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Project: Gracemere Catchments Flood Study

Hydrologic and Hydraulic Modelling Report

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1 Introduction

1.1 Study background

The township of Gracemere lies approximately 8km to the south-west of Rockhampton on the Capricorn Highway. Planning is underway for development of an industrial corridor south of the Capricorn Highway to the west of Gracemere. The Gracemere Catchments Flood Study is aimed at assessing the existing flood extents within this corridor in order to allow the development planning to adequately address flooding issues. Aurecon was commissioned to undertake this study in September 2011.

1.2 Study area

The location of the study area and the extents of the catchments contributing to flows in this area are presented in Figure 1 and Figure 2. The catchments were separated into four model areas as described in the following sections.

1.2.1 Middle Creek

Middle Creek runs through the township of Kabra, approximately 7km to the west of Gracemere. The catchment area is 35.9km^2 to the railway. This includes some areas to the north of the Capricorn Highway which drain in a southerly direction beneath the highway to join the creek. Middle Creek discharges to the north beneath the railway and the highway, on the eastern side of the Kabra township.

The Middle Creek catchment is largely undeveloped with the exception of Kabra itself and some rural residential properties to the north of the highway. A RAFTS hydrologic model of the upper catchment (to approximately 750m upstream of Murphy Road) was developed and a direct rainfall TUFLOW hydraulic model of the catchment from upstream of Murphy Road to approximately 750m downstream of the Capricorn Highway was used to predict flood characteristics in the study area.

1.2.2 Local Catchment

The Local Catchment model covers the two small catchments which discharge beneath the railway and the highway between Middle Creek and Gracemere Creek. These catchments cover an area of 6.7km^2 upstream of the railway and were modelled using a direct rainfall TUFLOW hydraulic model.

1.2.3 Gracemere Creek

Gracemere Creek runs through the western part of Gracemere before discharging north beneath the railway and the highway into Padgole Lagoon. The catchment area is 38.3km^2 to the railway.

Gracemere Creek runs through undeveloped land in the upper reaches, then passes through rural residential land in its middle reaches and residential and industrial property in the lower reaches closer to the township.

The Gracemere Creek catchment was modelled using a RAFTS hydrologic model of the upper reaches to approximately 700m downstream of Kabra Road. From this location to Padgole Lagoon at the downstream end, the area was modelled using a direct rainfall TUFLOW hydraulic model.

1.2.4 Washpool Creek

Washpool Creek doesn't fall within the planned industrial corridor, however there are future planned strategic road links through this area and therefore flood information is required. The Washpool Creek model includes Washpool Creek, Teatree Creek and Four Mile Creek as the flows from these three waterways interact significantly. The total catchment area of these three catchments to Gavial Gracemere Road is 90.0km^2.

The Washpool, Teatree and Four Mile Creek catchments are largely undeveloped. The lower reaches of Washpool Creek pass through an area which is currently being developed, however this is only a small portion of the catchment.

The upper reaches of Teatree and Four Mile Creeks were modelled using a RAFTS hydrologic model and the lower reaches were modelled using a direct rainfall TUFLOW hydraulic model. The entire Washpool Creek catchment was modelled within the TUFLOW model.

1.3 Study objectives

The key objectives of the study are:

- Development of comprehensive computer-based hydrologic and hydraulic models of the study area and its contributing catchments
- Determination and documentation of flood levels, inundation extents, velocities and depths across the study area for the 5, 10, 20, 50 and 100 year ARI design events
- Preparation of detailed maps and GIS layers for inclusion in Council's databases
- Detailed reporting of all project elements and their outcomes

2 Study data

The data collected for use in this study is detailed in the following sections.

2.1 Previous studies

No previous study data was available.

2.2 Topographic data

Rockhampton Regional Council (RRC) and the Department of Environment and Resource Management (DERM) commissioned LiDAR survey of a large part of the Gladstone and Rockhampton region which was flown in June 2009. This data was provided to Aurecon as 1m grid DEM (xyz) tiles over a large part of the study area. This data has a vertical accuracy of ± 0.15m and a horizontal accuracy of ± 0.30m.

For the upper reaches of the catchments, LiDAR data was not available. In these areas 10m contour data from DERM was used. The extent of each dataset and the areas over which each dataset was adopted is presented in Figure 3.

Topographic data was also provided for the following locations/developments:

- The Gracemere Overpass which is currently being constructed and mostly lies within the Local Catchment. This data was provided as a 12D model, as developed by the Department of Transport and Main Roads (TMR)
- Grace Heights Estate – this estate is in the Washpool Creek catchment and has been constructed since the LiDAR data was captured. This data was provided in 3D CAD format
- Wara Gardens – this estate is in on Middle Road in the Gracemere Creek catchment. Design drawings were provided and were used to provide information regarding drainage within the estate

2.3 Aerial photography

Two aerial images were provided to cover the catchments and study area. A detailed 10cm aerial was provided covering the study area and a 50cm aerial was provided covering the entire catchment areas. This aerial photography was used to identify and confirm topographic and vegetative characteristics of the study area.

2.4 Historical flood data

No historical flood data was available for calibration of the models. RRC's knowledge of flooding in the area was used to verify the flood behaviour of the various models (this was done by Bruce Russell).

2.5 Hydraulic structure data

Available Design or As-Constructed data for hydraulic structures beneath the Central Railway Line, the Capricorn Highway and Gavial Gracemere Road was sourced from Queensland Rail/QR National and TMR. Information for Council owned structures was sourced from Council in the form of:

- Design drawings where available
- GIS information from Council's GIS database
- Site measurements/verifications undertaken by Bruce Russell from RRC

2.6 GIS data

Council provided cadastral boundary data for use in the study and the mapping.

2.7 Site inspection

A site inspection was carried out on 4 October 2011. This was attended by Angus Russell and Bruce Russell from RRC and Talia Campbell from Aurecon and was used to review hydraulic roughness parameters and catchment details for input to the modelling.

2.8 Proposed development extents

Details of the proposed land use changes were provided by Council in GIS format (LandUseZones_GHD_20111213).

3 Hydrologic model development

Three hydrologic models were prepared for the upper reaches of Middle Creek, Gracemere Creek and Teatree/Four Mile Creeks. The following sections discuss the model development process. Figure 4 shows the model layouts for the three models. The adopted model parameters are provided in Appendix A.

3.1 Model layout

3.1.1 Sub-catchment delineation and slope

Sub-catchments were defined in GIS based on the available topographic data discussed in Section 2.2. A number of sub-catchments were delineated for each model and the sub-catchment areas were sourced from the GIS files.

Catchment slopes were also determined based on the available topographic data and the equal area slope method was used to calculate the adopted values.

3.1.2 Impervious area and PerN

The areas covered by the RAFTS models are largely rural and undeveloped, therefore a base impervious percentage of 5% was adopted. Rural residential areas were assigned higher impervious percentages. The overall percentage impervious for each sub-catchment was calculated based upon the proportional contribution of both rural residential and undeveloped areas.

Similar to the impervious percentages, the RAFTS roughness parameter, PerN, was set to a base value of 0.07 to represent undeveloped areas. Rural residential areas were assigned a lower PerN value to reflect smoother ground conditions and the overall value for each sub-catchment was calculated based on the proportional contribution of both developed and undeveloped areas.

3.1.3 Catchment links

The catchment flowpath links were defined using a lag time. Lag times were calculated using the slope and distance of the flowpath, with adopted average stream velocities of 0.3 – 0.7m/s dependent upon the slope of the catchment.

3.2 Rainfall losses

The initial and continuing loss method was used to represent rainfall losses. An initial loss of 0mm and a continuing loss of 2.5mm/hr was adopted. This initial loss may be conservative in the smaller events but is consistent with the recommendations of Australian Rainfall and Runoff (AR&R) for the larger events.

3.3 Modelled events and critical duration

The RAFTS models were run for the 5, 10, 20, 50 and 100 year ARI events using standard Australian Rainfall and Runoff temporal patterns and IFD parameters. The 45, 60, 90, 120, 180, 270, 360 540, 720 and 1080 minute events were simulated. Rainfall intensities for the modelled events are presented in Table 1.

Table 1 | Rainfall Intensities

Event Duration (mins)	Rainfall Intensity (mm/hr)				
	5yr ARI	10yr ARI	20yr ARI	50yr ARI	100yr ARI
45	64.3	72.4	83.4	89.9	98.3
60	54.8	61.6	70.9	76.3	83.3
90	42.3	47.8	55.2	59.6	65.3
120	35.0	39.7	46.1	49.9	54.7
180	26.8	30.6	35.6	38.7	42.6
270	20.5	23.5	27.5	29.9	33.0
360	16.9	19.5	22.9	25.0	27.6
540	13.0	15.0	17.7	19.4	21.5
720	10.7	12.5	14.8	16.2	18.0
1080	8.3	9.7	11.6	12.7	14.2

4 Hydraulic model development

4.1 Model set up

Four hydraulic models were prepared of the Middle Creek, Gracemere Creek, Washpool Creek and Local Catchment areas. The following sections discuss the model development process and the model layouts are presented in Figure 5 to Figure 8.

4.1.1 Model grid

For the Middle Creek, Gracemere Creek and Local Catchment models, a 5m grid spacing was adopted. This allows adequate representation of the topographic features of these catchments. For the Washpool Creek model, a 10m grid spacing was adopted. The Washpool Creek model covered a much larger area and run times would have been prohibitive if a 5m grid spacing was used. The Washpool Creek model was intended for use in determining discharges at strategic road locations, and not for developed case assessments; therefore a larger grid size was considered appropriate.

4.1.2 Topography

A 2m grid Digital Terrain Model (DTM) was developed from the LiDAR data described in Section 2.2. The model topographies were based upon this DTM.

Additional topographic modifications to the Existing Case were included as follows:

- In the Local Catchment model, the Gracemere Overpass was included as this overpass will soon be constructed
- In the Washpool Creek model, the Grace Heights Estate was included
- In the Gracemere Creek model, the drainage channel alongside Capricorn Street at the Wara Gardens Estate was included

4.1.3 Land use type

The aerial photography was used to define the land use type across the models, as presented in Figure 9.

4.1.3.1 Rainfall losses

Rainfall losses were applied spatially across each model area as an attribute of the land use type. Rainfall losses were based upon the standard losses recommended in AR&R and are consistent with those adopted in the RAFTS models. For each land use type losses were calculated based upon the ratio of impervious and pervious areas. The adopted percentage impervious and calculated continuing losses for each material/land use type are presented in Table 2.

Table 2 | Loss Parameters for Land Use Types

Material/Land Use Type	Percentage Impervious (%)	Continuing Loss (mm/hr)
Low Density Vegetation	0	2.5
Medium Density Vegetation	0	2.5
High Density Vegetation	0	2.5
Cleared Undeveloped Land	0	2.5
Grassed Land	0	2.5
Developed Land, Unvegetated	15	2.1
Rural Residential Lots – Low Density Vegetation	15	2.1
Rural Residential Lots – High Density Vegetation	15	2.1
Residential Lots	50	1.3
Roads and Other Impervious Surfaces	100	0.0
Permanent Surface Water	100	0.0

4.1.3.2 Manning's roughness values

Manning's roughness values were also applied as an attribute of the land use type. The roughness characteristics of each materials/land use type tend to vary as flow depth increases. For example, shallow flows in grassed areas are significantly restricted by the individual grass stalks while deeper flows travel easily over the grass. For this reason, when using the direct rainfall modelling approach, two separate Manning's n values are applied to each material/land use type. The first value represents shallow flow and the second represents deeper flows. In each model these values were applied to depths of 0.1m and 0.3m respectively. Between these two depths TUFLOW interpolates between the two Manning's roughness values. Table 3 presents the adopted Manning's roughness values.

Table 3 | Manning's n Roughness Values

Land Use Type	Shallow Flow Manning's n	Manning's n
Low Density Vegetation	0.080	0.045
Medium Density Vegetation	0.110	0.070
High Density Vegetation	0.150	0.090
Cleared Undeveloped Land	0.025	0.025
Grassed Land	0.040	0.035
Developed Land, Unvegetated	0.020	0.020
Rural Residential Lots – Low Density Vegetation	0.060	0.090
Rural Residential Lots – High Density Vegetation	0.060	0.120
Residential Lots	0.060	0.150
Roads and Other Impervious Surfaces	0.016	0.016
Permanent Surface Water	0.040	0.040

4.1.4 Hydraulic structures

The hydraulic structure details were sourced from available data and were then reviewed and updated by Bruce Russell from RRC. The modelled culverts and their details are presented in Table 4 and the modelled bridges and their associate details are presented in Table 5. The structure locations are presented on the model layout plans (Figure 5 to Figure 8).

Table 4 | Modelled Culvert Structures

	Culvert ID	Culvert Location	Dimensions (mm)	Upstream Invert Level (m AHD)	Down-stream Invert Level (m AHD)
Gracemere Creek	GC_Basin	Wara Gardens Detention Basin	5 / 750 RCP	18.25	18.23
	GC_CSt	Capricorn Street	1 / 900 * 900 RCBC	18.20	18.11
	GC_JR	Johnson Road	5 / 2400 * 2400 RCBC	19.70	19.60
	GC_JR_2	Johnson Road	2 / 1200 * 900 RCBC	21.17	19.65
	GC_MR	Middle Road	2 / 750 RCP	17.74	17.70
	GC_OAv	Owen Avenue	2 / 600 * 450 RCBC	18.79	18.71
	GC_R.W.Rd	O'Shanesy Street	13 / 3226 * 2438 RCBC	13.40	13.27
	GC_Rwy_1	Central Line Railway	1 / 900 RCP	14.36	14.34
	GC_Rwy_2	Central Line Railway	10 / 3000 * 2400 RCBC	12.65	12.63
	GC_Rwy_3	Central Line Railway	4 / 3000 * 1800 RCBC	13.86	13.84
	GC_SSt	Stewart Street	4 / 1200 * 600 RCBC	24.25	24.00
	GC_7A	New Overpass	1 / 1200 * 450 RCBC	39.31	39.16
Local Catchment	LC_1A	New Overpass	1 / 450 RCP	19.34	18.39
	LC_1B	New Overpass	4 / 1350 RCP	17.86	17.66
	LC_1C	New Overpass	1 / 450 RCP	19.11	19.06
	LC_3A	New Overpass	6 / 900 RCP	15.91	15.80
	LC_4A	New Overpass	1 / 3000 * 3000 RCBC	16.05	15.81
	LC_5A	New Overpass	2 / 1200 * 750 RCBC	28.26	27.44
	LC_6A	New Overpass	4 / 1200 * 900 RCBC	28.80	28.60
	LC_8A	New Overpass	2 / 1200 * 600 RCBC	15.30	15.25
	LC_8B	New Overpass	6 / 2400 * 1200 RCBC	14.99	14.94
	LC_9A	New Overpass	6 / 1800 * 600 RCBC	17.26	17.15
	LC_12A	New Overpass	1 / 1200 * 600 RCBC	15.88	15.84
	LC_C_Hwy_1	Capricorn Highway	2 / 900 RCP	18.30	18.06
	LC_C_Hwy_2	Capricorn Highway	5 / 1500 RCP	15.52	15.43
	LC_C_Hwy_3	Capricorn Highway	5 / 3000 * 1800 RCBC	15.98	15.92
	LC_C_Hwy_4	Capricorn Highway	7 / 1200 * 600 RCBC	21.11	21.04
	LC_Rwy_1	Central Line Railway	2 / 1200 * 525 RCBC	19.30	19.14
	LC_Rwy_2*	Central Line Railway	1 / 450 RCP	16.30	15.88
	LC_Rwy_3	Central Line Railway	3 / 1350 RCP	17.92	17.89
	LC_Rwy_4	Central Line Railway	1 / 1350 RCP	17.97	17.97

	Culvert ID	Culvert Location	Dimensions (mm)	Upstream Invert Level (m AHD)	Down-stream Invert Level (m AHD)
	LC_Rwy_5	Central Line Railway	4 / 3000 * 1800 RCBC	15.94	15.91
	LC_Rwy_6	Central Line Railway	3 / 900 RCP	21.48	21.30
Middle Creek	MC_Cap_1	Capricorn Highway	5 / 2100 * 1800 RCBC	24.92	24.77
	MC_Cap_2	Capricorn Highway	4 / 1200 RCP	25.60	25.20
	MC_Cap_3	Capricorn Highway	2 / 1200 * 900 RCBC	29.56	29.15
	MC_Cap_4	Capricorn Highway	2 / 1200 * 900 RCBC	29.52	29.20
	MC_Cap_5	Capricorn Highway	5 / 1200 * 900 RCBC	31.24	31.14
	MC_Cap_6	Capricorn Highway	1 / 1200 * 450 RCBC	35.40	35.10
	MC_Cap_7	Capricorn Highway	3 / 1200 * 900 RCBC	37.30	37.28
	MC_Cap_8	Capricorn Highway	1 / 900 RCP	40.25	40.14
	MC_Cap_9	Capricorn Highway	1 / 600 RCP	45.38	45.13
	MC_Cap_10	Capricorn Highway	3 / 900 RCP	46.90	46.52
	MC_Cap_11	Capricorn Highway	1 / 1200 * 450 RCBC	50.15	50.04
	MC_M-St._1	Morgan Street	5 / 375 RCP	26.70	26.68
	MC_M-St._2	Morgan Street	4 / 3300 * 1800 RCBC	25.20	25.12
	MC_Rwy_1	Central Line Railway	5 / 900 RCP	25.62	25.55
	MC_Rwy_2	Central Line Railway	2 / 1800 * 900 RCBC	27.94	27.75
	MC_Rwy_3	Central Line Railway	2 / 1200 * 900 RCBC	27.75	27.70
	MC_Rwy_4	Central Line Railway	4 / 1350 RCP	30.75	30.69
	MC_Rwy_5	Central Line Railway	3 / 1200 * 900 RCBC	36.95	36.85
	MC_Rwy_6	Central Line Railway	1 / 900 RCP	40.11	39.70
	MC_Rwy_7	Central Line Railway	1 / 600 RCP	44.20	43.90
	MC_Rwy_8	Central Line Railway	3 / 900 RCP	45.86	45.70
Washpool Creek	WC_GavRd	Gavial Gracemere Road	1 / 525 RCP	11.34	11.32

** Information provided late in the project indicates that this culvert is actually a 1200mm arch brick culvert. This information was provided following completion of the modelling, therefore the results presented in this report are not correct for this culvert.*

Table 5 | Modelled Bridge Structures

Catchment	Bridge Location	Dimensions (m)
Gracemere Creek	Capricorn Highway	5 * 12m spans
Middle Creek	Central Line Railway	2 * 15.2m spans + 1 * 9.3m span
	Capricorn Highway	3 * 13.7m spans
Washpool Creek	Gavial Gracemere Road	3 * 11m spans

4.1.5 Boundary conditions

The RAFTS model outputs were applied as inflows at the upstream end of the Middle Creek, Gracemere Creek and Washpool Creek models.

A discharge-water level relationship was applied as the downstream boundary condition in each model. This relationship is automatically generated by TUFLOW based upon the topography at the boundary location.

4.2 Model review and verification

The performance of the RAFTS and TUFLOW models in predicting runoff from the catchments was checked using Rational Method calculations. These calculations were undertaken at a number of locations throughout the models. The Rational Method parameters used and the discharge comparisons are presented in Table 6 and Table 7.

Table 6 | Rational Method Parameters

Location	Catchment Area (ha)	Stream Length (km)	Stream Slope (%)	Time of Concentration (hrs)
Gracemere Creek at Halfpenny Road	2793	13.1	0.8	6.0
Gracemere Creek at Railway	3774	18.9	0.5	9.2
Local Catchment at Railway	515	3.4	0.5	2.0
Local Catchment at new Malchi-Nine Mile Rd	684	4.4	0.3	2.8
Middle Creek at Murphy Road	2570	12.1	1.5	4.9
Middle Creek at Old Railway	3483	15.0	1.1	6.3
Washpool Creek at Midway through model – total Teatree Creek and Four Mile Creek	6627	18.5	0.7	8.0
Washpool Creek at Gavial Gracemere Road	8921	23.1	0.6	10.0

Table 7 | TUFLOW Model Hydrology Checks

Location	10yr ARI Modelled Peak Discharge (m^3/s)	10yr ARI Rational Method Peak Discharge (m^3/s)	100yr ARI Modelled Peak Discharge (m^3/s)	100yr ARI Rational Method Peak Discharge (m^3/s)
Gracemere Creek at Halfpenny Road	101	100	176	200
Gracemere Creek at Railway	111	110	212	230
Local Catchment at Railway	34	40	60	70
Local Catchment at new Malchi-Nine Mile Rd	38	40	68	80
Middle Creek at Murphy Road	125	130	220	230
Middle Creek at Old Railway	145	130	255	250
Washpool Creek at Midway through model – total Teatree Creek and Four Mile Creek	289	220	511	430
Washpool Creek at Gavial Gracemere Road	246	250	396	500

The peak discharge comparisons in Table 7 show that the modelled peak discharges are similar to those calculated using the Rational Method. This provides reassurance that the uncalibrated models are predicting flows to be similar to those of alternate standard methods.

Further to the Rational Method checks, animations of the 5 and 100 year ARI results were reviewed by Council. These animations showed that the models are predicting flood behaviour as it is understood to occur.

5 Design event results

5.1 Mapping

The TUFLOW model results were analysed and a series of maps (Figure 10 to Figure 24) were developed to present the results for each modelled return period. Two sets of maps were produced to display:

- Inundation extents with peak water surface levels and velocity vectors – these maps present 0.2m contours of the peak water surface levels, as well as peak velocities displayed as arrows. The velocity arrows show the direction of the flow and are scaled to represent the magnitude of the flow (ie larger arrows mean faster flow)
- Peak depths – the maps present peak depth contours in 0.5m bands up to a depth of 5m, with the lower band separated into two bands covering 0 to 0.3 m and 0.3 to 0.5 m
- Hazard maps – hazard is a function of flood depth and flood velocity and is related to safety of the flood waters. The peak low, medium, high and extreme hazard contours presented in these maps are based upon the recommendations in *Floodplain Management in Australia Best Practice Principles and Guidelines* produced by the Standing Committee on Agriculture and Resource Management (SCARM) (2000). Image 1 is an extract from the guidelines and presents the adopted hazard category relationship

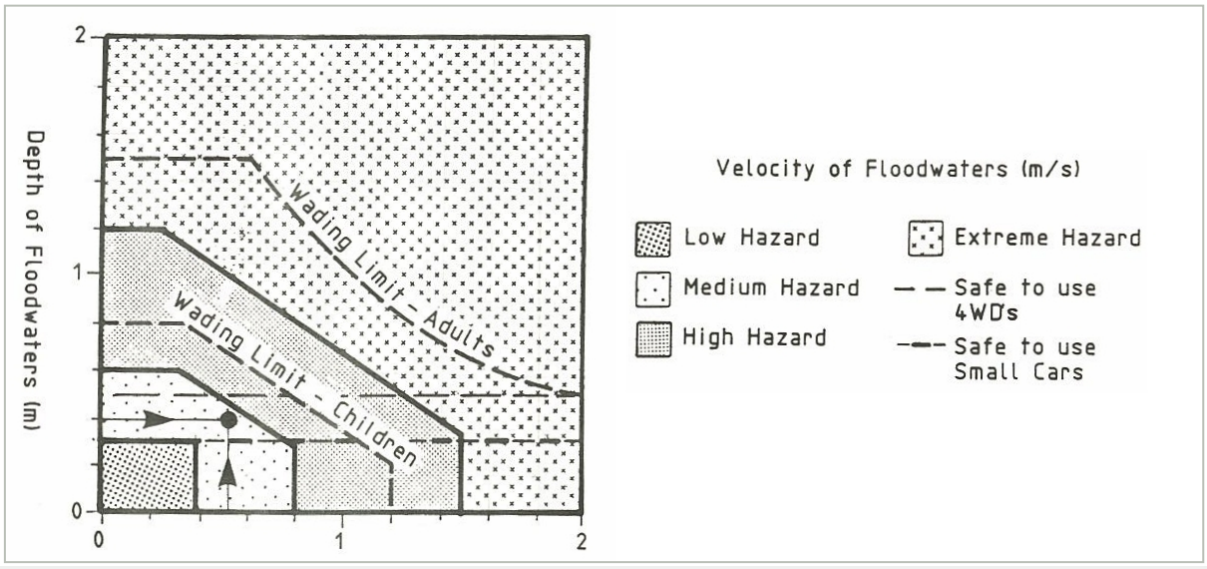


Image 1 | Hazard Categories

Direct rainfall modelling uses a process whereby rainfall is applied to every model cell. Mapping of these results would show that the entire model area was flooded. For this reason, areas where the flow depth is less than 10cm have been removed from the mapping. This compares to applied rainfall depths ranging between 48mm for the 5 year ARI 45 minute duration event to 256mm for the 100 year ARI 18 hour duration event. The results have also been modified so that small pockets of pooled water have been removed. The pockets occur as a result of using LiDAR data, where the topography is not smoothed and minor variations in levels between one cell and the next cause pooling of water.

5.2 Discharges

Modelled discharges at locations of strategic road links are presented in Graph 1 to Graph 10 and the peak values are presented in Table 8. These graphs are presented for the critical duration event (ie the event producing the largest discharge) at each location and these critical durations are presented in Table 9. The rainfall intensities associated with each duration can be found in Table 1. Some items to note with respect to Graph 1 to Graph 10 are:

- In some locations the critical duration varies for different magnitude events. For example, at Murphy Road on Middle Creek, the 270 minute duration is critical for the 5 year ARI event whilst the 360 minute duration is critical for the 10 to 100 year ARI events. For this reason the shape of the 5 year ARI hydrograph at this location is different to that of the hydrographs for the other events
- In Graph 2, the model results show a drop in the discharge when it reaches approximately 75m^3/s. This occurs when the road overtops and the flow regime in the culvert changes. Prior to overtopping the culvert flow is inlet controlled and water is driven through the culvert only. Once the road is overtopped there is less pressure forcing water through the culvert as it can now pass more easily over the road. For the reason the discharge through the culvert decreases even though there is an increase in the upstream water level
- In Graph 4 there is a minor instability in the culvert performance at the start of the event. This was investigated in detail and many options to improve stability were tested. This instability does not affect the culvert results throughout the main part of the event and is therefore considered to be insignificant

The model results show that overtopping of the existing road occurs in the 5 year ARI event at all strategic road locations, except at the Railway on Gracemere Creek which has immunity to the 5 year ARI event. Peak flood depths over each road are presented in Table 10.

Tabulated peak discharges through the culverts, at the discharge reporting locations and at a number of locations where the total flows were calculated are presented in Appendix B. The critical duration at each location is also presented in Appendix B.

Table 8 | Peak Discharges at Strategic Road Locations

Location	Peak Discharge (m^3/s)				
	5yr	10yr	20yr	50yr	100yr
Gracemere Creek, Halfpenny Road	84.5	100.6	123.6	151.3	176.1
Gracemere Creek, Johnson Road	81.3	98.2	122.2	153.1	179.2
Gracemere Creek, Macquarie Street	91.0	108.8	133.7	166.3	193.5
Gracemere Creek, Railway	92.5	111.0	140.6	181.4	211.7
Gracemere Creek, Middle Road	91.1	108.9	133.8	166.4	193.5
Local Catchment, New Road	29.9	37.0	45.4	58.5	67.9

Location	Peak Discharge (m^3/s)				
	5yr	10yr	20yr	50yr	100yr
Local Catchment, Somerset Road	30.1	34.3	39.9	51.0	62.0
Middle Creek, Murphy Road	104.7	124.5	154.0	188.1	220.1
Middle Creek, E Williams Road*	105.7	123.5	149.8	182.5	208.4
Teatree Creek, Tindall Road	188.6	234.3	283.4	330.1	369.7

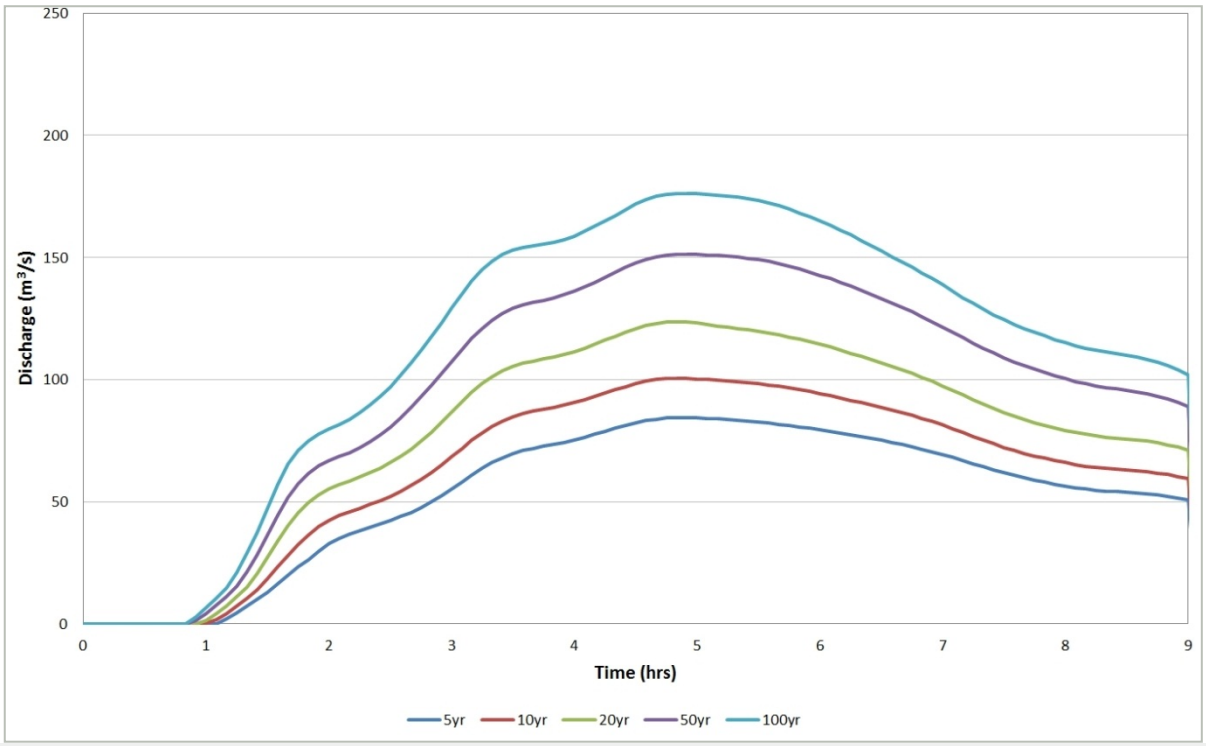
Table 9 | Critical Durations at Strategic Road Locations

Location	Duration (mins)				
	5yr	10yr	20yr	50yr	100yr
Gracemere Creek, Halfpenny Road	360	360	360	360	360
Gracemere Creek, Johnson Road	360	360	360	360	360
Gracemere Creek, Macquarie Street	360	360	360	360	360
Gracemere Creek, Railway	360	540	540	540	540
Gracemere Creek, Middle Road	360	360	360	360	360
Local Catchment, New Road	60	60	60	60	60
Local Catchment, Somerset Road	120	120	120	120	120
Middle Creek, Murphy Road	270	360	360	360	360
Middle Creek, E Williams Road*	270	270	360	360	360
Teatree Creek, Tindall Road	720	720	720	720	720

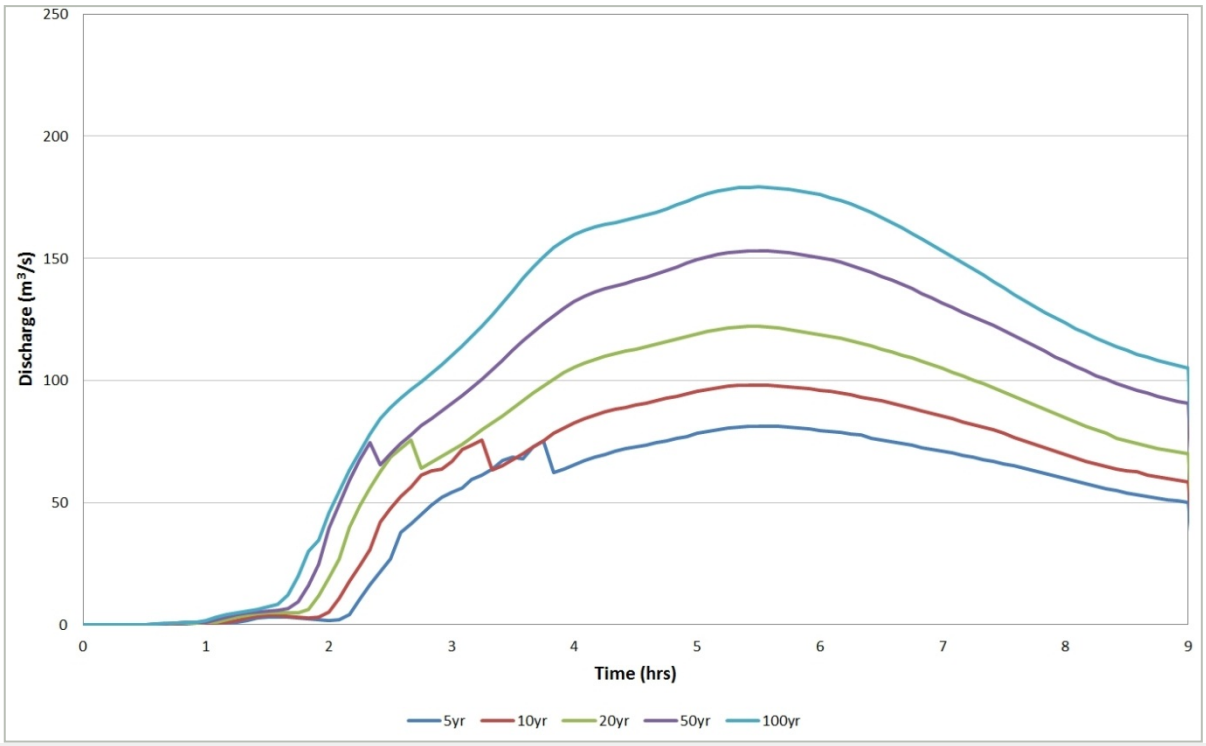
Table 10 | Peak Flood Depths at Strategic Road Locations

Location	Peak Depth# (m)				
	5yr	10yr	20yr	50yr	100yr
Gracemere Creek, Halfpenny Road	1.3	1.5	1.7	1.9	2.1
Gracemere Creek, Johnson Road	2.2	2.4	2.5	2.7	2.9
Gracemere Creek, Macquarie Street	3.0	3.1	3.2	3.4	3.5
Gracemere Creek, Railway	0.0	0.2	0.4	0.5	0.7
Gracemere Creek, Middle Road	2.0	2.1	2.2	2.4	2.5
Local Catchment, New Road	0.6	0.6	0.7	0.7	0.7
Local Catchment, Somerset Road	1.5	1.7	1.8	2.0	2.1
Middle Creek, Murphy Road	1.8	2.0	2.2	2.4	2.5
Middle Creek, E Williams Road*	3.2	3.3	3.3	3.4	3.4
Teatree Creek, Tindall Road	2.0	2.1	2.1	2.2	2.2

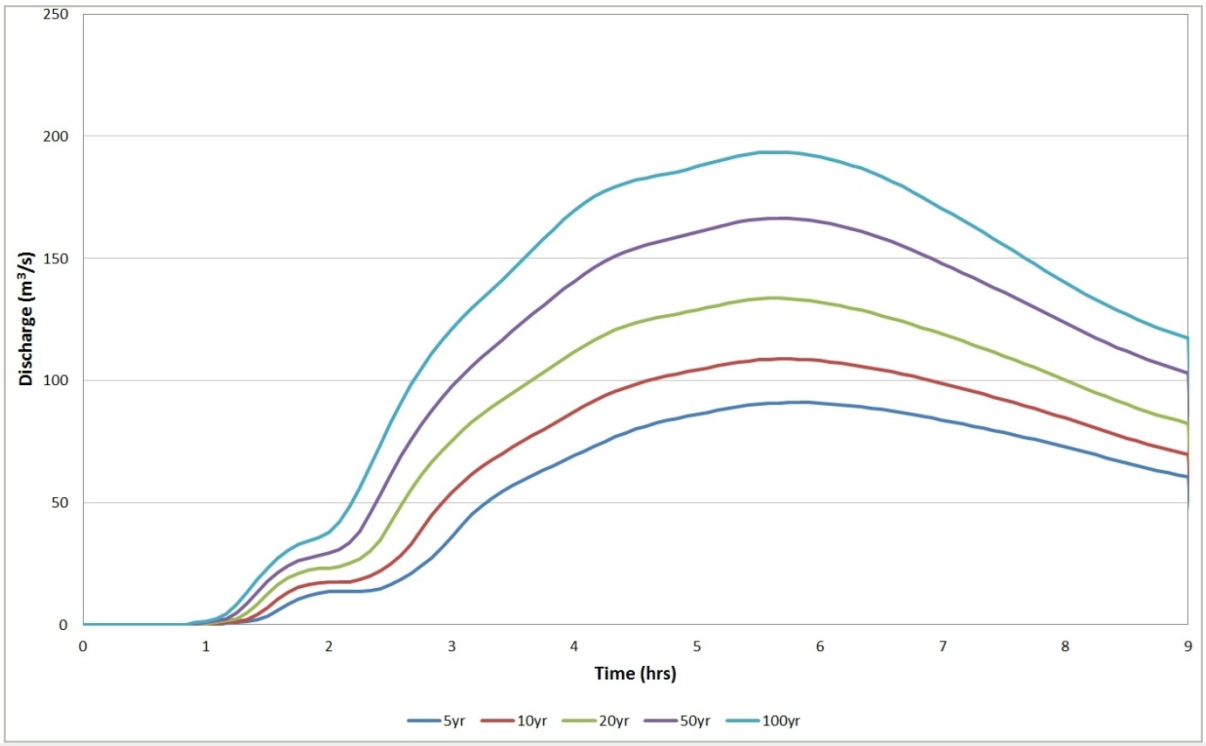
** E Williams Road has been used to maintain consistency with the model ID. This should have been named Gold Escort Road*
 # This represents the flood depth at the lowest elevation in the longitudinal profile of the road crest



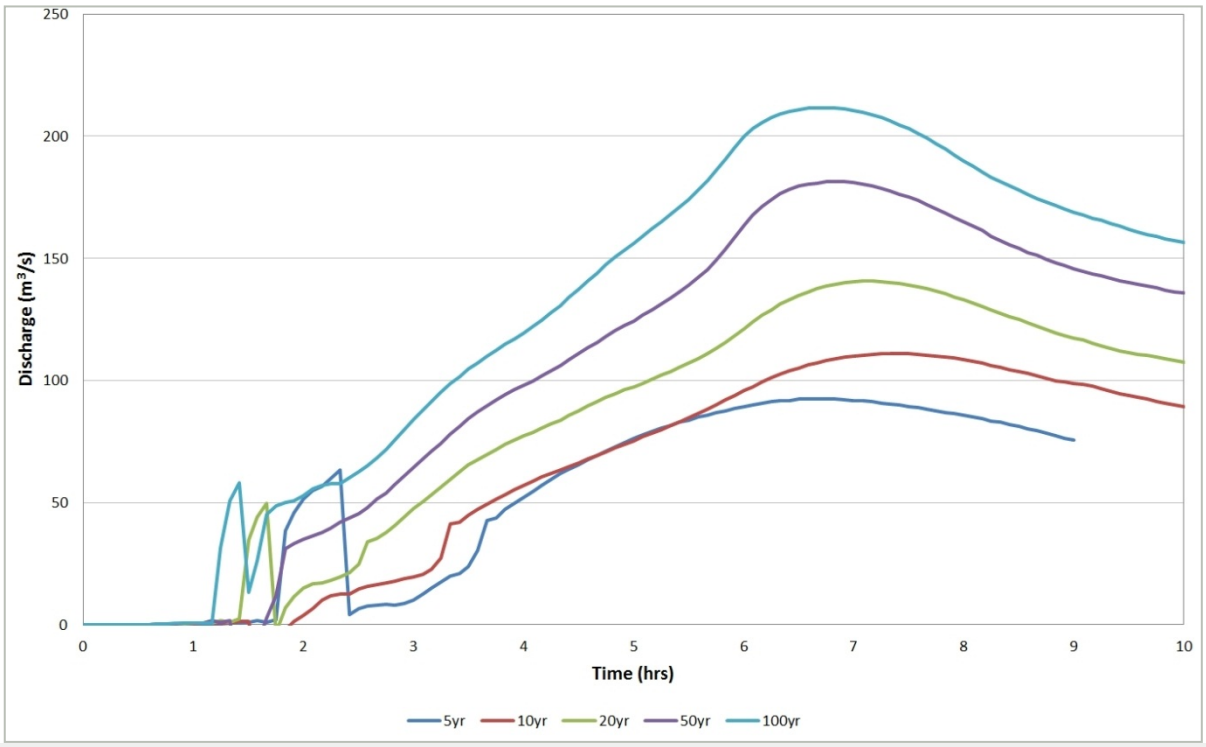
Graph 1 | Gracemere Creek, Halfpenny Road Discharge



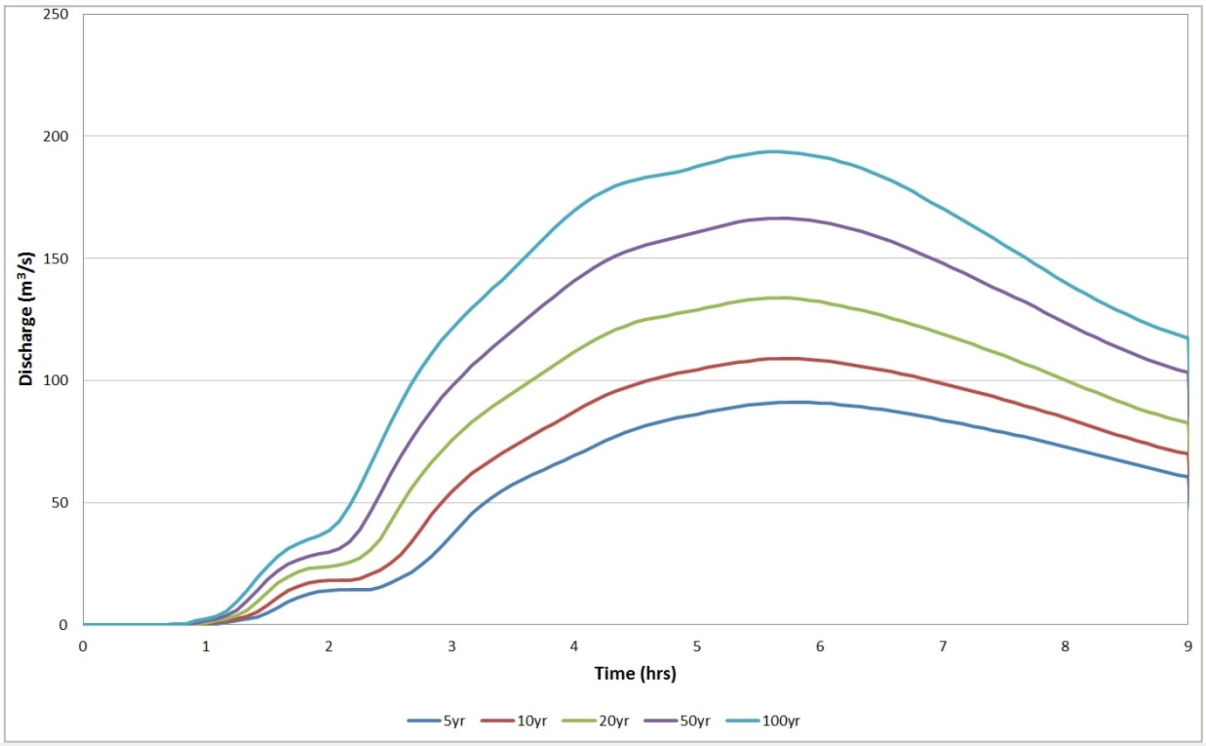
Graph 2 | Gracemere Creek, Johnson Road Discharge



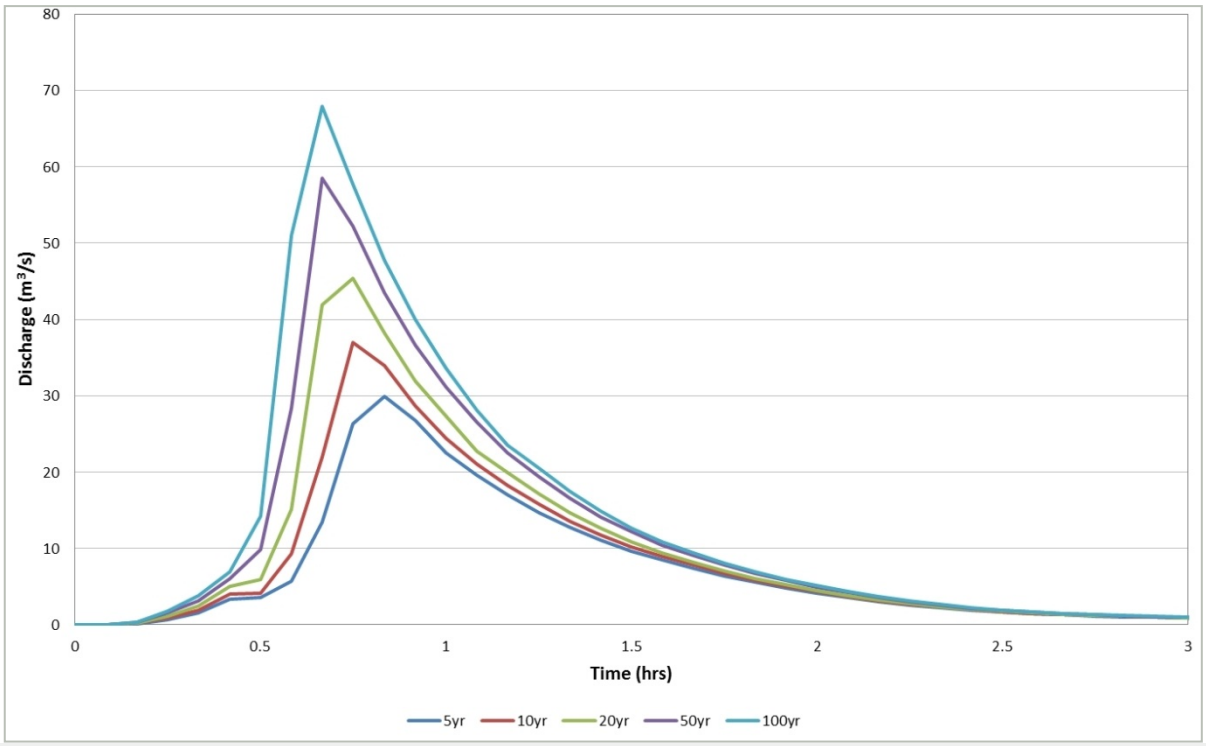
Graph 3 | Gracemere Creek, Macquarie Street Discharge



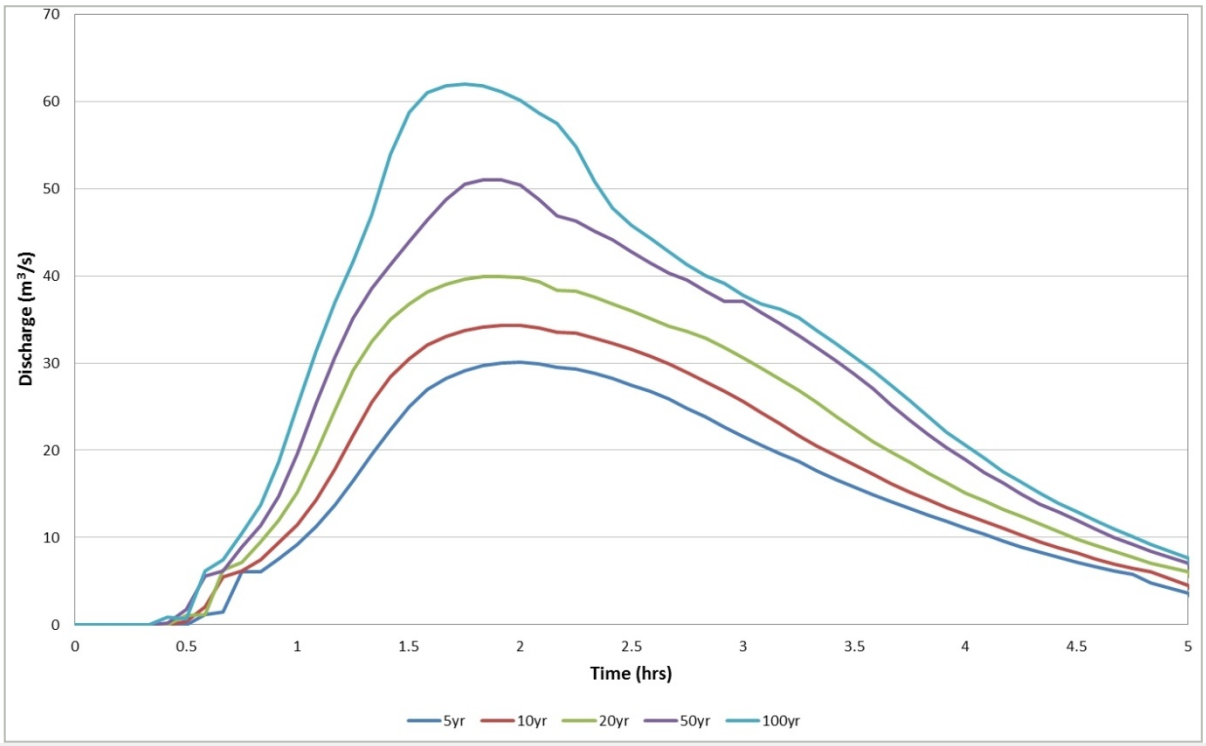
Graph 4 | Gracemere Creek, Railway Discharge



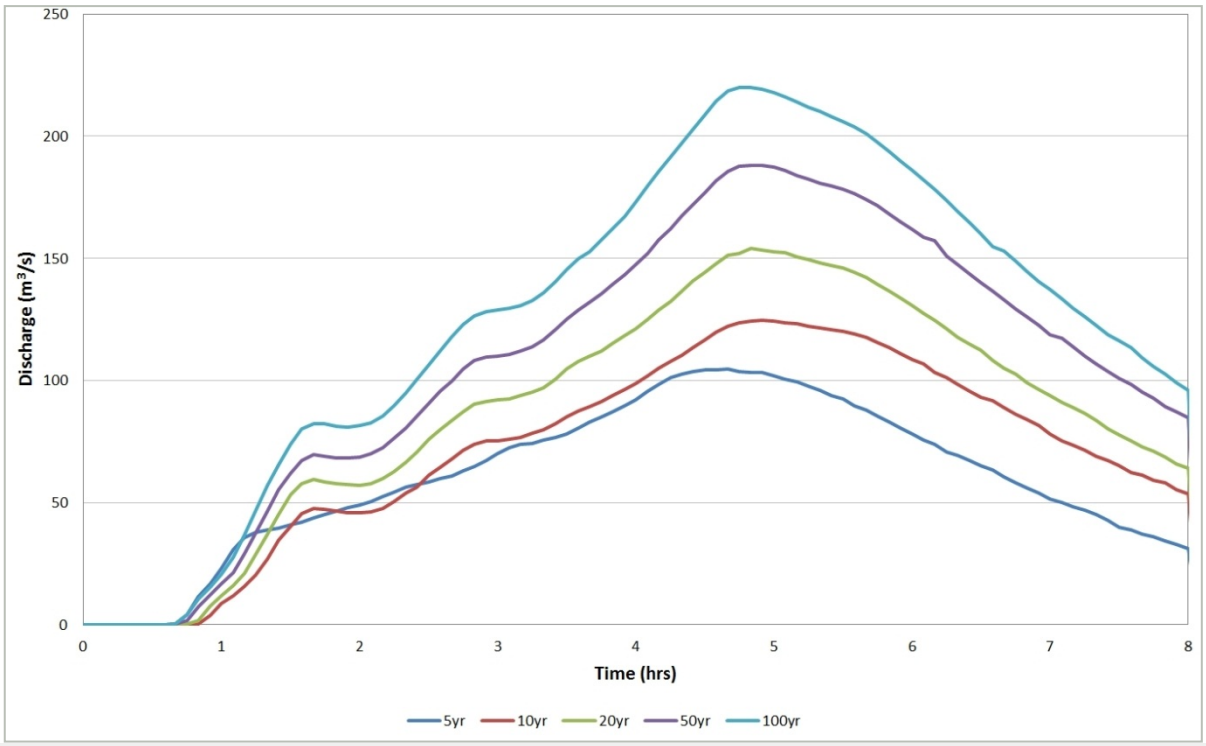
Graph 5 | Gracemere Creek, Middle Road Discharge



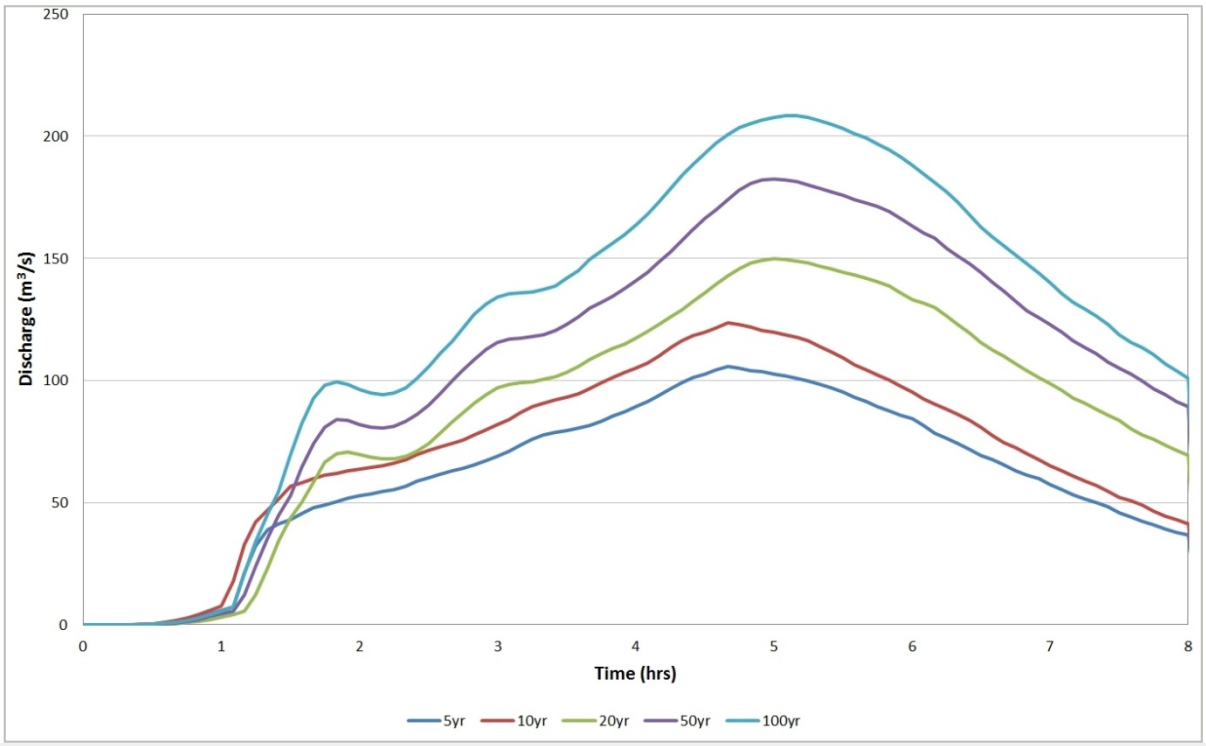
Graph 6 | Local Catchment, Discharge near New Road



Graph 7 | Local Catchment, Somerset Road Discharge

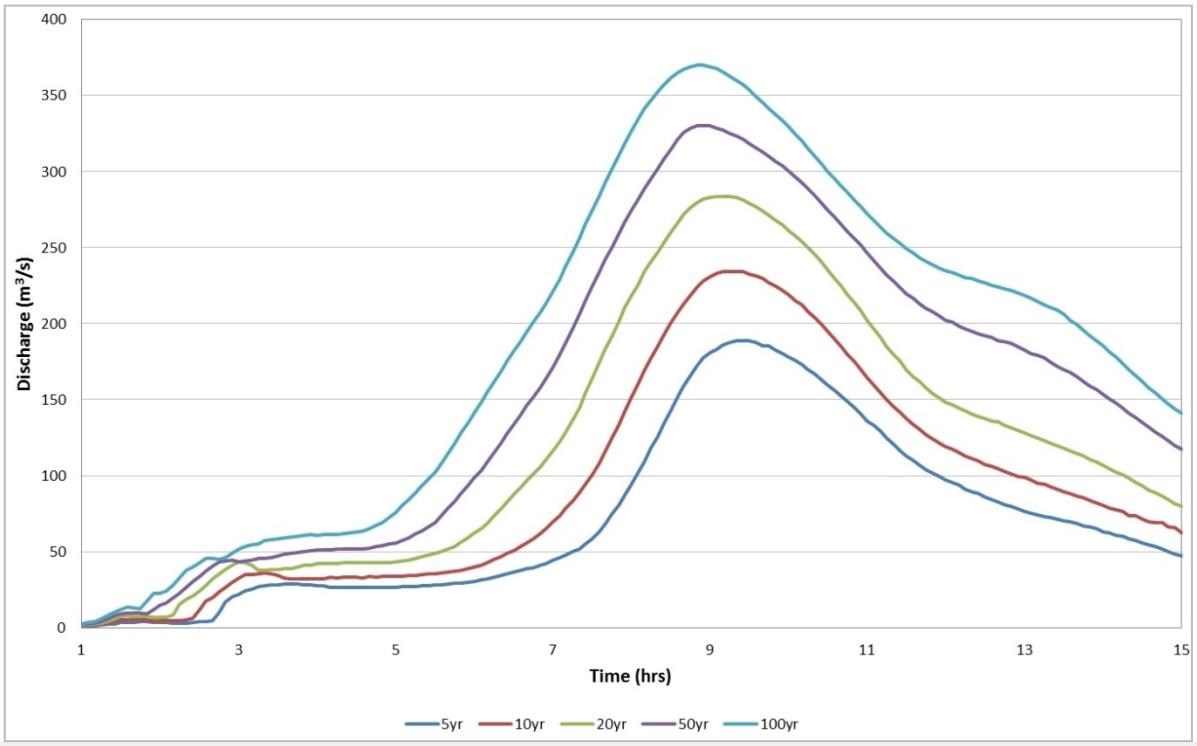


Graph 8 | Middle Creek, Murphy Road Discharge



Graph 9 | Middle Creek, E Williams Road* Discharge

** E Williams Road has been used to maintain consistency with the model ID. This should have been named Gold Escort Road*



Graph 10 | Teatree Creek, Tindall Road Discharge

5.3 Discussion

Some key points to note are:

- The maps show that in some areas, such as in the Local Catchment, the inundation extents do not change significantly between the 5 and 100 year ARI events. In these areas the flowpath is wide and flat, with steeper sides. The shape of the flowpath means that, although the discharge increases between the 5 and 100 year ARI events, the water is spread over such a large area that the depth increases are only minor. For example, in parts of Local Catchment the depth increases from approximately 0.2m in the 5 year ARI event to approximately 0.35m in the 100 year ARI event. Opportunity exists in the Developed Case to concentrate some of these flows in road corridors or floodway channels. This will increase the developable area but will require assessment of the downstream impacts to ensure flooding is not increased on external properties.
- Critical durations in the areas of interest in these catchments range from 1-2 hours in Local Catchment, to 4.5-9 hours in Middle Creek and Gracemere Creek and 12 hours in the lower end of the Washpool, Teatree and Four Mile Creek catchments. These are relatively short duration events when compared with the Fitzroy River event.
- The Gracemere Creek model has been developed using a rating curve as the downstream tailwater condition. This rating curve sets a tailwater level based upon the discharge in the creek and does not take into account coincident flooding in Neerkol/Scrubby Creek and Gracemere (Padgole) Lagoon. Flooding which occurred during December 2010 showed that coincident flooding does occur in the Gracemere Creek and Neerkol/Scrubby Creek systems and that the Gracemere Creek mapping presented in this report is not representative of these flood conditions downstream of the railway. It is recommended that assessment of flooding in Neerkol/Scrubby Creek flooding and the coincident flooding with Gracemere Creek should be assessed.
- Culvert LC_Rwy2 is undersized and as such the inundation extents upstream of this culvert show significant pooling of water. Additional information for this culvert was provided late in the project. This culvert is actually a 1.2m arch brick culvert. The modelling had been completed when this information was provided and therefore the results presented in this report will not be correct for this culvert and the upstream area. The increased size of this culvert will allow greater discharge and therefore reduce the upstream inundation extents. It is not expected that this will be significant and the 1.2m arch culvert is still likely to be significantly undersized.

6 Conclusions and recommendations

Detailed XP-RAFTS hydrologic and TUFLOW hydrologic/hydraulic models of the study area and its contributing catchments were developed. These catchments included:

- Middle Creek and the Kabra township
- Gracemere Creek and the western part of Gracemere
- The local catchments which drain beneath the Capricorn Highway between Middle Creek and Gracemere Creek
- Washpool, Teatree and Four Mile Creeks and south-eastern Gracemere

Maps and GIS layers of existing flood conditions were developed as key outputs from the study. These maps included flood levels, inundation extents, velocities and depths across the study area for the 5, 10, 20, 50 and 100 year ARI design events. Discharges, flood depths and critical durations for future strategic road upgrade locations were also extracted from the model results.

The following recommendations have been developed throughout the course of the study:

- Assessment of the flooding conditions in Neerkol/Scrubby Creek should be undertaken and this assessment should include an analysis of coincident flooding with Gracemere Creek
- Investigations into possible upgrades to the railway culvert “LC_Rwy2” should be carried out and discussed with QR National. These investigations should take into account that the results presented in this report will be conservative as the modelling undertaken for this study was based upon a 450mm RCP at this location, instead of a 1200mm arch culvert
- Assessment of the proposed works will be required. This assessment should include consideration of:
  - Increased runoff resulting from increases in impervious area
  - Detention basins to mitigate increased runoff
  - Potential for floodway channels to be incorporated into the development
  - Assessment of the impacts of development upon external properties

7 Explanatory notes and disclaimers

7.1 General notes

- This report and the associated mapping were developed to represent creek flooding in the developed/developable areas in Middle Creek, Gracemere Creek, Washpool Creek and the Local Catchment. Flooding continues beyond the upstream extents. No consideration of regional flooding from Neerkol Creek has been made. No consideration of flooding in areas of piped urban stormwater drainage has been made.
- The topographic data used in preparation of the hydraulic model and this report was based upon the best information available as at September 2011 and relied upon LiDAR survey captured in 2009. No bathymetric data was included.
- The results presented in this report are based upon model results from the Gracemere catchments XP-RAFTS and TUFLOW models as at April 2012.
- Information presented in this report is indicative only and may vary, depending upon the level of catchment and floodplain development. Filling of land or excavation and levelling may alter the ground levels locally at any time, whilst errors may also occur from place to place in the local ground elevation data from which the models have been developed
- The hydraulic modelling presented in this report was based upon 5 m and 10 m grid hydraulic models. This model resolution may not be representative of features such as small, local drainage channels.
- Flood hazard assessments have been based upon consideration of flood depths and velocities only. No consideration of evacuation times has been included.

7.2 Important things you should know about this report

7.2.1 Exclusive use

- This report has been prepared by Aurecon at the request of Rockhampton Regional Council ("Client") exclusively for the use of its Client
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7.2.2 Third parties

- It is not possible to make a proper assessment of this report without a clear understanding of the terms of engagement under which the report has been prepared, including the scope of the instructions and directions given to and the assumptions made by the consultant who has prepared the report
- The report is a report scoped in accordance with instructions given by or on behalf of Client. The report may not address issues which would need to be addressed with a third party if that party's particular circumstances, requirements and experience with such reports were known and may make assumptions about matters of which a third party is not aware
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7.2.4 Limits on investigation and information

- Where site inspections have been made, they have been limited in their scope to external visual inspections
- The report is also based on information provided to Aurecon by other parties. Although the providers of the information have not warranted the accuracy of the data and have waived liability in respect of its use, Aurecon's report is provided strictly on the basis that the information that has been provided is accurate, complete and adequate
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If the reader should become aware of any inaccuracy in or change to any of the facts, findings or assumptions made either in Aurecon's report or elsewhere, the reader should inform Aurecon so that it can assess its significance and review its comments and recommendations.

Nothing in this report shall be read or applied so as to purport to exclude, restrict or modify, or have the effect of excluding, restricting or modifying the application of all or any of the provisions of the Trade Practices Act 1974 or any other legislation which by law cannot be excluded, restricted or modified.

Appendices

Appendix A
RAFTS Model Parameters

Sub-catchment parameters

Catchment	Sub-Catchment ID	Area (km^2)	Slope (%)	% Impervious	Roughness (PerN)
Gracemere Creek	Node1	379.09	2.8	5.0	0.070
	Node2	230.60	4.5	5.0	0.070
	Node3	318.53	5.0	5.0	0.070
	Node4	322.25	0.4	5.0	0.070
	Node5	342.85	2.1	5.0	0.070
	Node6	443.08	3.2	5.0	0.070
	Node7	448.52	3.6	5.0	0.070
Middle Creek	Node1	250.80	1.5	5.0	0.070
	Node2	394.87	2.1	5.0	0.070
	Node3	231.25	0.9	5.0	0.070
	Node4	327.46	4.0	5.0	0.070
	Node5	170.70	1.5	5.0	0.070
	Node6	295.15	1.4	5.0	0.070
	Node7	351.38	1.7	5.0	0.070
	Node8	312.12	1.1	5.0	0.070
	Node9	141.03	2.6	5.0	0.070
Washpool Creek	Node1	118.02	0.8	5.0	0.070
	Node2	176.38	0.5	5.0	0.070
	Node3	178.11	0.5	5.0	0.070
	Node4	255.11	0.4	5.0	0.070
	Node5	303.18	0.6	5.9	0.068
	Node6	182.58	1.3	5.0	0.070
	Node7	286.19	1.0	5.0	0.070
	Node8	443.87	0.6	5.0	0.070
	Node9	258.52	0.7	5.0	0.070
	Node10	333.61	0.8	5.0	0.070
	Node11	363.6	2.1	5.0	0.070

Catchment	Sub-Catchment ID	Area (km^2)	Slope (%)	% Impervious	Roughness (PerN)
	Node12	454.77	2.5	5.0	0.070
	Node13	354.00	1.4	5.0	0.070
	Node14	481.92	1.5	5.0	0.070
	Node15	272.73	2.5	5.0	0.070
	Node16	310.62	5.8	5.0	0.070
	Node17	833.64	4.0	5.0	0.070
	Node18	644.23	4.7	5.0	0.070

Link parameters

Catchment	Link ID	Length (m)	Slope (%)	Adopted Velocity (m/s)	Lag Time (mins)
Gracemere Creek	GC7-GC4	2642	2.8	0.7	62.9
	GC4-GC2	3060	2.6	0.7	72.8
	GC9-GC8	1852	1.7	0.3	102.9
	GC8-GC6	2374	1.5	0.3	131.9
	GC5&GC6-GC3	2820	1.4	0.3	156.7
Middle Creek	MC7-MC6	1438	3.4	0.7	34.2
	MC6-MC5	1021	3.0	0.5	34.0
	MC4&MC5-MC3	1383	2.8	0.5	46.1
	MC3-MC1	2187	2.9	0.5	72.9
Washpool Creek	WC6-WC1	2013	1.1	0.3	111.8
	WC7-WC2	2461	0.8	0.3	136.7
	WC16-WC13	2467	3.5	0.7	58.7
	WC17-WC14	3736	3.1	0.7	89.0
	WC13&WC14-WC8	5452	2.7	0.5	181.7
	WC18-WC15	1478	4.0	0.7	35.2
	WC15-WC11	2047	3.5	0.7	48.7
	WC11-WC10	3151	2.6	0.5	105
	WC12-WC10	2868	1.7	0.3	159.3
	WC10-WC9	829	2.6	0.5	27.6
	WC8&WC9-WC5	978	2.4	0.5	32.6
	WC5-WC4	2336	2.4	0.5	77.9

Appendix B
TUFLOW Model Peak Discharges

Gracemere Creek

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
1d Culverts	GC_7A	0.1	0.2	0.2	0.3	0.3	60	60	60	60	60
	GC_Basin	1.4	1.4	1.4	1.4	1.4	45	90	60	45	45
	GC_CSt	1.9	1.9	1.9	1.9	1.9	90	90	120	45	90
	GC_JR	10.0	6.2	17.2	4.2	4.0	270	540	540	45	45
	GC_JR_2	1.3	1.4	1.4	1.5	1.6	60	60	60	60	45
	GC_MR	1.3	1.3	1.3	1.3	1.3	540	540	540	540	540
	GC_OAv	1.0	1.0	1.0	1.0	1.0	60	90	60	45	60
	GC_R.W.Rd	91.9	107.9	111.1	111.4	112.1	360	360	270	180	180
	GC_Rwy_1	0.9	1.1	1.1	1.2	1.1	60	90	90	90	90
	GC_Rwy_2	74.3	83.9	92.7	96.1	97.5	360	360	540	360	360
	GC_Rwy_3	17.0	21.4	24.9	26.1	26.5	540	540	540	270	360
	GC_SSt	5.6	5.8	5.9	6.1	6.2	60	60	60	60	60
2d Lines	ASt_1	6.5	7.6	9.0	10.3	12.0	60	60	60	60	60
	ASt_GC	88.5	105.4	129.4	159.8	185.8	360	360	360	360	360
	CSt_1	20.0	23.5	28.4	33.8	39.0	90	90	90	90	60
	CSt_GC	92.0	110.0	134.8	168.0	194.6	360	360	360	360	360
	HpRd_GC	84.5	100.6	123.6	151.3	176.1	360	360	360	360	360
	JRd_1	12.9	14.8	17.5	20.0	22.6	60	60	60	60	60
	JRd_GC	80.5	97.5	121.6	152.2	178.3	360	360	360	360	360
	MRd_1	20.2	23.7	28.6	34.2	39.3	90	90	90	60	60
	MRd_GC	91.0	108.8	133.7	166.3	193.5	360	360	360	360	360
	MSt_GC	91.0	108.8	133.7	166.3	193.5	360	360	360	360	360
	Ost_1	15.0	18.0	22.4	27.5	31.5	60	60	60	60	60
	RWRd_GC	92.4	111.0	141.2	182.1	213.7	360	540	540	540	540
	Rwy_1	0.0	3.9	16.0	44.6	81.4	540	540	540	540	540
	Rwy_GC	1.1	1.4	6.6	34.0	63.3	60	540	540	540	540
	SSt_1	6.7	8.8	12.4	15.5	18.7	60	60	60	60	60

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
	WSt_1	72.6	86.1	104.9	129.9	151.2	270	270	270	270	270
	WSt_2	11.2	13.2	15.8	18.5	21.1	60	60	60	60	60
	Wst_3	2.7	3.5	4.4	5.4	6.4	60	60	60	60	60
	ASt_1	6.5	7.6	9.0	10.3	12.0	60	60	60	60	60
Totals	Johnson Rd GC	81.3	98.2	122.2	153.1	179.2	360	360	360	360	360
	Middle Rd GC	91.1	108.9	133.8	166.4	193.5	360	360	360	360	360
	Railway Crossing Nth	75.4	88.1	109.3	127.5	135.8	360	540	540	540	540
	Railway Crossing Sth	17.1	22.9	31.3	54.5	75.8	540	540	540	540	540
	Railway Crossing Total	92.5	111.0	140.6	181.4	211.7	360	540	540	540	540
	Stewart St	12.4	14.6	18.3	21.6	24.9	60	60	60	60	60

Local Catchment

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
1d Culverts	C_12A	0.4	0.4	0.4	0.4	0.5	90	90	60	60	60
	C_1A	0.4	0.4	0.5	0.5	0.5	60	60	60	60	60
	LC_1B	6.3	7.3	8.6	9.7	10.7	60	60	60	60	60
	LC_1C	0.0	0.1	0.1	0.1	0.1	60	60	60	60	60
	LC_3A	3.7	4.7	5.9	7.2	8.1	90	90	90	90	90
	LC_4A	2.0	2.2	2.5	2.8	3.0	60	60	60	60	60
	LC_5A	1.7	2.0	2.3	2.6	2.9	60	60	60	60	60
	LC_6A	5.4	6.1	7.0	7.7	8.5	60	60	60	60	60
	LC_8A	3.3	3.3	3.3	3.3	3.3	180	180	120	90	90
	LC_8B	27.6	30.4	32.8	35.2	36.7	180	180	180	120	120
	LC_9A	5.5	7.4	9.5	10.3	10.7	90	90	90	60	60
	LC_C_Hwy_1	2.2	2.3	2.4	2.5	2.5	60	60	60	60	60
	LC_C_Hwy_2	1.4	1.6	1.8	3.2	5.6	60	60	60	360	270
	LC_C_Hwy_3	29.1	33.4	39.0	48.8	60.2	120	120	120	120	120
	LC_C_Hwy_4	2.5	2.9	3.4	3.9	4.5	60	90	90	60	60
	LC_Rwy_1	2.4	2.7	2.9	3.1	3.3	60	60	60	60	60
	LC_Rwy_2*	0.8	0.8	0.8	0.8	0.9	360	360	360	360	270
	LC_Rwy_3	3.0	3.4	4.2	5.5	6.4	60	60	90	90	90
	LC_Rwy_4	1.0	1.1	1.3	1.8	2.2	60	60	90	90	90
	LC_Rwy_5	29.1	33.4	37.6	39.3	39.9	120	120	120	90	120
	LC_Rwy_6	2.4	2.5	2.7	2.8	3.0	60	90	60	60	60

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
2d Lines	OP_8	1.4	4.9	10.6	19.2	29.4	180	180	180	180	180
	CHwy_LC	0.0	0.0	0.0	0.0	0.3	60	60	60	60	120
	LC_Q_1	14.8	17.7	21.1	23.8	28.4	60	60	60	60	60
	LC_Q_10	2.1	2.7	3.5	4.4	5.2	60	60	90	60	60
	LC_Q_11	5.3	7.1	9.9	13.2	15.9	90	90	90	90	90
	LC_Q_12	5.8	7.6	10.1	13.5	17.3	90	90	90	90	90
	LC_Q_13	33.2	38.9	46.3	57.9	69.7	180	180	180	120	120
	LC_Q_2	15.4	17.5	20.5	23.1	26.0	60	60	60	60	60
	LC_Q_3	29.9	37.0	45.4	58.5	67.9	60	60	60	60	60
	LC_Q_4	14.1	16.1	19.3	22.6	25.9	60	60	60	60	60
	LC_Q_5	2.2	2.4	2.9	3.2	3.4	60	60	60	60	60
	LC_Q_6	6.0	6.7	7.7	8.9	10.1	60	60	60	60	60
	LC_Q_7	40.8	50.9	64.9	81.7	96.4	60	90	90	60	60
	LC_Q_8	5.8	6.7	7.8	8.8	9.9	60	60	60	60	60
	LC_Q_9	40.1	49.6	62.9	78.2	92.0	90	90	90	60	90
	OP_9A	0.0	0.0	0.8	4.4	8.2	90	90	90	90	90
	Rwy_2	0.0	0.0	0.0	0.0	0.0	60	60	60	60	60
	Rwy_3	0.1	0.1	0.1	1.8	4.8	60	60	60	270	270
	Rwy_4	2.3	2.6	3.1	3.4	3.7	60	60	60	60	60
Totals	Cap Hwy East Catch 1	0.8	0.8	0.8	0.8	0.8	270	270	270	270	270
	Cap Hwy Easternmost Catch	2.4	2.7	3.0	3.2	5.5	60	60	60	60	270
	Capricorn Hwy Main	30.1	34.3	39.9	51.0	62.0	120	120	120	120	120
	Malchi Nine Mile Rd (New Xing)	32.6	38.5	46.6	57.3	69.1	180	180	180	180	180
	Overpass Somerset Rd Connection	5.7	7.6	10.2	13.9	17.6	90	90	90	90	90
	Rail East of Overpass	6.0	7.2	8.4	9.4	10.4	60	60	60	60	90

** Information provided late in the project indicates that this culvert is actually a 1200mm arch brick culvert. This information was provided following completion of the modelling, therefore the results presented in this report are not correct for this culvert.*

Middle Creek

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
1d Culverts	MC_Cap_1	19.8	32.1	46.2	56.9	61.0	360	360	360	360	540
	MC_Cap_10	6.0	6.0	6.1	6.1	6.2	60	60	45	45	60
	MC_Cap_11	0.5	0.6	0.7	0.8	0.9	60	60	60	60	60
	MC_Cap_2	0.1	0.2	4.4	8.1	9.0	360	360	360	360	360
	MC_Cap_3	0.8	1.0	1.1	1.3	2.1	60	60	45	45	60
	MC_Cap_4	3.0	3.6	4.4	4.9	5.2	60	60	60	60	60
	MC_Cap_5	12.4	12.7	13.2	13.2	13.1	60	90	60	45	60
	MC_Cap_6	1.0	1.0	1.0	1.0	1.0	60	45	45	60	60
	MC_Cap_7	2.2	2.2	2.2	2.2	2.1	60	90	270	720	180
	MC_Cap_8	1.4	1.4	1.5	1.5	1.5	60	60	60	60	60
	MC_Cap_9	0.6	0.6	0.6	0.6	0.6	60	60	60	60	60
	MC_M-St_1	0.4	0.3	0.4	0.4	0.4	45	120	60	45	90
	MC_M-St_2	27.6	27.3	26.4	25.7	27.9	180	180	180	180	60
	MC_Rwy_1	9.9	9.9	10.2	10.1	10.1	270	180	90	60	180
	MC_Rwy_2	3.9	4.4	4.9	5.2	5.3	60	60	60	90	60
	MC_Rwy_3	4.3	4.8	5.4	5.7	5.8	90	120	90	90	90
	MC_Rwy_4	13.1	13.4	14.4	15.5	16.5	60	45	60	60	60
	MC_Rwy_5	7.1	7.3	7.5	7.8	7.9	60	60	60	60	60
	MC_Rwy_6	0.5	0.6	0.6	0.6	0.6	60	60	60	60	60
	MC_Rwy_7	0.6	0.7	0.8	0.8	0.8	60	60	60	60	60
	MC_Rwy_8	5.4	5.5	5.6	5.7	5.6	60	60	60	45	60
2d Lines	CHwy_1	0.1	0.1	0.2	1.7	14.3	60	60	60	360	360
	CHwy_MC	95.6	105.2	114.3	126.8	135.1	360	360	360	360	540
	EWRd_1	20.3	23.3	28.9	36.0	42.1	60	60	60	60	60
	EWRd_MC	105.7	123.5	149.8	182.5	208.4	270	270	360	360	360
	FP_Q_10	7.8	9.1	10.6	12.8	14.7	60	60	60	60	60
	FP_Q_11	1.4	1.5	1.8	2.1	2.4	60	60	60	60	60
	FP_Q_12	14.1	16.5	20.5	25.6	30.5	60	60	60	60	60
	FP_Q_13	5.6	6.5	7.7	9.0	10.3	120	120	120	90	90
	FP_Q_14	6.3	8.8	13.5	20.3	25.6	360	360	360	360	360
	FP_Q_15	47.3	61.7	80.5	101.9	118.2	360	360	360	360	360
	FP_Q_16	25.8	30.6	37.0	45.5	53.2	60	60	60	60	60
	FP_Q_17	29.3	35.1	42.9	51.1	58.8	60	60	60	60	60
	FP_Q_18	0.1	0.1	0.2	0.2	0.2	60	60	60	60	60
	FP_Q_19	34.4	40.5	49.6	60.3	69.6	60	60	60	60	60
	FP_Q_20	47.4	61.8	80.7	102.3	118.8	360	360	360	360	360
	FP_Q_21	14.9	16.4	20.9	25.7	31.0	60	60	60	60	60

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
	FP_Q_22	23.0	37.8	57.3	76.5	97.6	360	360	360	360	360
	MC_Q_1	107.6	126.9	153.7	187.7	214.1	270	270	270	270	270
	MC_Q_2	58.3	62.8	69.6	79.1	88.7	270	270	270	360	360
	MC_Q_3	73.9	86.1	101.9	120.4	137.0	120	120	120	120	90
	MC_Q_4	93.2	101.4	111.2	122.7	130.9	360	540	540	540	540
	MRd_MC	104.7	124.5	154.0	188.1	220.1	270	360	360	360	360
	MSt_1	27.6	36.4	48.2	62.7	74.6	360	360	360	360	360
	MSt_2	37.4	45.7	57.4	73.5	86.8	540	540	540	360	540
	MSt_MC	32.7	38.8	47.2	58.7	67.5	360	360	360	360	360
	Orwy_1	50.4	64.8	81.8	101.2	115.7	360	360	360	360	360
	ORwy_2	16.6	20.4	26.4	33.2	39.4	60	90	90	60	540
	ORwy_MC	69.6	77.7	87.3	97.2	105.4	120	120	120	90	90
	Rwy_5	12.3	26.4	49.8	92.4	124.2	360	360	360	360	540
	Rwy_MC	97.8	109.1	121.0	126.5	133.4	360	360	360	270	90
	SsRd_1	5.1	5.7	6.5	7.0	8.1	60	60	60	60	60
	SsRd_2	2.3	2.5	2.9	3.2	3.4	60	60	60	60	60
	SsRd_3	5.4	5.5	5.8	5.9	6.1	60	60	60	60	60
	SsRd_4	13.2	13.1	14.6	16.2	18.2	60	90	60	60	60
	SsRd_5	4.4	4.9	5.4	5.7	5.8	90	120	90	90	90
Totals	Cap Hwy	95.5	105.2	118.5	134.8	144.2	360	360	360	360	540
	Cap Hwy East	19.6	31.8	46.1	58.6	75.0	360	360	360	360	360
	Morgan St	120.2	143.6	176.3	219.3	252.4	360	360	360	360	360
	Old Railway	120.5	144.2	177.3	220.4	253.9	360	360	360	360	360
	Railway East	22.0	35.5	57.2	98.0	129.3	360	360	360	360	360

Washpool Creek

Results Type	Location	Discharge (m^3/s)					Critical Duration (mins)				
		5yr	10yr	20yr	50yr	100yr	5yr	10yr	20yr	50yr	100yr
1d Culverts	WC_Gav_Rd	0.5	0.5	0.5	0.5	0.5	720	360	360	180	540
2d Lines	TTC_1	188.8	234.4	305.1	305.1	455.9	180	720	720	720	720
	GGRd_WC	183.3	215.7	255.4	255.4	379.4	720	720	720	720	720
	GGRd_3	16.1	31.8	44.8	44.8	67.8	720	720	720	720	720
	GGRd_2	11.5	17.1	22.0	22.0	30.5	720	720	720	720	720
	GGRd_1	13.5	13.5	15.9	15.9	22.6	60	60	720	720	540
	GGRd_FMC	32.2	32.0	32.0	32.0	32.2	60	60	60	60	720
	TRd_5	48.7	62.8	77.3	77.3	98.8	720	720	720	720	720
	TRd_TTC	99.7	112.7	125.4	125.4	145.9	720	720	720	720	720
	TRd_4	42.3	60.4	81.6	81.6	126.8	720	720	720	720	720
	TRd_3	4.8	5.6	23.6	23.6	83.1	90	90	720	720	720
	TRd_1	33.0	38.8	46.9	46.9	65.7	60	90	60	60	60
	TRd_2	25.9	30.8	38.0	38.0	53.9	90	90	90	90	90
	Ard_WC	90.0	110.0	136.4	136.4	196.3	180	180	180	180	180
	WArd_WC	94.3	114.2	140.4	140.4	199.8	180	180	180	180	180
	WC_1	83.1	101.0	124.3	124.3	177.8	180	180	180	120	120
	WPRd_2	22.8	27.3	33.4	33.4	47.7	120	120	120	90	90
	FP_Q_6	15.3	18.2	22.3	22.3	32.2	90	120	90	90	90
	WPRd_1	13.8	17.1	21.1	21.1	29.7	60	60	60	60	60
	FP_Q_5	11.7	13.3	15.4	15.4	21.3	60	60	60	60	60
	FP_Q_4	10.4	12.7	15.9	15.9	23.3	90	90	90	60	60
	FP_Q_2	6.0	7.0	8.2	8.2	11.7	60	60	60	60	60
	FP_Q_1	3.7	4.2	5.0	5.0	7.4	60	60	60	60	60
	FP_Q_3	5.6	6.2	7.2	7.2	9.1	60	60	60	60	60
	CRd_WC	76.8	93.8	117.2	117.2	169.6	90	90	90	90	90
	CRd_1	12.9	15.0	18.2	18.2	24.9	60	60	60	60	60
	FMC_1	58.7	58.8	59.3	59.3	59.6	120	90	90	60	60
	HpRd_1	18.9	23.3	28.3	28.3	44.2	60	90	60	60	60
	GwRd_1	32.8	39.7	49.5	49.5	74.5	90	90	90	60	60
Totals	Tindall Rd Teatree Ck	188.6	234.3	283.4	283.4	369.7	720	720	720	720	720

Appendix C
List of Figures

List of Figures

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