snug River Flood Study – Kingborough 2019

2. Data

2.1 Available Data

All data was gathered and collated from various sources including Kingborough Council, The LIST, ELVIS (LiDAR) etc. which included data such as:

- Photogrammetry/ UAV LiDAR capture by Flüssig Engineers
- The Land Information Service Tasmania (theLIST - DPIPWE)
- Bureau of Meteorology

- DEM/LAS data (available via ELVIS)
- Stormwater network data
- Cadastral Information
- Aerial Photography
- Council layers such as ownership and planning scheme zones
- Available records of past flooding events
- Any previous reports regarding relevant catchment analysis, if available
- Past storm rainfall recordings
- Land use layers

All data collected was assessed for its availability, completeness and suitability for the model as the first step in the catchment investigation.

2.2 Topography/Aerial Imagery

Topographic data was sourced from the ELVIS - Elevation Information System site, where there were three datasets that cover the entire Tramway Creek catchment as listed below.

- Geoscience Australia 5m DEM – National resampled DEM from a combination of sources
- Derwent 1m LiDAR – Climate Futures Project 2008
- Greater Hobart 1m LiDAR - Tas Coastal Project 2013

As the Greater Hobart 1m LiDAR covered the entire area, and was the most recent and detailed DEM, this was sourced as the starting point for the topography DEM. LiDAR point cloud data from the greater Hobart LiDAR survey typically produces a sampled grid cell every $1m^2$ with a variance of approximately +/- 0.3m at 68% confidence interval. Although this level of sampling and accuracy is more than sufficient for the purpose of modelling Tramway Creek, the age of the data introduces a larger margin of error.

Using LiDAR data from 2013 misses eight years of land development in the area, resulting in the possibility of missing data from new structures and roads that have been since developed that affect the creek's natural flow path. Similarly, the introduction of fill may also produce interference to major overland flow paths.

As such, this data was reviewed against collected survey information to verify the DEM accuracy for 2021.

2.2.1 Survey LiDAR

To verify changes in the DEM, Flüssig Engineers undertook a LiDAR survey of the main creek line and a photogrammetric survey of the contributing catchment. The purpose of the survey data was to verify the accuracy of the DEM for use in the flood model and correct for any changes that may have occurred in the eight years since the LiDAR was last captured.

The LiDAR was flown using a Flüssig owned LiDAR which utilises the Veledrone VLP-16 sensor which provides up to 700,000 points per second down to 5cm accuracy. Photogrammetry was also flown using the Phantom 4.

2.2.2 Data Quality

Fourteen ground control points were collected throughout the model to determine the variance of existing and collected LiDAR data. From the control points the existing data presented a RMSE of 0.26m while the obtained data produced a RMSE 0.15m at a 68% confidence.

2.3 Aerial Imagery

Southern Margate Aerial image dated 2020 was provided by Council as well as derived from an orthometric photo from the LIST database. These data sets were compared to flown orthometric photographs by Flüssig Engineers 2021 (Figure 2).

Figure 2. Orthophoto collected by Flüssig 2021

2.4 GIS Data

Council supplied all relevant GIS layers for the study area where data was missing. This was either corrected using a desktop assessment or via the methods described below.

- **Stormwater Pits** – Pit assets have information either surface level, invert level or both where relevant.
- **Stormwater Pipes** – Stormwater pipes and infrastructure have relevant information attached to each asset. There is information missing for Tramway Creek flowing underneath the Channel Highway where no assets displayed.
- **Roads Centre line** - All relevant road centre lines accounted for.

- **Kerb and Channel** – All relevant kerb and channels and channels displayed minus new development that might not have been updated.
- **Easements –** All displayed easements have relevant data and description attached.

2.4.1 Hydraulic Structures

Hydraulic structures play a large role in the conveyance of flooding, therefore the accurate inclusion of pipe, pit, culvert, and bridge data can be extremely important. Council supplied data was largely complete with little missing data. For regular pipes, missing data was inferred from surrounding assets.

Major culverts including a set of 3 x 675mm pipes crossing the Channel Highway and a 420 x 1800mm box culvert crossing Bundalla Road (Figure 3). These were verified for size and location during site visits.

Figure 3. Box Culvert, Bundalla Road (site visit)

2.4.2 Dams

Dams are another important hydraulic structure that can significantly influence flood behaviour. In Tramway Creek there are four main dams along the main creek line and tributary channels. Unfortunately, design information on these dams was not available. However, dam areas and embankment heights were clearly delineated in the DEM and therefore could be included as structures but not as storages within the models.

2.5 Planning Layers

Planning layers were provided by Kingborough Council. Planning layers along with aerial imagery were used to assist in land use definition (effective impervious area) as well as aided in the creation of 2D roughness zones.

2.6 Flood Frequency/ Past Event/ Anecdotal

As no anecdotal data was available for the study area, no attempt was made to validate against past events and therefore pluviography data was not obtained. There is no stream gauge on Tramway Creek and therefore the catchment could not be calibrated to a stream gauge.

In lieu of this information, annual maximum stream flow series were obtained from surrounding stream gauges, Northwest Bay River (5201.1) and Browns Rivulet (5200.1) gauges, for use in flood frequency scaling to validate hydrologic peak flows. Data from these two gauges provided periods of missing or incomplete data, with both gauges yielding >20years of useable data to derive a reasonable flood frequency analysis.

3. Methodology

3.1 Hydrology Model

The hydrology model was created using Infoworks ICM hydrology (RAFTS) module, which uses the Australian designed Laurenson method to calculate runoff to the open creek channel. RAFTS is an industry adopted hydrology method as outlined in ARR 2019 guidelines. The catchment characteristics (slope, % impervious, roughness etc.) were taken from best practice manuals. The hydrology catchment was connected to the main creek and their tributaries, either to the closest node or channel. The channel was derived from a single cross section of the DEM for each channel section with the Manning's sampled from a derived roughness layer.

3.1.1 Catchment/ Sub-catchment Delineation

Sub-catchments were delineated using QGIS – SAGA hydrology packages which utilise the DEM to determine flow direction and accumulation of each cell in a raster to determine watershed areas. Catchments were limited by a 1ha threshold to prevent the creation of micro catchments.

Slope for each catchment was applied as a median slope value from the DEM within the area of each catchment.

Figure 4 below shows the sub-catchments created for the hydrology model.

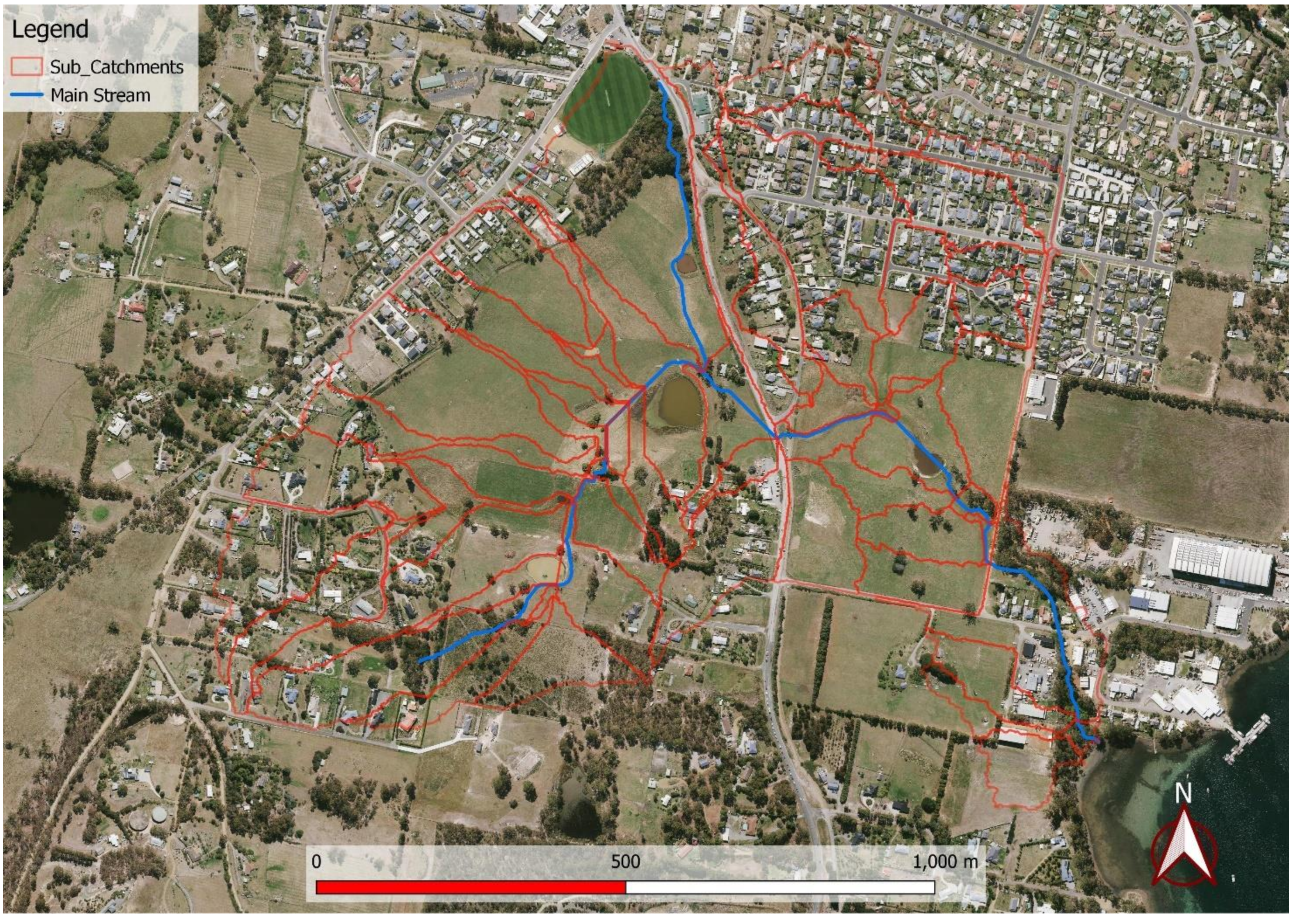

Figure 4. Tramway Creek Hydrology sub-catchments

3.1.2 Losses

As the catchment has no gauge to calibrate losses against, initial rainfall losses were derived from the ARR data hub 2016 for the southern Margate area (Table 1).

Table 1. Rainfall losses

Layer type	IL (mm)	CL (mm/hr)
Pervious	28 (ARR datahub)	3.5 (ARR datahub)
Effective Impervious	0.7*rural loss = 19.6	2.5 (ARR)
Impervious	1 (ARR)	0 (ARR)

Acquired losses were similar to the adjacent Margate catchment (Cardno, 2021). Therefore, these losses were applied to the hydrology model.

3.1.3 Impervious/ Effective Impervious Areas

No current available spatial layer exists that differentiates between impervious, effective impervious and pervious ground types. Therefore, a mixture of planning and GIS road and building layers were utilised to provide the closest representation of each land type.

ARR 2019 separates each land type into their surface material and connecting properties.

- Impervious areas (directly connected) - area types that provide little to no permeability and connect directly to receiving drainage system.

- Effective Impervious areas (indirectly connected) - impermeable surfaces that drain via a permeable surface prior to connecting to the receiving drainage system.
- Pervious area – Permeable surface that connects directly to receiving drainage system.

Keeping this in mind, the land use layers were separated into impervious (road, roofs etc), effective impervious (residential zones excluding impervious areas) and pervious area (rural, environmental zones etc.).

3.1.4 Rainfall

Design rainfall temporal patterns were sourced from the ARR data hub 2016, and combined with the BOM IFD curves (BOM 2016) for their respective 5%, 1% and 0.5% AEP frequency, for durations spanning between 10 min – 24 hours. Given the size of the catchment, durations over 24 hours were removed as unlikely to produce rainfall peaks. This allows a faster processing and post processing of the data. Table 2 below shows the result of the worst case duration hydrology runs.

Table 2. Worst case design storm per AEP frequency

Duration (min)	Frequency AEP		
	0.5%	**1%**	**5%**
10	0.41	0.36	0.26
15	0.42	0.34	0.25
20	1.10	0.42	0.23
25	1.70	0.88	0.20
30	2.33	1.35	0.22
45	4.28	2.63	1.00
60	5.92	3.82	1.87
90	6.43	4.65	2.06
120	7.21	5.19	3.10
180	7.71	6.37	3.48
270	9.80	8.37	3.45
360	7.06	6.02	4.32
540	5.68	4.88	3.16
720	4.89	4.16	2.68
1080	4.46	3.39	2.93
1440	3.41	2.90	2.42

3.1.5 Pre-burst Rainfall

As per ARR 2019 guidelines, pre-burst rainfalls should be considered in any modelling scenario. Pre-burst rainfall considers rainfall leading up to the main storm event falling onto the catchment and filling some storage losses prior to the storm.

Median pre-burst depths were downloaded from the ARR data hub (Table 3). This model applies pre-burst to the front of each storm event to ensure this is accurately captured within the model. Pre-burst from the data hub do not extend to durations less than an hour, to represent these smaller durations, the median 1 hour depth is adopted for all durations less than 1 hour as per best practice.

Table 3. Median Pre-burst depths (mm) ARR Data Hub 2016

Duration (min (h))	AEP(%)					
	50	20	10	5	2	1
10	4.5	5.7	6.5	7.2	5.7	4.6
15	4.5	5.7	6.5	7.2	5.7	4.6
20	4.5	5.7	6.5	7.2	5.7	4.6
25	4.5	5.7	6.5	7.2	5.7	4.6
30	4.5	5.7	6.5	7.2	5.7	4.6
45	4.5	5.7	6.5	7.2	5.7	4.6
60 (1.0)	4.5	5.7	6.5	7.2	5.7	4.6
90 (1.5)	3.3	3.9	4.2	4.6	5.4	6.1
120 (2.0)	3.7	5.2	6.1	7.1	5.9	4.9
180 (3.0)	6.6	7.1	7.4	7.7	13.7	18.2
360 (6.0)	4.3	7.2	9.1	11	18.7	24.5
720 (12.0)	2.9	6.4	8.7	10.9	11.3	11.7
1080 (18.0)	0.7	4	6.2	8.3	10.7	12.5
1440 (24.0)	0.4	3.5	5.6	7.6	7.5	7.4

3.1.6 Aerial reduction factors

Aerial reduction factors (ARF) temporal patterns have only been developed for catchments greater than 75km^2. As the total size of the Tramway Creek catchment is 1.1km^2, these patterns have not been applied.

As per ARR guidelines, catchments of this size apply an aerial reduction equation using factors supplied by ARR Data Hub for the centroid of the catchment (Table 4). These factors were applied to the rainfall patterns through the Infoworks ICM storm generator.

Table 4. ARF Reduction Factors ARR Data Hub 2016

Zone	a	b	c	d	e	f	g	h	i
Tasmania	0.0605	0.347	0.2	0.283	0.00076	0.347	0.0877	0.012	-0.00033

3.1.7 Peak Flow Assessment

This catchment has no stream gauge to calibrate the model against a real-world storm event. Similarly, there is little historical information available, and limited available past flood analysis undertaken to validate against the flows obtained in the model.

As such, a flood scaling method was used to derive likely maximum flows for Tramway Creek using flood frequency data from the surrounding gauges including North West Bay River (5201.1) and Browns Rivulet (5200.1). These figures are then used to compare modelled flows against scaled FFA figures. Table 5 shows the adopted scaling factor used to produce the scaled peak discharge for Tramway Creek. Scaled peak flows were then derived for Tramway Creek (Table 6).

Table 5. Scaling factor

River	Years of Record	Catchment Area (Km2)	Average Annual Rainfall (mm)	Scaling Factor
NW Rivulet (5201.1)	43	86.36	964.6	0.022786346
Browns River (5200.1)	29	11.76	691.5	0.156658519
Tramway Creek	0	1.08	731.7	1

Table 6. Scaled FFA Peak flow estimation.

AEP	Northwest Bay River Scaled (m^3/s)	Browns River Scaled (m^3/s)	Tramway Creek Modelled (m^3/s)
10	4.00	3.20	3.34
5	5.27	4.48	4.49
2	7.05	6.54	6.79
1	8.83	8.85	8.37

The scaling peak discharge method relies on homogenous properties from catchment to catchment to be relied on to provide an acceptable level of accuracy. This is rarely the case between catchments. However, given the size of the catchment, other regional flood frequency methods, have found a higher margin of error on catchments <10km^2, whilst scaling method adopted by ARR 2019, appears to have a lower error margin for catchment <10km^2.

Therefore, using the parameters adopted in this report the model produces peak discharge that shows a maximum variation from the averaged results of 0.35m^3/s. Given the difference between the discharge and the scaled discharge, the model would appear to have reliable parameters for the catchment and therefore have been adopted for use in the final hydrology model.

3.2 Hydraulic Model Set-up

3.2.1 DEM and Grid

The DEM for the Tramway Creek was sampled at 1m cell sizes for consistency, this cell size is more than adequate to represent the topography at this scale. For this model, the Infoworks ICM computational grid works of a flexible mesh (triangle) design, the mesh was given a cell range from 0.5m^2 to 25m^2. This allows the mesh to produce detail where it is required (around structures and topology changes) and allows a coarser grid where elevation/ structure variance is minimal.

For areas of interest (buildings, roads, creeks etc.) a refined mesh was applied to the boundaries to ensure a more detailed mesh is captured in these areas. This mesh ranges from 0.5m^2 to 5m^2.

3.2.2 Roughness 'n'

Hydraulic roughness values for this model were derived from the ARR 2019 Guidelines. The Manning's values are listed in Table 7.

Table 7. Manning's Coefficients (ARR 2019)

Land Use	Roads	Open Channel	Rural	Residential	Parks	Buildings	Piped Infrastructure
Manning's n	0.018	0.035	0.04	0.045	0.05	0.3	0.013

The values are placed in the model as land use polygons and sampled by the computational grid. To derive the land use categories, we used the planning layer from council along with road, building polygons and aerial images. Figure 5 shows the adopted Manning values for the hydraulic model for the Tramway Creek area.

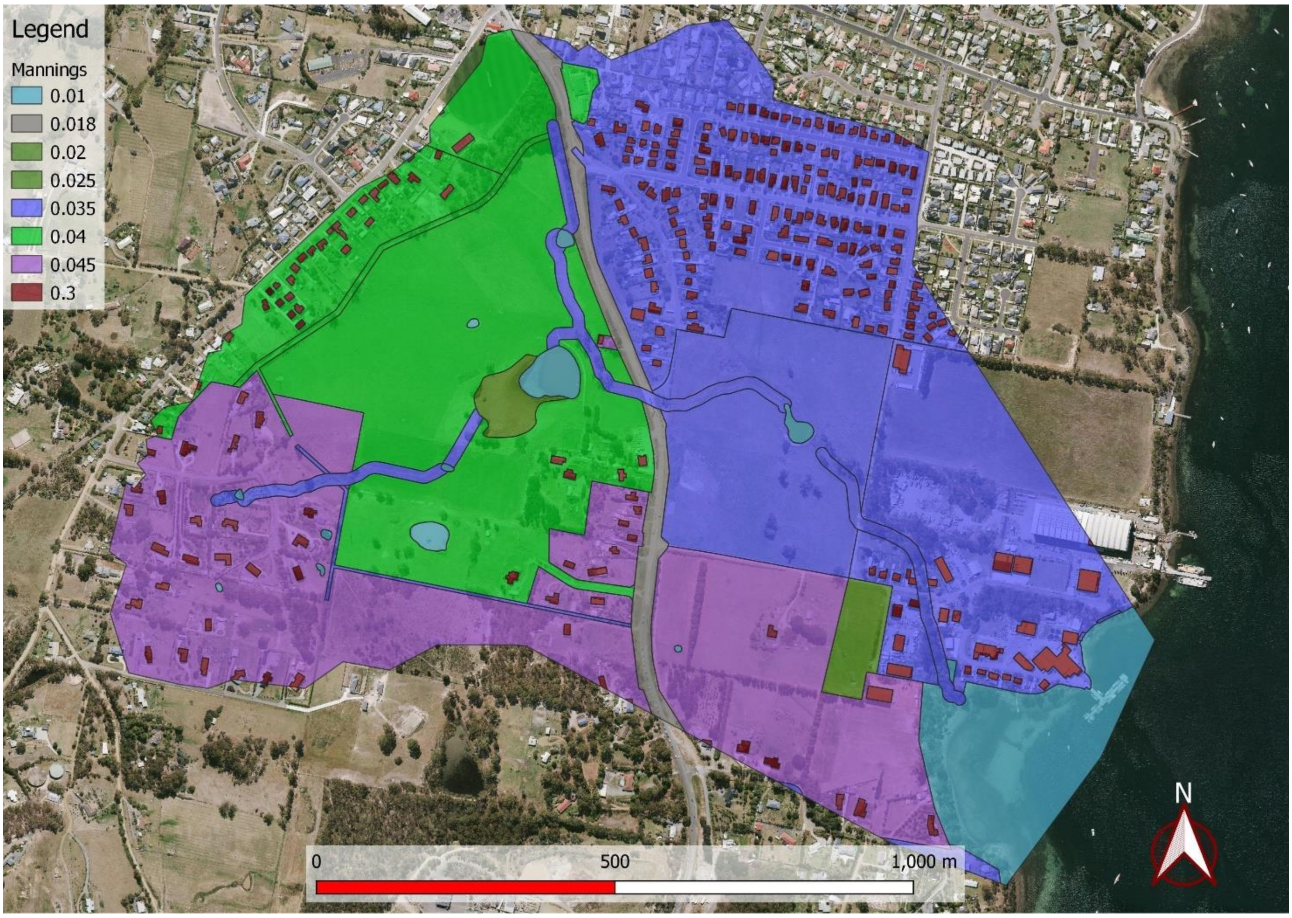

Figure 5. Manning's n derived polygon for the 2D hydraulic model

3.2.3 Hydraulic Structures

Hydraulic structures are included as either 1D or 2D structures throughout the model, where 1D structures exists a 1D/2D link is provided to allow flow to transition to and from the 2D surface.

Pipes and pits

Pipes and pits were modelled as 1D underground network within the Tramway Creek model. Pipe and pit data was supplied by Kingborough Council for inclusion in the model. Underground pipes were connected via 1D/2D connected pits. Pits adopted an inlet flow limitation based off a double grated pit depth/flow curve.

Culverts

There are 3 significant culverts along the Tramway Creek, firstly at the Channel Highway crossing. No data was supplied for these culverts and a site visit was required to determine culvert parameters. The Channel Highway culvert consisted of 3 DN675 concrete culverts which travel at a 45-degree angle from the inlet headwall. The second culvert lies under Bundalla Road and consists of a 420mm x 1800mm box culvert (measured onsite). Lastly, a DN600 concrete culvert crosses Gemalla Road and was taken from a site survey. Invert levels of the culverts are derived from the DEM, opposed to site surveys, as a variation in elevation can introduce some instability into the model.

Dams

Four main farm dams exist along the main channel, however little information was obtained about their design/ capacity, and they do not appear to be on the DPIPWE register. Therefore, all dams were included in the model based off the DEM. All dam levels were set to spill to remove unknowns around storage capacity.

Roads

Roads often form the basis for overland flow in high frequency events, however the kerb and channel are not always picked up by DEM surface. To correct for the drainage lines, mesh polygons were used to delineate road corridors with the roads being lowered by 0.1m to ensure the kerb is represent in the mesh.

Buildings

Buildings were represented as mesh polygons with a high Manning's n value within the model. Buildings with unknown floor levels were set with a minimum 300mm above ground.

This method allows for flow through the building if the flood levels/ pressure become great enough. The aim is to mimic flow through passageways such as doors, windows, and hallways.

3.2.4 Boundary Conditions

Infoworks ICM is a single use software meaning that the hydrology and hydraulic models can be run using the same model. This removes the requirement to have inflow boundary conditions as the hydrology model connects directly to the hydraulic model via a 1D or 2D link.

However, Tramway Creek outlets into North West Bay and is therefore tidally influenced. A boundary is set approximately 200m off the shore to allow for the interaction between riverine and coastal waters.

As per the requirement to maintain consistency with similar reports (Margate flood study, Snug flood study etc.) the 1% AEP run was set to the mean sea level and the climate change runs were set to the mean sea level with sea level rise (SLR). As well as these runs, coincidental storm surge and riverine flooding scenarios were run including;

- 1% AEP rainfall with a 5% AEP Storm surge
- 5% AEP rainfall with a 1% AEP Storm surge
- 0.5% AEP rainfall with a 0.5% AEP Storm surge

Storm surges are typically diurnal, however for design purposes, it is complicated to match peak water levels with peak flood levels. Therefore, each storm event was included as a static peak level within the model.

Levels were taken from a study into dynamic water levels at Snug River undertaken by Water Research Laboratory in 2017 (Smith, et. al. 2014). Table 8 shows the peak water levels for each storm duration. These levels have been adopted within the model for the various scenarios.

Table 8. Extract peak tide table Snug River WRL (2017)

Year	ARI	Sea Level Rise (m)	Tide at Peak (m AHD)	Anomaly at Peak (m)	Local Wind Setup at Peak (m)	Wave Setup at Peak (m) (Shoreline)	Peak Nearshore Water Level (m AHD)
Present Day	1	0	0.53	0.44	0	0.1	1.07
	10		0.53	0.68	0	0.16	1.37
	20		0.53	0.75	0	0.19	1.47
	50		0.53	0.84	0	0.13	1.5
	100		0.53	0.91	0	0.13	1.57
2050	1	0.3	0.53	0.44	0	0.1	1.37
	10		0.53	0.68	0	0.16	1.67
	20		0.43	0.75	0	0.19	1.67
	50		0.53	0.84	0	0.13	1.8
	100		0.53	0.91	0	0.13	1.87
2100	1	1	0.53	0.44	0	0.1	2.07
	10		0.53	0.68	0	0.16	2.37
	20		0.53	0.75	0	0.19	2.47
	50		0.53	0.84	0	0.13	2.5
	100		0.53	0.91	0	0.13	2.57

3.2.5 Calibration/Validation

Due to no available flood/ gauge data, hydraulic calibration could not be achieved. Therefore, this model relies on the accuracy of the input data and the model's sensitivity to variations to input parameters.

4. Summary of Results

4.1 Modelling Scenarios

The following scenarios were run through the hydraulic model with the output level, depth, velocity and hazard maps provided in the appendix.

- 5%, 1% and 0.5% AEP Existing Conditions
- 5%, 1% and 0.5% AEP Climate Change Conditions
- 5%, 1% and 0.5% AEP Fully Developed Conditions
- 5%, 1% and 0.5% AEP Storm Surge Conditions present
- 5%, 1% and 0.5% AEP Storm Surge Conditions 2100

4.1.1 Base Condition

From model runs undertaken as part of this catchment investigation, it is evident that flooding within Tramway Creek occurs at a shallow <300mm, slow moving <1m/s rate down the stream. This is expected due to the low-lying nature of the stream with a shallow invert providing a flood plain nature to the flood extent.

4.1.2 Assessment of Climate Change

The increase in rainfall due to climate change provides minimal impact to the overall flooding within Tramway Creek, as seen in Appendix A – Figure A13 – A24. A slight increase in extent is apparent throughout the model however, the affected properties remain mostly unchanged.

4.1.3 Assessment of Storm Surge

Similarly, to the climate change scenario the worst-case storm surge provides little change to the overall creek flooding, however localised flooding on the shore front is apparent, particularly along the lower portion of Gemalla Road.

4.1.4 Assessment of Fully Developed Scenario

The fully developed scenario shows a slight increase in flows and depths from the base condition but remains similar to the climate change extent. For the purpose of this model, a fully developed scenario did not review the possibility of rezoning some or all of the current farm area zoned for rural resource.

Although little change has occurred from the developed scenario, there is not a lot of available capacity in the main system. Therefore, all efforts should be made in maintaining or reducing current level of risk to the catchment and best practice stormwater management should be applied

4.1.5 Removal of Dams

The removal of farm dams scenario provided the largest difference from base scenario, in particular velocity, depth and extent appear to be relieved slightly as flooding is not held up in dam locations. However, given the velocities seen in Appendix A – Figure A25 – A36 the removal of dams increases velocities by 1 – 2 m/s, which may start to contribute to erosion and deposition in downstream culverts.

4.2 Flood Hazard

Under existing conditions, the main creek and tributaries for the most part experience inundation to <300mm flood depth and <1m/s velocity. This places the hazard rating as adopted by Australian Flood Resilience and Design Handbook as a maximum *H1 – safe for children, elderly, and vehicles* as shown in Appendix A – Figure A3, 7, 11. This excludes mainstream areas and areas of ponding either through dams or behind culverts. These areas experience hazard ratings of between H3 and H5 and should be treated with care during storm events.

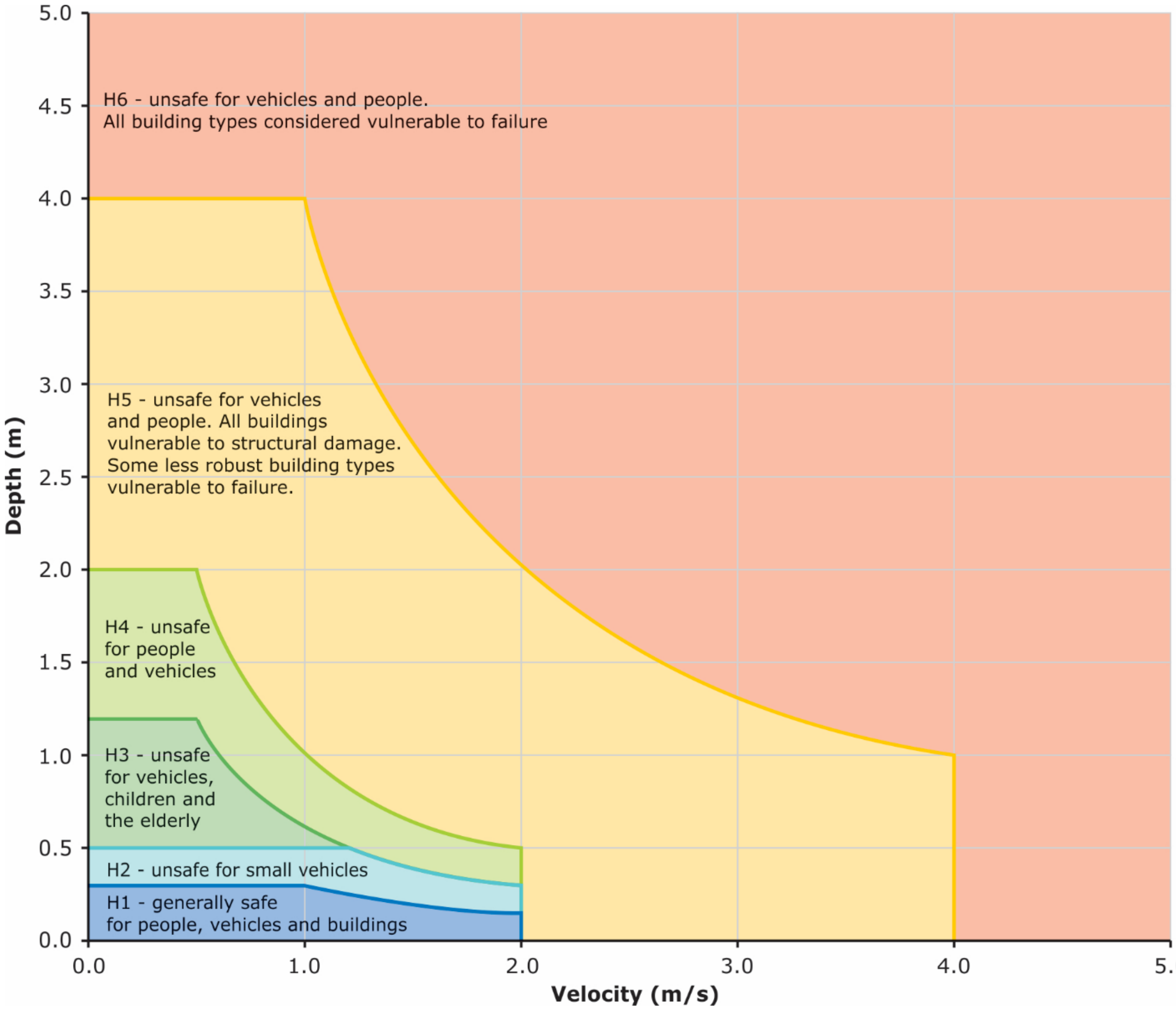

Figure 6. Hazard Categories Australian Disaster and Resilience Handbook

4.2.1 Sensitivity Testing

Sensitivity analysis was undertaken at six key locations along Tramway Creek to determine the hydraulic model's sensitivity to varying assumed parameters. The following analysis was undertaken with elevation and velocity being observed for each location.

- Roughness variation by +/- 20%
- Blockage of major culverts
- Variation of catchment inflow

Roughness Variation

Hydraulic roughness was adjusted up and down by 20% and compared to base model levels and velocities. Table 9 shows the recorded difference experienced in the model between the base scenario and the variation scenarios. As seen in the table below, a 20% variation had negligible effects on flood levels and velocities at all sites along the creek, therefore demonstrating little sensitivity to the roughness in the hydraulic model.

Table 9. Roughness Variation results

ID	Velocity (m/s)			Difference (m/s)		Elevation (mAHD)			Difference (m/s)	
	Base	-20%	20%	-20%	20%	Base	-20%	20%	-20%	20%
US Merediths Dam	0.89	1.04	0.82	0.14	-0.07	18.66	18.66	18.66	0.00	0.00
US Channel Highway	0.78	0.89	0.67	0.11	-0.11	12.31	12.30	12.31	0.00	0.00
DS Channel Highway	1.41	1.56	1.16	0.14	-0.25	10.59	10.59	10.59	0.00	0.00
US Bundalla Road	0.48	0.58	0.42	0.09	-0.06	8.41	8.41	8.42	-0.01	0.01
US Gemalla Road	0.78	0.82	0.75	0.04	-0.03	6.02	6.01	6.04	-0.01	0.02
Tramway Outlet	1.35	1.47	1.27	0.12	-0.09	4.93	4.93	4.93	0.00	0.00

Blockage

A blockage factor of 50% was applied to all major culverts along the creek as per ARR blockage suggestions for catchment conditions. Similarly, Table 10 shows little variation due to blockage with the slightest increase in level upstream of the Channel Highway. Therefore, the hydraulic results are insensitive to blockage with most water continuing its normal flow path.

Table 10. Variation in hydraulic results with blockage applied

ID	Velocity (m/s)		Difference (m/s)	Elevation (mAHD)		Difference (m)
	Base	50%		Base	50%	
US Merediths Dam	0.89	0.89	0.00	18.66	18.66	0.00
US Channel Highway	0.78	0.61	-0.17	12.31	12.33	0.03
DS Channel Highway	1.41	1.42	0.01	10.59	10.59	0.00
US Bundalla Road	0.48	0.49	0.00	8.41	8.42	0.00
US Gemalla Road	0.78	0.79	0.01	6.02	6.03	0.01
Tramway Outlet	1.35	1.38	0.03	4.93	4.93	0.00

Variation in inflow

Due to the directly connected catchment, variation of inflow is not a parameter that can be adjusted easily. Instead, the hydrology losses were modified +/- 20% to adjust inflow parameters into the hydraulic model. Table 11 shows the hydraulic model is still relatively insensitive to minor changes in hydrology losses.

Table 11. comparison of hydraulic results of variation of losses

ID	Velocity (m/s)			Difference (m/s)		Elevation (mAHD)			Difference (m)	
	Base	-20%	20%	-20%	20%	Base	-20%	20%	-20%	20%
US Merediths Dam	0.89	0.88	0.89	-0.02	0.00	18.66	18.66	18.66	0.00	0.00
US Channel Highway	0.78	0.78	0.80	0.00	0.02	12.31	12.32	12.28	0.02	-0.03
DS Channel Highway	1.41	1.47	1.32	0.06	-0.09	10.59	10.59	10.59	0.00	0.00
US Bundalla Road	0.48	0.50	0.46	0.02	-0.03	8.41	8.43	8.39	0.02	-0.02
US Gemalla Road	0.78	0.82	0.71	0.05	-0.07	6.02	6.06	5.97	0.03	-0.05
Tramway Outlet	1.35	1.45	1.22	0.09	-0.13	4.93	4.93	4.93	0.00	0.00

4.3 Flood Mitigation/Management

Outcomes from various flood scenarios have highlighted the following locations for management option review.

- Properties between Jacaranda Drive and the end of Lotus Court experience shallow low hazard flooding in all scenarios and events.
- Channel Highway culvert overtops in events >5%AEP
- Bundalla Road and Gemalla Road culverts overtop in all flooding scenarios and frequencies
- Ponding occurs above all major culverts listed above

Shallow property flooding is unlikely to cause risk to people or structures, both public or private, and therefore no immediate mitigation options need to be assessed. However, future developments in the area may contribute to blocking the overland flow path and development management options should be investigated.

Similarly, the Channel Highway culvert provides a level of service for existing 5% AEP events and overtops in the 1% AEP but only to a shallow, safe flow. Cleaning schedule at least once every three months should be implemented by **State Growth** authorities to maintain capacity, given the shallow grade of the pipe.

Culverts on Bundalla and Gemalla Road likely overtop on events <5% AEP, and given the condition of the roads, this overtopping is likely to cause further degradation to the road. Any future plans to upgrade these road sections should consider the frequency of flooding and a possible upgrade to a higher capacity.

4.3.1 Future development policies

Currently the future development scenarios do not adversely affect flood extents locally or on the overall catchment. However, future developments should also consider the effects of structures on overland flow paths and their effects on surrounding properties.

This is apparent along Bundalla Road where fill along a creek bed has begun to occur. This fill at its current level is causing overland flow diversion onto neighbouring properties with the full fill extent affecting all surrounding properties and infrastructure.

Planning policies around introduction of fill and structures into flood paths should be investigated.

5. Conclusion

Hydrologic and hydraulic modelling of the Tramway Creek area has been developed for an increased understanding of flood characteristics through the Tramway Creek catchment.

Mapping of 5%, 1% and 0.5% AEP frequencies through existing climate change and fully developed scenarios provide the information required to make considered decisions in relation to planning decision and policies, mitigation options and renewals and maintenance requirements for assets.

Assessment shows areas of concern for future development and current development applications, with suggestions of areas that would be beneficial to undertake further review for mitigation or future policy creation.

6. Recommendations

Flüssig Engineers recommends the following:

1. Further review of anecdotal evidence be undertaken to better calibrate the hydraulic model.

2. Further review of potential associated risk areas.

3. Review the risk on the overall catchment associated with rezoning of the lower section of Meredith's Orchard land.

4. Future use of areas to be limited to areas deemed safe under the ARR Disaster manual categories.

5. All future proposed structures within the flood extent require a separate report addressing their impacts.

7. Limitations

Flüssig Engineers were engaged by Kingborough Council, for the purpose of a flood study of the Tramway Creek catchment area in Margate. This study is deemed suitable for purpose at the time of undertaking the study. If the conditions of the site should change, the report will need to be reviewed against all changes.

This report is to be used in full and may not be used in part to support any other objective other than what has been outlined within, unless specific written approval to do otherwise is granted by Flüssig Engineers.

Flüssig Engineers accepts no responsibility for the accuracy of third-party documents supplied for the purpose of this flood study.

8. References

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Appendices

Appendix A Flood Study Maps

Figure A1 - Existing Conditions 0.5% AEP Depth
Figure A2 - Existing Conditions 0.5% AEP Velocity
Figure A3 - Existing Conditions 0.5% AEP Hazard
Figure A4 - Existing Conditions 0.5% AEP Levels (mAHD)
Figure A5 - Existing Conditions 1% AEP Depth
Figure A6 - Existing Conditions 1% AEP Velocity
Figure A7 - Existing Conditions 1% AEP Hazard
Figure A8 - Existing Conditions 1% AEP Levels (mAHD)
Figure A9 - Existing Conditions 5% AEP Depth
Figure A10 - Existing Conditions 5% AEP Velocity
Figure A11- Existing Conditions 5% AEP Hazard
Figure A12 - Existing Conditions 5% AEP Levels (mAHD)
Figure A13- Existing Conditions 0.5% AEP + CC @2100 Depth
Figure A14- Existing Conditions 0.5% AEP + CC @2100 Velocity
Figure A15- Existing Conditions 0.5% AEP + CC @2100 Hazard
Figure A16- Existing Conditions 0.5% AEP + CC @2100 Levels (mAHD)
Figure A17- Existing Conditions 1% AEP + CC @2100 Depth
Figure A18- Existing Conditions 1% AEP + CC @2100 Velocity
Figure A19- Existing Conditions 1% AEP + CC @2100 Hazard
Figure A20- Existing Conditions 1% AEP + CC @2100 Levels (mAHD)
Figure A21- Existing Conditions 5% AEP + CC @2100 Depth
Figure A22- Existing Conditions 5% AEP + CC @2100 Velocity
Figure A23- Existing Conditions 5% AEP + CC @2100 Hazard
Figure A24- Existing Conditions 5% AEP + CC @2100 Levels (mAHD)
Figure A25- Dams Removed 0.5% AEP Depth
Figure A26- Dams Removed 0.5% AEP Velocity
Figure A27- Dams Removed 0.5% AEP Hazard
Figure A28- Dams Removed 0.5% AEP Levels (mAHD)
Figure A29- Dams Removed 1% AEP Depth
Figure A30- Dams Removed 1% AEP Velocity
Figure A31- Dams Removed 1% AEP Hazard
Figure A32- Dams Removed 1% AEP Levels (mAHD)
Figure A33- Dams Removed 5% AEP Depth
Figure A34- Dams Removed 5% AEP Velocity
Figure A35- Dams Removed 5% AEP Hazard
Figure A36- Dams Removed 5% AEP Levels (mAHD)
Figure A37- Fully Developed 0.5% AEP Depth
Figure A38- Fully Developed 0.5% AEP Velocity
Figure A39- Fully Developed 0.5% AEP Hazard
Figure A40- Fully Developed 0.5% AEP Levels (mAHD)
Figure A41- Fully Developed 1% AEP Depth
Figure A42- Fully Developed 1% AEP Velocity
Figure A43- Fully Developed 1% AEP Hazard
Figure A44- Fully Developed 1% AEP Levels (mAHD)
Figure A45- Fully Developed 5% AEP Depth
Figure A46- Fully Developed 5% AEP Velocity
Figure A47- Fully Developed 5% AEP Hazard
Figure A48- Fully Developed 5% AEP Levels (mAHD)
Figure A49- Existing Conditions 0.5% AEP + 0.5% AEP Storm Surge Depth

Contact Project Manager: Max Moller

P: 03 6288 7704
M: 0431 080279
E: max@flussig.com.au
W: www.flussig.com.au
A: Level 4, 116 Bathurst Street
Hobart TAS 7000