CIVIL & STRUCTURAL ENGINEERS

EASTERN ALLIGATOR CREEK BASELINE FLOODING ASSESSMENT

EASTERN ALLIGATOR CREEK DRAINAGE MASTER PLAN – PHASE 1

FOR
TOWNSVILLE CITY COUNCIL

JOB No: **TCC0049**

REVISION: **D**

Phone: 07 4725 5550
Fax: 07 4725 5850
Email: mail@nceng.com.au
50 Punari Street Currajong Qld 4812
Milton Messer & Associates Pty Ltd
ACN 100 817 356 ABN 34 100 817 356

DOCUMENT CONTROL

Revision	Date	Details	Author	Approved		
				Name	RPEQ #	Signature
A	26/08/15	Draft issued to TCC for comment w/o figures	Dale Armbrust	Andrew Wallace	6743	
B	27/08/15	Draft issued to TCC for comment	Dale Armbrust	Andrew Wallace	6743	
C	27/05/16	Amendments incorporated from TCC review	Dale Armbrust	Andrew Wallace	6743	
D	01/06/16	Amendments incorporated from 2nd TCC review	Dale Armbrust	Andrew Wallace	6743	

TABLE OF CONTENTS

APPENDICIES

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

Northern Consulting Engineers (NCE) have been engaged by the Townsville City Council (TCC) to undertake a flood study of the eastern area of Alligator Creek in the vicinity of Williams Road and Tindall Court (the Study Area). This study will be used to aid in the development a Drainage Master Plan for the area.

The Berrima Park residential estate located off Williams Road is presently affected by flooding issues associated with a series of non-functioning infiltration/bioretention devices and a lack of positive drainage offsite. The device at the outlet of the estate is shown in Figure 1.1, with ponded water apparent.

Figure 1.1 Berrima Park Estate major infiltration/bioretention device

The goals of the Drainage Master Plan are to provide a baseline flooding assessment of the existing flooding regime within eastern Alligator Creek, and to identify opportunities to improve drainage within Berrima Park estate whilst also considering drainage of the broader eastern Alligator Creek area, over which extensive development is expected to occur in the coming years. The development of a cohesive drainage master plan for the area is crucial to ensure that fragmented land ownership and developments in the Study Area will not result in poor drainage outcomes for existing and future residents of the area.

To undertake this study, a fine-scale MIKE FLOOD model of eastern Alligator Creek (EAC) was developed. Additionally, the existing broad-scale Alligator and Whites Creek MIKE FLOOD model was acquired from TCC and updated to include features and roadworks that have occurred since its original development. Results from this existing model were input into the fine-scale model as upstream inflows and downstream boundary conditions. This existing model had been previously developed by AECOM, and was used to inform AECOM's 'Alligator and Whites Creek Flood Study: Baseline Flood Study' (2008).

1.2 Objectives

1.2.1 Phase 1

The development of this flood study represents the first phase of the Eastern Alligator Creek Drainage Master Plan, with the objective of this first phase being:

1. To develop a baseline model of the EAC study area in its current form.

1.2.2 Phase 2

The second phase of this project will involve the development of the Drainage Master Plan itself, with the objectives of this Master Plan being:

1. To reduce/mitigate the flood impacts presently experienced by residents of the area where possible; and

2. To make provisions for expected future developments in the area.

1.3 Limitations

Inflows from the broad-scale Alligator and Whites Creek flood model were used as inputs to the fine-scale EAC flood model. Whilst the broad-scale model was updated with new DEM features and drainage structures, an exhaustive check of all hydrodynamic parameters within the model was not undertaken, and is beyond the scope of this study. Elements critical to the study area, such as bridge structures and major culverts, have been verified against design drawings and ground-truthed via site investigation.

1.4 Supplied data

The following data was provided to undertake this assessment:

- Aerial topographic survey of the Study Area, based on 2009 LiDAR capture.

- The existing Alligator and Whites Creek MIKE FLOOD and XP-RAFTS models, supplied by TCC and originally developed by AECOM.

- ‘As constructed’ data for several developments within the EAC study area.

- ‘As constructed’ data for existing infrastructure within the EAC study area, including bridge structures, highway upgrades and culverts.

- Cadastral data of the Eastern Alligator Creek area, sourced from the Queensland Government’s QSpatial catalogue.

- Streamflow data for Alligator Creek (DNRM gauge ‘118106A Alligator Creek at Allendale’), sourced from the Queensland Government’s Department of Natural Resources and Mines (DNRM).

- Rainfall data from a storm event on 13/04/2014 associated with Severe Tropical Cyclone Ita, supplied by TCC.

- A submission by the residents of Berrima Park estate to TCC regarding flash flooding that occurred during Severe Tropical Cyclone Ita. This submission documented the concerns of the residents regarding the drainage design of Berrima Park, and included photos taken during the above-mentioned storm event.

1.5 Site description

The EAC area is comprised predominantly of freehold land zoned as rural residential. The area is bounded to the west by Alligator Creek, which is aligned north-south adjacent to Williams Road. The southern and eastern extent of the area's catchment is defined by a hilly ridgeline, reaching a maximum elevation of around 190 m. The Bruce Highway and Northcoast Rail line span across the site's northern boundary, which both cross Alligator Creek via bridge structures.

Many allotments within the Study Area are associated with active Development Approvals, with extensive development forecast in the area in the near future.

Two site visits were undertaken by NCE during the development of the EAC flood model to physically verify the location and configuration of major drainage infrastructure, and to assist in selecting appropriate hydraulic parameters for use in the model.

2.0 HYDROLOGIC ANALYSIS

2.1 XP-RAFTS

XP-RAFTS had been previously utilised to undertake the hydrologic analyses for the existing Alligator and Whites Creek flood models. Within XP-RAFTS, Laurenson hydrology had been adopted as the runoff routing method. This method utilises the Muskingum procedure to model a catchment's response to rainfall based on its surface characteristics, size and loss inputs. The Muskingum procedure utilises a non-linear storage function to model runoff routing within a catchment.

2.1.1 Loss model

The Initial-Continuing loss model had been utilised within the existing XP-RAFTS models for Alligator and Whites Creek.

As part of this baseline flooding assessment, a Flood Frequency Analysis was undertaken for Alligator Creek (refer to Section 2.4). This analysis had shown that higher loss values were required for certain catchments (high loss areas) for design storms with AEPs ≥ 4.9% in order to better match a probability model fitted to historic streamflow data. Table 2.1 compares the pervious loss values applied in the original versus the calibrated XP-RAFTS model for Alligator Creek. Table 2.2 shows the loss model classification for each of the Alligator Creek subcatchments.

Table 2.1 Alligator Creek pervious area losses

Model	Standard loss areas		High loss areas	
	Initial loss (mm)	Continuing loss (mm/h)	Initial loss (mm)	Continuing loss (mm/h)
Original model (supplied by TCC)	25	2.5	75	2.5
Calibrated model, AEPs ≥ 4.9%	25	2.5	95	8
Calibrated model, AEPs < 4.9%	25	2.5	75	2.5

Table 2.2 Alligator Creek subcatchment loss classifications

Standard loss subcatchments	High loss subcatchments
AC-1-2 AC-1-3a AC-1-3b-a AC-1-3b-b AC-1-DS AC-2-1 AC-2-2 AC-4 KM1-1 KM1-2 KM1-3 KM-1-4 KM-1-DS	AC-1-1 AC-2-3 AC-2-3-1 AC-2-4 AC-2-5 AC-3-1 AC-3-1a AC-3-1b AC-3-2a AC-3-a AC-3-b

For AEPs < 4.9%, the existing Alligator Creek XP-RAFTS output was shown to agree well with the FFA probability model, and as such the model was not rerun for these AEPs, with the existing results used 'as supplied' as inflows to the broad-scale model.

2.2 Direct Rainfall hydrology

Direct Rainfall is a method of hydrologic determination that applies rainfall directly to the surface of a 2D hydraulic model, rather than routing rainfall through a separate hydrologic model. Direct Rainfall parameters are specified within the MIKE21 flow model. This method of hydrologic analysis requires the modeller to combine temporal rainfall data with a land use map to create a time-varying net precipitation grid.

Direct Rainfall was adopted as the hydrologic determination method for the EAC MIKE21 model. Prior to adoption, two test catchments within the study area (one flat and one steep) were modelled in both XP-RAFTS (Laurenson) and MIKE21 (Direct Rainfall) to verify the appropriateness of Direct Rainfall. It was proposed that if good correlation between the two methods could be demonstrated for two extreme topology types (steep and flat), then the method would be appropriate across the full model domain (steep, flat and all intermediate slopes).

Table 2.3 summarises the parameters used to model the test catchments in XP-RAFTS. To model these catchments in MIKE21, Direct Rainfall was applied to the DEM within the areas bounded by the catchment extents. The same loss and roughness values used in XP-RAFTS were applied in MIKE21. For the purposes of this verification analysis, a 1% AEP 24 hour design storm was applied to the test catchments.

Table 2.3 XP-RAFTS catchment parameters for hydrology comparison

Catchment ID	Catchment area (ha)	Fraction impervious	Pervious loss model	Manning's n	Vectored slope (%)
Steep	11.668	0	25 mm initial, 2.5 mm/h continuing	0.05	9
Flat	3.521	0	25 mm initial, 2.5 mm/h continuing	0.05	0.937

Figure 2.1 and Figure 2.2 show the hydrology comparisons for the 'steep' and 'flat' catchments, respectively.

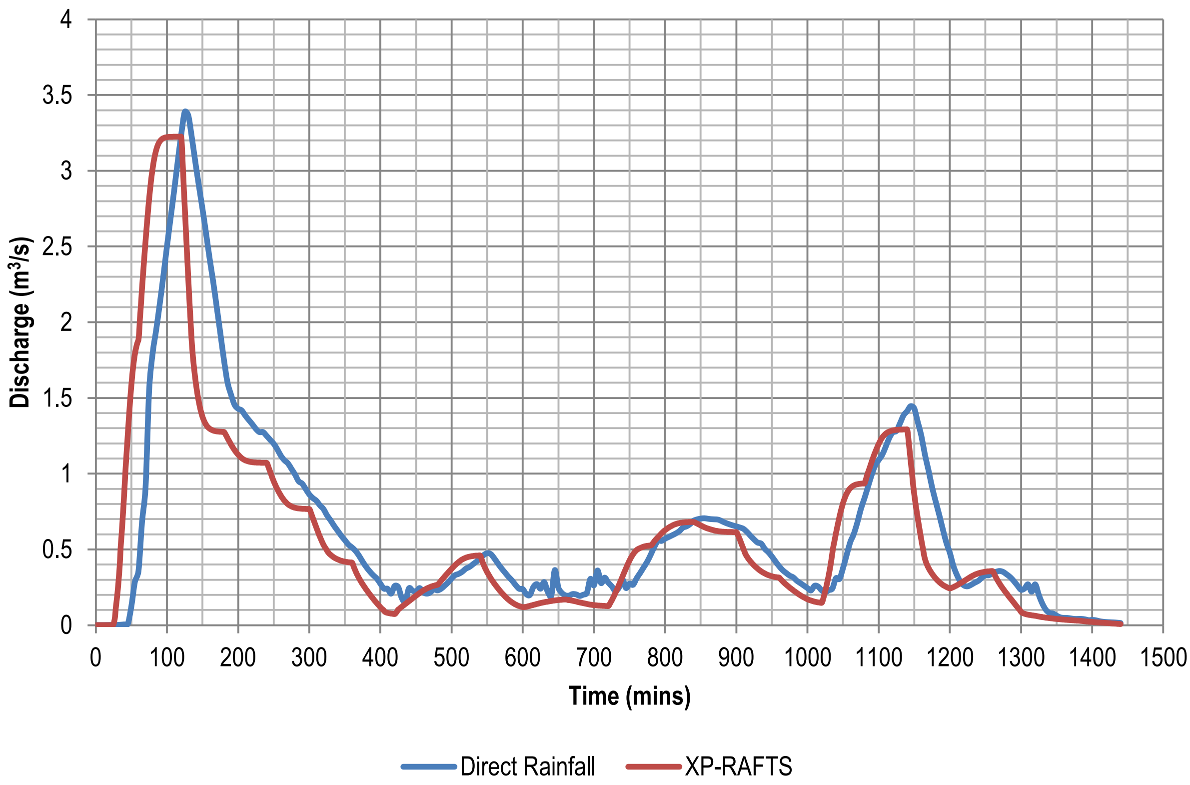

Figure 2.1 Hydrology comparison for 'steep' test catchment

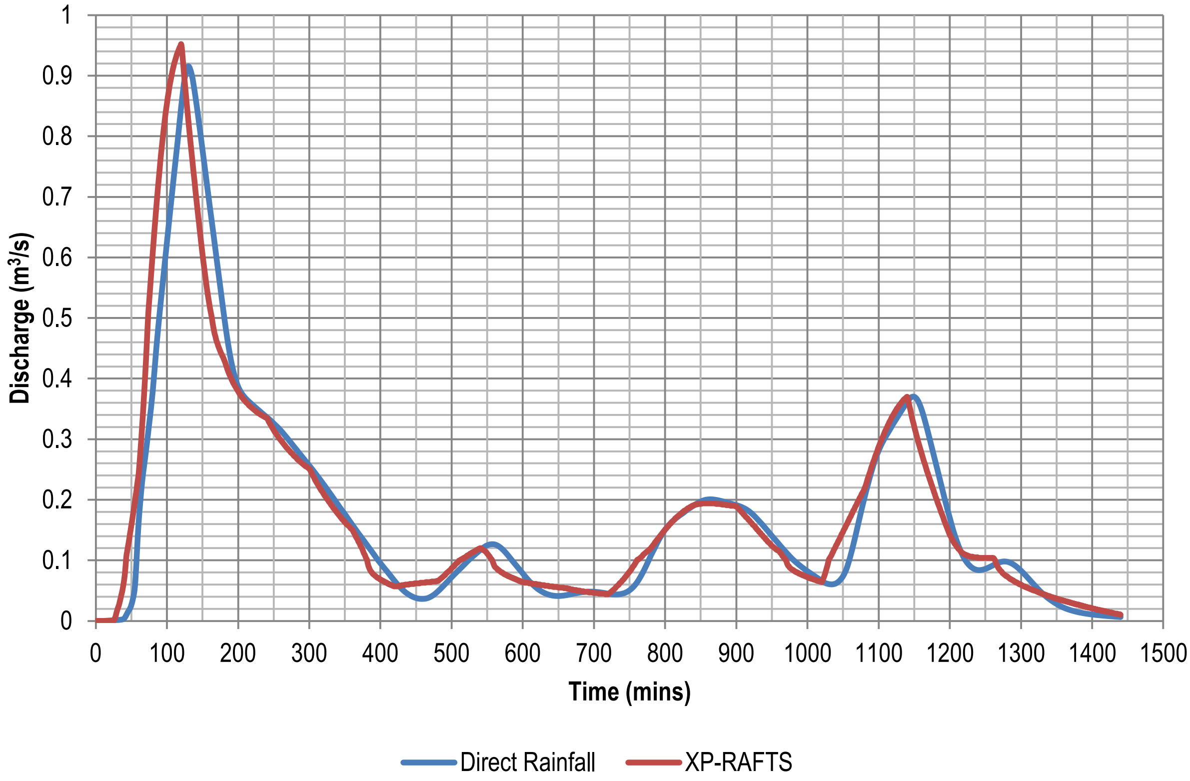

Figure 2.2 Hydrology comparison for 'flat' test catchment

The previous figures show tight agreement between the two hydrologic methods, with only a slight lag noted. This lag could be attributed to the average vectored slope applied in the XP-RAFTS analysis. An assumed/averaged slope is not required using Direct Rainfall, given that the flood wave's propagation is determined explicitly for each timestep over a digital representation of a catchment's surface, which is generally accepted as being more accurate. Given the agreement between the two methods, Direct Rainfall was adopted with confidence.

Net precipitation values were calculated for the land use areas described in Table 2.4.

Table 2.4 Fraction impervious values

Land use	Fraction Impervious
Open space, natural areas	0.00
Park residential zones	0.20
Roads	0.50

Figure A-2 of Appendix A shows the areas of the model to which these land uses apply.

Table 2.5 contains the loss values applied to the pervious and impervious subareas of the catchments modelled as part of this study. These values are in accordance with SC6.7.4.3.3 of the Townsville City Plan.

Table 2.5 Loss values

Catchment subarea	Initial loss (mm)	Continuing loss (mm/h)
Pervious	25	2.5
Impervious	1	0

2.3 Design rainfall

2.3.1 IFD data

IFD data for the Study Area was obtained from two sources. For standard AEPs (≥ 1%), IFD data was generated from coefficients sourced from the BOM's online ARR 1987 IFD tool using coordinates of 19.4°S, 146.958°E. For extreme events (between 1% AEP and PMP), IFD data was generated using the CRC-FORGE software package. A specific analysis was undertaken to generate the PMP data for this flood study (refer to Section 2.3.2).

The EAC IFD curves are shown in Figure 2.3. Also shown on the curve is rainfall data for the EAC area collected during Tropical Cyclone Ita (supplied by TCC). Further discussion on this storm event can be found in Section 3.6.1.

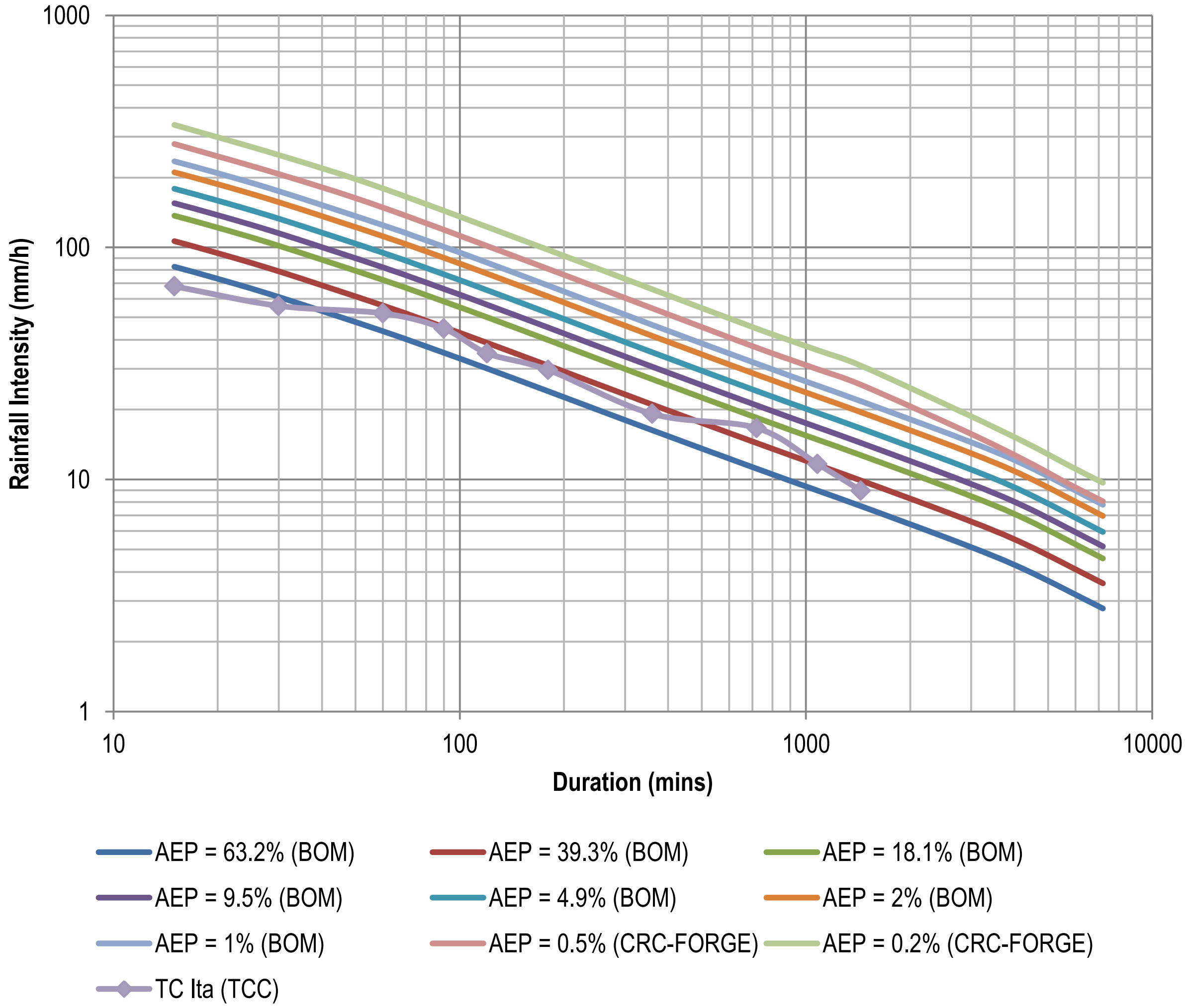

Figure 2.3 EAC IFD curves (19.4°S, 146.958°E)

2.3.2 PMP analysis

In order to generate rainfall data for the PMP 24 hour design storm, the methods outlined in the Bureau of Meteorology's (BOM) 'Guidebook to the Estimation of Probable Maximum Precipitation: GENERALISED TROPICAL STORM METHOD (GTSMR)' (2005) were implemented.

The parameters contained in Table 2.6 were calculated using raster data obtained from the BOM's GTSMR Guidebook CD-ROM and using a shapefile of the overall Alligator Creek catchment supplied by TCC (catchment area = 80 km^2, GTSMR zone = coastal).

Table 2.6 GTSMR catchment factors

Factor	Value
Topographical Adjustment Factor (TAF)	1.539
Decay Amplitude Factor (DAF)	1.000
Extreme Precipitable Water ($EPW_{catchment}$)	97.262 mm
Annual Moisture Adjustment Factor (MAF)	0.811

Using the data contained in Table 2.6, a PMP value of 1660 mm was calculated for the catchment. This rainfall depth was distributed temporally using the patterns provided on the BOM's GTSMR Guidebook CD-ROM, and applied to the EAC model via Direct Rainfall.

2.4 Flood Frequency Analysis

The DNRM operate a Stream Gauging Network across Queensland, with the collected data made available online via the DNRM's Water Monitoring Portal. One of these gauging stations, '118106A Alligator Creek at Allendale', is located in the Study Area and is positioned on Alligator Creek's eastern bank approximately 450 m downstream of the Bruce Highway. Streamflow data is available for this gauging station from 1975 through to the present (2015). Using this data, a flood frequency analysis (FFA) was undertaken for Alligator Creek.

To undertake this analysis, the web-based TUFLOW FLIKE software was utilised. FLIKE is an extreme value analysis software package, and is compliant with the latest draft revisions to ARR's flood estimation guidelines.

2.4.1 Gauge data

An annual maximum series (AMS) for streamflow data at the Alligator Creek gauging station was sourced from the DNRM for the period of 1974 to 2015. This data is contained in Table F-1 of Appendix F.

While there have been developments within the Alligator Creek catchment in this time period, notably upgrades to the Bruce Highway, it is considered that these developments would not significantly alter the flow characteristics of Alligator Creek itself. As such, the homogeneity of the DNRM dataset is considered to be sufficient to undertake this FFA.

2.4.2 Probability models

The following suite of probability distributions was assessed as part of this FFA:

- Generalised Extreme Value (GEV);
- Log Pearson III (LP3);
- Log-normal;
- Gumbel; and
- Generalised Pareto.

Appendix G of this report contains the FLIKE software output reports for each probability distribution modelled as part of this assessment.

2.4.3 Calibration

For both methods, Bayesian inference was selected as the calibration method, without a prior distribution.

ARR's 'Book 3 Peak Discharge Estimation' (2015) draft document strongly recommends the use of regional statistics to apply as a prior Gaussian distribution to improve FFA accuracy by combining site-specific and regional information. Regional statistics for the site were not available at the time of writing, and in future would be obtained using ARR's Regional Flood Frequency Estimation (RFFE) software, which is currently under development.

Future updates to this model may be able to incorporate this regional data (if available) as a further calibration to improve confidence in the FFA.

2.4.4 Results

Initial results using inflow data based on the original Alligator and Whites Creek hydrology model had revealed a discrepancy between the FFA results and the MIKE FLOOD output for design storm AEPs ≥ 4.9%. To correct this, the Alligator Creek loss model was modified in order to better match the model outputs to the FFA results. These loss model modifications are discussed in Section 2.1.1.

The final results of the FFA based on the updated loss model are contained in Figures H-1 to H-5 of Appendix H, with the GEV results also shown in Figure 2.4. Referring to these figures, it can be seen that of the five methods, the GEV and Gumbel distributions provide the best fit to the gauged data. While both distributions fit the gauged data well for higher AEPs (lower ARIs), the Gumbel distribution appears to underestimate discharge for lower AEPs (higher ARIs), particularly for values less than 4.9% (20 year ARI). Specifically, the 1978 annual maximum discharge (the highest discharge on record) is underpredicted by the Gumbel model, but shows tight agreement with the GEV model.

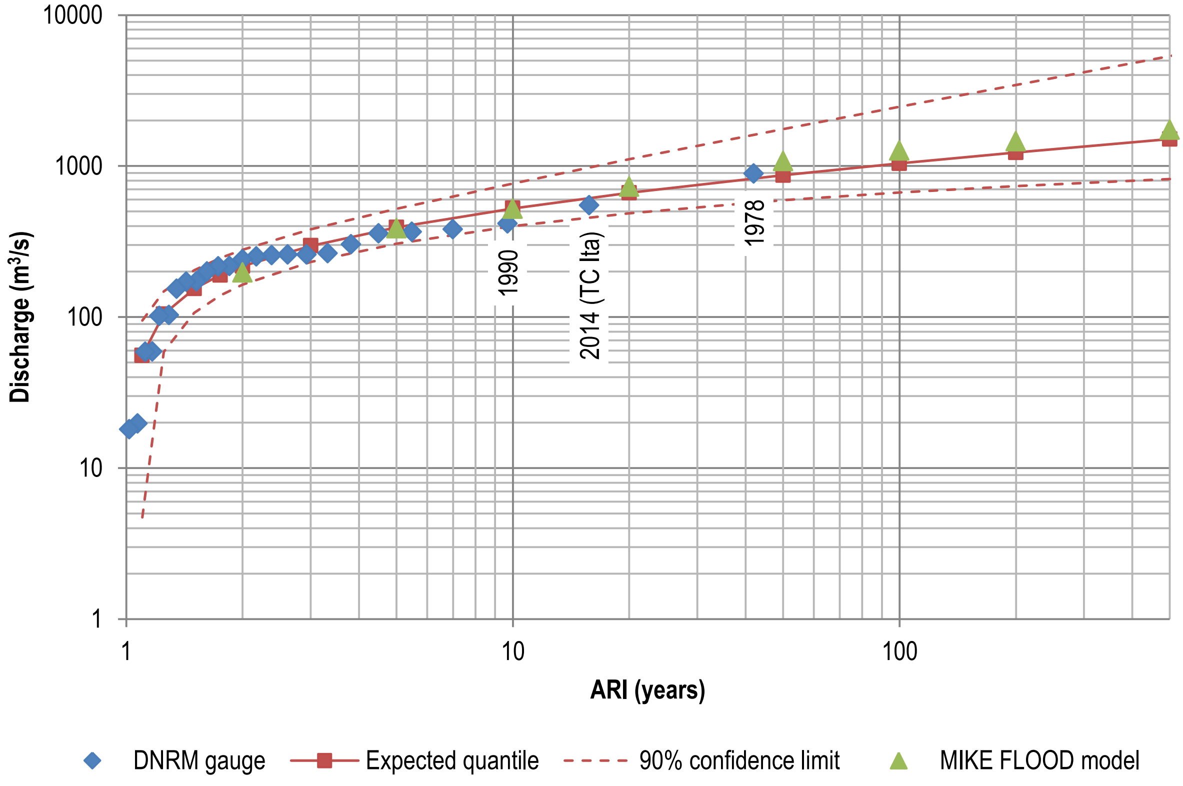

Figure 2.4 GEV probability distribution

Referring to the EAC MIKE FLOOD model results, the GEV model shows tighter agreement than the Gumbel model, particularly for AEPs < 9.5% (ARIs > 10 years). All MIKE FLOOD model datapoints are contained within the GEV distribution's 95% confidence envelope, whereas several points fall outside of this envelope for the Gumbel distribution.

In summary, it is considered that of the probability models considered in this assessment the GEV distribution provides the best fit to both the gauge data and MIKE FLOOD results.

3.0 <u>HYDRAULIC ANALYSIS</u>

3.1 MIKE FLOOD

The MIKE FLOOD modelling software was utilised to undertake the hydrodynamic modelling required for this flood study. This software package can link separate MIKE11 and MIKE21 models to run them simultaneously.

- MIKE11 – used to dynamically model one-dimensional, cross-road culvert and bridge structures.
- MIKE21 – used to dynamically model overland flows in two dimensions.

As mentioned previously, two models were utilised in this assessment:

- An existing broad-scale (10 m grid) Alligator and Whites Creek MIKE FLOOD model, originally developed by AECOM and updated by NCE as part of this flood study.
- A fine-scale (5 m grid) EAC MIKE FLOOD model, developed by NCE specifically for this flood study.

3.2 Modifications to existing Alligator and Whites Creek flood model

As part of this flood study, the following updates were made to the broad-scale Alligator and Whites Creek MIKE FLOOD model:

- 10 m DEM updated with 2009 LiDAR.
- The upgraded Bruce Highway formation in the EAC area was stamped into the model DEM.
- Alligator Creek bridge configurations updated within MIKE11 to better match 'as constructed' data supplied by DTMR and QR.
- Various culvert structures within the Bruce Highway and Northcoast Rail corridors were added, removed and updated to match the latest 'as constructed' data supplied by DTMR and QR.
- For AEPs ≥ 4.9%, the XP-RAFTS inflows for Alligator Creek were updated based on a calibrated loss model (refer to Section 2.1.1). To overcome instabilities encountered in rerunning these AEPs, the flooding and drying depths for these AEPs were reduced to 0.05 m and 0.02 from 0.1 m and 0.05 m.
- During the DEM update process, it was identified that many structures in the Whites Creek portion of the model were missing, misconfigured and/or incorrectly located. These were corrected as part of the broad-scale model updates.

3.3 Critical duration

AECOM's 'Alligator and Whites Creek Flood Study' (2008) report had identified that the critical storm duration for the Alligator Creek catchment was 24 hours.

An assessment was undertaken as part of this flood study to identify the design storm durations critical to the Study Area. Figure B-1 of Appendix B shows the critical durations throughout the Study Area and the areas to which they apply. Referring to this figure, it can be seen that the 2 and 24 hour storms control peak flood levels within the majority of the Study Area.

3.4 Model simulations

Table 3.1 summarises the baseline model simulations used to produce flood mapping of the Study Area.

Table 3.1 Baseline model simulations

Simulation #	AEP (%)	Duration (hours)	Boundary data
1	39.3 (2y)	2	39.3% AEP, 24 hour
2	39.3 (2y)	24	39.3% AEP, 24 hour
3	18.1 (5y)	2	18.1% AEP, 24 hour
4	18.1 (5y)	24	18.1% AEP, 24 hour
5	9.5 (10y)	2	9.5% AEP, 24 hour
6	9.5 (10y)	24	9.5% AEP, 24 hour
7	4.9 (20y)	2	4.9% AEP, 24 hour
8	4.9 (20y)	24	4.9% AEP, 24 hour
9	2 (50y)	2	2% AEP, 24 hour
10	2 (50y)	24	2% AEP, 24 hour
11	1 (100y)	2	1% AEP, 24 hour
12	1 (100y)	24	1% AEP, 24 hour
13	0.5 (200y)	24	0.5% AEP, 24 hour
14	0.2 (500y)	24	0.2% AEP, 24 hour
15	PMP	24	PMP, 24 hour

3.5 Hydrodynamics

3.5.1 Digital elevation model

A digital elevation model (DEM) of the Study Area was created from 2009 aerial survey (LiDAR). In order to appropriately define fine-scale hydraulic features within the Study Area, a 5 m grid was adopted. Thin hydraulic features (such as road centrelines and open drains), whose resolutions are typically lost during the LiDAR-to-DEM interpolation process, were stamped back into the DEM using DHI's Shape2MIKE Tool.

Figure A-3 of Appendix A shows the DEM used to model the Study Area.

3.5.2 Timestep

A timestep of 0.25 seconds was adopted for all simulations undertaken as part of this flood study. This value was adopted in accordance with DHI modelling guidelines, with consideration given to the grid size and the fact that Direct Rainfall is applied within the model domain.

3.5.3 Hydraulic structures

Cross-road drainage structures have been modelled utilising MIKE11, and coupled to the MIKE21 model using MIKE FLOOD. Appendix D of this report contains a summary of the MIKE11 structures included in the EAC flood model.

Figure 3.1 shows the Bruce Highway bridge over Alligator Creek, facing north towards Townsville.

Figure 3.1 Bruce Highway bridge over Alligator Creek

3.5.4 Boundary conditions

Table 3.2 summarises the boundary conditions used in the fine-scale MIKE21 model of the Study Area.

Table 3.2 MIKE21 boundary conditions

Boundary #	Boundary type	Boundary description
1	Outflow	Time series WSE extracted from broad-scale model
2	Outflow	Time series WSE extracted from broad-scale model
3	Outflow	Time series WSE extracted from broad-scale model
4	Inflow	Time series discharge extracted from broad-scale model

Figure A-1 of Appendix A shows the locations of the EAC flood model boundaries.

3.5.5 Eddy viscosity

A constant eddy viscosity of 2 m^2/s was applied globally to the model. This value was selected in order to satisfy model stability criteria with consideration given to the adopted grid size and timestep.

The velocity-based viscosity formulation method was selected, which is considered to be more appropriate over flux-based, the latter of which is only recommended for use in specific circumstances i.e. constant depth.

3.5.6 Hydraulic roughness

Table 3.3 shows the Manning's n values applied to the various surface types within the MIKE21 model. These values were confirmed visually during site investigations, verified as appropriate via calibration (refer to Section 3.6), and are in accordance with SC6.7.4.4.4 of the Townsville City Plan.

Table 3.3 2D Manning's n Values

Land use/surface type	Manning's n
Natural watercourses	0.025
Roads	0.030
Open grassland, rural residential zones	0.050
Low density vegetation, agricultural zones	0.080
High density vegetation, riparian zones	0.100

Figure 3.2 shows the characteristic surface roughness of rural grassland typical of the EAC area (photo taken from the Bruce Highway looking south into Lot 1 on RP886737).

Figure 3.2 EAC typical rural zone

Figure A-4 of Appendix A shows the roughness map used to model the Study Area.

3.5.7 Flooding & drying depths

Flooding and drying depths of 0.002 and 0.001 m were adopted, respectively. These values were selected in order to mitigate the risk of mass errors, and comply with DHI modelling guidelines.

3.6 Model verification

3.6.1 Verification to Severe Tropical Cyclone Ita (April 2014)

On 13 April 2014 Berrima Park estate experienced flash flooding due to heavy rainfall associated with Severe Tropical Cyclone Ita. The cyclone made landfall near Cape Flattery at 10pm on 11 April as a Category 4 system, and by the time it passed over Townsville it had weakened considerably to a Category 1 system, with its impacts being largely limited to rainfall at that stage.

Rainfall data supplied by TCC and obtained via BOM (graphed in Figure 3.3) indicates that Alligator Creek had experienced 215 mm of rainfall in the 24 hours to 2pm on 13 April 2014, with the peak average intensity occurring over a 12 hour period commencing around 9pm on 12 April 2014. Referring to the Cyclone Ita data plotted against the IFD curves in Figure 2.3, it can be seen that the peak rainfall correlates with an annual exceedance probability of around 18.1%.

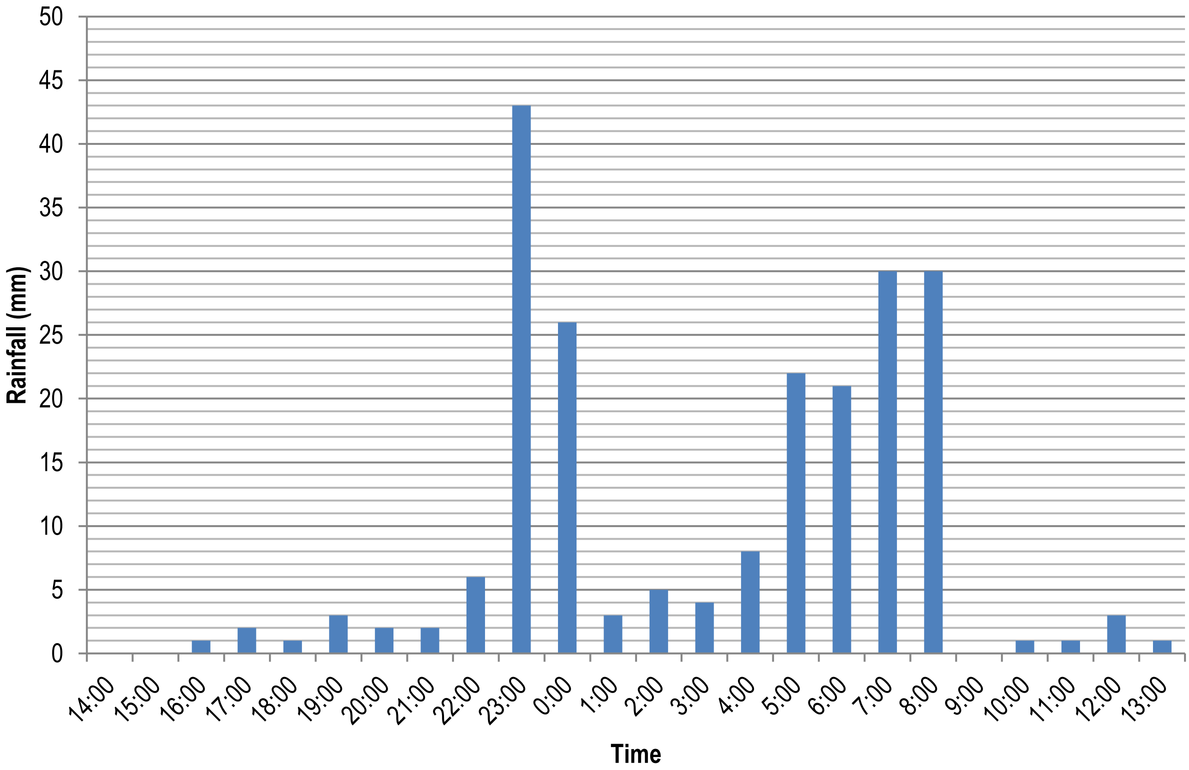

Figure 3.3 TC Ita – Rainfall at Alligator Creek from 2pm 14 April 2014

Due to the severity of flooding associated with a relatively high AEP/low ARI storm event, a detailed submission was compiled by the residents of Berrima Park estate which included photographs and sketch plans showing the extents of flooding. Appendix E of this report contains excerpts of this submission relevant to this flood study.

Given that rainfall data available from BOM could be correlated with photographic evidence of onsite flood impacts, this event was simulated using the EAC MIKE FLOOD model to verify adopted modelling parameters. Recorded rainfall data for the storm event was applied to the model via Direct Rainfall, and the results were compared against the Berrima Park submission to confirm that the extents and severity of flooding matched the data contained in the submission by the residents of Berrima Park.

Referring to the results of the Flood Frequency Analysis (Appendix H), it can be seen that the peak flow of the storm event within Alligator Creek correlates with a design storm with an annual exceedance probability of around 9.5%. As such, 9.5% AEP 24 hour design storm boundary conditions were applied to this simulation.

The results of this analysis are contained in Figure B-2 of Appendix B. These results show good correlation with the evidence collected onsite by local residents during the storm event. It was noted that the residents' submission show a slightly greater extent of flooding than the model results in certain areas, and this minor discrepancy could be attributed to blocked/ineffective culverts and/or sediment build-up within the table drains during the storm event. While this slight difference was noted, NCE considers the extent of flooding predicted by the model to match the onsite evidence sufficiently to give confidence in the adopted hydraulic parameters.

3.6.2 Comparison to DNRM rating curve

Rating curve data for DNRM station '118106A Alligator Creek at Allendale' was obtained from the DNRM for the purposes of verifying the Alligator Creek channel roughness parameters. Following a review of this data by NCE, it was found that there were errors associated with the data. At the time of writing, DNRM were in the process of amending the rating curve, and as such verified data was unavailable to undertake this assessment. It is proposed that a comparison will be undertaken as part of Phase 2 of this project if the updated rating curve is available at that time.

3.7 Sensitivity analyses

3.7.1 Sensitivity to roughness

During development of the model, two simulations were undertaken using preliminary data to assess the sensitivity of flood levels within the Study Area to the assumed hydraulic roughness values. These analyses are summarised in Table 3.4.

Table 3.4 Roughness sensitivity analyses

Roughness sensitivity analysis #	Description	Local runoff design storm	Boundary conditions	Appendix figure reference
1	All Manning's n values reduced by 10% from those shown in Figure A-4 of Appendix A.	1% AEP, 2 hour	1% AEP, 24 hour	Figure B-3
2	Alligator Creek channel Manning's n value increased from 0.025 to 0.035 (40% increase).	1% AEP, 24 hour	1% AEP, 24 hour	Figure B-4

The results of roughness sensitivity analysis 1 are shown in Appendix Figure B-3. These results show a mean reduction in flood levels of 39 mm, with a standard deviation of 13.5 mm. These results are skewed somewhat by results within Alligator Creek, which vary more significantly than across the EAC floodplain due to the volume of concentration of flows within the creek, making it more sensitive to changes in roughness.

Looking only at the statistics of the results to the east of Williams Road and south of the Bruce Highway (which represents the primary area of interest of this study), the mean reduction in levels is 7.8 mm, with a standard deviation of 14.8 mm. Given that the mean reduction in flood level is within standard modelling tolerance (10 mm), NCE do not consider the critical areas of the model to be overly sensitive to slight adjustments to roughness values.

Due to the higher sensitivity to hydraulic roughness demonstrated within Alligator Creek, a separate sensitivity analysis was undertaken for the creek only. The results of roughness sensitivity analysis 2 are shown in Appendix Figure B-4. Referring only to the subset of afflux greater than 1 mm, the mean increase in flood levels is 22 mm, with a standard deviation of 10.5 mm. While these results demonstrate a higher degree of sensitivity within the creek than the rest of the model, the roughness values selected for the creek were verified separately using DNRM data (refer to Section 3.6.2), greatly reducing the uncertainty associated with the adopted values and mitigating the risks associated with model sensitivity.

3.7.2 Sensitivity to boundary conditions

A simulation was undertaken to assess the sensitivity of flood levels within the Study Area to the adopted boundary conditions. The simulation applied a 1% AEP 24 hour local design storm via Direct Rainfall and 39.3% AEP 24 hour boundary data, which tests the effects of underestimating boundary data.

The results of this sensitivity analysis are shown in Appendix Figure B-5. Referring to this figure, it can be seen that the model's sensitivity to boundary conditions is isolated to the areas immediately surrounding the boundaries, and that flood levels within the Study Area beyond the influence of the boundaries are controlled by local runoff only.

It should be noted that for a 1% AEP 24 hour design storm, Alligator Creek does not break its banks upstream of the Bruce Highway. For design storms in which flows are not contained to the banks (AEP < 0.5%), the applied inflow data would influence flood levels upstream of the Bruce Highway more directly, particularly in the area of Noyland Road. This influence highlights the importance of correctly matching local and boundary data for these particular storm events.

It is for this reason that 2 hour analyses utilising 24 hour boundary conditions were not undertaken for design storm AEPs < 1%. 2 hour boundary conditions were not able to be applied to any simulations undertaken as part of this study, as 2 hour model setups for the existing Alligator and Whites Creek flood model were not provided, and setting up additional design storms for the broad-scale model was beyond the scope of this study.

3.7.3 Sensitivity to broad-scale 1D linking channel modifications

An additional check was undertaken to assess the sensitivity of WSEs in the EAC area to changes to the broad-scale model, specifically to major ground level changes at the interface of the broad-scale 2D model domain and a 1D linking channel that conveys runoff to a smaller 2D domain representing the ocean boundary. Levels at this location were increased by up to 1.5 m, which resulted in a WSE increase of 2 mm at the Alligator Creek gauging station in a 1% AEP storm event. This demonstrates that WSEs in the EAC area are not sensitive to major ground level changes at the linking channel interface.

4.0 RESULTS AND DISCUSSION

To summarise, this baseline flooding assessment has been commissioned by TCC as part of the first phase of a Drainage Master Plan for the EAC area. A fine-scale (5 m grid) MIKE FLOOD model was developed by NCE specifically for this project, utilising Direct Rainfall hydrology to model runoff from the local catchment. Boundary conditions were derived from the existing broad-scale (10 m grid) Alligator and Whites Creek MIKE FLOOD model, which was updated as part of this study with more recent LiDAR data.

The model was validated against a flood event associated with Severe Tropical Cyclone Ita (April 2014), and showed good correlation with observed flooding. An IFD assessment provided by TCC indicates that this event corresponded with a design storm AEP of just under 18.1%.

The critical durations were found to be 2 and 24 hours, with the 24 hour storm representing the dominant duration for the majority of design storm AEPs.

Appendix C of this report contains flood mapping for the simulations described in Table 3.1. The flood mapping includes plots of maximum surface elevation, depth and velocity.

It should be noted that the results have been filtered to exclude areas where the depth of flooding is less than 100 mm, unless the velocity exceeds 0.8 m/s. This is in accordance with TCC's guidelines for the presentation of flood mapping.

4.1 Flooding upstream of the Bruce Highway

Results for the 1% AEP design storm indicate that the immediate ~400 m of the Study Area upstream of the Bruce Highway experiences almost complete inundation, with the only portions unaffected being isolated areas closest to Williams Road and Tindall Court. The average maximum depth of flooding in this area is ~570 mm. Given the extent and severity of flooding in this area, any potential developments would need to be supported by specific analyses with the possible incorporation of mitigation measures and consideration of evacuation issues. Phase 2 of this project will further assess the potential for development in this area.

4.2 Berrima Park Estate

It is noted that a significant portion of allotments within Berrima Park Estate experience inundation in a 39.3% AEP (2 year ARI) design storm. Up to 10 residential allotments of 31 (~32%) are affected, with 6 allotments experiencing full or nearly-full inundation, and with 4 allotments experiencing partial inundation. The number of affected allotments increases with decreasing AEPs, and in a 1% AEP design storm event approximately 75% of the estate is significantly affected by inundation. The average depth of flooding over affected allotments in a 1% AEP design storm is approximately 250 mm. Lot 19 on SP210994 experiences near total inundation in a 1% AEP design storm, with an average depth of 590 mm and a maximum of 620 mm on this lot.

The results indicate that the flooding is caused by a lack of positive drainage offsite once flows accumulate within the major infiltration/bioretention device and table drains. The bulk of these flows originate offsite, with the top of the local catchment terminating at a hill close to Godier Road (Lot 20 on SP248103). NCE consider that the extent and severity of flooding within this estate could be alleviated by diverting upstream flows away from the estate and into a drainage channel that would direct flows to the Bruce Highway. The flat topography of the Study Area limits the potential for overland drainage, and these options and limitations will be considered further in Phase 2 of this project.

4.3 Alligator Creek overflows

Having updated the existing Alligator and Whites Creek MIKE FLOOD model with 2009 LiDAR over the Study Area, it is noted that a major overflow predicted upstream of the Bruce Highway adjacent to Noyland Road for design storm AEPs > 1% no longer occurs, and now occurs for design storm AEPs < 0.5% (overflow observed in 0.2% AEP storm, but not in 0.5% AEP storm).