PLANNING AND ENVIRONMENT COMMITTEE 13 JUNE 2018	5

FORENSIC REVIEW OF THE REDLYNCH VALLEY RAINFALL EVENT OF 26 MARCH 2018 – RESULTS OF INVESTIGATIONS

M Ringer | 1/3/21-20 | #5742616

RECOMMENDATION:

That Council notes the report and the independent assessment report for the rainfall and flooding event of 26 March 2018 in Redlynch Valley.

EXECUTIVE SUMMARY:

This report summarises the findings of an independent forensic review of the significant rainfall event associated with Cyclone Nora during the night of 26 March 2018 which caused major flooding in Redlynch Valley. The independent review is provided as Attachment 1, and details the outcome of Stage 1 investigations, including an analysis of rainfall, stream gauge data and an assessment of the magnitude of the rainfall and flood event.

Council also invited members of the public to provide submissions on the flood event for further investigation. A total of 23 submissions were received and considered by the independent consultant.

In summary, the flooding event that occurred in the Redlynch valley in the Rocks Road area had an average recurrence interval of about 100 years. The primary cause of the flooding in the Rocks Road area was floodwater in Freshwater Creek. Currunda Creek contributed approximately 25% of the total flood flow.

There was evidence of significant debris and sediment loads from erosion and landslips in the upper Freshwater and Currunda Creek catchments. There is no evidence of dam or levee collapses in Currunda Creek occurring or contributing to flooding downstream. Major flood debris blockage on the Currunda Creek crossing of Redlynch Intake Road exacerbated flooding locally in Currunda Creek and downstream in the Rocks Road area.

A Stage 2 report detailing the results of the hydraulic modelling and potentially confirming the findings of the Stage 1 report will be provided to Council by the end of June 2018.

BACKGROUND:

Council at the Ordinary Meeting on 24 April 2018 endorsed a recommendation to ‘note the report and the independent reviews that are currently underway relating to the recent rainfall associated with Cyclone Nora’.

A significant rainfall event occurred in the Freshwater Creek and Currunda Creek catchments on the evening of 26 March 2018 which resulted in flooding of several residential properties, the Crystal Cascades Holiday Park, the Redlynch Valley Tennis Centre and Equestrian Park, and Council parks and roads.

Following the flood event, Council engaged an experienced consultant to carry out an independent forensic review of the rainfall event, and report on the findings. This report presents those findings as Attachment 1.

Council also invited residents to provide submissions on flood related matters. There were 40 public submissions received by Council in relation to flooding in Redlynch Valley.

Key issues of concern identified were:

- The extreme nature of flooding in the Currunda Creek catchment and associated severe erosion, bank collapse and resulting flood debris.
- Currunda Creek culverts, flood debris blockage and sedimentation and associated flooding impacts.
- Flood debris blockage and associated flooding impacts on Freshwater Creek bridges, including the Mary Parker Drive bridge.
- Local stormwater drain siltation and lack of maintenance.
- Fences across flow paths and associated flood impact
- Alterations to Currunda Creek upstream of Redlynch Intake Road.
- A 2m surge of mud, water and debris at the caravan park site.
- Diversion of additional Currunda Creek flows due to 2m high debris dam at the Redlynch Intake Road crossing north-east and then north in the floodplain with an elevated flow path along The Rocks Road.

COMMENT:

Based on rainfall, radar and rainfall runoff modelling analysis, the flood event of 26 March 2018 at the Caravan Park site and adjacent tennis complex was about a 100 year average recurrence interval (ARI) flood event.

Major flood debris blockage on the Currunda Creek crossing of Redlynch Intake Road exacerbated flooding locally in Currunda Creek and downstream in the Rocks Road area, with significant flood flow breakout to the north-east occurring. The debris load also caused the guard rail to collapse which may have produced a flood wave. Detailed flood modelling is required to assess the potential magnitude and extent of any break-out flows or any flood wave which will occur in stage 2 of the consultancy.

The primary cause of flooding of the Caravan Park site was identified as Freshwater Creek flooding, with Currunda Creek contributing around 10% of the total combined catchment area and about 25% contribution to total flood flow.

Flood debris and sediment transported downstream in the event contributed to damage at the Caravan Park and tennis centre, and in The Rocks Road area. There is evidence that the debris and sediment load down Currunda Creek was higher in concentration than that in the main Freshwater Creek channel.

There is no evidence of dam or levee collapses in Currunda Creek occurring or contributing to flooding downstream. There was severe erosion and stream bank collapse in Currunda Creek, and there may have been land slips in the upper catchments of Currunda Creek and Freshwater Creek downstream of the dam which caused the very high debris and sediment load.

Detailed flood modelling to be incorporated in Stage 2 investigations will assist in confirming the above conclusions.

OPTIONS:

Option 1: (Recommended)

That Council notes the report and the independent assessment report for the rainfall and flooding event of 26 March 2018 in Redlynch Valley.

Or

Option 2:

That Council notes the report and arranges a further independent review of the Redlynch Valley rainfall event of 26 March 2018.

CONSIDERATIONS:

Risk Management:

The independent assessment report and the future stage 2 report will assist Council in mitigating the impacts of future flood events within the Freshwater Creek and Currunda Creek catchments.

Corporate and Operational Plans:

This report relates to the following strategic goal identified in Council's Corporate Plan: Liveability – ensure our community is prepared for disasters.

Statutory:

Council has statutory obligations under the *Disaster Management Act (2003)* for management of natural disasters such as floods and cyclones.

Policy:

There are no specific policies of Council relevant to this matter.

CONSULTATION:

Several of the residents most affected by the flood event were contacted by the independent consultant to provide further insights into the event.

ATTACHMENTS:

Attachment 1- Independent Assessment Report - Rainfall and Flooding Event of 26 March 2018 in Redlynch Valley Cairns (Stage 1 Report).

Michael Ringer
Co-ordinator Strategic Planning

Helius Visser
Manager Infrastructure Planning

Bruce Gardiner
General Manager Infrastructure Services

Independent Assessment Report Rainfall and Flooding Event of 26 March 2018 in Redlynch Valley Cairns Stage 1 of 2 Report

Prepared for Cairns Regional Council

Reference: R.B23195.001.01.Independent Assessment
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BMT WBM Pty Ltd
Level 8, 200 Creek Street
Brisbane Qld 4000
Australia
PO Box 203, Spring Hill 4004

Tel: +61 7 3831 6744
Fax: + 61 7 3832 3627

ABN 54 010 830 421

www.bmt.org

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Project Manager:	Neil Collins
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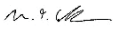
1	6 June 2018	Garry Lambourne		Neil Collins	

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1 Purpose of the Report

This report details the findings of an independent forensic review of the significant rainfall event during the night of 26 March 2018, which caused major flooding in the Redlynch Valley below Copperlode Falls Dam, and which impacted specifically on The Rocks Road Big 4 Crystal Cascades Caravan Park (the Caravan Park) and on nearby tennis courts and residential properties. The report details the outcomes of our Stage 1 investigation, and details:

- Rainfall analysis
- Stream gauge analysis
- Rainfall run-off modelling
- Radar rainfall imagery assessment
- Preliminary assessment of contribution to flooding from Freshwater Creek and Currunda Creek
- An assessment of the magnitude of the event

Stage 2 investigations, which were underway at the issue date of this report, include detailed hydraulic flood modelling to assess the extent of flooding, to refine the assessment of contributions to flooding from Freshwater Creek and Currunda Creek, and to further review the magnitude of the event.

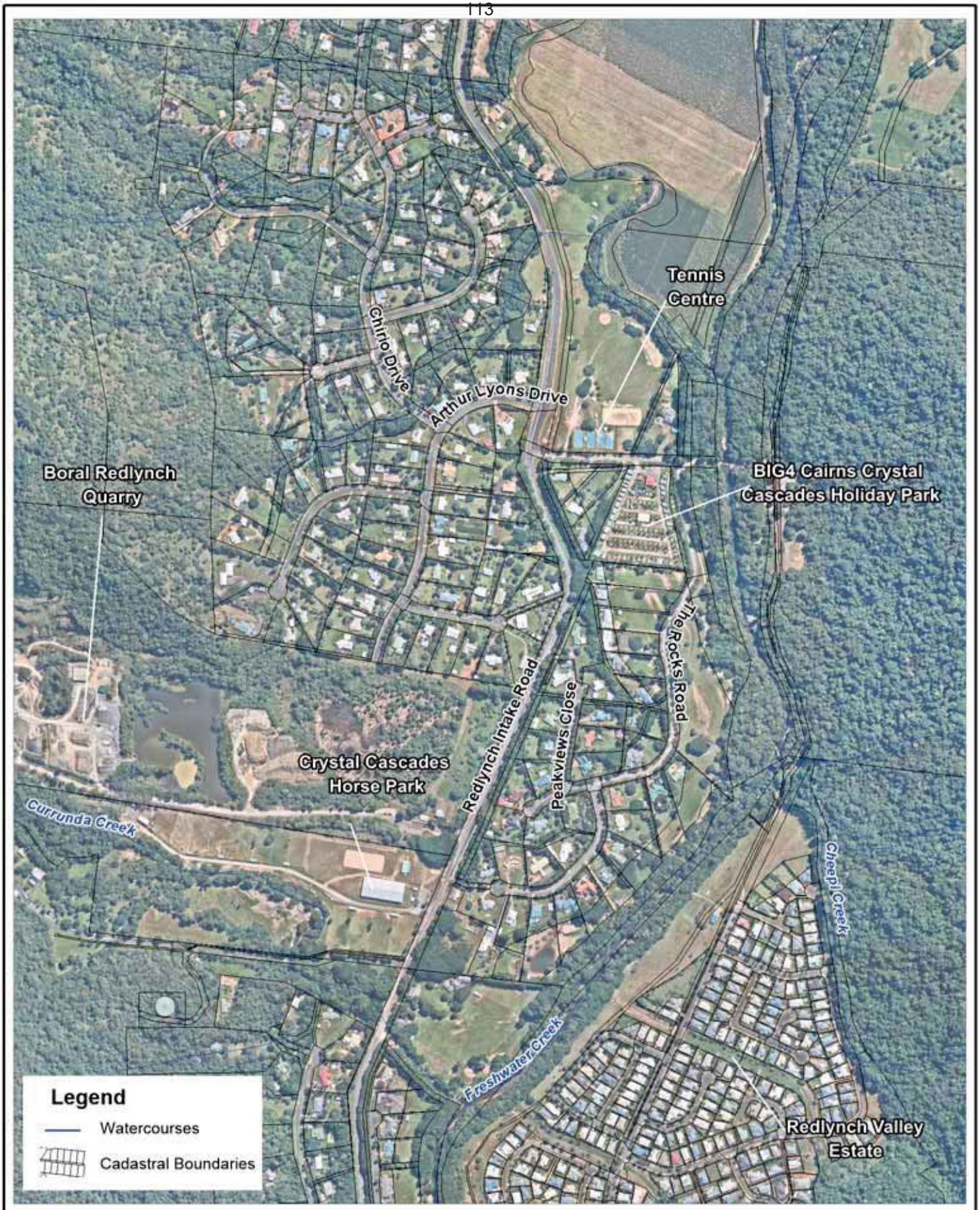
This report has been prepared by Neil Collins, a specialist in flood assessment. Neil's CV is included in Appendix A.

Photographs 1 and 2 show flooding damage at the caravan park and tennis centre.

Figure 1-1 shows the primary area of investigation

Photo 1 – Flooding at Crystal Cascades Caravan Park
(Photo Courtesy of Cairns Post)

Photo 2 – Damage to Tennis Centre
(Photo Courtesy of Cairns Post)



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Area of Investigation

Figure: **1-1**

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2 Background

2.1 Flooding in Redlynch Valley

There had been several significant rainfall events prior to the flooding late in the evening of 26 March 2018 (the Flood Event). Over 200mm rain fell over the valley on Sunday 25th March, with over 100mm recorded at Copperlode Falls Dam between midnight and 10:00 am on the 26th March. The Freshwater Creek catchment was saturated before the Flood Event with Copperlode Dam full and overflowing. 233mm of rain was recorded at Copperlode Falls Dam gauge between 7:00 pm on the 26th March and midnight.

Severe flooding occurred in Currunda Creek, with severe bank erosion, causing the bank to collapse and resulting in very large debris load, including large trees and boulders.

2.2 Description of the Flood Event of 26th March 2018

Based on anecdotal evidence, around 10:00 pm, flood waters had broken out of the main Freshwater Creek channels and flood levels were rising rapidly in Redlynch Valley estate, in The Rocks Road, and along Currunda Creek. Peak flooding in these areas occurred between 11:15 pm and 11:30 pm, after which flooding rapidly receded.

The worst affected areas were the Caravan Park, the adjacent tennis centre, several properties along The Rocks Road, a property at the north-western extent of Redlynch Valley Estate opposite The Rocks Road, and on properties adjacent to the Redlynch Intake Road crossing of Currunda Creek.

Flood depths of over a metre were experienced along The Rocks Road and through the Caravan Park and tennis centre.

The properties affected along Currunda Creek were both upstream and downstream of the crossing. A large amount of flood debris collected at the Redlynch Intake Road culvert crossing of Currunda Creek, exacerbating flooding.

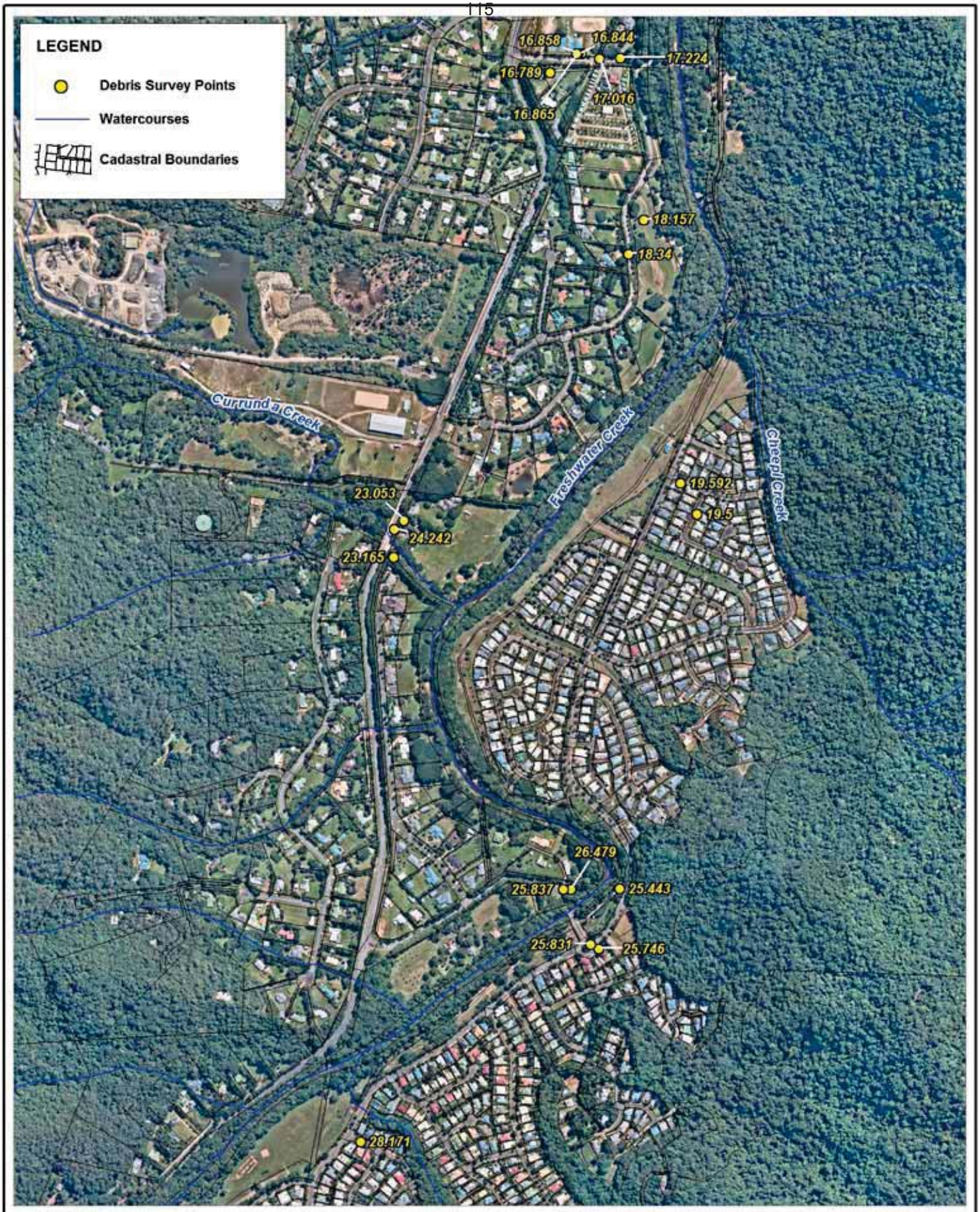
Further upstream in Currunda Creek, within Crystal Cascades Horse Park, major stream erosion and migration occurred, and a large amount of flood debris was collected on the private access driveway culvert crossing, which also exacerbated local flooding and flow paths within the Horse Park.

2.3 The Rocks Road Big 4 Cairns Crystal Cascades Caravan Park

Based on the caravan park owners' description, floodwaters rose rapidly at the Caravan Park, with a very large sediment and debris load inundating the park within minutes, with inundation lasting less than an hour with a rapid rate of fall after the peak.

2.4 Measured Peak Flood Debris Marks

During my inspection of the area on the 10th April 2018, peak flood debris marks were identified and subsequently surveyed. Figure 2-1 shows the results of this survey.



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Debris Survey Points

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3 Public Submissions on the Flood Event

In total, approximately 40 public submissions were received by Cairns Regional Council in relation to flooding in Redlynch Valley.

Key issues of concern identified were:

(a) The extreme nature of flooding in the Currunda Creek catchment and associated severe erosion, bank collapse and resulting flood debris.

(b) Currunda Creek culverts, flood debris blockage and sedimentation and associated flooding impacts.

(c) Flood debris blockage and associated flooding impacts on Freshwater Creek bridges, including the Mary Parker Drive bridge.

(d) Local stormwater drain siltation and lack of maintenance.

(e) Fences across flow paths and associated flood impact.

(f) Alterations to Currunda Creek upstream of Redlynch Intake Road.

(g) A 2m surge of mud, water and debris at the caravan park site.

(h) Diversion of additional Currunda Creek flows due to 2m high debris dam at the Redlynch Intake Road crossing north-east and then north in the floodplain with an elevated flow path along The Rocks Road.

Photograph 3 shows flood debris on the Redlynch Intake Road crossing of Currunda Creek.

Photograph 4 shows flood debris on the Mary Parker Drive bridge.

Photograph 5 shows the mud and debris deposited by the flood.

Photograph 6 shows the stream bank stabilisation works upstream of the Redlynch Intake Road on Currunda Creek.

Photo 3
(Photo Courtesy of Dean Simonis)

Photo 4
(Photo Courtesy of Dean Simonis)

Photo 5
(Photo Courtesy of Sharone Spannenburg)

Photo 6
(Photo Courtesy of Brownwyn Drayton)

4 Analysis of the Event

4.1 Inspection

On 10 April 2018, Neil Collins undertook an inspection of the Freshwater Valley where flooding had occurred. The inspection included:

- The full length of Redlynch Intake Road.
- The Rocks Road, Crystal Close and Parkviews Close.
- The caravan park site and tennis centre.
- Crystal Cascades Horse Park.
- Redlynch Intake Road Currunda Creek crossing.
- Redlynch Valley Estate including Mary Parker Drive crossing of Freshwater Creek, Gamburra Drive and Xavier Herbert Drive.
- Redlynch Intake Road crossing of Freshwater Creek near Cascades Drive.

Photographs 7 and 8 show the private access driveway crossing on the Horse Park and the flood debris that had been trapped at the bridge, whilst photos 9 and 10 show the erosion just downstream of the driveway crossing and associated large flood debris.

Photo 7
(Photo Courtesy of Pat Flanagan)

Photo 8
(Photo Courtesy of Pat Flanagan)

Photo 9 – Erosion Downstream from Driveway Crossing *(Photo from Site Inspection)*

Photo 10 – Erosion Downstream from Driveway Crossing *(Photo from Site Inspection)*

Photograph 11 shows the tennis centre and flood depth from debris marks.

Photographs 12 and 13 show the Mary Parker Drive crossing of Freshwater Creek.

Photographs 14 and 15 show Redlynch Intake Road crossing of Currunda Creek from upstream and downstream.

Photograph 16 shows existing fencing at the northern extend of Herbert Xavier Drive.

Photographs 17 and 18 shows the bridge crossing of Freshwater Creek and adjacent water supply pipeline crossing near Cascades Drive.

Photo 11 – Tennis Centre and Flood Depth Debris Marks *(Photo from Site Inspection)*

Photo 12 – Mary Parker Drive – Crossing of Freshwater Creek *(Photo from Site Inspection)*	**Photo 13 – Mary Parker Drive – Crossing of Freshwater Creek** *(Photo from Site Inspection)*

Photo 14 – Redlynch Intake Road Crossing of Currunda Creek from Upstream *(Photo from Site Inspection)*	**Photo 15 Redlynch Intake Road Crossing of Currunda Creek from Downstream** *(Photo from Site Inspection)*

Photo 16 – Existing Fencing at the Northern Extent of Herbert Xavier Drive *(Photo from Site Inspection)*

Photo 17 - Bridge Crossing of Freshwater Creek near Cascade Drive *(Photo from Site Inspection)*

Photo 18 - Water supply pipeline crossing near Cascade Drive *(Photo from Site Inspection)*

From these photographs, and from the inspection, some observations are as follows:

a) There was a very high flood debris load in Currunda Creek, possibly exacerbated by severe bank erosion and landslips.

b) There was a significant flood debris load in Freshwater Creek from Crystal Cascades to Mary Parker Drive and there is anecdotal evidence of upper catchment landslips.

c) Flood debris built up and partially blocked the culverts on the Redlynch Intake Road crossing of Currunda Creek, with break-out flow occurring to the north-east. There was up to 2m height of debris above road deck level.

d) Guard rails on the Redlynch Intake Road Currunda Creek crossing failed during the event due to overtopping and debris load. The rate of failure is unknown, but could have resulted in a localised rapid surge in downstream flood levels.

e) Mud and sediment deposition was significant in The Rocks Road, and along Currunda Creek.

f) Flooding through The Rocks Road, the Caravan Park and the tennis centre was generally 1 to 1.5m peak depth, with velocities in the vicinity in the overbank floodplain likely in excess of 2m/s.

4.2 Rainfall Station Analysis

There are two continuous rain gauges within the Freshwater Creek catchment, being the Copperlode Dam Alert Station and the Brinsmead Alert Station. Nearby rain gauges are at Bolton Road Alert and Kamerunga Bridge Alert.

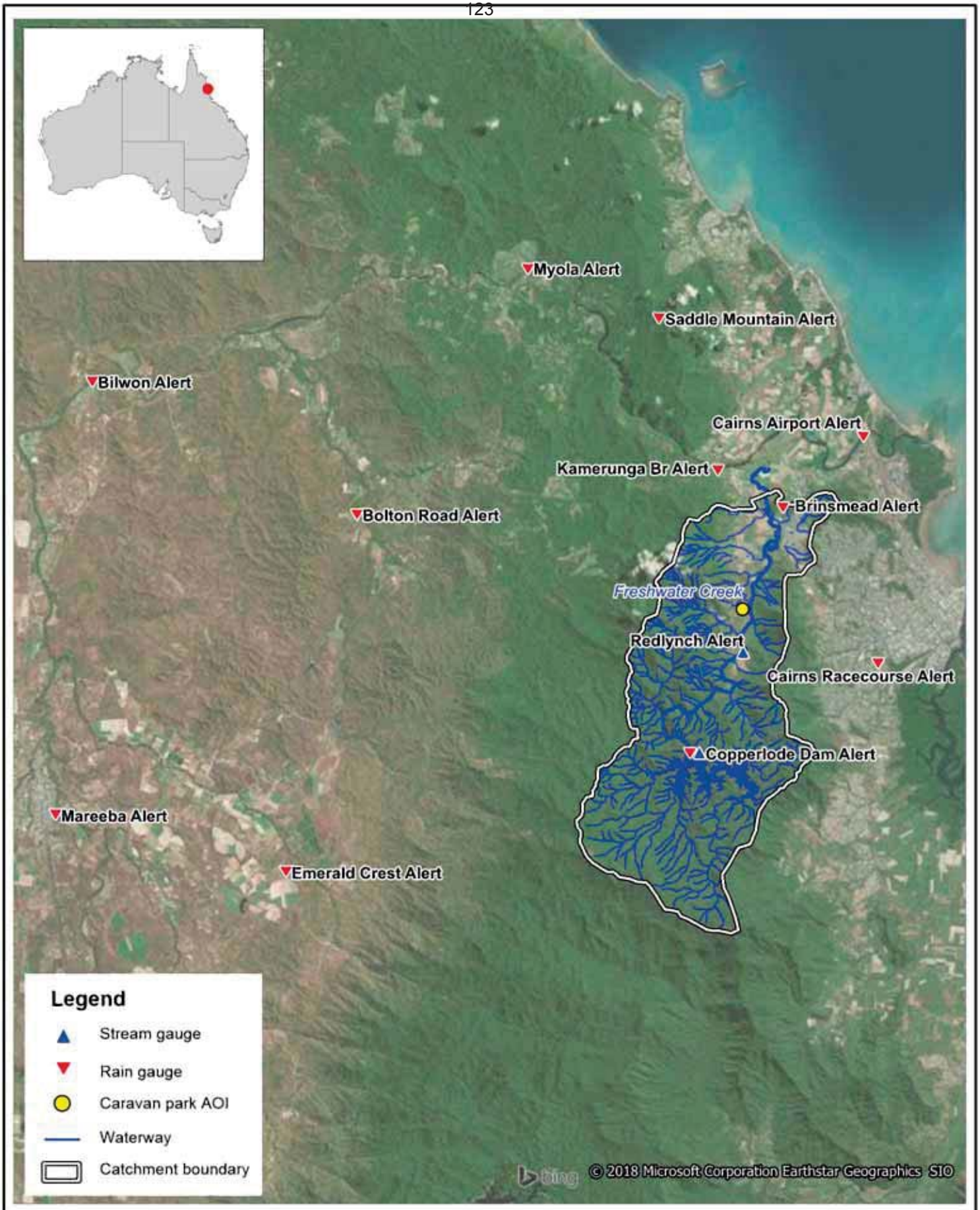
Figure 4-1 shows the locations of all rain gauges in the general area, as well as the stream gauges at the dam and at Redlynch.

A detailed analysis of all rain gauges for the event of 26 March 2018 was carried out. A summary of key results is as follows:

- Copperlode Dam Alert received greater than 100 year ARI (Average Recurrence Interval) rainfall burst for the 1 hour to 6 hour durations.
- Bolton Road Alert received greater than 100 year ARI rainfall burst for 3 to 6 hour duration events.
- Emerald Crest Alert received approximately 100 year ARI rainfall burst for 3 to 6 hour durations events.
- Myola Alert received approximately 70 year ARI rainfall burst for 2 to 3 hour duration event.

Brinsmead, Cairns Airport and Cairns Racecourse had much less intense rain with less than 3 year ARI bursts.

Detailed results are included in Appendix B.



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4.3 Stream Gauge Analysis

The recorded peak depth over the Copperlode Dam spillway was 2.409m. At this depth, the estimated flow from the spillway rating curve is 177 m^3/s.

The Redlynch gauge just upstream of Mary Parker bridge recorded a peak depth of 6.64mGH (26.111mAHD based on a Zero Gauge Datum of 19.475mAHD), between 10:00 pm and 11:40 pm; however there were significant gaps in the recording in that period. Based on an extrapolation of the gauge rating, this equates to a peak flow of 425m^3/s. It is important to note, however, that the rating curve at this depth is unreliable.

A flood frequency analysis was also carried out for the Copperlode Dam and Redlynch stream gauges; however there was insufficient record length to provide any level of confidence in the results, with 19 years record at Redlynch and only 14 years suitable at the dam. Hence, the results of this analysis will significantly underestimate the severity of the 26 March 2018 event.

Appendix C contains details of the steam gauge analysis, including stage recordings, rating curve reliability and flood frequency assessments.

4.4 Rainfall Run-off Modelling

BMT has utilised rainfall runoff catchment modelling to assess flood flows for a range of ARI events, and to assess flows for the actual event of 26 March 2018, particularly in Freshwater Creek at critical locations, and in Currunda Creek. This required expansion and initial refinement of an existing model previously developed by BMT in 2017 for Stage 1 investigations.

The methodology is based on Australian Rainfall and Runoff 1987, consistent with current flood planning for Redlynch Valley, and with previous development approvals.

Resultant design flood flow estimates for a range of ARI events is as shown in Table 4-1 below.

Table 4-1 Estimated Design Peak Flows WBNM Model

ARI (Years)	AEP (Annual Exceedance Probability) (%)	Copperlode Dam (Outflow) m^3/s	Redlynch Gauge m^3/s	Rocks Road Causeway m^3/s	Currunda Creek (upstream of Redlynch Intake Road)	Kamerunga Road m^3/s
100	1	262	468	612	207	870
50	2	222	399	527	181	748
20	5	173	318	467	168	658
10	10	137	261	386	141	544

Table 4-2 shows the estimated peak flow and magnitude estimate for the 26 March 2018 event, based on rainfall runoff modelling, at five critical locations in the catchment. It should be noted that the estimated peak flows and magnitude are based on the total rainfall depths and temporal patterns recorded at the Copperlode Dam rainfall gauge being applied across the whole Freshwater Creek catchment. However, total rainfall depths and temporal patterns will vary across the catchment as

demonstrated by the variance between the Brinsmead Gauge and Copperlode Dam Gauge. It is also expected that orographic effects along the valley's ridgelines could potentially influence rainfall intensities amongst the elevated watersheds of the catchment. The actual event also was highly variable in special extent of rainfall, rainfall intensity and duration of rainfall at high intensity and there are insufficient continuous rainfall gauges within the catchment to quantify fully the event.

Table 4-2 Estimated March 2018 Peak Flows and AEP

Location	Estimated WBNM Peak Flow (m3/s)	Modelled Time to Peak	Approximate AEP %*	ARI (Years)
Copperlode Dam outlet	168	2:50am 27th	5	20
Catchment A6 (approximate Redlynch Gauge)	489*	11:20pm 26th	<1.0	>100
Catchment A8 (approximate Rocks Road Causeway)	704*	11:20pm 26th	<1.0	>100
Currunda Creek A7H (upstream of Redlynch Intake Road)	209*	10:50pm 26th	1.0	100
Kamerunga Road A35	947*	11:30pm 26th	<1.0	>100

**These are preliminary estimates only for the Stage 1 Assessment and will be refined in Stage 2 investigations, based on joint hydrologic and hydraulic modelling. It should be recognised that these further investigations may impact on the evaluation of the approximate AEP of the event across different locations within the overall catchment.*

Catchment area details to various locations are provided in Table 4-3 below.

Table 4-3 Catchment Details

Location	Total Catchment Area (ha)
Copperlode Dam outlet	4,468
Catchment A6 (approximate Redlynch Gauge)	7,038
Catchment A8 (approximate Rocks Road Causeway)	8,251
Currunda Creek A7H (upstream of Redlynch Intake Road)	832

It is important to note that Currunda Creek only contributes about 10% of the total catchment area draining to The Rocks Road causeway.

Based on the hydrologic modelling, the critical Freshwater Creek catchment response time to peak at Rocks Road is around 2 to 3 hours, and that Currunda Creek peaks in under 2 hours.

Appendix D contains details of the rainfall runoff modelling and results, including hydrographs for the event.

4.5 Radar Data

An analysis of rainfall radar imagery for the event of 26 March 2018 has been carried out. Detailed enlargements of a time series of radar images is provided in Appendix E. Based on these images, the following can be determined in relation to the event of 26 March 2018.

- Rainfall from the main portion of the flooding event commenced as light rain around 8:00 pm.
- Moderate to heavy rain fell in the upper half of the catchment around 10:00 pm.
- By 10:30 pm, moderate to heavy rain was continuing in the upper catchment and extended downstream in the catchment to downstream of the Caravan Park site.
- Heavy rain occurred in the Currunda Creek catchment between 10:00 pm and 11:00 pm.
- By 11:30 pm, only light rain was falling in the upper catchment.

Anecdotal evidence from residents indicate that the main rain event was associated with a thunderstorm, and this storm approached from the north-west and moved to the south, south-west. There appears to be less total rainfall in the downstream areas of the catchment which is consistent with the available rain gauges.

5 Magnitude of the Event at the Caravan Park

Given that the stream gauge rating and period of record has been found to be unreliable, I base my assessment of event magnitude for this stage 1 investigation on rainfall analysis, coupled with rain radar data, and on the Stage 1 rainfall runoff modelling.

In terms of rainfall, the radar evidence indicates that the dam rain gauge is likely most representative of rainfall that fell over the majority of the catchment draining to the caravan park, for both Freshwater and Currunda Creeks.

5.1 Freshwater Creek

Based on the Copperlode Dam rain gauge analysis, the rainfall event leading to the flooding in Freshwater Valley was in excess of a 100 year ARI event, for all durations from the 1 hour to 6 hours with the critical duration to peak to the Caravan Park site being 2 to 3 hours. Based on the Stage 1 rainfall runoff modelling assuming the Copperlode Dam rainfall totals and temporal patterns across the entire catchment, the flood event was estimated to be approximately a 100 year ARI event at the Caravan Park site, and along The Rocks Road. There is anecdotal evidence that flooding in the main channel of Freshwater Creek adjacent to the junction with Currunda Creek was at a lower level than the adjacent western bank flooding. The large debris build-up at Redlynch Intake Road Crossing of Currunda Creek is likely to have elevated flood levels locally resulting in more extreme equivalent ARI event levels.Currunda Creek

Based on the Copperlode Dam rain gauge analysis and assuming similar rainfall totals and temporal patterns fell over the local catchment, the rainfall event in Currunda Creek that lead to flooding in its lower reaches was estimated to be greater than an 100 year ARI event, for the critical duration to peak of 2 hours.

Based on the Stage 1 rainfall runoff modelling, the flood event was estimated to be greater than an 100 year ARI event at the Redlynch Intake Road Crossing.

Around the Redlynch Intake Road Crossing and further downstream, more extreme equivalent ARI event levels may have occurred in some areas because of the debris blockage over 2m high above the road deck diverting flows.

The severe to extreme scour and debris load that occurred in Currunda Creek is another indication of how severe this event was.

5.2 Stage 2 Investigations

The above estimates of magnitude will be reviewed as part of Stage 2 investigations which are currently underway. Detailed two-dimensional flow modelling with joint hydrologic and hydraulic model calibration is being used to refine estimates of the event magnitude in both Freshwater Creek and Currunda Creek. An assessment of the impact of the debris blockage on the Currunda Creek crossing will also be carried out. It should be recognised that there are a number of variables which could impact on the joint calibration process and the ability to achieve a high reliability calibration. These variables include:

- Limited rainfall gauges across the catchment that could confirm the spatial variance in rainfall totals, intensities, timing and temporal patterns;
- The impact of blockages at the major road crossings which could result in alternative flow paths and elevated flood levels. The timing of blockages could also influence the flooding experienced during the actual event which may be difficult to replicate during the modelling process;
- The potential for scour and bed/bank movement along the creeks during the event which could provide increased conveyance capacity and lower relative flood levels with equivalent flows;
- Localised diversions or obstructions to flows due to debris loads on fences or structures;
- Accuracy of the LiDAR data used to represent the topography across the modelled area. Accuracy can be particularly affected in areas of dense vegetation and along creeks/streams where the bed is submerged; and
- The reliability of surveyed debris levels as accurate estimates of peak flood levels.

6 Contributions to Caravan Park Site Flooding

6.1 Freshwater Creek & Tributaries

Based on Table 4-3, which provides catchment areas to critical locations, there is 4,468 hectares of catchment to the dam and 3,783 hectares of catchment area downstream of the dam to The Rocks Road causeway. Currunda Creek to Redlynch Intake Road has an area of 832 hectares, or 10% of the total Freshwater Creek catchment area to Rocks Road causeway.

There is evidence that flooding in Currunda Creek may have been more severe than estimated and that the Redlynch Intake Road culvert crossing debris build-up worsened flooding locally and downstream. However, given that Currunda Creek flows are forced by topography to join Freshwater Creek flows by the time they reach the Caravan Park, the primary cause of flooding at the Caravan Park site and the tennis centre was floodwater from Freshwater Creek.

There is anecdotal evidence of a preferential flow path along The Rocks Road, elevated above the main Freshwater Creek channel flooding with Currunda Creek break-outflows significantly contributing to this flow path. Flood modelling in Stage 2 investigations will better define this flow path.

6.2 Flood Debris Blockage

Flood debris blockage had a significant effect on the Currunda Creek Redlynch Intake Road Crossing, and on the upstream private road crossing in the Crystal Cascades Horse Park. In terms of the latter, whilst localised flood levels increased and flow diversions resulted, there is no evidence that this had any effect on flooding at the Redlynch Intake Road Crossing.

Major flood debris blockage at the Redlynch Intake Road Crossing is likely to have increased flooding levels immediately upstream, and this resulted in additional flow diversion around the blockage, primarily in the north but also in the south.

At some stage during the flood event, the road culvert crossing guard rail gave way and collapsed, which would have released some of the debris build-up. Given the amount of debris likely to have accumulated, the failure is likely to have resulted in a localised surge in flood levels downstream. It is possible that such surge, on top of the already high level of flooding, could have added a transient rapid flood wave down Currunda Creek and its floodplain. Detailed flood modelling is required to assess the magnitude of any surge, and its likely persistence downstream.

The debris build-up on the Redlynch Intake Road Crossing is likely to have worsened flooding on the three adjacent properties (one upstream, two downstream).

Detailed flood modelling is required to assess the magnitude of any worsening due to the debris load.

It is important to appreciate that large debris loads in largely undeveloped forested catchments in the Wet Tropics is a natural phenomenon.

6.3 Levee Banks and Fences

There have been suggestions in public submissions of banks on dams failing in Currunda Creek that contributed to flooding. I have found no evidence to suggest that there were levees on structures of

any significance across the creek upstream of Redlynch Intake Road; however, there is evidence of significant stream bank collapse and erosion that contributed to sediment and debris load. There is also a low levee bank on the upstream and eastern sides of the Caravan Park; however, this is at a low level and was clearly overtopped in the event, and would have been completely drowned with minimal upstream impacts at the peak of the event.

In terms of fences, there are areas where large solid fences have been built across drainage easements or into floodways. An example of such a fence is provided in Photograph 16. Whether such fences have any material effect on major flood events requires detailed flood modelling to assess.

7 Conclusions

My key conclusions are as follows:

(1) Based on available rainfall, radar and initial Stage 1 rainfall runoff modelling analysis, the flood event of 26 March 2018, at the Caravan Park site and adjacent tennis complex was estimated to be approximately a 100 year ARI flood event.

(2) Stream flow analysis and the gauge rating for the Redlynch gauge are unreliable due to inadequate cross-section extent, lack of high flow measurement and due to inadequate lengths of records.

(3) Major flood debris blockage on the Currunda Creek crossing of Redlynch Intake Road exacerbated flooding locally in Currunda Creek and downstream, with significant flood flow breakout to the north-east occurring. This blockage alone may have affected flooding in The Rocks Road area. The collapse of the guard rail on the crossing may also have generated a localised flood wave on top of the creek flooding. Detailed flood modelling is required to assess the potential magnitude and extent of any break-out flows or any flood wave.

(4) The primary cause of flooding of the Caravan Park site was Freshwater Creek flooding, with Currunda Creek contributing around 10% of the total combined catchment area and about 25% contribution to total flood flow.

(5) Flood debris and sediment transported downstream in the event contributed to damage at the Caravan Park and tennis centre, and in The Rocks Road area. There is evidence that the debris and sediment load down Currunda Creek was higher than that in the main Freshwater Creek channel.

(6) There is no evidence of dam or levee collapses in Currunda Creek occurring or contributing to flooding downstream. There was severe erosion and stream bank collapse in Currunda Creek, and there may have been land slips in the upper catchments of Currunda Creek and Freshwater Creek, downstream of the dam, which caused the very high debris and sediment load.

(7) Detailed flood modelling to be incorporated in Stage 2 investigations would assist in confirming the above conclusions.

8 Qualifications

This report details Stage 1 investigations commissioned on 4 April 2018 for an independent, forensic review of the rainfall event of 26 March 2018, and the associated flooding, and specifically in relation to flooding in the vicinity of the Caravan Park site and the tennis centre. As such, it should not be applied to other locations without reference to the author.

The report findings will be reviewed and refined in Stage 2 investigations which are currently underway.

The investigation has included consultation with landowners and a review of public submissions, as well as an analysis of rainfall data provided by the Bureau of Meteorology, and stream gauge data by the Department of Natural Resources and Mines. The accuracy of this investigation is limited to the accuracy of that information.

Rainfall intensities, durations and spatial variance for individual storm events is dependent on numerous factors including topography and atmospheric influences. Without recording continuous gauges positioned across the full extent of the catchment, it should be recognised that the ability to satisfactorily replicate the flooding characteristics at all locations within the catchment is limited by the available information.

Appendix A Neil Collins CV

"Where will our knowledge take you?"

Neil Collins

CAREER OVERVIEW

Neil is BMT's Principal Flood and Water Resources Engineer. He has 37 years experience and is an acknowledged expert in planning, land and Supreme Courts across eastern Australia in flooding, water quality and coastal processes. He was the independent expert examining Callide Dam operations during the February 2015 floods, was project director for the Brisbane River flood study for the State Government, and is currently reviewing the Queens Wharf flood assessment for EDQ. Neil has worked on major projects as an Hydraulic Specialist including Sydney Third Runway, Sydney Harbour Tunnel, Gateway Bridge and Arterial, several coal ports in Queensland and in Indonesia, power stations in Queensland and Thailand, hydro-electric schemes in PNG and port dredging management at Cairns, Townsville, Weipa and Mackay. Neil was technical expert for the LGAQ and Ipswich City Council in the 2011 floods Inquiry.

POSITION

Principal Hydraulic and Water Resources Engineer

YEARS OF EXPERIENCE

38

ACADEMIC QUALIFICATIONS

MEng in Science from University of Queensland (1988)

BEng in Civil from University of Queensland (1979)

PROFESSIONAL AFFILIATIONS

- NPER
- RPEQ

AREAS OF EXPERTISE

- Hydraulics, Hydrology and Water Resources
- Provision of Expert Witness Services in Flooding, Floodplain Risk and Emergency Management, Stormwater, Quality Control and Coastal Engineering

EMPLOYMENT HISTORY

2010 to date	**Principal Hydraulic and Water Resources Engineer, BMT WBM**
2007 to 2010	**Principal Hydraulic and Water Resources Engineer, Gilbert and Sutherland Pty Ltd**
2004 to 2007	**Director, Queensland Manager, Cardno Lawson Treloar**
1993 to 2004	**Director, Lawson Treloar**
1981 to 1993	**Associate Director, Connell Wagner**

KEY AREAS OF EXPERTISE

Flooding

- Flood studies
- Floodplain management
- Risk assessment and mitigation
- Emergency flood management planning

Water Quality

- Stormwater management plans
- Receiving waters modelling
- Erosion and scour/geomorphologic assessments

Coastal Processes

- Storm tide
- Waves
- Coastal protection works
- Coastal erosion

Summary of Major Projects

- Callide Dam gate operation independent investigation of February 2015 flooding in Biloela and in Callide Creek Floodplain (2015)
- Queens Wharf Project – Flood Assessment Review (2015/2016) for EDQ
- Project Director (2014-2016) – Comprehensive Hydraulic Assessment - Brisbane River Catchment Flood Study
- AQUIS (2013/2014) a $8.5b Casino and Hotel Resort Development in Cairns – Flooding, Coastal and Water Quality Assessments in support of the EIS
- Lauderdale Quay, Hobart – Coastal Hydraulics, Water Sediment Quality for IIS on a Major Marina Residential Reclamation Project
- Brisbane Airport - International Terminal Drainage Design
- Sydney Harbour Tunnel - Hydraulics Engineer for Immersed Tube Tow and Placement
- Sydney Third Runway - Hydraulic Model Testing, Sea Wall Design and Environmental Management
- Gateway Arterial - South East Freeway to Lytton Road - Civil and Hydraulic Design Manager
- Gateway Bridge - Hydraulics and Approaches Services Relocations
- Trade Coast Central - Flooding Review for BCC
- Oak Flats to Yallah RTA Freeway Hydraulics
- Kedron Brook Flood Impacts due to Airtrain
- Tully and Murray River Floodplains Hydraulic Analysis and Modelling, for Drainage Scheme Design includes Large MIKE11 Modelling, with over 40 Bridges and 200 Channels
- Expert Review - Mossman Daintree Road, Saltwater Creek Crossing: Independent Review of the Hydraulic Design of two Large Bridges
- Hydraulic Design of Rock Armouring Works for the Barron River Bend at Cairns Airport
- Eastern Corridor Study - Hydraulics and Hydrology investigation for Department of Transport
- Relief Drainage Scheme Design for Albion Windsor Area Brisbane (Capital cost $2 million)
- Tarong Power Station - Design of Earthfill Dam (max. 23m height), Ash trench, Stormwater Diversion Channels

Expert Witness Experience

Neil has provided expert witness services in the following courts and tribunals:

- Planning and Environment Court (QLD) – more than 200 appeals
- Land Court (QLD)
  - over 50 resumption compensation claims
  - several mining lease objection hearings
- Supreme Court of Queensland
  - several damages actions, including three current actions
- Land and Environment Court (NSW)
- Supreme Court (NSW)
- Commission of Inquiry – QLD Flood
- Commission of Inquiry – Tasmania
- Administrative Appeals Tribunal (Commonwealth)
- Water Act objection hearings
- Fisheries Act objection hearings

PROFESSIONAL HISTORY

BMT Pty Ltd

Principal Hydraulic Engineer providing expert witness and expert peer review services in flooding, stormwater, quality control and coastal engineering.

- Over 60 appeals (2014/2016) which includes: Brisbane River Flood Class Action – Acting for State Government, Pacific National v Aurizon Train Derailment Action (2015/16), Boral Gold Coast Quarry v GCCC (2015/16) and Seppanen v Ipswich City Council (2016)
- NEBP and Trask Development Corporation (2014). Land proposal for flooding, coastal/estuarine dynamics and Water Quality Investigations
- Sunshine Coast Airport (2014) – peer review of flooding impact on new runway
- Over 50 appeals which includes P&E, Land Court Appeals (2012/2013). The majority of appeals were P&E Appeals and some of the key matters are: Karraman Quarries v Redland Shire Council, GCCC v McConnell Dowell, Moranbah Airport Expansion
- Peer Reviews (2012) Peer Review of QLD Flood Inquiry Implementation and Peer Review of BCC Flood Hazard

PROFESSIONAL HISTORY, CONTINUED...

Overlay Code

- Land & Environment Court, NSW (2012) Richmond Regional Council v Ison
- P & E Court, QLD (2012) Comiskey, Florina Gardens, Busby
- Land Court, QLD (2012) Silveressence, Milton Tennis Centre Resumption
- Quarry Water Management Investigations (2010/2012) Boral Ormeau, Stapleton and Cedars Quarries
- Over 25 appeals completed in 2010/2011.
- Flooding Commission of Inquiry (2010/2011) Technical expert for LGAQ and Ipswich City Council and had delegated authority on behalf of over a dozen local authorities including; Toowoomba, Western Downs, Balonne, Goondiwindi, Central Highlands, Lockyer Valley and flooding advice reports were prepared for each of these areas
- Cairns Airport (2010-2011) Review of Airport Flood Immunity and Risk
- Ipswich City Council (2010-2011) Assessed Brisbane and Bremer River flooding and effect of dam operation including modelling

Gilbert and Sutherland Pty Ltd

Wet 'n' Wild, Sunshine Coast – site and soil assessments, input to and review of AGE groundwater assessment, conceptual stormwater quality assessment, hydraulic and flooding assessments including yield, medli modelling for onsite and input to S&B water balance, contamination investigation.

- Stockland, Twin Waters – Flooding Assessment
- Mackay Boat Harbour – Wave Investigation
- Bourton Road, Alkira – Flooding and Stormwater Management Plan
- The Glades, Robina – Water Quality Compliance and Inspection Report

Expert Services:

2007: Truloff Pty Ltd -v- Gold Coast City Council

2008: Jimboomba Turf Co Pty Ltd -v- Logan City Council

2008: Lechaim -v- Gold Coast City Council

2008: Sunnygold International Pty Ltd -v- Brisbane City Council

2008: Bon Accord -v- Brisbane City Council

2008: Blue Eagle -v- Beaudesert Shire Council

2008: Brian Paddison -v- Redland Bay Shire Council

2008: Monarch Nominees -v- Brisbane City Council

2008: Kunda Park Pty Ltd -v- Maroochy Shire Council

2008: Owl Projects & Hyder -v- Gold Coast City Council

2008: Port Pacific Estates Pty Ltd -v- Cairns Regional Council

2008: Joanne Shepherd & Ors -v- Brisbane City Council

2009: Lenthalls Dam, Hervey Bay

2009: Testarossa -v- Brisbane City Council

2009: Heritage Properties & Ausbuild -v- Redland City Council

2009: Samantha Skippen -v- Miriam Vale Shire Council

2009: Anthony Wan Pty Ltd -v- Brisbane City Council

Cardno Lawson Treloar

Sovereign Waters, Wellington Point - flooding, tidal exchange and water quality management.

EMP Water Quality Management Plan preparation and site stormwater management, including hydrodynamic, advection/ dispersion and catchment pollutant yield modelling for:

- Emerald Lakes Project, Carrara
- Glenwood Estate, Mudgeeraba
- 'The Glades' (Greg Norman Design Course), at Robina
- Sovereign Waters, Wellington Point
- Pacific Palisades, Gavin
- Freshwater Valley Estate, Cairns
- Carrara Golf Course Re-development, Carrara
- The Broadwater Development, Mudgeeraba
- Over a Dozen Major Residential Development Projects.
- Full Two-dimensional (MIKE 21) Floodplain Modelling for Cairns Airport Inundation, Nerang River Floodplain and Martins Creek, Maroochydore.
- Noosa River System Flood Study: Includes full G.I.S. Interfacing, Colour Inundation Plan Production and MIKE11 Modelling.
- Detention Basin Design for Development Consulting, Calamvale, Brisbane: Hydrologic and Hydraulic Design using RAFTS.
- Hydraulic and Water Quality Design, Lucinda Drive Main Drain, Port of Brisbane, including Catchment Pollutant Runoff Management.
- Moreton Bay College Flood Investigation: MIKE11 Analysis of Flooding, Including Culvert and Channel Diversion Options.
- Input on EIS Report on Water Quality for Freshwater Valley Development, including EMP.
- Townsville Port Road and Rail Access Study - Hydraulics.
- Freshwater Creek Flooding, for Main Roads, included Bridge and Culvert Sizing and Positioning of Channel Training Works. (RORB/RUBICON).
- Mountain Creek Flooding Investigation Examination of 1992 Floods using detailed Hydrologic/Hydraulic Modelling and Design of Mitigation Works.

PROFESSIONAL HISTORY, CONTINUED...

Expert Services:

2004: T.M. Burke Appeal 2006: Leong - v- Redland Shire Council Appeal

2004: East Point Mackay 2006: Barry Hilson & Bach Pty Ltd - v- GCCC Appeal

2004: Dore Appeal 2006: 57 Longhill Road Appeal

2004: 900 Hamilton Road, McDowall 2006: 699 Bargara Road Appeal

2004: Milton Tennis Centre 2006: Chevellum Road Appeal

2005: P&E Appeal Mount Samonsvale 2006: 10 Karridawn Street, Nudgee Appeal

2005: BCC & George Pasucci 2006: Australian Hardboards Limited Appeal

2005: P&E Appeal 48 Comley Street Sunnybank 2006: Dell Road and Hawkin Drive, St Lucia Appeal

2005: P&E Appeal 398 Wondall Road, Tingalpa 2006: 106 Munro Street, Auchenflower Appeal

2005: Cabbage Tree Creek Appeal 2006: 10 Adsett Road, P&E Appeal

2006: 35 Suscatand Street, Rocklea Appeal 2006: Saunders Creek Appeal

2006: 64, 70 & 74 Washington Avenue, Tingalpa

Lawson Treloar

- Coastal Data Gathering and Analysis for Projects in Bali, Lombok and Malaysia.
- Pandorah Gas Project, Gulf of Papua. Neil was Responsible for Project Management of all Coastal and Oceanographic Aspects of this Project, including Preparation of the Relevant Components of EIS. This included Extreme Climate, Wind/Wave and Current Modelling.

Chevron PNG to Cape York Gas Pipeline Project, Gulf of Papua.

Neil Carried out Project Management for all Coastal/Oceanographic Components of this Project, including:

- Wind/Wave Modelling
- Extremal Climate
- Bed Current Prediction
- Kumul Platform Berthing
- Endeavor Passage Landfall
- Wave, Current and Wind Data Gathering
- Tidal Lagoon, Breakwater/Groynes, Water Quality and Quantity Management at Pecatu Indah Resort, Lombok.
- Marina and Reclamation, S-W Bali, (Putri Nyale) including Coastal Investigations and Hydraulic Design of Breakwaters and Revetments.
- Sediment Sampling and Monitoring Program for the Albatross Bay Dumpsite, Weipa, for Dept. of Transport. Job Manager for this Investigation which includes Monitoring of Movement of Material Following Dumping, and its Impact on Water Quality and Benthic Communities.
- Wellington Point Canal Estate - Coastal Hydraulic Investigation of Proposed Marina and Dredged Channel.
- Weipa, Embley Inlet Environmental Monitoring: Review and Planning for Long Term Monitoring and Assessment of Water Quality (for Comalco).
- Full 2D flooding assessments for Dept of Main Roads using MIKE 21 on Yarrabah, Cairns and Warrego Highway at Marburg.
- Current Profiling, Warrego River (1994).
- Sovereign Waters, Wellington Point - Flooding, Tidal Exchange and Water Quality Management.
- Responsible for all Flood and Water Quality aspects for several Gold Coast Projects, including Emerald Lakes, Nifsan's Glenwood and Broadlakes, including Lake, Wetland and EMP Design.
- Stream Diversion, including Sloping Drop Structure, Hydraulic Design, at 'Coops' Development, Brisbane (1993).
- Northumbria Lakes Estate, Flooding, Drainage, Gross Pollutant Trap and Trash Rack Modelling and Design (1994).
- Barron River Delta Prawn Farm I.A.S., including Flooding and Water Quality Monitoring and Modelling, using MIKE11 (1995).
- Hydraulic Manager for Cairns Airport Master Drainage Study, 1995, including Complex Fydrodynamic Flow and Catchment Management Analysis.

Expert Services:

- Over 40 appeals including Nifsan –v- Gold Coast City Council (1997)

Connell Wagner

- Current Profiling, Warrego River (1993).
- Sovereign Waters, Wellington Point - Flooding, Tidal Exchange and Water Quality Management.
- Responsible for all Flood and Water Quality Aspects for several Gold Coast Projects, including Emerald Lakes, Nifsan's Glenwood and Broadlakes, including Lake, Wetland and EMP Design.
- Stream Diversion, including Sloping Drop Structure, Hydraulic Design, at 'Coops' Development, Brisbane (1993).
- Northumbria Lakes Estate, Flooding, Drainage, Gross Pollutant Trap and Trash Rack Modelling and Design (1993).
- Barron River Delta Prawn Farm I.A.S., including Flooding and Water Quality Monitoring and Modelling, using MIKE11 (1995).

PROFESSIONAL HISTORY, CONTINUED...

- Hydraulic Manager for Cairns Airport Master Drainage Study, 1995, including Complex Hydrodynamic Flow and Catchment Management Analysis.
- Tarong Power Station. Design of earthfill dam (max. 23m height), Ash trench, Stormwater Diversion Channels.
- Callide B Power Station. Evaporation Ponds Simulation; Hydraulic Design and Stormwater Bypass Channel. Design of (25m) Ash Dam.
- Hay Point Multi-User Coal Export Facility. Design of Dams, Stormwater Drainage, Water Supply and General Civil.
- Townsville Container Terminal. Design of Stormwater Drainage and General Civil.
- Abbot Point Coal Terminal. Design of an Offshore Causeway.
- Subdivisional Design and Supervision, on over a dozen Projects.
- Bulk Sugar Terminal - Brisbane. Feasibility Studies, including Flooding.
- Gladstone Power Station. Ash Handling including Piping.
- Stanwell Power Station. Design Check on General Civil.
- Patrick Container Terminal - Port of Brisbane. Flooding and General Civil.

Expert Services:

1993: for Mulgrave Shire Council; Land Resumption Compensation Case in Land Court. (Flooding)

1993: for Mulgrave Shire Council; Development Appeal (Kamerunga Villas) in Planning and Environmental Court. (Flooding)

1994: for Pullenvale Residents Action Group, on Rezoning Appeal. (Flooding and Water Quality)

1994: for Development Consulting, on Rezoning Appeal for a Development with a Large Detention Basin at Calamvale. (Flooding and Drainage)

1994: for an Earthworks Contractor Regarding a Disputed Claim Over Levee Bank Construction at Mungindi. (Flooding)

1995: for a Developer on Bohle River Works. (Flooding and Water Quality)

1995: for Residents on Flooding, Murrumba Downs. (Flooding)

1995: for Residents on Flooding, Dayboro. (Flooding)

Expert Services for Phillips Fox; Caboolture Shopping Centre Extension Appeal in Planning and Environment Court. (Flooding)

Expert Services for Mulgrave Shire Council; Land Resumption Compensation Case in Land Court. (Flooding)

KEY PAPERS/PUBLICATIONS

May 2016 – 56th Floodplain Management Australia Conference 'Flooding Class Actions and Inquiries; How Certain is Accepted Modelling and Mapping Currently in Place?'

September 2015 – QELA presentation – Constrained by Codes

July 2015 – SIA Conference – Invited speaker – Ethics and Responsibilities of Practitioners in the Stormwater Industry

July 2014 – PIA Presentation / Paper – For Planners Series Hydrology & Hydraulics.

June 2014 – Stormwater Industry Association – Presentation - Flood Requirements for Development Post the QLD Floods Commission of Inquiry.

February 2013 – QELA Seminar Presentation – Taylor Made Series – Flooding 101

December 2012 – Stormwater Industry Association Presentation - The Local Government Perspective on the Flood Commission – Ethics and Responsibilities of Professionals when Reporting their Opinion or giving Evidence

September 2011 – River Symposium Presentation – 2011 Floods: Review & Way Forward

April 2011 – QELA Seminar Presentation – 2011 Floods: Review & Way Forward

November 2009 – QELA Seminar Presentation / Paper – Rising Sea Levels

May 2007 QELA Conference Presentation – The Approval and Appeal Process in QLD and NSW, Experts view on soil and water issues.

Nov 2004 Publication - 'Application of Australian Runoff Quality Draft Chapter 6 – A model approach', Water Sensitive Urban Design Conference, 2004, Adelaide.

Jul 2004 'Integrated High Order Water Quality and Hydrodynamic Analysis', 8th National Conference on Hydraulics in Water Engineering, July 2004.

Nov 2002 Publication - 'Hervey Bay Storm Surge', 30th PIANC Congress, Sydney 2002.

Nov 2001 'The Use of Runoff Event Monitoring in Validating Sediment Control Measures', 9th Annual Conference, International Erosion Control Association, Nov 2001.

Nov 2001 'Specialist 2D Modelling in Floodplains with Steep Hydraulic Gradients', 6th Conference on Hydraulics in Civil Engineering, Nov 2001.

Mar 2001 'Planning Implications of New Technology in Floodplains', RAPI Conference, Gold Coast, 2001.

Nov 1999 'Best Management Practices for Water Quality Control', and 'Zero Flooding Impact Assessments; the need for full two dimensional analysis', 8th International Conf. on Urban Stormwater Drainage, 1999.

KEY PAPERS/PUBLICATIONS, CONTINUED...

Jul 1999 'Desktop Ship Simulation for a new Port Facility in The Gulf of Papua', Coasts and Port '99.

Mar 1997 'Implications of the Nifsan -v- G.C.C.C. ruling on floodplain hydraulics', Qld Envir. Law Assoc., 1997.

Jul 1994 'What the Community Needs to Know – Approaches to Community Construction for Water Engineering Projects', I.E. Aust., Queensland Division, 1994.

Nov 1993 'Hydraulic Assessment of Floodplain Development: Case Studies', The Institute of Municipal Engineering, Goondiwindi, 1993.

Jul 1993 'Long Term Environmental Planning – Weipa Port Dredging', 11th Australasian Conf on Coastal and Ocean Engineering. Townsville, 1993.

Mar 1993 Integrated Hydrologic and Hydraulic Modelling', WATERCOMP '93. The Second Australasian Conference on Technical Computing.

Mar 1992 'Russell and Mulgrave River Catchment Management', Invited Guest speaker for Queensland River Trusts Conference, Cairns, 1992.

Nov 1990 'Recent Studies of Port Dredging and Offshore Spoil Dumps', Third Australasian Port and Harbour Conference 1990, IE Aust.

Aug 1990 'Barron River Airport Bend Study - An Exercise in Joint Numerical and Physical Modelling', Conf. on Hyd. in Civil Eng., 1990, IE Aust.

May 1989 'Comparison and Evaluation of Current Dynamic Flow Models', WATERCOMP '89. The First Australasian Conference on Technical Computing in the Water Industry, Melbourne, 1989.

May 1989 Publication - Dynamic Flow Modelling : Comparison and Evaluation of Current Models - final Report', ACADS International publication No. U-249, May 1989.

May 1988 'Comparison of Dynamic Flow Models', ACADS 2D Modelling of Flood Plains, Melbourne, 1988.

Jun 1985 'ACADS Project on Comparison of Unsteady Flow Models', ACADS workshop, Brisbane 1985.

Appendix B Station Analysis

Table B-1 Summary of Recorded Rainfall Intensities and Severities in Freshwater Creek Catchment and surrounds

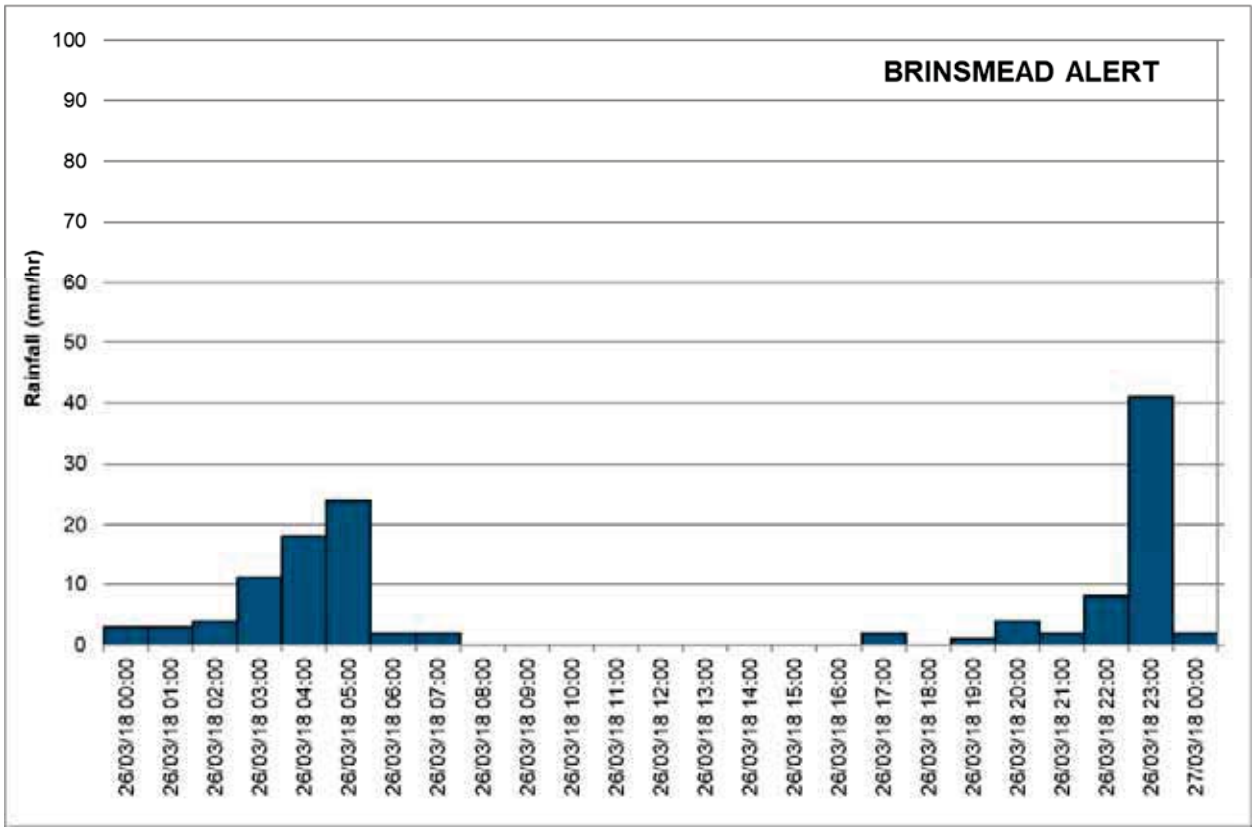
Duration	Brinsmead AL (531042)		Copperlode Dam AL (031205)		Kamerunga Br AL (531048)		Bolton Rd AL (531037)*	
	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)
1hr	41.0	<1	97.0	115	58.0	3	73.0	18
2hr	24.5	<1	94.5	186	37.5	3	55.5	46
3hr	17.7	<1	69.0	178	26.3	1	49.0	103
6hr	10.5	<1	39.0	116	14.3	<1	31.0	66
12hr	11.0	<1	19.8	18	11.6	1	16.3	15
24hr	9.1	3	14.3	17	10.0	3	11.2	14
48hr	5.8	2	10.1	16	6.9	4	7.2	11
72hr	4.5	2	8.1	16	5.5	4	5.3	9

Table B-1 (Cont'd)

Duration	Emerald Crest AL (531035)		Mareeba AL (531033)		Saddle Mountain AL (031043)		Myola AL (531040)	
	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)
1hr	43.0	3	46.0	3	45.0	2	65.0	8
2hr	42.5	15	39.0	9	36.5	4	62.5	72
3hr	42.7	86	32.0	15	32.3	5	50.7	72
6hr	29.0	97	18.8	10	21.8	4	28.7	16
12hr	15.1	19	10.7	6	14.7	4	15.9	5
24hr	9.0	10	6.3	4	13.8	8	15.1	13
48hr	5.3	6	4.1	4	8.5	5	11.6	16
72hr	3.9	5	3.0	4	6.8	5	8.8	13

Table B-1 (Cont'd)

Duration	Cairns Airport AL (531049)		Bilwon AL (531036)		Cairns Racecourse AL (031222)	
	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)	Intensity (mm/hr)	ARI (years)
1hr	21.0	<1	31.0	<1	22.0	<1
2hr	15.0	<1	26.5	1	14.4	<1
3hr	14.7	<1	25.0	3	11.7	<1
6hr	9.8	<1	18.8	5	7.5	<1
12hr	13.7	2	11.3	4	9.6	<1
24hr	9.9	3	6.3	3	7.4	<1
48hr	6.4	3	5.4	6	4.9	<1
72hr	4.7	2	4.0	5	3.9	1



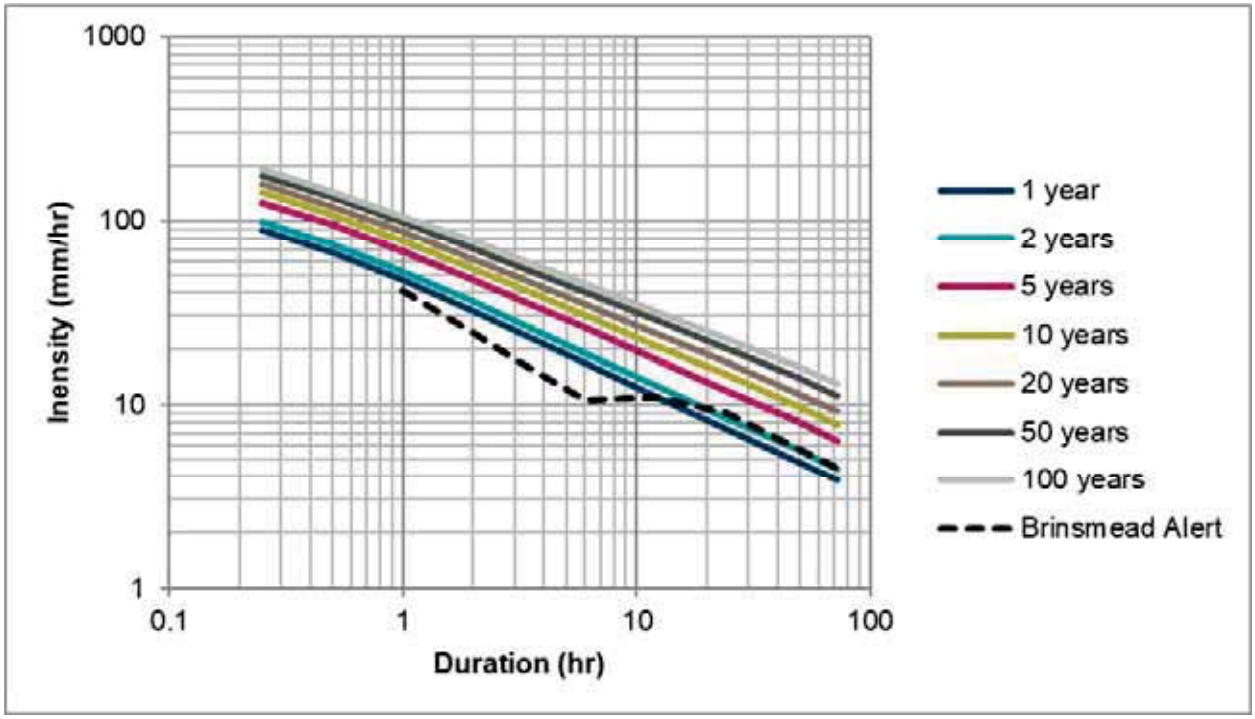


Figure B-1 Graph of Rainfall Intensity and Severity at Brinsmead Alert Rainfall Station for 26 to 27 March 2018

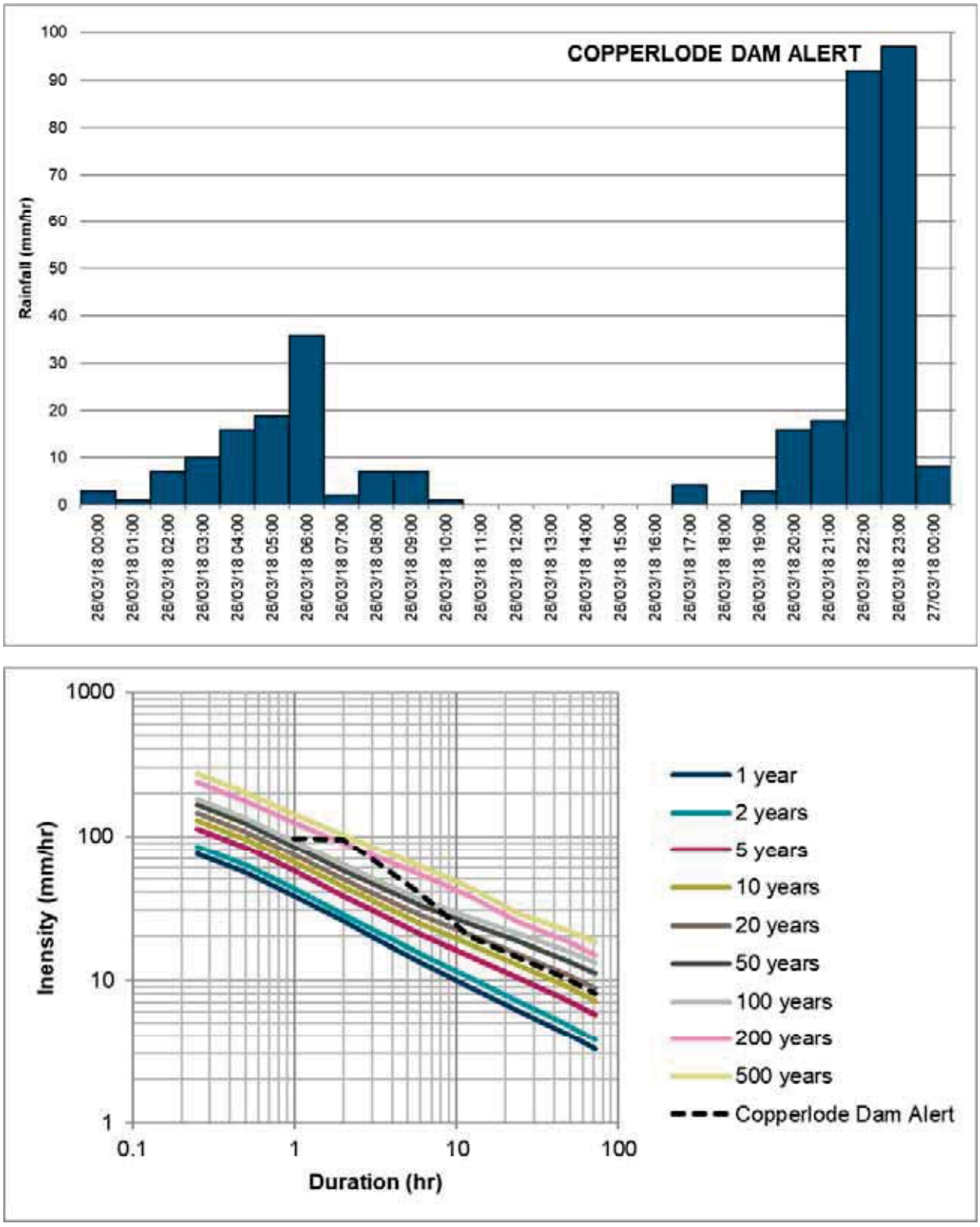


Figure B-2 Graph of Rainfall Intensity and Severity at Copperlode Dam Alert Rainfall Station for 26 to 27 March 2018

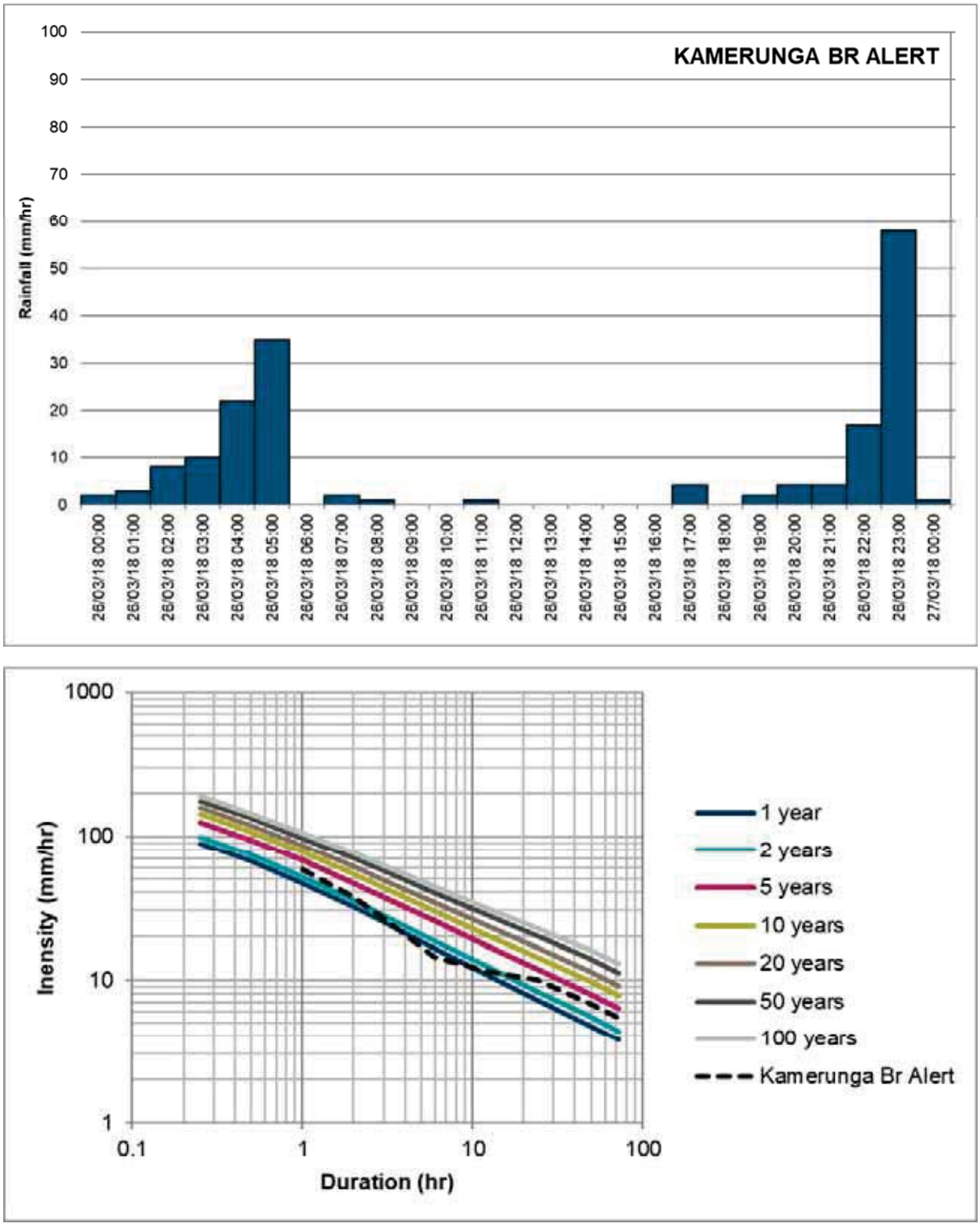


Figure B-3 Graph of Rainfall Intensity and Severity at Kamerunga Bridge Alert Rainfall Station for 26 to 27 March 2018

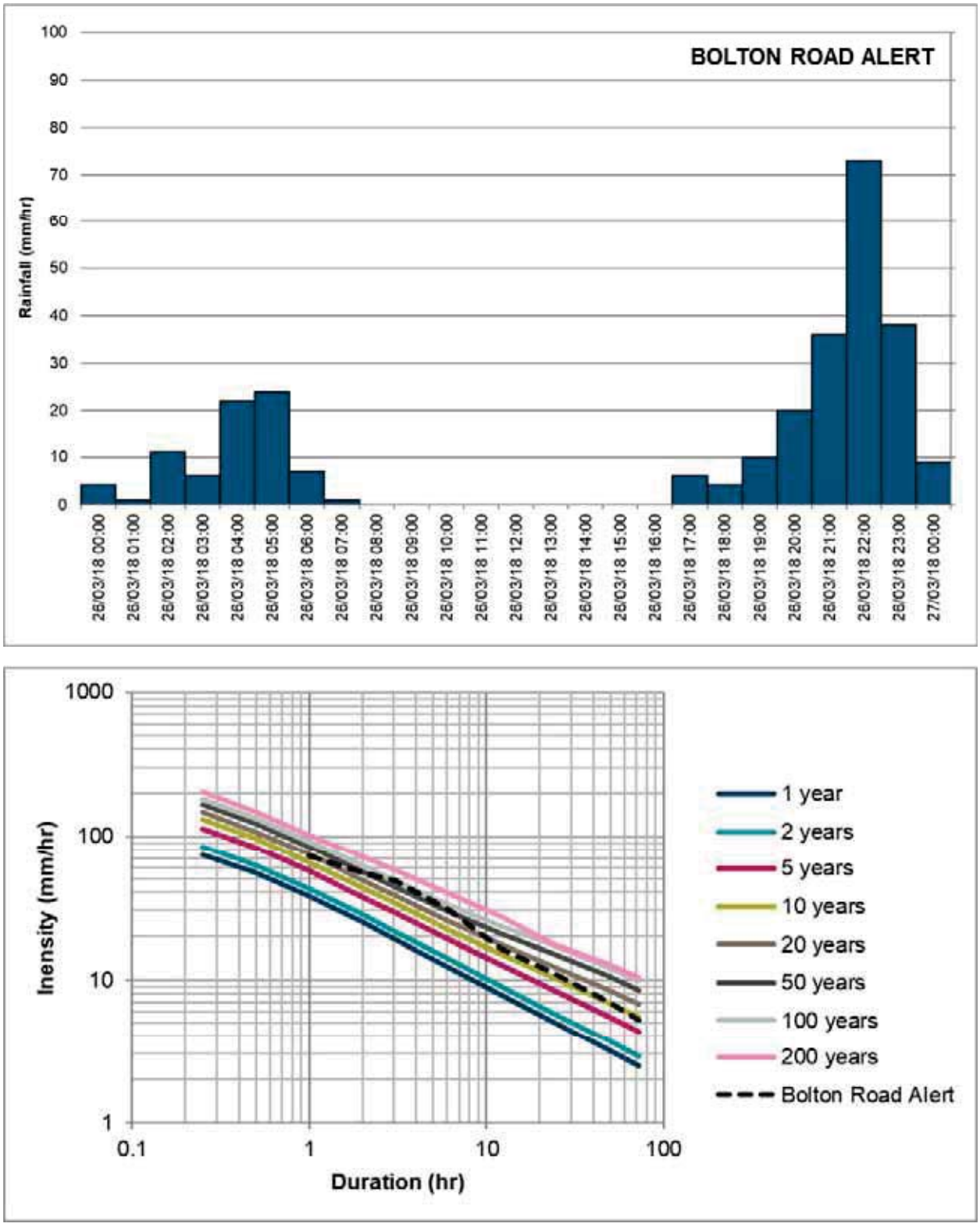


Figure B-4 Graph of Rainfall Intensity and Severity at Bolton Road Alert Rainfall Station for 24 to 27 March 2018

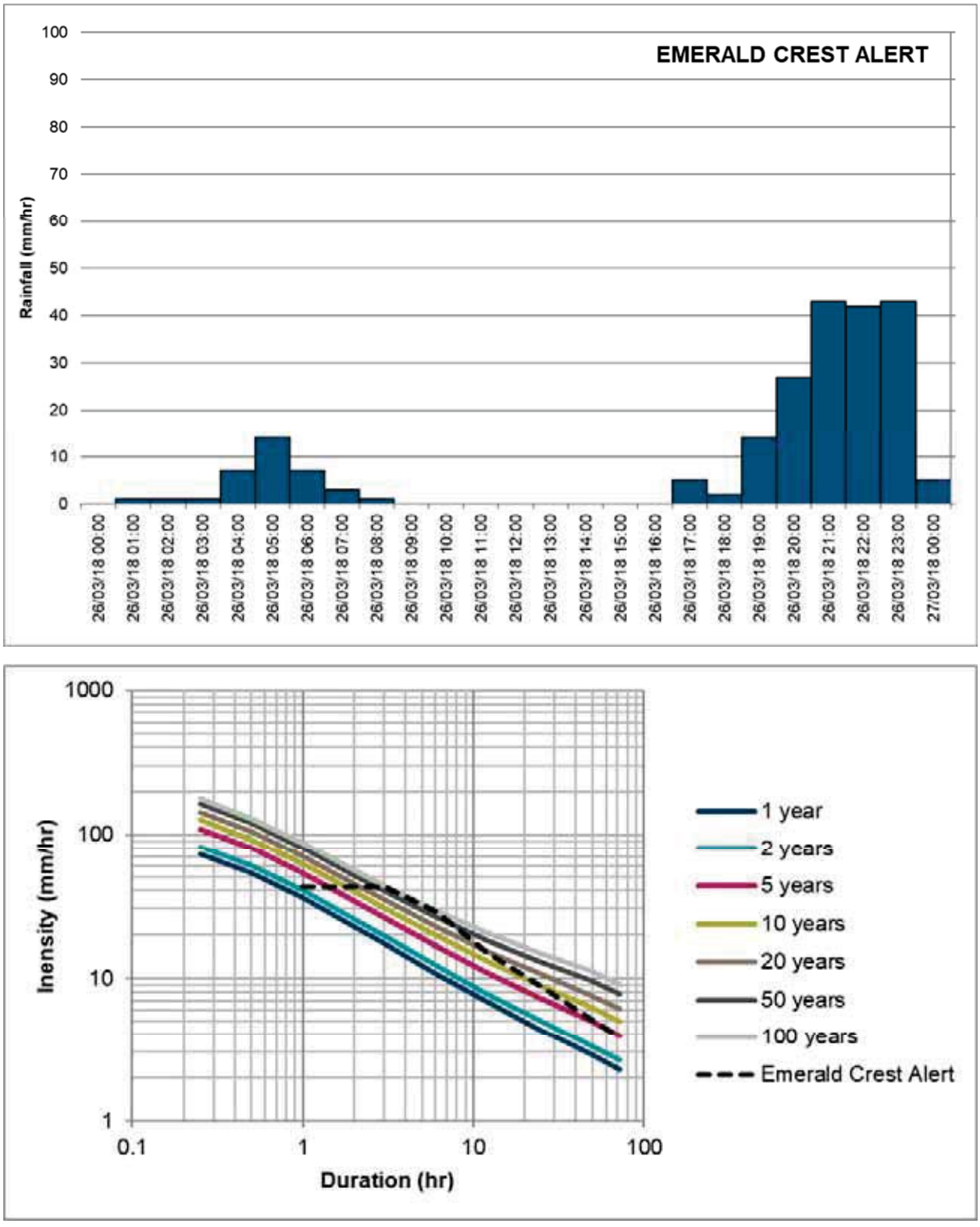
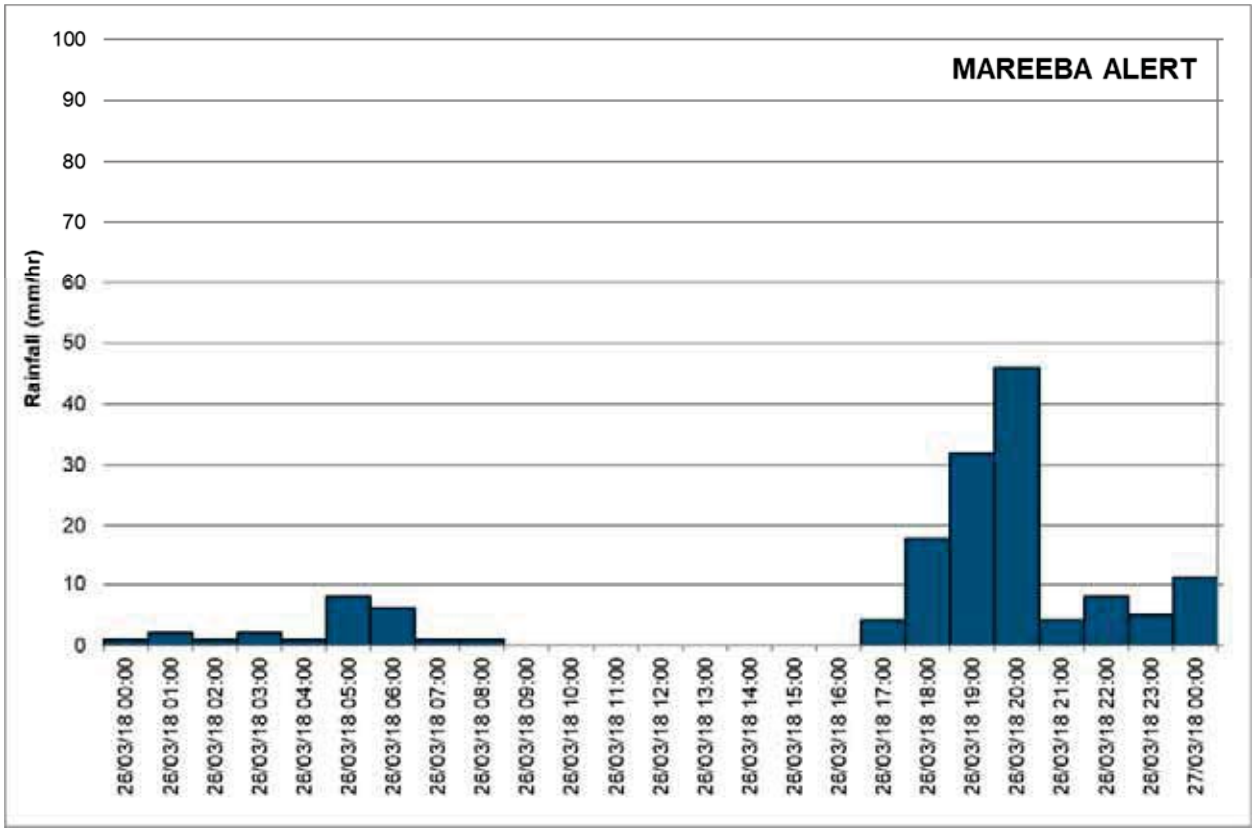


Figure B-5 Graph of Rainfall Intensity and Severity at Emerald Crest Alert Rainfall Station for 26 to 27 March 2018

4 to 27 March 2018



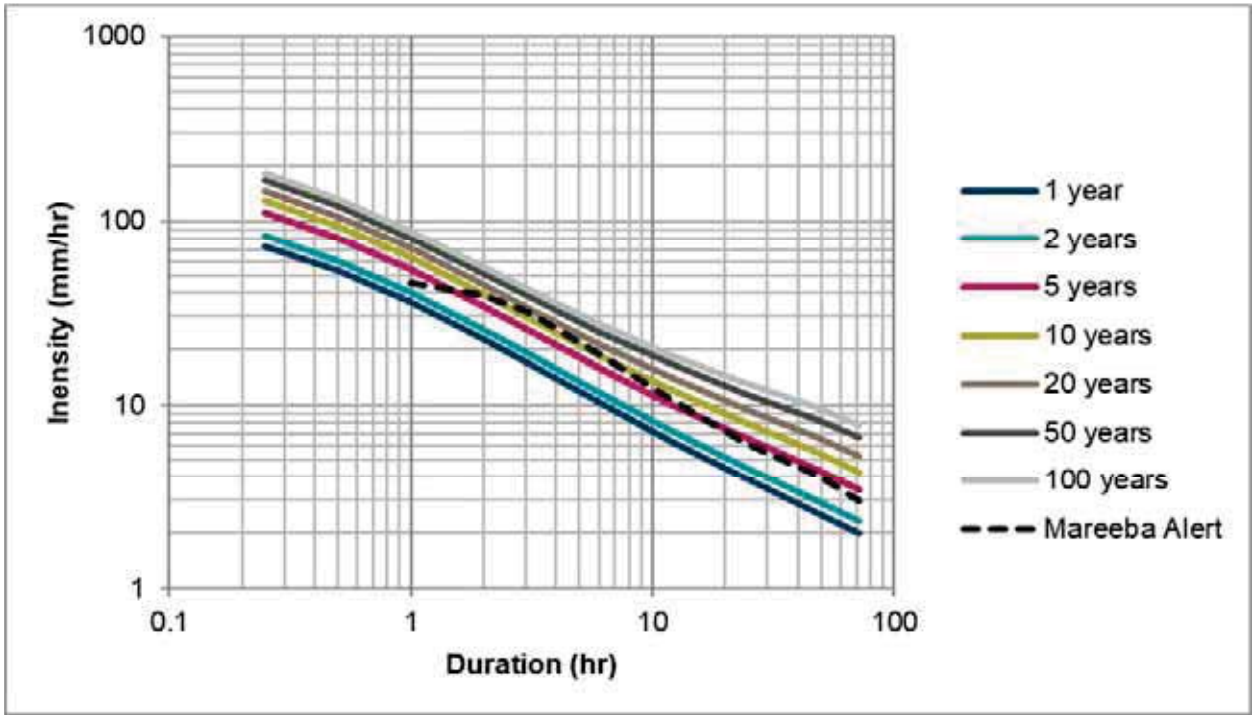
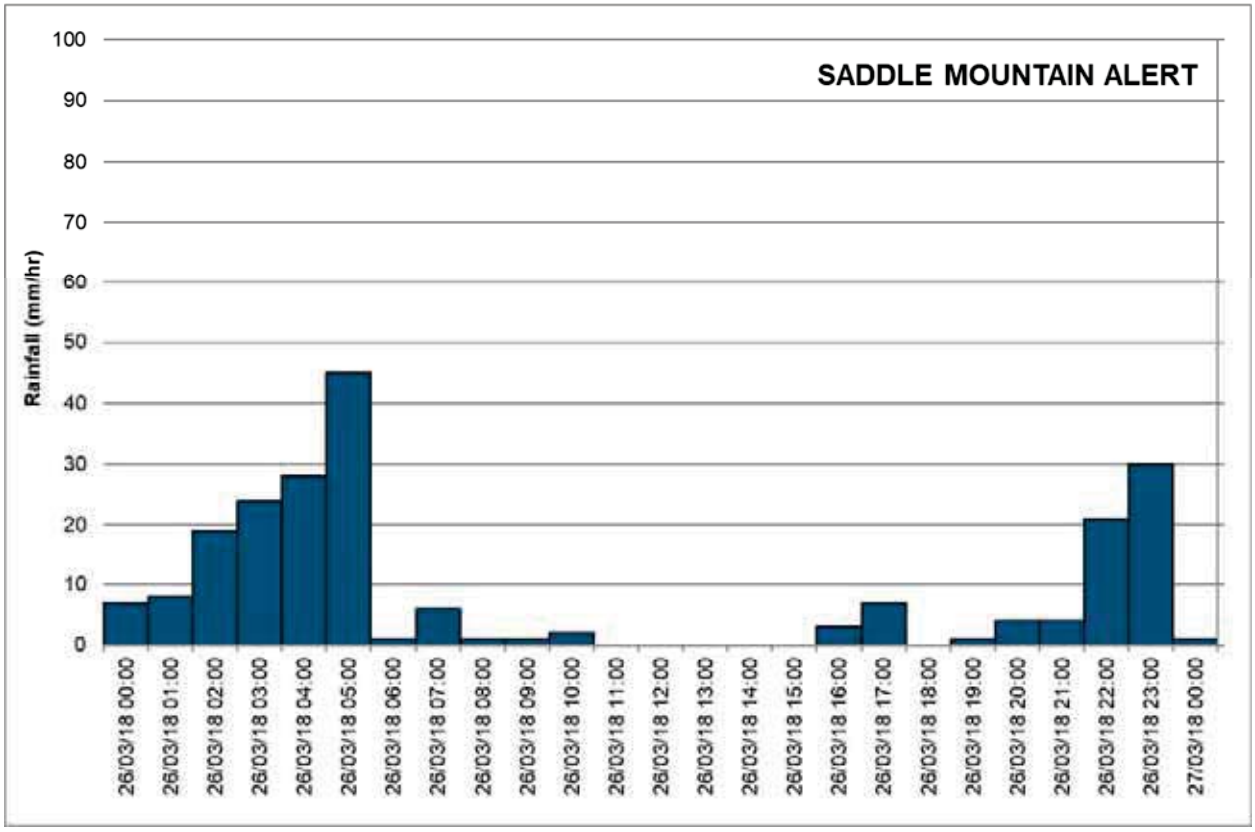


Figure B-6 Graph of Rainfall Intensity and Severity at Mareeba Alert Rainfall Station for 26 to 27 March 2018



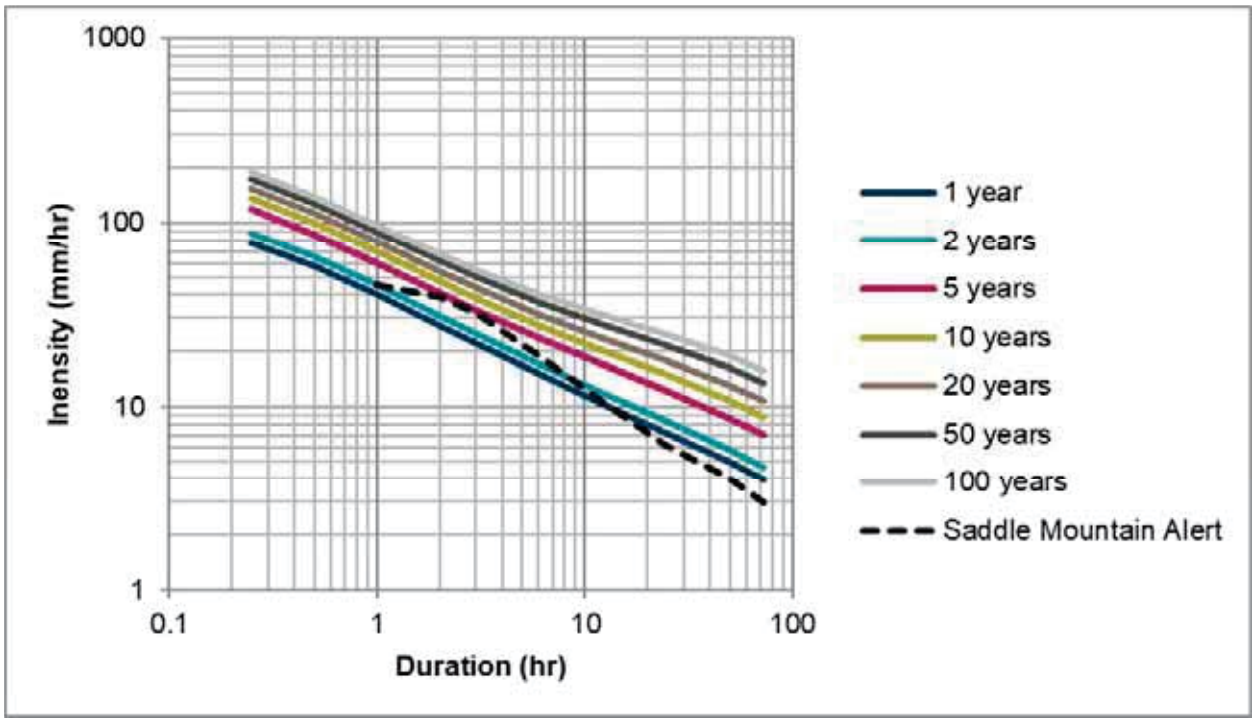


Figure B-7 Graph of Rainfall Intensity and Severity at Saddle Mountain Alert Rainfall Station for 26 to 27 March 2018

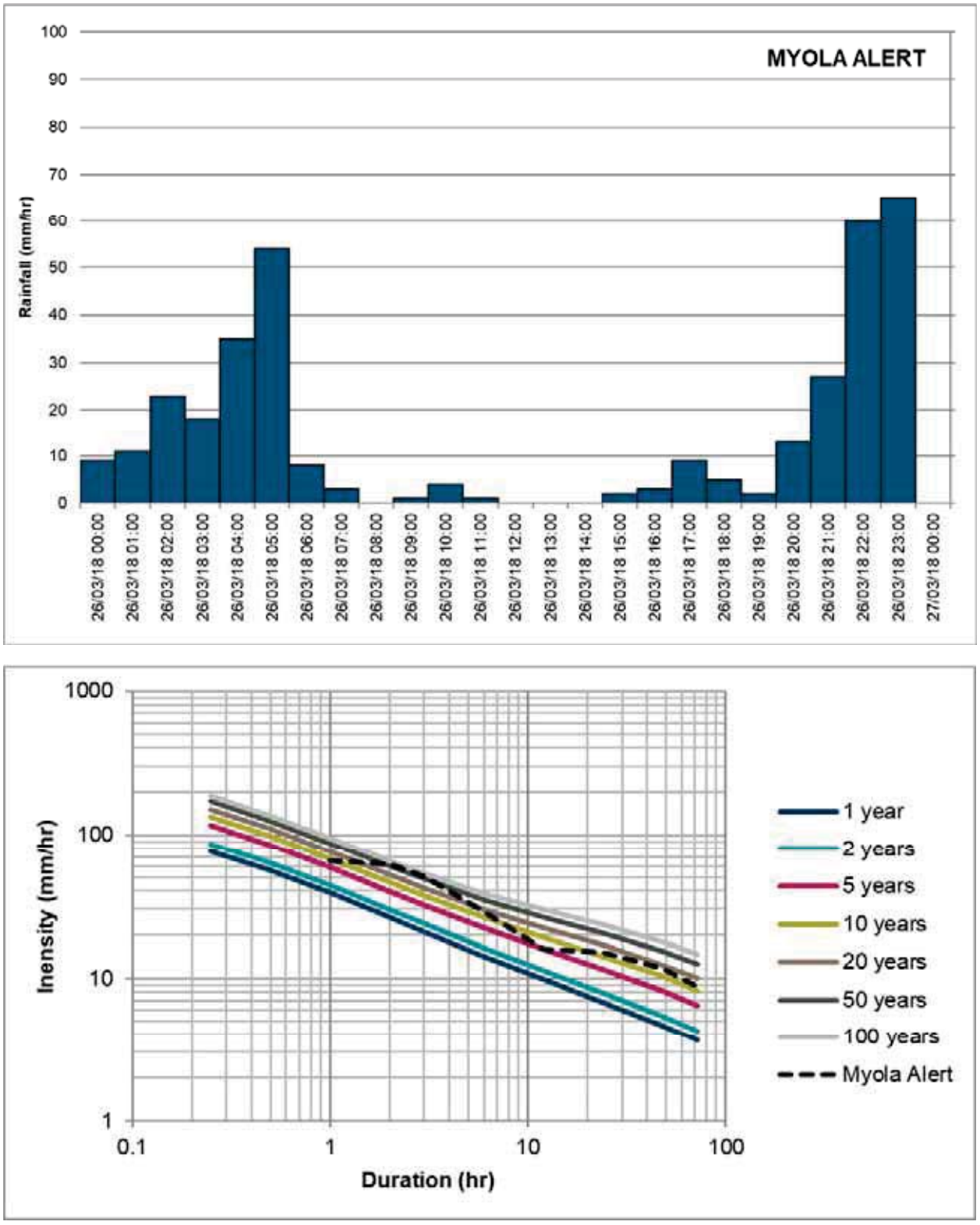


Figure B-8 Graph of Rainfall Intensity and Severity at Myola Alert Rainfall Station for 26 to 27 March 2018

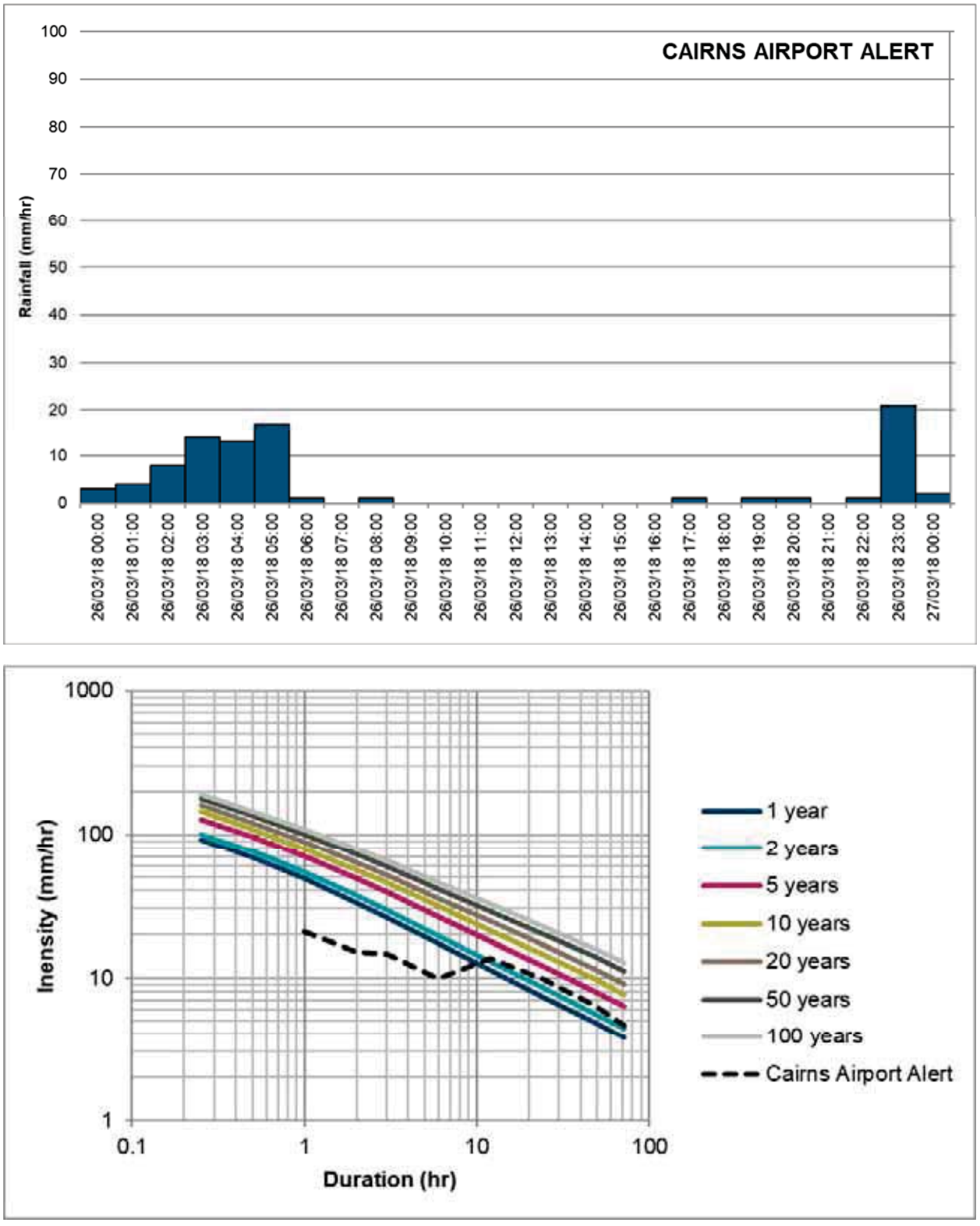


Figure B-9 Graph of Rainfall Intensity and Severity at Myola Alert Rainfall Station for 26 to 27 March 2018

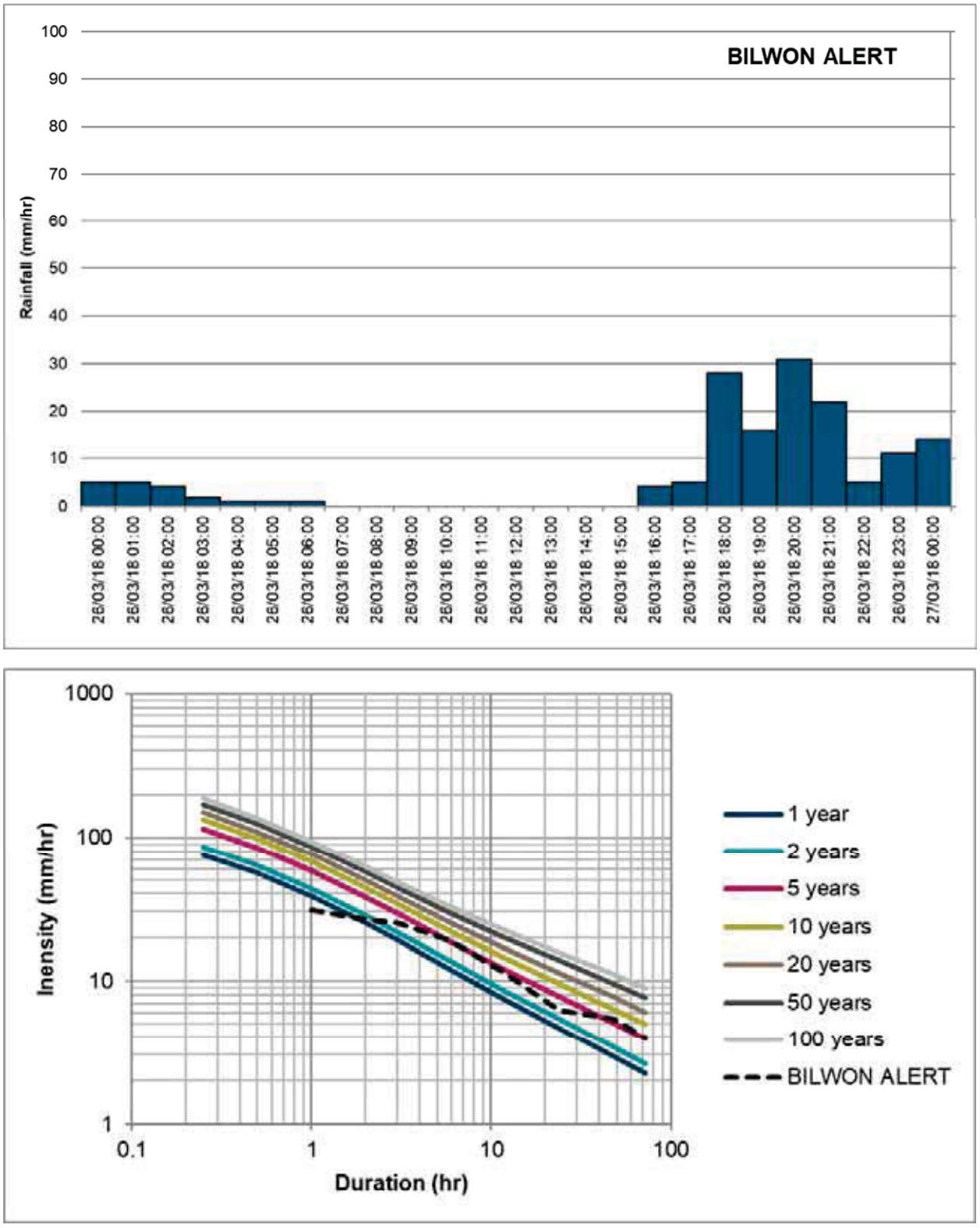


Figure B-10 Graph of Rainfall Intensity and Severity at Bilwon Alert Rainfall Station for 26 to 27 March 2018

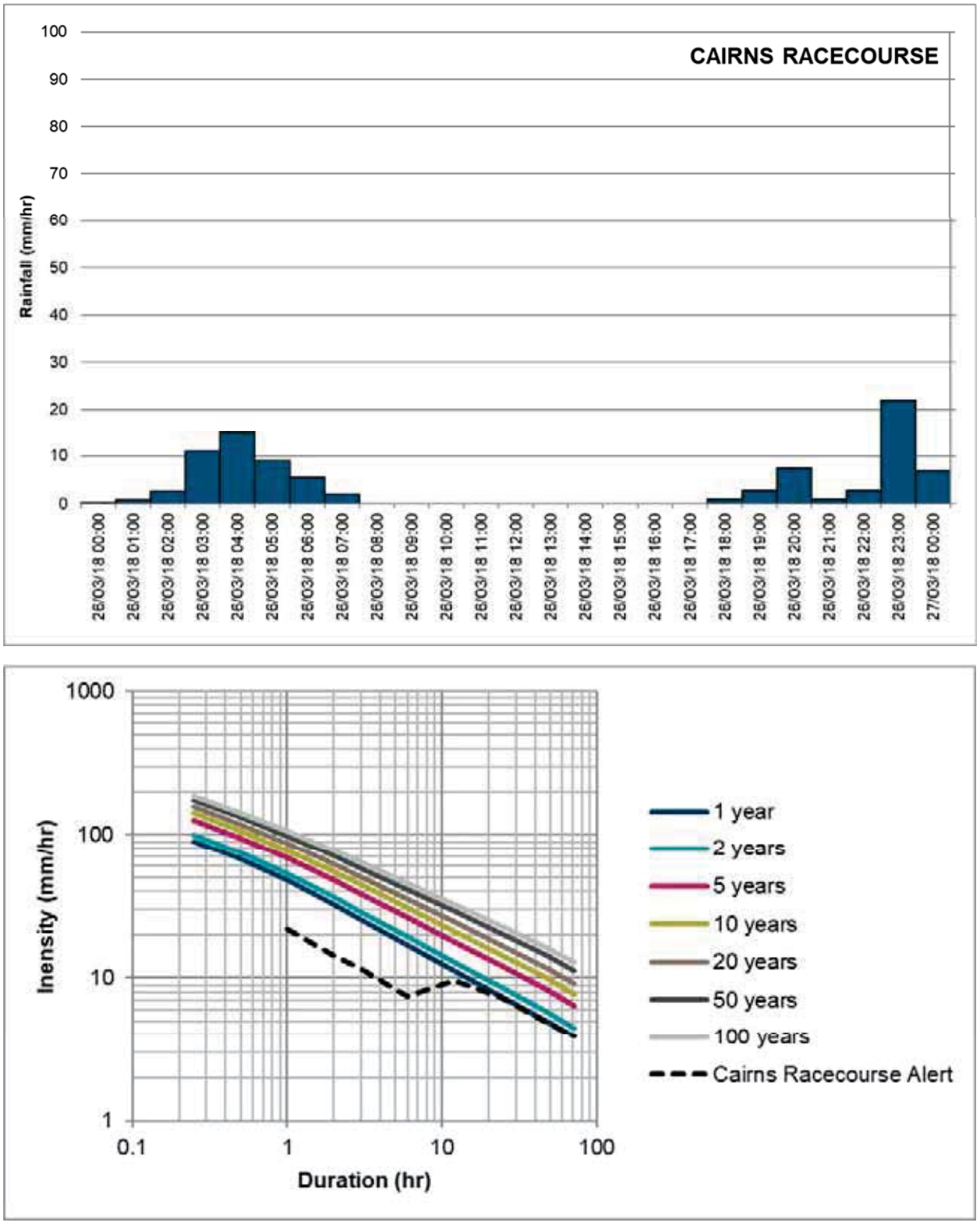


Figure B-11 Graph of Rainfall Intensity and Severity at Cairns Racecourse Alert Rainfall Station for 26 to 27 March 2018

Appendix C Gauge Data and Reliability Assessment

Event Analysis – 26 March 2018

Stage Recordings

The stream gauge heights for the Freshwater Creek at Redlynch Estate and Copperlode Dam spillway have been presented graphically in Figure C-1 and Figure C-2 respectively.

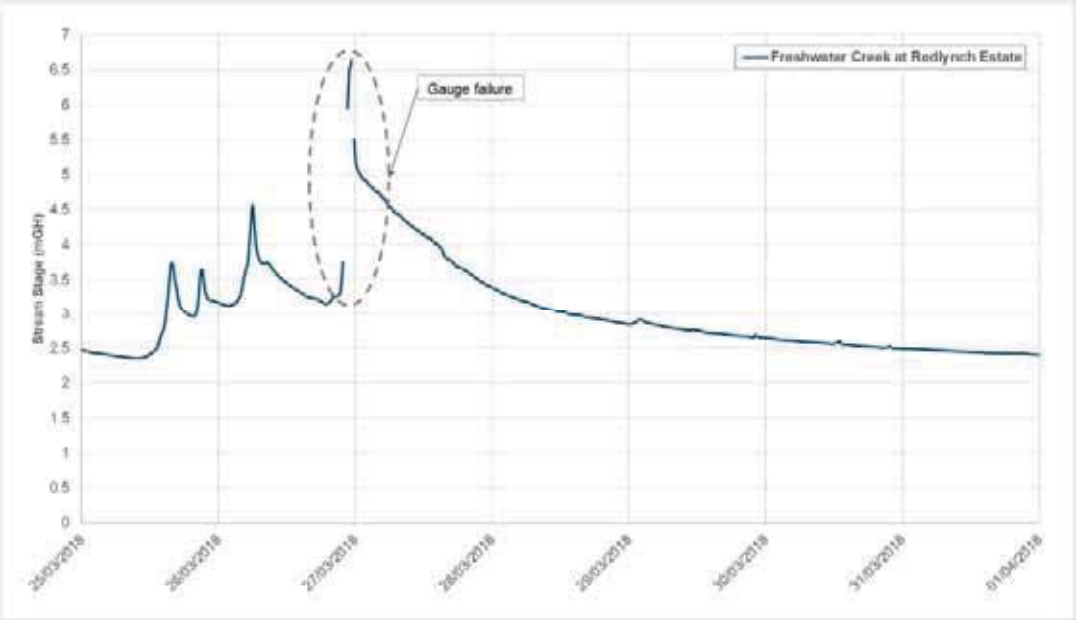


Figure C-1 Stream Stage at gauge 110104A (Freshwater Creek at Redlynch Estate)

As can be identified in Figure C-1, during the flooding event, the gauge experienced failure (between 10:00 to 11:40 hours) and did not comprehensively record. The peak recorded stage is RL 6.64mGH (26.111mAHD based on a Zero Gauge Datum of 19.475mAHD)

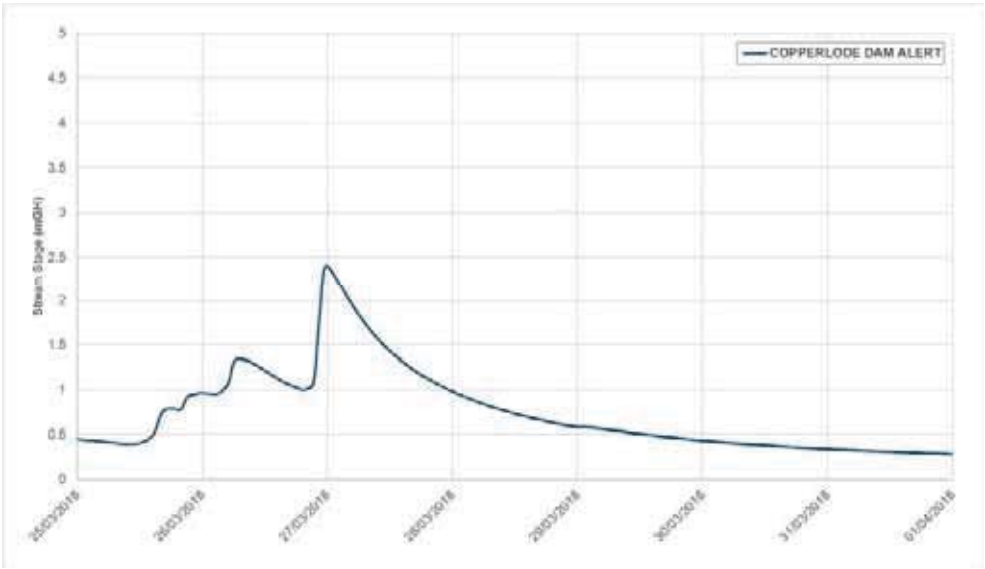


Figure C-2 Stream Stage at gauge 31205 (Copperlode Dam)

Figure C-2 represents the height of flow over the Copperlode Dam spillway. The peak recorded height of flow is 2.409 m above the spillway.

Stream gauge rating

A stream gauge rating curve has been provided by the Department of Natural Resources and Mines (DNRM) via their Water Monitoring Information Portal (WMIP) for the Freshwater Creek at Redlynch Estate stream gauge. This is graphically presented in Figure C-3.

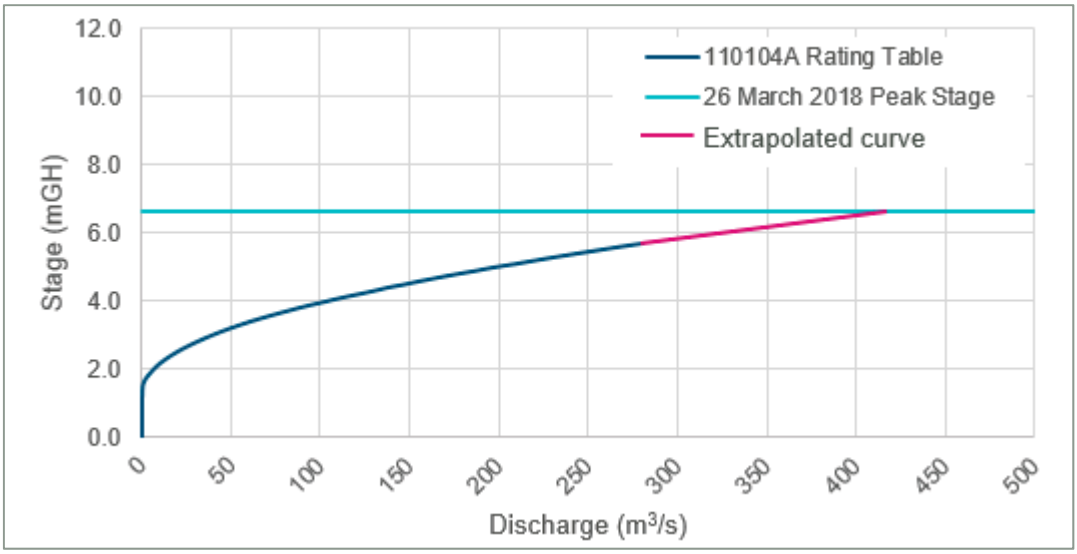


Figure C-3 Stream gauge rating curve for gauge 110104A (Freshwater Creek at Redlynch Estate)

As can be seen, the rating curve does not exceed 5.7 mGH. Further any stage greater than 3.5 mGH has a rating curve reliability of 'Estimate', indicates the lowest level of accuracy for a gauge. Regardless, an approximate extrapolation has been presented, identifying discharge approximate to 425 m^3/s.

A Depth-Storage-Flow relationship has been adopted for the Copperlode Dam, based on the estimated surface area of the Dam at the full stage and the spillway rating curve detailed in the Gilbert and Sutherland *Freshwater Creek Flood Hazard Study – Project Summary Report*, November 2014. This relationship is presented in Table C-1.

Table C-1 Copperlode Dam Depth-Storage-Flow relationship

Depth above spillway (m)	Storage* ($1000m^3$)	Flow (m^3/s)
0.000	0	0.0
0.100	420	1.3
0.200	840	3.7
0.300	1260	6.9
0.400	1680	10.8
0.500	2100	15.2
0.600	2520	20.1
0.700	2940	25.5
0.800	3360	31.4
0.900	3780	37.7
1.000	4200	44.5
1.200	5040	59.1
1.400	5880	75.2
1.600	6720	92.7
1.800	7560	111.6
2.000	8400	131.8
2.500	10500	187.5
2.900	12180	237.1
3.500	14700	319.9
4.100	17220	411.6
4.500	18900	477.0

**Estimate only based on 5m contour information*

Stream cross section reliability

The current stream cross section for the Freshwater Creek at Redlynch Estate has been provided by DNRM via their WMIP. A summary of recorded cross section date, maximum gauged level and peak 26 March 2018 flood level at this station has been presented in Table C-2.

Table C-2 Cross Section, Maximum Gauged and 2011 Flood Level Summary

Station ID	Station Location	Recorded Date	Max Gauged Level (m)	Peak Recorded Flood Level (mGH)
110104A	Freshwater Creek at Redlynch Estate	26/03/2010	2.702	6.636

As can be identified in Table C-2 the peak flood level exceeded the maximum gauged flood level by just under 4 metres.

The current cross section is presented by Figure C-4. This also presents the maximum gauged flood level and peak recorded flood level of the 26 March 2018 flood event.

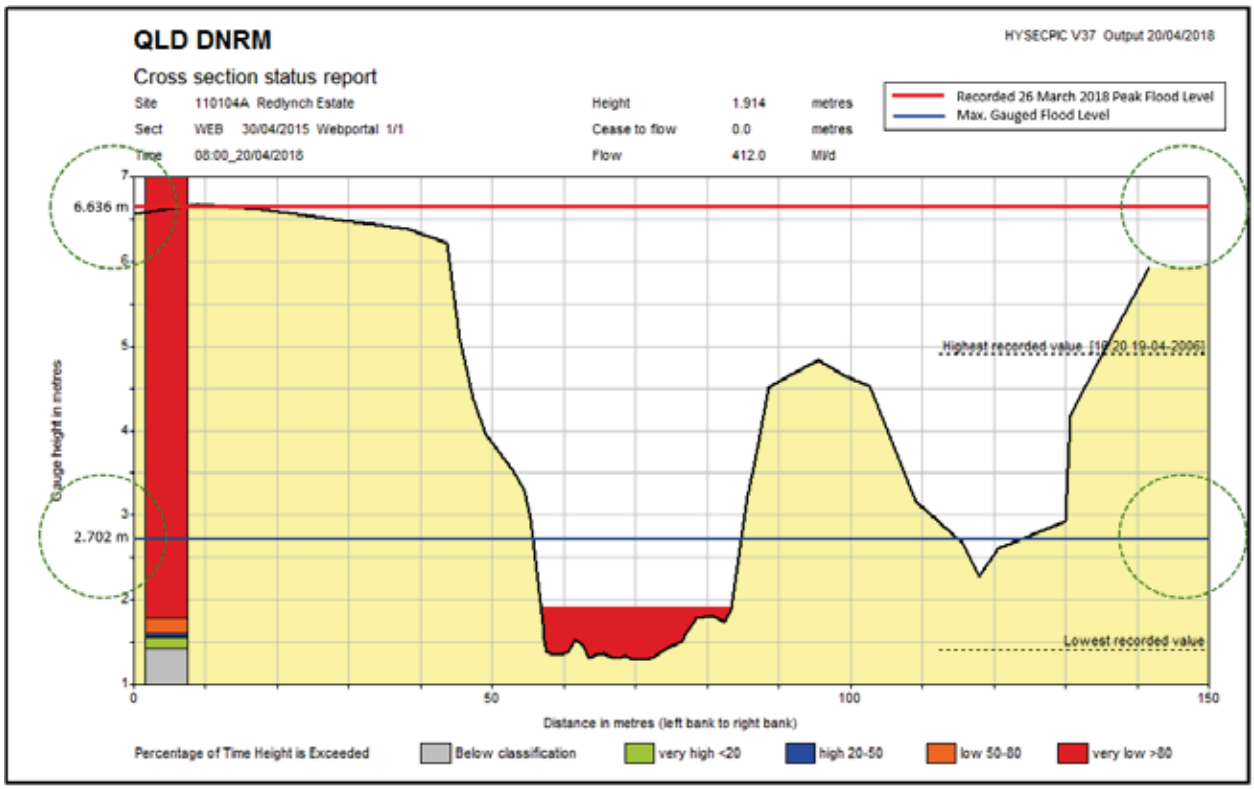


Figure C-4 Graph of Cross Section at Station 110104A (Freshwater Creek at Redlynch)

The cross section presented at station 110104A (Freshwater Creek at Redlynch) does not extend to the limit of the peak flooding recorded during the 2018 event. As the full cross section has not been presented, the reliability of the discharge calculated at the stream gauge for the 2018 flood event is lessened.

Log Pearson III analysis

Data review

A review of data obtained for both the Freshwater Creek at Redlynch Estate and Copperlode Dam gauge identified that there were a number of years not suitable to be included in analysis. These have been identified in Table C-3.

Table C-3 Years removed at stream gauge stations for Log Pearson III Analysis

Station ID	Location	Years removed	Justification of removing years	Total number of appropriate years
110104A	Freshwater Creek at Redlynch Estate	1999	Recording began in October of this year, it's likely the peak flow was not captured.	19
31205	Copperlode Dam at the spillway	2002, 2003, 2015, 2016	No flow was released over the spillway in these years.	14

As further identified, both stations have less than 20 years of appropriate data for use in a flood frequency analysis (FFA). Consequently, the values may be skewed as minimal data is available.

Flood frequency assessment results

The Log Pearson III flood frequency model was used to determine the stream gauge ARI for both the Freshwater Creek at Redlynch Estate and Copperlode Dam gauges. A summary of the results is presented in Table C-4.

Table C-4 Summary of Log Pearson III analysis ARIs

Station ID	Location	Stream gauge ARI
110104A	Freshwater Creek at Redlynch Estate	32.00
31205	Copperlode Dam at the spillway	23.67

It is important to note that record lengths of 14 and 19 years are grossly insufficient to estimate severe events such as the ARI 100 year event flows, and use of such a short record can significantly underestimate actual event magnitude.

Appendix D Stage 1 Rainfall-Runoff Modelling

Background

A WBNM hydrologic model was developed by BMT for the flood impact assessment of the Redlynch Cape York AFL Facility located on the Redlynch Connection north of the St Andrew's Catholic College. The assessment, undertaken in September 2017, involved the development of a full Freshwater Creek catchment model extending from upstream of Copperlode Dam to Kamerunga Road downstream. The total catchment area modelled was approximately 95.1km^2. The catchment delineation is shown attached.

In the absence of historical flood event data, the WBNM hydrologic model was validated to the 1% AEP peak flows for a number of local sub-catchments within the Freshwater Creek catchment as determined by the Rational Method. Design rainfall intensities were calculated based on the parameters as prescribed by Australian Rainfall and Runoff, 2001, noting that the resultant intensities were higher than the values determined using the latest 2016 ARR methodology for durations up to and including the 24 hour.

In addition to the Rational Method validation, an estimate of the peak design flow at Kamerunga Road was undertaken using the AR&R *Regional Flood Frequency Estimation Model* (RFFEM). It can be noted that the attenuation provided by the Copperlode Dam is not considered during this validation process.

The fraction impervious values adopted for each sub-catchment were based on review of the land use and aerial imagery. An initial loss of 0 mm and a continuing loss rate of 2.5 mm/h was also used for all storm events.

The model was run for durations ranging from 60 minutes to 24 hours to determine the peak rainfall event for each catchment used for the WBNM model validation. The resultant peak flows determined using the WBNM model are compared to the Rational Method and RFFEM peak flows in Table D-1.

Table D-1 WBNM Validation

Catchment	Rational Method/RFFEM 1% AEP Peak Flows (m^3/s)	WBNM	% Difference
A17	92.7	94.1	1.5
A25	54.5	54.5	-
Total to Kamerunga Road (A35)	1,030	1,177	14

Following commissioning to undertake a forensic review of the March 2018 flood event by Cairns Regional Council, the Currunda Creek catchment has been investigated in more detail for Stage 1. This included further refinement of the catchment into subcatchment areas and validation of flows from the total catchment to the Rational Method. To achieve peak flows approaching the Rational Method values, it was necessary to reduce the local WBNM stream lag factors within the Currunda Creek catchment to reflect shorter catchment response times associated with the relatively steep upper catchment topography. The resultant WBNM 1% AEP peak flow of 207m^3/s compared well with the Rational Method estimate of 205m^3/s. These values are consistent with the Lawson and Treloar assessment of Currunda Creek undertaken in 1998 but are approximately 40% higher than the peak flow determined using the previous WBNM model used for the Redlynch Cape York AFL Facility assessment. This catchment was not the focus for the previous studies and with reasonable validation achieved for our area of interest, it was not considered critical to check all sub-catchments to the Rational Method.

The increased flow in Currunda Creek has subsequently increased flows within Freshwater Creek downstream of the confluence.

Design Event Results from Hydrologic Model

The estimated peak design flows at the Copperlode Dam outflow, approximate Redlynch Gauge location (outlet to subcatchment A6), approximate Rocks Rock Causeway (A8), Currunda Creek (A7) and at Kamerunga Road (A35) are detailed below in Table D-2. The design flows have been determined assuming the Copperlode Dam is full at the start of the design event and includes the attenuation attributable to the storage upstream and above the level of the dam spillway.

Table D-2 Estimated Design Peak Flows WBNM Model

ARI (Years)	AEP (%)	Copperlode Dam (Outflow) m^3/s	Catchment A6 (approximate Redlynch Gauge) m^3/s	Catchment A8 (approximate Rocks Road Causeway m^3/s)	Currunda Creek A7 (upstream of Redlynch Intake Road)	Catchment A35 (Kamerunga Road) m^3/s
100	1	262	468	612	207	870
50	2	222	399	527	181	748
20	5	173	318	467	168	658
10	10	137	261	386	141	544

March 2018 Results from Hydrologic Model

To estimate the peak flows for the March 2018 flood event across the catchment, pluviograph data for the Copperlode Dam Alert Station was sourced and adopted within the WBNM model. It should be noted that the estimated peak flows and magnitude are based on the total rainfall depths and temporal patterns recorded at the Copperlode Dam rainfall gauge being applied across the whole Freshwater Creek catchment. However, total rainfall depths and temporal patterns will vary across the catchment as demonstrated by the variance between the Brinsmead Gauge and Copperlode Dam Gauge. It is also expected that orographic effects along the valley's ridgelines could potentially influence rainfall intensities amongst the elevated watersheds of the catchment.

The model parameters remained unchanged from the Rational Method validation including the adoption of 0mm initial loss and 2.5mm/hr continuing loss. The initial water level in the dam at the start of the event (4:30pm on the 26th March was adopted in the WBNM model) was set to 1.06m deep over the spillway based on recorded levels at the dam.

The resultant peak flows for the March 2018 event at the selected locations are shown in Table D-3 together with the corresponding estimated event AEP.

Table D-3 Estimated March 2018 Peak Flows and AEP

Location	Estimated WBNM Peak Flow (m3/s)	Modelled Time to Peak	Approximate AEP %*	ARI (Years)
Copperlode Dam outlet	168	2:50am 27th	5	20
Catchment A6 (approximate Redlynch Gauge)	489+	11:20pm 26th	<1.0	>100
Catchment A8 (approximate Rocks Road Causeway)	704+	11:20pm 26th	<1.0	>100
Currunda Creek A7H (upstream of Redlynch Intake Road)	209+	10:50pm 26th	1.0	100
Kamerunga Road A35	947+	11:30pm 26th	<1.0	>100

**These are preliminary estimates only for the Stage 1 Assessment and will be refined in Stage 2 investigations, based on joint hydrologic and hydraulic modelling. It should be recognised that these further investigations may impact on the evaluation of the approximate AEP of the event across different locations within the overall catchment.*

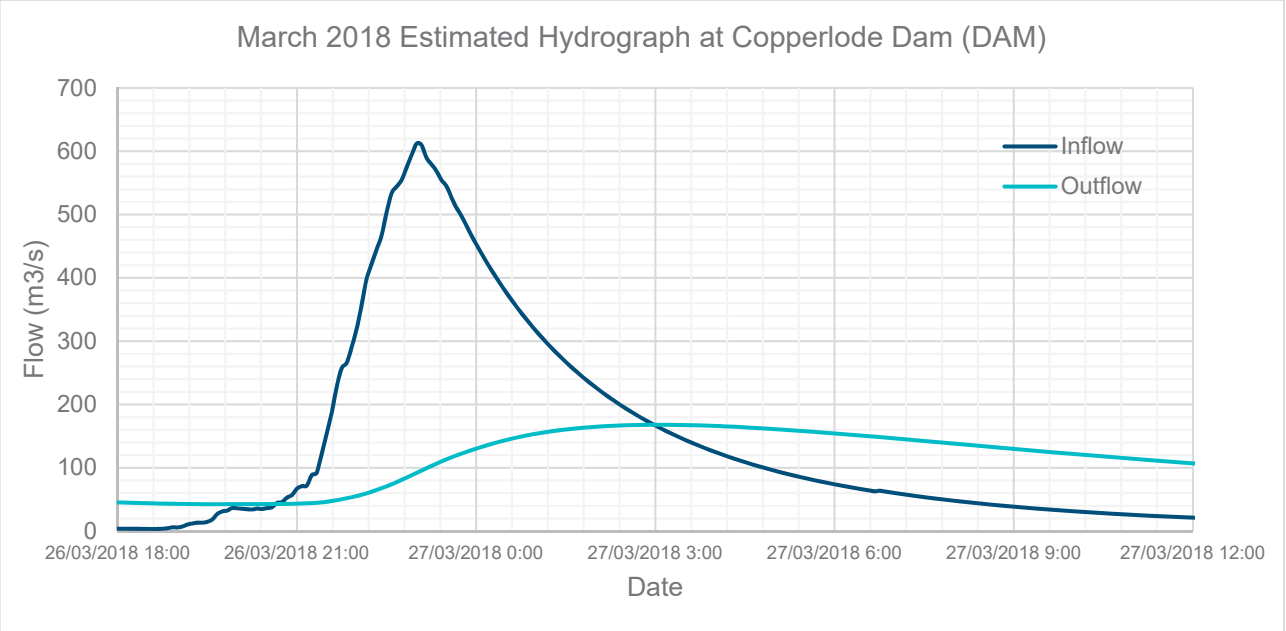
***It is important to note that the estimated AEP for the event is being compared to a scenario with the dam only full to the spillway level in the design events. Consideration of the effects of pre-burst rainfall is not part of this current scope but may need to be considered for future design assessments.**

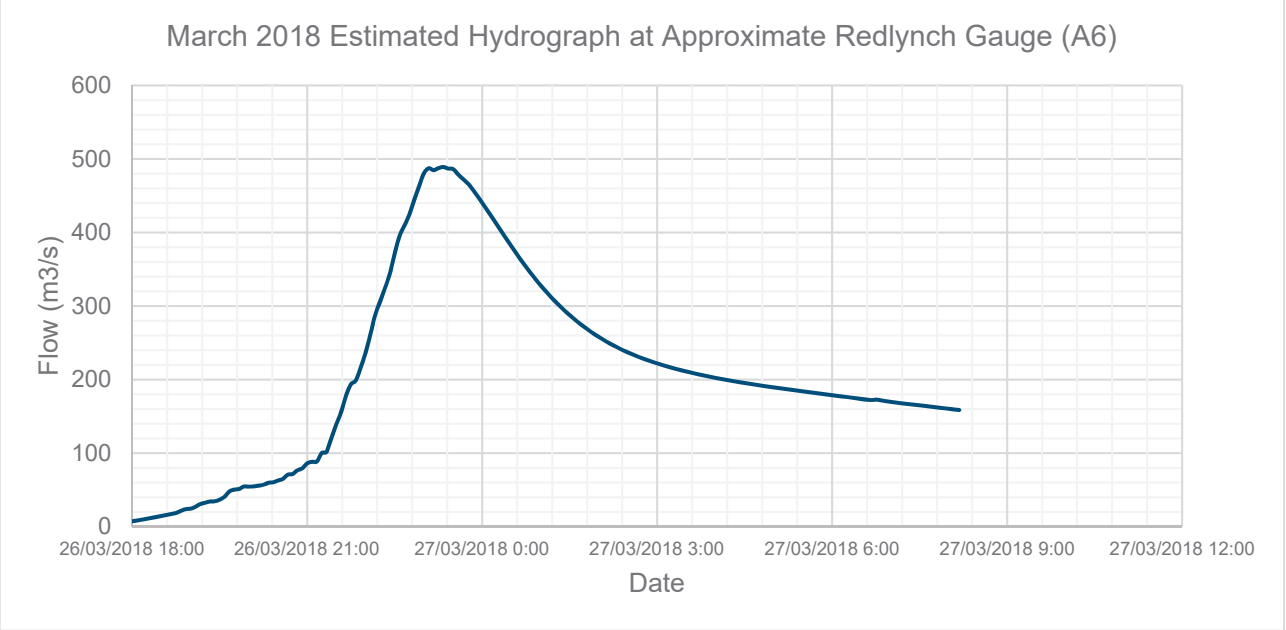
It should be noted that as the model utilised the Copperlode Dam pluviograph data across the whole catchment and the lower reaches appear to have received lesser total rainfall, the peak flows in these lower creeks may be overestimated. The detailed calibration of the revised hydraulic model for Stage 2 may provide a clearer understanding of the local flooding in the lower reaches

The hydrographs for the Copperlode Dam outlet (DAM), approximate Redlynch Gauge (at Mary Parker Drive [A6]), Rocks Road Causeway (A8) and Currunda Creek (A7H) are included in the charts below with the total catchment areas to each location included in Table D-4.

Table D-4 Catchment Details

Location	Total Catchment Area (ha)
Copperlode Dam outlet	4,468
Catchment A6 (approximate Redlynch Gauge)	7,038
Catchment A8 (approximate Rocks Road Causeway)	8,251
Currunda Creek A7H (upstream of Redlynch Intake Road)	832


March 2018 Estimated Hydrograph at Copperlode Dam (DAM)
Flow (m3/s)
700
600
500
400
300
200
100
0
Inflow
Outflow
26/03/2018 18:00
26/03/2018 21:00
27/03/2018 0:00
27/03/2018 3:00
27/03/2018 6:00
27/03/2018 9:00
27/03/2018 12:00
Date


March 2018 Estimated Hydrograph at Approximate Redlynch Gauge (A6)
Flow (m3/s)
600
500
400
300
200
100
0
26/03/2018 18:00
26/03/2018 21:00
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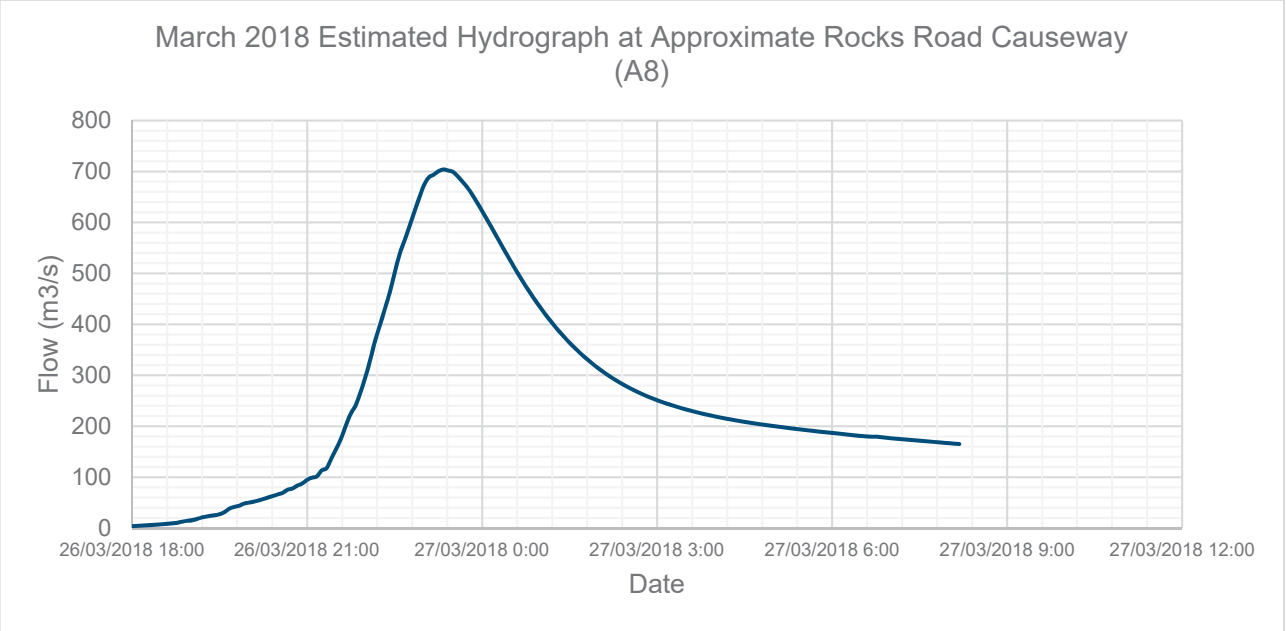
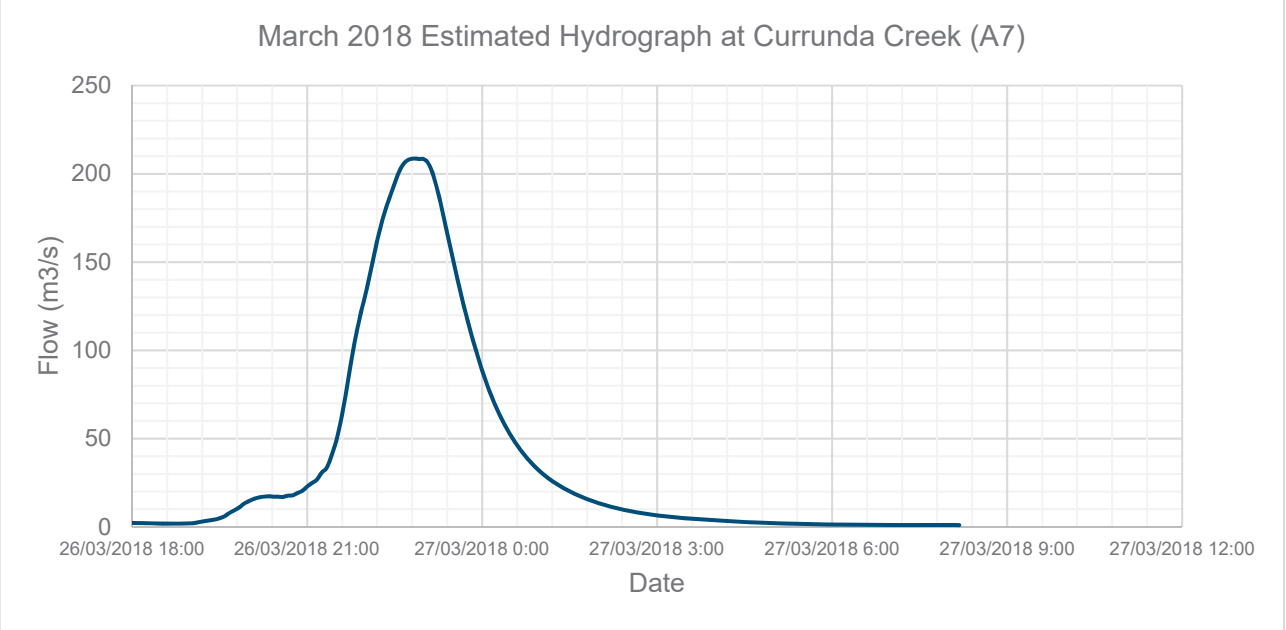
27/03/2018 3:00
27/03/2018 6:00
27/03/2018 9:00
27/03/2018 12:00
Date





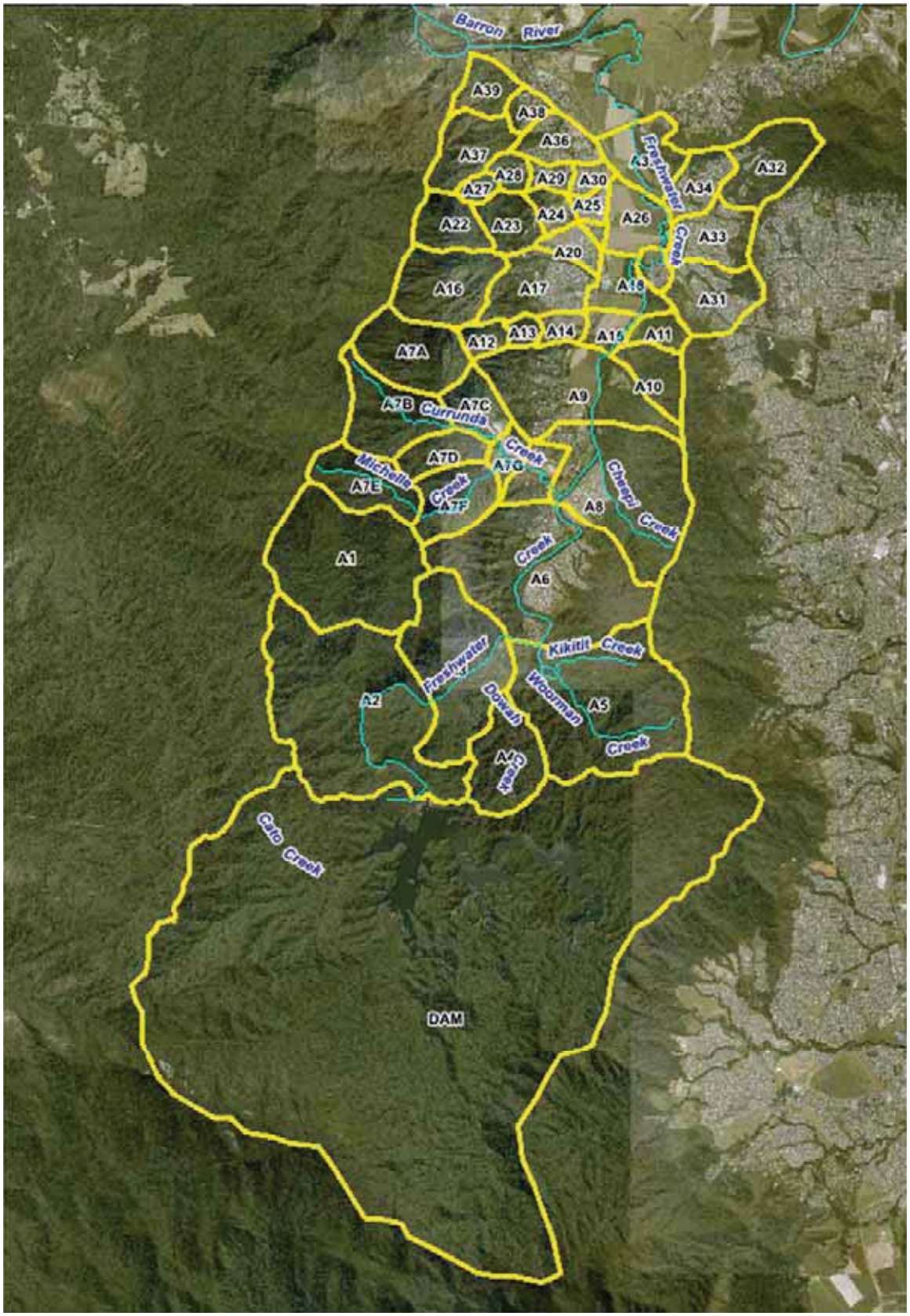
The WBNM catchment areas are included below. Cheepi Creek (contributes approximately 184ha of the total 441ha A8 catchment).

Table D-5 WBNM Catchments (includes Currunda Creek divided into subcatchments) Catchment ID Area (ha) % Impervious

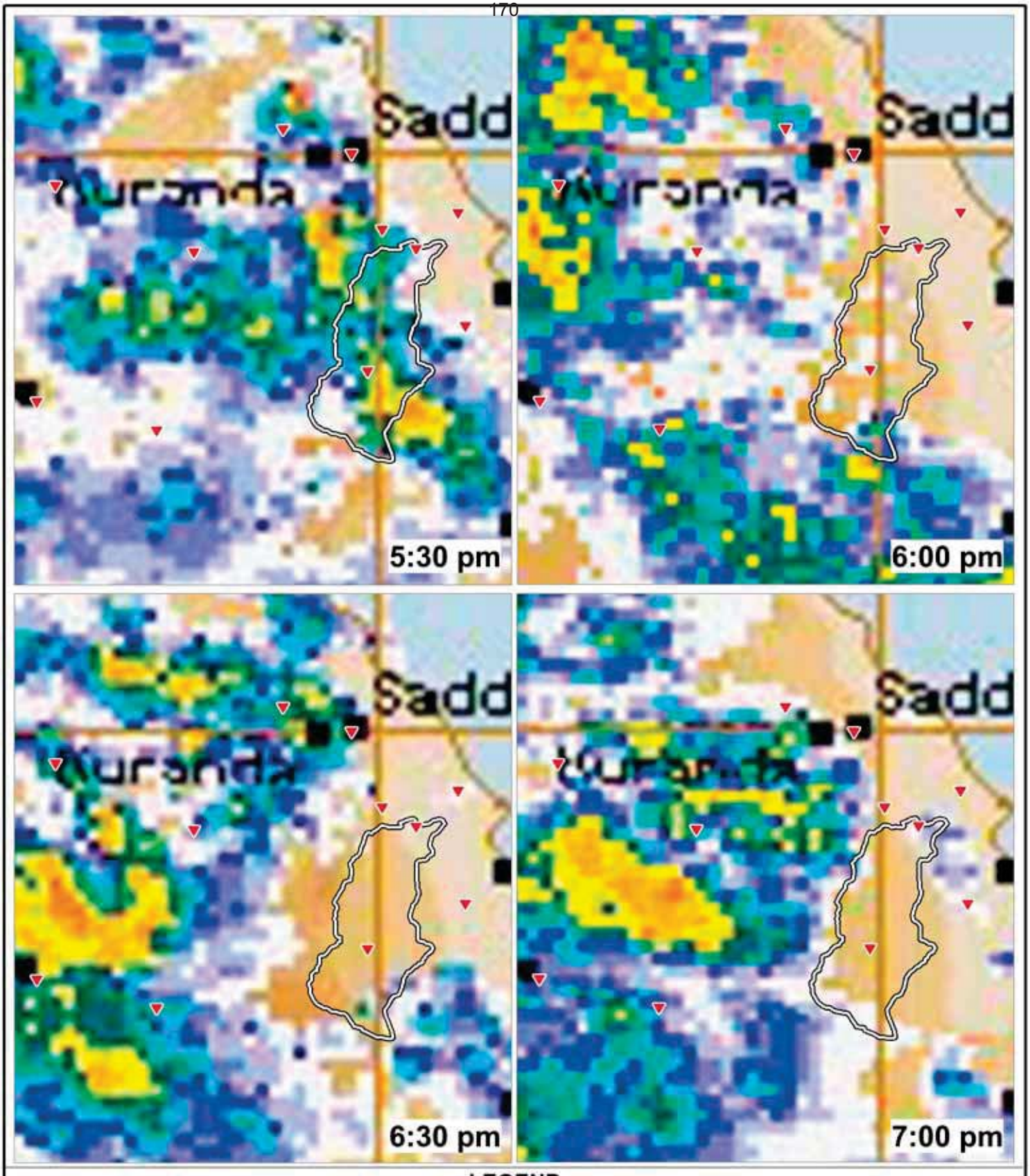
Catchment ID	Area (ha)	% Impervious
DAM	4468.323	0
A1	412.592	0
A2	636.352	0
A3	331.694	0
A4	161.609	0
A5	490.41	0
A6	537.382	15
A7A	166.1	0
A7B	159.8	0
A7C	78.61	0
A7D	71.76	0
A7E	130.3	0
A7F	124.5	0
A7G	40.12	0
A7H	60.85	10
A8	441.284	15
A9	293.173	10
A10	78.328	0
A11	41.752	0
A12	34.619	0
A13	22.511	0
A14	32.412	15
A15	43.371	1
A16	172.938	1
A17	146.691	30
A18	84.156	5
A19	28.234	20
A20	42.38	40
A21	10.389	0
A22	87.003	0
A23	76.225	5
A24	37.81	5
A25	25.673	55

Catchment ID	Area (ha)	% Impervious
A26	94.567	1
A27	22.196	0
A28	31.385	5
A29	29.016	20
A30	27.351	40
A31	132.977	40
A32	138.007	55
A33	111.981	55
A34	76.688	40
A35	113.741	0

Stage 1 Rainfall-Runoff Modelling



Appendix E Radar Images



Title:

Rainfall Radar Imagery - 26 March 2018
5:30 pm - 7:00 pm

Figure: **E-1**

Rev: **A**

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N

0 10 20km

Approx. Scale

BMT
www.bmt.org

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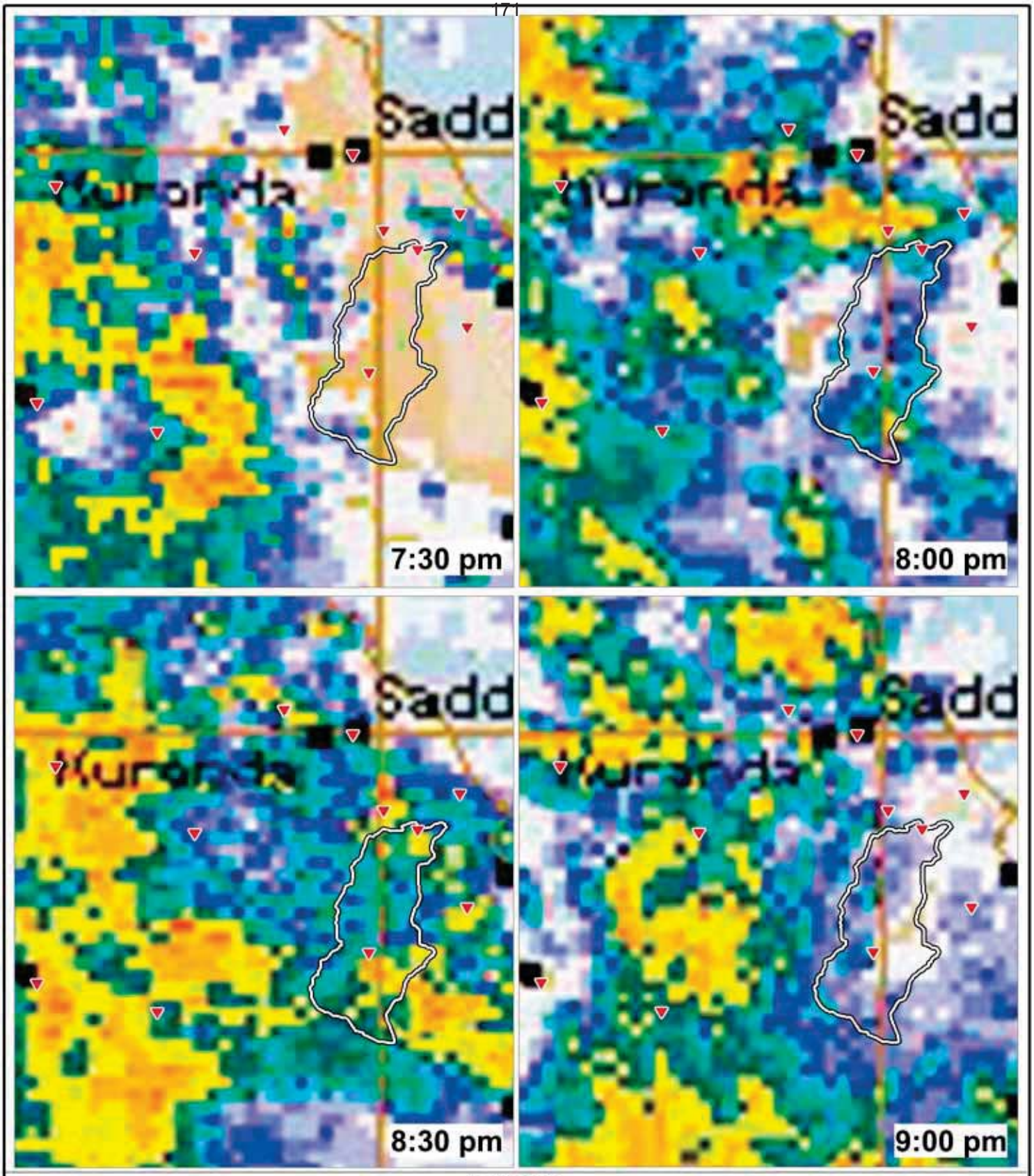

Title:

Rainfall Radar Imagery - 26 March 2018
7:30 pm - 9:00 pm

Figure: **E-2**

Rev: **A**

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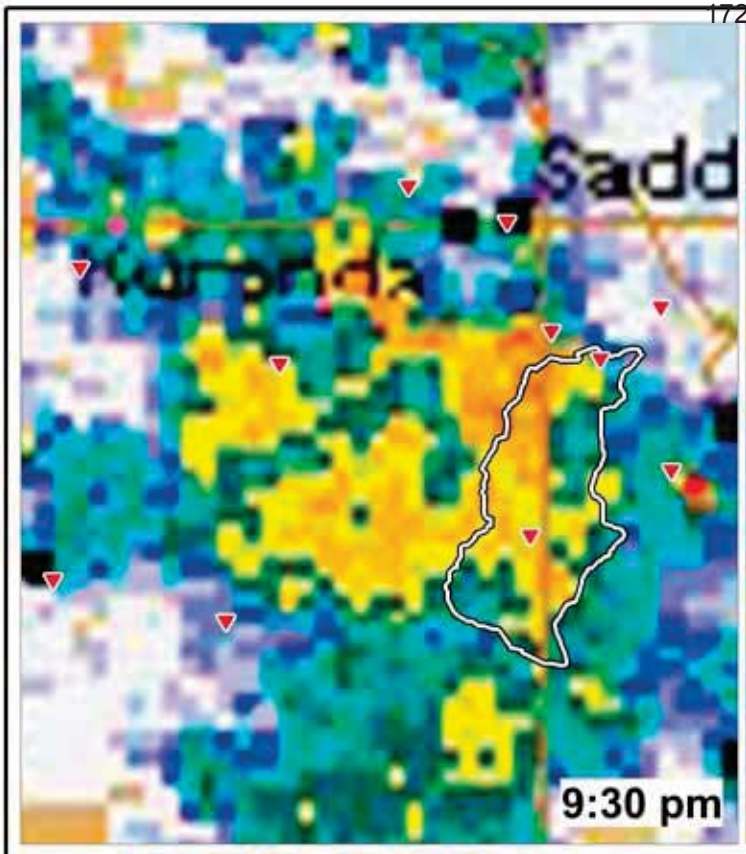
N

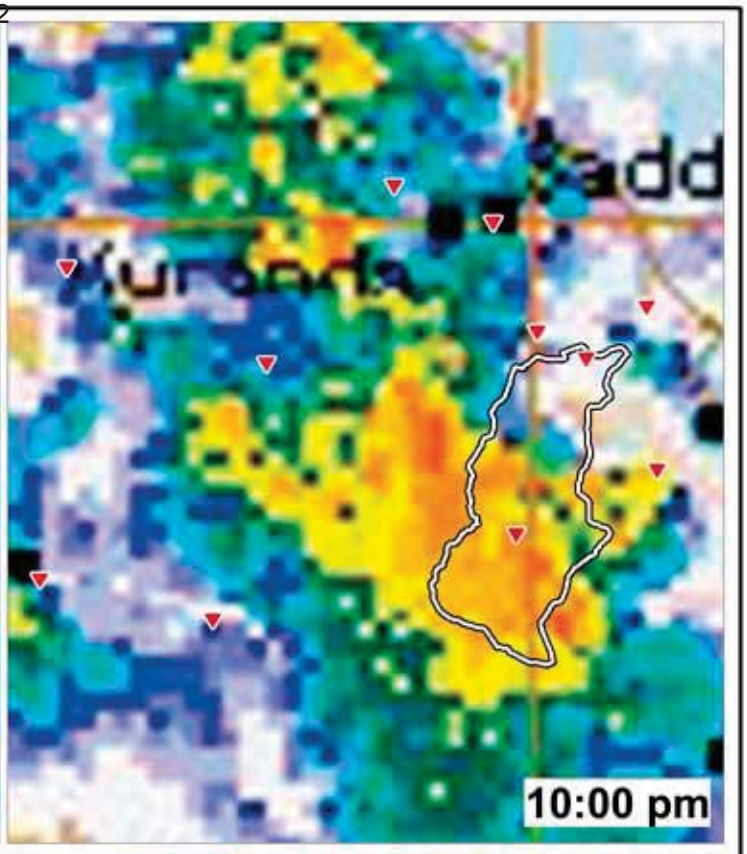
0 10 20km

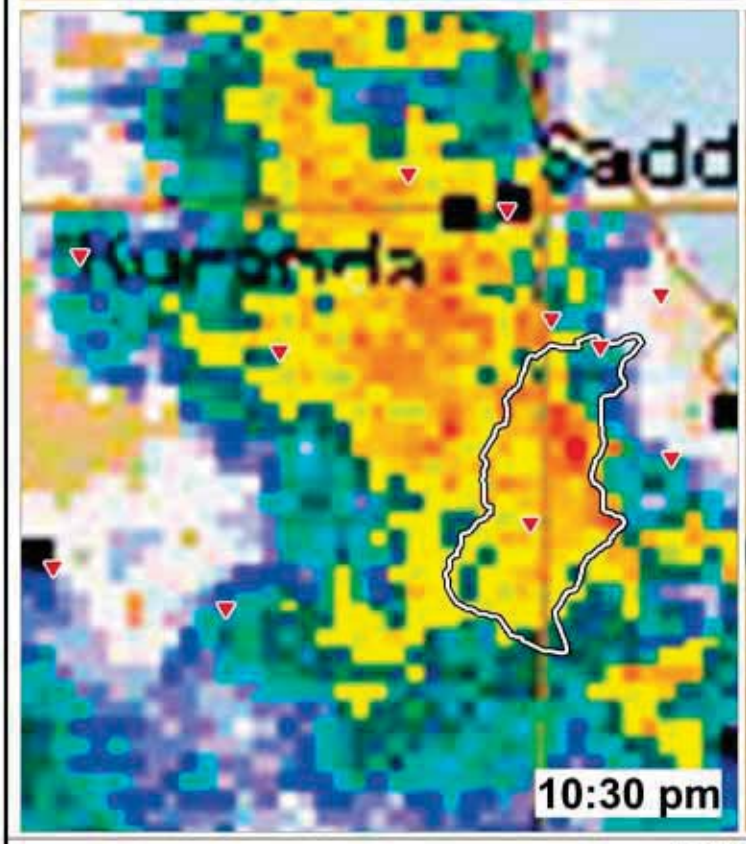
Approx. Scale

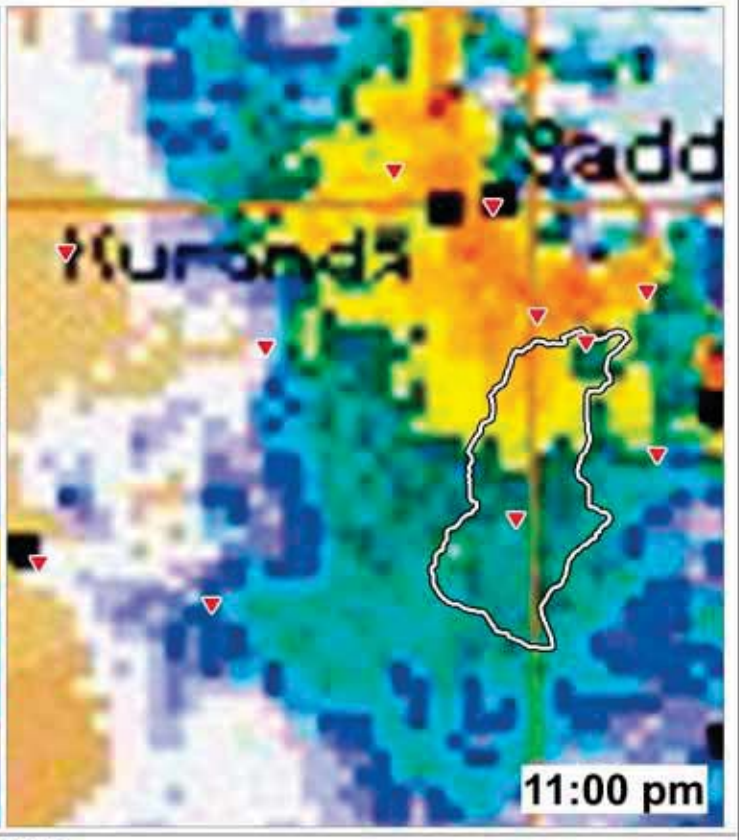
BMT
www.bmt.org

Filepath : G:\Admin\B23195.g.nc_Freshwater Creek Caravan Park\Drafting\DRG\EWS_003_180420_Rainfall_20180326_1930-2100.wor









LEGEND

Light — Moderate — Heavy

Rain Rate

Rain gauge

Freshwater Creek Catchment Boundary

Title:

Rainfall Radar Imagery - 26 March 2018
9:30 pm - 11:00 pm

Figure: E-3

Rev: A

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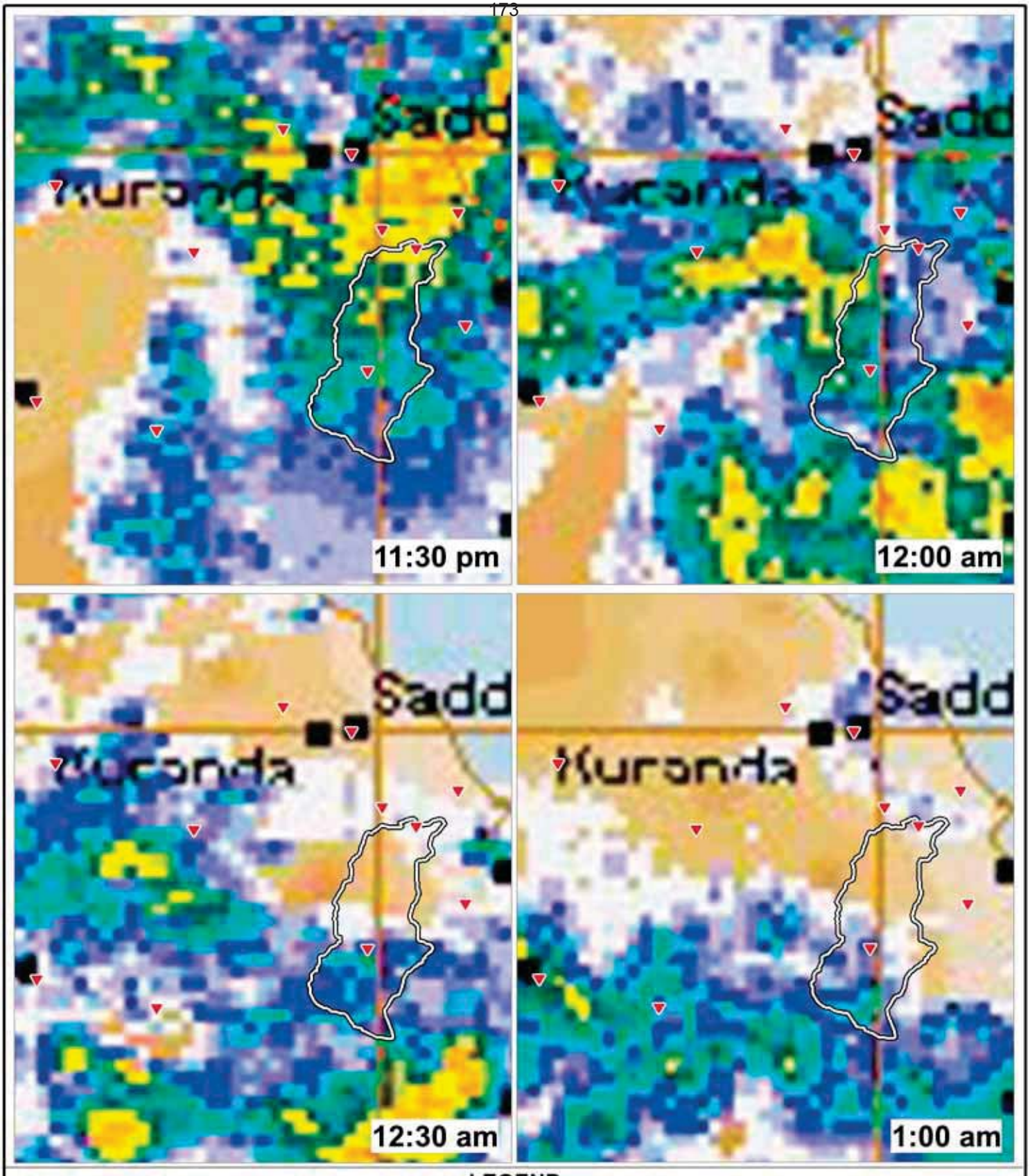
N

0 10 20km

Approx. Scale

BMT
www.bmt.org

Filepath : G:\Admin\B23195.g.nc_Freshwater Creek Caravan Park\Drafting\DRG\EWS_004_180420_Rainfall_20180326_2130-2300.wor



Title:

Rainfall Radar Imagery - 26 to 27 March 2018
11:30 pm - 1:00 am

Figure: **E-4**

Rev: **A**

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N

0 10 20km

Approx. Scale

BMT
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Filepath : G:\Admin\B23195.g.nc_Freshwater Creek Caravan Park\Drafting\DRG\EWS_005_180420_Rainfall_20180326_2330-0100.wor

Brisbane	Level 8, 200 Creek Street, Brisbane QLD 4000 PO Box 203, Spring Hill QLD 4004 Tel +61 7 3831 6744 Fax +61 7 3832 3627 Email brisbane@bmtglobal.com Web www.bmt.org
Denver	8200 S. Akron Street, #B120 Centennial, Denver Colorado 80112 USA Tel +1 303 792 9814 Fax +1 303 792 9742 Email denver@bmtglobal.com Web www.bmt.org
London	International House, 1st Floor St Katharine's Way, London E1W 1UN Tel +44 20 8090 1566 Fax +44 20 8943 5347 Email london@bmtglobal.com Web www.bmt.org
Melbourne	Level 5, 99 King Street, Melbourne 3000 Tel +61 3 8620 6100 Fax +61 3 8620 6105 Email melbourne@bmtglobal.com Web www.bmt.org
Newcastle	126 Belford Street, Broadmeadow 2292 PO Box 266, Broadmeadow NSW 2292 Tel +61 2 4940 8882 Fax +61 2 4940 8887 Email newcastle@bmtglobal.com Web www.bmt.org
Northern Rivers	6/20 Byron Street, Bangalow 2479 Tel +61 2 6687 0466 Fax +61 2 66870422 Email northernrivers@bmtglobal.com Web www.bmt.org
Perth	Level 4, 20 Parkland Road, Osborne, WA 6017 PO Box 2305, Churchlands, WA 6918 Tel +61 8 6163 4900 Email perth@bmtglobal.com Web www.bmt.org
Sydney	Suite G2, 13-15 Smail Street, Ultimo, Sydney, NSW, 2007 PO Box 1181, Broadway NSW 2007 Tel +61 2 8987 2900 Fax +61 2 8987 2999 Email sydney@bmtglobal.com Web www.bmt.org
Vancouver	Suite 401, 611 Alexander Street Vancouver, British Columbia V6A 1E1 Canada Tel +1 604 683 5777 Fax +1 604 608 3232 Email vancouver@bmtglobal.com Web www.bmt.org