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DAWSON RIVER FLOOD STUDY
STAGE 2

Hydrological Assessment Report

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Hydrological Assessment Report

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Revision History

Revision	Date	Comment	Signatures		
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1 Introduction

Kellogg Brown & Root Pty Ltd (KBR) was commissioned by Banana Shire Council (Council) to undertake a floodplain management study and plan for 10 towns within Council's Land Government Area (LGA).

This project will build a set of flood modelling tools that will provide a detailed understanding of flooding in Council's area of responsibility, assess a range of structural and non-structural measures to manage flooding, and develop a plan to reduce the impact of flooding on the community.

As part of the floodplain management study and plan, a flood study was undertaken to inform the management plan. The flood study estimates peak flood flows, levels, and timings used for emergency planning, flood damage assessment and potential mitigation options.

Council's objectives in undertaking a flood risk study and management strategy are to:

- provide the Shire with information on the extent, level and velocity of flood waters
- inform the Shire about potential flood hazards and risks in the region with an assessment of evacuation options and impacts to critical infrastructure
- develop strategies to allow the Shire to manage flood risk through mitigation, warning and planning and interaction with major stakeholders and nearby local authorities
- proactive consultation with stakeholders and the community to gather and distribute information and build confidence and acceptance in the strategy.

The study will also provide the Shire with useful information to guide future development.

1.1 APPRECIATION

The majority of the area governed by the Banana Shire Council Local Government Area is within the Dawson River catchment. There are several towns within the Shire that lie on the banks of the Dawson River and its tributaries. These include the main centres of Biloela and Moura and many smaller towns, many of which are exposed to some degree of flood risk.

The key economic drivers in the Shire include a strong agriculture sector and growing resources sector and there are great opportunities for further development within the Southern Bowen Basin and Northern Surat Basin. The community and business services are diverse and include health, education, retail and tourism.

The total catchment area of the Dawson River is approximately 50,000 km^2 meaning that widespread rainfall depressions can cause major flooding in the region, as witnessed by the December 2010/January 2011 event which impacted Taroom, Theodore, Moura and Baralaba along the Dawson River.

Flash flooding can also occur in the smaller, steeper tributaries on the eastern side of the Dawson catchment, closer to the coastline. These catchments can be hit by severe storms with intense rainfall, such as occurred in January 2013 caused by ex-tropical cyclone Oswald and February 2015 caused by tropical cyclone Marcia. Rapidly rising water in the creeks and rivers caused damage in the towns of Thangool, Biloela, Jambin, Goovigen, Dululu and Wowan.

During major flood events like those described above, communities can become isolated due to flooding and/or road damage. This can impact normal supply routes and limit access to essential services for residents of communities within the Shire. Crops, livestock and fencing can be destroyed and people displaced. Drinking water, power and sanitation can also be affected, as occurred in Theodore in the wake of the January 2011 flood.

The economic impact to residents and business recovering from flooding is very significant and this can be measured or estimated. The emotional and societal impacts are less tangible and, once the flood waters recede, the long road to recovery can be crushing to individuals and the community.

From a different point of view, all the rain from the January 2011 event filled the Callide Dam which up until that point had become alarmingly low with concerns for the future water supply of the region.

1.2 REPORT CONTEXT

During the conduct of the study a number of documents will be provided to Council. Some of these will assume knowledge contained in reports produced progressively and it is therefore important that the relationship between the reports is established early in the project and a common understanding can be gained.

The documents likely to be produced identified so far include:

- hydrologic and hydraulic modelling calibration and design event report (this document)
- several discussion papers covering structural and non-structural mitigation measures, emergency management and development control
- Floodplain Management Plan.

This report is the first major deliverable that will be produced as part of the project. This report describes the hydrological and hydraulic aspect of the flood study including model development, calibration and design event assessment.

The main body of text is intended for non-technical persons. There are several technical appendices which each describe in detail the hydrologic and hydraulic model setup and parameters. Volume 2 of this report contains mapping outputs from the hydraulic assessments.

1.3 SCOPE

Major components for the preparation of the study and plan are:

- The hydrological assessment and modelling involves the analysis of recorded stream flow data and the estimation of the design flood peaks and flood hydrographs. These are used as boundary conditions in hydraulic modelling.
- The flood assessment and hydraulic modelling involves the analysis and estimation of flood levels in the river systems which are an important component for the preparation of the Floodplain Management Plan (FPMP).
- The flood risk management study includes the assessment of the flood risks and hazards primarily using the outputs from the hydrologic and hydraulic flood models and comparing these with elements at risk and then preparing the flood risk management strategies.

The study area comprises the local government area of Council. The Shire of Banana embraces the Dawson River catchment, a sub-basin of the Fitzroy River, which includes the Don River catchment. Significant floods in the Dawson River in 2010 and again in the Don Catchment in 2013 and 2015 have highlighted the importance of understanding flooding and addressing flooding issues through a combination of development controls, flood warning systems, emergency management planning and structural measures all directed to improving community resilience.

The recent flood events, while causing considerable impacts on local communities, provided an excellent opportunity to gather a high quality dataset that together can produce a robust floodplain model and a reliable Floodplain Management Plan that minimises the impacts of flooding into the future.

While the flood study will attempt to appraise the flood risk within the majority of the Council area, an appreciation of the key townships that are most vulnerable to the impacts of flooding (direct or indirect) need to be understood. Within the Council area the townships of interest have been identified as follows:

- Dawson River Catchment
  - Taroom
  - Theodore
  - Moura
  - Baralaba
- Don River Catchment
  - Thangool
  - Biloela
  - Jambin
  - Goovigen
  - Dululu
  - Wowan

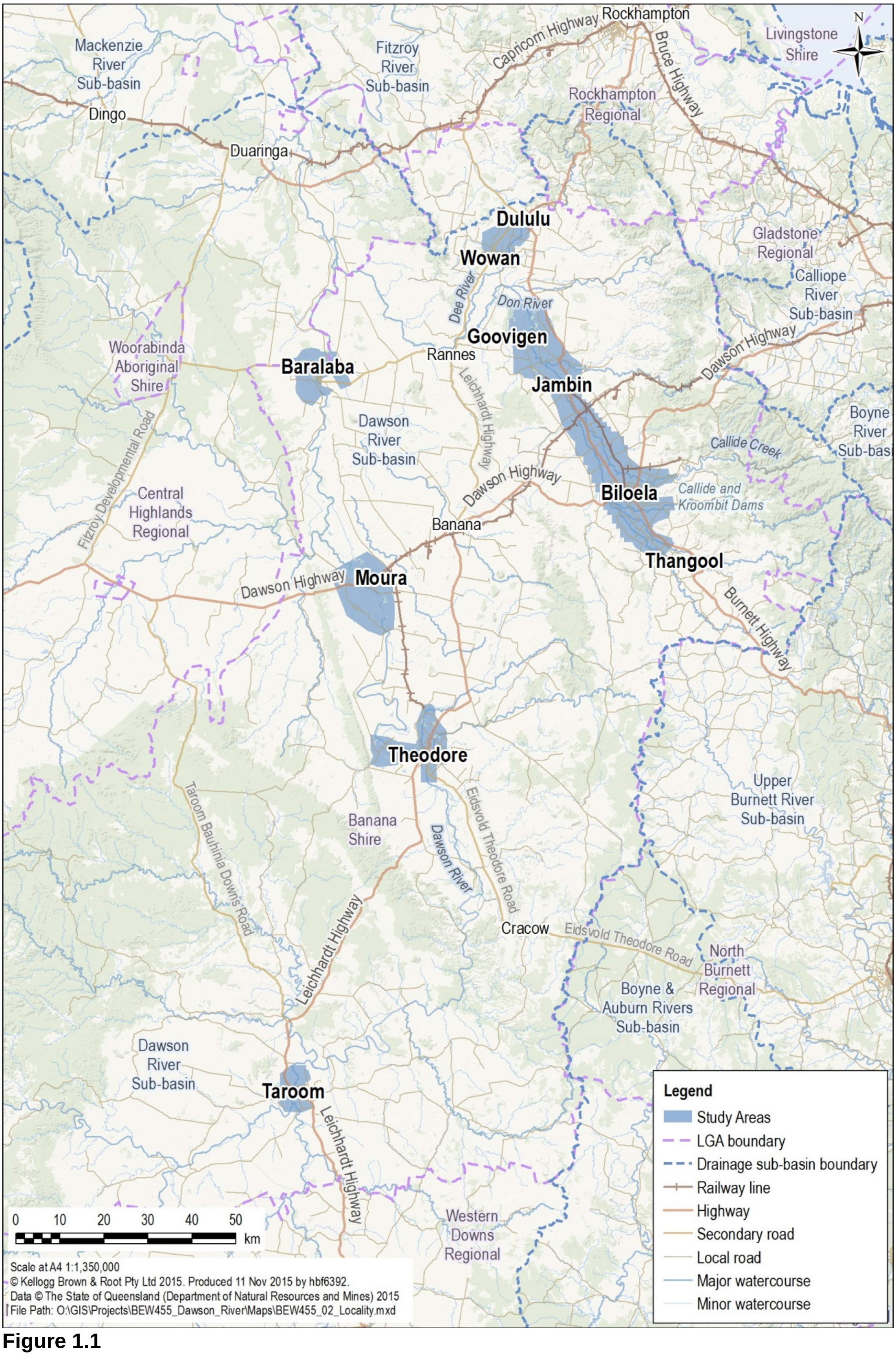

Figure 1.1
BANANA SHIRE COUNCIL STUDY AREAS

1.4 CALLIDE VALLEY FLOOD MITIGATION STUDY

The Inspector-General Emergency Management (IGEM) submitted a report to Government reviewing the circumstances of the 2015 TC Marcia flood event. The report also assessed the disaster management arrangements and identified opportunities to where improvements could be made. The report made thirteen recommendations to improve flood preparedness, some of which the Department of Energy and Water Supply (DEWS) are responsible for.

As part of the work completed to address Recommendation No. 1 from the IGEM review, DEWS is undertaking the Callide Valley Flood Mitigation Study (CVFMS) to determine whether or not is feasible to operate Callide Dam as a flood mitigation dam including alternative means of effecting improved community outcomes.

KBR was engaged to provide preliminary mitigation outcomes for the CVFMS.

By agreement between Council and DEWS, the outputs from the hydrologic and hydraulic models developed for the Banana Flood Study have been made available for the CVFMS. Similarly, any useful data or modelling enhancements brought about through the DEWS study have been made available to Council. This has been agreed to provide continuity and to make available the best set of modelling tools and information for both studies.

2 Community consultation

Flood management projects require a measured and strategic approach to communications. Consulting with local communities and engaging key stakeholders will enhance acceptance and support of the flood study. This is achieved by enabling meaningful two-way communication so that stakeholders and community ideas and opinions can inform project decision-making, including any concerns they might hold.

This chapter describes communications deliverables as well as the community interactions and feedback obtained during the community drop-in sessions conducted Monday 30 November and Tuesday 1 December 2015 and through questionnaires.

Table 2.1 outlines the proposed schedule and purpose of each community engagement session. Community feedback and local knowledge plays an important role in building an accurate flood model of the Dawson Catchment area.

The first two stages of the Banana Shire Flood Study, data gathering and flood (hydrologic and hydraulic) modelling, are now complete. The next two stages include an assessment of the range of flood risks for ten towns and the region as a whole, and finally the development of a Floodplain Management Plan.

Table 2.1 Proposed Community Engagements

Project Stage	Consultation Activity	Purpose of Activity
Stage 1 Flood Study	Community drop-in session #1	Outline the process that will be followed during the study and what outputs will be produced. It also allows us to gather any useful information on past flood events for calibrating the numerical models and may give early insight into the type of mitigation options that will be acceptable to the community.
Stage 4 Structural mitigation option testing	Community drop-in session #2	Discuss the individual mitigation options with the community to canvass community concerns and attitudes to the various floodplain management measures before the Draft Plan is prepared.

2.1 APPROACH AND OBJECTIVES

KBR has developed and agreed with Council a Community Consultation Action Plan that outlines the community consultation activities to be undertaken by KBR. The basis of this plan is to inform and consult external stakeholders and the broader community in relation to the Banana Shire Flood Study from November 2015 to mid-2016.

Several key information processes have been developed for the community, including website content, newspaper advertisement material, frequently asked questions, study area maps, fact sheets, community letters and hard copy and online questionnaires. A project email, 1800 free call phone number and reply paid mailing address were also established to allow free and easy access to the Project Team.

Community engagement for the Banana Shire Flood Study aimed to adopt an approach that:

- was mindful that the Project Team was representing Council at all times
- was consistent with Council's commitment to understanding the impact of flooding on people, property and industry
- was inclusive and respectful of a broad range of stakeholders from various locations within the Shire, particularly those that have been significantly affected by flood events in the past
- considered and respected the contributions that key organisational stakeholders could make to the Study
- carefully managed stakeholder expectations and fostered appropriate levels of stakeholder participation with upfront, honest and inclusive communication
- considered restraints in rural communications by providing multiple avenues of engagement including project phone, email, reply paid mail, hard copy questionnaires and online submissions
- was mindful that information must be presented in a relevant and meaningful way to non-technical audiences
- integrated with multidisciplinary project teams in both office and on-site environments to ensure accurate and timely information exchanges
- continually monitors the environment to identify issues early and manage potential impacts.

The approach taken aimed to achieve a number of objectives including:

- explain the study approach, stages, timeframes and anticipated outcomes
- communicate opportunities for community input and how this valuable information will be used
- gather any useful information on past flood events for calibrating numerical models
- gain insight into accepted mitigation options and proposals in the community
- gauge interest in future stages of the Study
- promote community feedback channels.

2.2 COMMUNITY INTERACTIONS

Between Monday 30 November and Tuesday 1 December 2015, the first community drop-in sessions were held at four community centres in Jambin, Biloela, Theodore and Taroom. The sessions were staffed by Banana Shire Council and KBR employees. Attendees were given a copy of the Flood Study questionnaire as well as a reply paid envelope, fact sheet, frequently asked questions and study area map. Many attendees chose to also collect information to distribute to neighbours and friends.

Community feedback was encouraged through multiple platforms. It was explained that community input would assist in creating accurate flood models and understanding the impact of flooding on people, property and industry. From the drop-in sessions held in Jambin and Biloela on Monday 30 November 2015 and in Theodore and Taroom on Tuesday 1 December 2015, six primary issues were identified:

- water flow and construction that changes water flow
- flood prevention and alleviation measures
- evacuation procedures and warning systems
- recovery coordination
- local disaster management
- communication disruption and improvement.

KBR received 42 responses to the questionnaire—18 submitted via an online platform (Wufoo) and 24 were submitted via the hardcopy format either through mail, at the consultation sessions or through email. Two community feedback forms were completed by a KBR staff member at the consultation sessions that recorded significant individual concerns. Following the sessions several phone calls and emails were received to the project team and responded to promptly.

All community input gathered through questionnaires, email and phone calls have been entered into a spreadsheet to collate data and analyse trends. Notes taken that detail community trends, comments and feedback during the drop-in sessions have been recorded and shared with the Project Team to assist in the development of the Study. The information is structured to enable further analysis on survey responses if needed in the future.

In January 2016, 29 government and/or local departments and agencies were contacted as part of the consultation process, to seek feedback and input into the study. Of the responses received, primary concerns focused on:

- a lack of situational awareness and risks
- communication disruption, poor communication and lack of filter mechanisms
- poor emergency warning systems
- isolation due to flooding and from other communities and assistance
- road heights to be raised.

These findings were gathered and will be used to inform the development of mitigation options in Stages 3 and 4 of the project.

2.3 CONCLUSION AND RECOMMENDATIONS

The feedback and data received during the Stage One community consultation process has been used to inform the flood models and will be incorporated into the development of the management plan.

The Project Team will continue to engage with the community during the process to provide notification of study progression and future participation opportunities. The project team has a formal process for receiving and quickly and effectively dealing with enquiries and complaints.

An additional round of drop-in sessions and a questionnaire is planned before the Draft Management Plan is prepared to discuss the individual mitigation options with the community to canvass community concerns and attitudes to the various floodplain management measures.

3 Data

A significant amount of data available from multiple sources has been collected, compiled and audited for this project. This section documents the status of the data set and provides a review of its suitability for the preparation of the Floodplain Management Study and Plan.

3.1 RAINFALL

3.1.1 Historic

Historic rainfall data was sourced from the Bureau of Meteorology (BOM), the Department of Natural Resources and Mines (DNRM), and SunWater.

Sub-daily rainfall (pluviograph) stations were used to obtain temporal patterns throughout the catchment. The temporal pattern describes the rainfall timing and is important in estimating flow as storms often move across the catchment, changing the severity of flooding.

Daily rainfall stations, which record depths totalled in 24 hours (9 am to 9 am), were used in conjunction with the pluviograph stations to generate a rainfall surface over the catchment. The rainfall surface defines the spatial variation in rainfall depth over the catchment, and estimates depths in parts of the catchment that fall between rainfall gauges.

The rainfall gauges were audited for quality and several pluviograph and daily stations were removed. A full list of the rainfall stations considered, used, and discarded is presented in Appendix A-1.

3.1.2 Design

Intensity Frequency Duration (IFD) curves were generated using CRC-FORGE up to the 0.05% AEP event. CRC-FORGE rainfall depths are estimated using a longer and more recent data set than BOM 1987. CRC-FORGE also estimates rainfall depths for events rarer than the 1% AEP event and are generally more conservative.

The latest BOM IFD curves were not adopted for this study as the full release of the updated Australian Rainfall & Runoff (ARR) revision was not released.

3.2 STREAMFLOW

Historic streamflow is used as part of the hydrological model calibration. Flows produced from the hydrological model are compared against the historic data and parameters in the model are changed within reason to achieve a close match.

Flow itself is difficult to measure automatically and accurately. Flow is therefore estimated using an inferred relationship with water level (stage), which is a much easier property to measure. The relationship is called a stage-discharge curve or rating curve.

Rating curves are usually constructed from a number of observed gaugings (measured flow) based on small flows with extrapolations of the rating curve for large flows. Because of the need for extrapolation for higher flows, there is potential for errors in the estimated rated flow at high stages.

A number of streamflow stations were identified as having inaccurate rating curves and are discussed in more detail in Appendix A. Dam spillways are generally good locations to estimate flow as they have known, consistent hydraulic parameters such as geometry, surface roughness, and water surface slope.

A full list of the streamflow stations provided, used, partially used, and discarded is presented in Appendix A-2.

3.3 TERRAIN

3.3.1 Catchment mapping

Terrain was used to define the hydrological properties such as catchment area, catchment slope, and stream length. Because the catchment is so large, complete coverage of detailed terrain data such as Light Detection and Ranging (LiDAR) is not available.

Shuttle Radar and Topography Mission (SRTM) data was used in this study. SRTM data was captured by an orbiting shuttle and has coverage for the entirety of Australia. However as a consequence of its height above the ground, it has a low horizontal and vertical accuracy and does not include subtle terrain features such as creeks and embankments. The DEM-S version used in this study has a vertical accuracy of 5 m (Geoscience Australia, 2011).

For the purpose of the hydrological study, SRTM is considered appropriate for use. Due to the size of the catchments assessed, the proportional error caused by SRTM would be negligible.

3.3.2 Flood models

Two-dimensional hydraulic models require extensive and detailed topographic data of the river channel and floodplain. A review of the survey data indicates the following:

High resolution LiDAR captured in 2011 and 2012 is available for the townships of interest in this study. The survey extents are generally sufficient for the development of hydraulic models and presented in Figure 3.1.

DERM prepared background studies for the proposed Rolleston Dam which included a large photogrammetric dataset at 2 m contour intervals. This dataset extends over the Dawson River below Gyranda Weir (between Theodore and Taroom) to the Capricorn Highway. This data was utilised to extend the flood model extents for Moura and Baralaba.

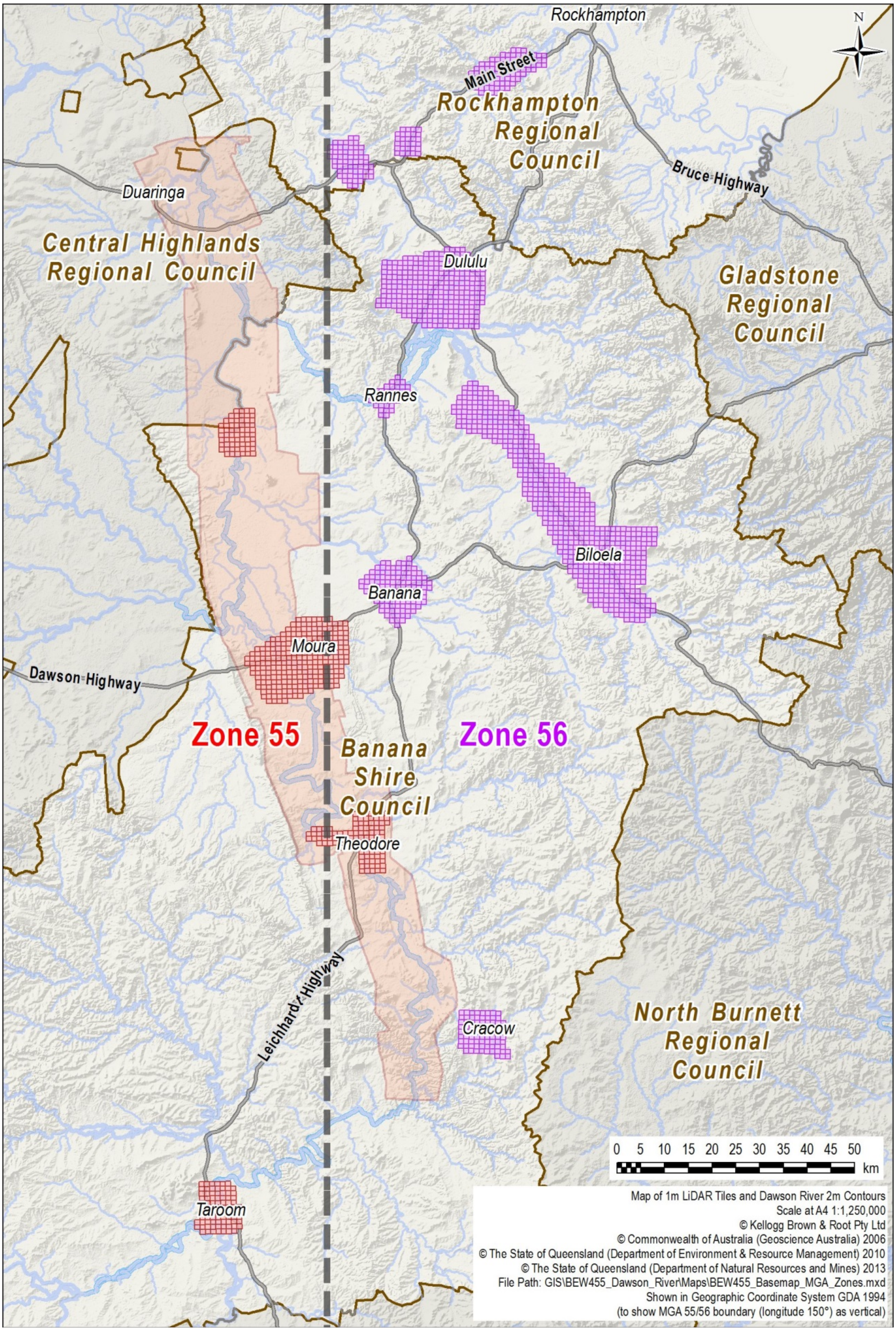

Figure 3.1
MAP OF LIDAR COVERAGE AND DAWSON 2 M CONTOURS

The flood modelled prepared for the Inspector General Emergency Management (IGEM) Independent Review of Callide Creek Flooding was made available to KBR and included a DEM that extended beyond the LiDAR data provided by DNRM. The source of this data is unknown however it compared well with the LiDAR and was used to extend the Callide Valley flood model.

Generally LiDAR data is of high quality even in relatively heavily forested areas. However some dense crops can introduce a ‘step’ in the terrain which should be removed as necessary. The main limitation of aerial survey is that areas of standing water cannot be penetrated and result in a flat ‘bed’ in rivers and creeks, this is mostly noticed in the towns along the Dawson River but generally this does not have any noticeable impact on major flood levels in the hydraulic models.

3.4 HYDROLOGICAL ROUGHNESS

3.4.1 Hydrologic modelling

Hydrological roughness was estimated using Geographical Information System (GIS) files from the Queensland Land Use Mapping Program (QLUMP). Hydrological roughness is used by hydrological runoff-routing modelling software to estimate catchment responses such as peak flow and timing.

3.4.2 Hydraulic modelling

Hydraulic roughness is a critical input into all hydraulic models and is a function of the resistance imposed upon the flow by vegetation or the natural roughness of the topography. Hydraulic roughness was initially estimated using GIS files from QLUMP. This was refined through inspection of aerial\satellite images in flood free conditions to set normal conditions for hydraulic roughness.

3.5 WATER STORAGE STRUCTURES

3.5.1 Weirs

Information on a number of weirs situated on the Dawson River was provided by SunWater. This information included stage-storage curves, spillway-discharge curves, structure drawings, and water level information.

A full list of the weir information provided is presented in Appendix A-3. Figure 3.2 presents a picture of Neville Hewitt Weir at Baralaba as an example of weirs along the Dawson River.

Figure 3.2
NEVILLE HEWITT WEIR ON THE DAWSON RIVER AT BARALABA

3.5.2 Dams

There are two dams in the Dawson catchment, both located in the Don River catchment. Callide Dam is located on Callide Creek upstream of Biloela and discharges via an automated gate system. The operation of the gates and the spillway-discharge curve are discussed and detailed in Appendix B. The stage-storage curve and water level readings at Callide Dam were provided by SunWater. Figure 3.3 shows the Callide Dam spillway from downstream.

Kroombit Dam is located on Kroombit Creek upstream of Biloela and discharges via an ungated spillway. Kroombit Dam spillway-discharge curve, stage-storage curve, and water level readings were provided by SunWater.

Figure 3.3
CALLIDE DAM SPILLWAY NEAR BILOELA

3.6 HYDRAULIC STRUCTURES

The alignment of existing road and rail networks is available through GIS layers from DNRM. DTMR has provided working sections and plans for a number of main roads and highways which include bridge and culvert crossings. A table of information regarding culverts and bridges was obtained from Aurizon. Banana Shire Council made available a GIS layer of existing culvert crossings including dimensions.

Figures 3.4 and 3.5 show a few examples of culvert crossings within the Dawson Catchment.

Figure 3.4
DAWSON RIVER OVERFLOW CULVERTS AT LEICHHARDT HWY, TAROOM

Figure 3.5
POCKET CREEK CULVERTS UNDER LEICHHARDT HWY, WOWAN

3.7 FLOOD OBSERVATION DATA

The flood assessment and hydraulic modelling involves the analysis and estimation of flood levels in the river systems which are an important component for the preparation of the FPMS&P.

3.7.1 Callide Valley

Flood data was collected by Council for the 2015 TC Marcia flood in the Callide Valley including debris marks and mud lines which provides an excellent source of calibration information. Photos of each location were captured by KBR and some debris marks were also captured at Wowan and Dululu. For the 2013 Ex-TC Oswald flood and the 2010 flood there are only a handful of debris points which can be used for verification of the flood model. Figure 3.6 is an example of a mud line that was captured after the 2015 TC Marcia flood.

Figure 3.6
FLOOD DEBRIS LINE IN COUNCIL CAR PARK POST TC-MARCIA, BILOELA

DEWS also supplied some flood debris points at Jambin, Biloela and Thangool that were collected during trips to the Callide Valley as part of its Flood Mitigation Study.

The Queensland Reconstruction Authority (QRA) partnership with Queensland Fire and Emergency Services (QFES) undertook rapid damage assessments following severe tropical cyclone Marcia. Damage Assessment and Reconstruction Monitoring (DARM) teams helped QFES with Rapid Damage Assessments of multiple properties within the Callide Valley. Photos and GIS data was provided to KBR. The information included an approximate depth of water through buildings which was used to confirm approximate flood depths throughout the model.

Several residents provided images taken during the recent flood events from a variety of locations within the shire including townships to agricultural areas. Where possible, the images were used to confirm where flood waters reached. However in all but a few cases the information could not be used to determine flood levels sufficiently accurate for calibrating the hydraulic models. Also a number of images are taken at locations outside of the modelled areas.

On the morning after tropical cyclone Marcia, Council arranged for a helicopter to fly over the valley to observe the extent of flood impacts and take numerous photographs for record. Figure 3.7 presents an example photograph taken from the helicopter after TC Marcia.

Figure 3.7
AERIAL PHOTO OF THANGOOL STATE SCHOOL AFTER TC-MARCIA

The Gladstone District Disaster Management Group (DDMG) has the Banana Shire Council within its boundary. The DDMG provided photos of the 2010, 2013 and 2015 flood events covering response and recovery activities. The information helped to validate areas of flooding in the Theodore model.

3.7.2 Dawson River towns

Aerial photography of the 2010 flood from Taroom, Theodore, Moura and to Baralaba was sourced from the QRA. The imagery has been used to develop a detailed flood line of the area (by others). No other township or floodplain within the Council area is included in the QRA survey.

3.8 IMAGERY

Aerial photographs and satellite imagery can be used to determine the extent of flooding. Aerial images can also identify the location and extent of breaches in levees and linear infrastructure.

Aerial photography is available for the 2010 flood for the townships of Taroom, Theodore, Moura and Baralaba sourced from the QRA. The imagery has been used to develop a detailed flood line of the area (by others). No other township or floodplain within Council's area is included in the QRA survey.

DEWS supplied colour satellite imagery for the Callide Valley floodplain including the townships of Thangool, Biloela, Jambin and Goovigen. This imagery was captured the day after the TC Marcia flood in 2015 and provides a visual approximation of the flood extents.

3.9 PREVIOUS STUDIES

3.9.1 Callide Valley Flood Risk Study, Phase 1 – Flood Study (AECOM, 2010)

AECOM undertook a flood study of the Callide Valley in 2010. The report outlines hydrological calibration to events in February 1978, January 1991, and March 1994.

The report also outlines the 1d hydraulic modelling methodology and results of the Callide Valley.

3.9.2 Dawson River Flood Mitigation Study: Stage 1 Report – Project Initiation and Scoping (Engeny, 2011)

Engeny undertook a scoping report for the Dawson catchment for Banana Shire Council in 2011. The report audits the available data, undertakes a Flood Frequency Analysis (FFA), and scopes varying stages of the study.

3.9.3 Callide Valley Flood Risk Study, Phase 1 – Flood Study Addendum (AECOM, 2012)

An addendum to the Callide Valley Flood Risk Study by AECOM was issued to take into consideration queries by a number of State Government Departments. AECOM were also able to produce flood maps for the 2010 event.

3.9.4 Review of Callide Dam Gate Operations in the January 2013 Flood Event (Water Solutions, 2013)

In January 2013, Tropical Cyclone Oswald caused significant flooding in the Callide Valley. Water Solutions subsequently undertook a review of the Callide Dam gate operations.

The review focuses on the 2013 event, with hydrological calibration to the 2013 event only and no hydraulic model developed. The review also considers scenario modelling at Callide Dam.

3.9.5 Baralaba North Continued Operations Project: Flood Study (Water Solutions, 2014)

As part of the Baralaba North Continued Operations Project’s Environmental Impact Statement (EIS), Water Solutions undertook a flood study at Baralaba Mine in 2014.

The report outlines Water Solutions’ hydrological calibration of the Dawson catchment, rating curve corrections, FFA, design hydrology, and hydraulic calibration.

3.9.6 Dululu Flood Hazard Mapping Study (WRM, 2013)

The Dululu Flood Hazard Mapping Study was prepared as part of the Queensland Flood Mapping Program (QFMP) and focuses on hydraulic modelling only. The hydraulic model was calibrated to the 2010 flood event.

3.9.7 Goovigen Flood Hazard Mapping Study (WRM, 2013a)

The Goovigen Flood Hazard Mapping Study was prepared as part of the QFMP and focuses on hydraulic modelling only. The hydraulic model was calibrated to the 2010 flood event.

3.9.8 Flood Hazard Mapping – Jambin (DHI, 2013)

The Jambin Flood Hazard Mapping Study was prepared as part of the QFMP and focuses on hydraulic modelling only. The hydraulic model was calibrated to the 2010 flood event.

3.9.9 DNRM Flood Hazard Mapping: Phase 3b – Theodore (DHI, 2014)

The Theodore Flood Hazard Mapping was undertaken as part of the QFMP and focuses on hydraulic modelling only.

During the hydraulic model calibration to the 2010 event, DHI increased the peak inflow by a factor of 1.27 to achieve calibration.

3.9.10 DNRM Flood Hazard Mapping: Phase 3b – Taroom (DHI, 2015)

The Taroom Flood Hazard Mapping was undertaken as part of the QFMP and focuses on hydraulic modelling only.

During the hydraulic model calibration to the 2010 event, DHI increased the peak inflow by a factor of 2.2 to achieve calibration.

3.9.11 Independent Review of Callide Creek Flooding, Tropical Cyclone Marcia, February 2015 (BMT WBM, 2015)

In February 2015, Tropical Cyclone Marcia caused severe flooding in the Callide Valley. Post the event, the Inspector General of Emergency Management (IGEM) commissioned BMT WBM to undertake an independent review of Callide Creek Flooding.

The report focuses on the 2015 event, with hydrological and hydraulic calibration to that event only. The report reviews previous studies, rating curves, Callide Dam operating rules, and emergency response actions.

4 Flood hydrology

4.1 OVERVIEW

4.1.1 Catchment description

Banana Shire is located in Central Queensland within the Dawson River Catchment, situated east of Central Highlands Regional Council, west of Gladstone Regional Council, and south of Rockhampton Regional Council. The Dawson River catchment is part of the Fitzroy basin and constitutes approximately a third of its total catchment area. The Dawson River's confluence with Mackenzie River marks the start of the Fitzroy River and the northern boundary of Council's LGA.

The Dawson River catchment is approximately 50,000 km^2 and flows from south to north, with the upper, southern section of the catchment contributing the majority of flow along the river until its confluence with Roundstone Creek approximately 150 km upstream of the Dawson River's confluence with Mackenzie River. The Dawson River is characterized by a well-defined main channel with areas of wide, flat floodplain. There are a number of water supply weirs along the main channel that would be drowned during large flood events.

The towns of Taroom, Theodore, and Moura are situated along the Dawson River from south to north respectively and are located upstream of Roundstone Creek's confluence. Baralaba is the north most town along the Dawson River and situated downstream of Roundstone Creek's confluence. As a consequence, Baralaba is subject to large peak flows from both Dawson River and Roundstone Creek.

The Don River catchment is approximately 6,500 km^2 and is situated in the north-east portion of the Dawson River catchment. The catchment is made up of the Don River subcatchment (1,000 km^2), the Dee River catchment (1,000 km^2) and the Callide Creek catchment (4,500 km^2). The Callide Creek catchment in turn is made up equally of the Callide Creek subcatchment, Kroombit Creek catchment, Kariboe Creek catchment, Grevillea Creek catchment, and Bell Creek catchment.

Biloela is affected by flooding from both the upstream Callide Creek and Kroombit Creek catchments. Dams are located on both creeks upstream of Biloela, with Callide Dam releasing water via an automated gate system, and Kroombit Dam via an ungated spillway. Thangool Township is located on Kariboe Creek, south of the Kroombit catchment. The towns of Goovigen and Jambin are located on Callide Creek downstream of its confluence with Kroombit Creek, Kariboe Creek, and Grevillea Creek. Wowan and Dululu are located on the Dee River, upstream of its confluence with the Don River.

The Don River's confluence with the Dawson River is located approximately 50 km upstream of Dawson River's confluence with Mackenzie River. No towns are located downstream of the Don River's confluence within the LGA.

Figure 4.1 presents the location of the Banana Shire Council and the Dawson catchment.

4.1.2 Purpose

The purpose of this section is to document the hydrological assessment undertaken on the Dawson catchment. The hydrological assessment estimates flows from historic and design events to be used as inputs to the hydraulic flood model.

The main body of this report is intended to be read by non-technical persons, giving an overview of the methodology and results. Included as part of this report is a technical appendix (Appendix A), that details the technical aspects involved in the hydrological assessment.

4.1.3 Scope

The scope of works included as part of the hydrological study was:

- Dawson River catchment calibration to the 2010 and 2013 flood events
- Don-Dee catchment calibration to the 2015, 2013 and 2010 flood events
- design flow estimation for the 10%, 5%, 2%, 1%, 0.2%, 0.05% Annual Exceedance Probabilities (AEPs) and the Probably Maximum Precipitation (PMP) event
- climate change sensitivity analysis on the 1% AEP event.

Figure 4.1
DAWSON CATCHMENT LOCATION

4.1.4 Hydrologic model setup

The following section describes briefly the hydrological model setup. Appendix A describes in detail the parameterisation, configuration, and assumptions adopted.

Two hydrological runoff-routing models were developed as part of this study. One was developed to simulate the larger Dawson catchment (herein referred to as 'the Dawson Model'), and another separate model was developed for the Don-Dee catchment (herein referred to as 'the Don-Dee Model') to capture detail that could be missed in the larger Dawson model. The Don-Dee model would also allow focus on the 2013 and 2015 historic flood events that primarily affected the Callide Valley area.

Runoff-routing models use hydrological properties such as area, slope, and stream length to estimate flow. The catchment is delineated into a number of subcatchments, each receiving rainfall and producing a runoff hydrograph after rainfall losses are considered. The subcatchment hydrographs are then routed through downstream subcatchment reaches, causing delay and attenuation. Flow is accumulated as subcatchment hydrographs are added and drainage lines converge. Peak flows and volumes are dependent on the rainfall losses and the flow timings of tributaries.

The hydrological modelling software XP-RAFTS was used in this study. Figures 4.2 and 4.3 present the subcatchment delineation of the Dawson catchment and the Don-Dee catchment respectively. Subcatchment locations were chosen to best simulate rainfall and runoff in the catchment with consideration to key locations such as dams, weirs, stream gauges, and towns.

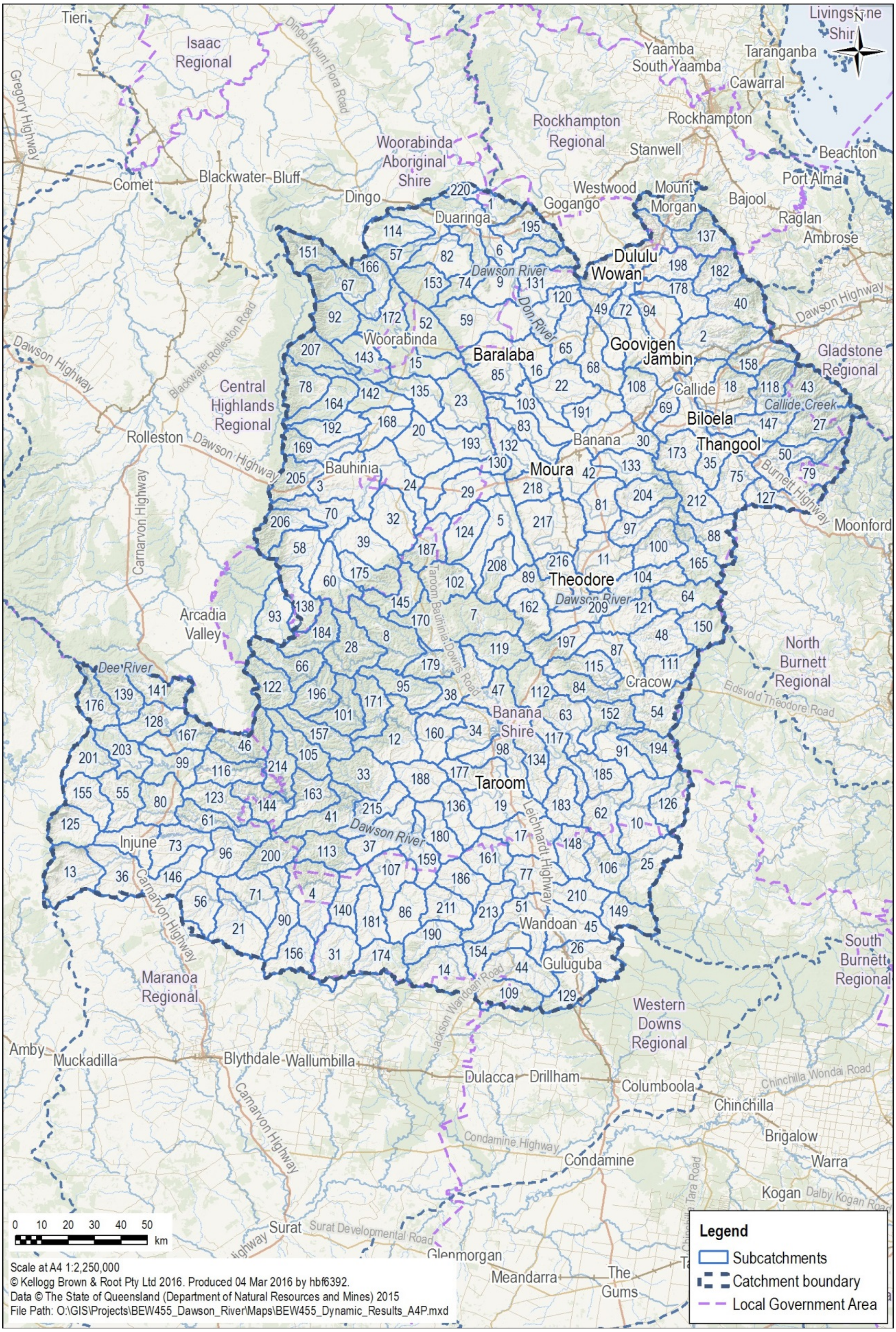

Figure 4.2
DAWSON SUBCATCHMENT DELINEATION

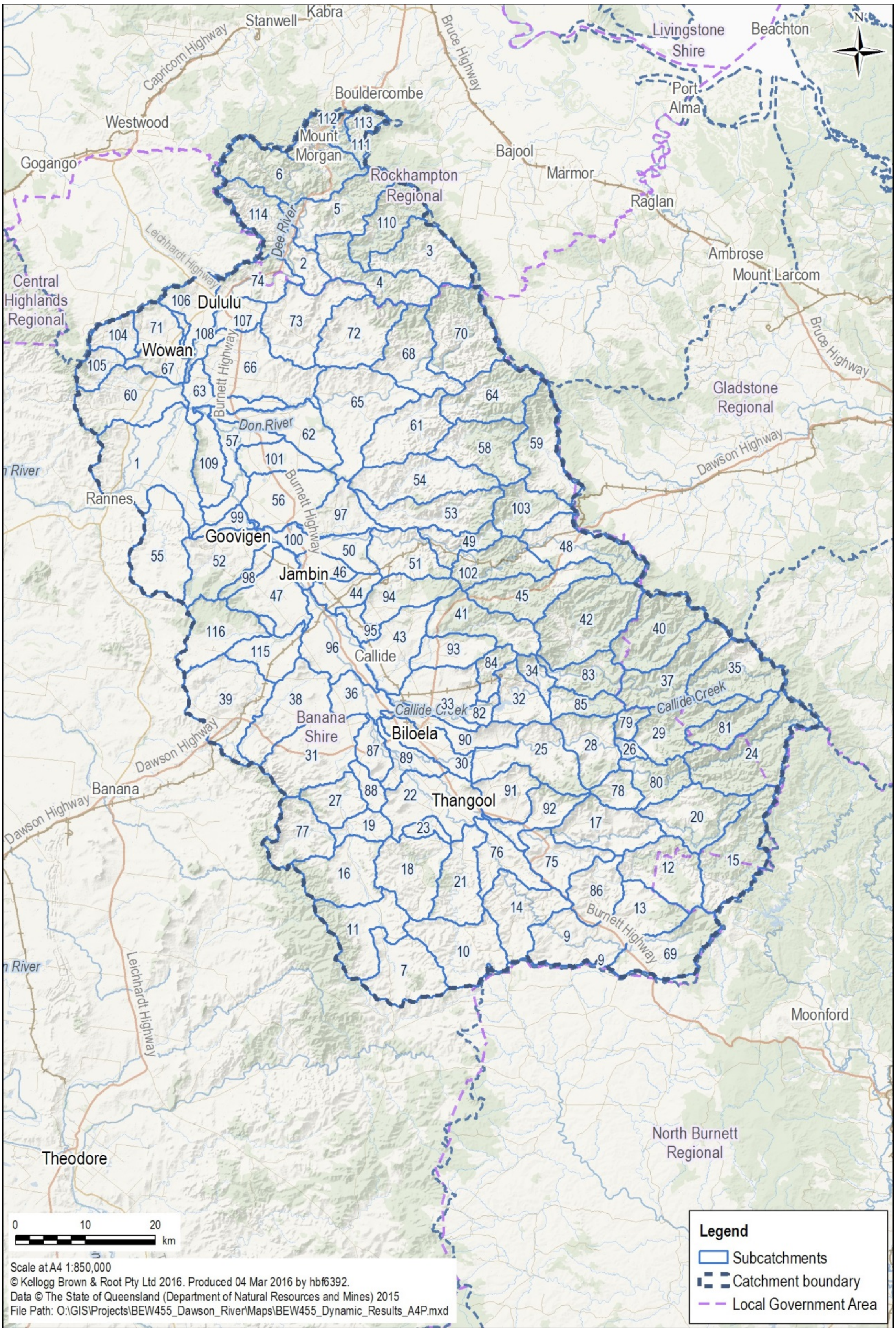

Figure 4.3
DON-DEE SUBCATCHMENT DELINEATION

4.2 CALIBRATION

4.2.1 Calibration events

A brief description of the historic events used in calibration is given below. A detailed review of the historic rainfall events is given in Appendix B.

30 January 1978 – 4 February 1978

A rainfall event occurring in January and February 1978 (herein referred to as the '1978 event') caused significant rainfall on the Callide catchment causing the Callide Dam to spill.

At the time of the 1978 event, Callide Dam was ungated and had a temporary structure in place to raise the full supply level.

As a consequence, flooding of the Callide Valley occurred.

18 December 2010 – 6 January 2011

A long rainfall event in December 2010 (herein referred to as the '2010 event') caused significant flooding in the Dawson River, and moderate flooding in the Callide Valley.

The event came from the west through the neighbouring Nogoa and Comet catchments, causing significant rain to fall on most of the Dawson Catchment. This event is the largest flood to impact towns along the Dawson River in recent history.

In the Callide Valley, Callide Dam was filled during the event which absorbed most of the upstream discharge and resulted in only minor flow to be released. Other creeks draining into Callide Valley contributed to the significant flood event.

21 January 2013 – 30 January 2013

In January 2013, Ex-Tropical Cyclone Oswald (herein referred to as the '2013 event') caused heavy rainfall on the Dawson catchment, with a lot of rainfall on the Don-Dee catchment including significant rainfall upstream of Callide and Kroombit Dams.

It is estimated that the average depth over the Callide Dam catchment was 670 mm which led to significant release required from the gated spillway. The outflow from the dam was estimated to peak at approximately 2,000 m^3/s.

The rain fell over a three day period at a fairly constant rate. Appendix B presents a comparison between the historic temporal pattern and design temporal patterns given in ARR (ARR, 1987).

As a result of the heavy rainfall, in many places in the Callide Valley this was the worst flooding on record, causing damages to property, machinery, fences, infrastructure, as well as causing loss of livestock.

18 February 2015 – 23 February 2015

In February 2015, Tropical Cyclone Marcia (herein referred to as the '2015 event') crossed the Callide Creek catchment and up to 370 mm of rainfall was recorded, with over 250 mm having fallen in under 6 hours at some locations.

The rain fell as the cyclone passed over the Calliope Range over an intense 6 to 12 hour period. The temporal pattern during this intense period closely matched the design temporal pattern given for the 6 hour duration by ARR. Appendix B presents a graph of this comparison.

As a result of the intense rainfall, significant flooding occurred in the Callide Valley causing damages to property, machinery, fences and infrastructure.

The 2015 event did not cause significant flooding of the Dawson River.

4.2.2 Calibration process

Calibration is the process of matching modelled results with those recorded during historic events to demonstrate accuracy. Separate storm events often vary, such as in magnitude or rainfall pattern. Models are therefore often calibrated to one or two storm events and then verified to at least one other if data is available. The verification step is to test the applicability of the calibrated model under different conditions.

The Dawson Model was calibrated to the 2010 event and verified to the 2103 event. The Don-Dee Model was calibrated to the 2015 event and the 2013 event, and verified against the 2010 event and the 1978 event.

The historic storm events were input into XP-RAFTS using rainfall data from both sub-daily and daily rainfall stations. Sub-daily rainfall stations define the temporal pattern (rainfall timing) of the storm event, and used in conjunction with daily rainfall stations to define the rainfall depth locally.

Both the timing and depth of the rainfall can vary spatially over the catchment and this was taken into consideration by applying unique rainfall onto each subcatchment. Subcatchments were assigned a temporal pattern from a nearby sub-daily rainfall station using Thiessen polygons which was then scaled up or down using a rainfall surface generated by KBR for each historic event.

Figure 4.4 and 4.5 present the rainfall surface for the Dawson catchment for the 2010 and 2013 events respectively. Figures 4.6 to 4.9 present the rainfall surface for the Don-Dee catchment for the 1978, 2010, 2013, and 2015 events respectively.

The rainfall is simulated by the hydrological XP-RAFTS model which calculates resulting flow. A number of parameters within XP-RAFTS can be adjusted to change the estimated flow to obtain a closer match with historic recordings. These parameters include rainfall losses, hydrological roughness, lag times, and flow attenuation. During verification, parameters such as lag times and flow attenuation should not be adjusted as these are catchment properties that are unlikely to change between events. However, because rainfall losses are dependent on the antecedent conditions of the catchment, it is acceptable to change these values from calibration to verification. Appendix A lists the adopted rainfall losses for the calibration and verification events for the Dawson Model and the Don-Dee Model.

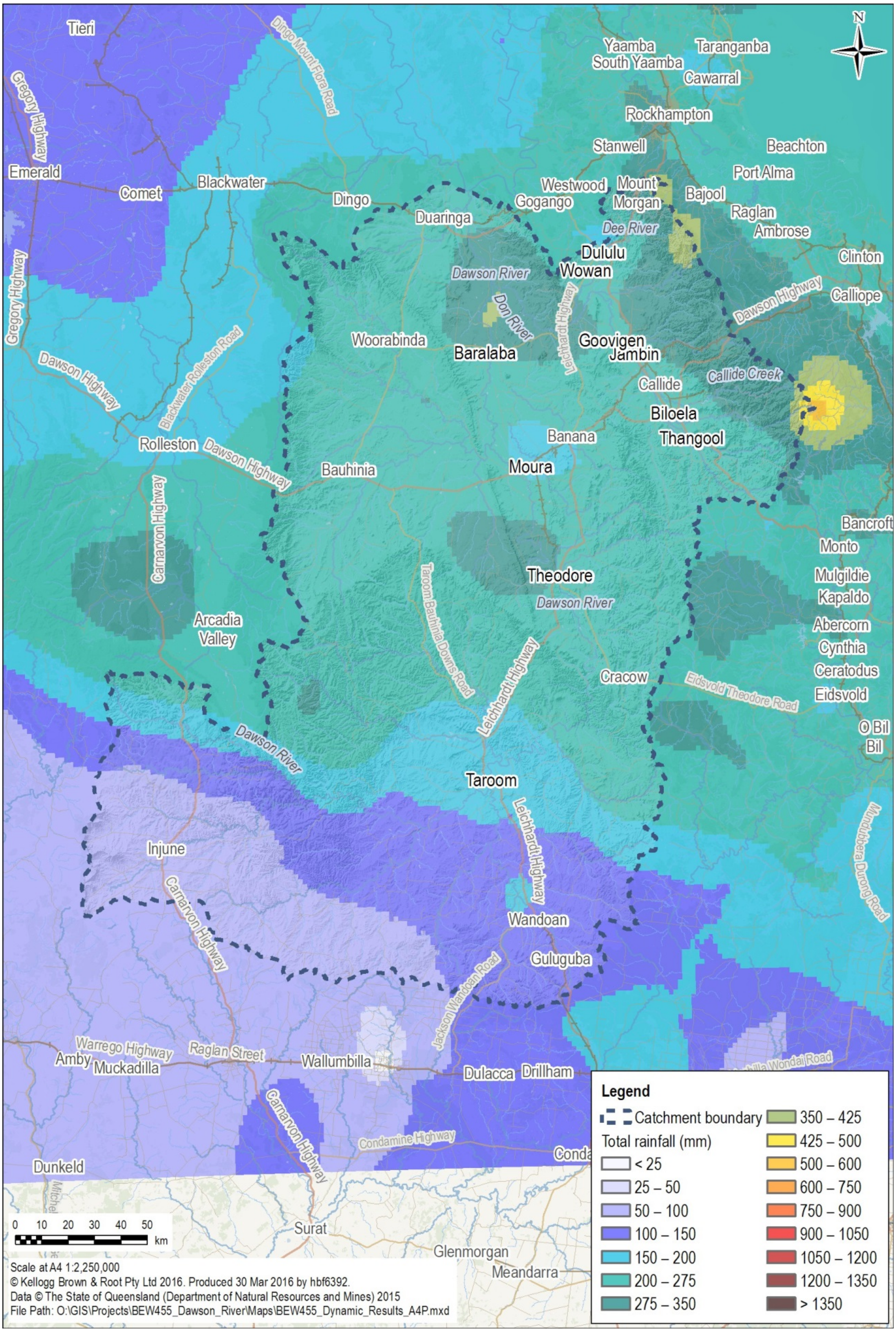

Figure 4.4
2010 RAINFALL SURFACE – DAWSON CATCHMENT

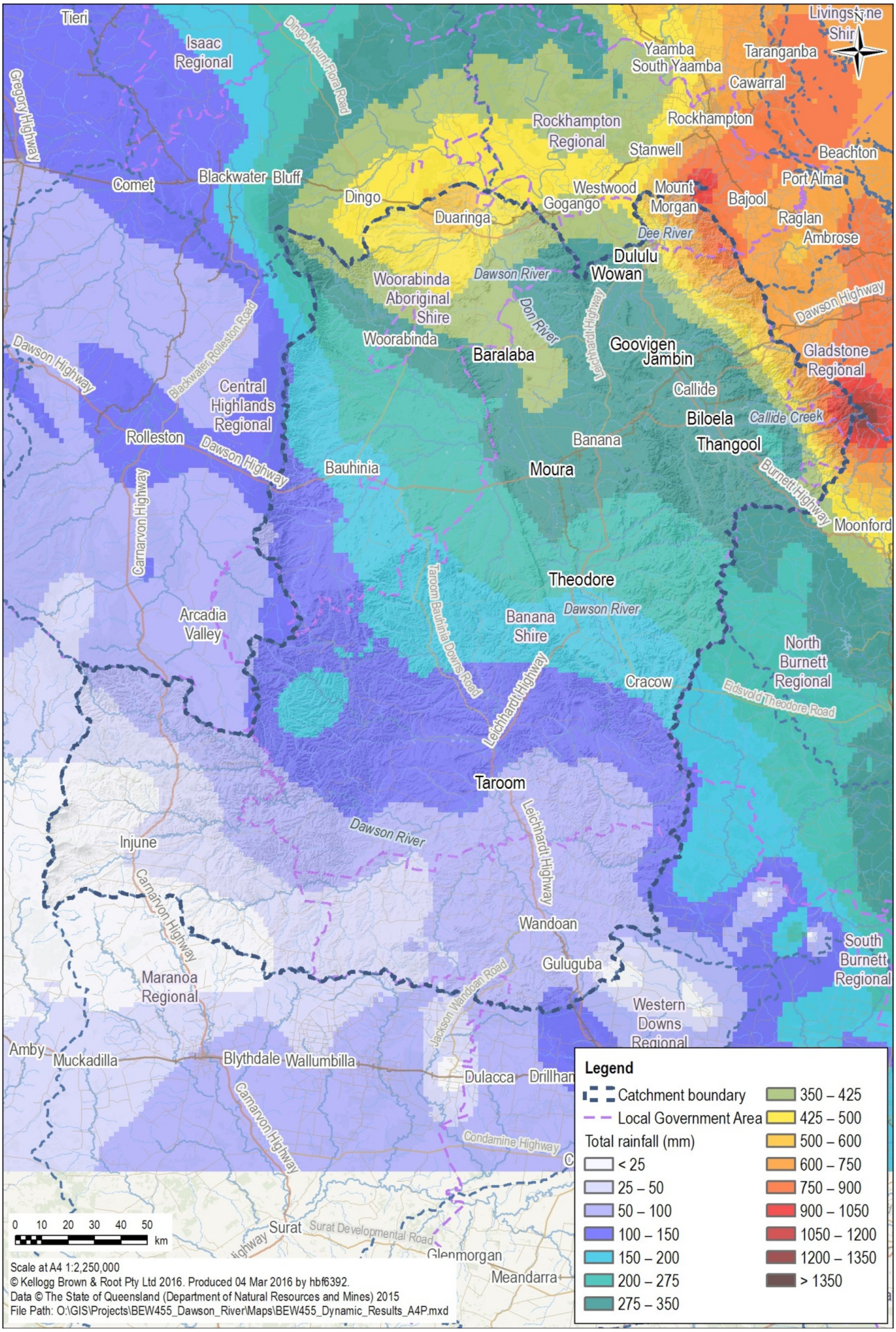

Figure 4.5
2013 RAINFALL SURFACE – DAWSON CATCHMENT

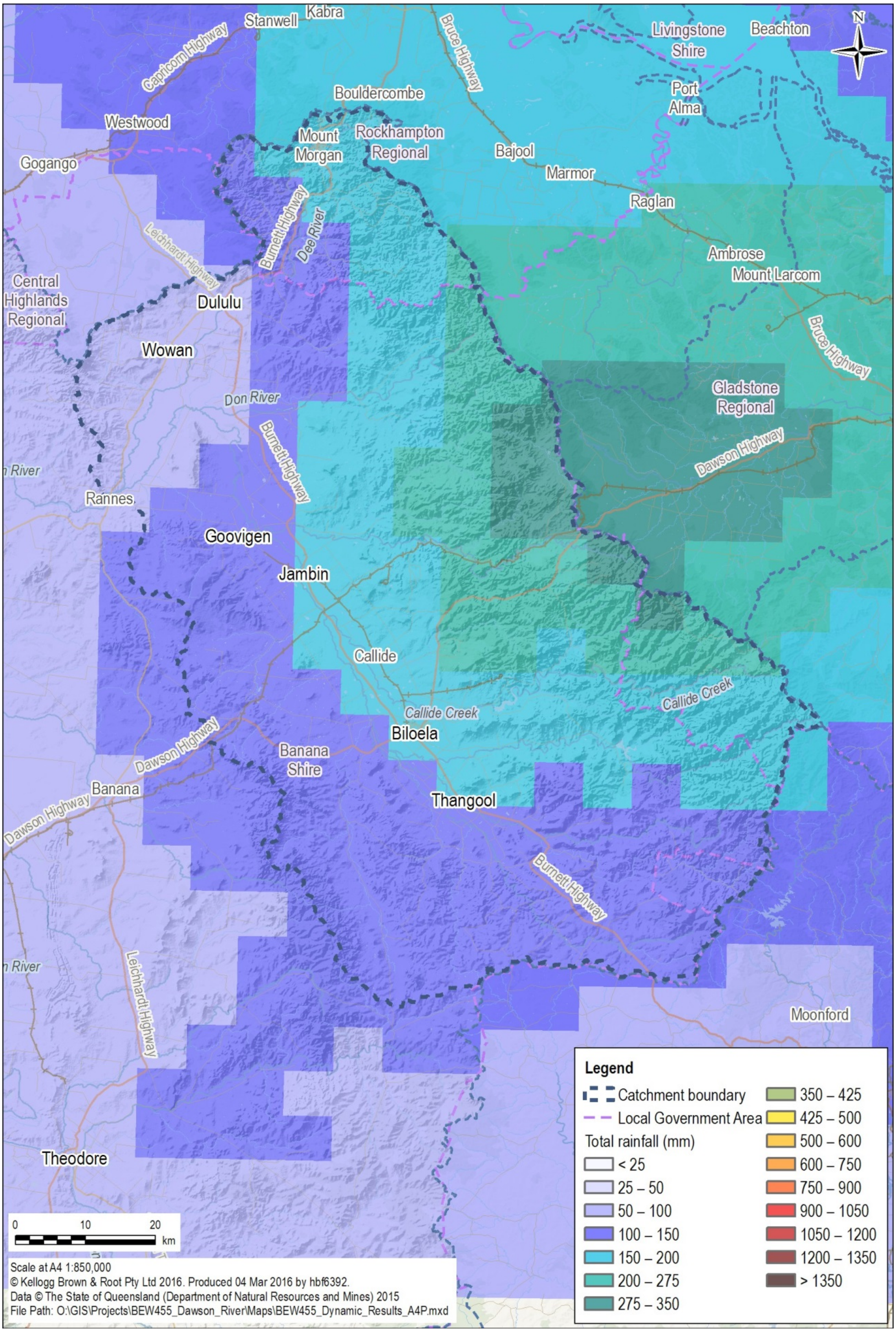

Figure 4.6
1978 RAINFALL SURFACE – DON-DEE CATCHMENT

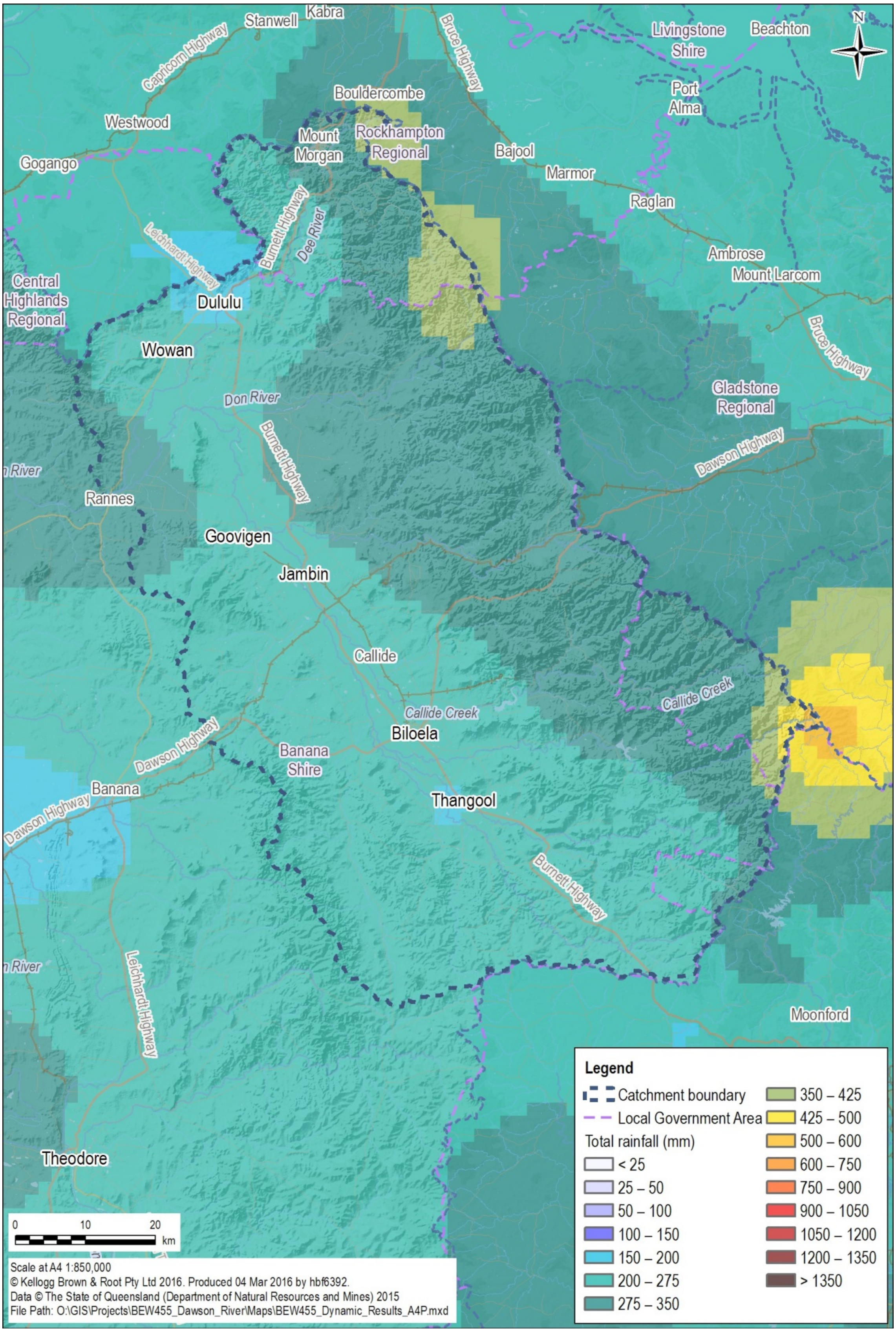

Figure 4.7
2010 RAINFALL SURFACE – DON-DEE CATCHMENT

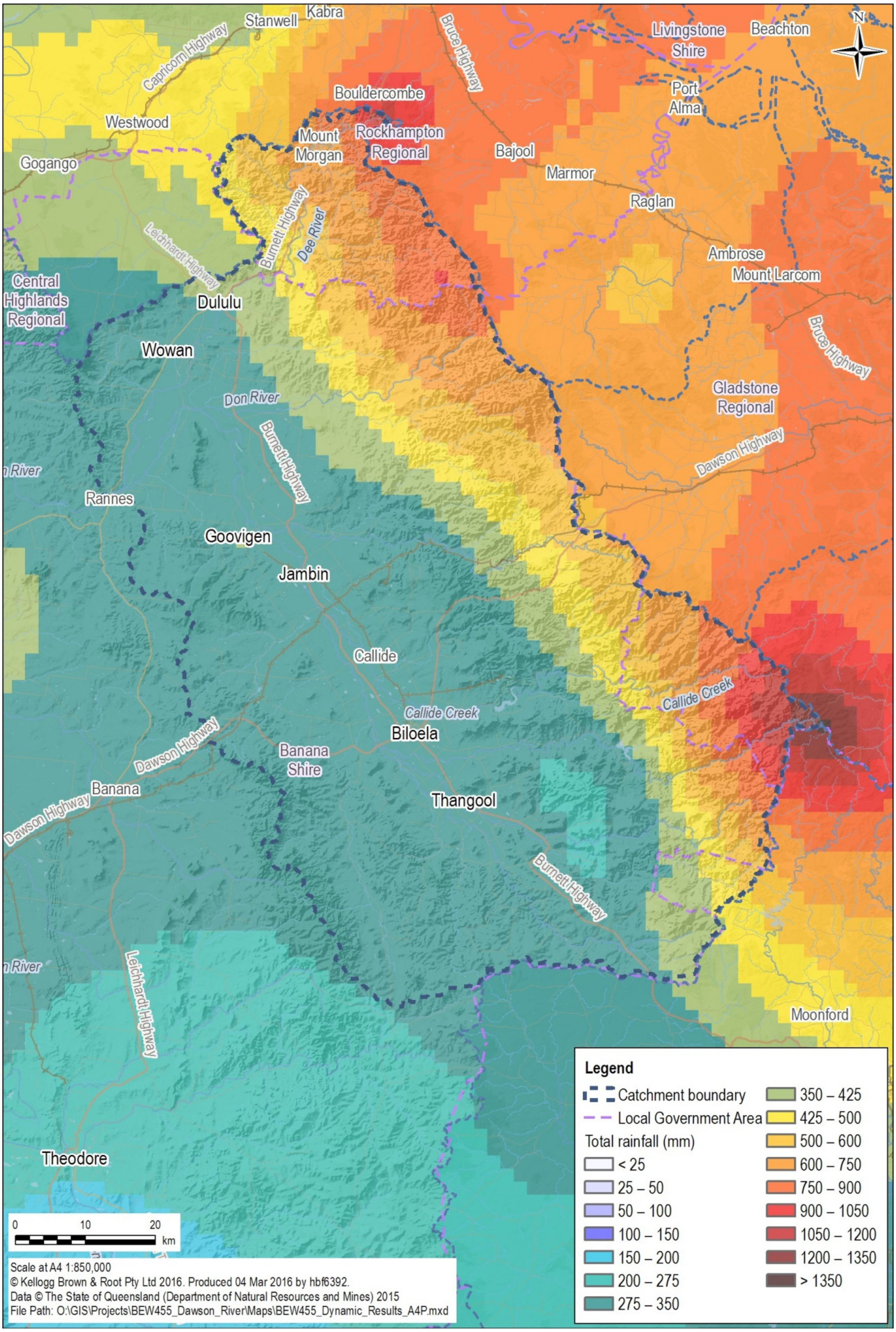

Figure 4.8
2013 RAINFALL SURFACE – DON-DEE CATCHMENT

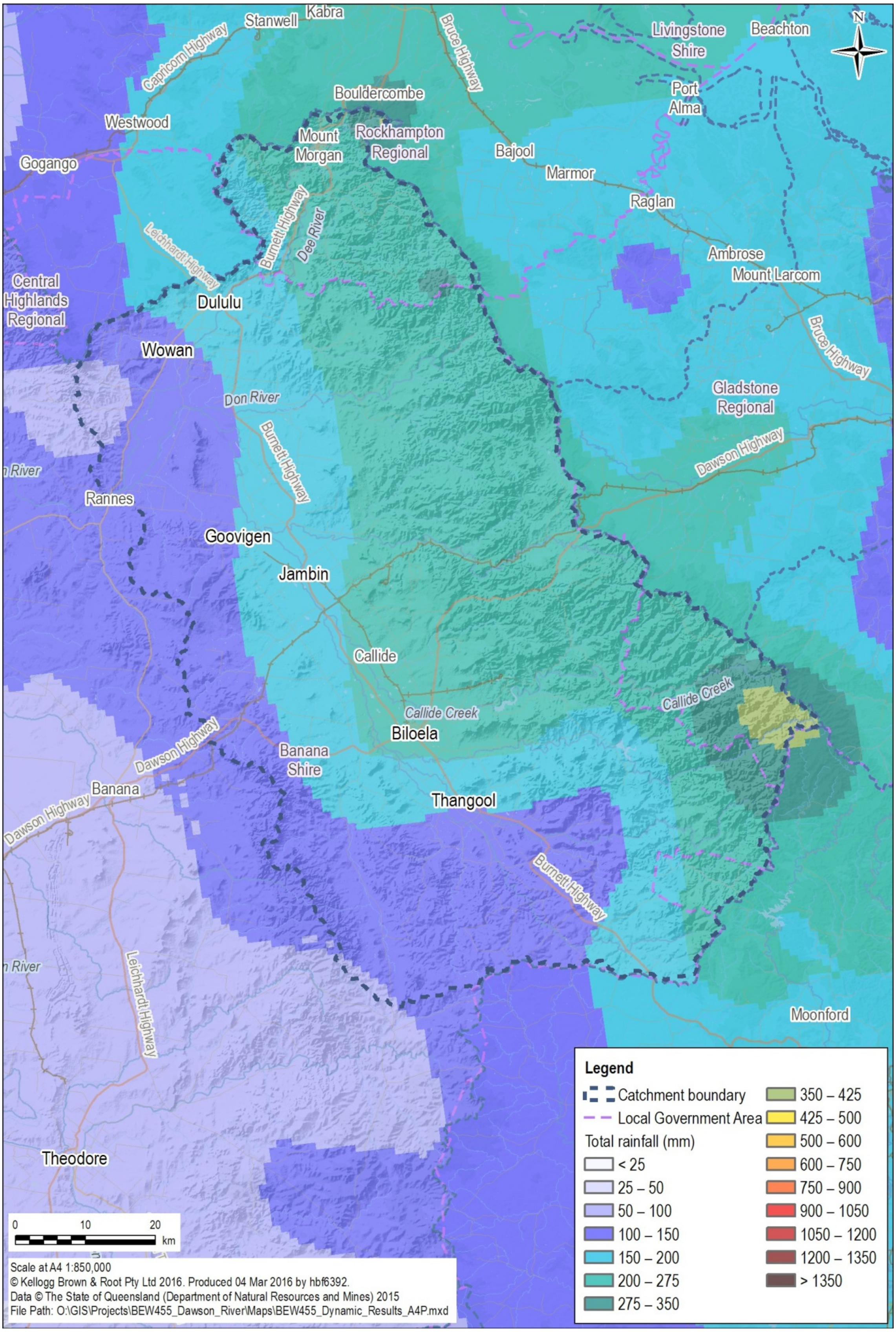

Figure 4.9
2015 RAINFALL SURFACE – DON-DEE CATCHMENT

The hydrological model estimates flow which is compared against historic recorded streamflow. However, streamflow is not measured directly and is usually inferred from measured stream level gauges using a rating curve. Rating curves can be inaccurate during high stages and can mislead hydrological calibration. Dams are generally considered to have high accuracy rating curves due to the controlled nature of the outflow and were therefore given priority in the calibration process. Other gauging locations were primarily used to check flow timings; however, the magnitude of the flow was often discarded due to concerns regarding the rating curve and information obtained through the joint hydraulic calibration. Along with dam spillways, joint calibration using the hydraulic models was used to calibrate peak flows.

4.2.3 Results

The results of the calibration for the Dawson Model (2010 event) at key locations from upstream to downstream are presented in Figures 4.10 to 4.14 and the verification (2013 event) presented in Figures 4.15 to 4.17. A more complete set of calibration and verification results are presented in Appendix A.

The Dawson Model does not contain any dams and therefore accurate streamflow calibration locations were not available. Instead, joint calibration with a number of hydraulic models was used to obtain peak flow rates. Theodore in particular is an ideal location for joint calibration as a natural constriction in the terrain downstream of a wide floodplain controls the water levels during large floods. Because terrain is measurable and is considered to have a high level of accuracy in the hydraulic model, and results are not sensitive to the more subjective roughness parameter, there is a higher confidence in the obtained peak flow.

The results of the calibration of the Don-Dee model (2015 and 2013 event) are presented in Figures 4.18 to 4.22, and the results of the verification (2010 and 1978 events) are presented in Figures 4.23 to 4.25. As stated earlier dam spillways are generally good locations to estimate flow due to accurate rating curves. For this reason, calibration at Callide Dam and Kroombit Dam were given priority and show a good match. The Callide Dam was not used for calibration for the 2013 event because the gates were operated manually which is not able to be input into XP-RAFTS (discussed in Appendix B).

Continuing loss parameters were adopted from the Callide and Kroombit Dam catchments for the rest of the Don-Dee catchment which showed to have a good comparison in the joint calibration process.

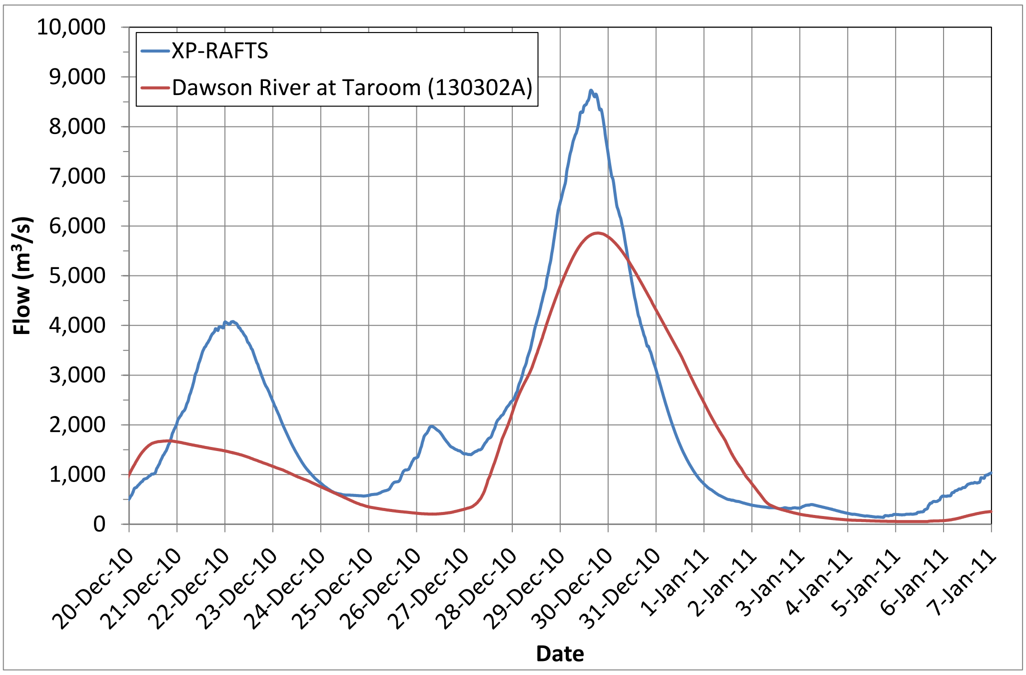

Figure 4.10
DAWSON RIVER AT TAROOM (130302A) – 2010 EVENT

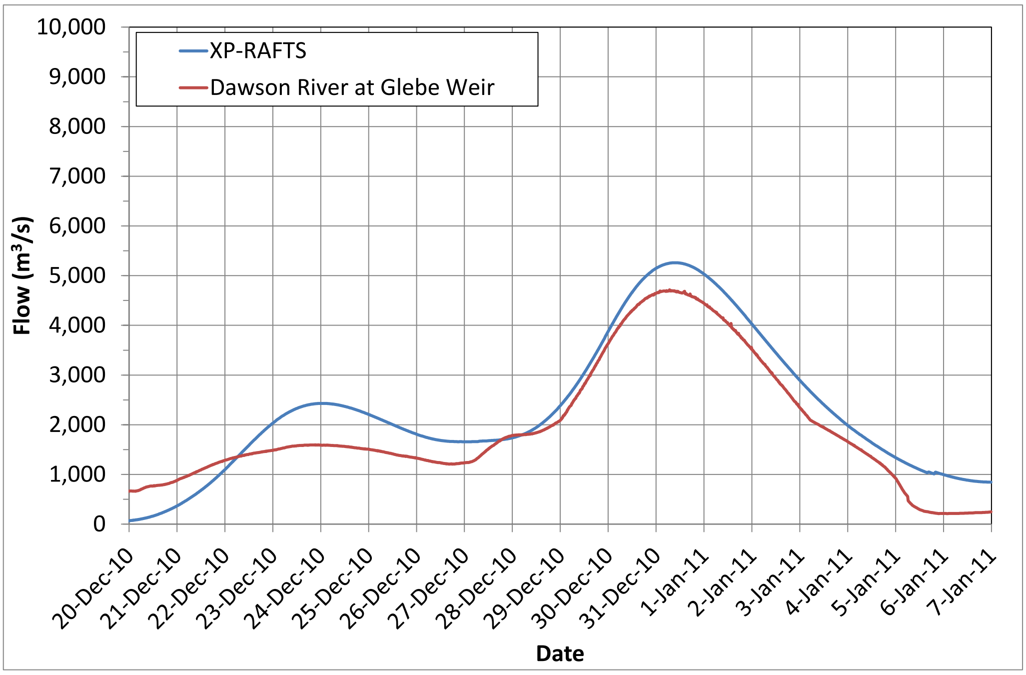

Figure 4.11
DAWSON RIVER AT THE GLEBE WEIR – 2010 EVENT

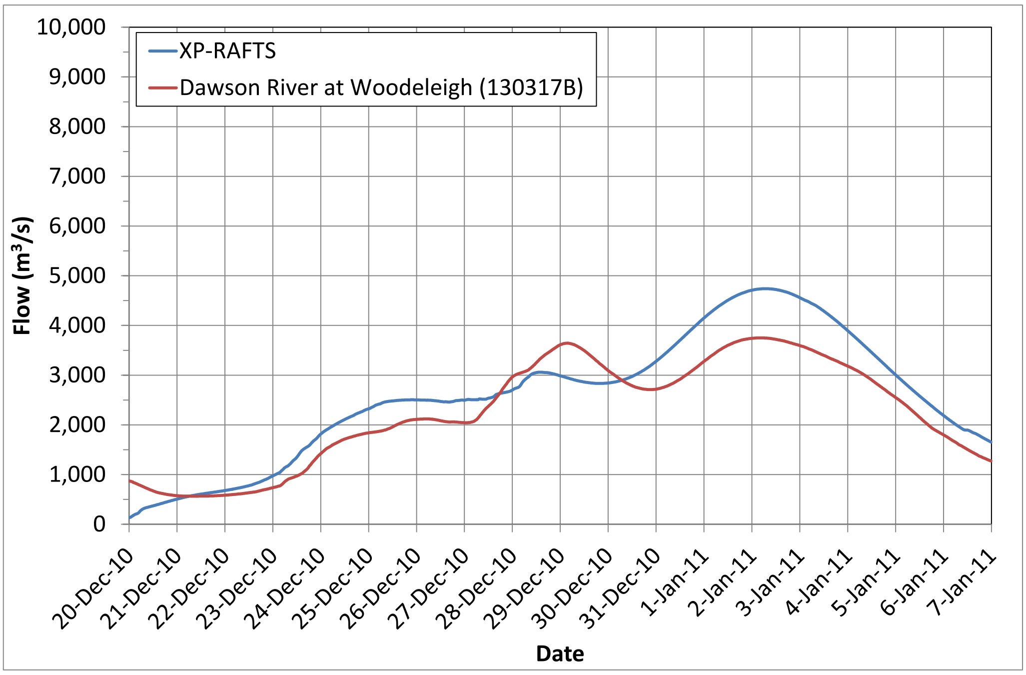

Figure 4.12
DAWSON RIVER AT WOODLEIGH (130317B) – 2010 EVENT

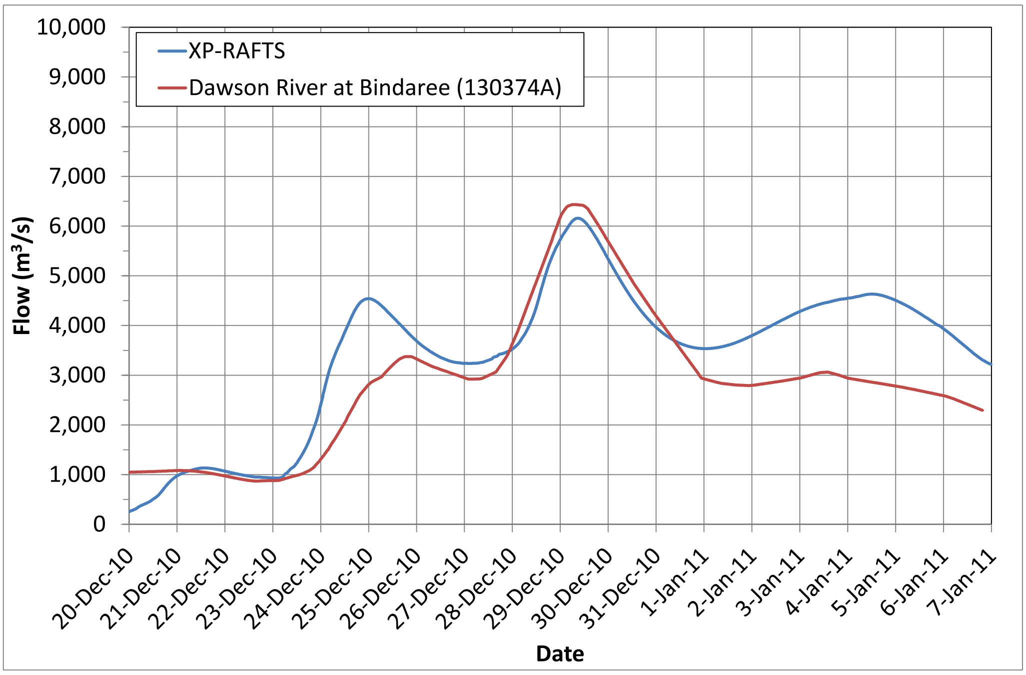

Figure 4.13
DAWSON RIVER AT BINDAREE (130374A) – 2010 EVENT

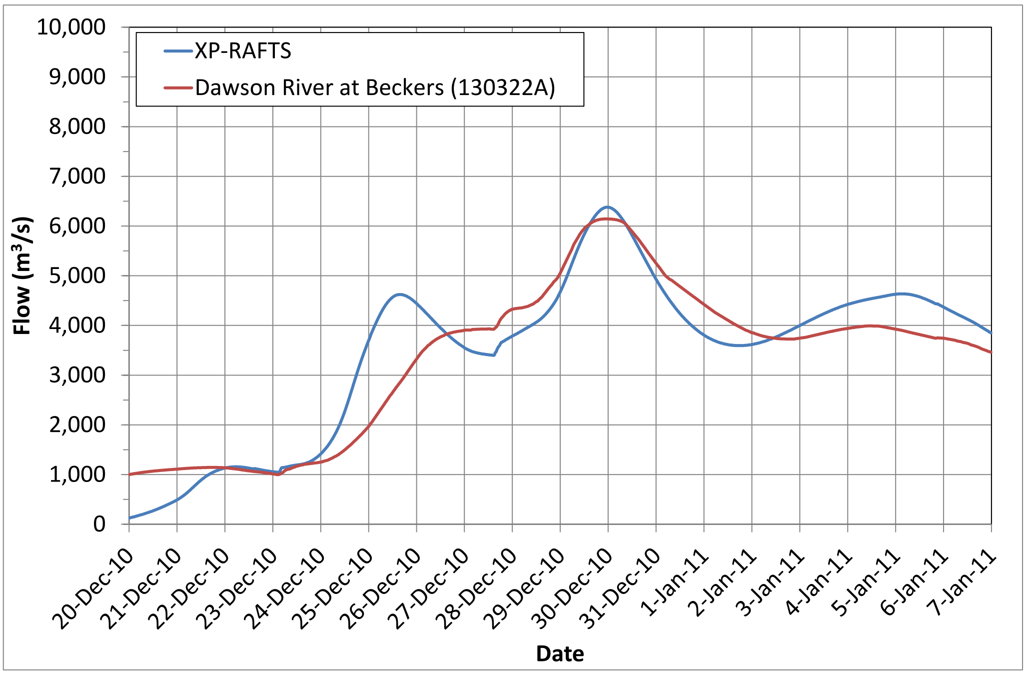

Figure 4.14
DAWSON RIVER AT BECKERS (130322A) – 2010 EVENT

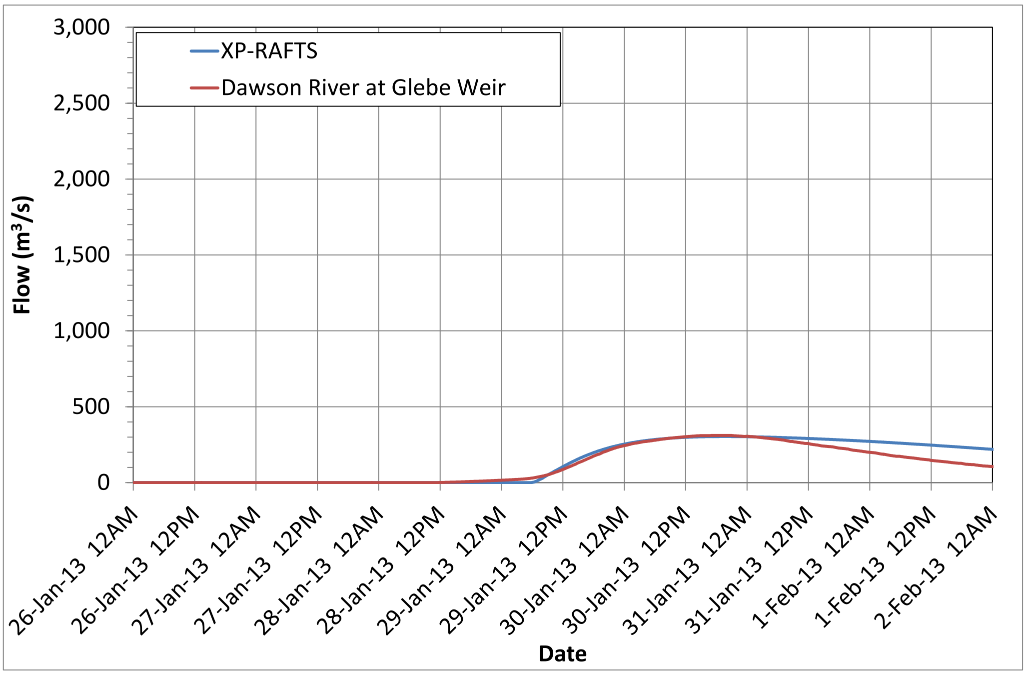

Figure 4.15
DAWSON RIVER AT THE GLEBE WEIR – 2013 EVENT

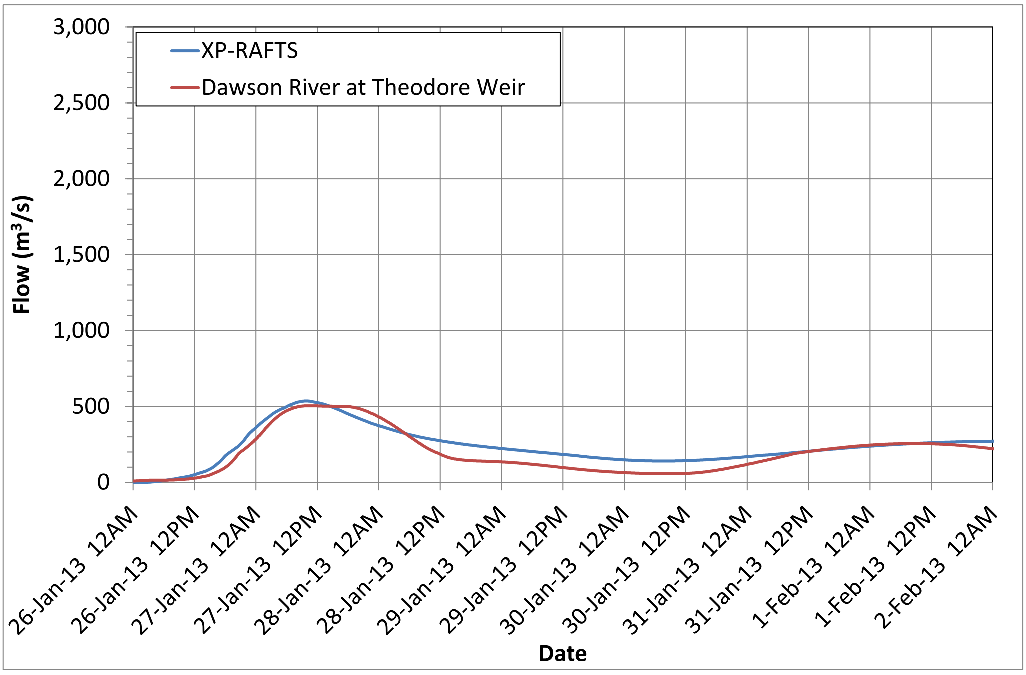

Figure 4.16
DAWSON RIVER AT THEODORE WEIR – 2013 EVENT

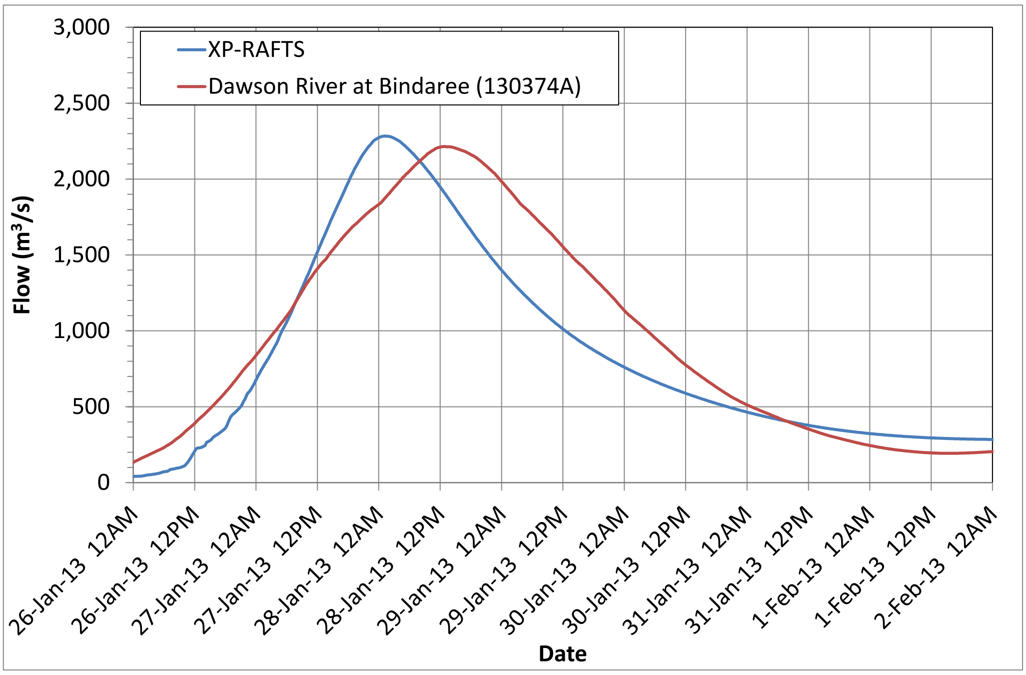

Figure 4.17
DAWSON RIVER AT BINDAREE (130374A) – 2013 EVENT

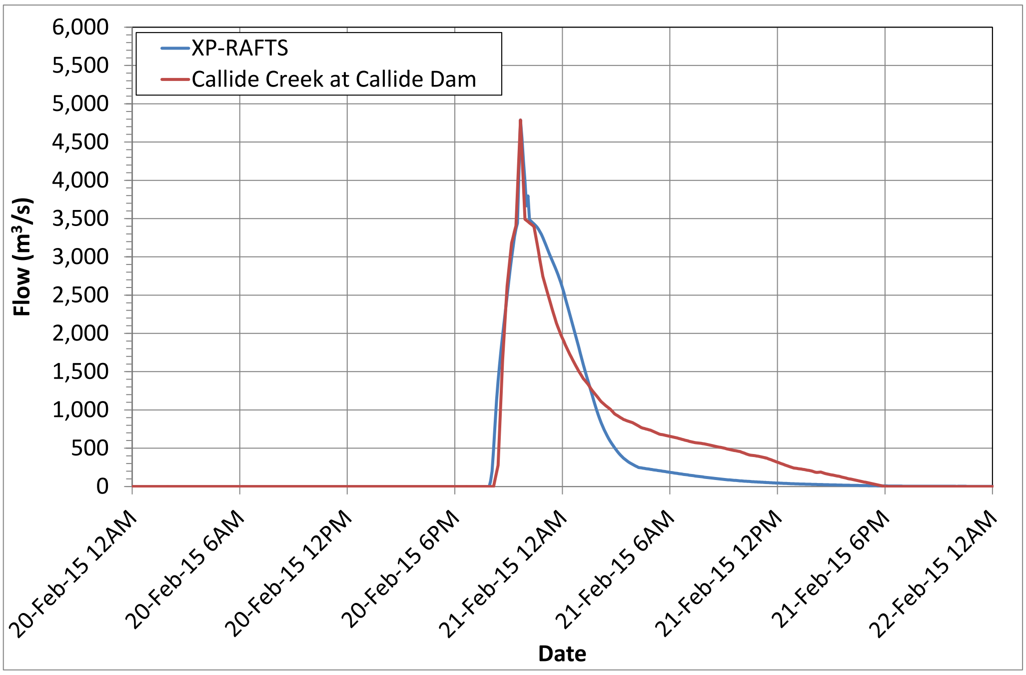

Figure 4.18
DON-DEE CATCHMENT CALLIDE DAM – 2015 EVENT

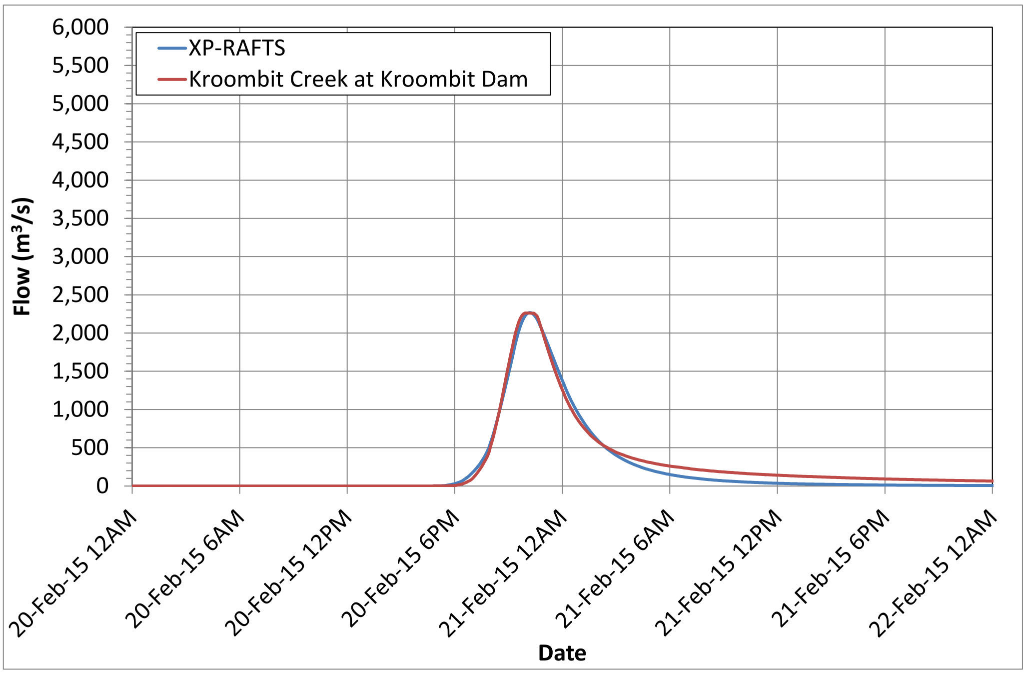

Figure 4.19
DON-DEE CATCHMENT KROOMBIT DAM – 2015 EVENT

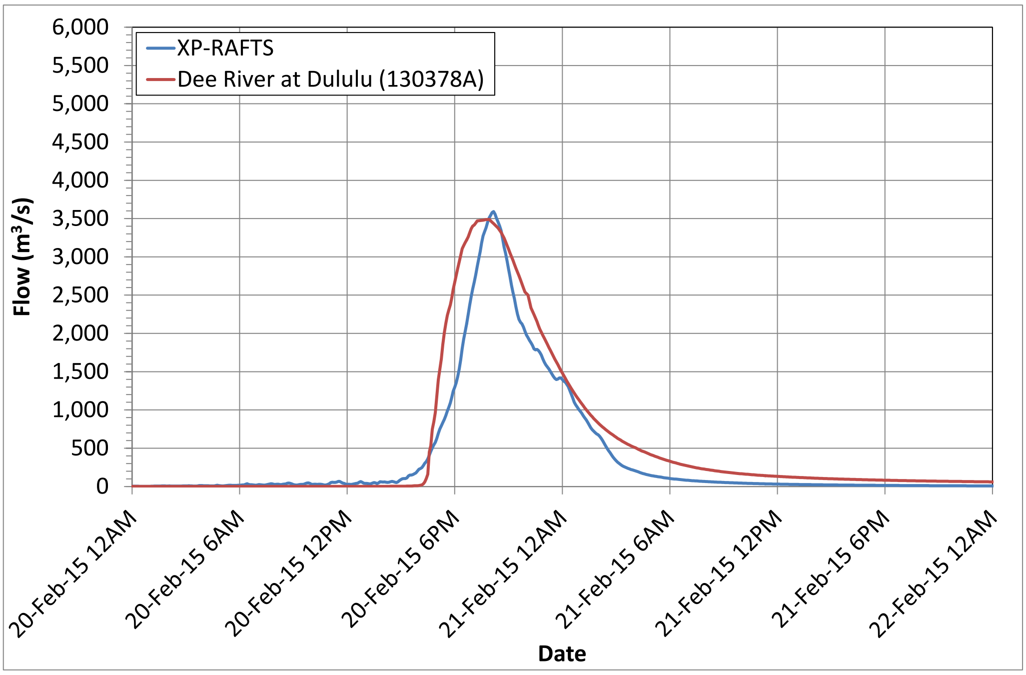

Figure 4.20
DON-DEE CATCHMENT DEE RIVER AT DULULU (130378A) – 2015 EVENT

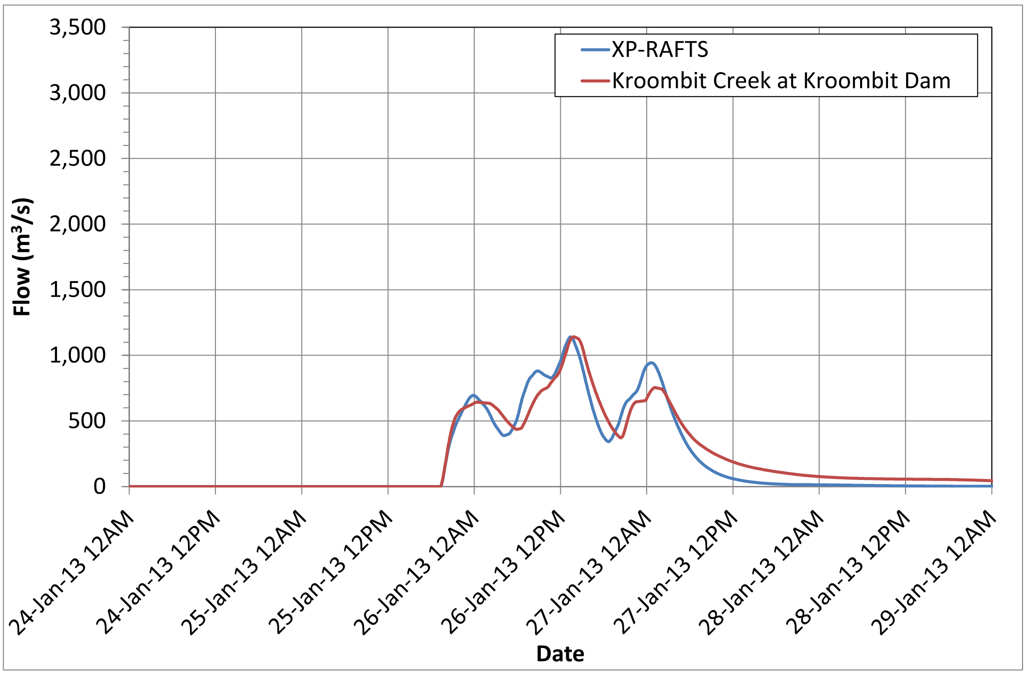

Figure 4.21
DON-DEE CATCHMENT KROOMBIT DAM – 2013 EVENT

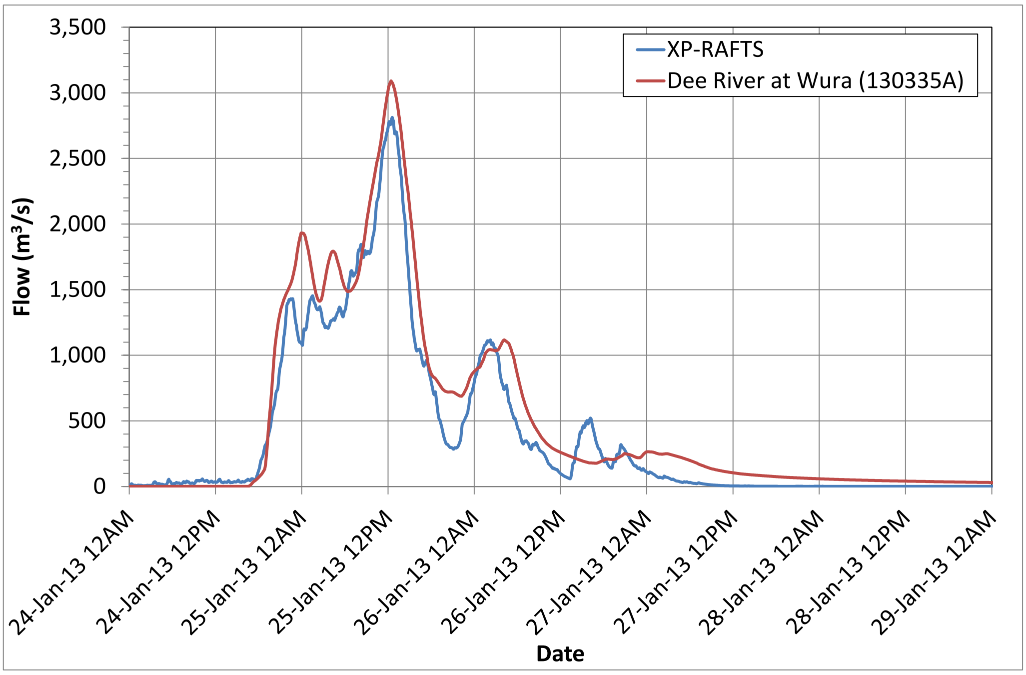

Figure 4.22
DON-DEE CATCHMENT DEE RIVER AT WURA (130335A) – 2013 EVENT

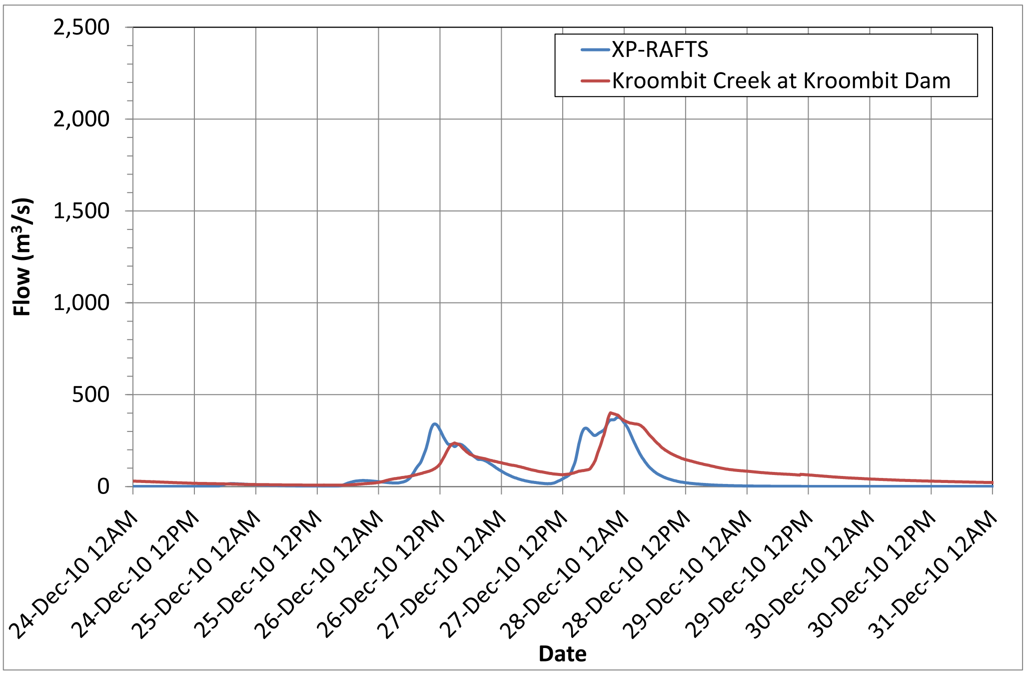

Figure 4.23
DON-DEE CATCHMENT KROOMBIT DAM – 2010 EVENT

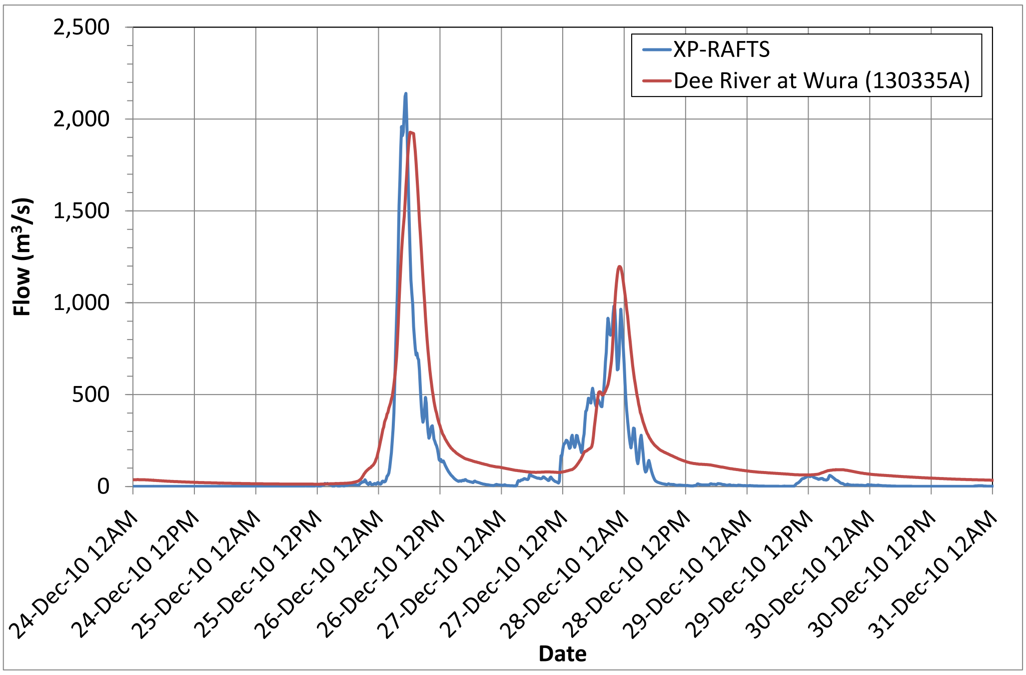

Figure 4.24
DON-DEE CATCHMENT DEE RIVER AT WURA (130335A) – 2010 EVENT

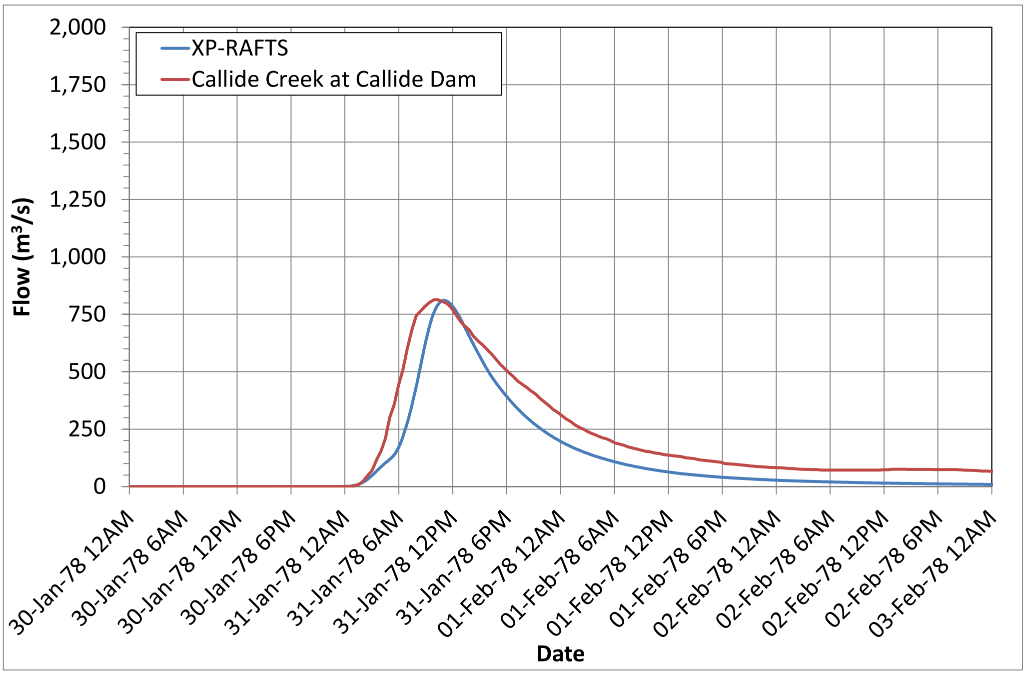

Figure 4.25
DON-DEE CATCHMENT CALLIDE DAM – 1978 EVENT

4.3 DESIGN

4.3.1 Methodology

Design storm events are used to obtain design flows that have a designated AEP, that is, they have a designated probability of occurring in any given year. The design flows are simulated in the hydraulic model to obtain design water levels that are then used in conjunction with the design flows for a number of assessments such as planning, flood damages, flood mitigation, and cost benefit analyses.

Dawson Model

The Dawson Model design flows were estimated using the standard single design storm approach with AEP neutral rainfall losses. That is, each AEP storm event was simulated in the hydrological model trialling a number of differing durations with Zone 3 temporal patterns obtained from ARR (ARR, 1987). The durations that resulted in the highest peak flow at the locations of interest in any given AEP event were chosen as the critical durations.

Due to the determined inaccuracies of high stage rating curves, an FFA was not undertaken for the gauges in the Dawson catchment as this would be misleading. However, in the flood study undertaken for Baralaba mine site (Water Solutions, 2014), Water Solutions updated the rating curves at Bindaree (1303074A) and Beckers (130322A) and subsequently undertook an FFA at Beckers using the updated rating curve. For this study KBR has adopted Water Solutions FFA at Beckers. Table 4.1 presents the adopted FFA.

Table 4.1 Flood Frequency Analysis results at Beckers (130322A) (Water Solutions, 2010)

Design event (AEP)	Flood frequency peak flow (m^3/s)	90% confidence limits (m^3/s)	
1 in 2	350	250	470
1 in 5	1,000	730	1,500
1 in 10	1,800	1,200	2,800
1 in 20	2,800	1,800	4,800
1 in 50	4,700	2,800	8,800
1 in 100	6,600	3,800	13,000

Don-Dee Model

The Don-Dee Model design flows estimation methodology is described in Appendix B. The methodology uses a novel approach, adopting spatially varying embedded storms and rainfall depth. This approach was developed in consultation with the Department or Energy and Water Supply (DEWS), the Department of Science, Information Technology and Innovation (DSITI), and SunWater.

The catchment was categorized into eight key areas depending on the catchment size and spatial position. A unique embedded storm was developed for each area based on the critical duration at the outlet to that area, and downstream areas. The total volume of water was maintained in comparison to the standard ARR87 approach.

The spatial variation in rainfall was developed to increase the rainfall depth in areas of high elevation on the eastern catchment border of the Calliope Range. This attempted to replicate historic events which showed higher rainfall depths in these areas for all assessed events.

4.3.2 Design rainfall depths

The design rainfall depths were estimated using CRC-FORGE. Rainfall was extracted separately for the Dawson catchment, as well as for each of the eight separate areas in the Don-Dee catchment. The adopted rainfall depths are presented in Appendix A-4.

Aerial Reduction Factors (ARF) are automatically calculated using the CRC-FORGE method. An ARF has therefore been applied for each of the rainfall extractions. Appendix A presents the adopted ARF for each area.

4.3.3 Design rainfall losses

Initial loss

Initial Loss (IL) represents the depth of rain that is taken in by the soil before runoff occurs. The IL has been adjusted in the design events to match the results of the FFA at Beckers. Due to the presence of dams within the Don-Dee catchment as well as the poor quality of rating curves, no FFA as undertaken and the IL from the Dawson Model were adopted.

Table 4.2 presents the adopted losses for both the Dawson Model and the Don-Dee Model.

Continuing loss

Continuing Loss (CL) represents the depth of rainfall per hour that is taken in by the soil once runoff occurs. A CL of 2.5 mm/hr has been adopted for all design events in both the Dawson Model and the Don-Dee Model as based on the recommended range in ARR (ARR, 1987).

Table 4.2 Adopted design rainfall losses for pervious areas*

Event (AEP)	IL (mm)	CL (mm/hr)
10%	30	2.5
5%	30	2.5
2%	10	2.5
1%	0	2.5
0.2%	0	2.5
0.05%	0	2.5
PMP	0	2.5

* *Losses adopted for impervious areas was an IL of 0mm and a CL of 0 mm/hr*

4.3.4 Results

The results of the Dawson Model design runs at key locations in the catchment are presented in Table 4.3. The results of the model at Beckers match well with the FFA.

The critical duration was found to be 72 hours for events below the PMP for all key locations along the Dawson River including all towns assessed in this study. For the PMP, the 96 hour duration was found to be critical.

The results of the Don-Dee Model design runs at key locations in the catchment are presented in Table 4.4.

Table 4.3 Dawson Model design flow results

AEP	Key locations							
	Taroom	Glebe weir	Theodore	Woodleigh	Moura	Bindaree	Baralaba	Beckers
2013 event	243	304	536	587	370	2,283	2,570	2,592
2010 event	8,733	5,261	4,726	4,740	4,442	6,159	6,352	6,380
10%	2,659	1,719	1,572	1,582	1,480	1,681	1,814	1,832
5%	3,823	2,545	2,319	2,332	2,181	2,574	2,767	2,790
2%	5,678	4,154	3,789	3,806	3,567	4,298	4,601	4,634
1%	7,278	5,454	4,972	4,991	4,679	5,706	6,092	6,131
1% CC*	9,606	7,250	6,590	6,612	6,197	7,709	8,213	8,259
0.2%	10,384	7,861	7,141	7,164	6,714	8,390	8,934	8,983
0.05%	13,302	10,153	9,204	9,230	8,648	10,968	11,661	11,719
PMP	38,025	25,824	23,720	23,766	22,397	28,559	30,584	30,926

* *1% CC is the 1% AEP event Climate Change sensitivity simulation*

Table 4.4 Don-Dee Model design flow results

AEP	Key locations								
	96k (Callide Dam inflow)	Callide Dam outflow	Kroombit Dam outflow	Pump Station	Folding Hills	Red Hill	Craiglands	Kings-borough	Dululu
1978	1,684	811	697†	93	39	103	1,238	1,412	1,080
2010	2,116	890	378	363	440	404	358	1,225	2,277
2013	-**	2,071#	1,140	487	361	288	652	2,421	3,132
2015	4,429	4,788	2,267	956	375	170	1,711	2,417	3,592
10%	1,584	1,370	565	263	36	50	198	291	1,443
5%	2,094	1,798	796	364	72	98	281	420	1,858
2%	3,419	2,978	1,502	681	210	285	524	761	3,066
1%	4,232	4,788	2,009	889	309	421	739	1,094	3,912
1%CC*	5,228	4,826	2,571	1,144	409	559	952	1,404	5,099
0.2%	5,919	4,898	2,926	1,236	460	629	1,030	1,514	5,357
0.05%	7,682	5,120	3,875	1,570	620	855	1,288	1,888	6,860
PMP	14,430	6,231	8,496	4,679	3,798	4,482	7,620	10,809	12,916

* *1% CC is the 1% AEP event Climate Change sensitivity simulation*
** *Inflow to Callide Dam not calculated in XP-RAFTS model*
\# *Peak flow not estimated in XP-RAFTS model, flow calculated using recorded gate opening and water level*
† *Kroombit Dam not constructed in 1978 event, flow taken at Kroombit Dam site*

4.4 DISCUSSION

4.4.1 Dawson Model

The towns assessed in the Dawson Model are all located along the Dawson River, and with the exception of Baralaba, which is flooded from the Roundstone Creek catchment, are flooded from rainfall on the upper Dawson catchment during the 2010 event. During the 2010 event, a flood peak progresses downstream along the Dawson River from Taroom, with lateral inflows adding little flow and often passing before the Dawson River peak.

As a result of this, the hydrological routing of the flood along the Dawson River from Taroom is critical to the flooding characteristics and calibration. The calibration data and the hydrological model suggest that the highest peak flow occurs at Taroom, and significant attenuation occurs downstream to Roundstone Creek's confluence with the Dawson River, causing a reduction in the flood peak.

The attenuation is most likely due to a number of reasons. These include; the small addition of inflow from lateral systems, a number of weirs along the Dawson River, wide floodplains with a large quantity of flood storage, and topographic features such as the gorge downstream of the Glebe weir and the flow constriction downstream of Theodore that restricts the floodplain flow width.

During the 2013 event, flooding along the Dawson River upstream of Roundstone Creek's confluence with Dawson River is minor. The majority of the flow would be conveyed in the creek's banks, and as a result much of the attenuation that is seen in the larger 2010 event would not occur. The hydrological model does a reasonable job at representing both events, however has been biased toward the larger event.

The reason for this bias is that more data was available for the 2010 event allowing for a better calibration but also because the larger events are considered more important for the flood risk and management study. The focus of the flood risk and management study is on flood events that break the creek's banks and potentially flood roads and properties, causing damage and isolating communities.

The 2010 event is similar to a 1% AEP event with a few of the key locations receiving flows greater than the 1% AEP event, and a few key locations receiving flow less than the 1% AEP event. This is a result of the fairly consistent rainfall across the catchment. The 2013 event however receives more variable rainfall across the catchment. This is apparent in the flow results; all key locations upstream of Roundstone Creek's confluence with the Dawson River have flows much less than the 10% AEP, and downstream flows are close to the 5% AEP.

Care should be taken when using the hydrological model for flood events that differ from those that it has been calibrated to. As discussed above, smaller events that do not activate the floodplain may alter catchment responses, as well as events that are significantly larger. It is important that the model be recalibrated as flood events occur to ensure its reliability as a floodplain management tool.

It was also found during the calibration process that rating curves adopted for a number of stations within the catchment lose accuracy at high stages. This is due to high stages usually being estimated from extrapolated recorded low flow gaugings, and basic hydraulic formula. Unfortunately these are the flood events that models are calibrated to. It is therefore recommended that synthetic rating curves be developed using 2D hydraulic models for a select number of stream gauges in the catchment. The 2D hydraulic model would be used to obtain accurate high stage discharges, and be amalgamated with the current rating curve for in-bank stages where recorded gaugings have been captured.

4.4.2 Don-Dee Model

The Don-Dee catchment has two good hydrological calibration locations in the form of Callide and Kroombit Dams. It has also been joint calibrated with the hydraulic model to stream level gauges and surveyed flood marks for the Callide Valley and Dululu and Wowan towns.

It should be noted however that while calibration has been achieved, Callide and Kroombit Dams, as well as the inflows to the hydraulic models are all located within the upper sections of the catchment. Goovigen gauge is the only gauge located along Callide Creek downstream of the Dams. The Callide Valley downstream of the dams is generally characterised by wide, flat floodplains that could cause significant flow attenuation to occur.

Due to the poor location of the Goovigen gauge, it was discarded from the hydrologic model. The Goovigen gauge is situated on a perched creek that spills to a floodplain that is 4 m lower on both sides than the top of bank of the main channel. As a result, once water does spill over the creek’s banks, the water level in the main channel does not continue to increase with flow until the floodplain is completely full.

Care should therefore be taken when using hydrological flow results from the Don-Dee Model downstream of Jambin, particularly downstream of the Don River’s confluence with the Dee River at Rannes. The model has not been calibrated at this gauge.

It is recommended that the Goovigen gauge is relocated or install one or two secondary gauges on the floodplain. The gauge should be moved to a more appropriate location and be used for any recalibration of the model to future events as it would provide data at a key location within the catchment.

The calibrated hydraulic model uses inflows from the upper sections of the catchment where calibration has been achieved and would explicitly route the flow along the floodplain. It is therefore considered to be an accurate representation of the floodplain and flow characteristics. As an interim measure, the hydrological model in these uncertain areas could be compared against flows extracted from the hydraulic model to increase confidence in its results.

It is recommended that synthetic rating curves using the 2D hydraulic model be developed for a number of stream gauges within the catchment. Although calibration is considered good, development of synthetic rating curves would allow greater confidence in the model’s performance.

4.5 CONCLUSION AND RECOMMENDATIONS

KBR developed two hydrological models for the Dawson catchment. One model was developed for the larger Dawson Catchment and another model for the Don-Dee catchment to capture detail that could be missed in the larger Dawson model. The

Don-Dee model would also allow focus on the 2013 and 2015 historic flood events that primarily affected the Callide Valley area.

The Dawson Model was joint calibrated to the 2010 event, and verified to the 2013 event. The Don-Dee model was joint calibrated to the 2013 and 2015 events, and verified to the 1978 and 2010 events.

Design storm events were simulated in the calibrated hydrological model to obtain design discharges at key location in the catchment.

As an outcome of this study, the following items are recommended:

- update a number of rating curves within the Dawson and Don-Dee catchment using 2D hydraulic models
- recalibrate the hydrological model(s) using the updated rating curves
- undertake a FFA using the updated rating curves
- relocate the Goovigen gauge to a more suitable location, or install one or two secondary gauges on the floodplain
- as an interim measure, compare hydrological results to extracted flows from the calibrated hydraulic model in the Callide Valley downstream of Biloela
- recalibrate the hydrological model to any future flood events.

Based on the scope of services, available data, uncertainties in measurements, and software capabilities it is recommended that the calibrated hydrological models for the Dawson and Don-Dee catchments are accepted and the design event discharges are used to complete the Banana Shire Council Flood Risk Management Plan.

5 Flood hydraulics

5.1 PURPOSE

Flood hydraulics describes the mechanics of flow in open channels and pipes. For a given flow, flood hydraulics estimates properties such as flood depth, velocity, shear stress, and stream power.

The purpose of undertaking hydraulic modelling for the towns within Banana Shire Council is to estimate design flood levels and velocities for a range of design AEP events. Once existing conditions are established, the hydraulic model can then be used as a tool to better inform emergency planning, establishing evacuation routes, and to test the benefit of flood mitigation solutions,

By definition, each AEP has a known probability of occurring in any given year. The design hydraulic results can therefore be used to calculate flood damage probability, which in turn is used to estimate the benefits of mitigation solutions in an economic analysis.

This flood hydraulics section of the report describes the hydraulic model setup, calibration, and final design results. As before, the main body of text is intended for non-technical persons. Appendix C describes in technical detail the Callide Valley hydraulics, and Appendix D describes in technical detail the hydraulics of the other areas.

5.2 SCOPE

The towns and events included as part of the scope of works of the hydraulic study is outlined in Table 5.1.

Table 5.1 Towns and events assessed in study

Town	Historic event				Design event (AEP)							
	1978	2010	2013	2015	10%	5%	2%	1%	1%CC*	0.2%	0.05%	PMF
Biloela	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thangool	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Jambin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Goovigen	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wowan	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dululu	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Taroom	-	✓	-	-	-	✓	✓	✓	✓	-	-	✓
Theodore	-	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
Moura	-	✓	-	-	-	✓	✓	✓	✓	-	-	✓
Baralaba	-	✓	-	-	-	✓	✓	✓	✓	-	-	✓

* *1%CC is the 1% AEP event with Climate Change allowance sensitivity event*

5.2.1 Hydraulic description

Biloela

Biloela is located between Callide and Kroombit Creeks downstream of the Callide and Kroombit Dams. Flooding in Biloela is predominately caused by the Washpool Gully breakout from Kroombit Creek approximately 9 km upstream of Biloela that runs through the town.

Callide Creek is located approximately 2 km north of Biloela and is characterised by a deep (10 m) main channel and wide 2 to 3 km floodplain. Kroombit Creek is located approximately 3 km south of Biloela and is characterised by a perched channel with a number of breakouts. The floodplain to the south of the main channel is approximately 3 m lower than the top of bank, and the floodplain to the north can be up to 7 m lower than the top of bank.

Floodplain flow from Kariboe Creek, south of Kroombit Creek and Biloela, joins Kroombit Creek adjacent to Biloela increasing the total floodplain width south of town to over 4 km wide.

Discounting the Washpool Gully Breakout, Callide Creek and Kroombit Creek's floodplain flow join immediately downstream of Biloela. The majority of Biloela itself is located outside of the floodplain of even large events. However due to its location between two major creeks, it can become isolated as roads become flooded.

Thangool

Thangool is a small town located 11 km south-east of Biloela on Kariboe Creek. Kariboe Creek at Thangool is a perched system that runs parallel to the smaller perched Grevillea Creek. During large events, Kariboe and Grevillea Creeks share a centralised floodplain.

Flooding in Thangool and Thangool airport is caused by breakout flow from Kariboe Creek that occurs approximately 1 km upstream of town. Breakout flow travels via a gully adjacent to Thangool parallel to the main channel that is almost 6 m lower than the main channel top of bank. The breakout flow and the main channel are almost completely disconnected at Thangool and flooding is controlled by the upstream breakout.

Jambin

Jambin is a small town located 30 km north-west of Biloela on the Callide Creek approximately 6 km upstream of its confluence with Bell Creek. Callide Creek at Jambin is characterised by a 6 to 7 m deep main channel with a wide 4 to 5 km floodplain containing a number of secondary channels ranging between 1.5 to 3 m deep.

Jambin Hotel and surrounding properties are located on slightly higher terrain than surrounding areas, however is between the Callide Creek main channel and an eastern secondary channel that could flood roads, cutting access. During large events the area itself becomes inundated.

Water levels are influenced by backwater from Bell Creek as well as the upstream Moura railway embankment that has a higher immunity level than surround infrastructure.

Goovigen

Goovigen is a small town located 40 km north-west of Biloela on the Callide Creek at its confluence with Bell Creek. Callide Creek at Goovigen is characterised by a perched main channel that has a top of bank that is 7 m higher than its western floodplain, and 4 m higher than its eastern floodplain.

During large events, flow from Bell Creek travels via a breakout channel upstream of its confluence with Callide Creek, bypassing the stream gauge at Goovigen. Breakout flow joins the Callide Creek floodplain approximately 3 km downstream of Goovigen.

Taroom

Taroom is the most upstream town located on the Dawson River assessed in this study. It is approximately 4 km downstream of the Dawson River's confluence with Jundah Creek, and 15 km upstream of the confluence with Palm Tree Creek.

Dawson River at Taroom is characterised by a 5 m deep main channel and a wide, 2.5 km, floodplain on the western side. The Leichardt Highway crosses the Dawson River at Taroom Township, and would control flooding at Taroom stream gauge, however is overtopped in large events.

Taroom Township is located adjacent to the Dawson River, however is at a significantly higher elevation, with most of the town approximately 10 m above the floodplain. During large events, a few properties on the western side of town are vulnerable to flooding.

Theodore

Theodore is the next town downstream of Taroom located on the Dawson River at its confluence with Castle Creek and just upstream of the Dawson River's confluence with Lonesome Creek.

Flooding at Theodore would be controlled by Theodore Weir for flood events contained within the river's banks. As floodplain flow is activated, flooding is controlled by the natural constriction point in the terrain approximately 1.5 km downstream of the weir.

Theodore Township is vulnerable to flooding in large events as high flows struggle to pass through the constriction point, causing upstream areas to act as a flood basin. As flow increases, water levels upstream rise, flooding farmland and eventually properties in the main town.

Moura

Moura is the next town downstream of Theodore located on the Dawson River. It is located approximately 20 km upstream of the Dawson River's confluence with Roundstone Creek.

Flooding in the Dawson River at Moura is controlled by Moura Weir and the Dawson Highway crossing, which is located 1.3 km upstream of the weir. A secondary channel located 2 km west of the weir is able to bypass flow around the weir, joining with the main flow path 4 km downstream of the weir.

Moura Township itself is not vulnerable to flooding from the Dawson River. It is located approximately 7 km from the main channel, and 30 m above the floodplain.

Baralaba

Baralaba is the final town located on the Dawson River. It is located approximately 50 km downstream of the Dawson River's confluence with Roundstone Creek, and 40 km upstream of the confluence with the Don River.

Flooding at Baralaba is controlled by the Neville-Hewitt Weir located at the town, and the Baralaba anabranch weir located approximately 1.7 km upstream. The anabranch directs water to the north-west around the northern side of Baralaba Mine, rejoining the main channel 5 km downstream of Neville-Hewitt Weir. The anabranch is approximately 13 km long, 6 km longer than the main channel between the same points.

Baralaba Township itself is vulnerable to flooding, particularly the properties adjacent to Dawson River on the north-west side of town.

Dululu

Dululu is located in the Don-Dee catchment, and is the most upstream town assessed in this study located on the Dee River.

The Dee River at Dululu is characterised by a 13 m deep main channel that spills onto a 1.7 km wide floodplain. A small gully runs through Dululu itself, conveying overflow from Dee River to the downstream floodplain.

Wowan

Wowan is located on Pocket Creek, a tributary of the Dee River. Wowan is approximately 3 km from the Dee River main channel, however only 1.5 km from the low point in its floodplain which conveys significant flow from upstream breakouts.

The majority of Wowan is located outside of the Dee River's floodplain and is not vulnerable to regional flooding in most storm events.

5.3 HYDRAULIC MODEL DEVELOPMENT

5.3.1 An overview of two-dimensional models

Two-dimensional (2D) hydraulic models have become the standard approach for predicting flood behaviour. Two-dimensional models allow for flow in both the X and Y direction and explicitly model complexities such as floodplain storage, flow breakouts, and hydraulic controls.

The software platform used in the hydraulic assessment of towns with Banana Shire Council was TUFLOW. TUFLOW stands for Two-dimensional Unsteady FLOW, and solves the full 2D, depth average, momentum and continuity equations for free surface flow. It also includes the viscosity or sub-grid-scale turbulence term.

TUFLOW uses square grid cells in its computation scheme. The cells consist of cell centres that determine active volume of water in the cell, and cell sides that control flow from one cell to another. The resolution (grid cell size) of 2D models is a trade-off between the level of detail represented in the model and model run times. This is especially important in the calibration stage where it is an iterative process. The use of a more detailed grid can reduce the number of iterations run (due to project schedules), resulting in a worse calibration.

The resolution of the model should be such that key hydraulic features such as storages and controls are adequately represented. The TUFLOW user manual (BMT WBM, 2010) recommends that major flow paths be represented in the model by at least three to four grid cells. The hydraulic models developed as part of this study have used appropriate grid cell sizes based on major flow paths, however the catchment is typically characterised by wide floodplains that would increase flow width further during large events.

Terrain roughness, represented as a Manning's 'n' value, is the next most important parameter used in 2D hydraulic modelling and the key parameter changed in the calibration process. Roughness estimates how flood levels and velocities are affected by differing land covers and uses.

It is important to understand that the use of roughness values attempt to model the complexities of flood behaviour through use of single values. The roughness parameter represents complex flood behaviour such as the vertical velocity profile caused by flow obstructions (vegetation or cropping) in any given model grid cell. Often model grid cells are too large to be able to represent every change in land cover in the model, and often sections are represented broadly by one value. For example, cropping would be represented by one Manning's 'n' value even though there can be open, unobstructed spaces between the crop rows. Roughness is also depth dependent, with small shrubs only impeding flow at low depths and trees causing greater impediment when depths reach the foliage. The obstruction of land cover is dynamic during a flood, with some vegetation leaning over once flood depths and velocities increases past a threshold.

The selection of roughness Manning's 'n' values are chosen based on best modelling practice and requires engineering judgement. The chosen values should be within a reasonable range for any given land cover type.

It is important to understand the limitations of hydraulic models. Models simplify many complex processes through the use of key parameters and schematisation. They are also constrained by computational power, trading terrain resolution for run time speed. AR&R Project 15 (EA, 2012) summarises these limitations:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data and the reliability/uncertainty of the inflow data.

- A poorly constructed model can usually be calibrated to the observed data but will perform poorly in events both larger and smaller than the calibration data set.
- No model is 'correct' therefore the results require interpretation.
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.

The implication of the statements above is crucial to the interpretation and use of the results of the hydraulic models developed as part of this study.

5.3.2 Model setup

The following section provides an overview of the hydraulic model setup. Appendix C describes in detail the development of the Callide Valley hydraulic model setup, and Appendix D describes in detail the model setup of all other town hydraulic models.

The floodplain management study requires the hydraulic assessment of 10 towns within Council's LGA. Six hydraulic models were developed for this purpose and cover the 10 towns required.

As stated previously, the hydraulic modelling package TUFLOW was adopted for use in this study. The classic TUFLOW modelling software was used for five of the hydraulic models developed.

One of the hydraulic models was developed within TUFLOW GPU. TUFLOW GPU is a module within the TUFLOW software that utilises the Graphic Processing Units (GPUs) in the computers graphics card. Typically the graphics card has many more GPU cores than the computer has Central Processing Unit (CPU) cores and is therefore able to process a larger number of grid cells, sometimes up to 20 times faster than classic TUFLOW. As a result, large detailed models are capable of being developed and run in manageable timeframes. However a number of features, such as hydraulic structures, are not able to be implemented in TUFLOW GPU to the same degree of complexity, and therefore TUFLOW classic is generally preferred until model sizes become impractical.

The following is a list of the hydraulic models developed and the towns located within their model extent. The locations of the models are presented in Figure 5.1 and individually in Figures 5.2 to 5.7. The naming convention for the hydraulic models will herein be adopted as below:

- 'Callide Valley TUFLOW GPU model' – encompasses Biloela, Thangool, Jambin, and Goovigen
- 'Taroom TUFLOW model' – encompasses Taroom
- 'Theodore TUFLOW model' – encompasses Theodore
- 'Moura TUFLOW model' – encompasses Moura
- 'Baralaba TUFLOW model' – encompasses Baralaba
- 'Wowan TUFLOW model' – encompasses Dululu and Wowan.

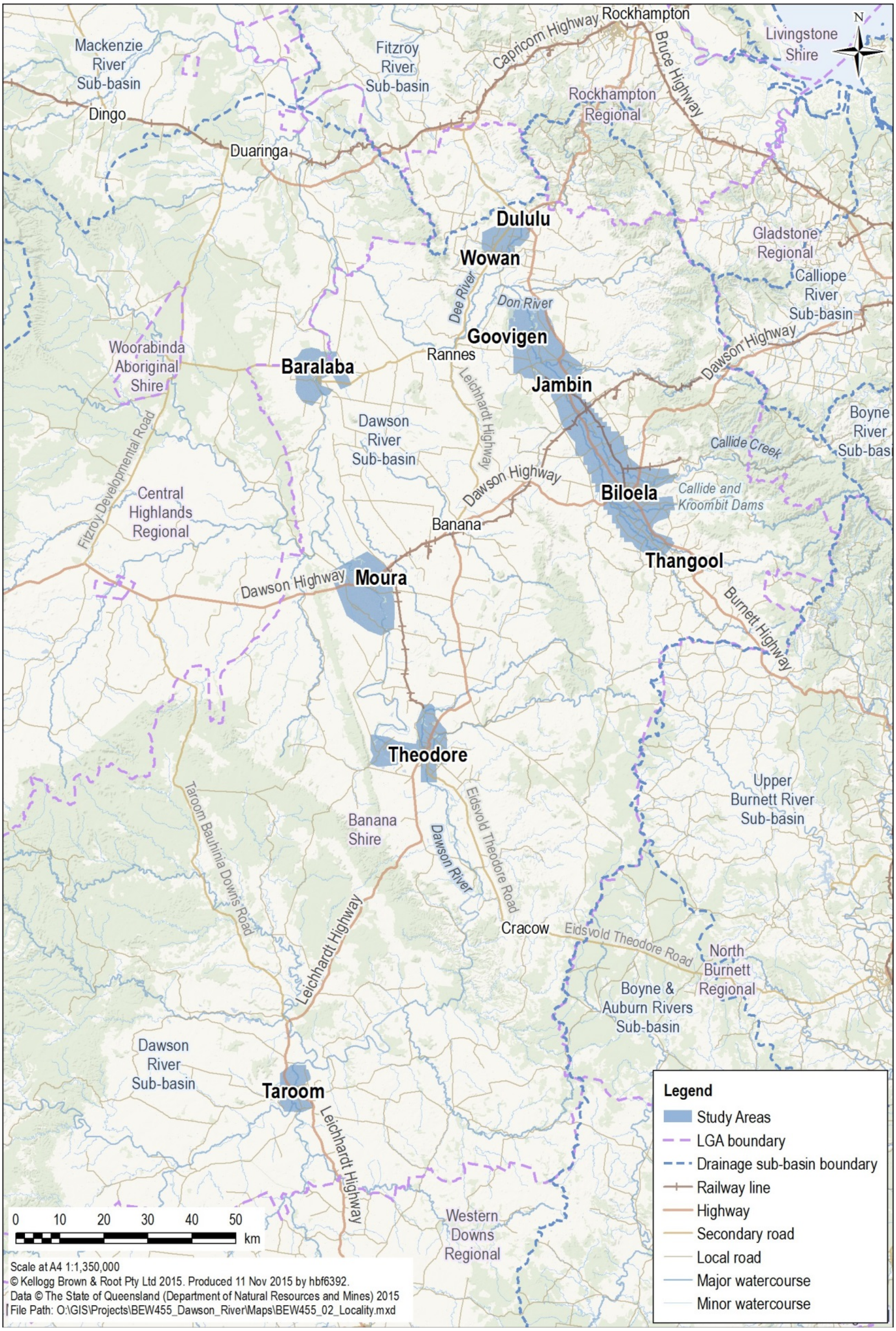

Figure 5.1
HYDRAULIC MODELS WITHIN THE DAWSON CATCHMENT

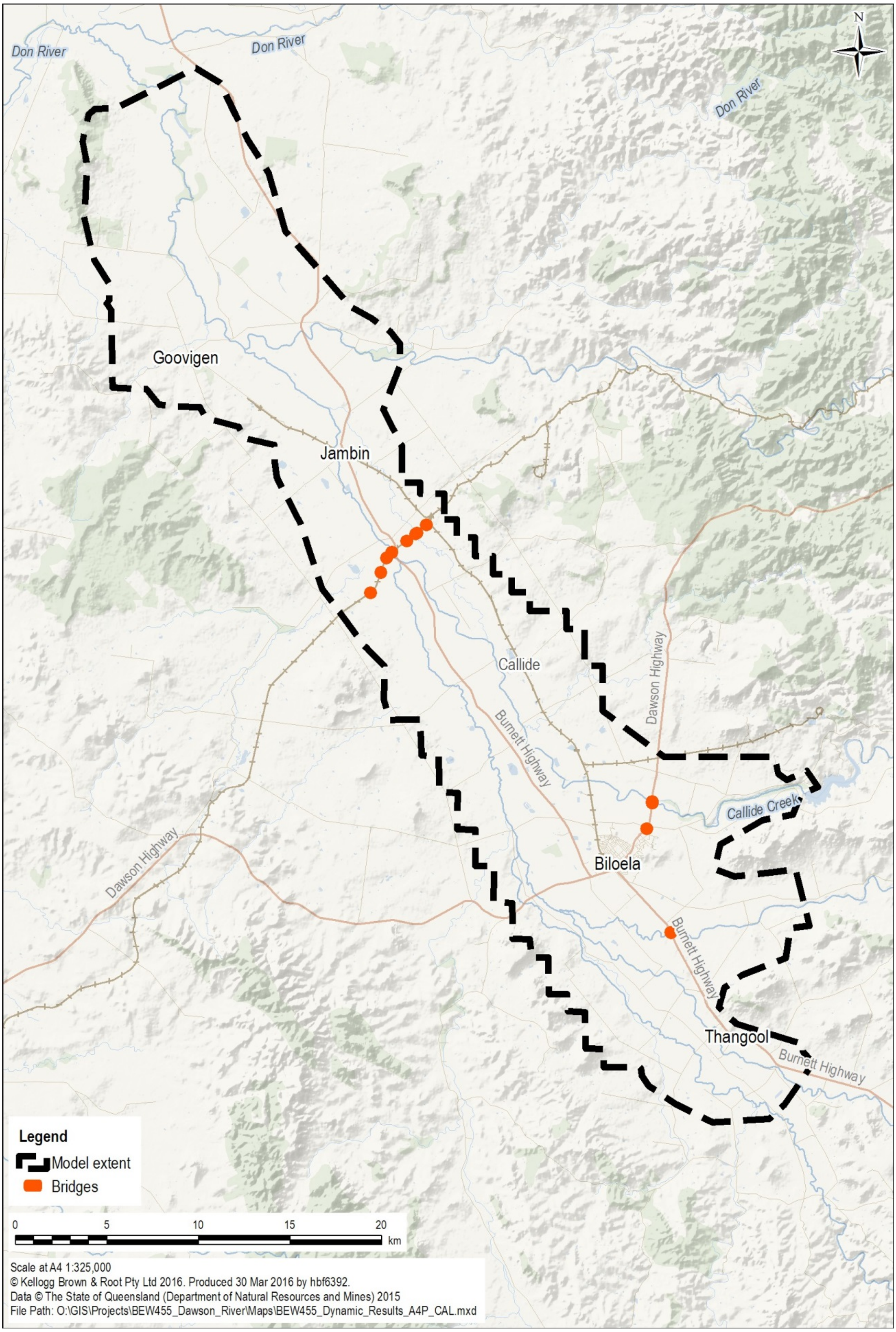

Figure 5.2
CALLIDE VALLEY TUFLOW GPU MODEL

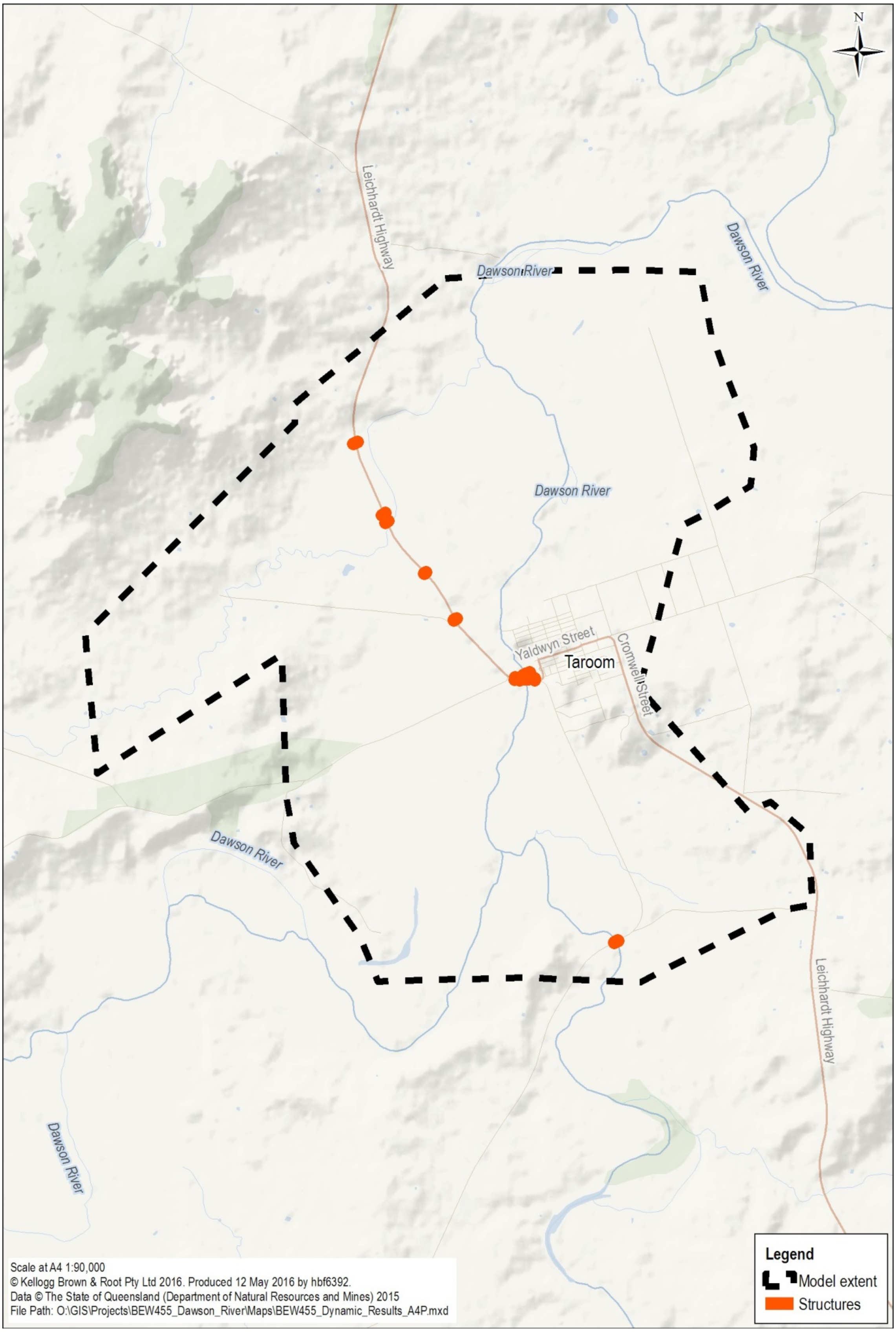

Figure 5.3
TAROOM TUFLOW MODEL

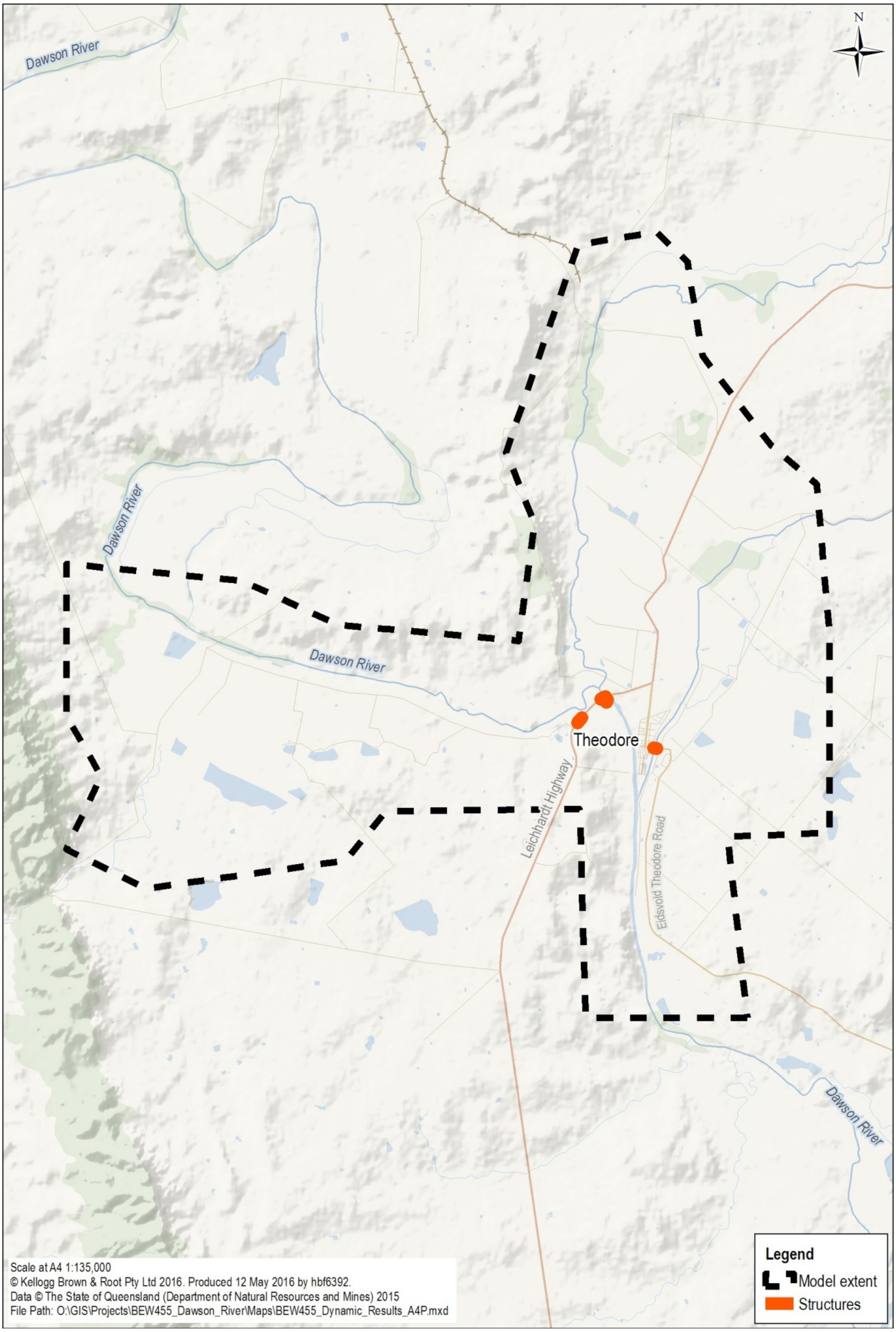

Figure 5.4
THEODORE TUFLOW MODEL

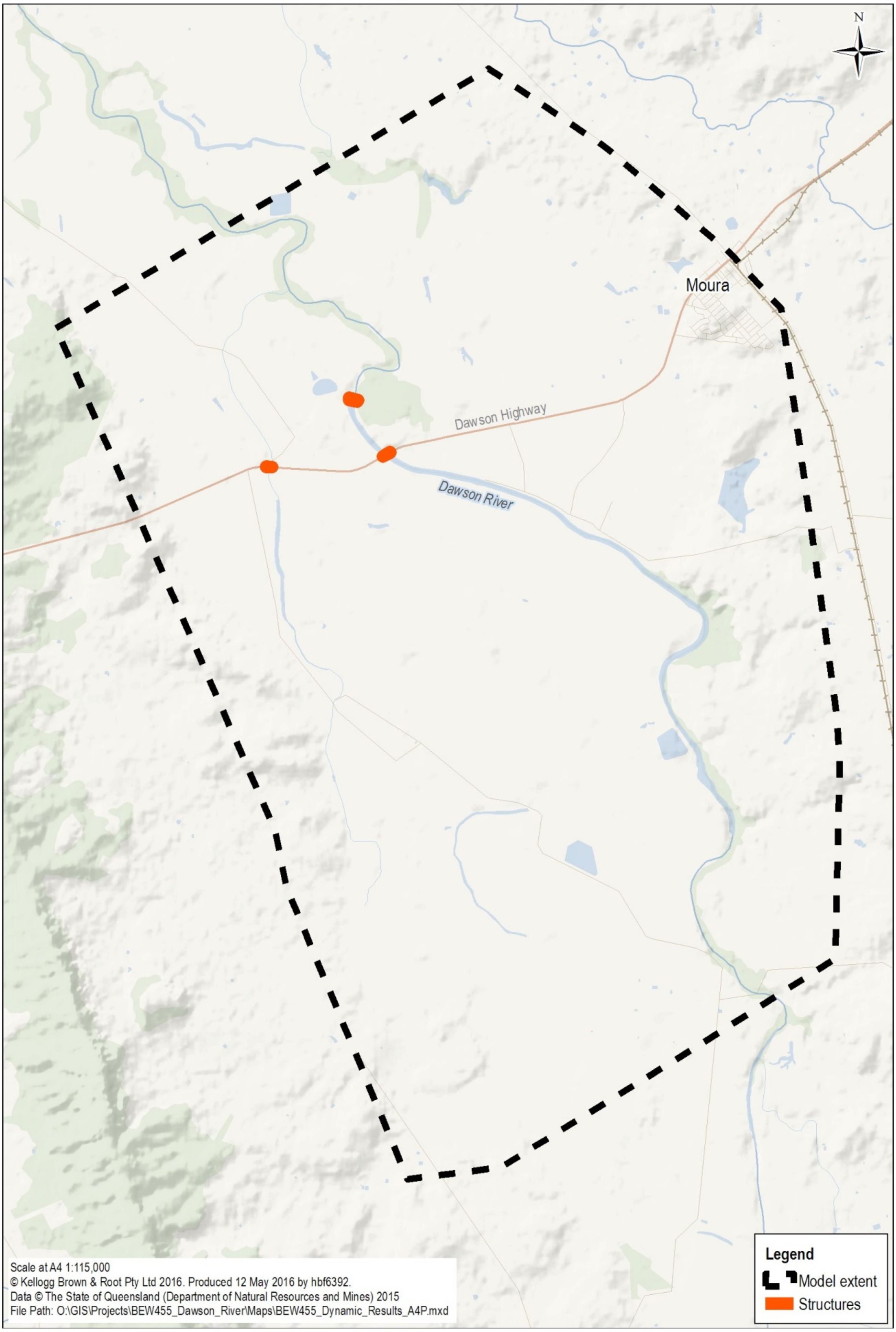

Figure 5.5
MOURA TUFLOW MODEL

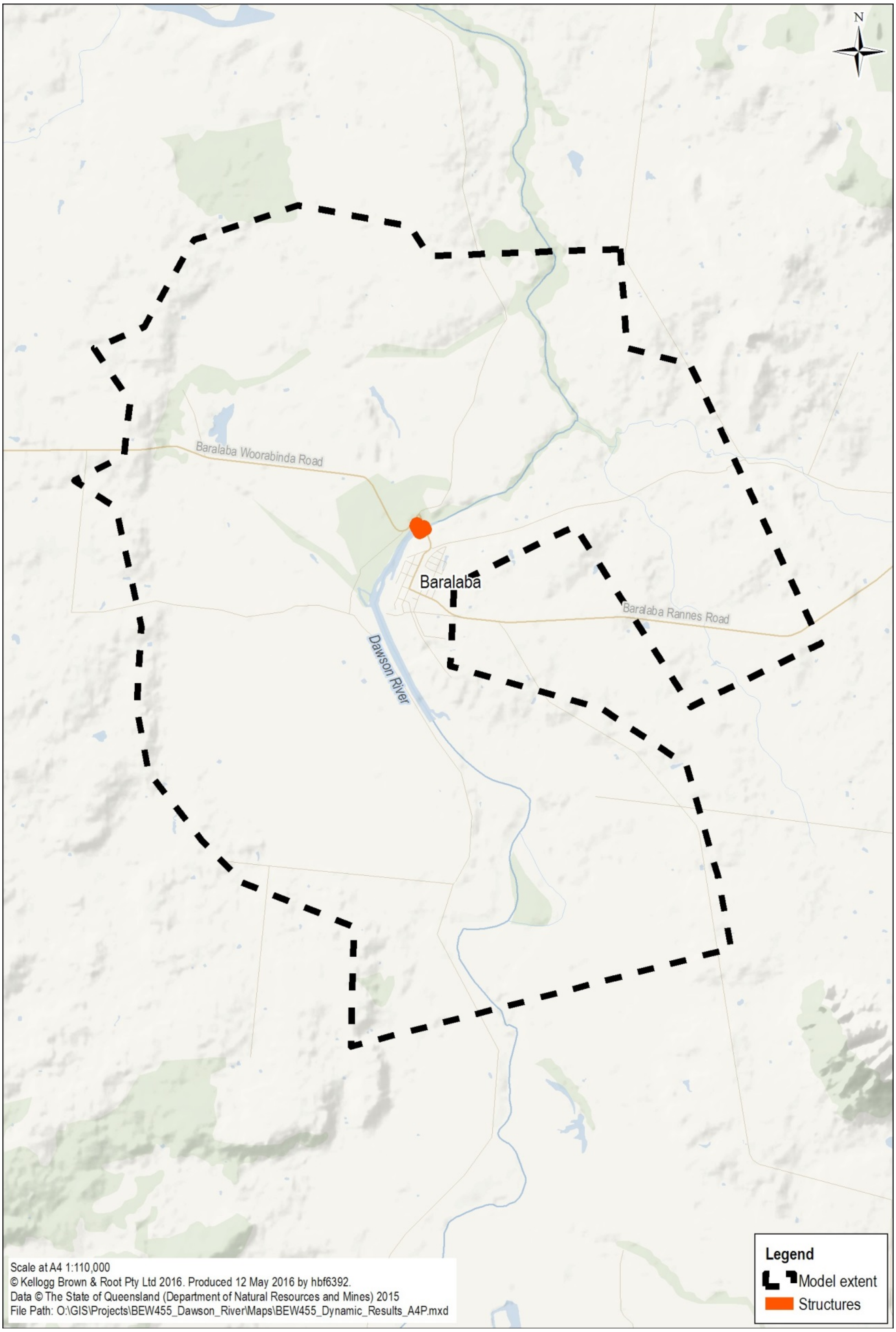

Figure 5.6
BARALABA TUFLOW MODEL

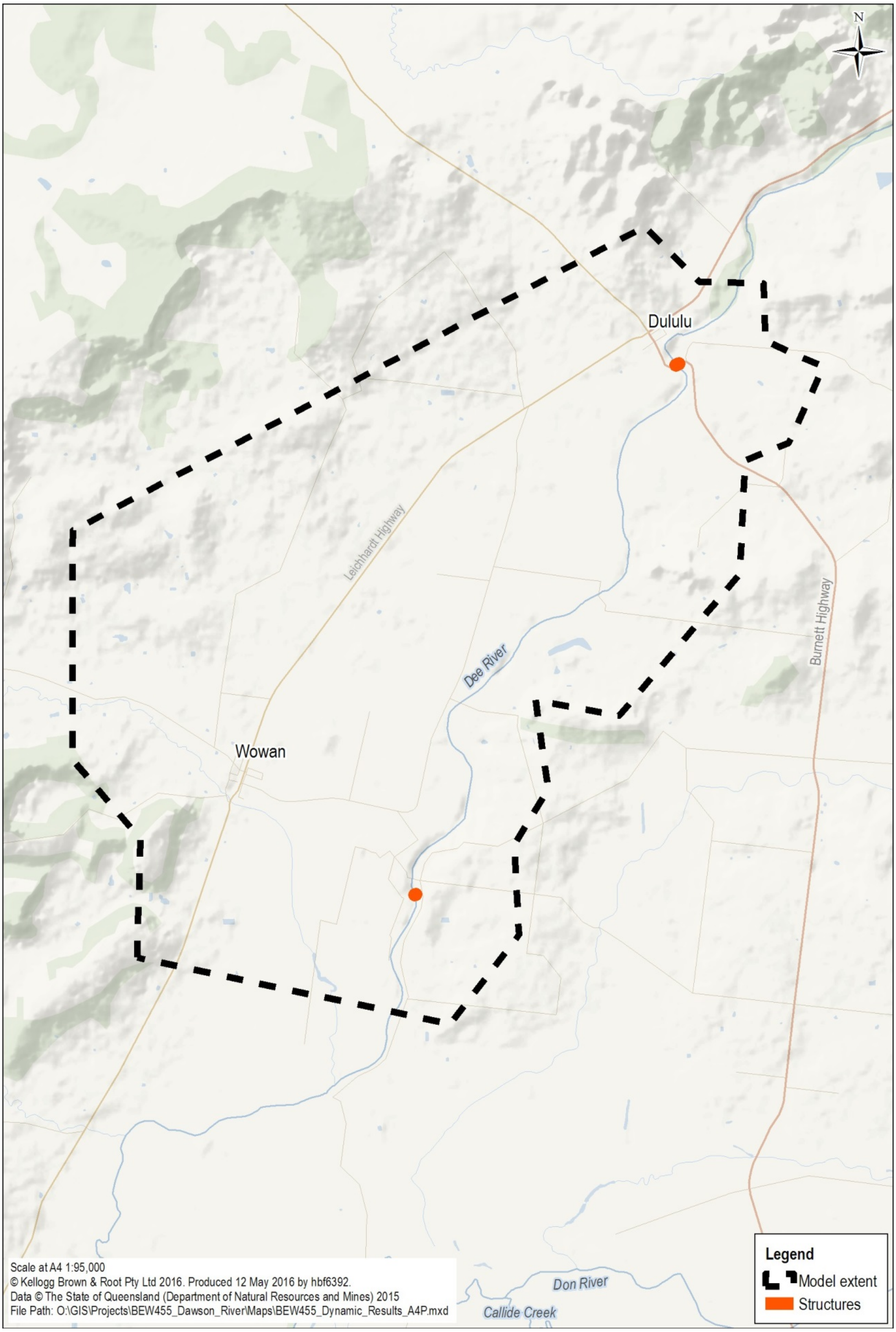

Figure 5.7
WOWAN TUFLOW MODEL

5.4 HYDRAULIC CALIBRATION

5.4.1 Calibration process

Hydraulic models are developed to realistically estimate flood levels and velocities during design events, informing emergency and development planning among other uses. To give confidence in the model schematisation and adopted key parameters, calibration is undertaken when data is available. Calibration demonstrates that the hydraulic model is capable of reproducing flood behaviour within acceptable parameter bounds.

Defining an acceptable calibration is crucial to the process. Generally values within ±200 to 300 mm are considered acceptable, especially when calibrating to numerous observed points. It is rare that the model exactly matches any or all the measured points, and a balance is found that gives the best overall match. The accuracy of the calibration data is also critical to defining an acceptable calibration, with consideration given to the type of data and the measurement technique. For example, higher priority might be given to matching levels at a gauge station than surveyed debris marks.

The ability to match a calibration point also depends on the accuracy of the underlying terrain. The LiDAR used in this study has a quoted vertical accuracy of ±0.15 m, however in areas of dense vegetation or standing water, the error in elevation can be significantly greater.

ARR Project 15 – Two-Dimensional Modelling in Urban and Rural floodplains: Stage 1 & 2 Report (EA, 2012) makes the important point that:

> ‘It is far more important to understand why a model may not be calibrating well at a particular location than to use unrealistic parameter values to ‘force’ the model to calibrate.’

This statement warns the use of unrealistic hydraulic parameters, such as Manning’s ‘n’ values, to achieve calibration. An example of why this may be undesirable is that though water levels may be matched through the use of unrealistic Manning’s ‘n’ values, other hydraulic properties such as velocity may become unrealistic. This in turn affects flood hazard and warning times which are used in emergency evacuation planning.

5.4.2 Calibration events

Three historic events were used for calibration of the hydraulic models; the 2010, 2013, and 2015 events.

As listed in Table 5.1, the 2015 event was used for calibration for the towns within the Callide Valley TUFLOW GPU model, and the Wowan TUFLOW Model. The 2010 event was used for calibration for the town along the Dawson River which include the Taroom TUFLOW model, Theodore TUFLOW model, Moura TUFLOW model, and Baralaba TUFLOW model.

The 2013 event was used as verification for the Callide Valley TUFLOW GPU model and the Theodore TUFLOW model. The 2013 event was also simulated in the Wowan TUFLOW model, however no data was available to calibrate or verify to. The Callide Valley TUFLOW GPU model was also verified to the 2010 and 1978 events.

5.4.3 Results

Calibration results are mapped for all TUFLOW models in Volume 2 of this report. The maps include all calibration points and their comparison to the modelled flood surface. Table 5.2 presents a summarised list of the calibration and verification results.

The results show a good comparison to the hydraulic models with the exception of Moura. The Moura TUFLOW model estimates water levels 800 mm lower than the calibration point at Moura Weir. It was concluded, after inspecting an aerial photograph taken during the flood (after the peak), to discard the peak water level measurement at the weir due to either inaccuracy or local turbulence at the weir not able to be simulated in TULFOW. This is further enforced by the recorded peak level at Neville-Hewitt Weir (at Baralaba) also recording higher than the modelled water surface. At Neville-Hewitt Weir however, there is a BOM stream station a few hundred metres upstream that compares well with the TUFLOW model, along with confirmation from aerial photography taken during the flood at Baralaba.

On further inspection of the detailed aerial imagery flown in the morning after the 2010 event there are some areas where the peak flood extent is more clearly discernible. Five points were identified that were used to assist the joint calibration process of the Dawson River RAFTS model and the Moura TUFLOW model. Three points on the Dawson Highway as the road profile rose in and out of the flood water, one point on the road to the Moura Weir and one point at the Moura and District Golf Club near the club house. The peak water level at these points was estimated using the LiDAR and compared to the model results, which showed a good match.

The 2013 event in Theodore was used as verification. The Theodore TUFLOW model is predicting water levels 860 mm higher than the measured water level at Theodore Weir. This discrepancy is most likely due to the underlying terrain data used. The LiDAR capture is unable to penetrate the standing water stored behind the weir, and as a result the majority of the conveyance capacity in the river is lost. In large events, the majority of flow is conveyed via the floodplain. However the 2013 event at Theodore is minor, and is contained within the river's banks, and therefore would be sensitive to the river's bathymetry.

Table 5.2 Difference between modelled water surface and calibration data at key locations (m)*

Town	Event			
	1978	2010	2013	2015
Taroom	n/a	0.18	n/a	n/a
Theodore	n/a	0.17	0.86	n/a
Moura	n/a	-0.8	n/a	n/a
Baralaba	n/a	0.24	n/a	n/a
Dululu	n/a	n/a	n/a	-0.24
Wowan	n/a	n/a	n/a	0.16

* *Positive values denote a higher modelled water surface, negative values denote a lower modelled water surface*

Because there were a lot of calibration data for the Callide Valley TUFLOW GPU model, the calibration results are summarised separately in Table 5.3. Majority of 2015 points fall within 300 mm target range, with high percentage within 100 mm tolerance.

Table 5.3 Callide Valley TUFLOW GPU model calibration summary

Calibration Point Confidence Rating	Total Points	Outside 300 mm	Between 300–200 mm	Between 200–100 mm	Within 100 mm
High	19	1	2	7	9
Medium	15	4	1	3	7
Low	19	4	1	10	4
Total	53	9	4	20	20

Figures 5.8 to 5.10 present four flow hydrographs in the Callide Valley TUFLOW GPU model, in both Kroombit and Callide Creeks, for the 2015, 2013, and 2010 flood events. Callide Creek at Links Road and Kroombit Creek at Dawson Highway are flow locations upstream of the Callide Creek and Kroombit Creek confluence. Callide Creek at Jambin and Goovigen are downstream of the confluence. Measuring flows at these locations enable a comparison and analysis of contributing flows to the flooding in Callide Valley. Kroombit Creek catchment at Dawson Highway includes contributing flow from Kroombit Dam and Kariboe Creek catchments.

In the 2015 event, peak flows from Callide and Kroombit Creek are approximately 4,200 m3/s and 3,200 m3/s respectively. The peak from Callide Dam rises and falls rapidly, and this would be reduced in the wide floodplain between Biloela and Jambin. At Jambin the flow from Callide Dam arrives first, followed by the flows from Kroombit a few hours later. Both catchments contribute to the total flood volume and peak flow at Jambin and Goovigen.

In the 2013 event, peak flows from Callide and Kroombit Creek are approximately 2,000 m^3/s and 2,500 m^3/s respectively The peak flow at Jambin is approximately 4,000 m^3/s indicating that there is some coincidence timing between the catchments to enable a higher peak flow than either of the contributing catchments individually. In the 2013 event, Kroombit Creek is shown to contribute the highest peak and the most flood volume.

During the 2010 event, there was little discharge from Callide Dam, and flooding was predominately caused by the Kroombit Catchment and local runoff in Callide Valley.

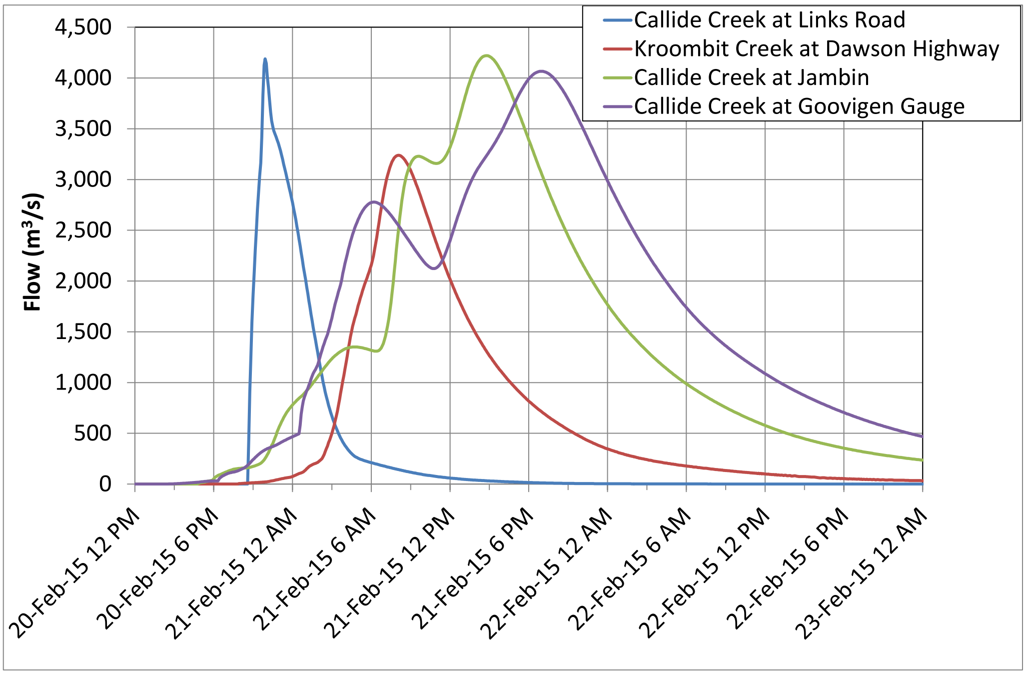

Figure 5.8
2015 EVENT - FLOW HYDROGRAPHS CALLIDE AND KROOMBIT CREEKS

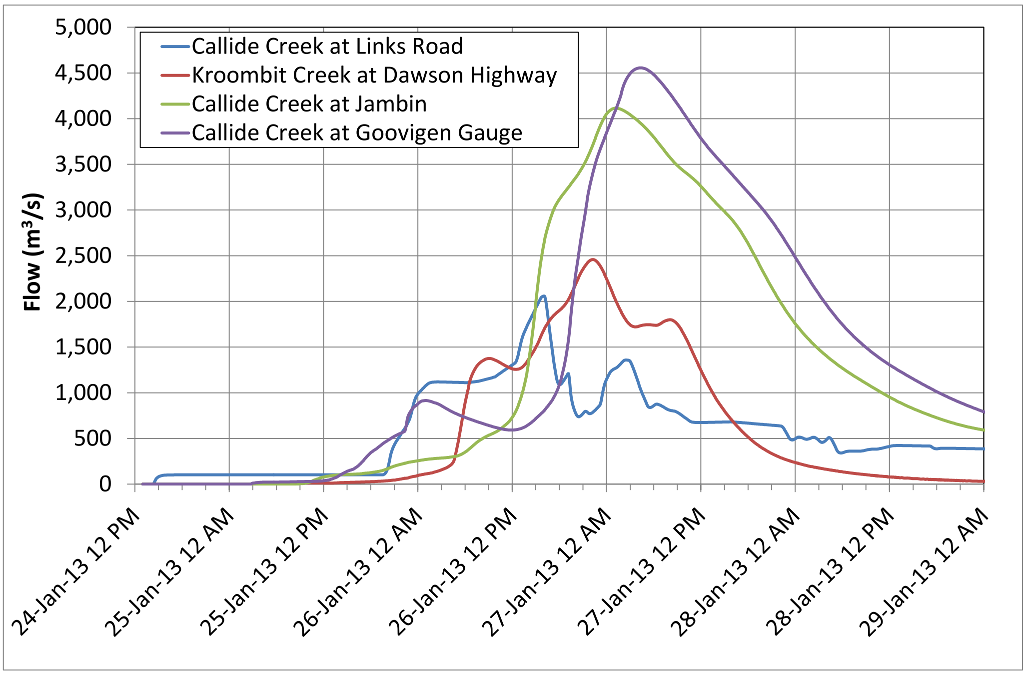

Figure 5.9
2013 EVENT - FLOW HYDROGRAPHS CALLIDE AND KROOMBIT CREEKS

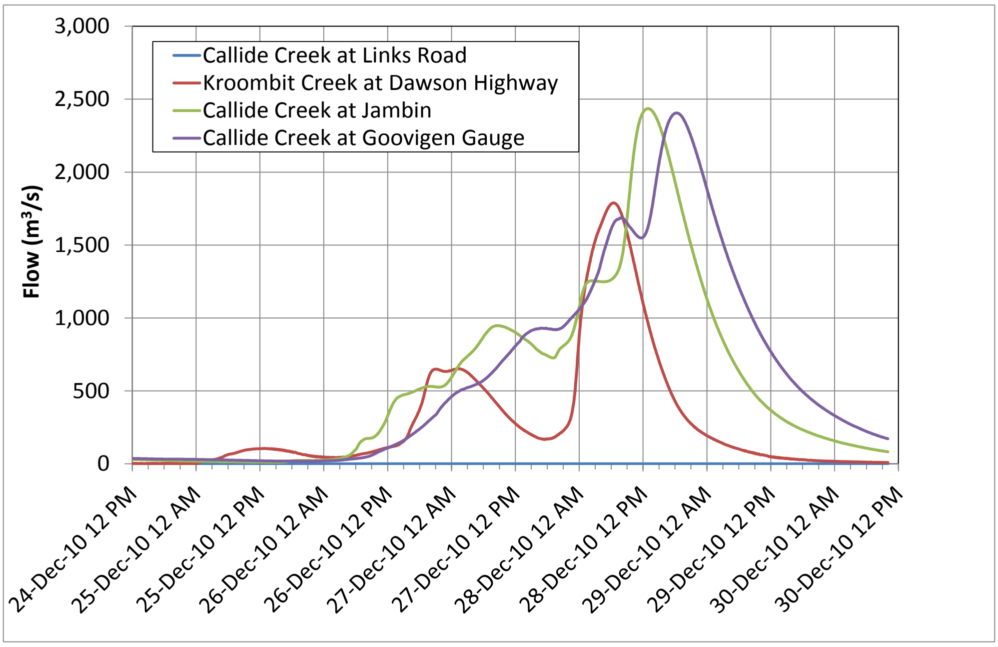

Figure 5.10
2010 EVENT - FLOW HYDROGRAPHS CALLIDE AND KROOMBIT CREEKS

5.5 HYDRAULIC DESIGN EVENTS

Design AEP flows from the appropriate hydrologic model is used as an input into the design hydraulic models to obtain design levels. Design levels are used for the purpose of planning, flood damage assessment, and flood mitigation scenarios.

Table 5.1 lists the design events simulated for each town.

5.5.1 Results

The results of the hydraulic design events are presented in Volume 2 of this report. They show the depth, water level, and velocity of all the design events simulated.

Table 5.4 presents a summary table of the water level at each town, typically taken at the nearby stream gauge for comparison.

Table 5.4 Summary of design flood level results at each town (m AHD)

Town	Historic event*				Design event (AEP)						
	1978	2010	2013	2015	10%	5%	2%	1%	1%CC*	0.2%	PMF
Biloela	122.37	122.47	122.61	122.60	122.26	122.37	122.57	122.64	122.71	122.75	124.21
Thangool	133.01	133.13	133.46	133.48	132.84	132.99	133.35	133.63	133.92	134.07	137.27
Jambin	192.00	193.55	194.40	194.47	193.33	194.21	194.46	194.47	194.49	194.50	195.36
Goovigen	170.84	166.35	174.09	174.56	172.04	173.22	174.43	174.57	174.74	174.82	175.19
Wowan	#	#	114.08	114.10	111.29	112.50	114.08	114.11	114.15	114.17	114.34
Dululu	#	#	125.69	125.89	122.28	123.21	125.42	125.82	126.76	127.17	129.00
Taroom	#	190.93	#	#	#	189.24	190.00	190.57	191.22	#	195.62
Theodore	#	142.05	137.61	#	139.07	140.16	141.46	142.19	142.92	143.13	149.83
Moura	#	110.84	#	#	#	110.39	110.70	110.86	110.99	#	111.86
Baralaba	#	86.75	#	#	#	85.42	86.24	86.68	87.10	#	90.87

* *Modelled historic event levels*
\# *Event not simulated for town*

5.6 DISCUSSION

5.6.1 Callide Valley TUFLOW GPU model

Calibration results from the 2015 Ex-Tropical Cyclone Marcia flood event show peak flows from a majority of the catchments within the Callide Valley floodplain were large enough to exceed the capacity of many ‘perched’ creeks and spill across the adjacent landform and floodplain.

Results demonstrate the majority of flooding experienced at Biloela during Tropical Cyclone Marcia was a consequence of break out flow from Kroombit Creek into Washpool Gully. Considerable effort was undertaken to match predicted flood levels at Browns gully adjacent to Council Chambers and Contact Creek upstream of the Dawson Highway. Results indicate modelled levels are approximately 300 mm higher than recorded levels at Browns Gully Flood levels through this area are dependent on the volume of flow to break out of Kroombit Creek at Washpool Gully and the Burnett Highway.

Flooding at Thangool is dominated by flows originating from Kariboe Creek. Results indicate a significant ‘break out’ flow from Kariboe Creek upstream and adjacent to Thangool Airport. The predicted flood levels match to within 70 mm of recorded debris data at this location and modelled flood extents closely match mud outlines evident in SPOT aerial imagery.

Flood levels across the floodplain between Biloela and Jambin match recorded debris data to within 200 mm in the majority of locations. Flood heights were recorded in three locations at Jambin. The calibration point with the highest confidence rating matches modelled levels to within 140 mm.

Results show the township of Goovigen is not affected by a regional flood event from Callide Creek. It should be noted that localised flooding from Eleven Mile Creek (adjacent to Goovigen) has not been assessed as part of this study. Localised flooding may still result in inundation of private properties and roads at Goovigen. This was demonstrated in the Goovigen Flood Hazard Mapping Study undertaken by WRM Water and Environment for QRA.

5.6.2 Taroom TUFLOW model

The comparison between the modelled water level and the historic level is shown on the map in Volume 2 of this report, and the resulting modelled water surface is 0.18 m higher. Through the calibration process, it was found that inflows from the hydrological model were required to be significantly higher than what the stream gauge suggested. This indicates either that the model is under predicting water levels, or that there are inaccuracies in the gauge rating curve.

The 1% AEP design flood is of similar to magnitude to the 2010 flood event. Taroom is situated on a high bank above the floodplain and only the periphery is flooded up to the 1% AEP event. The most susceptible locations include the areas around Lion’s Park and some lower areas to the west of Dawson Street. Access is severed across the floodplain even in smaller events including the 5% AEP event.

5.6.3 Theodore TUFLOW model

Calibration flood surfaces for the 2010 and 2013 events are presented in Volume 2 of this report. The comparison between the historic level shows the model is 0.17 m higher for the 2010 event, and 0.32 m high for the 2013 event.

During large storm events, where flood waters overtop the river banks and onto the floodplain (as is present in the 2010 event), water levels are controlled by the natural downstream constriction in the terrain. A larger difference in modelled water levels exists for the 2013 event most likely caused by the ‘false bottom’ in the creek captured by the LiDAR due to standing water behind the weir.

The 1% AEP design flood is of similar to magnitude to the 2010 flood event. Theodore is surrounded by large areas of cropping and irrigated cropping to the east and north of the township. These lower lying areas are inundated in the 5% AEP event as well as lying areas of the Theodore township around Eleventh Avenue. Most of Theodore up to Third Avenue is inundated in the 2% AEP event and by the 1% AEP event the entire town in flooded.

5.6.4 Moura TUFLOW model

The calibration flood surface for the 2010 event is presented in Volume 2 of this report. The comparison between the historic level and the model water surface is 0.82 m lower for the 2010 event. However, additional calibration points were identified using detailed aerial imagery flown in the morning after the 2010 event where the peak flood extent is discernible. The peak water level at these points was estimated using the LiDAR and compared to the model results, which showed a reasonable match.

The 1% AEP design flood is of similar to magnitude to the 2010 flood event. Moura is situated above the floodplain and it not directly impacted by Dawson River flooding. Access is severed across the floodplain even in smaller events including the 5% AEP event.

The small group of properties at the junction of River Road and Saleyards Road are initially protected by the high banks of the Dawson River in the 5% AEP event, but breakout flows along River Road start to occur in the 2% AEP event although the number of properties impacted is small. In the 1% AEP event there is shallow flooding of almost all properties in this area.

5.6.5 Baralaba TUFLOW model

The comparison between the modelled water level and the historic level is presented in Volume 2 of this report and the model is predicting water levels 0.24 m higher. The peak water level recording at Neville-Hewitt Weir was discarded as it appeared to be much higher than both the ALERT stream gauge (39143) and aerial photography suggests. The modelled water surface also compares well with additional calibration points presented as part of the Baralaba North Continued Operations Project Flood Study undertaken as part of the Environmental Impact Statement (EIS) (Water Solutions, 2014).

The 1% AEP design flood is of similar to magnitude to the 2010 flood event. Baralaba is located adjacent to the Dawson River, however is mostly above the floodplain.

During large events, the lower part of Baralaba State School is vulnerable to flooding. Access is severed across the floodplain even in smaller events including the 5% AEP event.

5.6.6 Wowan TUFLOW model

The 2015 and 2013 calibration maps are presented in Volume 2 of this report. The calibration shows a good comparison between modelled and historic flood levels for the 2015 flood. No historic data was available for the 2013 event.

The 1% AEP design flood is of similar to magnitude to the 2015 flood event. There are no noticeable flood impacts up to the 5% AEP event as the Dee River contains all flow. In the 2% AEP event and above the river breaks its banks and begins filling the large western floodplain, inundating several farm buildings. Dululu is also flooded in the 2% AEP event.

Pocket Creek was not the focus of modelling in this study, however flooding in Wowan begins in the 2% AEP event, though this may occur for more frequent flood events focussed on the Pocket Creek catchment.

5.7 CONCLUSION

KBR developed six hydraulic models, encompassing the 10 towns assessed in this study within Banana Shire Council. The hydraulic models located along the Dawson River were calibrated to the 2010 event, and the Towns located within the Don-Dee catchment were calibrated to the 2015 event.

The Theodore TUFLOW model was verified to the 2013 event, and the Callide Valley TUFLOW GPU event was verified to the 2013, 2010, and 1978 flood events.

The calibrated hydraulic models were used to obtain design flood levels using design flows from the appropriate hydrologic model.

6 References

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WRM 2013, *Dululu Flood Hazard Mapping Study* Prepared for the Queensland Reconstruction Authority on 30 April 2013

WRM 2013a, *Goovigen Flood Hazard Mapping Study* Prepared for the Queensland Reconstruction Authority on 1 May 2013

Appendix A

HYDROLOGY TECHNICAL REPORT

1 Introduction

Kellogg Brown & Root Pty Ltd (KBR) was commissioned by Banana Shire Council (Council) to undertake a floodplain management study and plan for 10 towns within Council's Land Government Area (LGA).

Appendix A reports in technical detail the assumptions, set-up and results of the hydrological assessment.

2 Data

Rainfall stations

The rainfall station data was audited for the 2010, 2013, and 2015 historic calibration events. Sub-daily rainfall stations were able to be used to simulate the temporal pattern as well as be used in conjunction with the daily rainfall stations for the rainfall surface.

Appendix A-1 lists which rainfall stations were considered, which were used and which aspect they were used for.

Only the Blue Hills TM rainfall station was used for the 1978 storm event calibration to define the temporal pattern. The 1978 event was only simulated in the Don-Dee catchment. Due to the limitation of data, KBR did not generate a rainfall surface. The gridded rainfall surface generated as part of the Australian Water Availability Project (AWAP) was adopted.

Streamflow stations

The stream gauge station data was audited for the 2010, 2013, and 2015 historic calibration events. This included checking the recorded water levels as well as the rating curve.

Rating curves often extrapolate flow for high stages based on gaugings that have been captured during low flow events. For this reason, there are often inaccuracies in rating curves at high flow and this needs to be considered when calibrating hydrological models for large historic events.

Goovigen stream gauge was discarded for all the calibration events due to the poor location of the gauge. The gauge is located in a stretch of creek where the stream is perched. As water overtops the creek banks it fills the floodplain which is 3–4 m lower than the top of bank of the main channel. As flow increases, the floodplain continues to fill, keeping the water level in the creek constant.

Appendix A-2 presents the stream gauges considered in this study, marking the gauges used or partially used in this study.

Structure information

Appendix A-3 presents the provided structure information for the dams and weirs within the Dawson catchment.

Callide Dam Spillway Rating

Some uncertainty exists regarding the Callide Dam Spillway rating (i.e. discharge versus storage level) under automatic operation of the gates. Additionally, if the gates open automatically it is necessary that the heights are manually recorded if the information is to be used for hydrologic modelling.

Apart from the 2011 flood during which the centre gate pier opened by 0.175 m, no floods prior to the 2015 event have had fully automatic gate operation. Due to the cyclonic weather conditions only one observation of gate openings was made in the rising phase of the flood storage during the 2015 flood. This observation was made from an adverse position and is hence regarded with caution as it deviates significantly from the theoretical gate opening. For the 2013 flood event the gates were operated manually and gate openings were sourced from the emergency event report (EER).

As part of the Callide Valley Flood Mitigation Study (CVFMS) being undertaken by DEWS, they have made a significant effort with SunWater's assistance to investigate and reassess the measurement, configuration and operation of the radial flood gates. A Callide Dam proposed spillway rating curve has been endorsed by SunWater and adopted for the purpose of the CVFMS. It is presented in Figure A1.

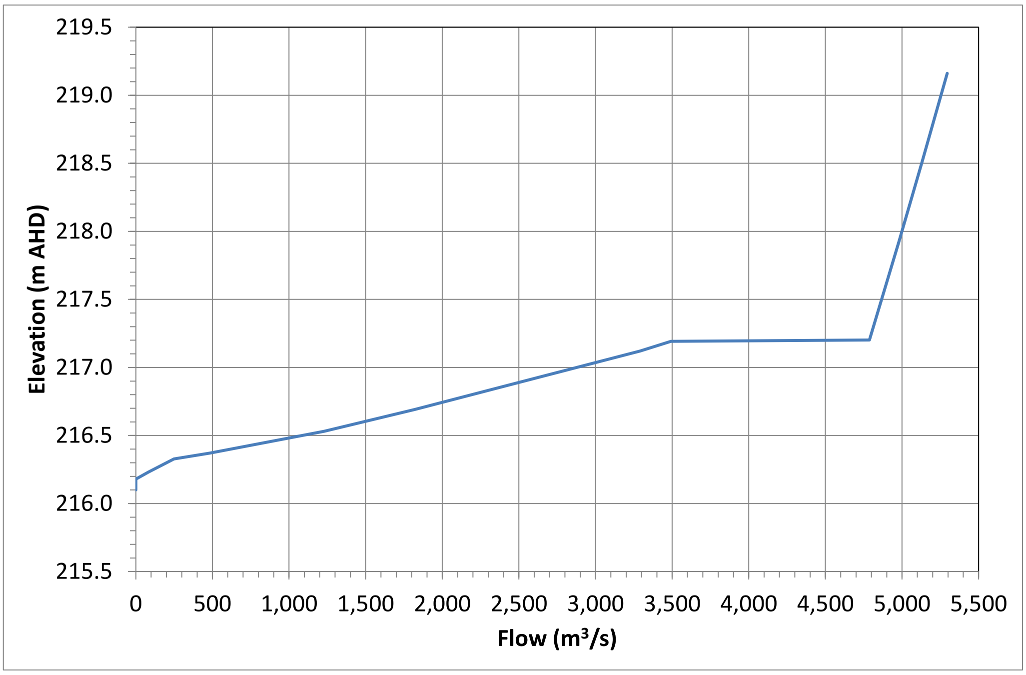

Figure A1
CALLIDE DAM PROPOSED SPILLWAY RATING CURVE

Kroombit Dam Spillway Rating

Kroombit Dam has an ungated spillway that discharges when water levels exceed the spillway invert. The spillway rating curve was provided by SunWater and is presented in Figure A2.

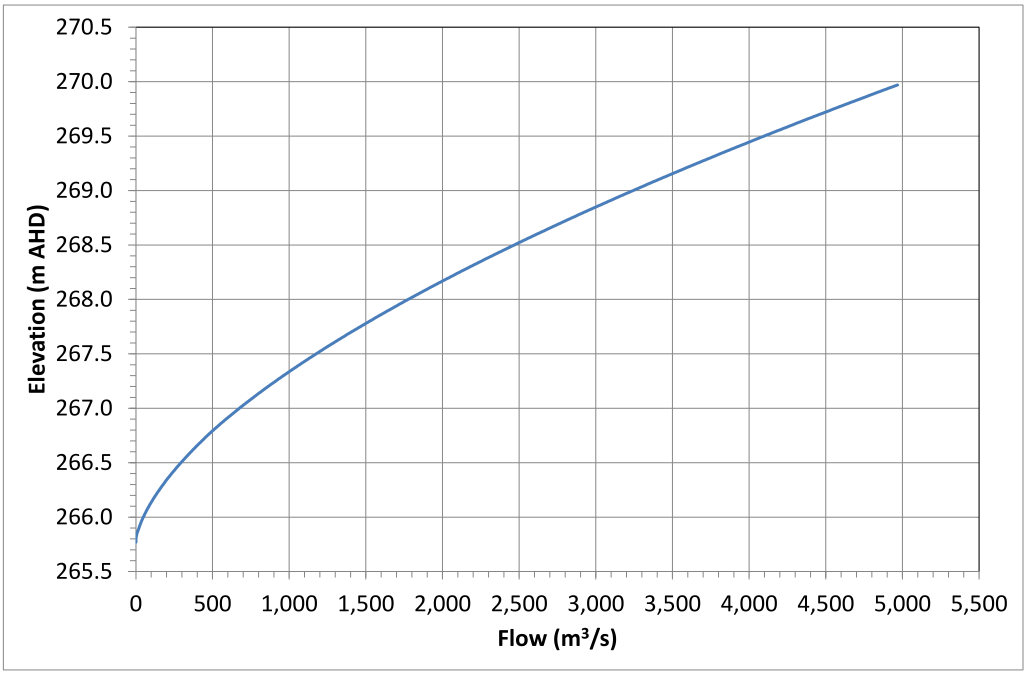

Figure A2
KROOMBIT DAM SPILLWAY RATING CURVE

3 Hydrological model setup

Hydrological modelling software

The hydrological modelling software XP-RAFTS was used for this study. XP-RAFTS utilises catchment area, catchment slope, hydrological roughness to estimate outflow from each subcatchment.

Subcatchment runoff is then routed to through downstream subcatchments until the catchment outlet.

Catchment delineation

Catchments were delineated using CatchmentSIM. CatchmentSIM is a GIS based tool specifically designed for hydrological modelling.

Delineated subcatchment area and slope and initial lag time (travel time) were calculated using CatchmentSIM and input into XP-RAFTS.

Figures A3 and A4 present the catchment delineation of the Dawson and Don-Dee catchment respectively. Appendix A-5 presents the area and slope of each subcatchment.

Hydrological roughness

Hydrological roughness was set based on land use planning obtained from the Queensland Land Use Mapping Program (QLUMP).

CatchmentSIM was used to calculate the hydrological roughness for each subcatchment. Appendix A-5 presents the hydrological roughness adopted for each subcatchment.

Impervious areas

Impervious areas were estimated using road GIS layers. The overall impervious area of the Dawson catchment is estimated to be less than 0.1%, and estimated to be 1.9% for the Don-Dee catchment.

Appendix A-5 presents the impervious fraction for each subcatchment.

Routing

Routing through both the Dawson Model and Don-Dee Model was estimated using flow lagging and Muskingam routing.

Lag times were generally adopted in the upper sections of catchment that tended to be characterised by steeper terrain.

Muskingam routing was adopted along major flow paths in areas that were characterised by wide flat, floodplains. Adjustments to flow lagging and Muskingam parameters was undertaken during an iterative process to achieve a satisfactory comparison with hydrograph timings recorded at streamflow gauging stations.

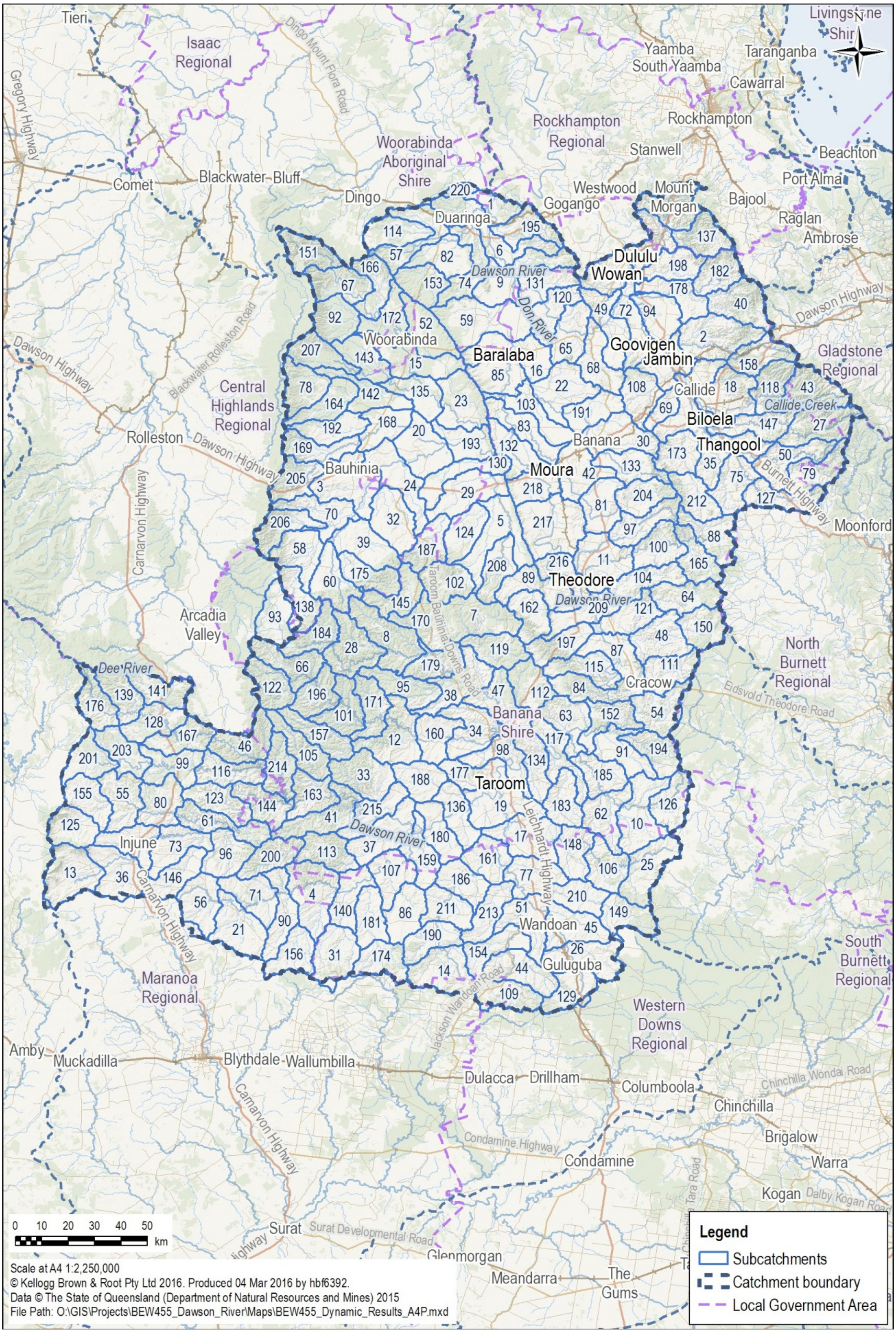

Figure A3
DAWSON SUBCATCHMENT DELINEATION

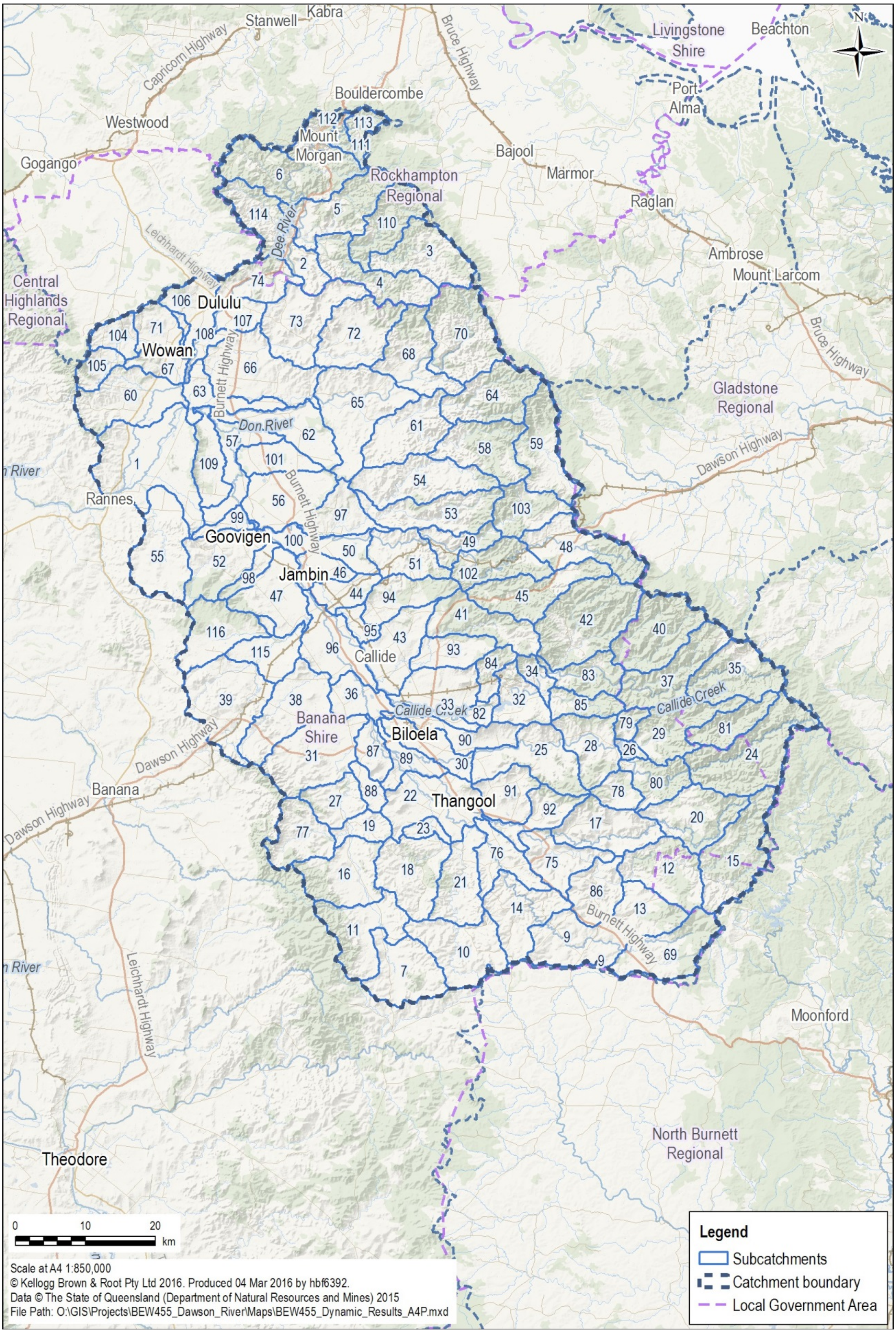

Figure A4
DON-DEE SUBCATCHMENT DELINEATION

4 Calibration

Rainfall

Historic rainfall was applied to the catchment by applying rainfall from pluviograph stations to each subcatchment, using storm multipliers to scale the rainfall depth up or down to match the calculated rainfall depth surface. This process was done for each of the models, for each historic storm assessed.

Historic temporal pattern

Temporal patterns were defined using pluviograph stations. All subcatchments were assigned a pluviograph station using Thiessen polygons. Thiessen polygons define the area that is closest to each pluviograph station.

Figure A5 and A6 present the pluviograph rainfall stations used, and their Thiessen polygon derived subcatchment assignment for the Dawson Model for the 2010 and 2013 event respectively. Figures A7 to A9 present the same for the Don-Dee Model for the 2010, 2013, and 2015 event respectively.

Historic rainfall depth

The calculated rainfall surface defines the rainfall depth in each subcatchment and corrects for spatial variation in rainfall.

The rainfall surface was calculated using pluviograph and daily rainfall stations, using the total depth in the Kriging technique to produce an estimate of the rainfall depth over the entire catchment with the data available.

For the 1978 flood event in the Don-Dee catchment, the AWAP rainfall surface was used.

Figures A10 and A11 present the rainfall surface for the Dawson Model for the 2010 and 2013 events respectively. Figures A12 to A15 present the rainfall surface for the Don-Dee Model for the 1978, 2010, 2013 and 2015 events respectively.

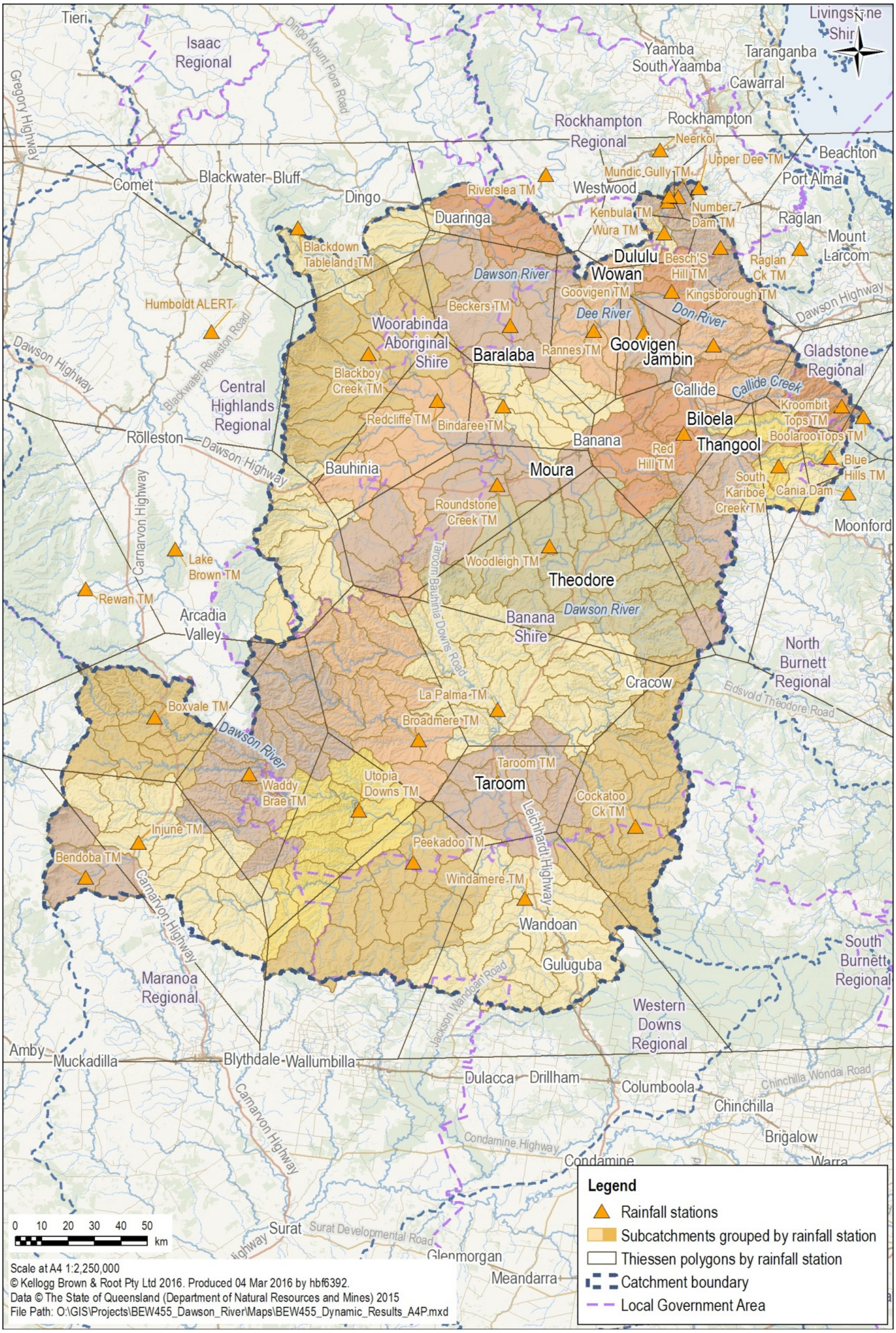

Figure A5
DAWSON PLUVIOGRPAHS AND THIESSEN POLYGONS - 2010 EVENT

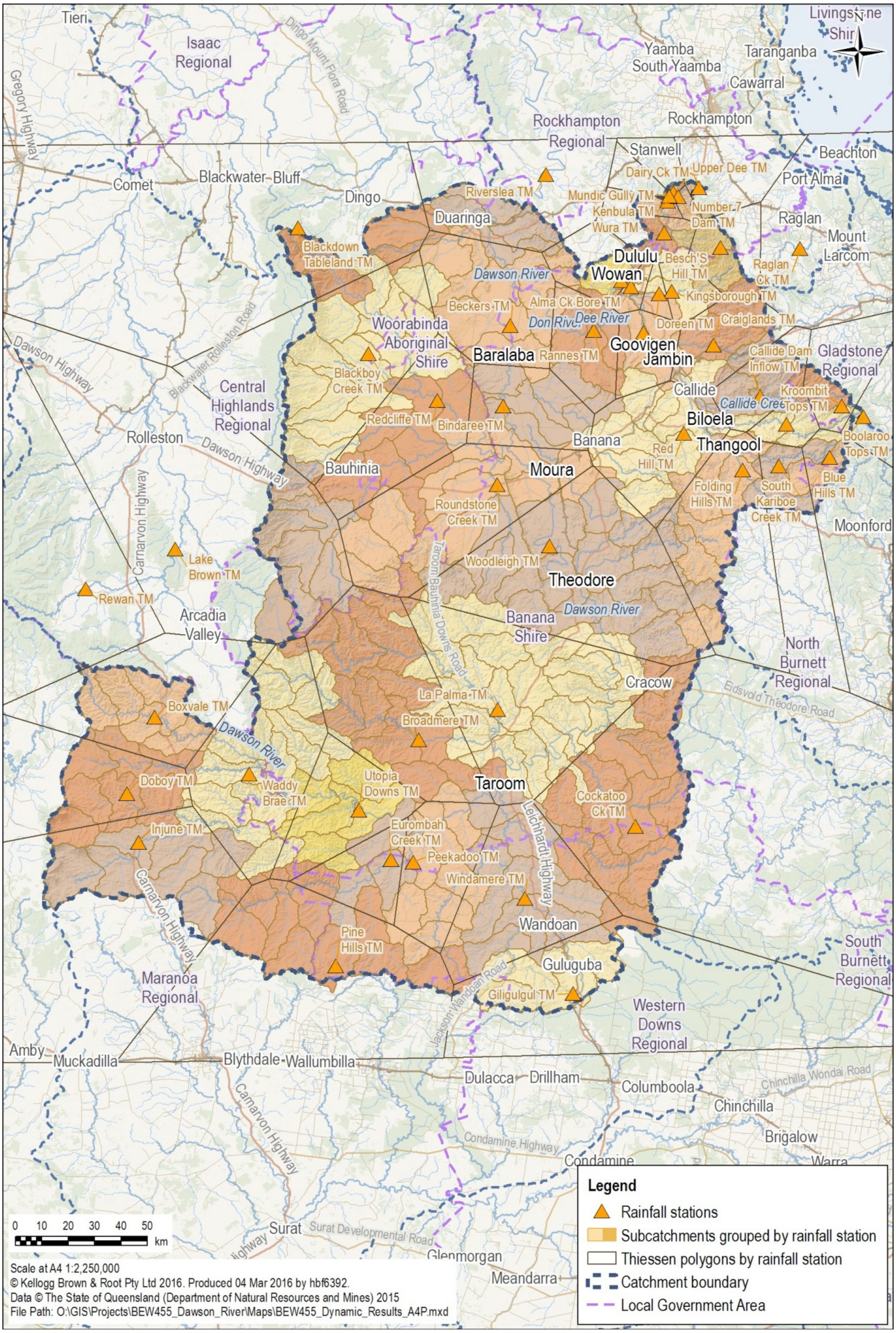

Figure A6

DAWSON PLUVIOGRPAHS AND THIESSEN POLYGONS - 2013 EVENT

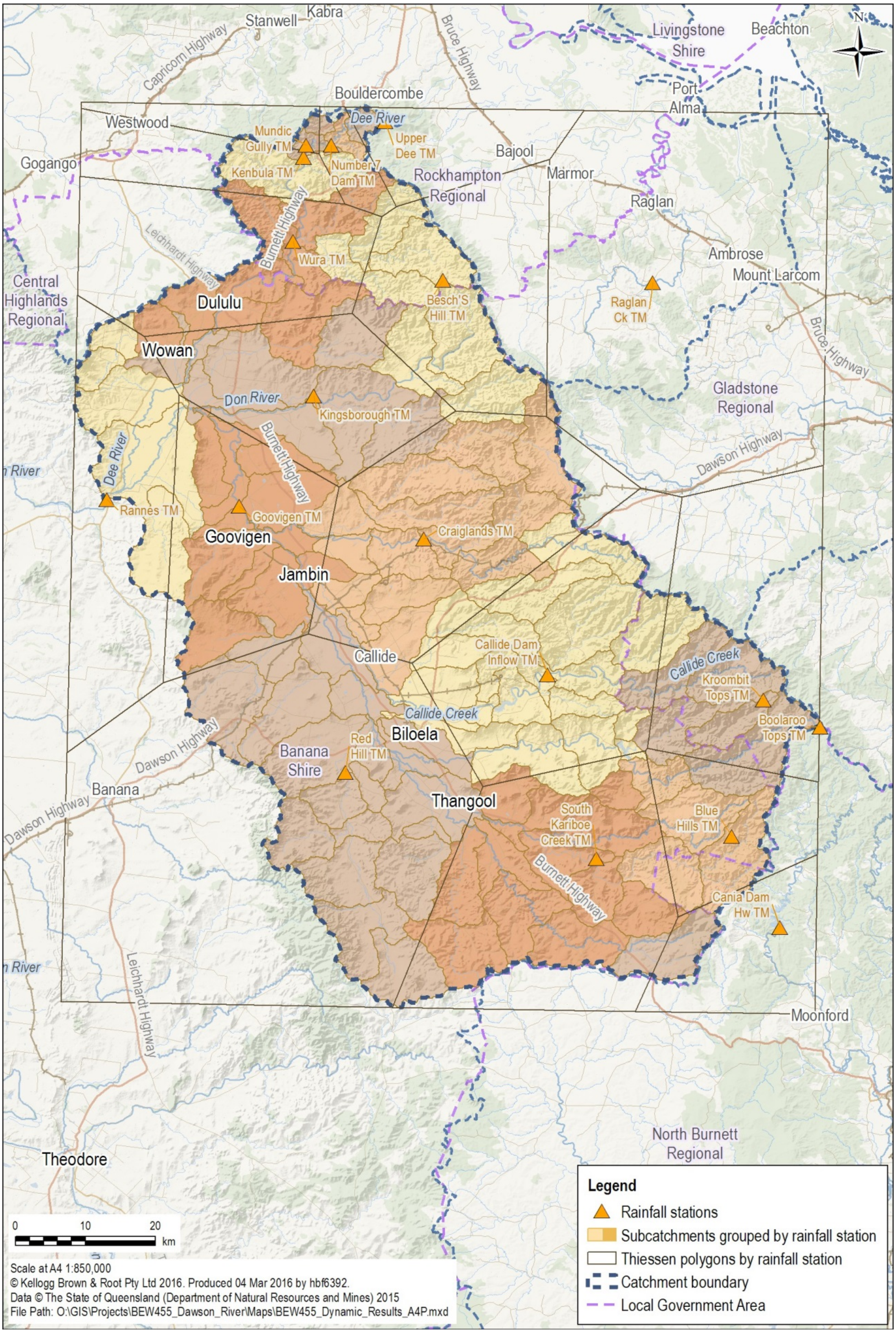

Figure A7

DON-DEE PLUVIOGRPAHS AND THIESSEN POLYGONS - 2010 EVENT

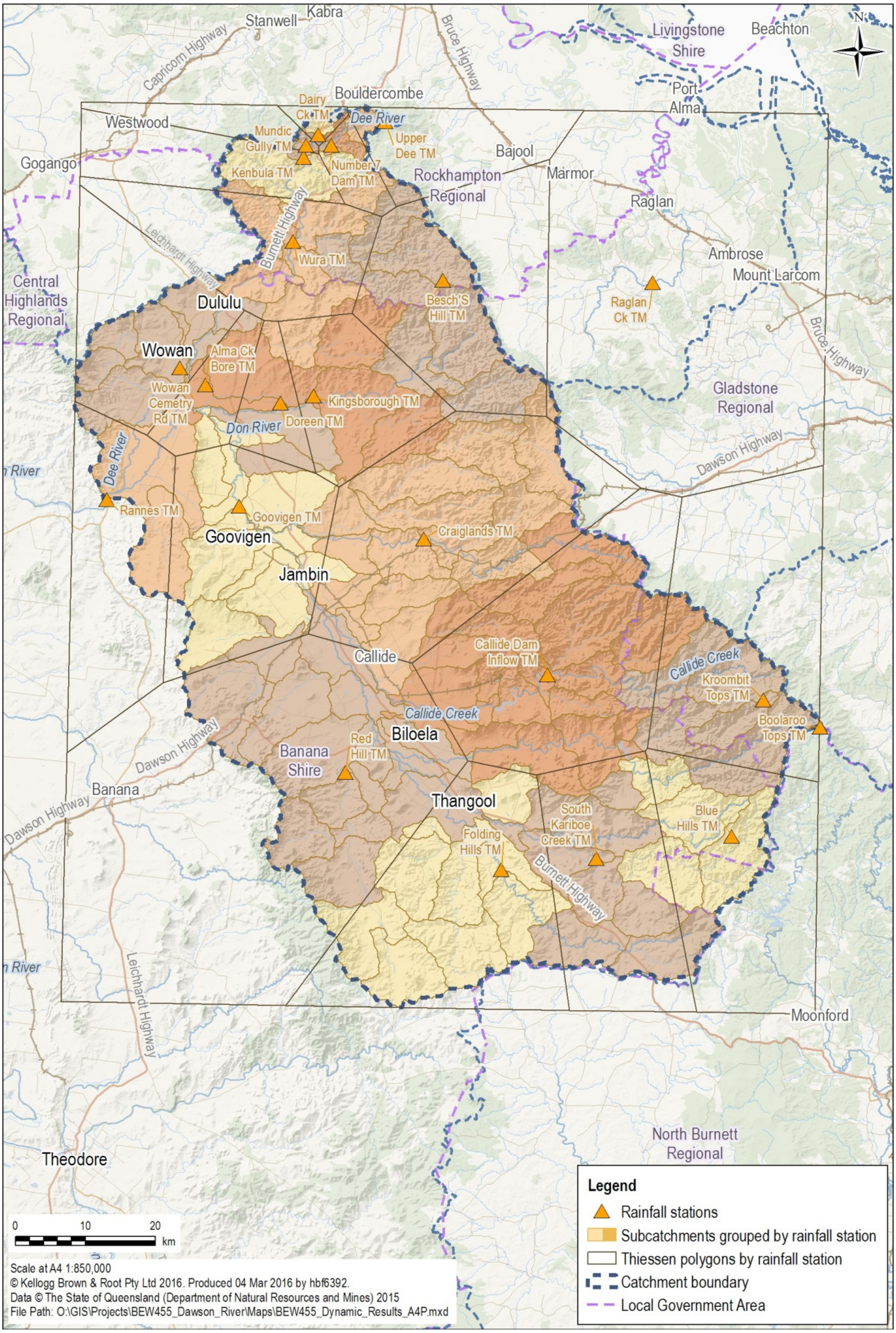

Figure A8
DON-DEE PLUVIOGRPAHS AND THIESSEN POLYGONS – 2013 EVENT

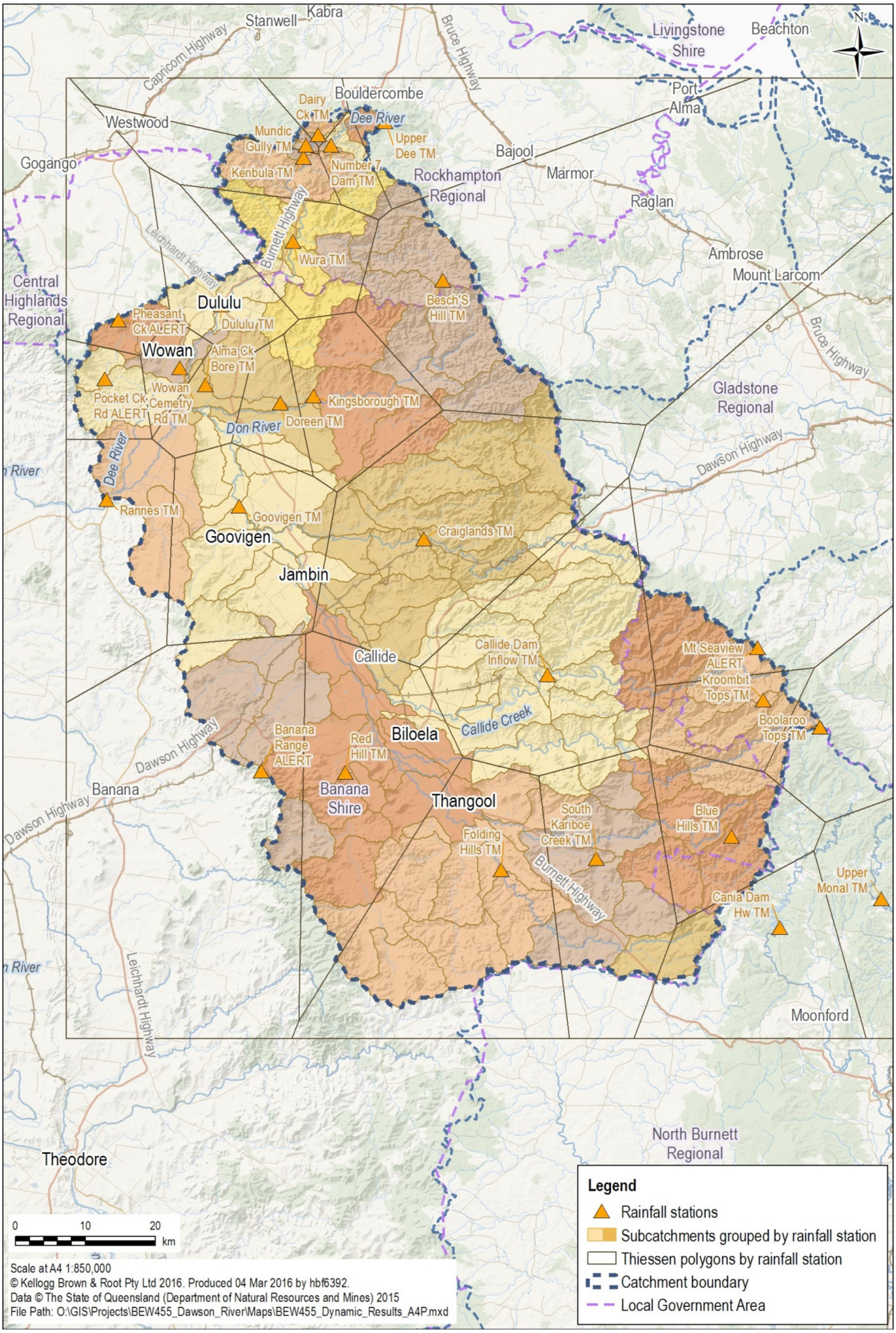

Figure A9
DON-DEE PLUVIOGRPAHS AND THIESSEN POLYGONS – 2015 EVENT

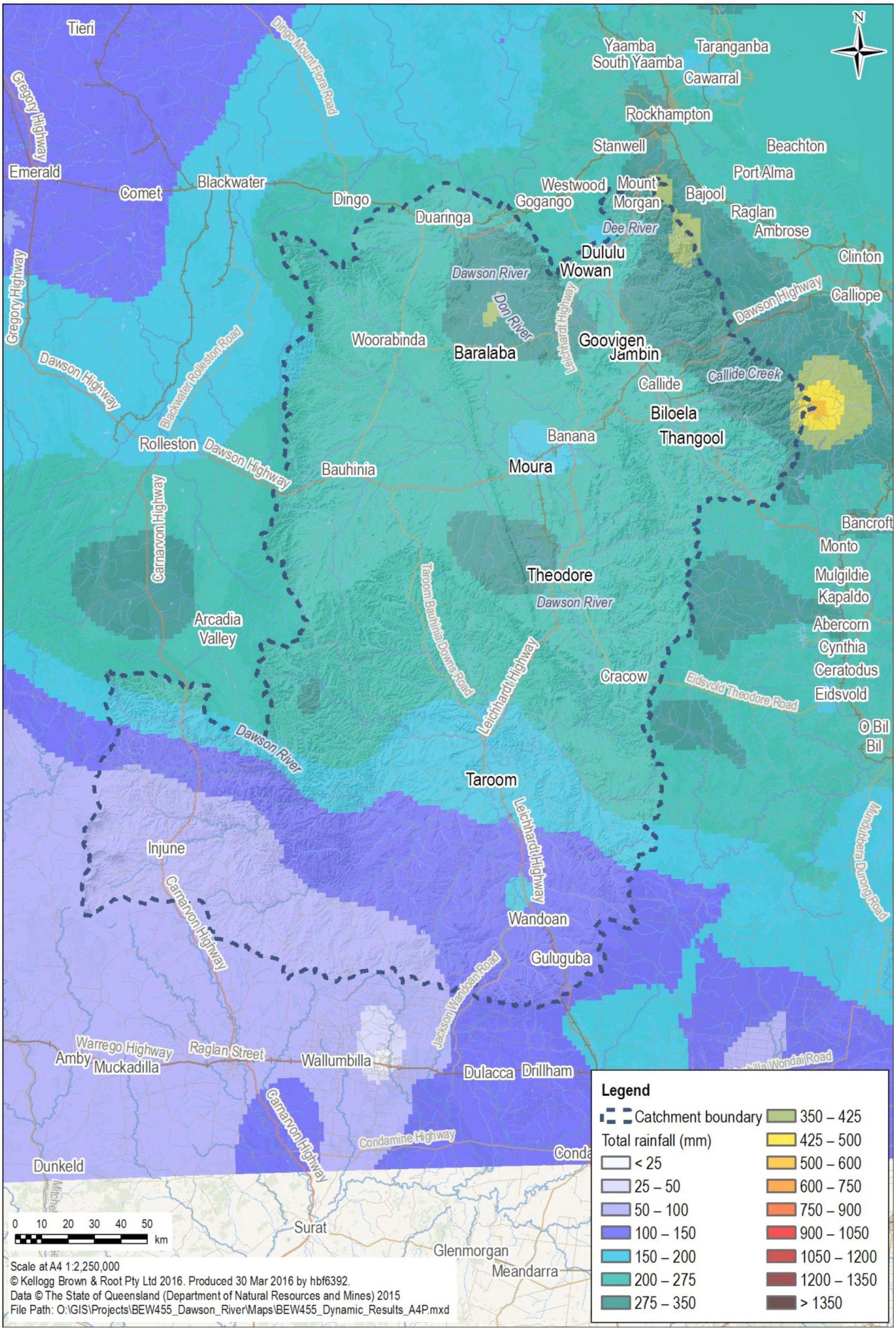

Figure A10
DAWSON RAINFALL SURFACE – 2010 EVENT

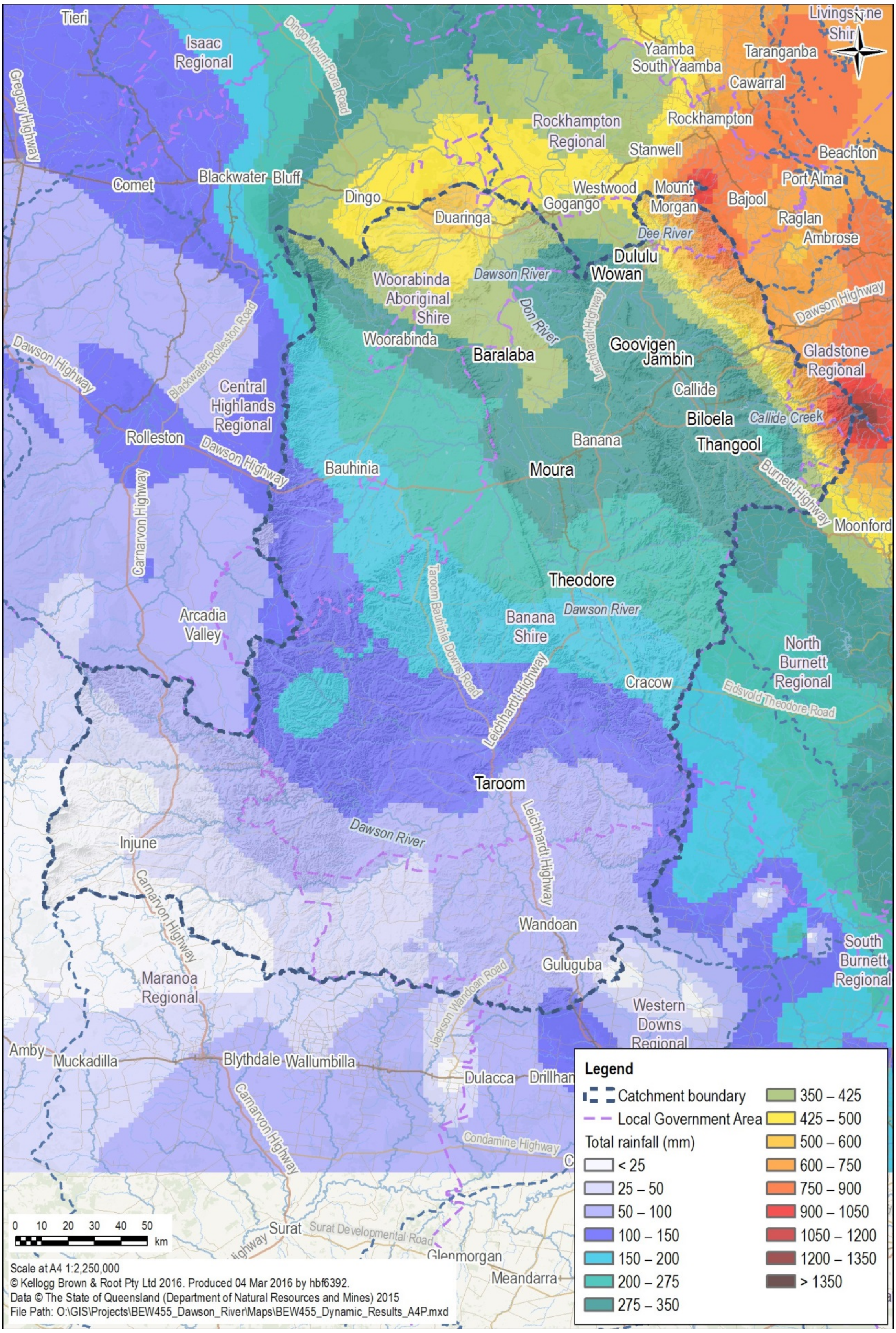

Figure A11
DAWSON RAINFALL SURFACE – 2013 EVENT

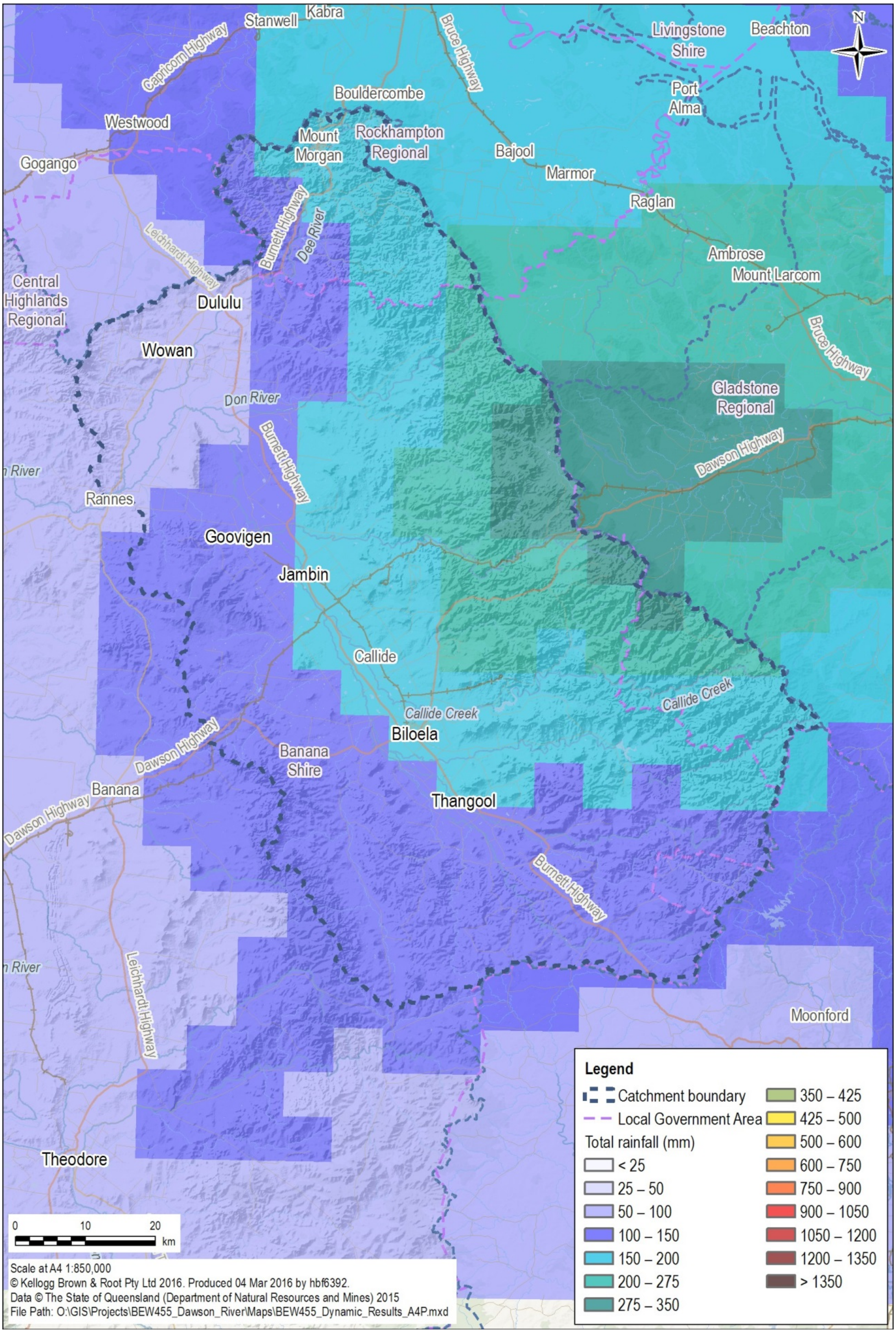

Figure A12
DON-DEE RAINFALL SURFACE – 1978 EVENT

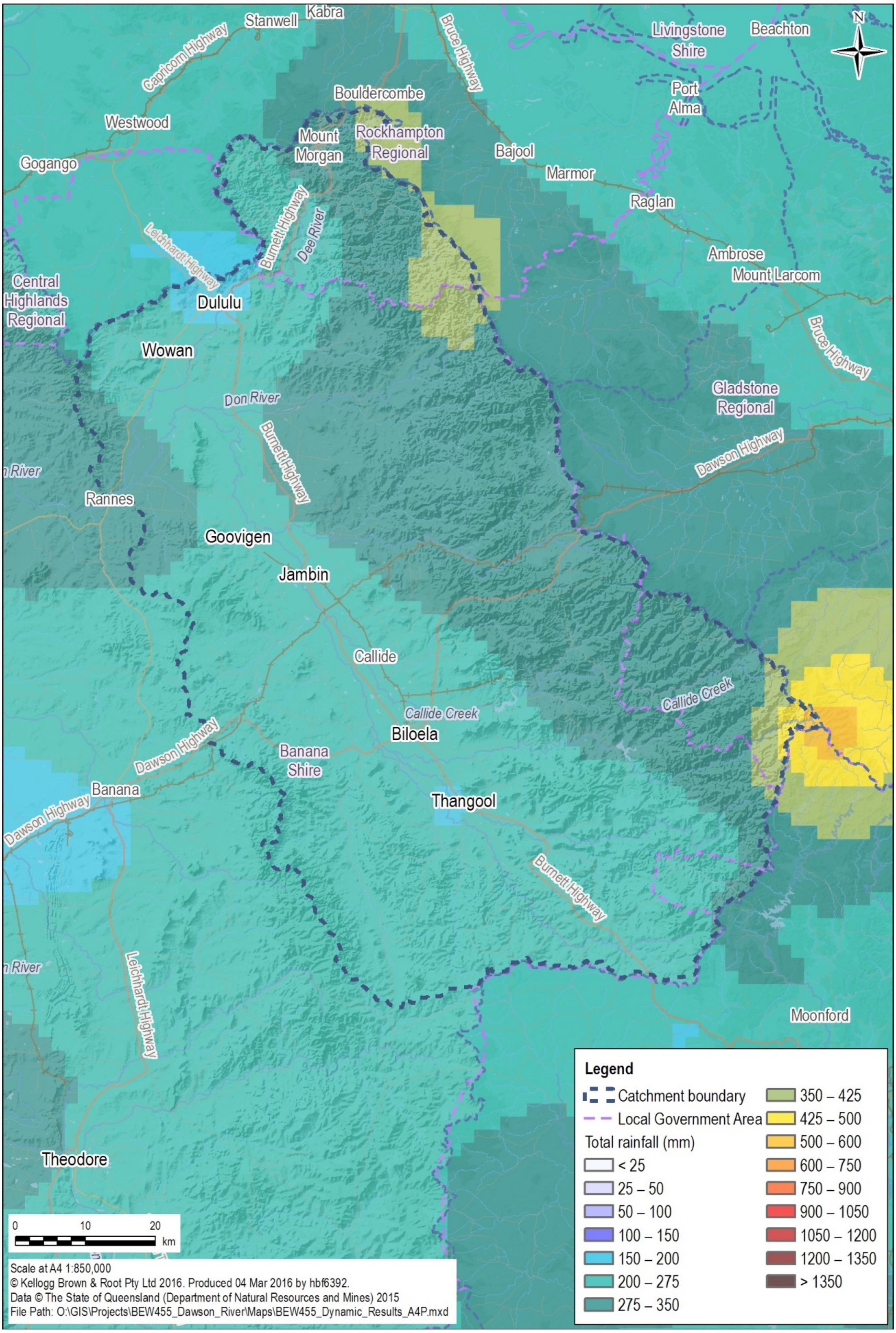

Figure A13
DON-DEE RAINFALL SURFACE – 2010 EVENT

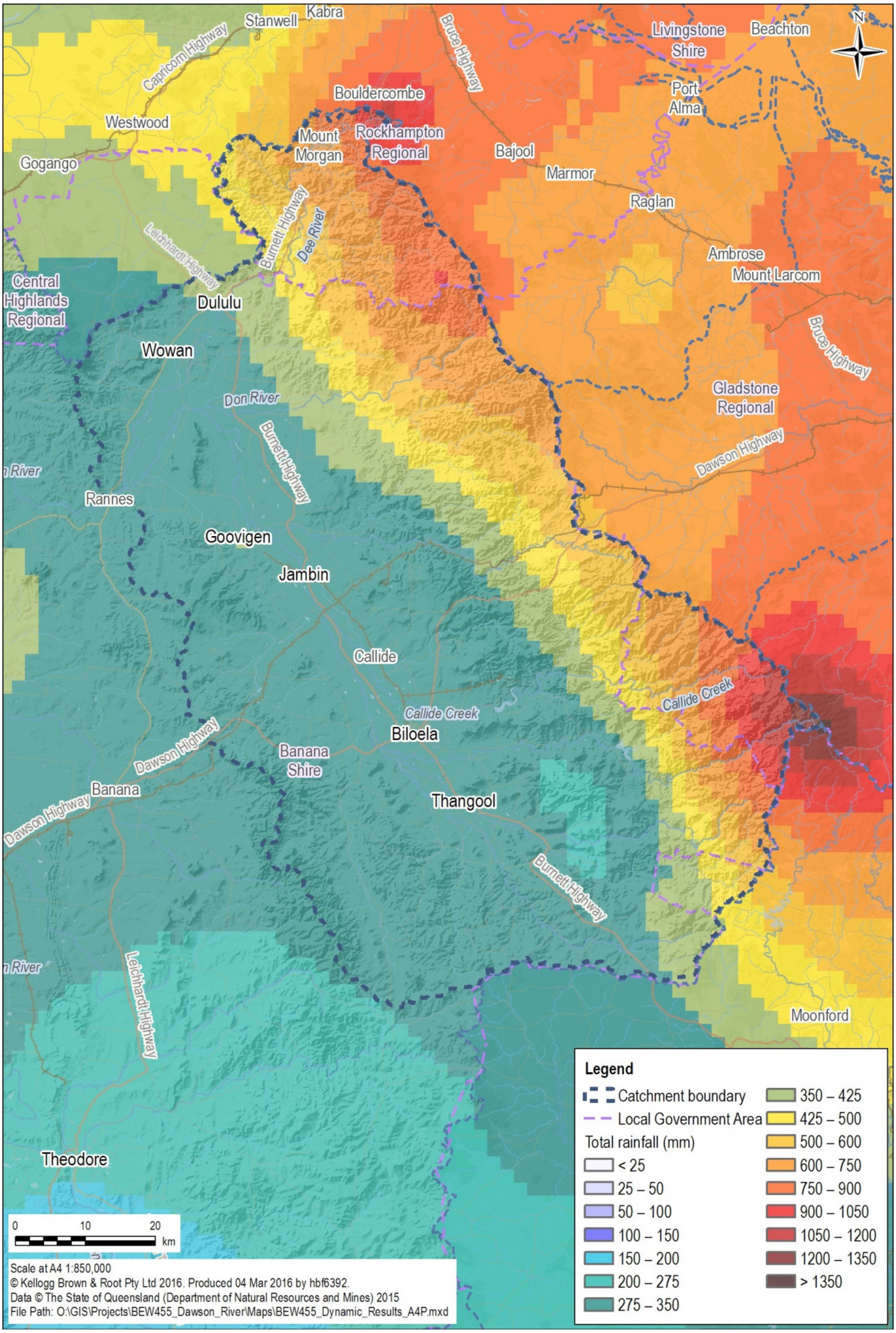

Figure A14
DON-DEE RAINFALL SURFACE – 2013 EVENT

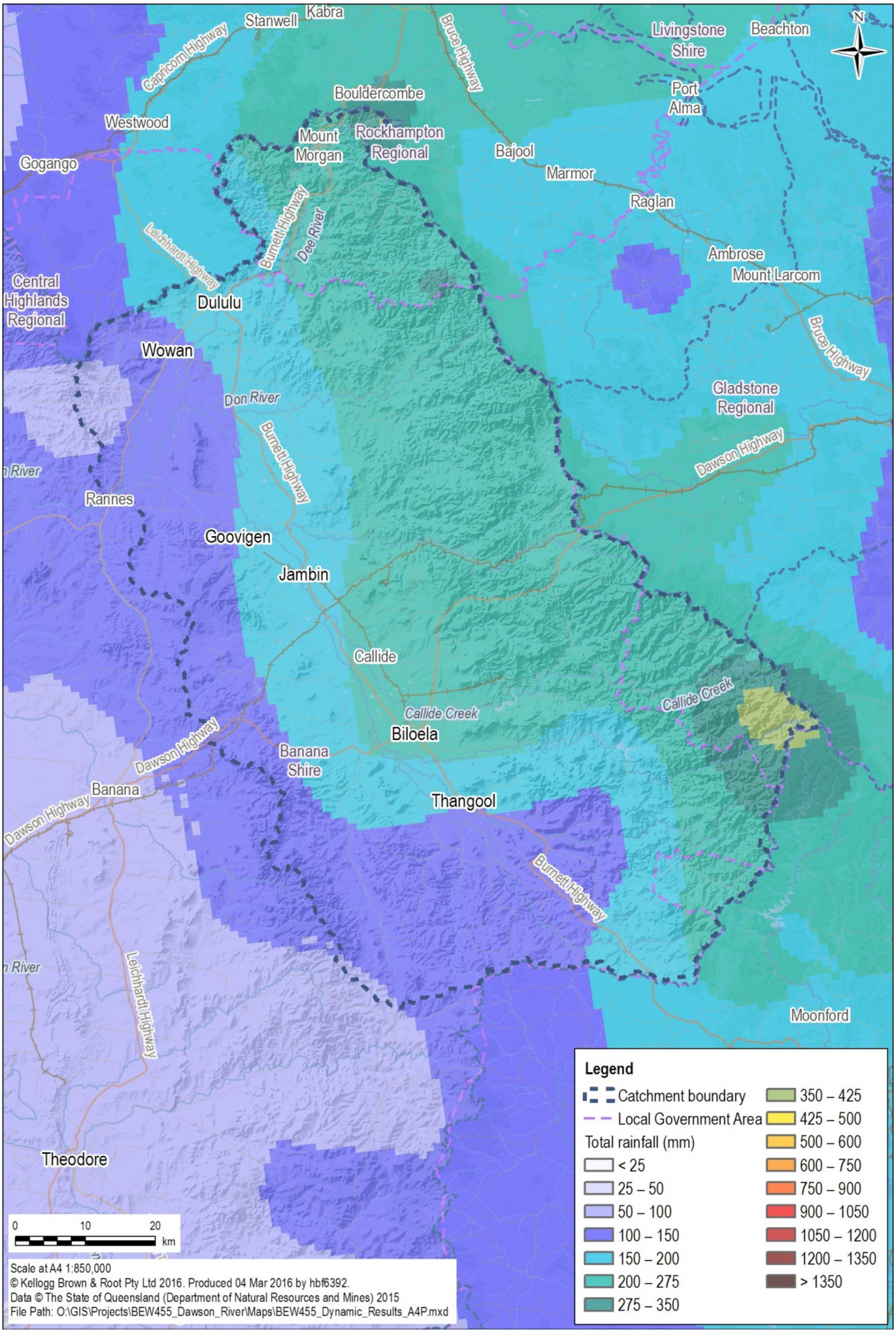

Figure A15
DON-DEE RAINFALL SURFACE – 2015 EVENT

Losses

Initial Loss (IL) and Continuing Loss (CL) were adjusted to achieve calibration and verification and were varied between historic events. The IL and CL were also varied spatially within the models in each historic event to create models that reproduced the varied flow characteristics of each event.

Where there was no calibration information, the IL and CL from neighbouring catchments were applied.

Tables A1 and A2 present the adopted IL and CL for the historic storm events in the Dawson and Don-Dee model respectively. The IL and CL for impervious areas were assumed to be 0 mm and 0 mm/hr respectively.

Table A1 Dawson Model calibrated pervious areas IL and CL values#

Catchment section	2010 event		2013 event	
	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)
Dawson River at Taroom	0	0*	70	2.5
Robinson Creek	0	5.0	70	2.5
Palm Tree Creek	0	5.0	130	1.0
Dawson River at Moura	0	7.5	135	4.0
Mimosa Creek	0	2.0	125	5.0
Roundstone Creek	0	2.0	100	1.0
Dawson River at Baralaba	0	7.5	120	4.5
Don River at Dululu	50	3.0	50	3.0

* Joint calibration with Taroom hydraulic model required high flow resulting in nonstandard continuing loss

\# *Impervious areas were assigned an IL of 0 mm and a CL of 0 mm/hr*

Table A2 Don-Dee Model calibrated pervious areas IL and CL values#

Catchment section	1978 event		2010 event		2013 event		2015 event	
	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)	IL (mm)	CL (mm/hr)
South Kariboe Creek	90	4.3	75	5.0	150	3.0	50	4.0
Kroombit Creek	90	4.3	75	5.0	308	3.0	100	4.0
Callide Creek	90	4.3	20	3.5	*	*	60	0.25
Grevillea Creek	90	4.3	75	5.0	140	3.0	75	4.0
Prospect Creek	90	4.3	0	5.0	150	3.0	85	4.0
Bell Creek	90	4.3	245	3.5	205	3.0	85	1.3
Don River	90	4.3	125	3.5	175	3.0	75	1.3
Dee River	90	4.3	130	3.5	200	3.0	100	1.3

* *Callide Dam not modelled in 2013 event as manual dam operation rules cannot be input into XP-RAFTS*

\# *Impervious areas were assigned an IL of 0 mm and a CL of 0 mm/hr*

Catchment storage coefficient multiplication factor

The catchment storage coefficient multiplication factor (B) within XP-RAFTS allows the user to globally adjust the catchment storage in the model to change the calculated hydrograph shape.

This can be used between calibration and verification events to achieve better matches between modelled and historic flow. This is considered acceptable as catchment properties can vary between events due to antecedent conditions.

Table A3 presents the adopted B parameter for the Dawson and Don-Dee Models for the historic events.

Table A3 XP-RAFTS global B parameter adopted for historic events

Model	Event			
	1978	2010	2013	2015
Dawson	*	1.0	0.8	*
Don-Dee	1.0	0.75	1.0	1.0

* *Event not assessed for Dawson Model*

Results

The results of the 2010 calibration in the Dawson Model are presented in Figures A16 to A26. The results of the 2013 verification in the Dawson River are presented in Figures A27 to A37.

The results of the 2015 calibration in the Don-Dee Model are presented in Figures A38 to A45 and the 2013 calibration in Figures A46 to A53. The results of the 2010 verification in the Don-Dee Model are presented in Figures A54 to A60, and the 1978 verification in Figure A61.

Appendix A-6 presents the total peak flow at each subcatchment.

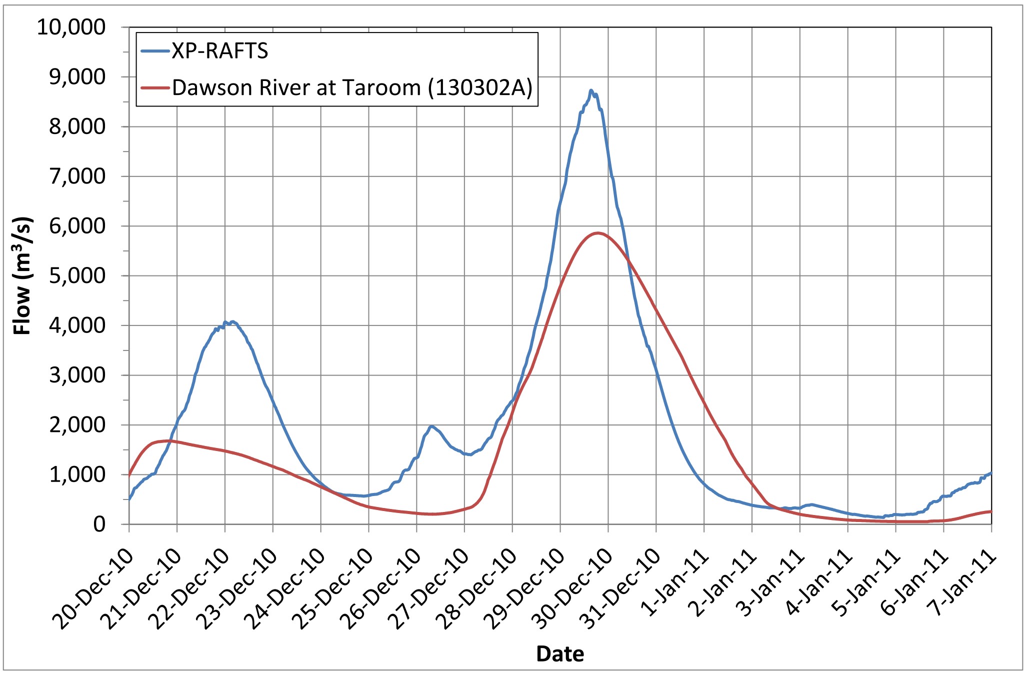

Figure A16
DAWSON RIVER AT TAROOM (130302A) – 2010 EVENT

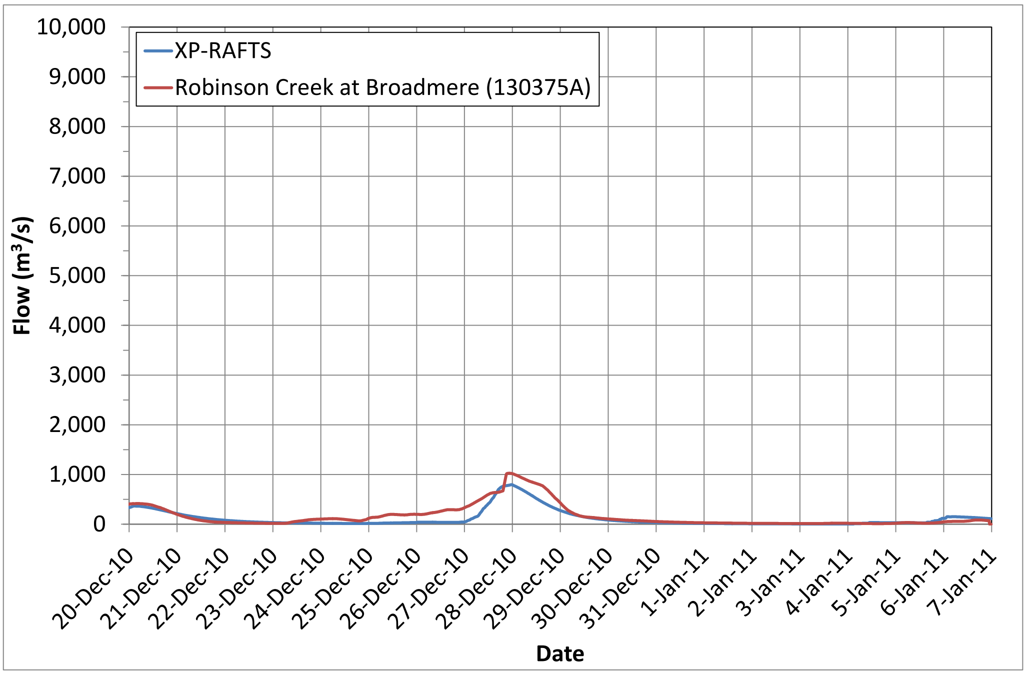

Figure A17
ROBINSON CREEK AT BROADMERE (130375A) – 2010 EVENT

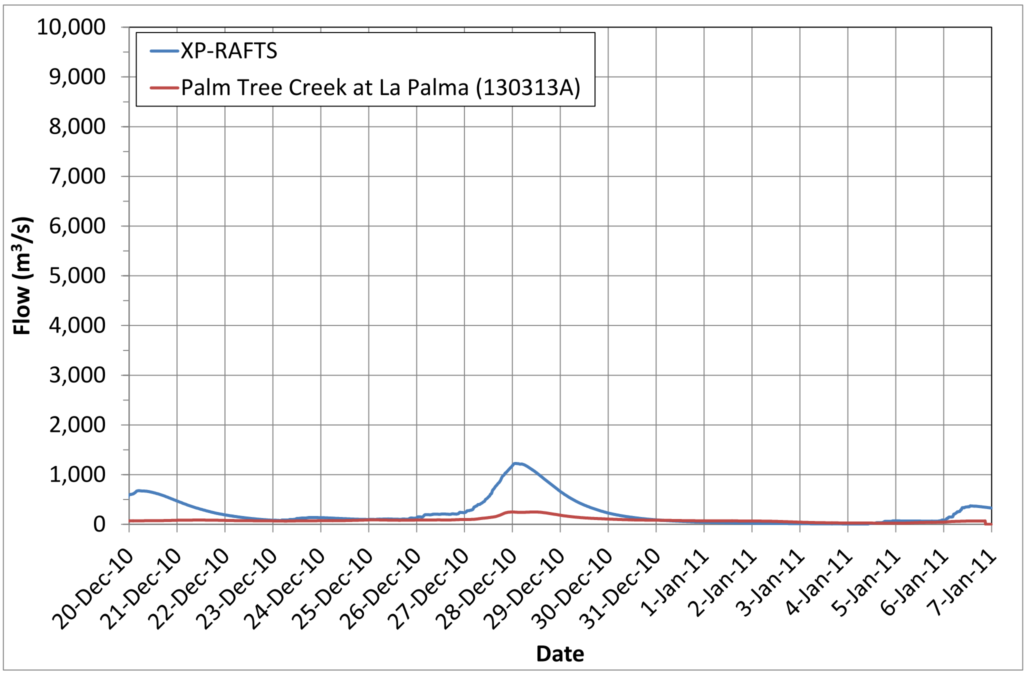

Figure A18
PALM TREE CREEK AT LA PALMA (1303013A) – 2010 EVENT

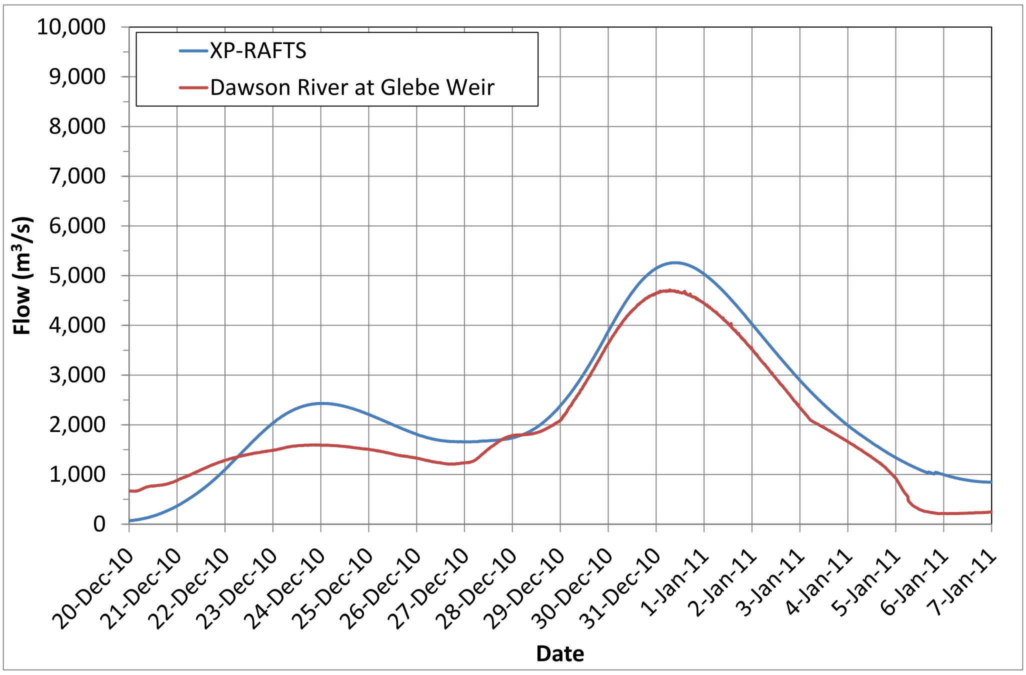

Figure A19
DAWSON RIVER AT THE GLEBE WEIR – 2010 EVENT

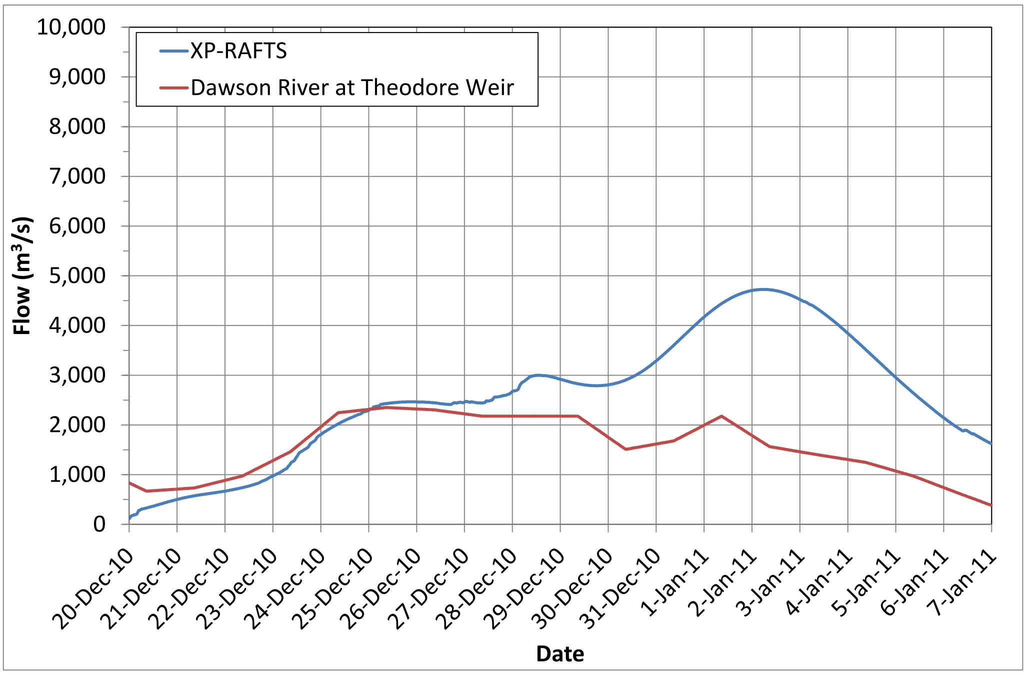

Figure A20
DAWSON RIVER AT THEODORE WEIR – 2010 EVENT

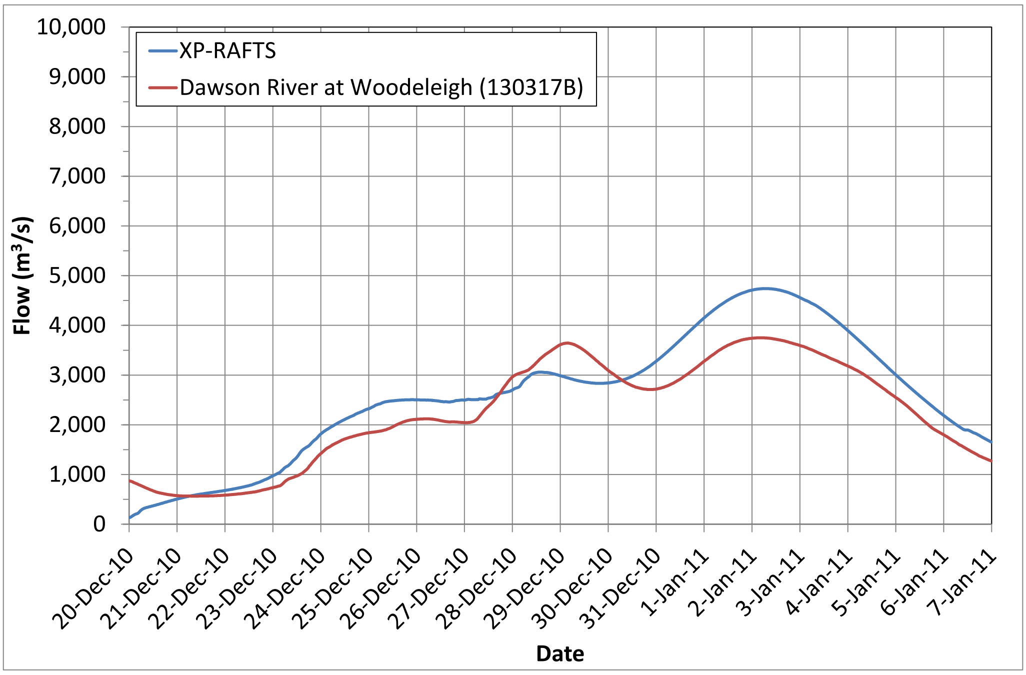

Figure A21
DAWSON RIVER AT WOODLEIGH (130317B) – 2010 EVENT

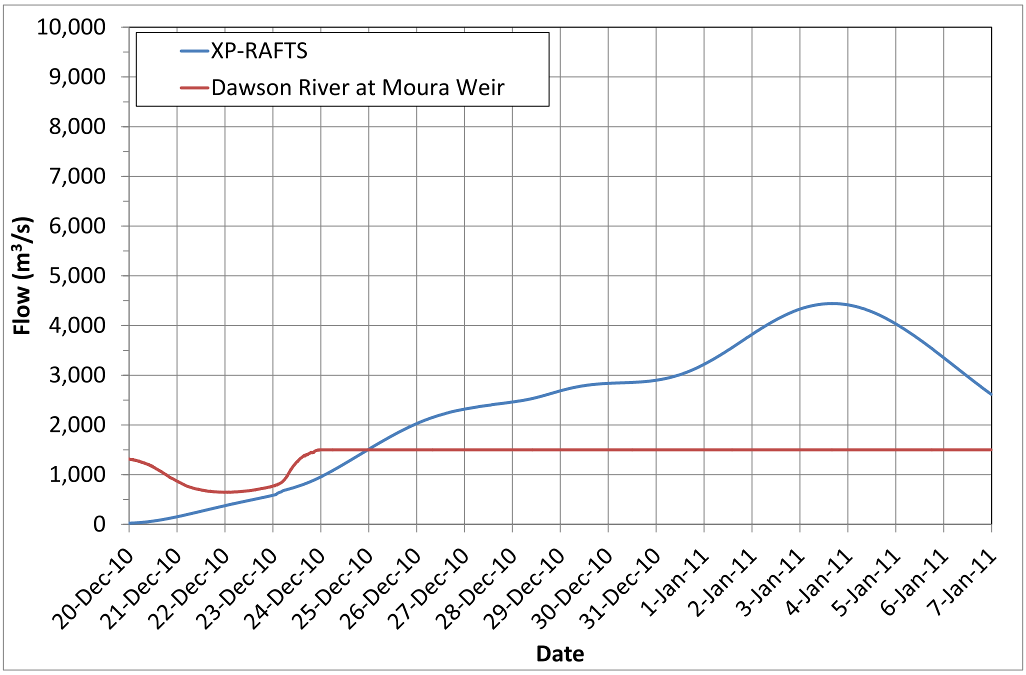

Figure A22
DAWSON RIVER AT MOURA WEIR – 2010 EVENT

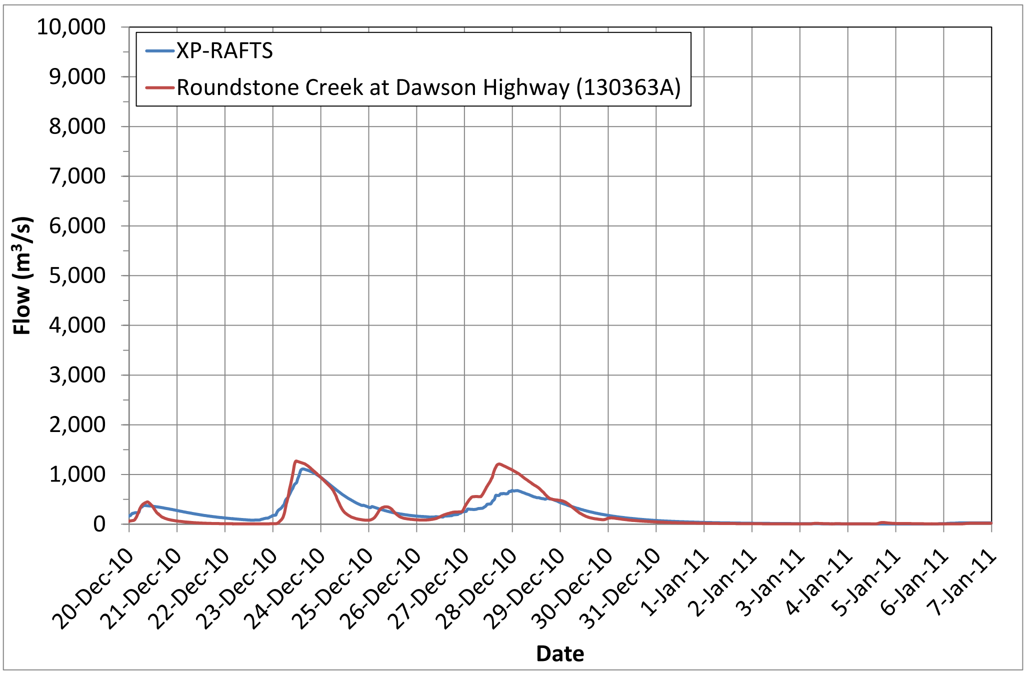

Figure A23
ROUNDSTONE CREEK AT DAWSON HIGHWAY (130363A) – 2010 EVENT

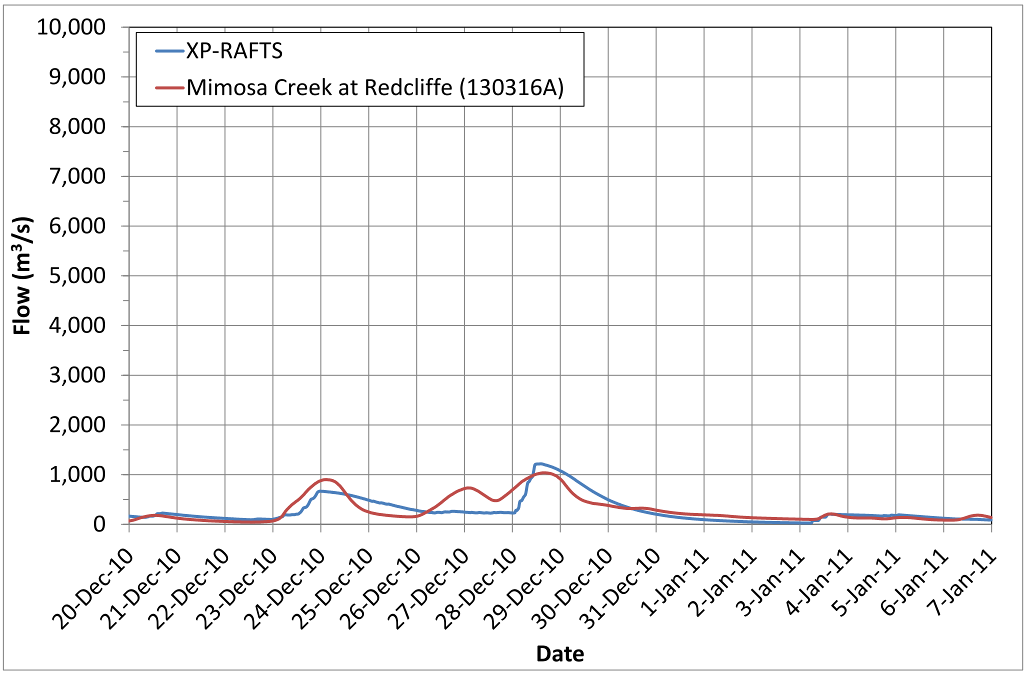

Figure A24
MIMOSA CREEK AT REDCLIFFE (130316A) – 2010 EVENT

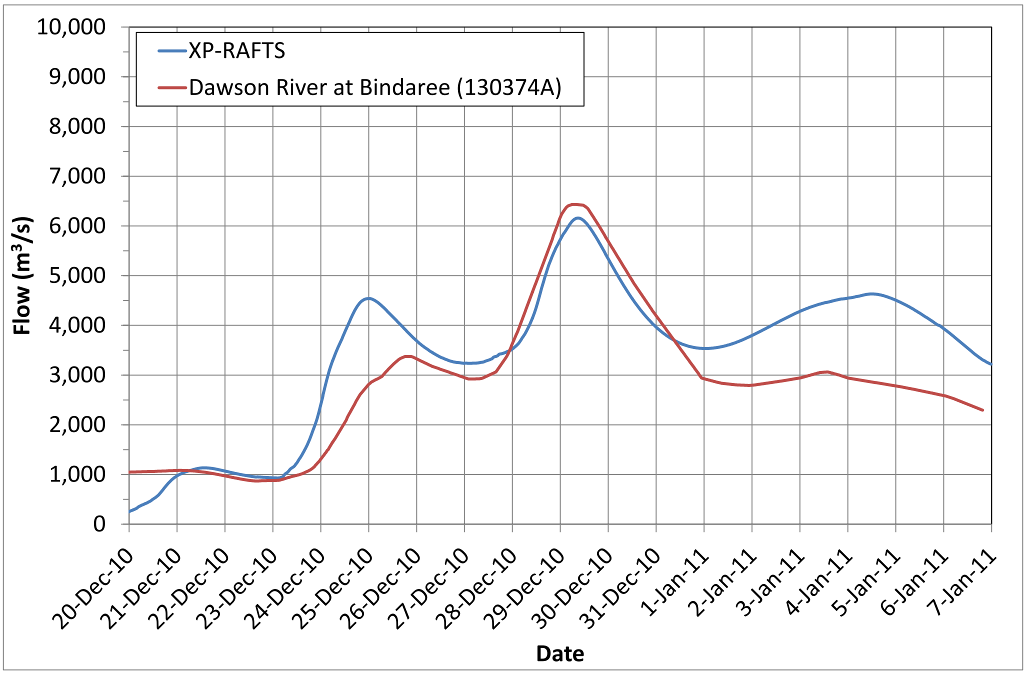

Figure A25
DAWSON RIVER AT BINDAREE (130374A) – 2010 EVENT

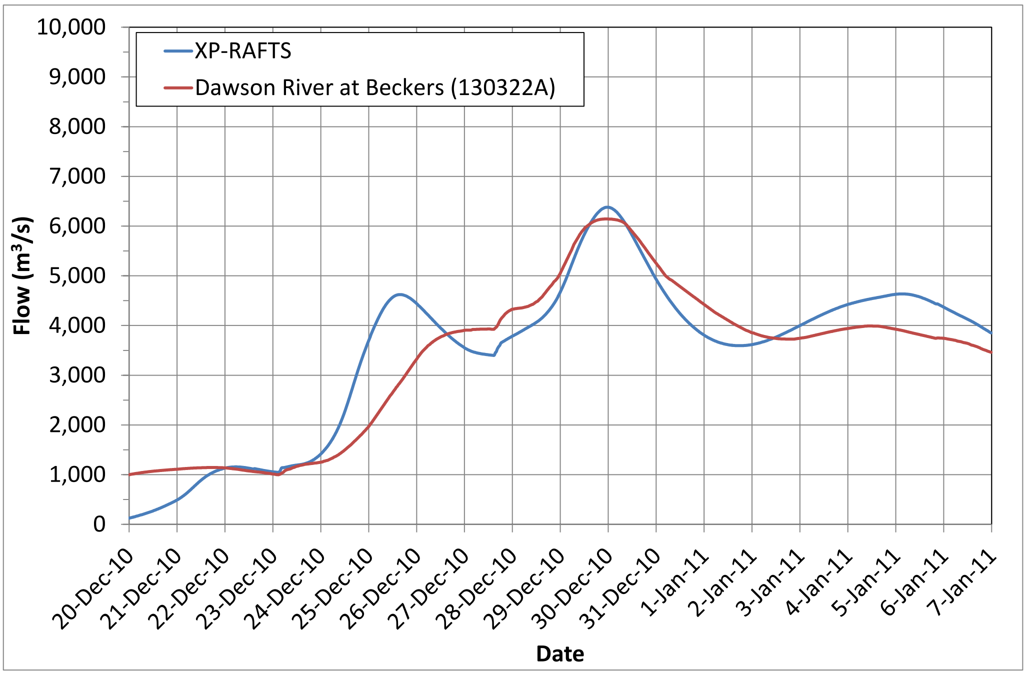

Figure A26
DAWSON RIVER AT BECKERS (130322A) – 2010 EVENT

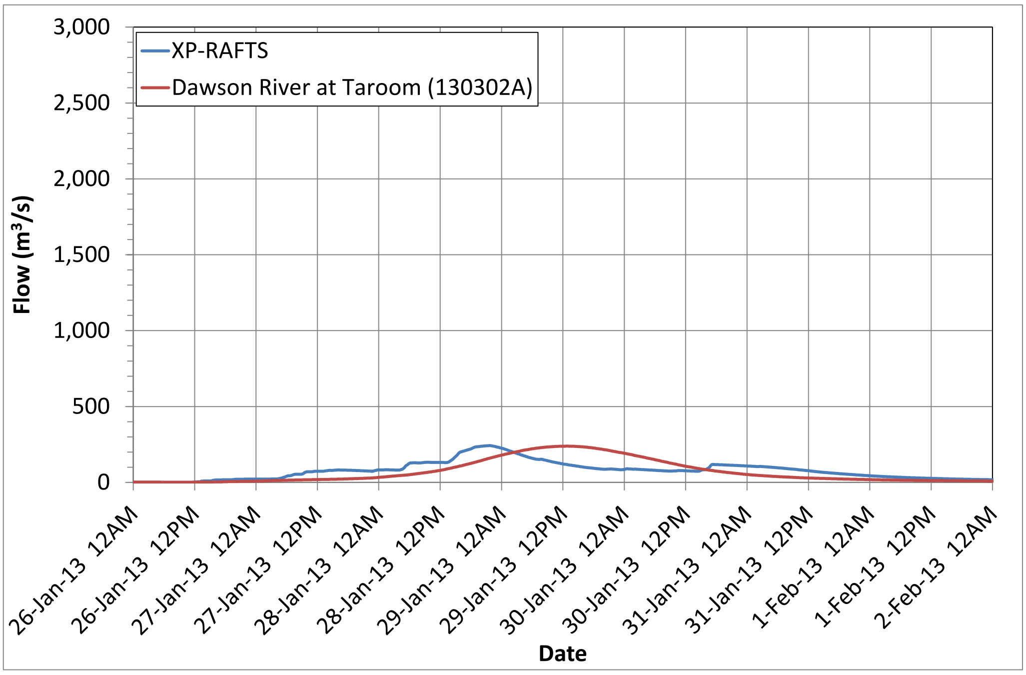

Figure A27
DAWSON RIVER AT TAROOM (130302A) – 2013 EVENT

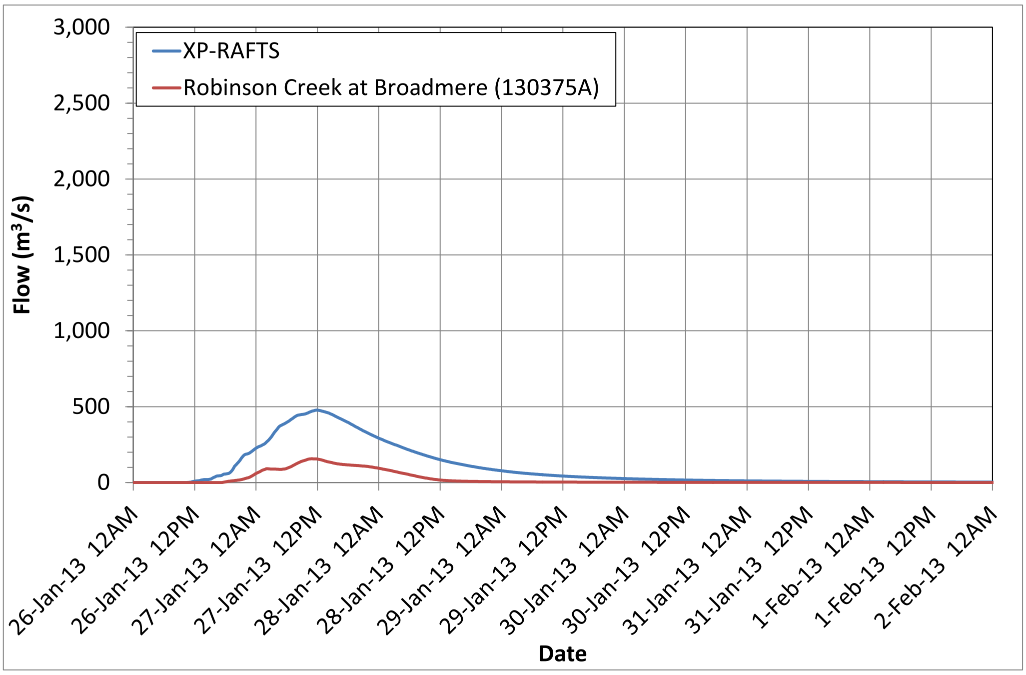

Figure A28
ROBINSON CREEK AT BROADMERE (130375A) – 2013 EVENT

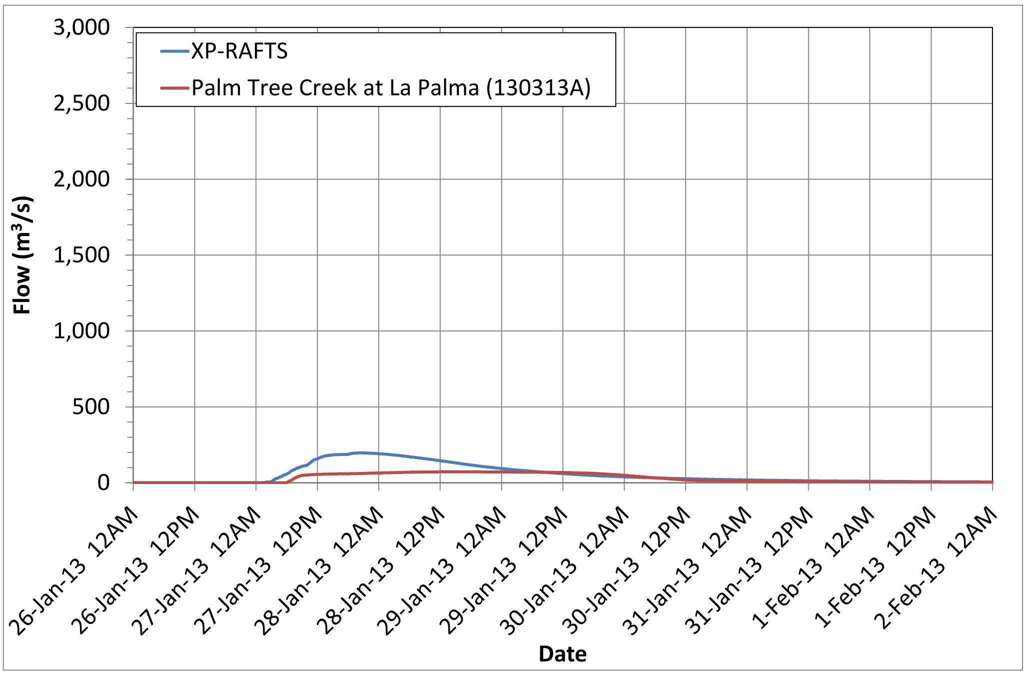

Figure A29
PALM TREE CREEK AT LA PALMA (1303013A) – 2013 EVENT

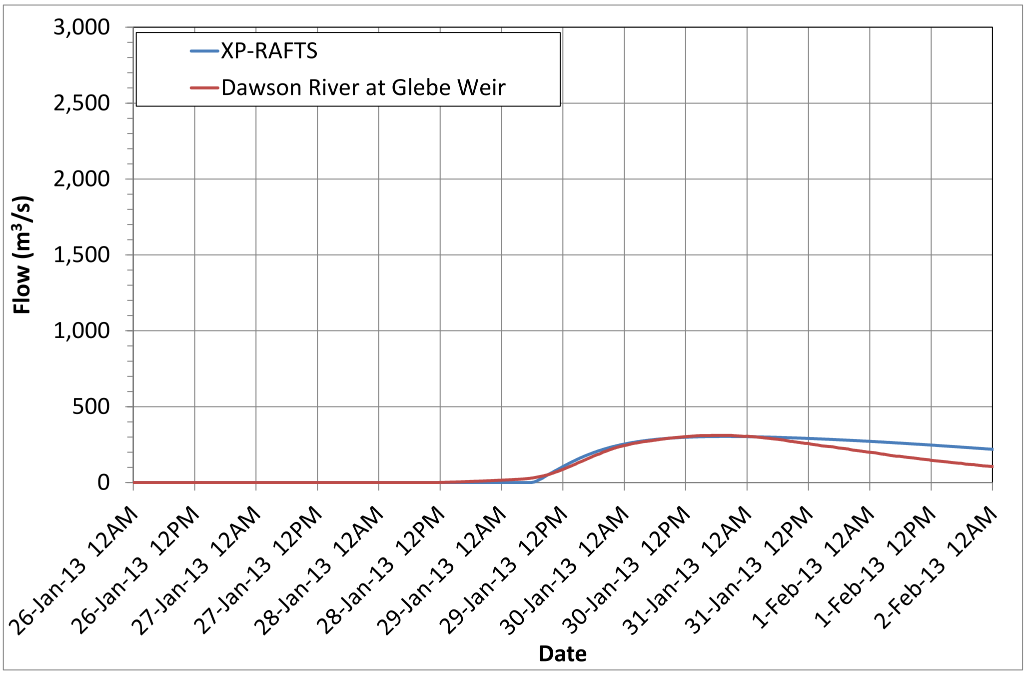

Figure A30
DAWSON RIVER AT THE GLEBE WEIR – 2013 EVENT

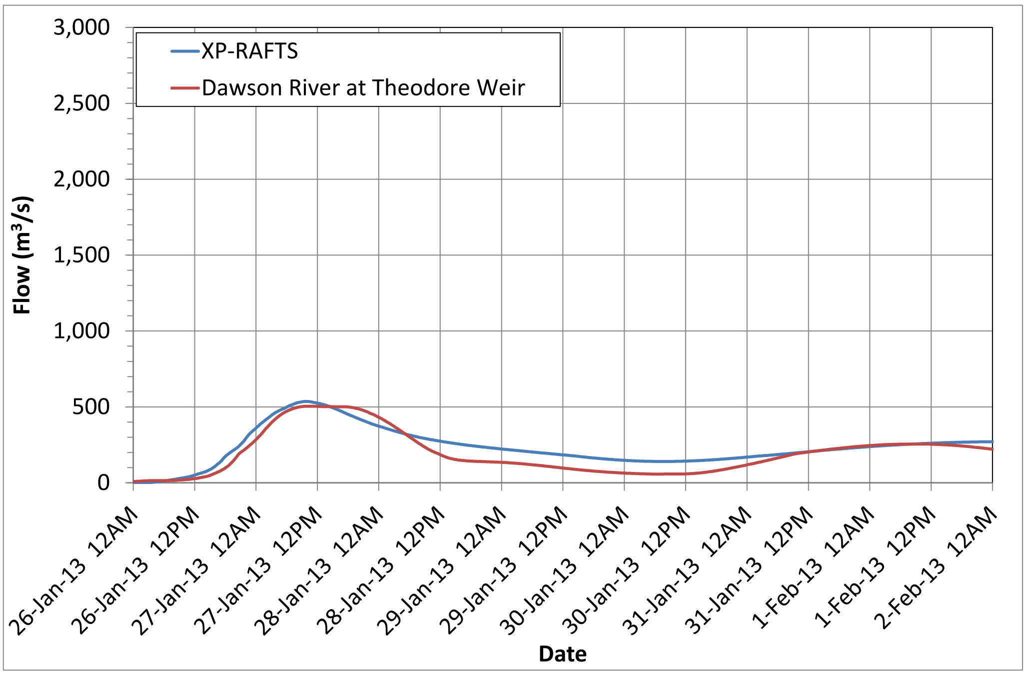

Figure A31
DAWSON RIVER AT THEODORE WEIR – 2013 EVENT

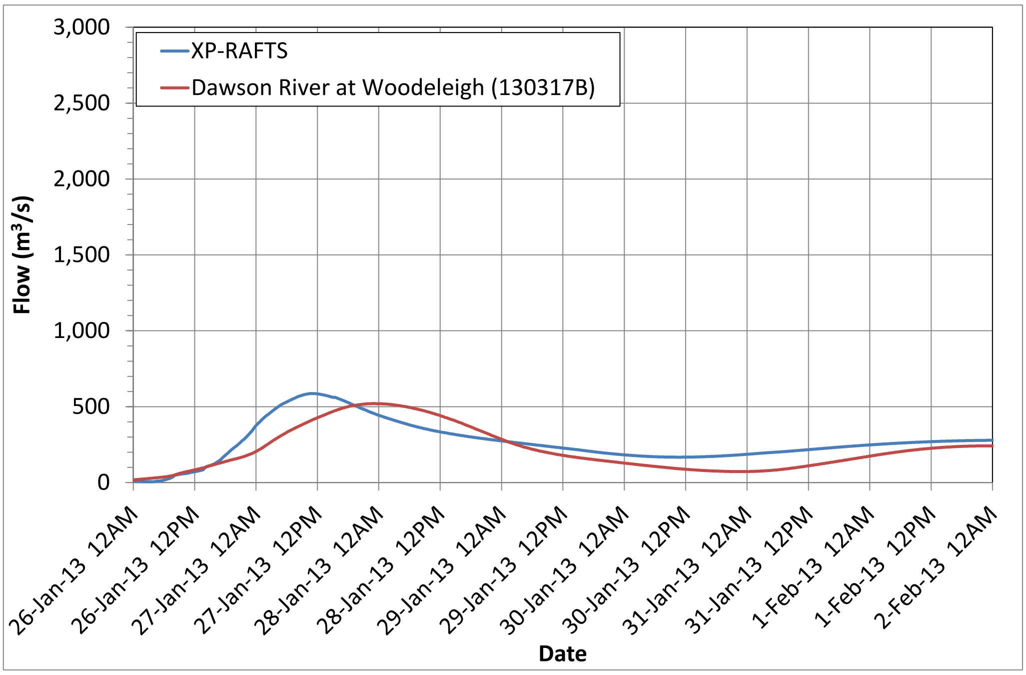

Figure A32
DAWSON RIVER AT WOODLEIGH (130317B) – 2013 EVENT

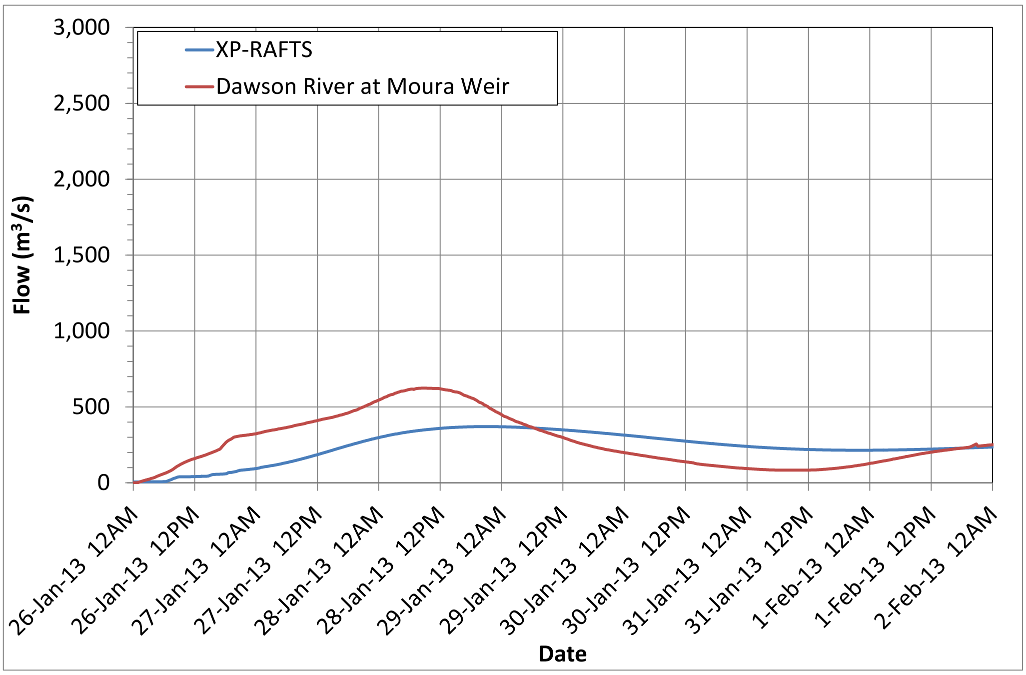

Figure A33
DAWSON RIVER AT MOURA WEIR – 2013 EVENT

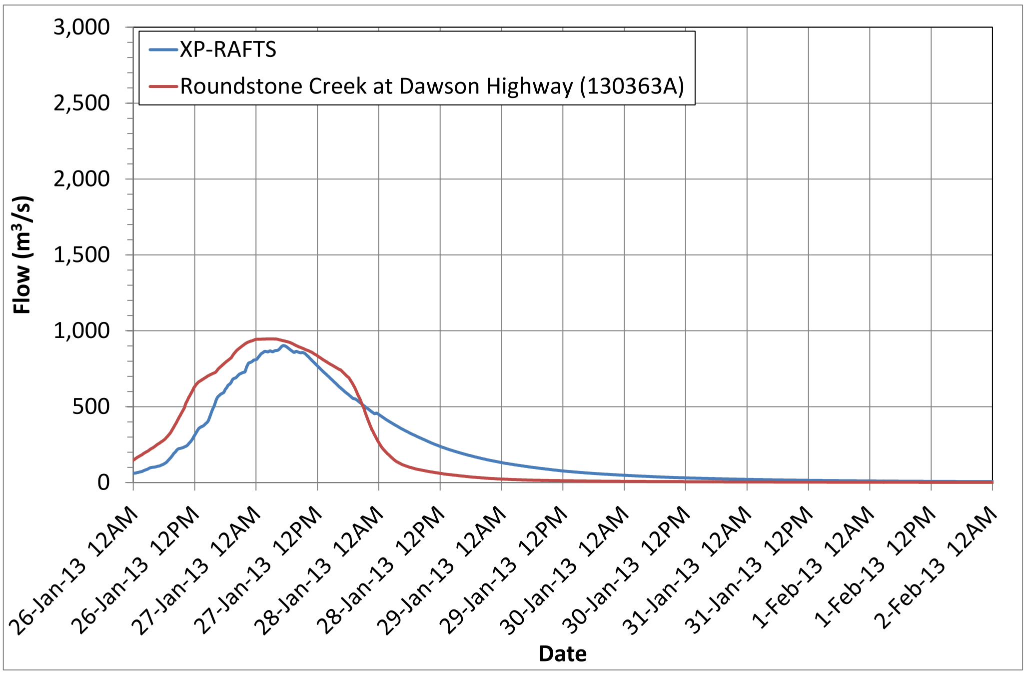

Figure A34
ROUNDSTONE CREEK AT DAWSON HIGHWAY (130363A) – 2013 EVENT

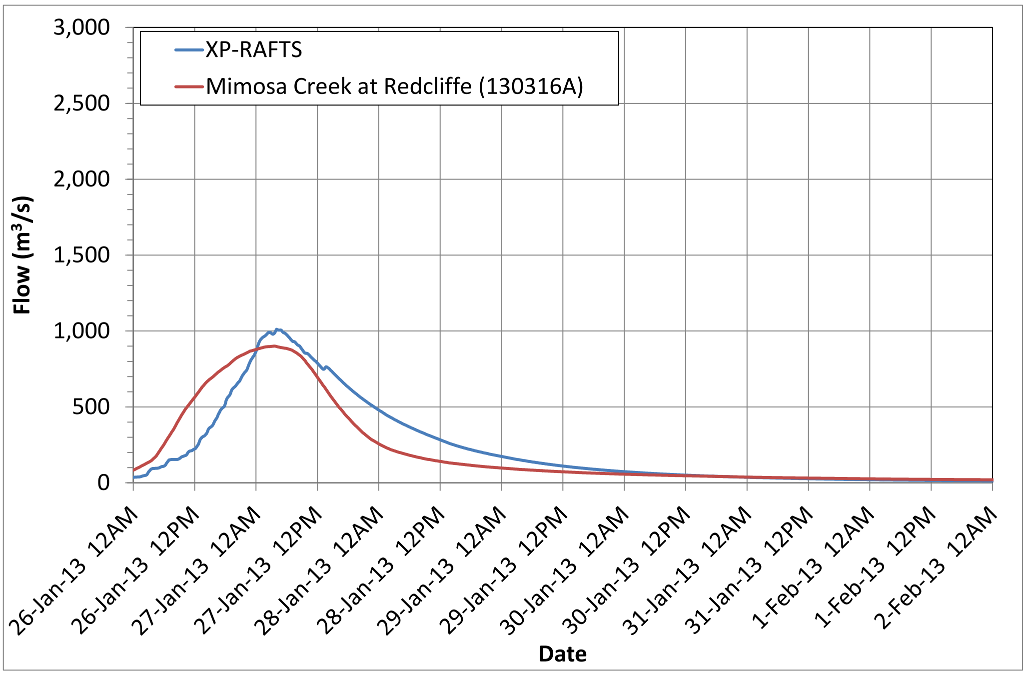

Figure A35
MIMOSA CREEK AT REDCLIFFE (130316A) – 2013 EVENT

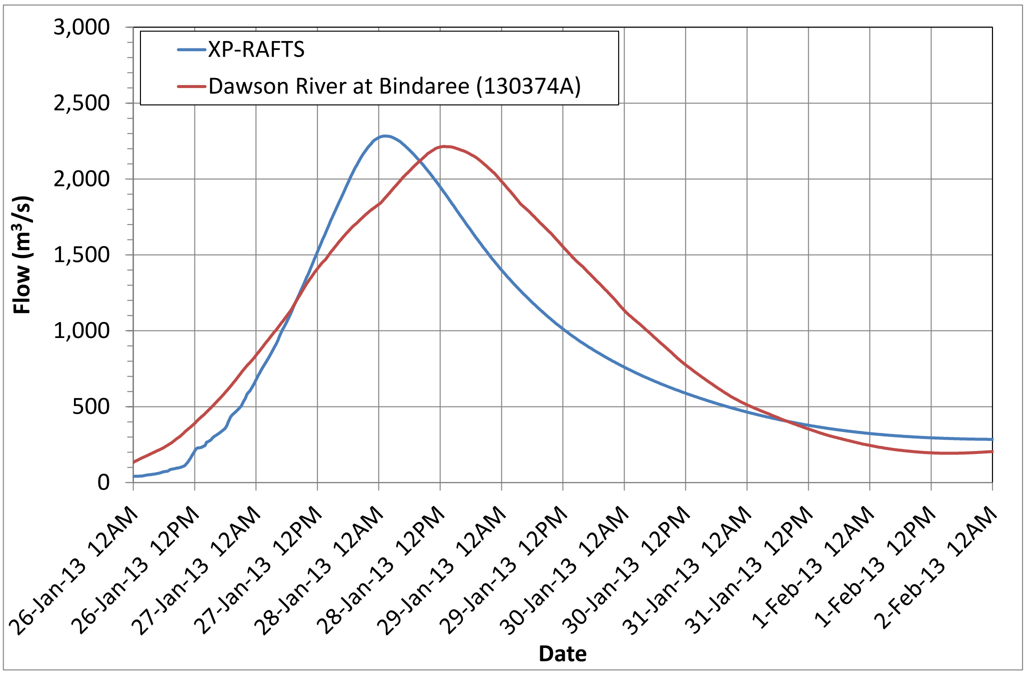

Figure A36
DAWSON RIVER AT BINDAREE (130374A) – 2013 EVENT

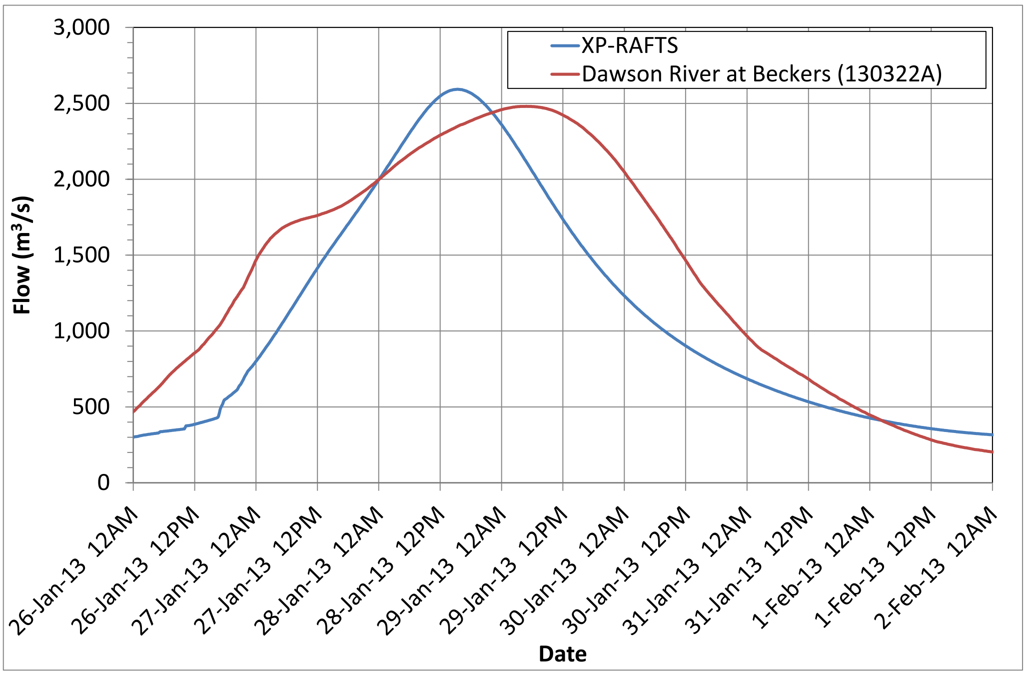

Figure A37
DAWSON RIVER AT BECKERS (130322A) – 2013 EVENT

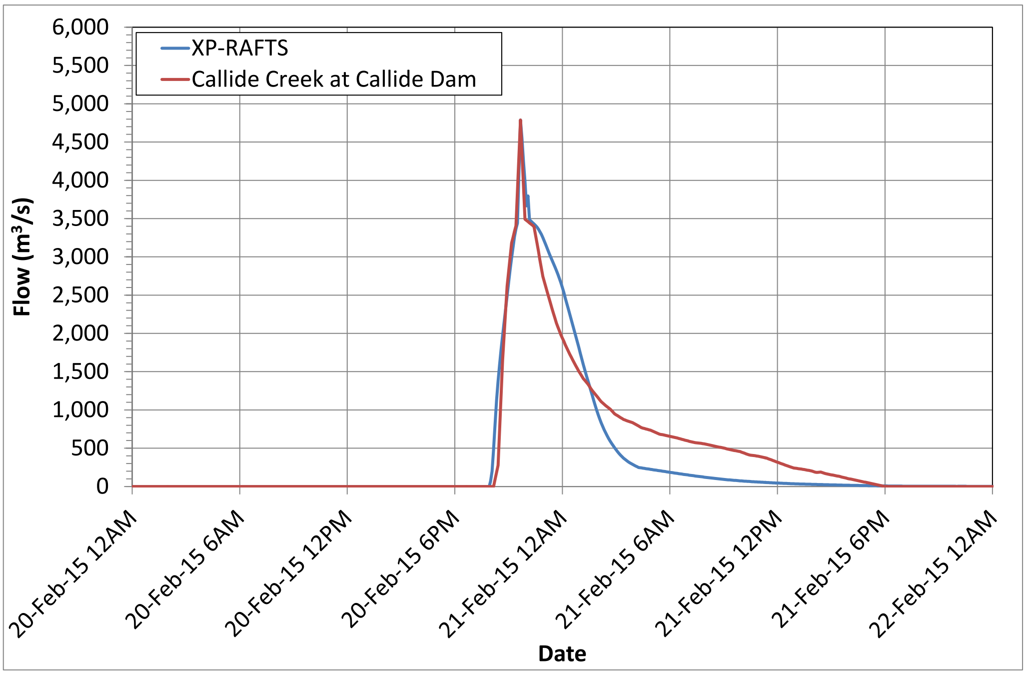

Figure A38
DON-DEE CATCHMENT CALLIDE DAM – 2015 EVENT

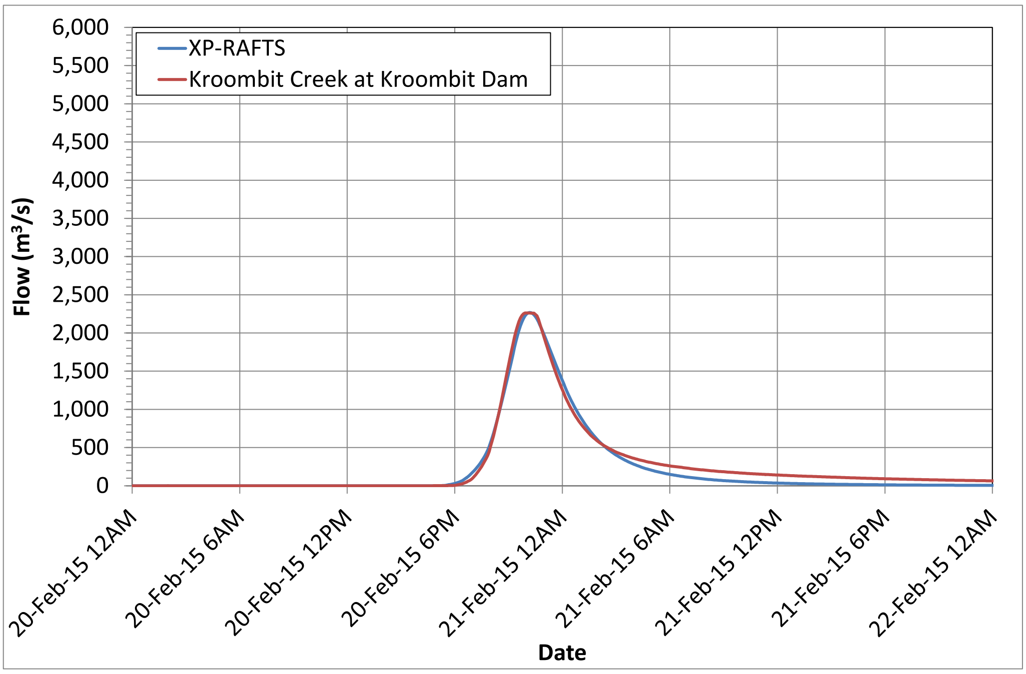

Figure A39
DON-DEE CATCHMENT KROOMBIT DAM – 2015 EVENT

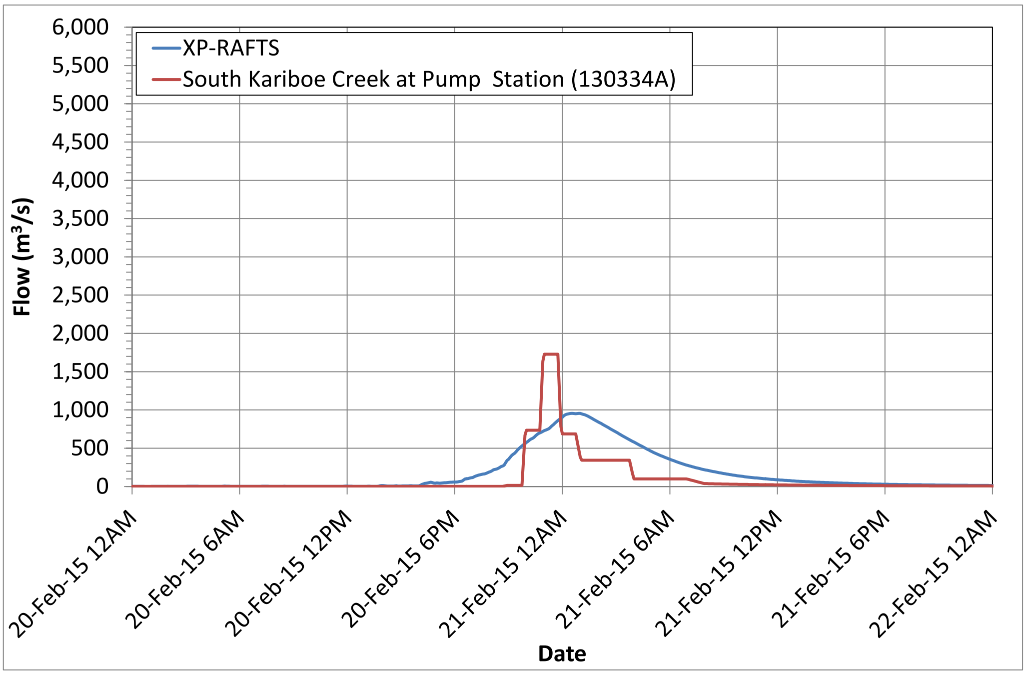

Figure A40
DON-DEE CATCHMENT SOUTH KARIBOE CREEK AT PUMP STATION (130334A) – 2015 EVENT

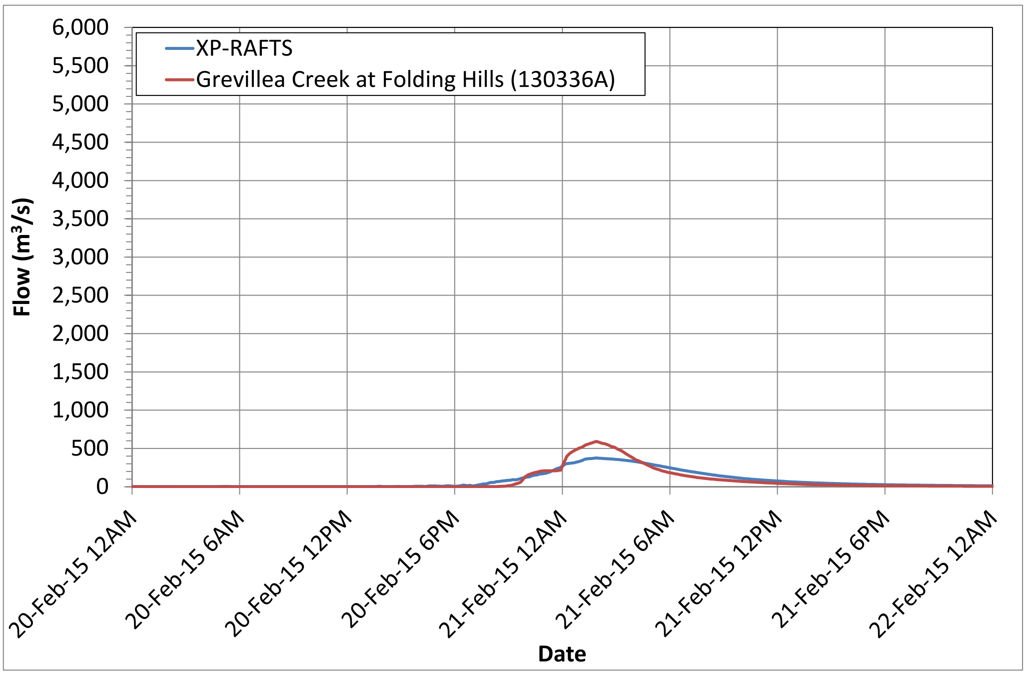

Figure A41
DON-DEE CATCHMENT GREVILLEA CREEK AT FOLDING HILLS (130336A) – 2015 EVENT

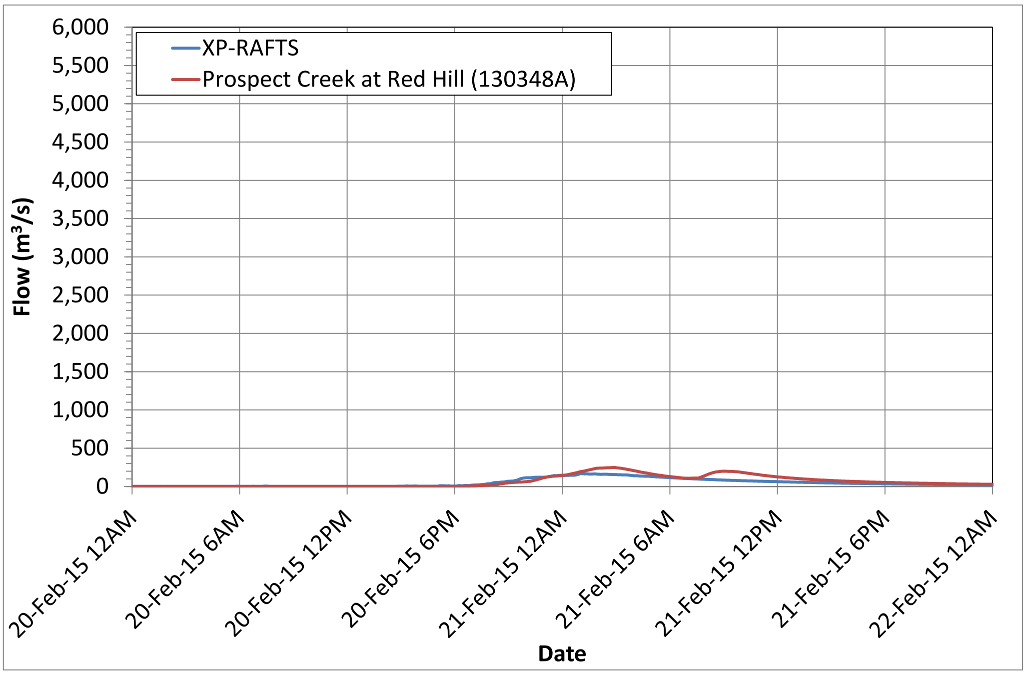

Figure A42
DON-DEE CATCHMENT PROSPECT CREEK AT RED HILL (130348A) – 2015 EVENT

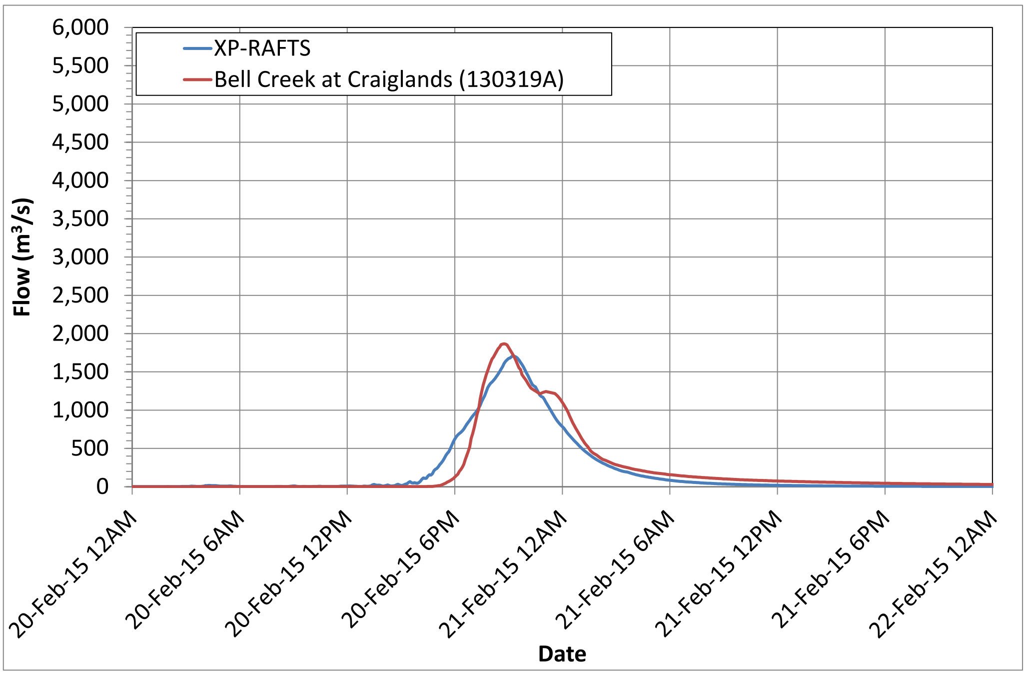

Figure A43
DON-DEE CATCHMENT BELL CREEK AT CRAIGLANDS (130319A) – 2015 EVENT

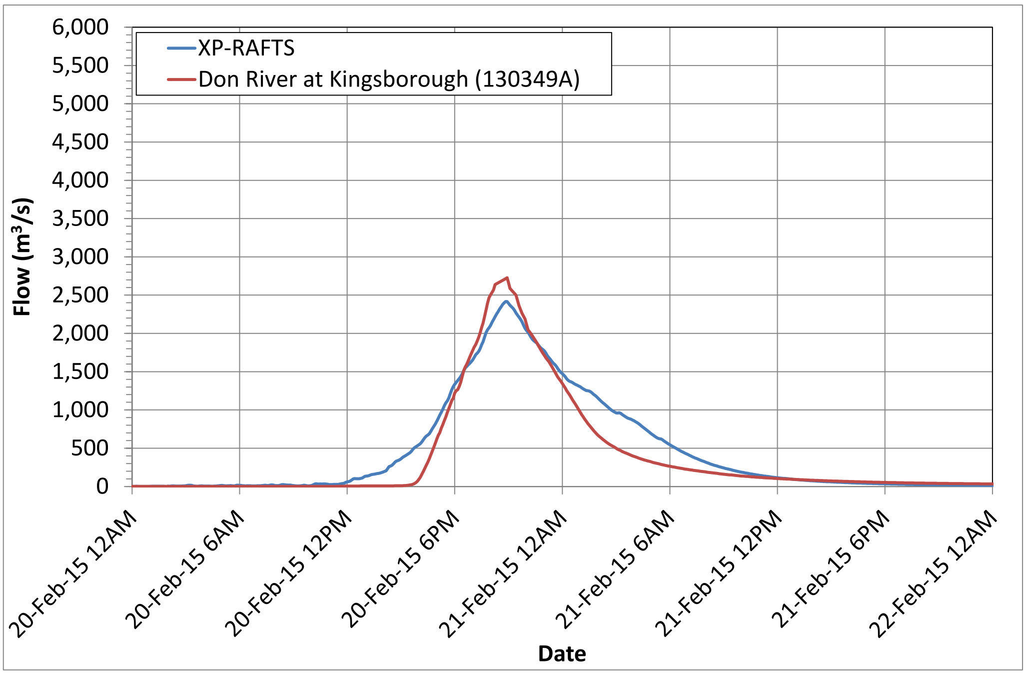

Figure A44
DON-DEE CATCHMENT DON RIVER AT KINGSBOROUGH (130349A) – 2015 EVENT

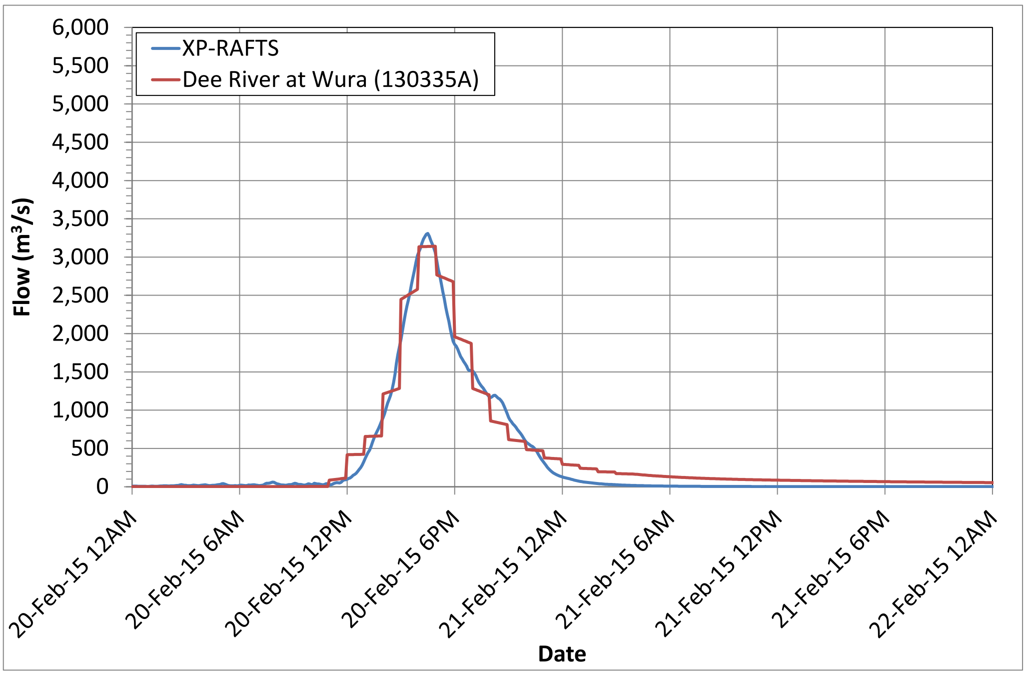

Figure A45
DON-DEE CATCHMENT DEE RIVER AT WURA (130335A) – 2015 EVENT

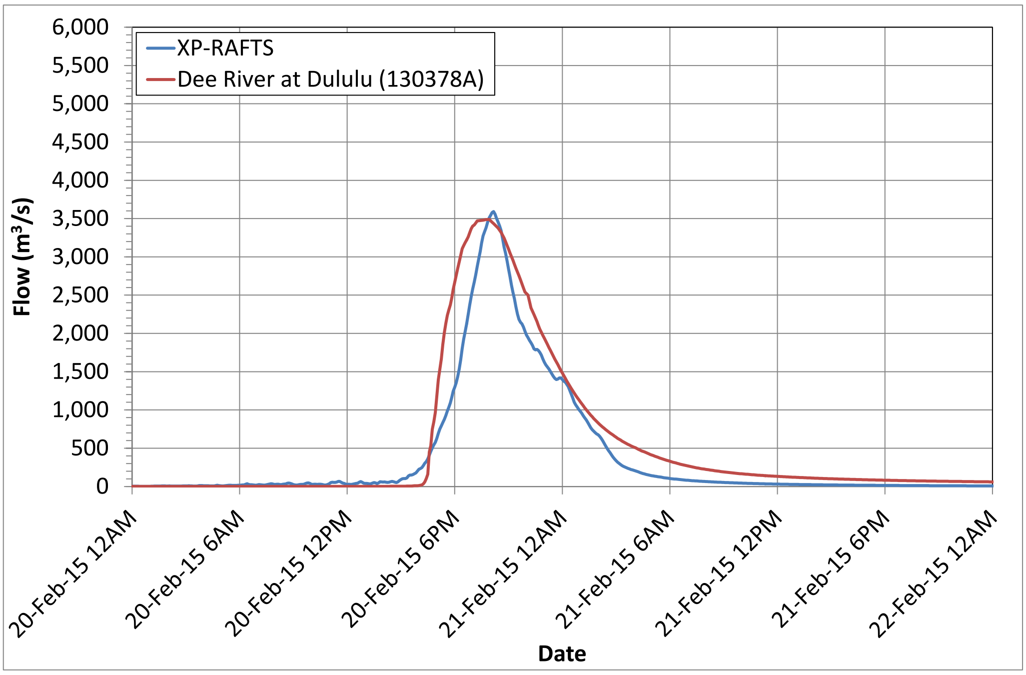

Figure A46
DON-DEE CATCHMENT DEE RIVER AT DULULU (130378A) – 2015 EVENT

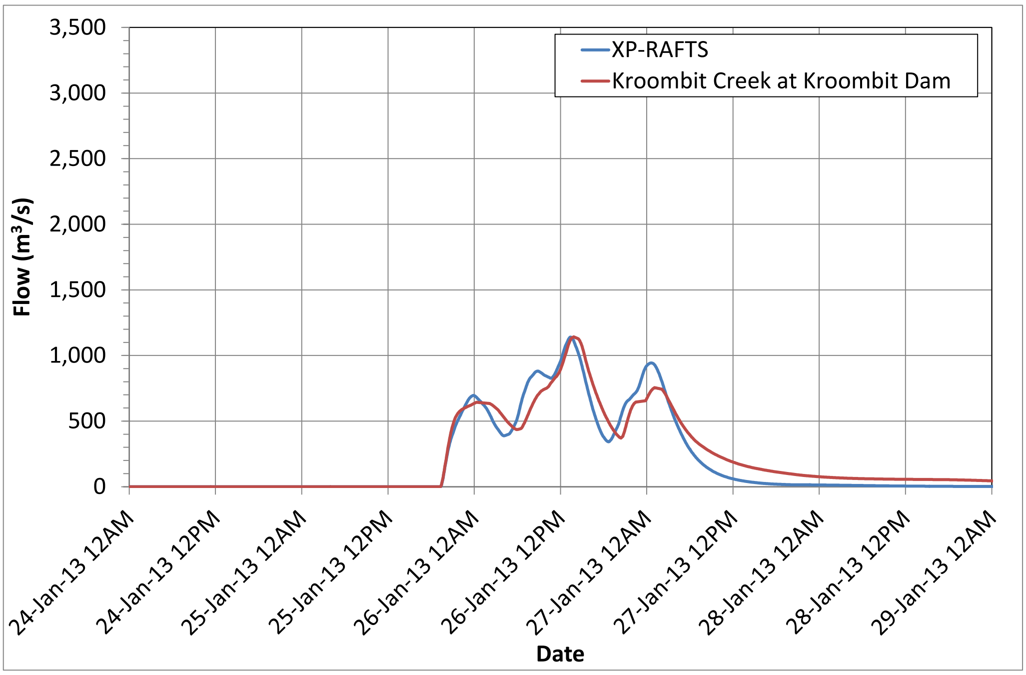

Figure A47
DON-DEE CATCHMENT KROOMBIT DAM – 2013 EVENT

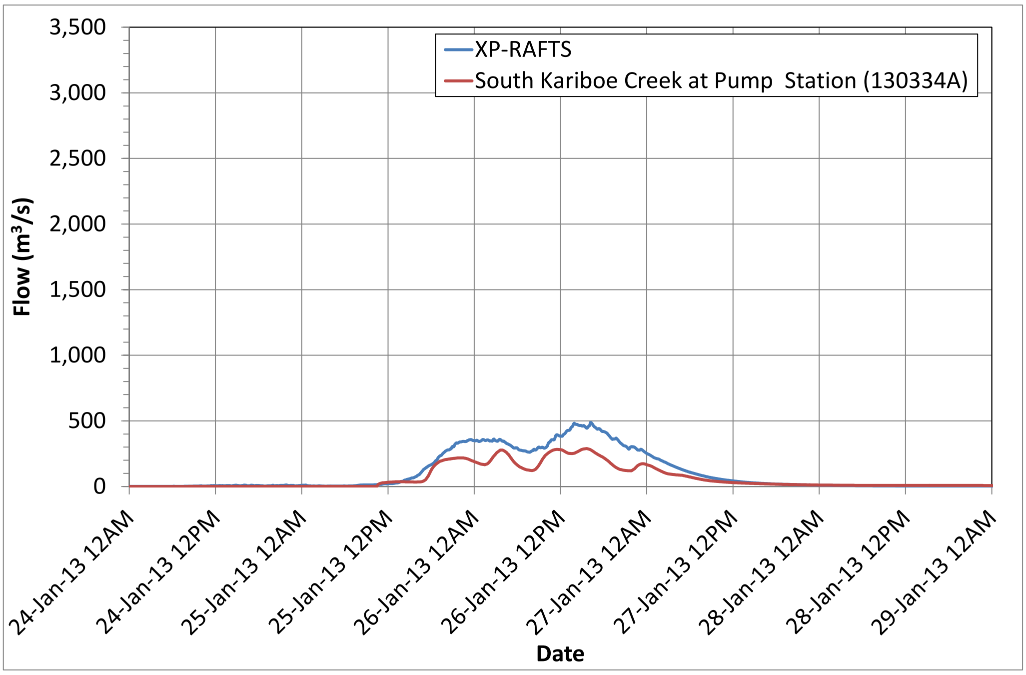

Figure A48
DON-DEE CATCHMENT SOUTH KARIBOE CREEK AT PUMP STATION (130334A) – 2013 EVENT

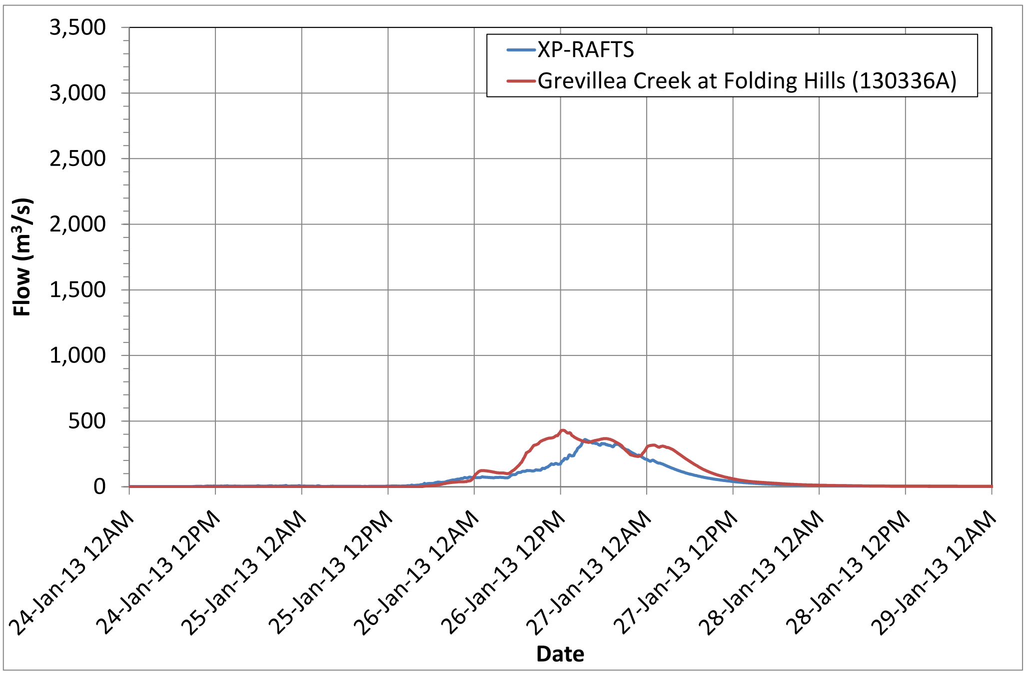

Figure A49
DON-DEE CATCHMENT GREVILLEA CREEK AT FOLDING HILLS (130336A) – 2013 EVENT

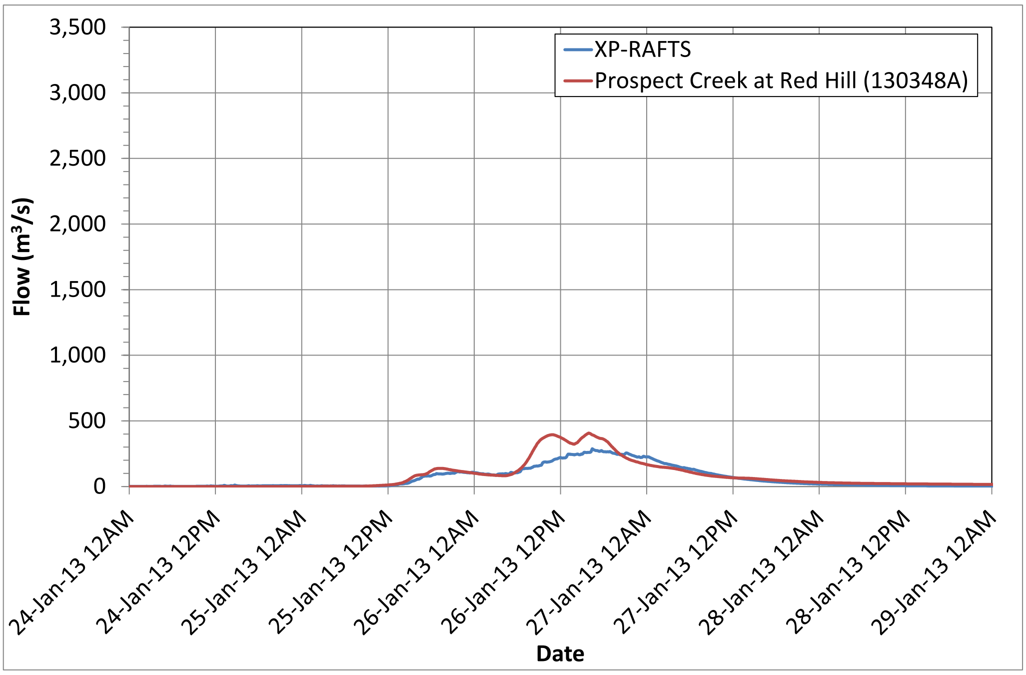

Figure A50
DON-DEE CATCHMENT PROSPECT CREEK AT RED HILL (130348A) – 2013 EVENT

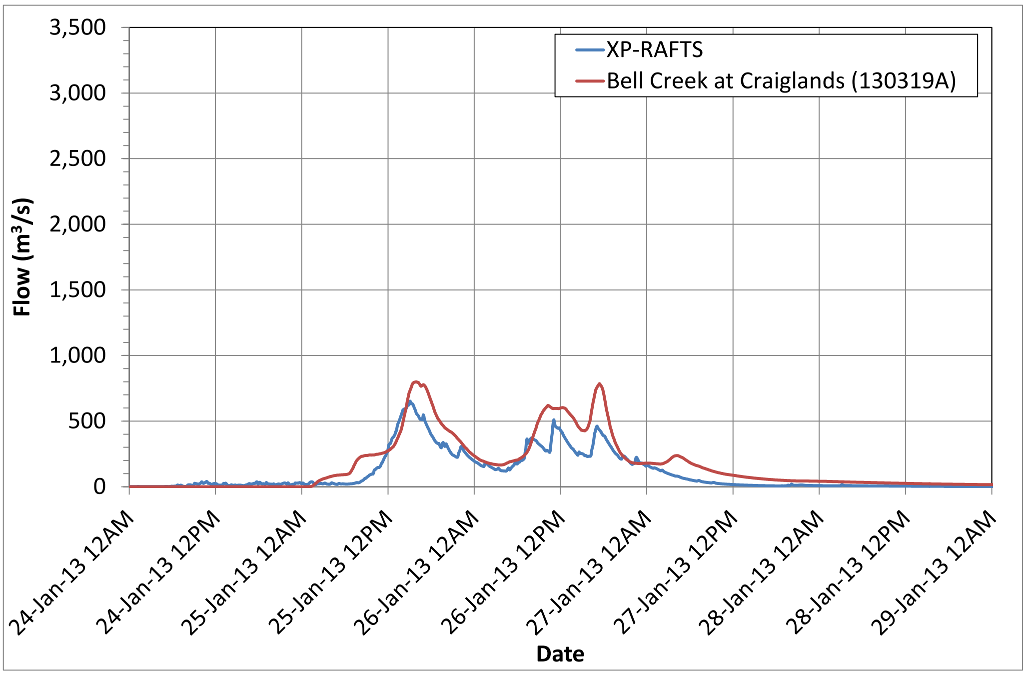

Figure A51
DON-DEE CATCHMENT BELL CREEK AT CRAIGLANDS (130319A) – 2013 EVENT

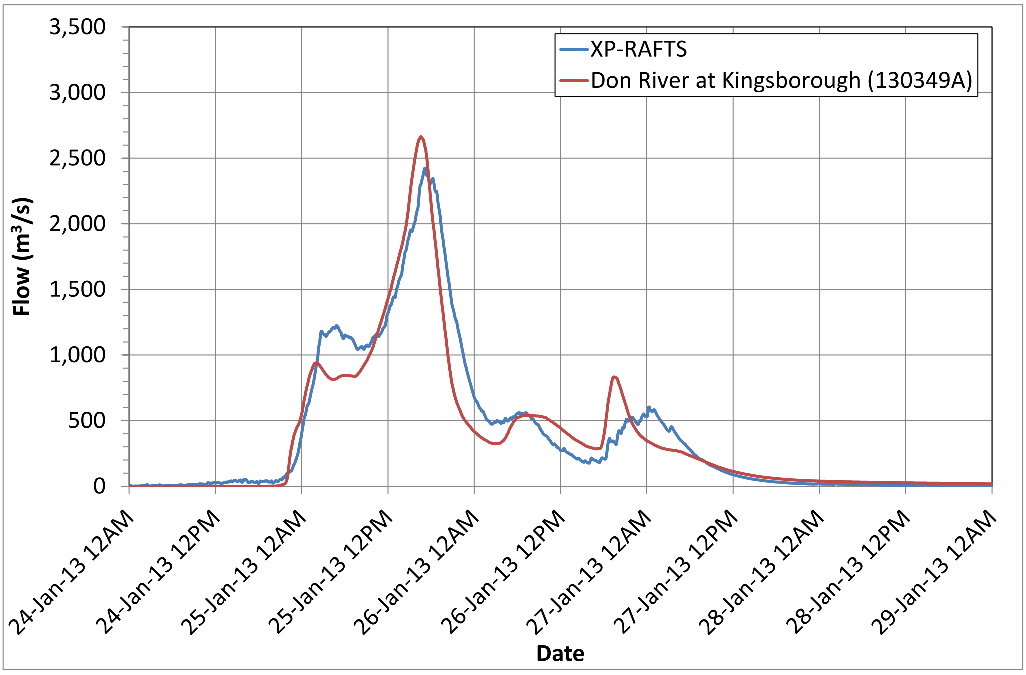

Figure A52
DON-DEE CATCHMENT DON RIVER AT KINGSBOROUGH (130349A) – 2013 EVENT

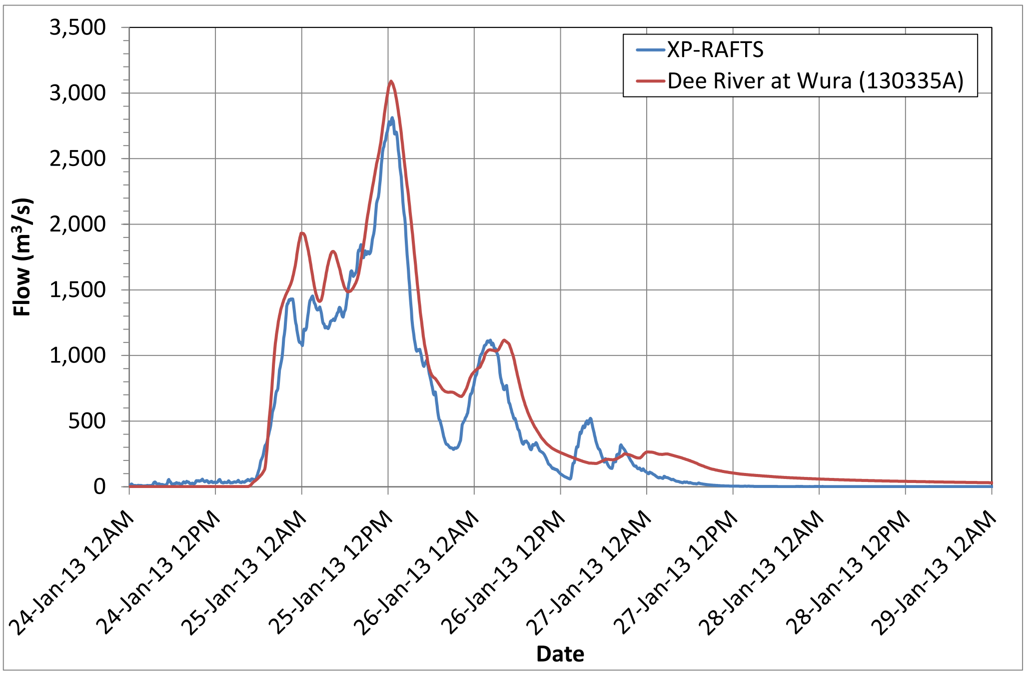

Figure A53
DON-DEE CATCHMENT DEE RIVER AT WURA (130335A) – 2013 EVENT

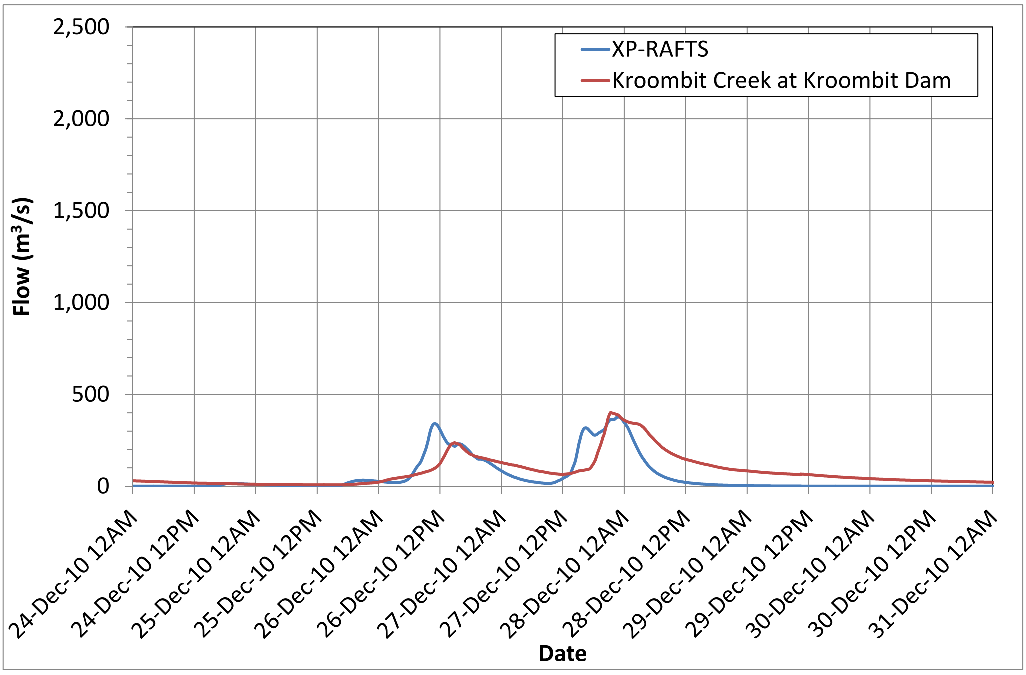

Figure A54
DON-DEE CATCHMENT KROOMBIT DAM – 2010 EVENT

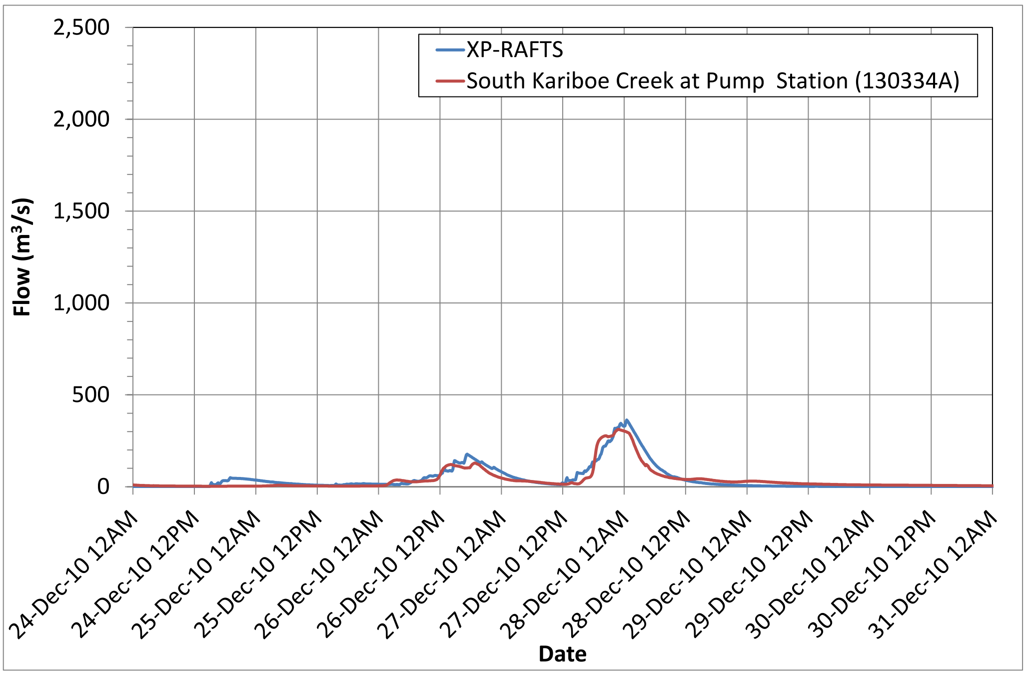

Figure A55
DON-DEE CATCHMENT SOUTH KARIBOE CREEK AT PUMP STATION (130334A) – 2010 EVENT

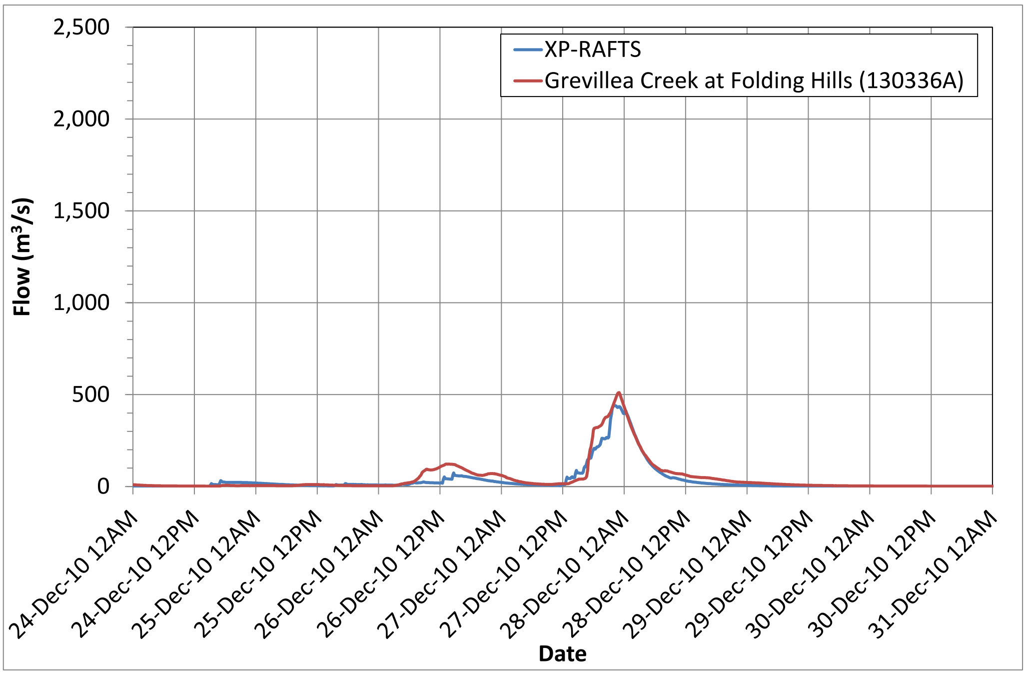

Figure A56
DON-DEE CATCHMENT GREVILLEA CREEK AT FOLDING HILLS (130336A) – 2010 EVENT

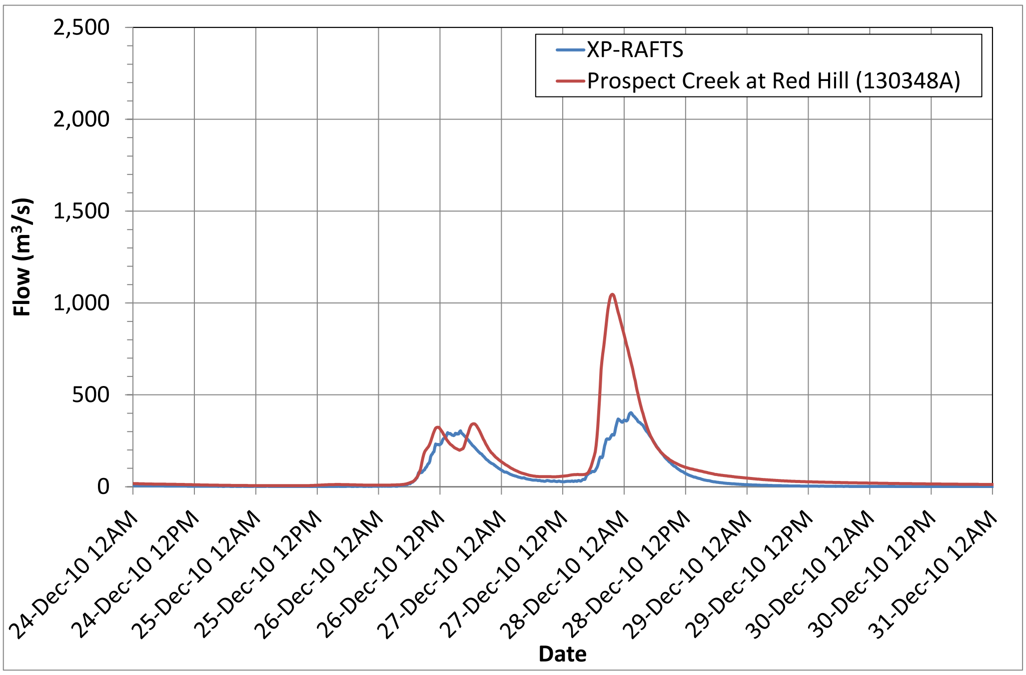

Figure A57
DON-DEE CATCHMENT PROSPECT CREEK AT RED HILL (130348A) – 2010 EVENT

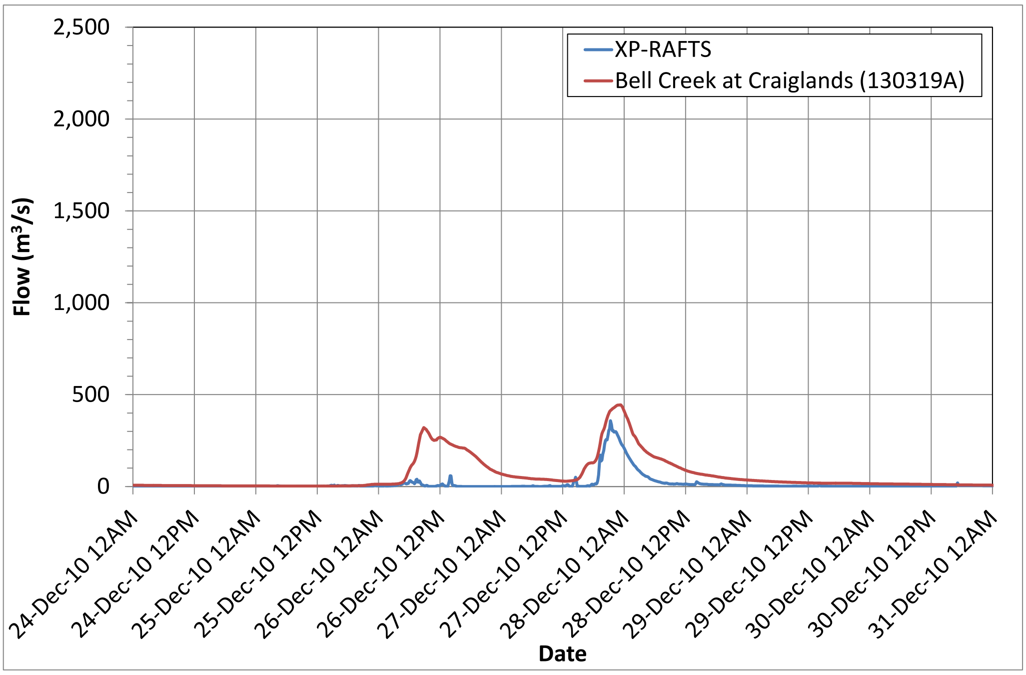

Figure A58
DON-DEE CATCHMENT BELL CREEK AT CRAIGLANDS (130319A) – 2010 EVENT

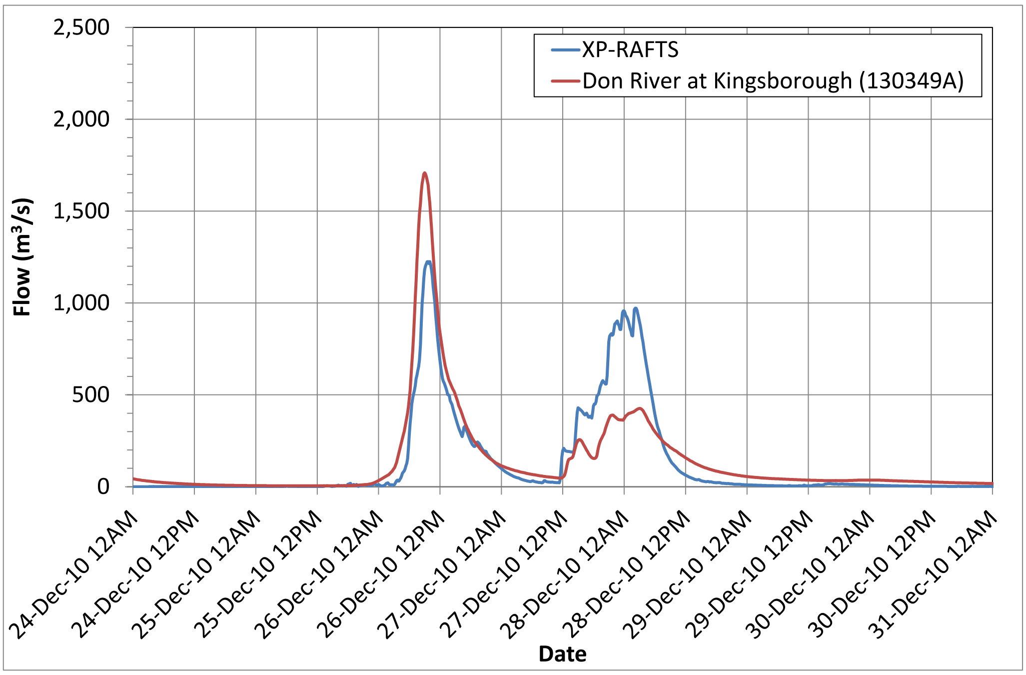

Figure A59
DON-DEE CATCHMENT DON RIVER AT KINGSBOROUGH (130349A) – 2010 EVENT

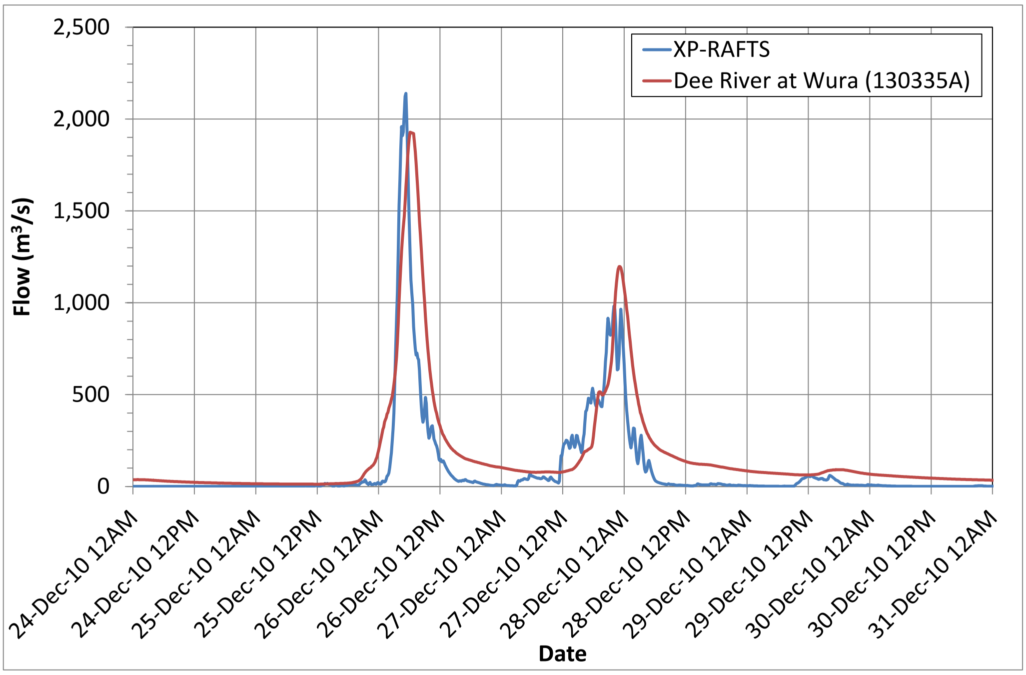

Figure A60
DON-DEE CATCHMENT DEE RIVER AT WURA (130335A) – 2010 EVENT

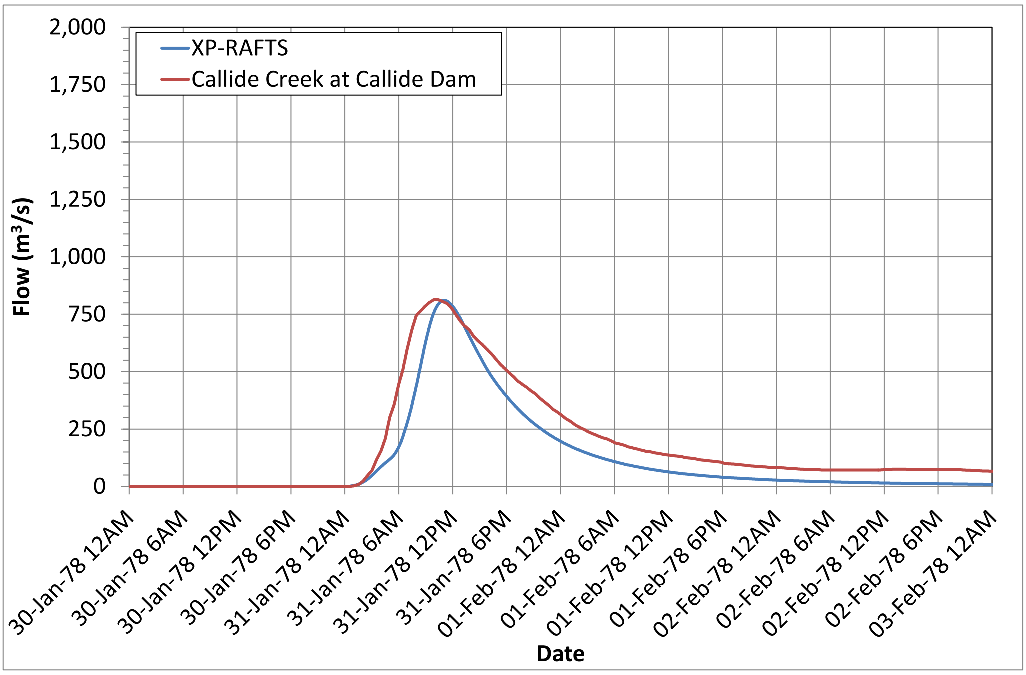

Figure A61
DON-DEE CATCHMENT CALLIDE DAM – 1978 EVENT

5 Design

Design rainfall

The design rainfall depths were estimated using CRC-FORGE. Rainfall was extracted separately for the Dawson catchment, as well as for each of the eight separate areas in the Don-Dee catchment. The adopted rainfall depths are presented in Appendix A-4.

Aerial Reduction Factors (ARF) are automatically calculated using the CRC-FORGE method. An ARF has therefore been applied for each of the rainfall extractions. Table A4 presents the adopted ARF for each area.

Table A4 ARF applied to design rainfall

Catchment	Duration					
	Below 24 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
Dawson	0.68	0.68	0.77	0.81	0.83	0.85
Don-Dee	0.79	0.79	0.85	0.88	0.90	0.91
Dee	0.89	0.89	0.93	0.84	0.85	0.96
Jambin	0.82	0.82	0.88	0.90	0.91	0.92
Thangool	0.89	0.89	0.93	0.84	0.85	0.96
Lower Kroombit	0.89	0.89	0.93	0.95	0.96	0.96
South Kariboe at the Pump Station	0.91	0.91	0.94	0.96	0.97	0.97
Kroombit Dam	0.91	0.91	0.94	0.96	0.96	0.97
Callide Dam	0.89	0.89	0.93	0.95	0.96	0.96

Rainfall losses

Initial loss

The IL represents the depth of rain that is taken in by the soil before runoff occurs. The IL has been adjusted in the design events to match the results of the FFA at Beckers. Due to the presence of dams within the Don-Dee catchment as well as the poor quality of rating curves, no FFA as undertaken and the IL from the Dawson Model were adopted.

Table A5 presents the adopted losses for both the Dawson Model and the Don-Dee Model.

Continuing loss

Continuing Loss (CL) represents the depth of rainfall per hour that is taken in by the soil once runoff occurs. A CL of 2.5 mm/hr has been adopted for all design events in both the Dawson Model and the Don-Dee Model as based on the recommended range in ARR (ARR, 1987).

Table A5 Adopted design rainfall losses for pervious areas*

Event (AEP)	IL (mm)	CL (mm/hr)
10%	30	2.5
5%	30	2.5
2%	10	2.5
1%	0	2.5
0.2%	0	2.5
0.05%	0	2.5
PMP	0	2.5

* *Losses adopted for impervious areas was an IL of 0mm and a CL of 0 mm/hr*

Results

Design flow results are summarised at key locations in Table A6 and A7 for the Dawson Model and the Don-Dee Model respectively. Peak flows at each node is presented in Appendix A-5.

Table A6 Dawson Model design flow results

AEP	Key locations							
	Taroom	Glebe weir	Theodore	Woodleigh	Moura	Bindaree	Baralaba	Beckers
2013	243	304	536	587	370	2,283	2,570	2,592
2010	8,733	5,261	4,726	4,740	4,442	6,159	6,352	6,380
10%	2,659	1,719	1,572	1,582	1,480	1,681	1,814	1,832
5%	3,823	2,545	2,319	2,332	2,181	2,574	2,767	2,790
2%	5,678	4,154	3,789	3,806	3,567	4,298	4,601	4,634
1%	7,278	5,454	4,972	4,991	4,679	5,706	6,092	6,131
1% CC	9,606	7,250	6,590	6,612	6,197	7,709	8,213	8,259
0.2%	10,384	7,861	7,141	7,164	6,714	8,390	8,934	8,983
0.05%	13,302	10,153	9,204	9,230	8,648	10,968	11,661	11,719
PMP	38,025	25,824	23,720	23,766	22,397	28,559	30,584	30,926

* *1% CC is the 1% AEP event Climate Change sensitivity simulation*

Table A7 Don-Dee Model design flow results

AEP	Key locations								
	96km (Callide Dam inflow)	Callide Dam outflow	Kroombit Dam outflow	Pump Station	Folding Hills	Red Hill	Craig-lands	Kings-borough	Dululu
1978	1,684	811	697†	93	39	103	1,238	1,412	1,080
2010	2,116	890	378	363	440	404	358	1,225	2,277
2013	-**	2,071#	1,140	487	361	288	652	2,421	3,132
2015	4,429	4,788	2,267	956	375	170	1,711	2,417	3,592
10%	1,584	1,370	565	263	36	50	198	291	1,443
5%	2,094	1,798	796	364	72	98	281	420	1,858
2%	3,419	2,978	1,502	681	210	285	524	761	3,066
1%	4,232	4,788	2,009	889	309	421	739	1,094	3,912
1%CC*	5,228	4,826	2,571	1,144	409	559	952	1,404	5,099
0.2%	5,919	4,898	2,926	1,236	460	629	1,030	1,514	5,357
0.05%	7,682	5,120	3,875	1,570	620	855	1,288	1,888	6,860
PMP	14,430	6,231	8,496	4,679	3,798	4,482	7,620	10,809	12,916

* *1% CC is the 1% AEP event Climate Change sensitivity simulation*

** *Inflow to Callide Dam not calculated in XP-RAFTS model*

Peak flow not estimated in XP-RAFTS model, flow has been calculationed using recorded gate opening and water level

† *Kroombit Dam not constructed in 1978 event, flow taken at Kroombit Dam site*

6 Conclusion

KBR developed two hydrological models for the Dawson catchment. One model was developed for the larger Dawson Catchment and another model for the Don-Dee catchment to capture detail that could be missed in the larger Dawson model. The Don-Dee model would also allow focus on the 2013 and 2015 historic flood events that primarily affected the Callide Valley area.

The Dawson Model was joint calibrated to the 2010 event, and verified to the 2013 event. The Don-Dee model was joint calibrated to the 2013 and 2015 events, and verified to the 1978 and 2010 events.

Design storm events were simulated in the calibrated hydrological model to obtain design discharges at key location in the catchment.

7 References

ARR 1987, *Australian Rainfall & Runoff* Prepared by Engineers Australia in 1987 and reprinted in 2001

Appendix A-1
Rainfall Stations

Station name	Station No.	Owner	Daily/ sub-daily	Used for 2010 event		Used for 2013 event		Used for 2015 event	
				Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface
Giligulgul TM	35039	BOM	sub-daily	–	–	✓	✓	–	–
Westgrove TM	35039	BOM	sub-daily	–	–	–	–	–	–
Waddy Brae TM	35068	BOM	sub-daily	✓	✓	✓	✓	–	✓
Woorabinda	35083	BOM	sub-daily	–	–	–	–	–	–
The Glebe	35096	BOM	sub-daily	–	–	–	–	–	–
Karamea AL	35227	BOM	sub-daily	–	–	–	–	–	✓
Bungaban TM	35242	BOM	sub-daily	–	–	–	–	–	–
Newlands	35270	BOM	sub-daily	–	–	–	–	–	–
Tarana Crossing AL	35271	BOM	sub-daily	–	–	–	–	–	✓
Chilgerrie Hill	35273	BOM	sub-daily	–	–	–	–	–	–
Baralaba	39143	BOM	sub-daily	–	–	–	–	–	–
Moura	39296	BOM	sub-daily	–	–	–	–	–	–
Barwood	39345	BOM	sub-daily	–	–	–	–	–	–
Westwood TM	39349	BOM	sub-daily	–	–	–	–	–	–
Mooga Hills TM	43006	BOM	sub-daily	–	–	–	–	–	–
Springdale TM	43008	BOM	sub-daily	–	–	–	–	–	–
Pine hills TM	43051	BOM	sub-daily	–	–	✓	–	–	✓
Injune TM	43054	BOM	sub-daily	✓	✓	✓	–	–	–
Bendoba TM	43108	BOM	sub-daily	✓	✓	–	–	–	✓
Humboldt AL	535091	BOM	sub-daily	✓	–	–	–	–	–
Foleyvale AL	535113	BOM	sub-daily	–	–	–	–	–	–
Bundi Road AL	535129	BOM	sub-daily	–	–	–	–	–	✓
Waikola AL	535130	BOM	sub-daily	–	–	–	–	–	✓
Glenhaughton AL	535131	BOM	sub-daily	–	–	–	–	–	✓
Coorada AL	535132	BOM	sub-daily	–	–	–	–	–	✓
Ghinghinda AL	535133	BOM	sub-daily	–	–	–	–	–	✓
Weringa Creek AL	535134	BOM	sub-daily	–	–	–	–	–	✓
Bauhinia Downs AL	535135	BOM	sub-daily	–	–	–	–	–	✓
Krismark Downs AL	535138	BOM	sub-daily	–	–	–	–	–	✓
Orana Park AL	535139	BOM	sub-daily	–	–	–	–	–	✓
Ruined Castle AL	535140	BOM	sub-daily	–	–	–	–	–	✓
Sandra Downs AL	535141	BOM	sub-daily	–	–	–	–	–	✓
Dawson Range South AL	535143	BOM	sub-daily	–	–	–	–	–	✓
Mt Seaview AL	539128	BOM	sub-daily	–	–	–	–	✓	✓
Cedar Vale AL	539138	BOM	sub-daily	–	–	–	–	–	–
Camboon AL	539160	BOM	sub-daily	–	–	–	–	–	✓
Cracow AL	539161	BOM	sub-daily	–	–	–	–	–	✓
Downfall Ck AL	539162	BOM	sub-daily	–	–	–	–	–	✓
Gyranda Weir AL	539163	BOM	sub-daily	–	–	–	–	–	✓
Isla-delusion Crossing AL	539164	BOM	sub-daily	–	–	–	–	–	–

Station name	Station No.	Owner	Daily/ sub-daily	Used for 2010 event		Used for 2013 event		Used for 2015 event	
				Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface
Theodore AL	539166	BOM	sub-daily	–	–	–	–	–	–
Mt Hopeful AL	539167	BOM	sub-daily	–	–	–	–	–	–
Upper Castle AL	539168	BOM	sub-daily	–	–	–	–	–	–
Pheasant Ck AL	539169	BOM	sub-daily	–	–	–	–	✓	✓
Pocket Ck Rd AL	539170	BOM	sub-daily	–	–	–	–	✓	✓
Upper Lonesome AL	539171	BOM	sub-daily	–	–	–	–	–	✓
Castle Creek AL	539172	BOM	sub-daily	–	–	–	–	–	–
Wowan Westwood Rd AL	539173	BOM	sub-daily	–	–	–	–	–	–
Banana Range AL	539174	BOM	sub-daily	–	–	–	–	✓	✓
Riverslea TM	130003B	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Raglan Ck TM	130004A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Taroom TM	130302A	DNRM	sub-daily	✓	–	–	–	–	✓
Rannes TM	130306B	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
La Palma TM	130313A	DNRM	sub-daily	✓	✓	✓	–	–	✓
Redcliffe TM	130316A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Woodleigh TM	130317B	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Craiglands TM	130319A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Beckers TM	130322A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Utopia Downs TM	130324A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Goovigen TM	130327A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
South Kariboe Creek TM	130334A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Wura TM	130335A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Folding Hills TM	130336A	DNRM	sub-daily	–	–	✓	✓	✓	✓
Windamere TM	130344A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Red Hill TM	130348A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Kingsborough TM	130349A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Kenbula TM	130355A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Roundstone Creek TM	130363A	DNRM	sub-daily	✓	✓	✓	✓	–	–
Dairy Ck TM	130364B	DNRM	sub-daily	–	–	✓	✓	✓	✓
Number 7 Dam TM	130369A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Mundic Gully TM	130372A	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Bindaree TM	130374A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Broadmere TM	130375A	DNRM	sub-daily	✓	✓	✓	–	–	✓
Eurombah Creek TM	130376A	DNRM	sub-daily	–	–	✓	–	–	✓
Dululu TM	130378A	DNRM	sub-daily	–	–	–	–		✓
Lake Brown TM	130502B	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Rewan TM	130509A	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Upper Monal TM	136108A	DNRM	sub-daily	–	✓	–	✓	✓	✓
Tabers TM	422210A	DNRM	sub-daily	–	✓	–	✓	–	✓
Blackdown Tableland TM	1301P001	DNRM	sub-daily	✓	✓	✓	✓	–	✓

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Boxvale TM	1303P001	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Cockatoo Ck TM	1303P002	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Kroombit Tops TM	1303P003	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Besch's Hill TM	1303P004	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Blackboy Creek TM	1303P005	DNRM	sub-daily	✓	✓	✓	✓	–	
Blue Hills TM	1303P006	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Upper Dee TM	1303P007	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Peekadoo TM	1303P008	DNRM	sub-daily	✓	✓	✓	✓	–	✓
Katrina TM	1305P004	DNRM	sub-daily	–	✓	–	✓	–	✓
Red Rock TM	1305P005	DNRM	sub-daily	–	✓	–	✓	–	✓
Boolaroo Tops TM	1361P002	DNRM	sub-daily	✓	✓	✓	✓	✓	✓
Doreen TM	13030332A	DNRM	sub-daily	–	–	✓	–	✓	–
Doboy TM	13030613A	DNRM	sub-daily	–	–	✓	✓	–	–
Wowan Cemetry Rd TM	13030791A	DNRM	sub-daily	–	–	✓	–	✓	–
Alma Ck Bore TM	13030880A	DNRM	sub-daily	–	–	✓	–	✓	–
Neerkol	130008A	DNRM (closed)	sub-daily	✓	–	–	–	–	–
Cania Dam	539064	SunWater	sub-daily	✓	✓	–	–	✓	✓
Callide Dam Inflow TM	539111	SunWater	sub-daily	–	✓	✓	✓	✓	✓
Kroombit Dam HW TM	539112	SunWater	sub-daily	–	–	✓	–	–	–
Balmoral Station	33003	BOM	daily	–	–	–	✓	–	–
Byfield Childs Road	33008	BOM	daily	–	✓	–	✓	–	✓
Yaamba	33076	BOM	daily	–	✓	–	✓	–	✓
Pacific Heights	33077	BOM	daily	–	✓	–	✓	–	✓
Marlborough Helipad TM	33111	BOM	daily	–	✓	–	–	–	✓
Tilpal Station	33129	BOM	daily	–	✓	–		–	
Brampton Vale	33163	BOM	daily	–	–	–	–	–	–
Strathmuir	33189	BOM	daily	–	✓	–		–	✓
Monavale	33198	BOM	daily	–	✓	–	–	–	✓
Belmont AGforce	33229	BOM	daily	–	✓	–		–	✓
Cerberus	33248	BOM	daily	–	✓	–	✓	–	✓
Svendsen Beach	33260	BOM	daily	–	✓	–	✓	–	✓
The Gap TM	33285	BOM	daily	–	✓	–	✓	–	✓
Yeppoon The Esplanade	33294	BOM	daily	–	✓	–	–	–	✓
Samuel Hill Aero	33308	BOM	daily	–	✓	–	✓	–	✓
South Yaamba TM	33310	BOM	daily	–	✓	–	✓	–	✓
Hedlow Airfield TM	33312	BOM	daily	–	✓	–	–	–	✓
The Glen TM	33313	BOM	daily	–	✓	–	✓	–	✓
Junee Station	34061	BOM	daily	–	–	–	–	–	–
Ardurad	35003	BOM	daily	–	–	–	✓	–	–
Babbiloora Station	35004	BOM	daily	–	✓	–	✓	–	✓

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Marama	35006	BOM	daily	–	✓	–	✓	–	✓
Bauhinia Downs Store	35007	BOM	daily	–	✓	–	✓	–	✓
Currajong	35008	BOM	daily	–	✓	–	✓	–	✓
Wandoan Post Office	35014	BOM	daily	–	✓	–	✓	–	✓
The Sandstone	35015	BOM	daily	–	✓	–	✓	–	✓
Coorada	35022	BOM	daily	–	–	–	–	–	–
Dingo Post Office	35025	BOM	daily	–	–	–	–	–	–
Duaringa Post Office	35026	BOM	daily	–	–	–		–	–
Giligulgul	35029	BOM	daily	–	✓	–	–	–	✓
Giligulgul TM	35039	BOM	daily	–	–	–	–	–	–
Westgrove TM	35040	BOM	daily	–	✓	–	✓	–	✓
Orion	35051	BOM	daily	–	–	–	–	–	–
Somerby	35063	BOM	daily	–	✓	–	✓	–	✓
Waddy Brae TM	35068	BOM	daily	–	–	–	–	–	–
Taroom Post Office	35070	BOM	daily	–	✓	–	✓	–	✓
Warrinilla	35077	BOM	daily	–	✓	–	✓	–	✓
Woleebee Nevasa	35081	BOM	daily	–	–	–	✓	–	–
Mt Moffatt National Park	35093	BOM	daily	–	✓	–	✓	–	✓
Eurombah	35113	BOM	daily	–	✓	–	✓	–	✓
La Palma	35117	BOM	daily	–	✓	–	✓	–	✓
Carinya	35119	BOM	daily	–	✓	–	✓	–	✓
The Canal	35123	BOM	daily	–	✓	–	✓	–	✓
Rolleston Airport	35129	BOM	daily	–	✓	–	✓	–	✓
New Caledonia	35132	BOM	daily	–	✓	–	✓	–	✓
Blackwater Airport	35134	BOM	daily	–	–	–	–	–	–
Hornet Bank Homestead	35135	BOM	daily	–	✓	–	✓	–	✓
Moonah	35148	BOM	daily	–	–	–		–	–
Brigalow Research Stn	35149	BOM	daily	–	✓	–	–	–	✓
Mount Kingsley	35151	BOM	daily	–	✓	–	✓	–	✓
Moorabinda	35154	BOM	daily	–	✓	–	–	–	✓
Melmoth	35172	BOM	daily	–	–	–	–	–	–
Yantumara	35174	BOM	daily	–	–	–	✓	–	–
Mount Nicholson	35175	BOM	daily	–	✓	–	–	–	✓
Broadmere	35178	BOM	daily	–	✓	–	✓	–	
Kinnoul	35182	BOM	daily	–	✓	–	✓	–	✓
Blackdown Tableland al	35186	BOM	daily	–	–	–	✓	–	–
Consuelo	35189	BOM	daily	–	–	–	✓	–	–
Wyseby	35194	BOM	daily	–	✓	–	✓	–	✓
Bungawarra	35206	BOM	daily	–	✓	–	✓	–	✓

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Albinia Downs	35209	BOM	daily	–	✓	–	–	–	✓
Cometside	35220	BOM	daily	–	✓	–	✓	–	✓
Karamea	35227	BOM	daily	–	–	–	–	–	–
Carina Downs	35235	BOM	daily	–	✓	–	–	–	✓
Bungaban TM	35242	BOM	daily	–	✓	–	–	–	✓
Wallaroo	35244	BOM	daily	–	–	–	–	–	–
Darkwater	35248	BOM	daily	–	✓	–	✓	–	✓
Waikola	35249	BOM	daily	–	–	–	✓	–	–
Newlands	35270	BOM	daily	–	✓	–	✓	–	✓
Tarana Crossing	35271	BOM	daily	–	✓	–	✓	–	✓
Aqua Park	35272	BOM	daily	–	✓	–	✓	–	✓
Chilgerrie Hill	35273	BOM	daily	–	✓	–	✓	–	✓
Springsure Creek Junction al	35276	BOM	daily	–	✓	–	✓	–	✓
Allambee	35280	BOM	daily	–	✓	–	✓	–	✓
Taroom TM	35282	BOM	daily	–	–	–	–	–	–
Bingegang Weir HW AL	35295	BOM	daily	–	–	–	✓	–	–
Abercorn	39000	BOM	daily	–	✓	–	✓	–	✓
Bajool Post Office	39002	BOM	daily	–	✓	–	✓	–	✓
Banana Post Office	39003	BOM	daily	–	–	–	–	–	–
Baralaba Post Office	39004	BOM	daily	–	✓	–	–	–	✓
Boona-Choppa	39009	BOM	daily	–	✓	–	✓	–	✓
Goondicum	39010	BOM	daily	–	✓	–	✓	–	✓
Monduran	39011	BOM	daily	–	–	–	–	–	–
Burnett Heads Niell St	39017	BOM	daily	–	✓	–	✓	–	✓
Bustard Head Lighthouse	39018	BOM	daily	–	✓	–	✓	–	✓
Callemondah Station	39019	BOM	daily	–	✓	–	✓	–	✓
Calliope Station	39020	BOM	daily	–	✓	–	✓	–	✓
Camboon Station	39022	BOM	daily	–	✓	–	✓	–	✓
Darts Creek	39030	BOM	daily	–	✓	–	–	–	✓
Melrose	39035	BOM	daily	–	✓	–	✓	–	✓
Eidsvold Post Office	39036	BOM	daily	–	✓	–	✓	–	✓
Fairymead Sugar Mill	39037	BOM	daily	–	✓	–	–	–	✓
Gayndah Post Office	39039	BOM	daily	–	–	–	–	–	–
Gin Gin Post Office	39040	BOM	daily	–	✓	–	✓	–	✓
Glenlands	39043	BOM	daily	–	✓	–	✓	–	✓
Riverslea TM	39044	BOM	daily	–	✓	–	✓	–	✓
Goovigen	39048	BOM	daily	–	✓	–	✓	–	✓

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Gracemere – Lucas St	39049	BOM	daily	–	✓	–	✓	–	✓
Jambin Post Office	39054	BOM	daily	–	✓	–	✓	–	✓
Kalpowar Forestry	39057	BOM	daily	–	✓	–	✓	–	✓
Mount Wallaby	39064	BOM	daily	–	✓	–	✓	–	✓
Gayndah Airport	39066	BOM	daily	–	✓	–	✓	–	✓
Moonmera	39067	BOM	daily	–	✓	–	✓	–	✓
Mount Larcom Post Office	39068	BOM	daily	–	✓	–	✓	–	✓
Walterhall	39069	BOM	daily	–	✓	–	✓	–	✓
Mt Perry The Pines	39070	BOM	daily	–	✓	–	–	–	✓
Moura Post Office	39071	BOM	daily	–	✓	–	✓	–	✓
Mundubbera	39073	BOM	daily	–	✓	–	✓	–	✓
Euleilah Creek	39077	BOM	daily	–	✓	–	✓	–	✓
Rockhampton Aero	39083	BOM	daily	–	✓	–	✓	–	✓
Rosedale Post Office	39084	BOM	daily	–	✓	–	–	–	✓
Thangool Airport	39089	BOM	daily	–	✓	–	✓	–	✓
Ubobo Store	39091	BOM	daily	–	–	–	–	–	–
Miara	39092	BOM	daily	–	✓	–	✓	–	✓
Watalgan Winfield Rd	39095	BOM	daily	–	✓	–	✓	–	✓
Wateranga	39096	BOM	daily	–	✓	–	✓	–	✓
Waterloo	39097	BOM	daily	–	✓	–	✓	–	✓
Wowan Post Office	39102	BOM	daily	–	–	–	✓	–	–
Bancroft	39103	BOM	daily	–	✓	–	✓	–	
Monto Township	39104	BOM	daily	–	✓	–	✓	–	✓
Mount Kroombit	39106	BOM	daily	–	✓	–	✓	–	✓
Gladstone Radar	39123	BOM	daily	–	✓	–	✓	–	✓
Bundaberg Aero	39128	BOM	daily	–	✓	–	✓	–	✓
Malakoff	39129	BOM	daily	–	✓	–	✓	–	✓
Didcot	39132	BOM	daily	–	✓	–	–	–	✓
Bargara	39135	BOM	daily	–	✓	–	✓	–	✓
Woodleigh	39142	BOM	daily	–	✓	–	✓	–	✓
Barfield	39149	BOM	daily	–	–	–	–	–	–
Callide Open Cut	39150	BOM	daily	–	✓	–	–	–	✓
Gonyelinka	39151	BOM	daily	–	✓	–	–	–	✓
Dululu Post Office	39156	BOM	daily	–	✓	–	–	–	✓
Theodore	39158	BOM	daily	–	–	–	–	–	–
Lynwood	39160	BOM	daily	–	✓	–	✓	–	✓
Rockybar	39167	BOM	daily	–	✓	–	✓	–	✓
Bundaberg Ashfield Rd	39174	BOM	daily	–	✓	–	✓	–	✓
Lovandee	39175	BOM	daily	–	✓	–	✓	–	✓
Glenwood	39177	BOM	daily	–	✓	–	–	–	✓
Paradise Dam	39184	BOM	daily	–	–	–	–	–	–

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Bingera Sugar Mill	39186	BOM	daily	–	✓	–	✓	–	✓
Mt Lawless TM	39193	BOM	daily	–	✓	–	–	–	✓
Fig Tree	39197	BOM	daily	–	–	–		–	–
Miriam Vale TM	39199	BOM	daily	–	✓	–	✓	–	✓
Redbank	39200	BOM	daily	–	✓	–	✓	–	✓
Belvedere	39201	BOM	daily	–	–	–	✓	–	–
Tannymorel	39203	BOM	daily	–	✓	–	✓	–	✓
Colodan	39204	BOM	daily	–	✓	–	✓	–	✓
Wingfield	39205	BOM	daily	–	✓	–	✓	–	✓
Newlyn - Cynthia	39208	BOM	daily	–	✓	–	–	–	✓
Geijera	39211	BOM	daily	–	✓	–	–	–	✓
Ampthill TM	39215	BOM	daily	–	–	–	✓	–	–
Moolboolaman	39218	BOM	daily	–	✓	–	✓	–	✓
Charnwood	39220	BOM	daily	–	✓	–	✓	–	✓
Elliott Heads Road	39221	BOM	daily	–	–	–	✓	–	–
Cania Gorge Park	39222	BOM	daily	–	✓	–	✓	–	✓
Wuruma Dam	39236	BOM	daily	–	✓	–	✓	–	✓
Deepbank	39237	BOM	daily	–	✓	–	–	–	✓
Kroombit	39240	BOM	daily	–	–	–	✓	–	–
Southend Curtis Island	39241	BOM	daily	–	✓	–	✓	–	✓
Broadmeadows	39242	BOM	daily	–	✓	–	✓	–	✓
Tecoma	39248	BOM	daily	–	✓	–	✓	–	✓
Rockley	39250	BOM	daily	–	✓	–	✓	–	✓
Hillview	39251	BOM	daily	–	✓	–	✓	–	✓
Ferndale	39252	BOM	daily	–	✓	–	✓	–	✓
Rowanlea	39253	BOM	daily	–	✓	–	✓	–	✓
Springs	39255	BOM	daily	–	✓	–	✓	–	✓
Dingle Dell	39256	BOM	daily	–	✓	–	–	–	✓
Eidsvold Bridge	39259	BOM	daily	–	✓	–	✓	–	✓
Turkey Station	39261	BOM	daily	–	✓	–	✓	–	✓
Thangool Evap	39269	BOM	daily	–	✓	–	✓	–	✓
Glenhaven	39278	BOM	daily	–	✓	–	✓	–	✓
Strathdee	39284	BOM	daily	–	✓	–	✓	–	✓
Biloela - Valbona	39290	BOM	daily	–	✓	–	✓	–	✓
Builyan Gum Street	39297	BOM	daily	–	✓	–	✓	–	✓
Childers South	39303	BOM	daily	–	✓	–	✓	–	✓
Bing	39306	BOM	daily	–	✓	–	✓	–	✓
Rannes	39308	BOM	daily	–	–	–	–	–	–
Glandore	39311	BOM	daily	–	✓	–	✓	–	✓
Walla TM	39313	BOM	daily	–	–	–	✓	–	–
Seventeen Seventy	39314	BOM	daily	–	✓	–	✓	–	✓
Abercorn TM	39319	BOM	daily	–	–	–	–	–	–
Eidsvold TM	39321	BOM	daily	–	✓	–	–	–	✓

Station name	Station No.	Owner	Daily/ sub-daily	Used for 2010 event		Used for 2013 event		Used for 2015 event	
				Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface
Yandaran Monduran Road	39325	BOM	daily	–	✓	–	✓	–	✓
Gladstone Airport	39326	BOM	daily	–	✓	–	✓	–	✓
Makowata	39327	BOM	daily	–	✓	–	✓	–	✓
Stanwell Power Station	39328	BOM	daily	–	✓	–	✓	–	✓
Lloyona	39332	BOM	daily	–	✓	–	✓	–	✓
Rocky Springs	39333	BOM	daily	–	✓	–	–	–	✓
Hazeldean	39334	BOM	daily	–	✓	–	✓	–	✓
Woongarra TM	39337	BOM	daily	–	–	–	✓	–	–
Bungadoo TM	39338	BOM	daily	–	–	–	✓	–	–
Dingle Dell TM	39339	BOM	daily	–	–	–	–	–	–
Sauers TM	39340	BOM	daily	–	✓	–	–	–	✓
Byrnestown TM	39341	BOM	daily	–	✓	–	✓	–	✓
mt yeatman tm	39342	BOM	daily	–	–	–	✓	–	–
Malanda	39343	BOM	daily	–	✓	–	✓	–	✓
Barwood	39345	BOM	daily	–	✓	–	✓	–	✓
Glenrock	39346	BOM	daily	–	✓	–	✓	–	✓
Westwood TM	39349	BOM	daily	–	✓	–	✓	–	✓
Upper Ulam Road	39351	BOM	daily	–	–	–	✓	–	–
Bundaberg AL	39352	BOM	daily	–	–	–	–	–	–
Biggenden Post Office	40021	BOM	daily	–	✓	–	✓	–	✓
Biggenden TM	40334	BOM	daily	–	–	–	✓	–	–
Brian Pastures	40428	BOM	daily	–	✓	–	✓	–	✓
Dunollie	40455	BOM	daily	–	✓	–	✓	–	✓
Monogorilby - Home	40708	BOM	daily	–	✓	–	✓	–	✓
Boondooma Dam	40722	BOM	daily	–	✓	–	✓	–	✓
Brigalow Post Office	41007	BOM	daily	–	✓	–	✓	–	✓
Fernflat	41012	BOM	daily	–	✓	–	✓	–	✓
Chinchilla Water Treatment Plant	41017	BOM	daily	–	✓	–	✓	–	✓
SEVEN OAKS TM	41020	BOM	daily	–	✓	–	✓	–	✓
Ballon al	41092	BOM	daily	–	✓	–	✓	–	✓
Riverview Hopeland	41215	BOM	daily	–	✓	–	✓	–	✓
Ehlma Park	41291	BOM	daily	–	✓	–	✓	–	✓
Beruna	41409	BOM	daily	–	–	–	✓	–	–
Warra-Kogan Rd BR	41486	BOM	daily	–	✓	–	✓	–	✓
Brigalow Bridge TM	41490	BOM	daily	–	✓	–	✓	–	✓
Barakula Forest Stn	42000	BOM	daily	–	–	–	✓	–	–
Possum Park	42004	BOM	daily	–	✓	–	✓	–	✓
Drillham	42009	BOM	daily	–	✓	–	✓	–	✓
Dulacca Truck Stop	42010	BOM	daily	–	✓	–	✓	–	✓

Station name	Station No.	Owner	Daily/ sub-daily	Used for 2010 event		Used for 2013 event		Used for 2015 event	
				Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface	Temporal pattern	Rainfall surface
Miles Post Office	42023	BOM	daily	–	✓	–	✓	–	✓
Horse Creek Al	42025	BOM	daily	–	✓	–	✓	–	✓
Shelbourne	42033	BOM	daily	–	✓	–	✓	–	✓
Jackson Community Postal Agency	42035	BOM	daily	–	✓	–	✓	–	✓
Bawnduggie Al	42036	BOM	daily	–	–	–	–	–	–
Kilbeggan	42042	BOM	daily	–	✓	–	✓	–	✓
Condamine	42048	BOM	daily	–	–	–	✓	–	–
Auburn	42059	BOM	daily	–	–	–	✓	–	–
Bawnduggie	42075	BOM	daily	–	✓	–	✓	–	✓
Harewood	42078	BOM	daily	–	✓	–	✓	–	✓
Wombalano	42082	BOM	daily	–	✓	–	✓	–	✓
Dungaden	42109	BOM	daily	–	✓	–	✓	–	✓
Miles Constance Street	42112	BOM	daily	–	✓	–	✓	–	✓
Mooga Hills TM	43006	BOM	daily	–	✓	–	✓	–	✓
Springdale TM	43008	BOM	daily	–	✓	–	✓	–	✓
Injune Post Office	43015	BOM	daily	–	–	–	✓	–	–
Mitchell Post Office	43020	BOM	daily	–	✓	–	✓	–	✓
Finsbury Park	43037	BOM	daily	–	✓	–	✓	–	✓
Wallumbilla Post Office	43038	BOM	daily	–	✓	–	✓	–	✓
Yuleba Garden St	43043	BOM	daily	–	✓	–	✓	–	✓
Yuleba State Forest	43044	BOM	daily	–	✓	–	✓	–	✓
Pine Hills TM	43051	BOM	daily	–	✓	–	✓	–	✓
Injune TM	43054	BOM	daily	–	–	–	–	–	–
Fairfield	43056	BOM	daily	–	✓	–	✓	–	✓
Havelock	43060	BOM	daily	–	✓	–	✓	–	✓
Somerset	43071	BOM	daily	–	✓	–	✓	–	✓
Munnaweena	43075	BOM	daily	–	–	–	✓	–	–
Garrabarra	43077	BOM	daily	–	–	–	✓	–	–
Sunnybank	43081	BOM	daily	–	✓	–	✓	–	✓
Dalmally	43112	BOM	daily	–	✓	–	✓	–	✓
Angellala Downs Homestead	44001	BOM	daily	–	✓	–	✓	–	✓
Eversfield	44033	BOM	daily	–	✓	–	✓	–	✓
Ivanhoe Downs	44044	BOM	daily	–	✓	–	✓	–	✓
Lowan Hills	44047	BOM	daily	–	✓	–	✓	–	✓
Mungallala	44056	BOM	daily	–	✓	–	✓	–	✓
Albury	44079	BOM	daily	–	✓	–	✓	–	✓
Chesterton	44115	BOM	daily	–	✓	–	✓	–	–
Warida	44138	BOM	daily	–	✓	–	✓	–	✓
Tantallon	44195	BOM	daily	–	✓	–	✓	–	✓
Dulbydilla	44203	BOM	daily	–	–	–	✓	–	–
Callide Dam		SunWater	daily	–	–	–	✓	–	–

Appendix A-2

Streamflow Stations

Stream station name	Stream gauge station number	Owner	Stream height	Streamflow	Used in 2010	Used in 2013	Used in 2015
The Glebe	35096	BOM	✓				
Taroom	35115	BOM	✓				
Karamea	35227	BOM	✓				
Newlands	35270	BOM	✓				
Tarana Crossing	35271	BOM	✓				
Chilgerrie Hill	35273	BOM	✓				
Baralaba	39143	BOM	✓				
Moura	39296	BOM	✓				
Rannes	39308	BOM	✓				
Theodore	39315	BOM	✓				
Karamea AL	535124	BOM	✓				
Tarana Crossing AL	535142	BOM	✓				
Gyranda Weir AL	539163	BOM	✓				
Isla-Delusion Crossing AL	539164	BOM	✓				
Moura Weir AL	539165	BOM	✓				
Theodore AL	539166	BOM	✓				
Castle Creek AL	539172	BOM	✓				
Wowan Westwood Rd AL	539173	BOM	✓				
Lonesome Creek AL	539175	BOM	✓				
Callide Creek Inflow (96k)		Sunwater	✓	✓			
Callide Dam		Sunwater	✓	✓			✓
Kroombit Dam		Sunwater	✓	✓		✓	✓
The Glebe		Sunwater	✓	✓	●	●	
Gyranda Weir		Sunwater	✓	✓			
Moura Weir		Sunwater	✓	✓	●	●	
Neville Hewitt Weir		Sunwater	✓	✓	✓	✓	
Theodore Weir		Sunwater	✓	✓			
Taroom	130302A	DNRM	✓	✓	●	●	
Rannes	130306B	DNRM	✓	✓		●	●
La Palma	130313A	DNRM	✓	✓	●	●	
Redcliffe	130316A	DNRM	✓	✓	●	●	
Woodleigh	130317B	DNRM	✓	✓	●	●	
Craiglands	130319A	DNRM	✓	✓	●	●	
Beckers	130322A	DNRM	✓	✓	●	●	
Utopia Downs	130324A	DNRM	✓	✓			

Stream station name	Stream gauge station number	Owner	Stream height	Streamflow	Used in 2010	Used in 2013	Used in 2015
Goovigen	130327A	DNRM	✓	✓		●	●
South Kariboe Creek	130334A	DNRM	✓	✓		✓	✓
Wura	130335A	DNRM	✓	✓		✓	✓
Folding Hills	130336A	DNRM	✓	✓		✓	✓
Windamere	130344A	DNRM	✓	✓		✓	✓
Red Hill	130348A	DNRM	✓	✓		✓	✓
Kingsborough	130349A	DNRM	✓	✓		✓	✓
Kenbula	130355A	DNRM	✓	✓			
Roundstone Creek	130363A	DNRM	✓	✓			
Dairy Creek	130364B	DNRM	✓	✓			
Arnold's Gully	130365A	DNRM	✓	✓			
Nelson's Gully	130366A	DNRM	✓	✓			
Workshop drain	130367A	DNRM	✓	✓			
Henry's Gully	130368A	DNRM	✓	✓			
Number 7 Dam Headwater	130369A	DNRM	✓	✓			
Fletcher Creek	130370A	DNRM	✓	✓			
Mundic Gully	130372A	DNRM	✓	✓			
Bindaree	130374A	DNRM	✓	✓	✓	✓	
Broadmere	130375A	DNRM	✓	✓			
Brookfield	130376A	DNRM	✓	✓			
Dululu	130378A	DNRM	✓	✓			✓

- *Gauge used partially for timing*

Appendix A-3
Structure Information

Structure	Drawings	Stage-Storage	Spillway discharge curve
Callide Dam	✓	✓	✓
Kroombit Dam	✓	✓	✓
Glebe Weir	✓	✓	✓
Neville Hewitt Weir	✓	✓	✓
Orange Creek Weir	✓	✓	✓
Theodore Weir	✓	✓	✓
Mour Weir	✓	✓	✓
Gyranda Weir	✓	✓	✓
Baralaba Anabranch weir			

Appendix A-4

Design Rainfall

Dawson catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	77.32	89.88	107.00	120.60	144.72	154.90	188.00	-
30 min	55.16	64.02	76.04	85.72	102.86	110.10	133.70	-
1 hour	37.88	43.88	52.02	58.64	70.37	75.33	91.44	-
2 hours	22.56	26.18	31.09	35.04	42.05	45.02	54.65	-
3 hours	16.66	19.35	23.01	25.93	31.12	33.31	40.44	-
4.5 hours	12.23	14.22	16.93	19.08	22.90	24.51	29.76	-
6 hours	9.83	11.43	13.62	15.35	18.42	19.72	23.94	-
9 hours	7.23	8.42	10.04	11.32	13.58	14.54	17.64	-
12 hours	5.81	6.77	8.09	9.11	10.94	11.71	14.21	39.49
18 hours	4.47	5.23	6.27	7.07	8.48	9.08	11.02	24.44
24 hours	3.70	4.35	5.23	5.89	7.07	7.57	9.19	16.92
36 hours	3.02	3.54	4.26	4.79	5.74	6.10	7.34	13.88
48 hours	2.61	3.06	3.68	4.13	4.96	5.24	6.26	12.21
72 hours	2.04	2.40	2.88	3.24	3.89	4.11	4.90	10.28
96 hours	1.67	1.96	2.35	2.64	3.17	3.34	3.97	8.64
120 hours	1.41	1.65	1.99	2.23	2.67	2.81	3.33	7.11

Don-Dee catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	90.36	105.20	125.30	142.00	170.40	185.00	227.40	336.60
30 min	64.16	74.45	88.43	100.20	120.24	130.60	160.50	255.75
1 hour	43.82	50.69	59.98	67.96	81.55	88.56	108.80	195.53
2 hours	26.71	30.98	36.77	41.66	49.99	54.28	66.71	158.81
3 hours	19.99	23.23	27.62	31.29	37.55	40.77	50.11	126.50
4.5 hours	14.89	17.33	20.64	23.39	28.07	30.48	37.46	-
6 hours	12.08	14.08	16.79	19.03	22.84	24.79	30.47	81.54
9 hours	9.01	10.52	12.57	14.25	17.10	18.56	22.82	-
12 hours	7.32	8.56	10.24	11.61	13.93	15.12	18.59	48.37
18 hours	5.71	6.72	8.12	9.20	11.04	11.99	14.74	36.78
24 hours	4.77	5.65	6.87	7.79	9.34	10.15	12.47	29.85
36 hours	3.90	4.62	5.62	6.36	7.63	8.20	9.95	23.27
48 hours	3.38	4.01	4.88	5.51	6.61	7.05	8.47	19.79
72 hours	2.66	3.16	3.84	4.34	5.21	5.56	6.66	15.99
96 hours	2.16	2.56	3.11	3.52	4.22	4.49	5.37	13.67
120 hours	1.79	2.12	2.58	2.92	3.50	3.72	4.45	11.51

Dee catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	109.90	127.20	150.50	170.80	204.96	222.20	271.40	336.60
30 min	78.18	90.16	106.30	120.60	144.72	156.90	191.70	255.75
1 hour	53.48	61.46	72.17	81.91	98.29	106.50	130.10	195.53
2 hours	33.76	39.21	46.61	52.91	63.49	68.80	84.04	158.81
3 hours	25.80	30.15	36.09	40.97	49.16	53.28	65.08	126.50
4.5 hours	19.62	23.06	27.81	31.57	37.88	41.06	50.15	-
6 hours	16.15	19.07	23.12	26.24	31.49	34.13	41.69	81.54
9 hours	12.29	14.61	17.84	20.25	24.30	26.34	32.17	-
12 hours	10.13	12.09	14.84	16.85	20.22	21.91	26.77	48.37
18 hours	7.90	9.49	11.72	13.30	15.96	17.30	21.13	36.78
24 hours	6.60	7.96	9.89	11.22	13.46	14.60	17.83	29.85
36 hours	5.45	6.57	8.16	9.24	11.09	11.84	14.21	23.27
48 hours	4.76	5.74	7.13	8.05	9.66	10.20	12.10	19.79
72 hours	3.68	4.43	5.50	6.22	7.47	7.89	9.34	15.99
96 hours	2.97	3.59	4.45	5.03	6.03	6.34	7.48	13.67
120 hours	2.45	2.95	3.66	4.13	4.96	5.22	6.16	11.51

Jambin catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	90.21	105.20	125.80	142.30	170.76	185.60	228.80	336.60
30 min	63.94	74.38	88.59	100.30	120.36	130.80	161.10	255.75
1 hour	43.59	50.54	59.98	67.88	81.46	88.53	109.10	195.53
2 hours	26.18	30.37	36.05	40.81	48.97	53.21	65.58	158.81
3 hours	19.43	22.54	26.77	30.30	36.36	39.51	48.69	126.50
4.5 hours	14.34	16.64	19.77	22.38	26.86	29.18	35.96	-
6 hours	11.56	13.42	15.95	18.05	21.66	23.54	29.00	81.54
9 hours	8.55	9.92	11.80	13.35	16.02	17.41	21.45	-
12 hours	6.90	8.01	9.52	10.78	12.94	14.06	17.32	48.37
18 hours	5.37	6.29	7.55	8.55	10.25	11.15	13.74	36.78
24 hours	4.48	5.28	6.39	7.23	8.68	9.43	11.63	29.85
36 hours	3.61	4.26	5.16	5.83	6.99	7.53	9.16	23.27
48 hours	3.10	3.66	4.43	5.00	6.00	6.41	7.73	19.79
72 hours	2.43	2.86	3.46	3.91	4.70	5.03	6.05	15.99
96 hours	1.96	2.31	2.80	3.16	3.80	4.05	4.86	13.67
120 hours	1.63	1.92	2.32	2.62	3.14	3.35	4.01	11.51

Thangool catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	97.53	113.90	136.20	153.20	183.84	196.00	236.90	336.60
30 min	68.90	80.16	95.50	107.40	128.88	137.50	166.10	255.75
1 hour	46.80	54.24	64.33	72.36	86.83	92.59	111.90	195.53
2 hours	28.10	32.55	38.57	43.39	52.07	55.52	67.11	158.81
3 hours	20.85	24.14	28.60	32.17	38.60	41.17	49.76	126.50
4.5 hours	15.38	17.81	21.09	23.72	28.47	30.35	36.69	-
6 hours	12.40	14.35	16.99	19.11	22.93	24.45	29.55	81.54
9 hours	9.16	10.60	12.55	14.11	16.93	18.05	21.82	-
12 hours	7.40	8.55	10.12	11.38	13.66	14.56	17.60	48.37
18 hours	5.67	6.62	7.92	8.91	10.69	11.40	13.78	36.78
24 hours	4.68	5.51	6.64	7.47	8.97	9.56	11.56	29.85
36 hours	3.66	4.30	5.19	5.85	7.02	7.47	8.99	23.27
48 hours	3.07	3.61	4.35	4.91	5.90	6.27	7.53	19.79
72 hours	2.36	2.78	3.35	3.78	4.53	4.82	5.79	15.99
96 hours	1.88	2.21	2.66	3.00	3.60	3.83	4.59	13.67
120 hours	1.55	1.82	2.20	2.47	2.97	3.15	3.77	11.51

Lower Kroombit catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	105.50	123.30	147.50	167.70	201.24	220.00	271.50	336.60
30 min	74.72	87.03	103.80	118.00	141.60	154.80	191.00	255.75
1 hour	50.89	59.08	70.21	79.81	95.77	104.70	129.20	195.53
2 hours	31.06	36.03	42.78	48.63	58.35	63.78	78.72	158.81
3 hours	23.27	26.98	32.02	36.39	43.67	47.73	58.91	126.50
4.5 hours	17.34	20.10	23.84	27.10	32.51	35.54	43.86	-
6 hours	14.08	16.31	19.34	21.98	26.38	28.83	35.58	81.54
9 hours	10.51	12.17	14.42	16.39	19.67	21.50	26.54	-
12 hours	8.55	9.89	11.71	13.31	15.97	17.46	21.55	48.37
18 hours	6.63	7.75	9.29	10.56	12.67	13.85	17.09	36.78
24 hours	5.52	6.50	7.86	8.94	10.73	11.72	14.47	29.85
36 hours	4.37	5.15	6.23	7.08	8.49	9.21	11.27	23.27
48 hours	3.70	4.37	5.28	6.00	7.19	7.77	9.44	19.79
72 hours	2.82	3.33	4.02	4.58	5.50	5.96	7.25	15.99
96 hours	2.25	2.65	3.21	3.65	4.38	4.74	5.77	13.67
120 hours	1.86	2.19	2.65	3.00	3.60	3.90	4.74	11.51

South Kariboe at the Pump Station catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	101.70	118.60	141.90	159.30	191.16	203.00	244.30	336.60
30 min	71.75	83.43	99.35	111.60	133.92	142.20	171.10	255.75
1 hour	48.68	56.38	66.83	75.05	90.06	95.63	115.10	195.53
2 hours	29.37	33.98	40.23	45.18	54.22	57.57	69.29	158.81
3 hours	21.86	25.27	29.90	33.58	40.30	42.78	51.49	126.50
4.5 hours	16.17	18.69	22.10	24.81	29.78	31.62	38.05	-
6 hours	13.06	15.09	17.83	20.02	24.02	25.51	30.70	81.54
9 hours	9.68	11.18	13.20	14.82	17.78	18.88	22.72	-
12 hours	7.83	9.03	10.66	11.97	14.36	15.25	18.35	48.37
18 hours	5.99	6.98	8.33	9.36	11.23	11.92	14.35	36.78
24 hours	4.94	5.80	6.98	7.84	9.41	9.99	12.02	29.85
36 hours	3.84	4.50	5.42	6.10	7.32	7.76	9.32	23.27
48 hours	3.21	3.76	4.53	5.10	6.12	6.49	7.78	19.79
72 hours	2.47	2.89	3.48	3.92	4.71	4.99	5.98	15.99
96 hours	1.96	2.30	2.76	3.11	3.73	3.96	4.74	13.67
120 hours	1.61	1.89	2.28	2.56	3.07	3.26	3.89	11.51

Kroombit Dam catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	110.40	129.00	154.40	176.10	211.32	232.70	289.10	336.60
30 min	78.21	91.10	108.70	123.90	148.68	163.70	203.40	255.75
1 hour	53.26	61.84	73.50	83.79	100.55	110.70	137.60	195.53
2 hours	32.84	38.08	45.21	51.53	61.84	68.10	84.62	158.81
3 hours	24.75	28.68	34.02	38.78	46.54	51.25	63.67	126.50
4.5 hours	18.56	21.49	25.47	29.03	34.84	38.37	47.67	-
6 hours	15.13	17.51	20.74	23.64	28.37	31.24	38.82	81.54
9 hours	11.36	13.13	15.55	17.73	21.27	23.42	29.10	-
12 hours	9.27	10.71	12.67	14.45	17.34	19.09	23.72	48.37
18 hours	7.17	8.39	10.06	11.46	13.75	15.15	18.82	36.78
24 hours	5.96	7.03	8.52	9.71	11.65	12.83	15.94	29.85
36 hours	4.74	5.59	6.77	7.71	9.25	10.10	12.42	23.27
48 hours	4.02	4.75	5.75	6.54	7.85	8.53	10.41	19.79
72 hours	3.08	3.63	4.40	5.02	6.03	6.57	8.02	15.99
96 hours	2.46	2.90	3.51	4.01	4.81	5.23	6.39	13.67
120 hours	2.03	2.40	2.90	3.30	3.96	4.31	5.26	11.51

Callide Dam catchment design rainfall intensity (mm/hr)

Duration	AEP							
	10%	5%	2%	1%	1%CC	0.20%	0.05%	PMP
15 min	112.70	131.30	156.60	179.40	215.28	239.20	299.20	336.60
30 min	80.01	92.97	110.60	126.70	152.04	168.90	211.30	255.75
1 hour	54.65	63.32	75.09	85.99	103.19	114.70	143.40	195.53
2 hours	33.55	38.96	46.31	53.04	63.65	70.73	88.47	158.81
3 hours	25.22	29.33	34.91	39.98	47.98	53.31	66.69	126.50
4.5 hours	18.86	21.96	26.18	29.99	35.98	39.98	50.02	-
6 hours	15.35	17.89	21.35	24.45	29.34	32.60	40.78	81.54
9 hours	11.50	13.42	16.04	18.36	22.04	24.49	30.64	-
12 hours	9.37	10.94	13.09	14.99	17.99	19.99	25.01	48.37
18 hours	7.44	8.80	10.67	12.22	14.66	16.30	20.39	36.78
24 hours	6.31	7.52	9.21	10.55	12.66	14.07	17.60	29.85
36 hours	5.02	5.99	7.34	8.38	10.06	11.06	13.67	23.27
48 hours	4.27	5.09	6.24	7.12	8.55	9.33	11.42	19.79
72 hours	3.30	3.93	4.81	5.52	6.62	7.26	8.90	15.99
96 hours	2.67	3.19	3.91	4.46	5.36	5.84	7.14	13.67
120 hours	2.22	2.64	3.24	3.69	4.43	4.83	5.89	11.51

Appendix A-5

Hydrology Model Setup

Dawson Model

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DW1	133.6	0.0%	0.3%	0.057
DW2	366.8	0.0%	0.4%	0.059
DW3	365.3	0.0%	0.2%	0.058
DW4	360.1	0.0%	0.3%	0.038
DW5	354.9	0.0%	0.2%	0.059
DW6	194.4	0.0%	0.2%	0.059
DW7	347.6	0.0%	0.3%	0.060
DW8	339.1	0.0%	0.5%	0.059
DW9	335.9	0.0%	0.3%	0.059
DW10	328.6	0.0%	0.5%	0.059
DW11	327.6	0.0%	0.2%	0.056
DW12	326.6	0.0%	0.3%	0.059
DW13	324.4	0.0%	0.5%	0.038
DW14	307.2	0.0%	0.4%	0.038
DW15	307.1	0.0%	0.2%	0.059
DW16	305.3	0.0%	0.2%	0.059
DW17	304.0	0.0%	0.2%	0.037
DW18	302.9	1.1%	0.4%	0.060
DW19	302.8	0.0%	0.1%	0.038
DW20	301.1	0.0%	0.1%	0.057
DW21	300.8	0.0%	0.5%	0.038
DW22	299.8	0.0%	0.2%	0.059
DW23	298.3	0.0%	0.1%	0.059
DW24	297.5	0.0%	0.2%	0.057
DW25	297.0	0.0%	0.4%	0.038
DW26	296.4	0.0%	0.4%	0.037
DW27	295.5	0.0%	1.2%	0.066
DW28	294.8	0.0%	0.5%	0.060
DW29	289.8	0.0%	0.2%	0.058
DW30	289.4	0.0%	0.4%	0.059
DW31	289.2	0.0%	0.4%	0.038
DW32	283.9	0.0%	0.3%	0.058
DW33	283.4	0.0%	0.3%	0.038
DW34	282.3	0.0%	0.2%	0.059
DW35	279.4	0.0%	0.4%	0.059
DW36	279.4	0.0%	0.3%	0.038
DW37	278.5	0.0%	0.1%	0.038
DW38	273.3	0.0%	0.3%	0.059
DW39	271.1	0.0%	0.4%	0.061

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DW40	269.6	0.0%	0.6%	0.060
DW41	269.6	0.0%	0.2%	0.038
DW42	266.7	3.2%	0.2%	0.063
DW43	264.8	0.0%	0.9%	0.063
DW44	262.3	0.0%	0.4%	0.038
DW45	260.5	0.0%	0.3%	0.038
DW46	260.4	0.0%	0.7%	0.041
DW47	259.3	0.0%	0.2%	0.059
DW48	257.2	0.0%	0.8%	0.059
DW49	254.4	0.0%	0.3%	0.059
DW50	254.1	0.0%	0.7%	0.060
DW51	254.1	0.0%	0.2%	0.038
DW52	251.6	0.0%	0.3%	0.059
DW53	251.1	1.2%	0.6%	0.062
DW54	247.4	0.0%	0.7%	0.059
DW55	245.6	0.0%	0.5%	0.038
DW56	245.3	0.0%	0.4%	0.038
DW57	245.2	0.0%	0.3%	0.059
DW58	244.9	0.0%	0.5%	0.059
DW59	442.8	0.0%	0.3%	0.059
DW60	241.3	0.0%	0.5%	0.062
DW61	239.3	0.0%	0.4%	0.038
DW62	238.6	0.0%	0.4%	0.059
DW63	238.5	0.0%	0.2%	0.059
DW64	237.4	0.0%	0.5%	0.059
DW65	236.3	0.0%	0.3%	0.059
DW66	235.6	0.0%	0.5%	0.069
DW67	235.6	0.0%	0.4%	0.061
DW68	234.0	0.0%	0.4%	0.059
DW69	233.8	0.0%	0.3%	0.059
DW70	233.4	0.0%	0.3%	0.059
DW71	233.4	0.0%	0.5%	0.038
DW72	232.6	0.0%	0.1%	0.059
DW73	231.8	0.0%	0.3%	0.038
DW74	231.8	0.0%	0.3%	0.060
DW75	231.5	0.0%	0.6%	0.059
DW76	230.9	0.0%	0.2%	0.057
DW77	230.5	0.0%	0.2%	0.037
DW78	230.2	0.0%	0.6%	0.059
DW79	229.9	0.0%	1.0%	0.060
DW80	229.9	0.0%	0.6%	0.038
DW81	229.6	0.0%	0.3%	0.057

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DW82	228.4	0.0%	0.3%	0.059
DW83	228.2	0.0%	0.1%	0.059
DW84	227.3	0.0%	0.8%	0.062
DW85	226.6	0.0%	0.2%	0.058
DW86	225.9	0.0%	0.3%	0.038
DW87	225.4	0.0%	0.3%	0.059
DW88	224.8	0.0%	0.7%	0.059
DW89	224.4	0.0%	0.4%	0.059
DW90	224.2	0.0%	0.4%	0.038
DW91	223.1	0.0%	0.5%	0.059
DW92	221.3	0.0%	0.4%	0.059
DW94	220.9	0.0%	0.2%	0.059
DW95	220.7	0.0%	0.4%	0.059
DW96	220.6	0.0%	0.5%	0.038
DW97	219.9	0.0%	0.5%	0.059
DW98	219.9	0.0%	0.2%	0.059
DW99	219.8	0.0%	0.3%	0.038
DW100	219.7	0.0%	0.5%	0.059
DW101	219.3	0.0%	0.5%	0.059
DW102	219.1	0.0%	0.8%	0.059
DW103	217.9	0.0%	0.1%	0.059
DW104	217.8	0.0%	0.6%	0.059
DW105	217.6	0.0%	0.7%	0.039
DW106	216.6	0.0%	0.3%	0.038
DW107	216.6	0.0%	0.2%	0.038
DW108	215.8	0.0%	0.5%	0.059
DW109	215.6	0.0%	0.6%	0.038
DW110	215.6	0.5%	0.2%	0.059
DW111	215.4	0.0%	0.6%	0.059
DW112	214.9	0.0%	0.6%	0.059
DW113	214.6	0.0%	0.4%	0.038
DW114	214.0	0.0%	0.3%	0.059
DW115	213.8	0.0%	0.3%	0.060
DW116	213.6	0.0%	0.7%	0.039
DW117	213.6	0.0%	0.1%	0.059
DW118	213.1	0.0%	1.0%	0.059
DW119	212.8	0.0%	0.5%	0.059
DW120	212.7	0.0%	0.4%	0.059
DW121	212.5	0.0%	0.3%	0.059
DW122	211.9	0.0%	0.8%	0.069
DW123	211.8	0.0%	0.7%	0.038
DW124	211.3	0.0%	0.4%	0.059

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DW125	210.6	0.0%	0.9%	0.038
DW126	210.6	0.0%	0.6%	0.059
DW127	209.8	0.0%	0.7%	0.059
DW128	209.8	0.0%	0.3%	0.038
DW129	209.7	0.0%	0.4%	0.038
DW130	209.7	0.0%	0.2%	0.059
DW131	209.4	0.0%	0.3%	0.059
DW132	209.2	0.0%	0.2%	0.058
DW133	209.1	0.0%	0.5%	0.059
DW134	208.4	0.0%	0.2%	0.059
DW135	208.1	0.0%	0.1%	0.059
DW136	207.8	0.0%	0.2%	0.038
DW137	207.6	0.0%	1.1%	0.060
DW138	176.6	0.0%	0.8%	0.059
DW139	207.4	0.0%	0.5%	0.039
DW140	207.3	0.0%	0.2%	0.038
DW141	207.2	0.0%	0.5%	0.038
DW142	207.2	0.0%	0.2%	0.059
DW143	207.2	0.0%	0.3%	0.059
DW144	206.9	0.0%	0.3%	0.039
DW145	206.8	0.0%	0.5%	0.060
DW146	206.7	0.0%	0.3%	0.038
DW147	206.6	0.0%	0.3%	0.059
DW148	206.4	0.0%	0.3%	0.038
DW149	205.8	0.0%	0.4%	0.038
DW150	205.6	0.0%	0.6%	0.059
DW151	205.6	0.0%	1.8%	0.067
DW152	205.6	0.0%	0.3%	0.061
DW153	205.2	0.0%	0.4%	0.059
DW154	205.1	0.0%	0.3%	0.038
DW155	205.0	0.0%	0.5%	0.038
DW156	205.0	0.0%	0.5%	0.038
DW157	204.8	0.0%	0.7%	0.059
DW158	204.8	0.0%	0.8%	0.059
DW159	204.8	0.0%	0.2%	0.037
DW160	204.4	0.0%	0.3%	0.059
DW161	204.3	0.0%	0.2%	0.038
DW162	204.1	0.0%	0.6%	0.061
DW163	204.0	0.0%	0.1%	0.039
DW164	203.8	0.0%	0.3%	0.059
DW165	203.4	0.0%	0.8%	0.059
DW166	203.3	0.0%	0.3%	0.059

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DW167	202.9	0.0%	0.4%	0.039
DW168	202.8	0.0%	0.2%	0.059
DW169	202.7	0.0%	0.3%	0.059
DW170	202.6	0.0%	0.5%	0.059
DW171	202.6	0.0%	0.4%	0.059
DW172	202.6	0.0%	0.1%	0.059
DW173	202.3	0.0%	0.5%	0.059
DW174	202.3	0.0%	0.4%	0.038
DW175	202.1	0.0%	0.5%	0.065
DW176	201.9	0.0%	0.5%	0.039
DW177	201.8	0.0%	0.2%	0.038
DW178	201.8	0.0%	0.2%	0.059
DW179	201.4	0.0%	0.2%	0.059
DW180	201.4	0.0%	0.3%	0.038
DW181	201.2	0.0%	0.2%	0.038
DW182	201.1	0.0%	0.5%	0.059
DW183	200.9	0.0%	0.4%	0.059
DW184	205.3	0.0%	0.3%	0.060
DW185	200.8	0.0%	0.2%	0.059
DW186	200.8	0.0%	0.3%	0.038
DW187	200.8	0.0%	0.5%	0.059
DW188	200.6	0.0%	0.4%	0.038
DW189	200.6	0.0%	0.3%	0.039
DW190	200.6	0.0%	0.4%	0.038
DW191	200.6	0.0%	0.2%	0.059
DW192	200.6	0.0%	0.3%	0.059
DW193	200.6	0.0%	0.1%	0.059
DW194	200.5	0.0%	0.7%	0.059
DW195	200.4	0.0%	0.4%	0.059
DW196	200.3	0.0%	0.8%	0.062
DW197	200.3	0.0%	0.5%	0.061
DW198	200.3	0.0%	0.3%	0.059
DW199	200.3	0.0%	0.2%	0.059
DW200	200.3	0.0%	0.5%	0.038
DW201	200.2	0.0%	0.2%	0.039
DW202	200.2	0.0%	0.2%	0.059
DW203	200.1	0.0%	0.1%	0.038
DW204	200.1	0.0%	0.7%	0.059
DW205	200.1	0.0%	0.6%	0.059
DW206	200.1	0.0%	0.5%	0.059
DW207	200.1	0.0%	0.4%	0.059
DW208	200.1	0.0%	0.4%	0.059

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DW209	200.1	0.0%	0.3%	0.059
DW210	200.1	0.0%	0.2%	0.037
DW211	200.1	0.0%	0.4%	0.038
DW212	200.1	0.0%	0.6%	0.059
DW213	200.1	0.0%	0.3%	0.038
DW214	200.1	0.0%	0.5%	0.043
DW215	200.1	0.0%	0.2%	0.038
DW216	200.1	0.0%	0.1%	0.060
DW217	436.3	1.0%	0.1%	0.060
DW218	201.4	0.0%	0.1%	0.059
DW219	160.1	0.0%	0.4%	0.052

Don-Dee Model

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DD1	152.3	2.9%	0.1%	0.039
DD2	29.9	3.1%	0.6%	0.039
DD3	75.1	1.8%	0.9%	0.011
DD4	69.8	1.6%	1.1%	0.010
DD5	80.6	2.6%	0.6%	0.009
DD6	106.0	3.0%	0.7%	0.009
DD7	75.2	1.1%	0.6%	0.039
DD8	16.3	9.7%	1.2%	0.007
DD9	75.7	1.7%	0.7%	0.035
DD10	85.4	0.7%	1.3%	0.035
DD11	82.2	0.8%	1.0%	0.042
DD12	75.1	1.5%	0.9%	0.040
DD13	51.8	0.5%	1.4%	0.042
DD14	76.0	1.4%	1.0%	0.035
DD15	94.1	0.9%	1.2%	0.044
DD16	78.6	0.9%	0.7%	0.043
DD17	75.1	1.8%	0.7%	0.039
DD18	82.4	1.3%	0.7%	0.035
DD19	24.6	2.2%	1.0%	0.039
DD20	76.1	0.4%	1.2%	0.042
DD21	66.5	1.5%	0.4%	0.036
DD22	88.1	2.5%	0.4%	0.048
DD23	12.8	1.1%	0.8%	0.037
DD24	117.9	0.0%	3.0%	0.035
DD25	84.0	1.8%	0.4%	0.025
DD26	8.1	0.4%	0.6%	0.018

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DD27	41.0	1.1%	0.6%	0.039
DD28	60.2	2.8%	0.7%	0.024
DD29	67.8	1.0%	1.6%	0.028
DD30	42.4	4.4%	0.2%	0.029
DD31	99.3	1.2%	0.4%	0.040
DD32	44.2	1.8%	0.5%	0.010
DD33	70.0	1.5%	0.3%	0.017
DD34	17.5	2.5%	1.2%	0.012
DD35	76.7	1.4%	1.8%	0.016
DD36	41.3	1.6%	0.1%	0.033
DD37	76.4	1.8%	0.9%	0.015
DD38	88.4	1.1%	0.5%	0.039
DD39	107.8	1.7%	0.7%	0.039
DD40	88.3	0.5%	1.6%	0.012
DD41	69.6	0.8%	1.2%	0.016
DD42	122.3	3.6%	1.0%	0.012
DD43	67.4	2.1%	0.3%	0.013
DD44	31.3	2.0%	0.3%	0.013
DD45	75.1	4.2%	1.0%	0.020
DD46	27.7	3.0%	0.2%	0.013
DD47	71.5	1.5%	0.2%	0.051
DD48	76.0	3.5%	0.6%	0.020
DD49	33.6	1.7%	0.5%	0.020
DD50	29.9	2.6%	0.4%	0.019
DD51	55.7	1.6%	0.6%	0.019
DD52	75.1	1.8%	0.5%	0.022
DD53	76.5	0.9%	0.8%	0.019
DD54	89.6	0.8%	0.8%	0.020
DD55	91.6	1.1%	0.5%	0.040
DD56	78.0	2.2%	0.2%	0.023
DD57	49.7	3.1%	0.0%	0.020
DD58	75.1	2.9%	0.7%	0.026
DD59	76.0	1.0%	0.7%	0.025
DD60	89.1	1.9%	0.3%	0.039
DD61	75.1	1.9%	0.6%	0.019
DD62	67.2	2.4%	0.1%	0.021
DD63	37.9	4.0%	0.1%	0.025
DD64	76.8	0.5%	1.4%	0.024
DD65	114.0	1.7%	0.3%	0.020
DD66	109.5	2.5%	0.2%	0.020
DD67	31.8	4.2%	0.2%	0.042
DD68	75.1	1.3%	0.7%	0.019

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DD69	77.6	0.6%	1.0%	0.041
DD70	99.8	2.2%	0.8%	0.019
DD71	33.9	3.5%	0.5%	0.041
DD72	84.0	1.5%	0.8%	0.019
DD73	89.8	1.9%	0.7%	0.020
DD74	49.6	3.5%	0.3%	0.040
DD75	54.5	2.3%	0.5%	0.040
DD76	47.1	3.1%	0.4%	0.037
DD77	58.8	1.0%	1.0%	0.040
DD78	25.5	5.4%	2.1%	0.023
DD79	13.9	0.0%	2.7%	0.023
DD80	43.3	1.6%	0.7%	0.028
DD81	41.7	0.0%	3.2%	0.035
DD82	13.5	5.2%	0.5%	0.011
DD83	44.3	1.4%	0.6%	0.012
DD84	23.1	0.0%	1.4%	0.012
DD85	30.6	1.1%	1.5%	0.039
DD86	51.8	2.8%	0.7%	0.039
DD87	27.7	2.4%	0.2%	0.042
DD88	17.3	2.0%	0.8%	0.039
DD89	31.2	2.2%	0.2%	0.056
DD90	40.4	3.2%	0.2%	0.028
DD91	47.3	1.5%	0.6%	0.045
DD92	41.7	1.0%	0.5%	0.042
DD93	42.1	1.2%	0.8%	0.013
DD94	52.7	1.2%	0.8%	0.012
DD95	16.1	2.4%	0.3%	0.014
DD96	69.4	2.0%	0.1%	0.031
DD97	47.0	2.5%	0.3%	0.021
DD98	18.5	0.8%	0.5%	0.050
DD99	15.0	2.0%	0.4%	0.019
DD100	19.6	2.0%	0.1%	0.032
DD101	38.4	2.3%	0.4%	0.019
DD102	58.1	2.3%	0.7%	0.020
DD103	51.6	0.4%	1.1%	0.020
DD104	26.7	2.5%	0.7%	0.039
DD105	24.4	2.5%	1.0%	0.040
DD106	45.9	4.1%	0.2%	0.045
DD107	26.7	4.5%	0.3%	0.040
DD108	12.8	6.3%	0.0%	0.043
DD109	45.8	2.8%	0.1%	0.019
DD110	61.2	2.4%	1.5%	0.012

Subcatchment ID	Catchment Area (km2)	Percent Impervious (%)	Catchment Slope (%)	Manning's 'n'
DD111	16.8	3.0%	1.4%	0.009
DD112	8.7	6.6%	1.9%	0.008
DD113	16.5	5.5%	0.8%	0.009
DD114	52.2	1.9%	1.0%	0.039
DD115	47.4	0.8%	0.2%	0.040
DD116	67.9	1.4%	0.4%	0.051

Appendix A-6
Hydrology Model Results

Dawson Model

Subcatchment ID	Historic events		Design							
	2010 event	2013 event	10%	5%	2%	1%	1% CC	0.20%	0.05%	PMF
DW1	10,167	8,283	2,757	4,174	6,976	9,294	12,553	13,658	17,841	47,577
DW2	637	673	117	180	309	443	610	682	928	4,932
DW3	1,695	18	382	586	989	1,413	1,949	2,187	2,982	14,723
DW4	756	0	313	453	726	976	1,291	1,425	1,887	4,463
DW5	644	599	165	258	449	625	872	982	1,360	6,896
DW6	10,149	8,140	2,742	4,152	6,942	9,253	12,505	13,606	17,779	47,184
DW7	156	49	50	79	142	198	274	305	411	1,892
DW8	456	41	145	224	384	538	736	827	1,115	5,320
DW9	10,061	7,267	2,661	4,036	6,752	9,012	12,195	13,271	17,349	45,844
DW10	211	0	110	170	287	414	574	645	879	4,539
DW11	416	486	290	433	755	1,062	1,439	1,606	2,193	10,959
DW12	796	478	292	434	718	1,002	1,360	1,519	2,031	8,270
DW13	247	0	96	142	253	357	485	543	717	4,192
DW14	258	0	76	116	201	288	395	443	607	3,246
DW15	602	932	259	397	675	955	1,307	1,462	1,998	9,263
DW16	6,352	2,570	1,782	2,727	4,581	6,091	8,215	8,938	11,667	30,747
DW17	2,895	89	787	1,155	1,736	2,373	3,155	3,488	4,608	11,017
DW18	713	774	70	116	216	297	427	472	650	3,194
DW19	8,711	238	2,622	3,792	5,791	7,760	10,219	11,268	14,760	37,856
DW20	2,231	80	558	860	1,459	2,047	2,808	3,146	4,280	13,479
DW21	315	0	142	206	352	477	638	700	917	4,099
DW22	275	505	153	242	423	577	802	903	1,246	6,013
DW23	1,278	1,039	461	709	1,181	1,657	2,261	2,547	3,504	9,539
DW24	1,876	49	457	700	1,188	1,682	2,316	2,595	3,529	14,841
DW25	303	57	77	116	203	289	396	443	605	3,281
DW26	524	7	124	181	313	423	560	622	822	3,603
DW27	258	835	76	113	210	294	399	446	603	3,424
DW28	283	14	83	131	229	314	434	490	672	3,308
DW29	1,111	902	243	377	655	909	1,266	1,423	1,964	9,762
DW30	168	218	95	148	251	356	495	557	768	3,862
DW31	127	0	78	118	208	295	402	449	610	3,373
DW32	253	21	43	68	126	174	239	264	359	1,747
DW33	375	56	66	102	173	249	345	388	535	2,788
DW34	2,090	686	822	1,244	2,075	2,925	4,008	4,490	6,101	20,247
DW35	890	1,394	281	422	742	1,046	1,428	1,594	2,148	11,238
DW36	402	0	156	232	411	576	778	870	1,143	6,244
DW37	4,620	200	1,309	1,865	2,869	3,941	5,215	5,765	7,623	18,797
DW38	1,112	197	411	631	1,099	1,525	2,111	2,370	3,249	14,967
DW39	498	11	132	206	357	496	694	782	1,082	5,367
DW40	343	665	57	89	150	217	301	338	468	2,379
DW41	4,161	137	1,209	1,722	2,726	3,727	4,956	5,490	7,301	17,485

Subcatchment ID	Historic events		Design							
	2010 event	2013 event	10%	5%	2%	1%	1% CC	0.20%	0.05%	PMF
DW42	94	183	68	106	191	262	362	400	541	2,439
DW43	210	858	72	109	192	272	372	415	566	3,139
DW44	525	0	130	188	337	458	611	678	906	4,389
DW45	725	7	169	243	405	561	761	847	1,146	4,604
DW46	1,342	2	308	435	738	1,007	1,329	1,467	1,934	5,991
DW47	1,225	198	479	736	1,268	1,759	2,419	2,715	3,704	15,982
DW48	117	84	111	168	291	409	557	621	829	4,309
DW49	3,856	5,886	1,062	1,604	2,548	3,517	4,750	5,296	7,109	20,721
DW50	399	699	130	192	345	481	653	727	974	5,283
DW51	1,509	9	363	524	869	1,204	1,622	1,801	2,405	6,483
DW52	149	136	35	56	99	139	194	215	293	1,278
DW53	300	170	60	91	149	215	296	332	456	2,260
DW54	273	81	108	164	284	404	550	619	833	4,273
DW55	574	0	205	292	525	758	995	1,102	1,427	6,530
DW56	162	0	69	104	184	260	355	396	537	2,975
DW57	58	957	69	109	201	276	378	419	574	2,780
DW58	571	0	99	150	261	374	509	570	773	4,139
DW59	6,380	2,592	1,801	2,751	4,613	6,129	8,260	8,984	11,721	30,933
DW60	283	2	48	77	129	184	257	291	401	1,984
DW61	1,731	0	619	872	1,498	2,057	2,740	3,030	3,995	14,338
DW62	270	0	151	233	392	564	779	873	1,191	5,891
DW63	5,278	304	1,708	2,532	4,161	5,482	7,282	7,893	10,190	25,956
DW64	52	47	47	75	127	180	252	284	393	2,035
DW65	4,067	6,276	1,121	1,690	2,653	3,637	4,895	5,450	7,294	19,030
DW66	278	114	91	140	236	342	475	534	734	3,737
DW67	126	490	114	168	302	415	558	622	846	4,954
DW68	3,953	6,087	1,092	1,648	2,591	3,573	4,816	5,366	7,190	18,599
DW69	1,753	3,355	548	841	1,462	2,086	2,872	3,215	4,395	20,729
DW70	1,401	13	305	469	790	1,140	1,575	1,767	2,420	12,314
DW71	423	0	185	260	429	603	807	898	1,195	4,466
DW72	3,277	4,402	896	1,361	2,236	3,122	4,211	4,683	6,329	16,201
DW73	735	0	284	412	714	973	1,305	1,455	1,974	8,359
DW74	295	1,445	169	267	479	652	889	996	1,379	6,485
DW75	336	483	107	162	283	402	549	614	830	4,389
DW76	2,476	3,835	715	1,085	1,852	2,611	3,556	3,969	5,360	18,454
DW77	2,070	13	502	727	1,162	1,612	2,157	2,388	3,165	7,966
DW78	163	2	53	82	139	201	279	313	430	2,297
DW79	182	431	70	103	187	260	353	392	528	3,066
DW80	715	0	251	350	618	867	1,122	1,236	1,608	6,759
DW81	32	75	36	57	106	146	199	219	306	1,475
DW82	183	1,320	138	218	393	534	730	819	1,136	5,477
DW83	6,159	2,283	1,651	2,535	4,280	5,706	7,714	8,396	10,979	28,559
DW84	5,287	306	1,716	2,542	4,174	5,498	7,298	7,910	10,208	26,014
DW85	6,319	2,542	1,764	2,704	4,547	6,049	8,164	8,883	11,601	30,545

Subcatchment ID	Historic events		Design							
	2010 event	2013 event	10%	5%	2%	1%	1% CC	0.20%	0.05%	PMF
DW86	159	0	56	86	148	213	293	328	447	2,380
DW87	5,296	308	1,723	2,550	4,185	5,510	7,312	7,924	10,223	26,057
DW88	116	153	58	88	154	220	302	338	459	2,483
DW89	106	38	83	129	220	311	433	488	674	3,384
DW90	525	0	221	312	507	699	922	1,020	1,337	4,041
DW91	224	0	96	146	250	360	495	556	757	3,922
DW92	135	56	43	66	115	160	224	252	350	1,740
DW94	2,613	3,891	741	1,127	1,910	2,693	3,666	4,090	5,519	14,131
DW95	93	2	41	64	113	154	217	244	340	1,682
DW96	196	0	67	99	179	250	338	376	506	2,949
DW97	123	153	99	150	258	370	507	568	772	4,020
DW98	9,413	765	2,960	4,284	6,578	8,835	11,805	12,813	16,593	44,469
DW99	282	0	113	170	282	389	527	588	790	3,348
DW100	261	307	158	234	412	575	775	865	1,154	5,875
DW101	561	316	181	269	457	633	858	955	1,276	5,611
DW102	164	122	60	91	161	228	312	348	471	2,608
DW103	6,311	2,519	1,751	2,685	4,521	6,017	8,125	8,842	11,551	30,364
DW104	53	44	52	80	136	197	272	306	418	2,187
DW105	480	117	78	112	210	291	390	434	586	3,457
DW106	398	66	115	169	275	374	498	552	731	2,358
DW107	1,256	0	535	770	1,223	1,642	2,168	2,386	3,137	7,701
DW108	178	172	45	70	117	169	235	265	366	1,852
DW109	298	0	72	105	196	265	360	401	542	3,234
DW110	1,626	3,256	515	791	1,381	1,972	2,720	3,047	4,170	21,219
DW111	130	55	50	78	132	192	265	299	408	2,126
DW112	90	0	48	75	126	183	254	287	393	2,019
DW113	347	0	118	171	305	417	560	619	828	4,100
DW114	27	452	33	51	96	132	181	201	274	1,324
DW115	5,290	306	1,719	2,545	4,178	5,502	7,303	7,915	10,213	26,029
DW116	1,795	2	438	627	1,014	1,392	1,872	2,080	2,786	7,809
DW117	5,261	304	1,691	2,511	4,133	5,449	7,244	7,854	10,147	25,824
DW118	503	1,088	134	198	353	485	649	724	963	5,149
DW119	254	63	90	140	249	338	467	524	723	3,594
DW120	4,134	6,369	1,144	1,722	2,699	3,677	4,941	5,499	7,376	19,358
DW121	5,302	311	1,728	2,556	4,193	5,519	7,321	7,934	10,233	26,087
DW122	157	60	51	79	136	196	270	303	414	2,177
DW123	1,826	0	646	913	1,531	2,095	2,784	3,076	4,052	12,668
DW124	229	150	35	56	102	139	190	215	301	1,459
DW125	210	0	85	123	227	337	450	504	664	3,910
DW126	104	0	49	76	129	187	258	291	398	2,070
DW127	184	286	56	85	151	214	292	327	442	2,432
DW128	998	0	227	327	594	816	1,102	1,226	1,643	8,192
DW129	275	7	57	86	153	217	297	332	447	2,477
DW130	3,638	1,998	1,233	1,886	3,102	4,157	5,656	6,318	8,535	22,012

Subcatchment ID	Historic events		Design							
	2010 event	2013 event	10%	5%	2%	1%	1% CC	0.20%	0.05%	PMF
DW131	4,205	6,444	1,165	1,750	2,739	3,712	4,983	5,543	7,448	19,653
DW132	6,337	2,286	1,621	2,504	4,216	5,611	7,596	8,272	10,833	28,098
DW133	77	90	45	71	117	171	238	268	370	1,890
DW134	9,394	760	2,967	4,292	6,599	8,871	11,842	12,853	16,641	44,570
DW135	1,218	1,011	440	674	1,127	1,593	2,170	2,444	3,361	9,136
DW136	5,870	222	1,865	2,658	4,112	5,559	7,331	8,095	10,630	26,852
DW137	412	1,173	68	99	183	250	336	374	506	3,015
DW138	306	0	52	78	141	198	267	299	398	2,291
DW139	518	0	122	176	319	439	591	659	875	4,508
DW140	1,136	0	484	696	1,146	1,550	2,041	2,252	2,964	6,964
DW141	340	0	62	92	167	233	317	352	471	2,738
DW142	365	24	106	166	289	402	560	630	872	4,398
DW143	213	39	64	102	185	252	344	385	538	2,656
DW144	3,698	14	1,131	1,608	2,599	3,572	4,739	5,242	6,965	16,596
DW145	134	52	45	71	117	171	238	268	369	1,890
DW146	119	0	49	75	127	184	255	287	393	2,050
DW147	364	967	106	160	288	409	558	627	853	4,634
DW148	471	73	139	201	300	402	531	582	765	2,095
DW149	184	2	60	89	160	225	306	341	457	2,597
DW150	54	58	47	73	123	179	249	280	384	1,967
DW151	86	327	77	111	207	295	391	437	588	3,483
DW152	5,287	306	1,715	2,541	4,173	5,497	7,298	7,910	10,208	26,011
DW153	86	245	41	63	108	152	213	239	332	1,621
DW154	654	0	166	238	411	559	733	811	1,066	3,747
DW155	389	0	146	210	383	561	747	832	1,091	5,682
DW156	108	0	63	93	170	236	319	355	472	2,793
DW157	130	113	52	80	139	200	273	306	416	2,195
DW158	282	348	58	87	156	220	300	334	448	2,556
DW159	5,783	200	1,840	2,623	4,085	5,519	7,286	8,049	10,579	26,356
DW160	829	501	322	478	780	1,094	1,481	1,652	2,227	8,596
DW161	2,467	15	655	954	1,419	2,018	2,690	2,974	3,934	9,229
DW162	53	13	46	71	118	172	239	270	371	1,908
DW163	4,038	134	1,180	1,680	2,677	3,669	4,871	5,400	7,193	17,123
DW164	276	11	84	132	224	322	446	503	692	3,570
DW165	229	256	113	168	298	416	560	624	834	4,412
DW166	130	618	142	214	375	519	704	784	1,062	6,031
DW167	1,117	0	269	383	680	934	1,246	1,380	1,834	8,669
DW168	294	19	87	135	250	348	479	533	715	3,420
DW169	127	2	33	53	96	131	178	201	281	1,363
DW170	237	83	88	135	227	328	454	509	697	3,535
DW171	653	360	215	319	539	745	999	1,115	1,508	6,293
DW172	327	738	202	304	528	737	1,005	1,122	1,525	8,088
DW173	301	309	89	136	231	333	461	517	706	3,578
DW174	104	0	59	88	158	222	302	336	450	2,548

Subcatchment ID	Historic events		Design							
	2010 event	2013 event	10%	5%	2%	1%	1% CC	0.20%	0.05%	PMF
DW175	221	4	41	64	109	155	217	243	337	1,694
DW176	263	0	64	94	172	237	320	355	477	2,825
DW177	8,733	243	2,627	3,801	5,797	7,769	10,228	11,278	14,770	38,025
DW178	677	1,846	123	192	332	464	648	728	1,012	5,048
DW179	738	131	255	391	671	940	1,302	1,462	2,018	9,551
DW180	5,801	203	1,847	2,634	4,093	5,530	7,299	8,062	10,593	26,426
DW181	195	0	92	137	238	330	440	487	645	2,911
DW182	274	859	42	65	110	158	221	249	344	1,734
DW183	55	0	36	57	102	137	194	219	306	1,537
DW184	102	1	31	47	87	121	167	185	249	1,152
DW185	319	0	177	273	461	658	909	1,018	1,393	6,731
DW186	344	0	148	213	329	449	600	651	850	2,240
DW187	259	125	44	68	113	164	229	258	356	1,778
DW188	262	38	54	81	143	205	279	313	423	2,317
DW189	512	0	199	292	512	706	948	1,055	1,377	7,009
DW190	306	0	113	166	266	364	484	538	717	2,560
DW191	211	332	121	190	327	455	632	712	984	4,843
DW192	118	9	31	49	91	125	171	190	262	1,262
DW193	3,082	1,143	1,011	1,546	2,547	3,547	4,877	5,468	7,471	19,090
DW194	128	0	51	78	135	194	266	299	407	2,177
DW195	96	337	36	57	102	137	193	218	305	1,534
DW196	427	255	139	209	355	497	676	754	1,017	4,710
DW197	63	0	41	64	108	154	216	243	337	1,692
DW198	223	523	32	51	94	128	175	195	273	1,325
DW199	801	1,525	153	233	399	565	772	863	1,174	6,344
DW200	159	0	64	94	173	238	320	355	479	2,840
DW201	87	0	38	60	104	143	202	227	316	1,562
DW202	821	1,722	178	271	461	656	899	1,006	1,375	7,267
DW203	171	0	67	106	187	253	353	398	552	2,663
DW204	89	89	51	78	135	194	266	299	406	2,175
DW205	232	2	46	71	120	174	241	271	373	1,929
DW206	230	0	45	69	115	168	233	263	362	1,859
DW207	112	9	36	57	102	137	193	218	305	1,532
DW208	117	132	36	56	101	135	190	214	300	1,462
DW209	5,307	313	1,731	2,560	4,197	5,524	7,327	7,940	10,239	26,105
DW210	321	2	92	136	233	318	423	467	613	1,540
DW211	327	0	136	197	289	390	524	569	750	2,231
DW212	167	198	47	73	124	180	249	280	383	1,964
DW213	217	0	44	68	113	164	229	258	355	1,779
DW214	2,062	14	465	665	1,049	1,458	1,955	2,169	2,896	8,297
DW215	4,373	199	1,254	1,785	2,789	3,820	5,070	5,612	7,442	18,059
DW216	4,726	536	1,546	2,287	3,769	4,966	6,582	7,133	9,195	23,720
DW217	4,740	587	1,556	2,300	3,785	4,986	6,604	7,156	9,220	23,766
DW218	4,442	370	1,455	2,151	3,547	4,674	6,189	6,705	8,638	22,397

Subcatchment ID	Historic events		Design							
	2010 event	2013 event	10%	5%	2%	1%	1% CC	0.20%	0.05%	PMF
DW219	75	467	37	57	98	141	196	220	302	1,557

Don-Dee Model

Subcatchment ID	Historic events				Design						
	1978 event	2010 event	2013 event	2015 event	10%	5%	2%	1%	1% CC	0.20%	0.05%
DD1	4,000	3,910	4,983	4,168	1,905	2,695	4,601	5,928	7,726	8,518	11,096
DD2	1,067	2,253	3,060	3,536	1,436	1,846	3,014	3,837	4,992	5,243	6,701
DD3	250	631	777	798	421	543	867	1,135	1,541	1,657	2,128
DD4	622	1,514	1,811	1,959	1,011	1,297	2,085	2,658	3,442	3,627	4,663
DD5	1,012	2,140	2,813	3,310	1,381	1,766	2,829	3,573	4,630	4,858	6,173
DD6	325	764	777	1,035	420	567	968	1,297	1,766	1,858	2,451
DD7	10	118	86	8	12	19	62	94	126	144	200
DD8	163	338	450	625	308	409	638	772	1,007	1,057	1,333
DD9	19	363	272	317	24	46	146	217	288	325	440
DD10	25	142	125	65	19	37	106	155	201	224	296
DD11	24	222	167	21	24	44	136	203	269	304	413
DD12	66	263	343	689	222	302	521	678	875	947	1,211
DD13	14	94	126	211	32	50	110	157	206	225	289
DD14	39	440	361	375	36	72	210	309	409	460	620
DD15	32	171	264	498	170	227	363	463	600	649	830
DD16	38	305	206	50	33	62	193	284	380	429	586
DD17	136	248	239	514	175	238	429	569	733	799	1,026
DD18	44	132	108	68	15	25	76	115	155	175	239
DD19	81	380	266	119	45	88	258	385	512	577	782
DD20	88	153	186	384	137	182	300	387	499	544	696
DD21	41	210	191	99	25	50	153	224	296	333	448
DD22	445	1,319	1,581	2,188	529	804	1,679	2,268	2,934	3,225	4,209
DD23	57	153	126	94	16	30	89	133	179	202	275
DD24	269	248	727	1,394	328	448	786	1,047	1,340	1,530	2,036
DD25	829	728	1,142	2,401	627	890	1,711	2,284	2,921	3,320	4,382
DD26	697	378	1,140	2,267	565	796	1,502	2,009	2,571	2,926	3,875
DD27	103	404	288	170	50	98	285	421	559	629	855
DD28	773	547	1,142	2,326	609	859	1,623	2,162	2,764	3,140	4,149
DD29	284	239	471	1,040	279	387	695	908	1,153	1,301	1,709
DD30	846	768	1,142	2,455	630	897	1,736	2,321	2,973	3,380	4,465
DD31	149	462	347	279	62	117	345	511	678	765	1,035
DD32	811	890	2,071	4,788	1,370	1,798	2,978	4,788	4,826	4,898	5,120
DD33	844	906	2,099	4,951	1,409	1,860	3,092	4,933	5,008	5,100	5,387
DD34	1,793	2,309	0	4,763	1,622	2,151	3,549	4,416	5,497	6,226	8,094
DD35	265	422	0	1,268	524	668	1,073	1,376	1,738	2,013	2,638
DD36	1,396	2,397	2,868	4,072	975	1,432	3,077	4,282	5,527	6,205	8,208
DD37	534	591	0	1,516	810	1,055	1,695	2,151	2,667	3,063	3,981

DD38	44	103	74	91	13	20	64	99	134	153	211
DD39	31	160	96	55	38	55	85	133	180	197	257
DD40	447	900	0	1,346	522	674	1,142	1,478	1,866	2,131	2,840
DD41	282	481	146	773	37	61	171	255	326	360	470
DD42	642	942	0	1,242	364	519	943	1,262	1,617	1,860	2,505
DD43	807	926	1,803	2,620	848	1,151	2,010	2,577	3,195	3,606	4,433
DD44	780	850	1,692	2,199	674	919	1,617	2,080	2,580	2,910	3,683
DD45	320	102	213	599	57	81	156	220	280	302	376
DD46	2,059	2,676	4,219	5,143	1,447	2,060	4,092	5,470	6,932	7,755	10,087
DD47	89	409	201	147	83	126	191	253	344	377	494
DD48	374	85	274	399	45	63	118	175	231	250	319
DD49	1,238	358	652	1,711	198	281	524	739	952	1,030	1,288
DD50	1,332	410	660	1,871	231	324	592	848	1,086	1,171	1,456
DD51	1,308	398	656	1,834	222	312	573	820	1,052	1,135	1,414
DD52	52	44	143	119	37	54	104	151	199	216	275
DD53	546	285	343	791	99	141	263	373	479	517	642
DD54	293	179	230	454	54	78	154	229	299	323	407
DD55	4	28	97	36	29	44	66	101	137	150	198
DD56	58	36	69	116	27	40	58	91	124	135	178
DD57	2,738	3,166	4,421	4,711	1,409	2,025	3,940	5,232	6,650	7,411	9,617
DD58	516	509	524	607	69	102	182	276	363	394	501
DD59	299	297	315	338	36	53	101	148	195	212	270
DD60	4,240	4,090	5,504	4,965	2,020	2,842	4,765	6,103	7,960	8,772	11,447
DD61	875	682	1,137	996	146	210	383	560	722	780	977
DD62	29	51	75	67	23	33	48	68	93	102	133
DD63	4,495	4,445	6,528	7,033	2,162	3,005	4,885	6,178	8,061	8,848	11,541
DD64	298	376	481	507	51	73	145	213	274	296	368
DD65	1,412	1,225	2,421	2,417	291	420	761	1,094	1,404	1,514	1,888
DD66	1,632	1,719	3,071	3,200	398	571	1,010	1,432	1,841	1,985	2,493
DD67	14	117	273	90	54	82	123	189	250	273	352
DD68	437	653	1,065	1,062	109	154	290	411	526	566	706
DD69	10	270	168	223	13	25	76	115	153	173	237
DD70	314	502	752	731	65	93	179	267	346	373	469
DD71	6	78	182	56	36	54	95	144	190	207	265
DD72	172	425	511	561	56	79	156	231	298	321	400
DD73	256	673	648	744	103	147	283	407	523	564	704
DD74	1,080	2,277	3,132	3,592	1,443	1,858	3,066	3,912	5,099	5,357	6,860
DD75	241	616	782	1,467	430	610	1,138	1,474	1,886	2,047	2,597
DD76	60	480	411	405	42	83	242	357	471	532	722
DD77	36	90	51	43	11	22	64	96	127	143	193
DD78	60	91	16	94	26	41	113	158	200	227	301
DD79	46	119	49	114	36	51	105	142	178	200	260
DD80	372	267	760	1,571	379	526	970	1,304	1,668	1,899	2,531
DD81	121	126	273	606	155	210	357	461	576	648	846
DD82	814	892	2,079	4,841	1,393	1,830	3,020	4,836	4,889	4,974	5,229
DD83	1,684	2,116	0	4,429	1,584	2,094	3,419	4,232	5,228	5,919	7,682
DD84	91	214	66	343	18	24	77	106	139	156	210

DD85	59	166	0	214	23	37	97	142	184	212	287
DD86	93	363	487	956	263	364	681	889	1,144	1,236	1,570
DD87	13	36	22	40	5	6	16	24	33	39	55
DD88	20	34	17	55	4	8	23	33	42	46	61
DD89	454	1,338	1,597	2,221	531	807	1,690	2,285	2,957	3,251	4,247
DD90	30	78	12	78	9	10	29	45	60	69	96
DD91	29	65	58	102	8	12	40	59	80	91	126
DD92	259	639	831	1,510	438	625	1,171	1,517	1,945	2,109	2,674
DD93	354	541	194	939	53	83	227	323	409	451	583
DD94	193	379	123	425	30	48	140	203	255	282	362
DD95	796	870	1,748	2,410	761	1,036	1,816	2,331	2,887	3,255	4,073
DD96	1,338	2,369	2,658	3,393	909	1,334	2,799	3,797	4,861	5,396	7,025
DD97	608	317	357	923	117	167	311	440	566	610	768
DD98	98	428	207	158	88	135	204	269	363	397	518
DD99	2,802	3,209	4,480	4,948	1,449	2,082	4,087	5,436	6,897	7,692	9,985
DD100	2,863	3,235	4,518	5,088	1,474	2,115	4,157	5,538	7,014	7,825	10,152
DD101	102	61	145	184	48	70	109	160	208	225	284
DD102	861	203	495	1,309	140	197	374	532	682	735	920
DD103	296	147	220	322	42	59	117	162	206	222	279
DD104	4	39	121	27	25	37	68	102	134	146	187
DD105	2	21	63	7	13	19	36	52	68	74	95
DD106	6	44	66	28	13	20	30	38	50	54	69
DD107	1,088	2,297	3,145	3,621	1,446	1,865	3,086	3,942	5,140	5,402	6,917
DD108	1,088	2,297	3,145	3,621	1,446	1,865	3,086	3,942	5,140	5,402	6,917
DD109	2,665	3,139	4,361	4,534	1,396	2,008	3,862	5,110	6,502	7,239	9,393
DD110	449	1,080	1,308	1,357	731	948	1,486	1,914	2,500	2,678	3,465
DD111	103	221	311	415	200	256	400	512	675	708	903
DD112	34	120	97	139	101	133	198	232	301	317	398
DD113	55	158	221	254	143	184	281	359	482	506	653
DD114	36	137	191	152	36	54	148	200	274	293	390
DD115	69	322	167	119	69	103	153	218	296	325	425
DD116	22	111	72	39	19	29	44	54	74	82	108

Appendix B

DEWS DESIGN EVENT DISCUSSIONS PAPER

CONTENTS

1 Purpose

The purpose of this discussion paper is to present an approach for the selection of design Annual Exceedence Probability (AEP) rainfall depths, temporal patterns and intensities for a range of AEP events to facilitate pre-feasibility level assessments that will inform determinations regarding IGEM 2015 Callide Creek Flood Review Recommendation No. 1:

> *"The Department of Energy and Water Supply and SunWater, undertake the necessary studies to determine whether or not it is feasible to operate Callide Dam as a flood mitigation dam. Such studies should include matters in relation to, but not limited to:*
>
> - *the effect on the Callide Valley water supply*
> - *dam safety issues*
> - *actual mitigation outcomes*
> - *cost-benefit analysis of alternative strategies*
> - *alternative means of effecting improved community outcomes.*
>
> *The results of this work should be made public to enhance public knowledge and provide confidence regarding dam operations."*

This paper provides some background information on the catchment and alternate approaches to design event modelling for consideration by the Project Working Group (PWG). The paper recommends an approach that considers the project objectives to:

- facilitate the comparative assessment of pre-feasibility mitigation options with cost/benefit assessment that requires consideration of AEP at multiple locations.
- consider utilising temporal and spatial distributions from historic flood events.
- maintain a degree of certainty regarding the final AEPs that will be derived if deviating from the traditional (AEP neutral) approach.
- meet project delivery timeframes and the need to limit the number of runs while attempting to report AEP at multiple locations (which normally requires separate runs for each AEP location).

Background

The Banana Shire Council (Council) is conducting a flood study for the Dawson River catchment and has engaged engineering consultants Kellogg Brown & Root Pty Ltd (KBR) to undertake this work. The calibrated hydrologic and hydraulic models will be made available to the Department of Energy and Water Supply (DEWS) for the Callide Valley Flood Mitigation Study to test the regional flood mitigation outcomes of dam augmentation and alternative flood mitigation storages.

Given the different nature of both Tropical Cyclones Oswald and Marcia the PWG are unsure of the appropriateness of the standard AR&R approach to design flood estimation and consider that more than one hydrological approach should be investigated before developing design criteria to determine future operations.

2 Catchments of Callide Creek

The main tributaries of Callide Creek are shown in the Figure 1 below and summarised in Table 1. The hydrologic model has a much more refined subcatchment breakdown for regional flood mitigation. The catchment areas listed in Table 1 are based on the IGEM report.

Table 1 Tributaries of Callide Creek

Catchment	Area (km^2)
Kariboe Creek (to Kroombit Creek)	590
Grevillea Creek (to Kroombit Creek)	620
Prospect Creek (to Kroombit Creek)	500
Kroombit Creek (to Biloela)	630
Upper Callide Creek (Callide Dam)	520
Lower Callide (to Jambin) approx.	800
Total to Jambin	3,660

Figure 1
CATCHMENT PLAN (SOURCE: IGEM 2015 CALLIDE CREEK FLOOD REVIEW)

3 Design storm events

Council's flood study includes the modelling of eight regional storm events, the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events and the PMP as shown in Table 2. The DEWS study is based on the objective of a feasibility investigation into flood mitigation storages. An investigation into the design or failure assessments of any potential storage is not part of this pre-feasibility assessment. The range of AEP design events in the DEWS project are shown in Table 2 and are based on Attachment 1 of the Hydrologic and Hydraulic Modelling Statement of Work Request (SoW).

The 0.01% AEP event would be estimated based on a log-normal interpolation of rainfall depth from the 0.05% AEP event (CRC-FORGE) and the PMP design rainfall depth estimated using the latest Bureau of Meteorology Revised Generalised Tropical Storm Method (coastal zone) and Generalised Short Duration Method with corresponding temporal patterns.

It is also recommended that at least the 2015 (Marcia) and 2013 (Oswald) events are included as these provide a basis for comparison that has more meaning to the community.

Table 2 Selection of design flood events

ARI (years)	AEP (%)	Council	DEWS
5	18.1%	*	
10	9.5%	*	
20	4.9%	*	
50	2%	*	*
100	1%	*	*
200	0.5%	*	
500	0.2%	*	*
2,000	0.05%		*
10,000	0.01%		*
PMP		*	

In most studies a single point of AEP determination is usually adopted which is often sufficient for the project objectives and more manageable for numerical modelling. Defining a single point of AEP at Biloela or Jambin would likely not be sufficient to adequately undertake damage and benefit assessments throughout the valley required for flood mitigation studies or for investigations into alternative strategies for improved outcomes, such as alternative flood mitigation storages on Kroombit Creek. It would be difficult to relate flows downstream to event probabilities in relevant contributing catchments.

Another consideration is the starting level of Callide and Kroombit Dams for design flood events. Using information from real events that have occurred in the more recent wet period (higher dam levels) is not likely to be a reasonable technique to deliver sound cost/benefit that is properly weighted over time based on the probability of occurrence. Initial hydrologic assessment will include modelling Callide Dam at full supply volume (FSV) and 60% FSV to provide some guidance. It may also be possible to incorporate variations in starting water level within the economic modelling.

The points of interest where determination of AEP may be required is presented in Attachment 2 of the SoW. These points are widely distributed throughout the catchment and floodplain, which requires a review of the approach to design rainfall.

The Callide Valley Flood Mitigation Study - Scenarios Discussion Paper (DEWS) proposes three stages of hydrologic assessment. The third stage includes hydrologic and hydraulic assessment of redefined scenarios against four historic floods and the 2%, 1%, 0.2%, 0.05% and 0.01% AEP design events. It is proposed there will be a total of 11 scenarios comprising the base case, 6 individual options and four combined option scenarios.

If each design event included (say) 5 locations for determining AEP that would constitute 5 runs in the hydrologic and hydraulic models. Combining that with 11 scenarios would generate a total of 275 runs which is unmanageable given the project reporting timeframe and budget constraints. Therefore an alternate approach is required.

4 Approaches to design rainfall

Three hydrologic approaches are proposed for estimating design flood discharges, including sensitivity tests as described below.

1. AR&R Standard

Industry practice for design floods estimation is currently based on the approach where all parameters (other than rainfall) are fixed, single values. Considerable effort is made to ensure that the single values of the adopted parameters are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall (AR&R Discussion Paper D2).

- Calculate catchment area upstream of Jambin (approximately 3,500 km^2).
- Determine CRC-FORGE rainfalls for the catchment with an appropriate Areal Reduction Factor (ARF) applied.
- Apply design rainfall depth uniformly to entire catchment.
- Use standard rainfall loss parameters. Normally these losses are adjusted to match peak design flow estimates with the results of Flood Frequency Analysis (FFA) where streamflow data is available. The perched location of the DNRM Goovigen gauge makes it unsuitable for FFA analysis as floodplain flows bypass the gauge. Additionally the presence of upstream storages (Callide and Kroombit) would complicate any FFA downstream.
- Set Callide and Kroombit storages to full supply level. The Department of Science, Information Technology and Innovation (DSITI) may advise otherwise for Callide

Dam based on the IQQM modelling. Alternately sensitivity of different starting levels can be tested and the impact this has on the downstream floodplain.

- Simulate events based on AR&R87 temporal patterns (Zone 3).
- Determine critical duration using hydrologic model.
- Timing of peak flows from each creek will depend on each sub-catchment area, slope and length.

2. Historic Spatial Patterns

- Same as AR&R Standard approach but the design rainfall event is concentrated on the catchments rising in the Calliope Range (Callide, Kroombit and Kariboe Creeks) and the rainfall surface is not uniform.
- This is based on a review of rainfall isohyetal maps from the recent 2010, 2013 and 2015 flood events in the Callide Valley (refer to isohyetal maps in Appendix A Figures 2 to 4). In the 2013 and 2015 flood events the highest rainfall follows the Calliope Range with lower rainfall totals in the Callide Valley. The higher rainfall depths impact the upper reaches of Callide Creek (above Callide Dam), Kroombit Creek and Kariboe Creek. In the 2010 flood event the overall spatial patterns is more evenly distributed over the whole Callide Creek catchment. Therefore the synthetic spatial distribution of rainfall presented in Figure 2 has been derived for design event analysis and is based on the isohyet surfaces from the 2013 and 2015 events.
- Determine CRC-FORGE rainfall estimates for the new catchment encompassing Callide, Kroombit and Kariboe Creeks. The catchment centroid will be further up the Calliope Range and may result in a slight increase in rainfall intensity which, when combined with a lower ARF for the smaller area, will equate to a small increase in intensity under this approach.
- The CRC-FORGE rainfall depths are then applied to the rainfall surface in Figure 2 such that the total volume of rain falling within the Callide, Kroombit and Kariboe Creek combined catchment is maintained (i.e. a lower rainfall depth is applied in lower elevations). This step is intended to maintain the AEP neutrality approach (the concept of ensuring that the average recurrence interval of the design flood discharge is the same as the AEP of the design rainfall input).
- Smaller coincident events would be simulated for creeks rising in the Dawes Range (Grevillea and Prospect Creeks) and the timing of these peaks could be aligned to the Calliope Range discharges.
- It is expected this approach would result in a faster rate of rise at Biloela compared to the AR&R Standard approach.

3. Historic Temporal Patterns

- Same as the Historic Spatial Patterns approach but generate revised temporal patterns based on historic pluviograph records typical of major flood events in the catchment. This may be more relevant to the Callide Valley and it is probable that such design rainfall temporal patterns may increase the reliability of design flood estimates.

- Due to the influence of the temporal pattern on the shape of the flood hydrograph, timing and rate of rise, it is likely the flows from the hydrologic model would be more realistic.
- It also allows the temporal pattern of rainfall prior to and post the peak burst of rainfall to be considered which can be important.
- However, historic temporal patterns would need to be categorised by their duration as some are high-intensity with short-duration (Marcia) and others are longer (Oswald). A review of multiple historic events would be necessary to generate a sufficient range of storm durations such that the correct time of concentration can be adopted for each catchment. A much wider range of temporal patterns is available from AR&R (87).
- A review of historic temporal patterns and comparison to design temporal patterns is provided in Appendix A Figures 8 and 9 which essentially shows reasonable similarity between the two.
- However, combining historic temporal patterns with a synthetic spatial pattern is unlikely to result in AEP neutral flows for the AEP of the CRC-FORGE design rainfall input. This damages the value of this approach as the project requires a cost/benefit assessment that relies on appropriate determination of AEP.

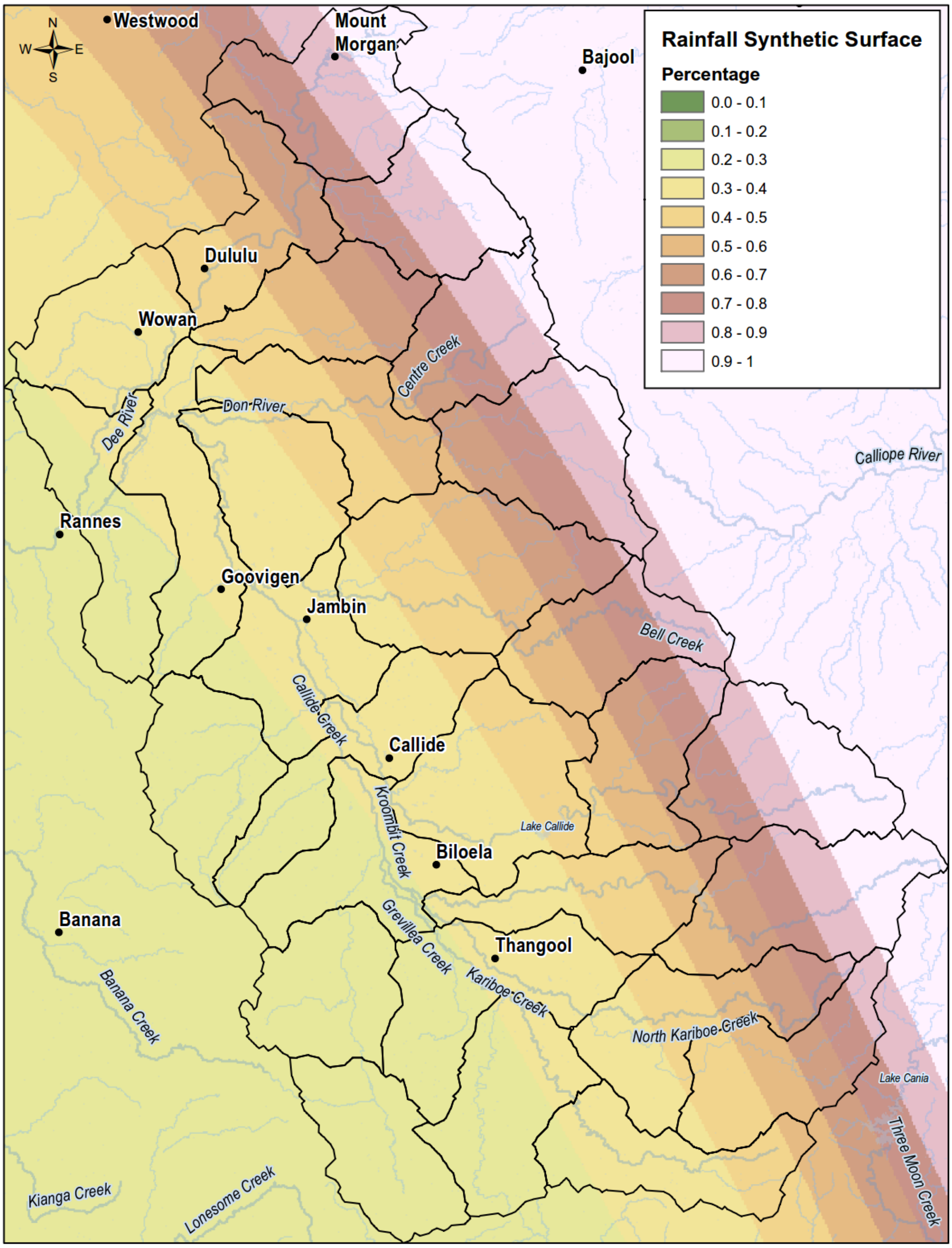

Figure 2
RECOMMENDED SYNTHETIC SPATIAL PATTERN

5 Recommended approach

A review of the approaches described in the previous section has determined that none of them adequately meet the objectives of the project to:

- determine AEP at multiple locations
- consider utilising historic temporal and spatial distributions
- maintain a degree of certainty regarding AEP neutrality
- limit the number of runs required while attempting to report AEP at multiple locations (which normally requires separate runs for each AEP location).

Therefore the following approach is based on varied design rainfall which combines Approaches 1 and 2 from the previous section. This approach attempts to derive AEP flows down the Callide Valley at most key points of interest presented in Attachment 2 of the Statement of Work Request (SoW). Approach 3 has been withdrawn for the reasons stated in the previous section.

The recommended approach is presented graphically in Figure 3 which shows the breakup of catchments in the Callide Valley where different design rainfall parameters will be applied. The figure also shows the points of interest from the SoW. It is intended that this approach will be simulated once in the hydrologic and hydraulic model for each AEP design event.

It is worth noting that in the hydrologic assessment all scenarios will be tested against the four historic floods. Therefore the natural variability of these events will ensure flood mitigation options are tested against short and long duration rainfall, widespread and concentrated distributions, actual rates of rise and moving storm cells.

Catchments 1, 2 & 3

In catchments 1, 2 and 3 the synthetic (non-uniform) spatial pattern presented in Figure 2 will be combined with standard AR&R temporal patterns using the steps identified in Approach 1. This approach is considered applicable up to 0.05% AEP event.

It is expected this approach would result in a faster rate of rise at the outlet of each catchment compared to the AR&R Standard approach. This could be important when considering flood mitigation options such as early-release and alternate gate operating principles.

In catchment 1 (upper Kroombit and Kariboe Creeks) and catchment 3 (Callide Dam catchment) the design rainfall depths are applied to the rainfall surface in Figure 2. This is adjusted to ensure the total volume of rain falling within each catchment is maintained when compared to the standard (uniform) approach. This step is intended to maintain the AEP neutrality approach but it cannot be guaranteed (refer to Section 6 for discussion on uncertainty).

In catchment 2 (lower Kroombit and Kariboe Creeks) the design rainfall depths will still be applied using the synthetic spatial pattern however it is likely the rainfall values will be discontinuous with catchment 1 rainfalls due to the change in total catchment area. This would be represented by the true AEP in catchment 1 and a lesser AEP in catchment 2 to maintain the overall AEP for catchment 2.

AEP flows will not be directly determined at Biloela, however the determination of AEP at Callide Dam, Kroombit Creek at the start of Washpool Gully and Kariboe Creek at Thangool is expected to give appropriate results for Biloela.

Catchment 4

In catchment 4 (remaining Callide Creek catchment) it is proposed that design rainfall depths are applies using Approach 1 with standard temporal and spatial patterns. This is partly due to the historic rainfall surface maps (Appendix A Figures 2 to 4) suggest more uniform rainfall over this part of the catchment.

The three points of interest at Callide, Jambin and Goovigen are fairly closely connected with similar contributing catchments. It is expected the peak flood level in this zone will depend more on the volume of the flood rather than the peak flow.

Peak flows will be validated at Jambin by comparing results from the standard AR&R approach and adjusting rainfall depths (refer to Section 6 for uncertainty assessment). This would allow for the true AEP in catchments 1 and 3, and a lesser AEP in catchment 2, to maintain the overall AEP for the whole catchment at Jambin.

It is noted that in the Pre-Release scenario flows will begin draining Callide Dam up to 24 hours before the onset of rain. Based on estimated travel times, the flow leaving Callide Dam (up to 260 m^3/s) is likely to coincide with flows from the Bell Creek catchment. At present the synthetic spatial pattern in Figure 2 is not being used for Bell Creek which would potentially worsen the coinciding flows. However the Pre-Release scenario will be tested against the four historic floods which include the short and duration and concentrated distributions of the 2013 and 2015 events.

Extreme Rainfall Events

The 0.01% AEP event would be estimated based on a log-normal interpolation of rainfall depth from the 0.05% AEP event (CRC-FORGE) and the PMP design rainfall depth estimated using the latest Bureau of Meteorology Revised Generalised Tropical Storm Method (coastal zone) and Generalised Short Duration Method with corresponding temporal patterns.

The spatial distribution of design rainfall is expected to be more even for very large flood events and will be applied uniformly across the entire catchment upstream of Goovigen. The synthetic rainfall pattern will not be used.

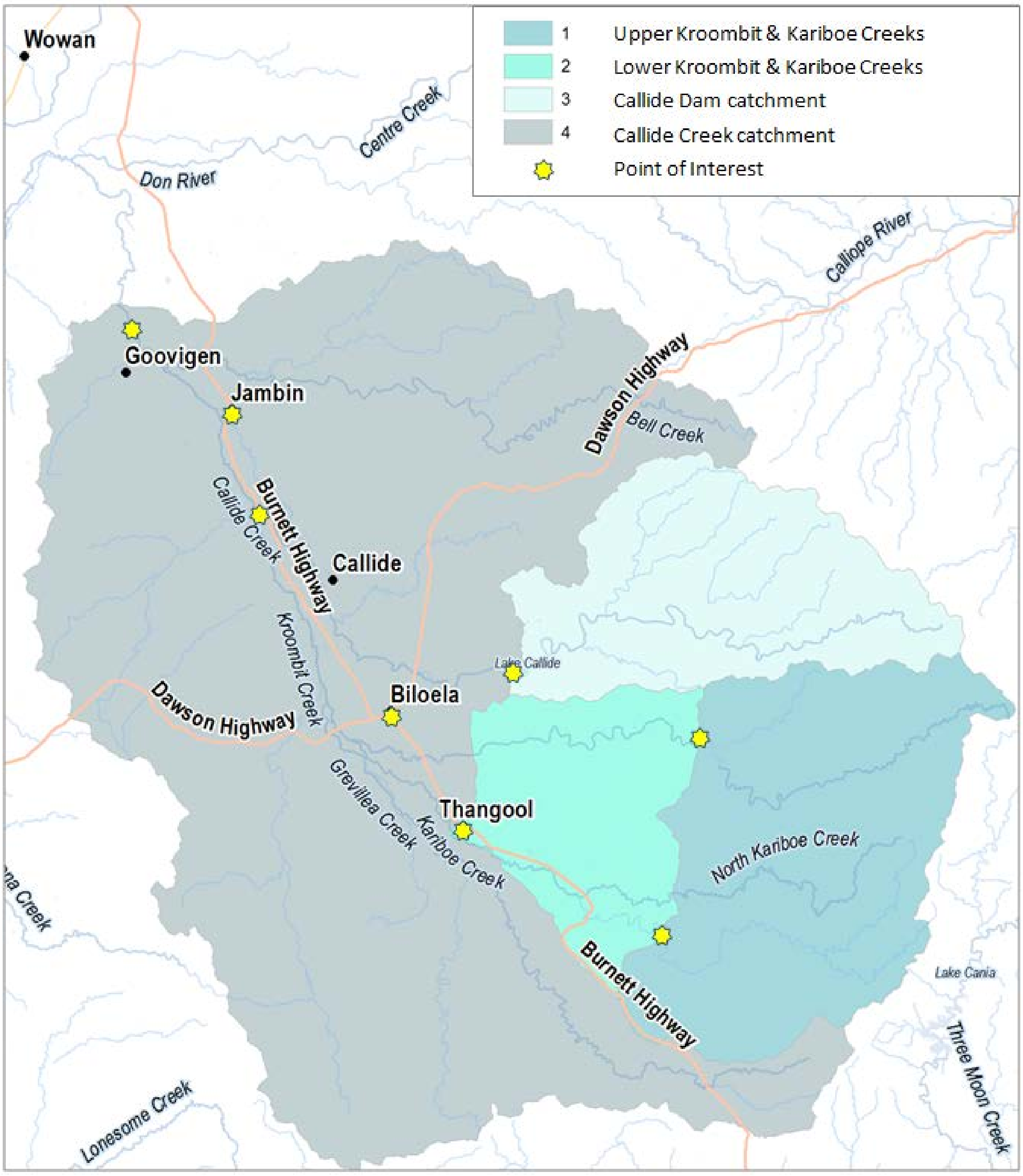

Figure 3
RECOMMENDED DESIGN RAINFALL APPROACH

6 Discussion

Uncertainty in AEP flows

While it is recognised that there are deficiencies in the traditional AR&R87 design event approach, altering important flood producing factors (such as intensity, loss, duration, temporal and spatial distribution) based on a small sample of historic events may produce floods with a different annual exceedance probability (AEP) as the causative rainfall.

There is some uncertainty about how to guarantee the AEP of the flows in the recommended approach. Therefore the outputs of the recommended approach will be compared against the results of the standard design flood from Approach 1. In this way the peak flow estimates for a range of AEP flood events and at a number of key locations in Callide Valley will be estimated for the existing scenario. These peak flows will be compared against the results of the recommended approach for the existing scenario at the same locations.

Deviations in the peak flow between the two approached will be considered and, where there is too great a difference, the recommended approach will be validated against the standard design event approach. Adjustments to the recommended approach would be made through scaling the rainfall depths (within acceptable limits) until the peak flows more closely align with the standard estimates.

The proposed locations for comparison on peak flows are:

- South Kariboe Creek (proposed site for new flood storage) and Kariboe Creek at Thangool
- Kroombit Creek at Kroombit Dam and also the start of Washpool Gully
- Callide Creek at Callide Dam (inflow to Dam) and at Jambin.

Monte-Carlo Analysis

In a complex catchments like Callide Creek a Monte-Carlo approach is the only real way to considering the multiple objectives of the project. Monte Carlo simulation offers an alternative to the design event method that recognises any design flood characteristics (e.g. peakflow) could result from more than a single combination of flood producing factors (AR&R Discussion Paper D2).

The Monte-Carlo approach stochastically includes the occurrence of rainfall, its temporal and spatial distribution, and antecedent conditions such as losses and initial reservoir levels. Probabilistic sampling of model inputs from their defined distributions is how the random factors are represented in the simulation.

More detailed analysis of historic events, including Monte-Carlo can be considered in the next stage of assessment.

7 References

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Appendix A

REVIEW OF PREVIOUS FLOOD EVENTS

Appendix A

Review of Previous Flood Events

INTRODUCTION

This appendix provides a review of historic rainfall data for the whole Callide Creek catchment and is intended as a supporting document to the Design Rainfall Discussion Paper. This information is provided to help determine the most appropriate approach for applying rainfall intensity, including temporal and spatial distributions, to deliver acceptable estimates of the prescribed AEP flood events.

REVIEW OF FLOOD EVENT RAINFALL INTENSITY

Figure 1 presents the at-site rainfall analysis for data recorded at DNRM Station 1303P003 (Kroombit Tops) which is located at the top of Callide Creek and Kroombit Creek catchments. The figure compares the extreme rainfall generated by Tropical Cyclone Marcia (Marcia) and ex-Tropical Cyclone Oswald (Oswald) with Design Point Intensity estimates from AR&R(87) up to 1% AEP and CRC-FORGE beyond 1% AEP.

As can be seen from the graph both rainfall events exceed the estimated 1% AEP rainfall intensity for different durations. Rainfall from Marcia was most intense over a period of 6 to 9 hours and reached intensities equivalent to about a 0.2% AEP event. Rainfall from Oswald was more severe than Marcia over longer periods and extreme for durations greater than 24 hours. Marcia produced a more extreme response in the catchment upstream of Callide Dam as the rainfall was more intense over the duration equal to the time of concentration.

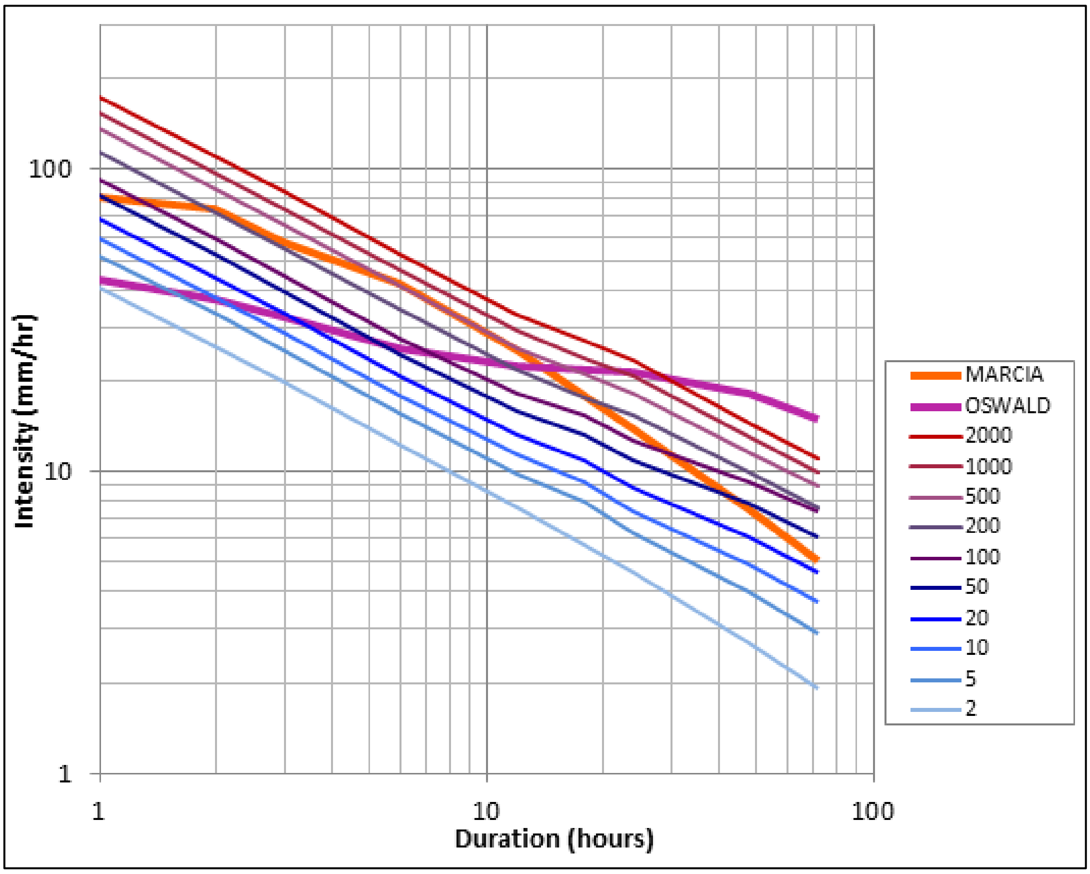

Figure A1
RAINFALL EVENT FREQUENCY ANALYSIS FOR KROOMBIT TOPS

REVIEW OF FLOOD EVENT SPATIAL PATTERNS

A detailed review of historic spatial patterns has been completed for a selection of major flood events in the Callide Valley using sub-daily and daily rainfall data. This has included the collection, processing and review of rainfall data for over 350 stations including 260 daily recording stations and nearly 90 continuous (pluviograph) stations.

For each flood event the rainfall data quality was reviewed prior to spatial analysis. This included removing stations with data gaps at key periods or inconsistencies in the data for the selected period. This mostly applied to daily rainfall stations due to missing records. The remainder of stations were either good quality or marked for further checking if minor irregularities were detected in the data (for example, missing daily records adjacent to the period of interest or long periods of accumulation for continuous records).

Table 1 presents a summary of the final rainfall stations selected for each historic event. This table excludes stations with poor data quality.

Following ex-TC Oswald the Banana Shire Council implemented an upgrade to the flood warning system in the Callide and Dawson catchments which included the supply and installation of 29 ALERT flood warning gauges all of which record rainfall. The installations were completed in late 2013 and early 2014 thus for the flood events in this study only the 2015 event was captured.

The rainfall totals for each event were plotted spatially in GIS and a small number of stations with data that strongly contradicted surrounding stations were removed. A range of surface fitting methods were trialed and Ordinary Kriging with exponential semi-variogram type was selected as the giving the most realistic looking output for all flood events. The resulting patterns are presented in Figures 2, 3 and 4 and are an idealisation of the real spatial patterns thus will carry uncertainty. Further testing of the surface estimation method might include using elevation covariates to surface fit the rainfall data.

The rainfall patterns for 2013 and 2015in Figures 2 and 3 suggest the highest rainfall follows the ridge of the Calliope Range with lowering rainfall totals moving westward into the Callide Valley. In both events the higher rainfall depths impact the upper reaches of Callide Creek (above Callide Dam), Kroombit Creek and Kariboe Creek. In the 2010 flood event the Calliope Range again received higher rainfall totals however the overall spatial pattern was more evenly distributed over the whole Callide Creek catchment.

Table 1 Rainfall Station Summary for historic events

Type	Provider	2010 23-29 Dec 2010	2013 24-28 Jan 2013	2015 19-22 Feb 2015
Daily	BOM	215	207	174
	SunWater	1	2	2
Continuous	BOM	3	4	31
	SunWater	3	2	2
	DNRM	39	42	42
	Total	261	257	251

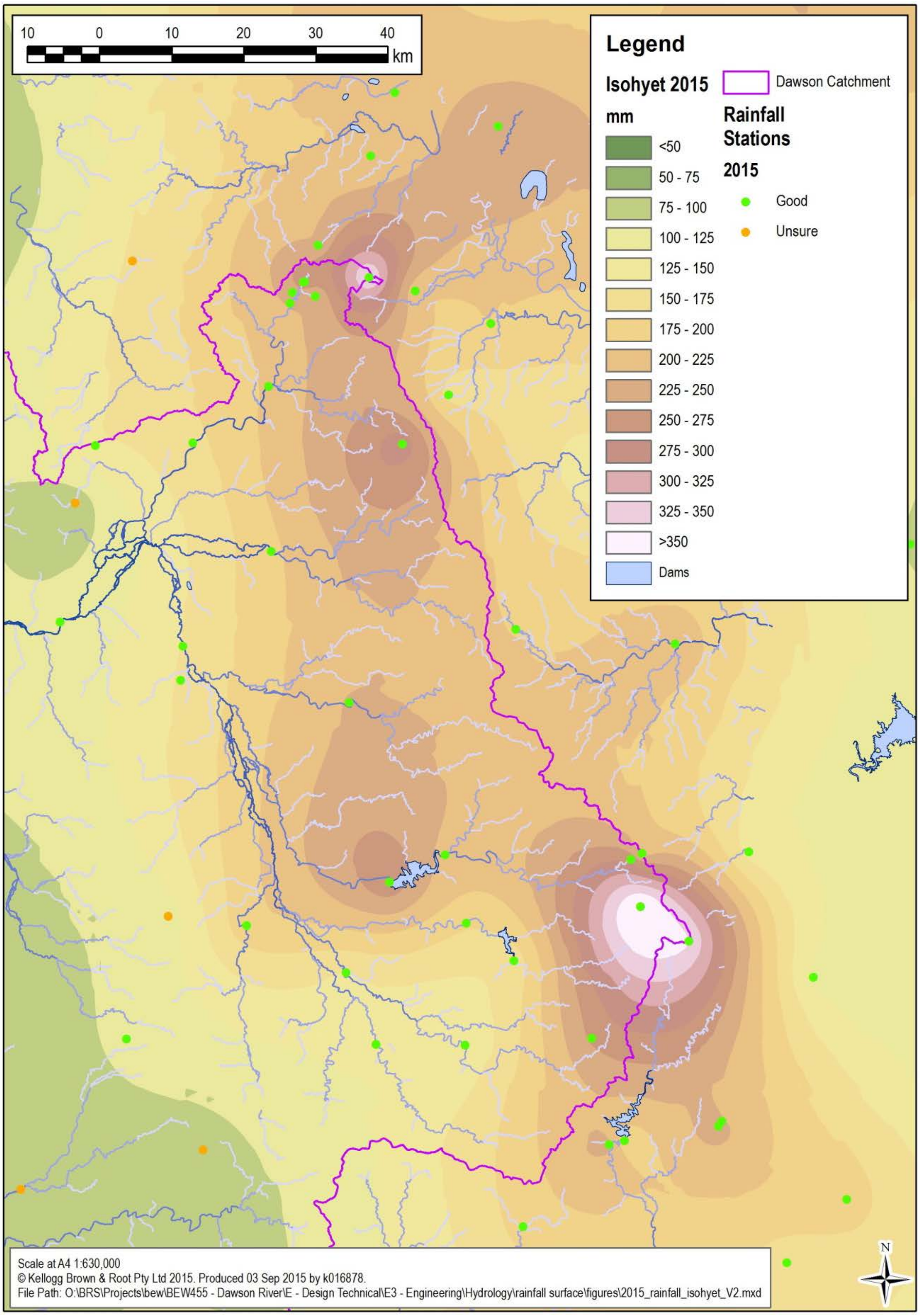

Figure A2
RAINFALL ISOHYET SURFACE FOR TC MARCIA (2015)

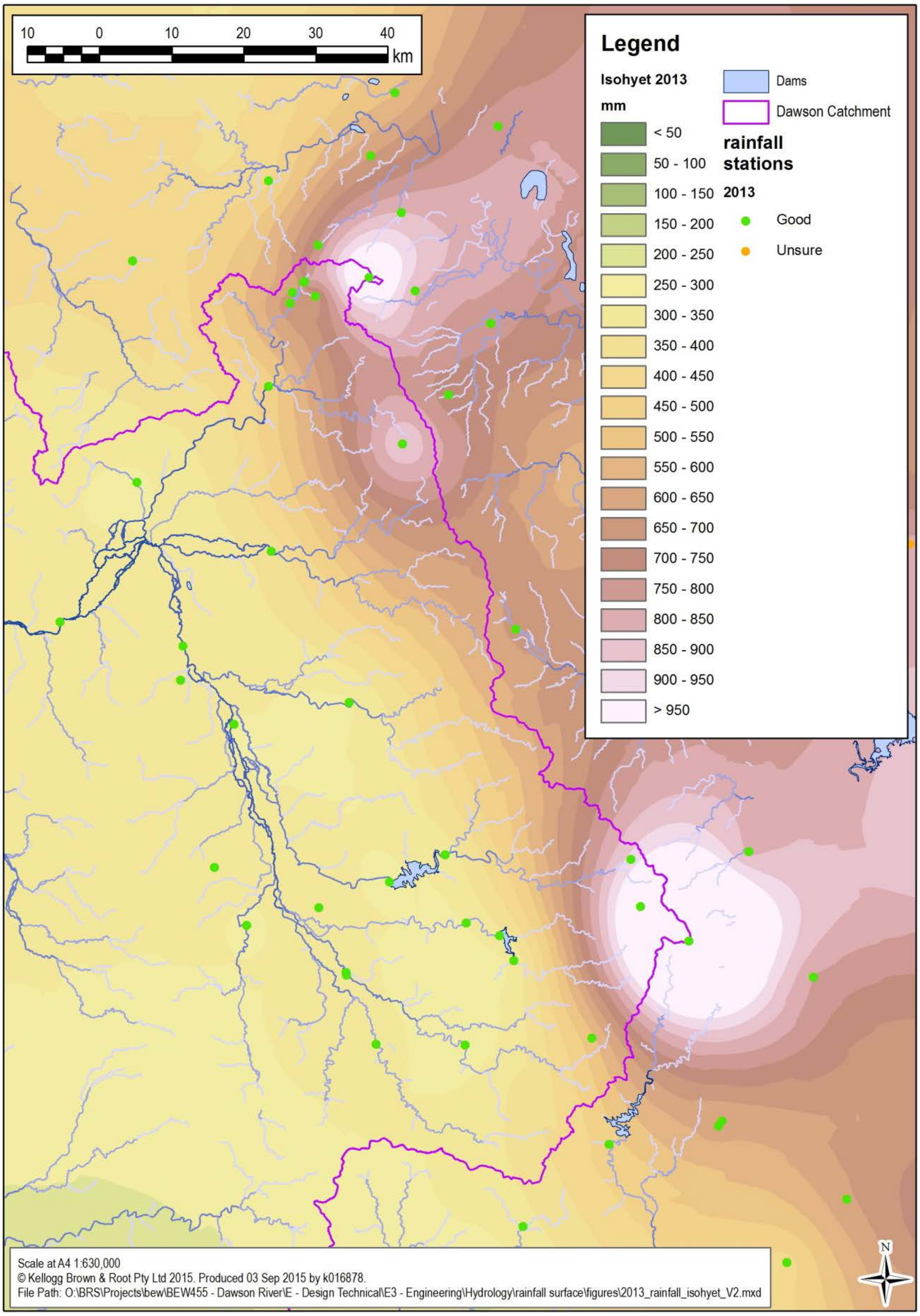

Figure A3
RAINFALL ISOHYET SURFACE FOR EX-TC OSWALD (2013)

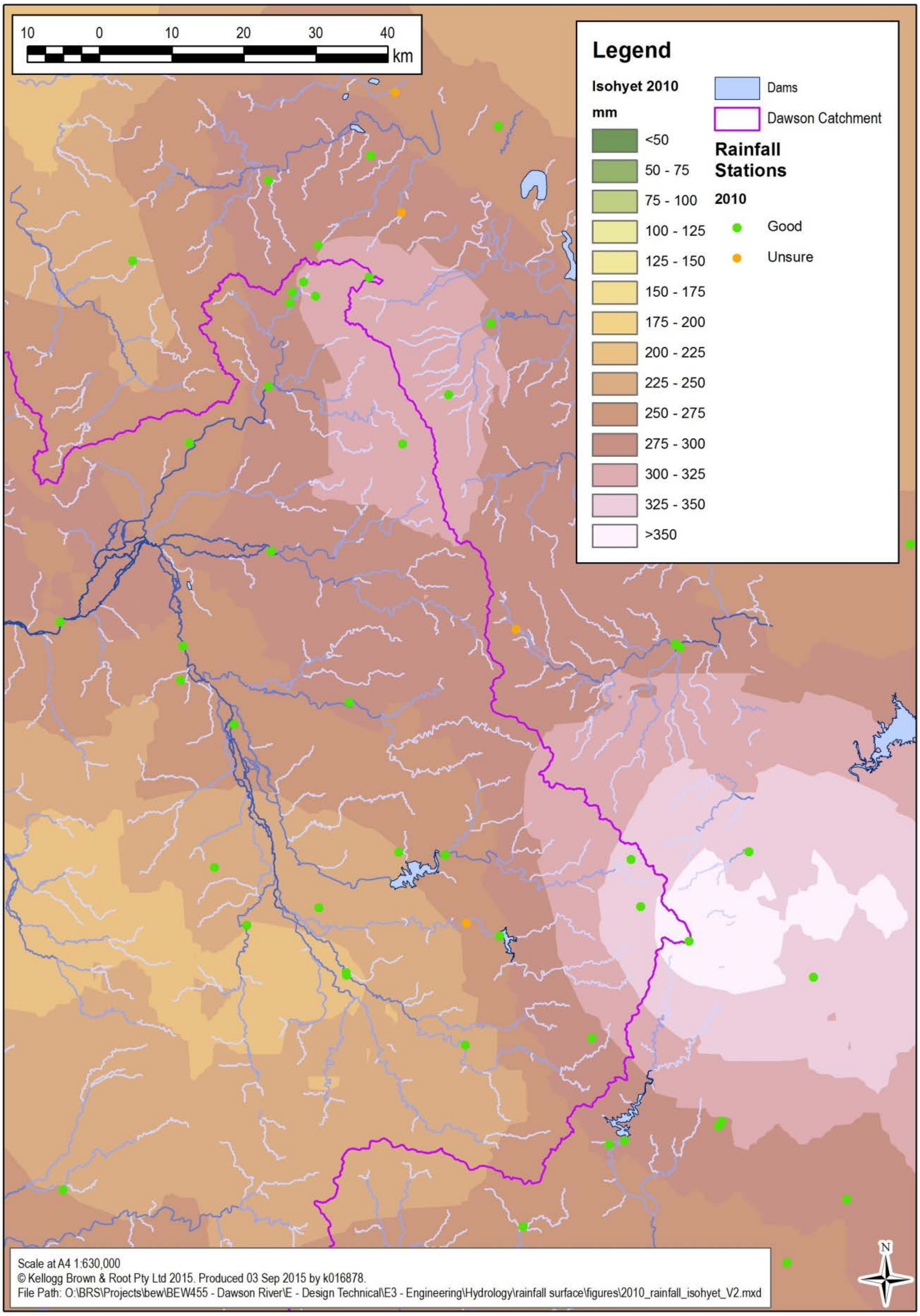

Figure A4
RAINFALL ISOHYET SURFACE FOR 24-28 DECEMBER 2010

REVIEW OF FLOOD EVENT TEMPORAL PATTERNS

It is recommended that temporal patterns of large historic events are investigated and summarised ahead of the hydrologic model being completed. This will facilitate sensitivity testing to determine the most appropriate method to apply design rainfall events to the Callide Valley as agreed by the Project Working Group.

A detailed review of historic temporal patterns has been completed using all available sub-daily rainfall data in the Callide Valley from the 2015, 2013 and 2010 flood events. Figure 5 presents the temporal patterns recorded in the February 2015 flood event which shows a single high-intensity short-duration storm burst that has a similar shape across all gauges (allowing for difference in rainfall totals). In Figure 6 the temporal patterns for the January 2013 event show a long-duration event with fairly constant rainfall intensity for the entire event. The December 2010 rainfall event is presented in Figure 7 and is characterized by an initial burst early on 27 December and a second burst late on 28 December.

A preliminary review of standard AR&R temporal patterns (Zone 3) and rainfall data from both Tropical Cyclones Marcia and Oswald has been prepared in Figures 8 and 9 respectively. Figure 8 shows the 6 and 12 hour temporal patterns are representative of the rainfall recorded at Kroombit Tops in the 2015 event. The preceding rainfall is not represented in the design temporal patterns which only include the storm burst; however for this reason initial rainfall losses are normally lower in design flood estimation compared to major historic events.

Figure 3 shows the temporal pattern recorded during the 2013 event was a prolonged storm very similar in duration to the 72 hour temporal pattern. It has a fairly uniform intensity whereas the 72 hour design pattern includes three small bursts.

One of the ARR Revision Projects relates to temporal patterns for design rainfall bursts (Project 3) however at this stage the Revision Project Report for Project 3 is not yet available for download. The drafts of ARR chapters available for download at present do not cover temporal patterns.

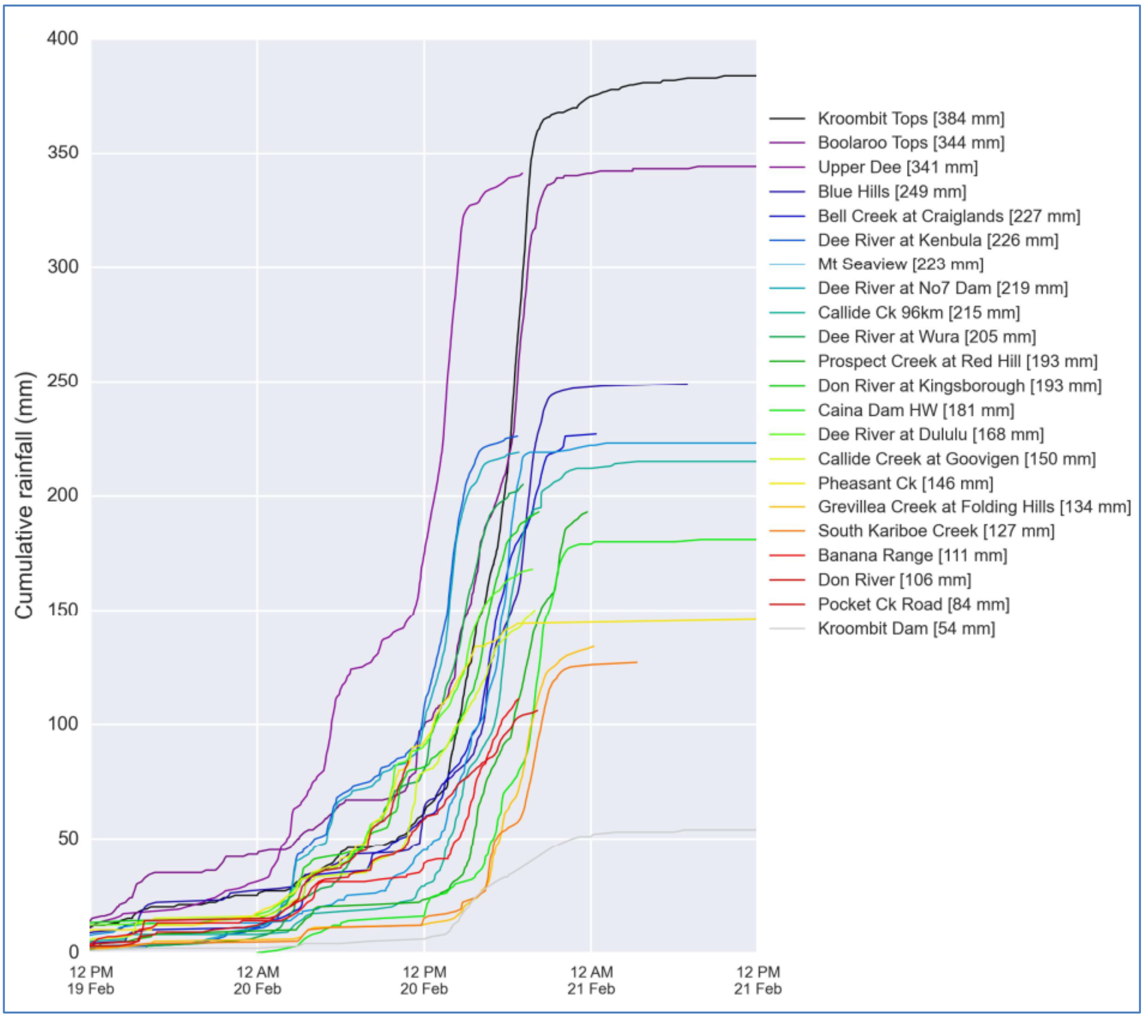

Figure A5
TEMPORAL PATTERNS DURING TC MARCIA (2015)

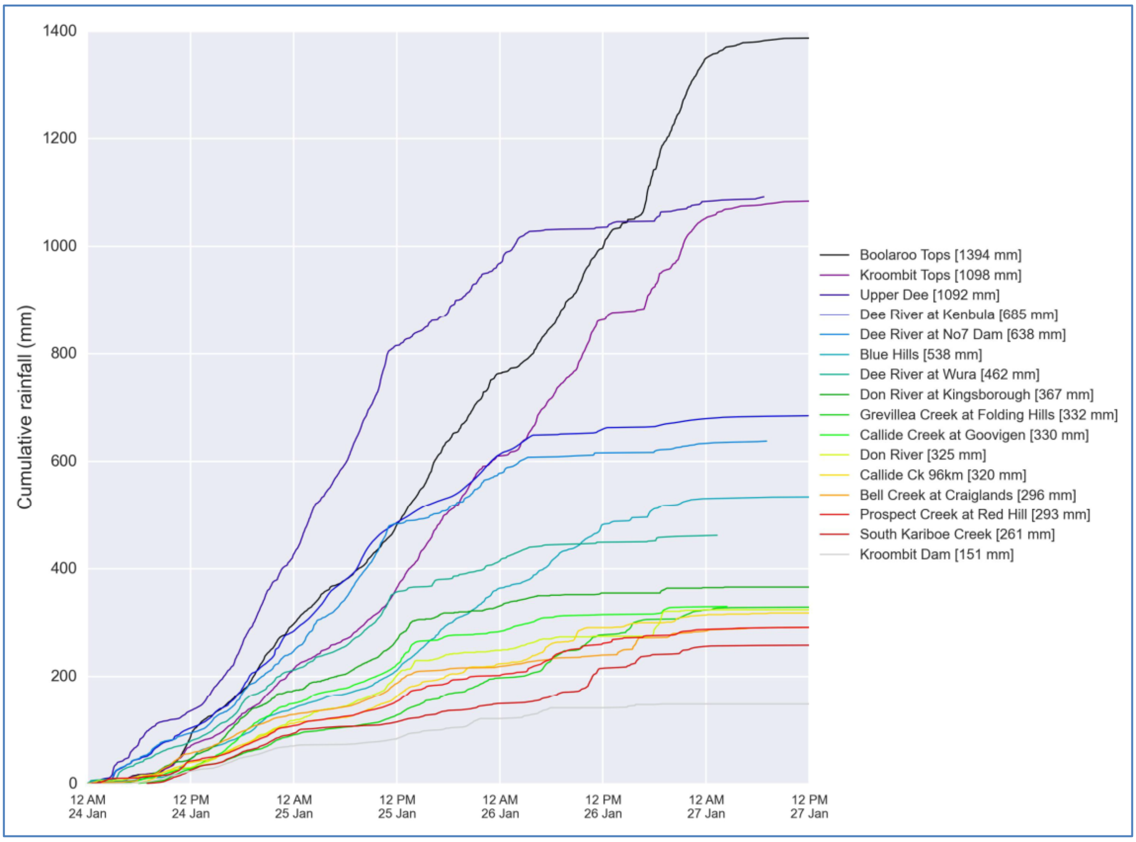

Figure A6
TEMPORAL PATTERNS DURING EX-TC OSWALD (2013)

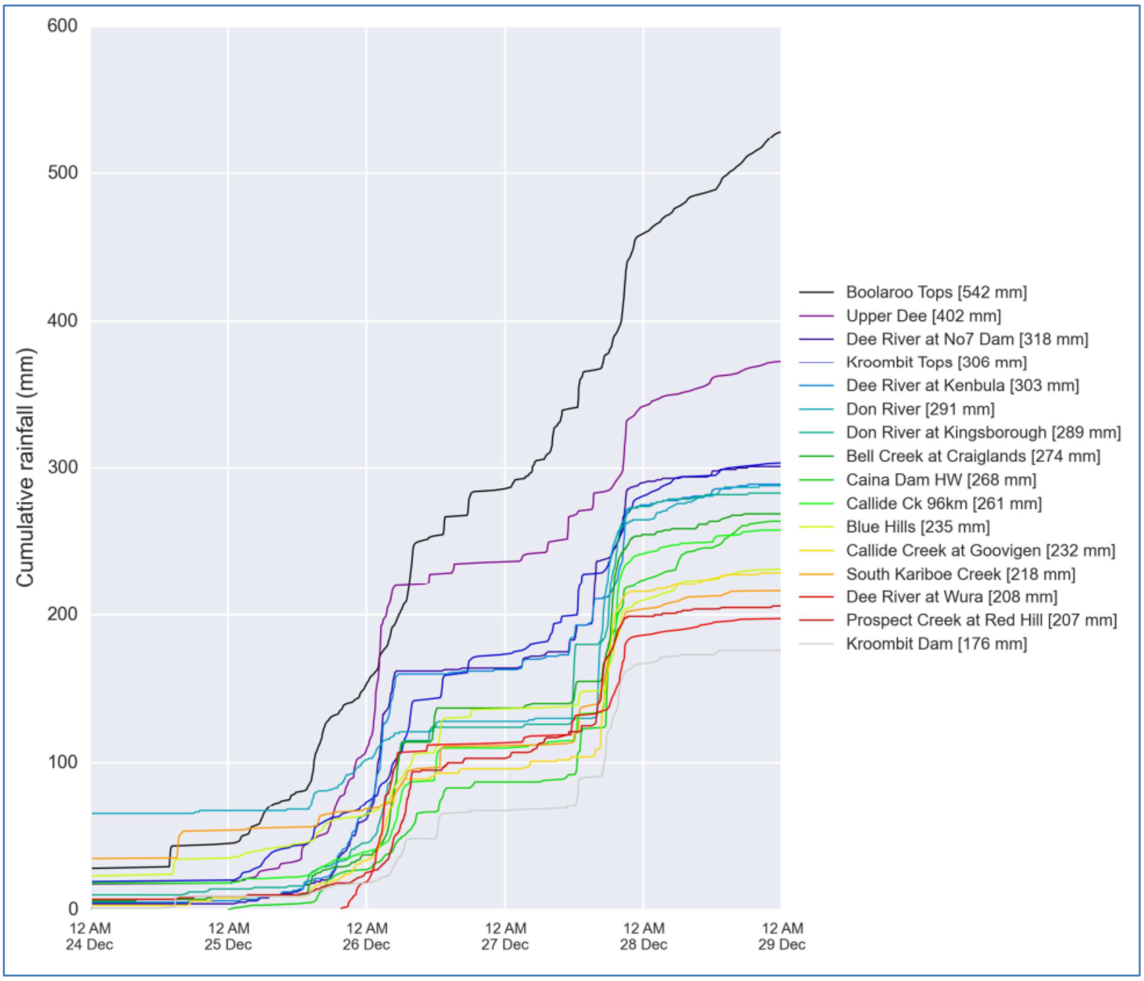

Figure A7
TEMPORAL PATTERNS DURING DECEMBER 2010

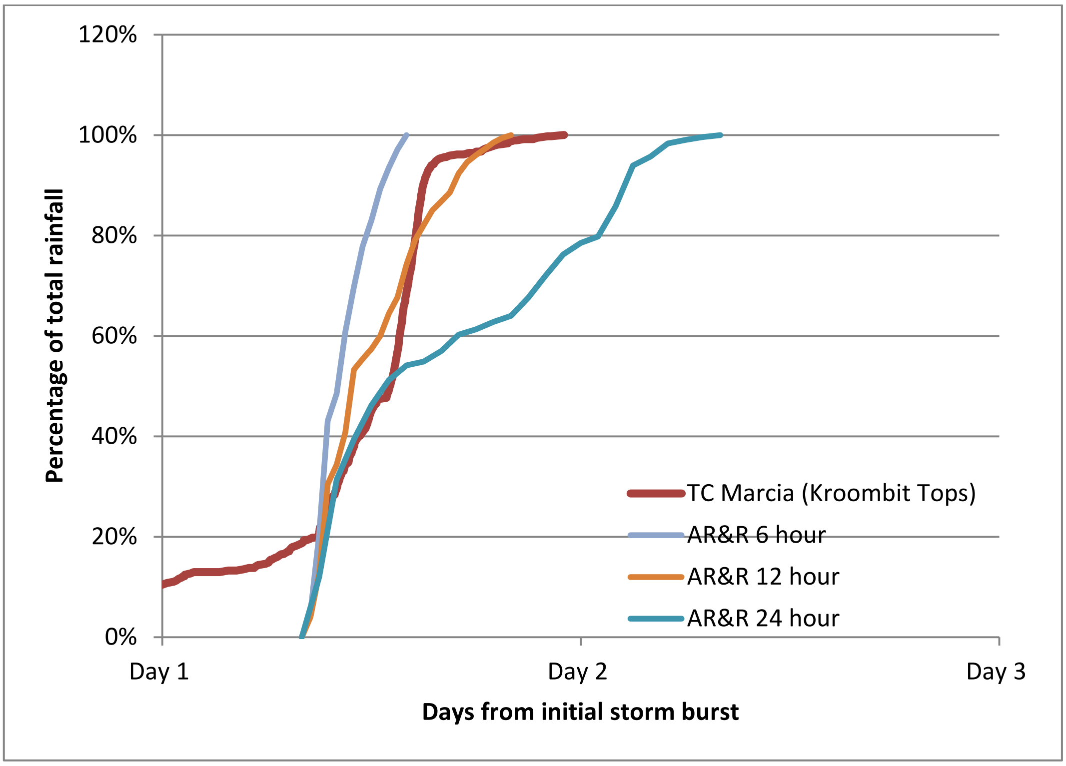

Figure A8
COMPARISON OF AR&R TEMPORAL PATTERNS WITH TC MARCIA AT DNRM STATION 1303P003 (KROOMBIT TOPS)

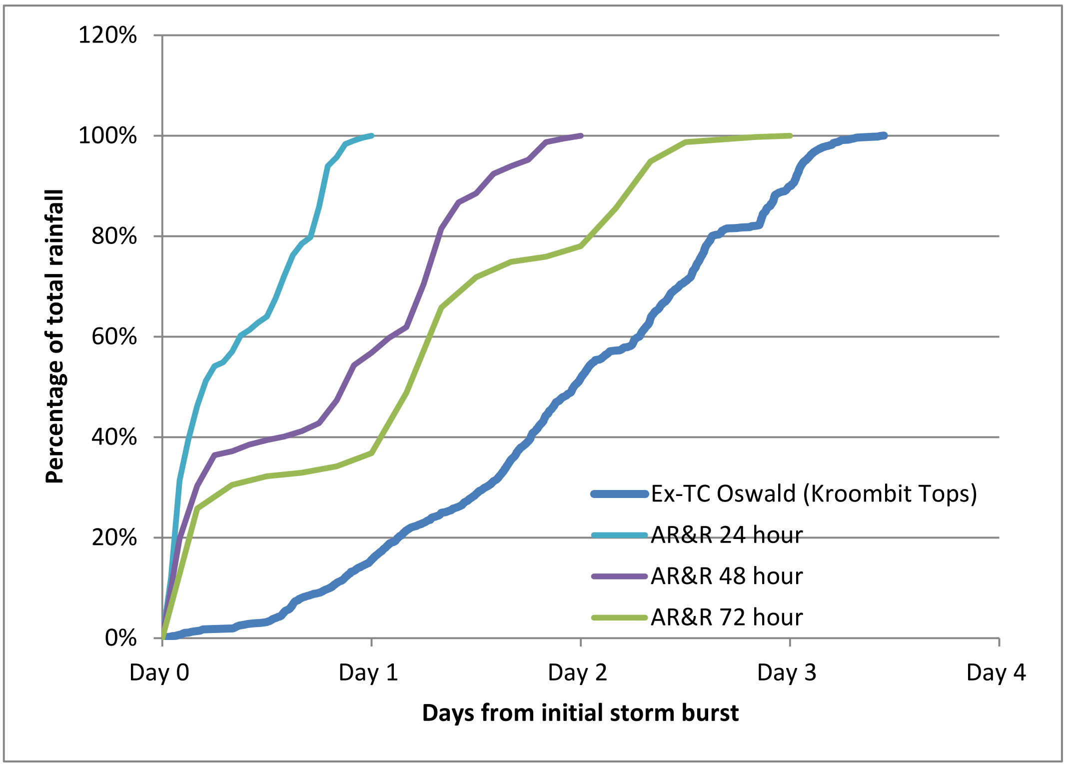

Figure A9
COMPARISON OF AR&R TEMPORAL PATTERNS WITH EX-TC OSWALD AT DNRM STATION 1303P003 (KROOMBIT TOPS)

Appendix C

CALLIDE VALLEY HYDRAULIC REPORT

Data

DEM

The primary source of a Digital Elevation Model (DEM) has been obtained by Light Detection and Ranging (LiDAR) survey. A series of 1 m DEM tiles were provided by the Department of Natural Resources and Mines (DNRM) which were combined into three DEM's for input into TUFLOW.

The accuracy of 1 m LiDAR data is quoted as ±0.15 m in the vertical and ±0.45 m in the horizontal. Horizontal coordinates were given in Geocentric Datum of Australia (GDA) 1994, Map Grid of Australia Zone 56 (MGA94 zone 56).

At some of the model boundaries the DEM has been sampled from data found in the IGEM Flood Model. The source and quality of this data is unknown, however it is much better than SRTM.

AERIAL PHOTOGRAPHY

SPOT satellite imagery, captured the day after tropical cyclone Marcia was used to verify and update hydraulic surface roughness throughout the hydraulic model extent. It was also important for interrogation of terrain features, flow paths, inlet and outlet structures, hydraulic roughness and locating approximate flood extents, where appropriate. The data was collected by DEWS following tropical cyclone Marcia (2015) and covers the majority of the Callide Valley floodplain from upstream of Thangool to downstream of Goovigen.

STRUCTURES

Information and data on significant floodplain structures has been provided from a variety of sources.

Aurizon have provided working plan and section drawings (in PDF) of the rail network from Mount Rainbow to Moura and Moura Mine. These drawings show major culverts and bridges. The majority of these drawings are dated 1972.

Department of Transport and Main Roads (DTMR) provided a set of working plans (in PDF) of the major highways through the Banana Shire. These drawings also include locations of major culverts and bridges.

The drawing sets listed above have been assessed by KBR for significant structures within the floodplain. Significant structures have been identified and 1tilizati to inform 1tilization1on of the TUFLOW hydraulic model. More information on how these structures were included in the model can be found in the model development section.

Banana Shire Council has provided records of documented bridges and culverts within the shire. Data has been provided in PDF and GIS format.

Hydraulic Model Development

MODEL PLATFORM

TUFLOW-GPU has been used to model the Callide Valley floodplain. TUFLOW-GPU solves the full 2D shallow water equations including inertia and the sub-grid scale turbulence (eddy viscosity) terms to simulate complex flood flow paths across the surface of the catchment.

The primary advantage of using TUFLOW-GPU is 1tilization of multiple GPU cores, which increase the speed of hydraulic calculations and reduces model run times. This advantage facilitates modelling large urban areas or regional floodplains like the Callide Valley.

MODEL EXTENT

The TUFLOW hydraulic model covers an area of approximately 655 square kilometres and includes the townships of Thangool, Biloela, Jambin, Callide and Goovigen.

The model extends upstream of Biloela on Callide Creek to the Callide dam spillway, the model was extended south to the limit of available LiDAR and includes upstream reaches of Grevillea Creek, Kroombit Creek and Kariboe Creek. The extent of the model ensures any break out flow from Kroombit Creek, through washpool gully will be modelled hydraulically.

The model was extended north of the Goovigen stream gauge by approximately 9.5 km to ensure any potential drawdown from the downstream boundary condition would not impact on predicted flood levels at the Goovigen gauge.

The eastern and western model extent generally extends across the width of the Callide Valley floodplain. The eastern extent of the model was widened to ensure upstream inflows could be applied from Oakey Creek, Gate Creek and Bell Creek.

The eastern model extent was further widened to ensure break out flows from Bell Creek would be included and modelled hydraulically.

The extent of the hydraulic model can be seen in the figures presented in the main report.

MODEL GEOMETRY

The 1 m DEM supplied by DNRM was used as the base terrain in the hydraulic model. The 1 m DEM was input into Tuflow at a 10 m grid spacing with the elevations used in Tuflow interrogated directly from the DEM.

Where significant terrain modification will not be represented accurately by the adopted cell size (i.e. ring tanks, narrow road embankments and farm levees), other modelling methods described in the next section on topographic features have been employed to ensure the terrain is represented more accurately.

The geographic rotation of the model grid was set to a rotation angle of approximately 35 degrees. The grid was rotated in order to reduce mass error and ensure the majority of flow occurred orthogonal to cell edges.

TOPOGRAPHIC FEATURES

The base DEM has been supplemented with terrain data sourced from the IGEM TUFLOW model. The application of this 5 m DEM set was limited to locations outside the supplied LiDAR extent and only where additional data was required to capture break out flows.

The boundaries of overlapping DEMs were checked for differences, which were found to be generally less than 200 mm.

Ridge lines have been included within the TUFLOW model along major road / rail embankments, levees and ring tanks. These have been included to ensure at least one row of cells within the model represent the DEM terrain height at these locations.

Openings in ridge lines were included at the locations of bridges and major culverts.

Streamlines have not been included within the model. The majority of major creeks and watercourses are generally wider than 30 m and are assumed to be adequately represented by the 2D grid. The minor watercourses are generally insignificant when the entire valley is flooding.

The invert of the drainage channel adjacent to the Burnet highway north of Browns gully has been enforced within the model. This channel was enforced in order to aid model calibration.

MODEL ROUGHNESS AND LAND USE PARAMETERS

Hydraulic roughness, represented as Manning's 'n', is the measure of the frictional resistance water experiences when passing over land and channel features. The Manning's 'n' roughness values used for the Callide TUFLOW-GPU model were kept consistent with industry standard values.

Table C-1 lists the adopted Manning's 'n' value and the corresponding land use type. The delineated roughness map of the Callide Valley floodplain can be seen in Figure C-1.

Table C-1 Adopted Manning's 'n' value

Land use	Manning's 'n' value
Cropping	0.07
Intensive animal production	0.09
Land in transition	0.04
Livestock grazing	0.5
Manufacturing and industrial	0.3
Reservoir/dam	0.03
Residential	0.1
Services	0.05
Utilities	0.3
National park	0.1
Abbotoirs	0.05
Rural residential/Recreation/Public services	0.06
Commercial services	0.2
Roads	0.02
Dense Vegetation	Depth varied
Medium Vegetation	Depth varied
Low Vegetation	0.06

Initial manning roughness values were based on land use GIS layers developed by the QLUMP and road reserve extents based on DCDB data available from DNRM. Manning roughness was updated using an iterative process through the calibration phase of model development.

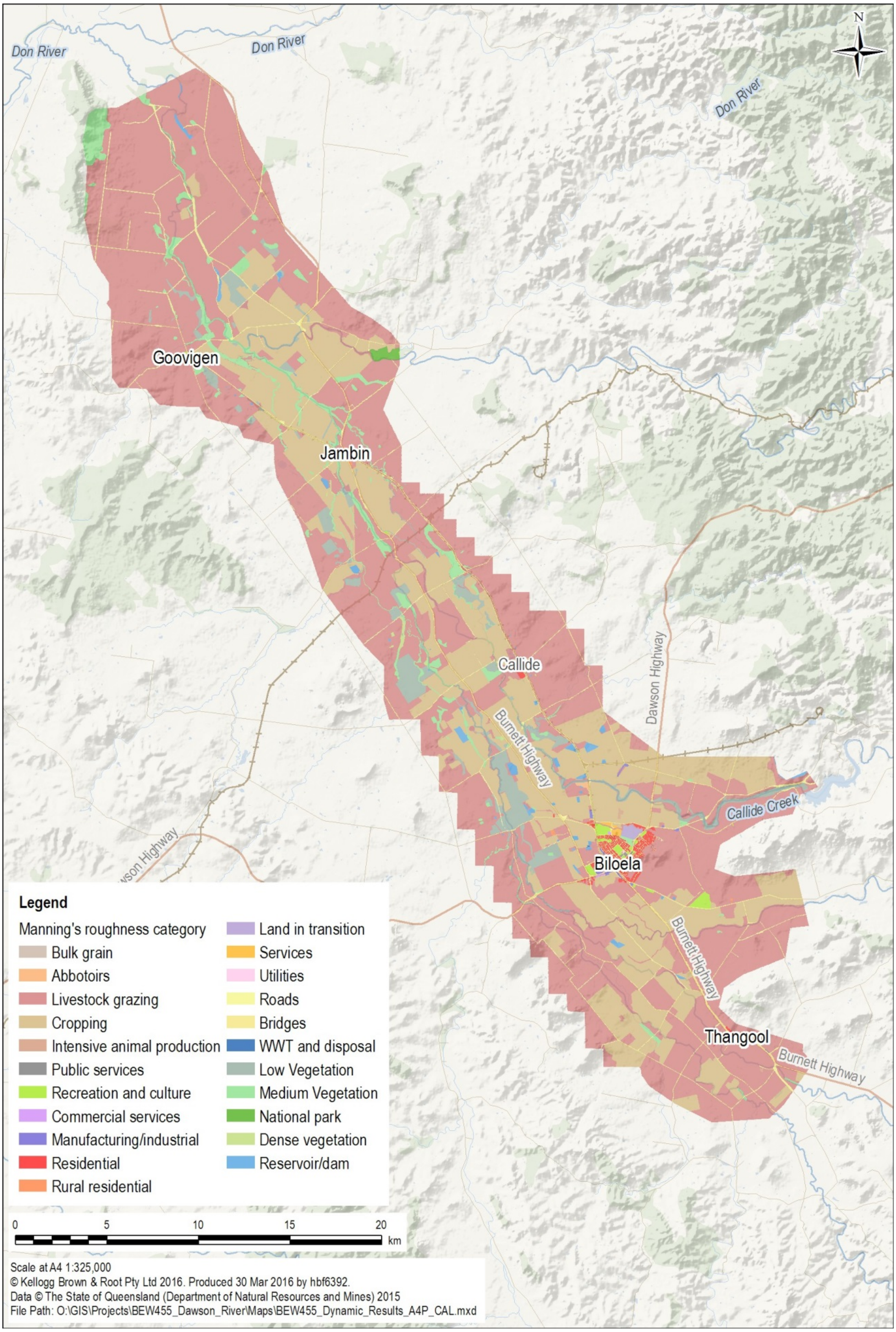

Figure C1
Callide Valley Roughness Map

BRIDGES AND CULVERTS

The main disadvantage of implementing TUFLOW-GPU is the exclusion of 1 dimensional elements, which most commonly take the form of culverts, pipes and bridges.

This disadvantage is less critical in large floodplains where flood waters extend across the majority of the floodplain and where the majority of road embankments are relatively low compared to natural terrain.

In locations where large structures should be considered and may alter regional flooding characteristics, alternate methods to replicate 1 dimensional elements can be included. The following sections provide a brief discussion on the methods that were utilised in the Callide Valley TUFLOW-GPU model.

Culverts

Testing was undertaken during model development whereby pumps (2d_bc) were trialled as culverts using a pump curve which simulated culverts under inlet control. This method showed a lot of potential but was ultimately abandoned due to model stability issues.

Therefore, important culverts with the potential to alter flood levels in sensitive locations have been represented by openings in the applicable road and rail embankment. The width of the opening is based on the equivalent opening area of culvert. In most locations, opening widths are multiples of 10 m (whole grid cells) and no additional form loss or cell flow width reduction has been applied. A summary of culverts that were schematized into the model are presented in Table C-2.

In most cases, culverts with opening area of 2 square metres or less have not been included. The flow through individual small structures is generally insignificant in comparison to the volume of water flowing across the floodplain.

Table C-2 Summary of modelled culverts

Road / Rail Name	Latitude	Longitude	Culvert Size Description	TUFLOW Opening Width (m)
Burnett Highway	-24.4072	150.5158	5/7'x7' RC Culvert (26')	10
Burnett Highway	-24.4122	150.5207	2/1200x375 RCBC + 2/24"x15"	10
Burnett Highway	-24.4134	150.5218	2/1200x375 RCBC + 2/1200x375 RCBC + 2/24"x15" + 2/24"x15"	10
Burnett Highway	-24.4208	150.5291	Exist 4/2120x1520 RCC - Extend L & R	10
Jambin Dakenba Road	-24.3866	150.4888	1/2400x1200 RCBC + Concrete Floodway	20
Dawson Highway	-24.3612	150.5341	12/2400x1800 RCBC + 8/2130x1220	30
Dawson Highway	-24.3732	150.5322	3/2100x900 RCBC	10
Dawson Highway	-24.3641	150.5334	Unidentified	10
Dawson Highway	-24.3818	150.5303	Exist 8/2130x2250 RCC - Lengthen L&R with 8/2100x2250 RCBC	20
Dawson Highway	-24.3758	150.5317	Exist 3/2130x750 RCC - Lengthen R with 3/2100x750 RCBC	10
Dawson Highway	-24.4075	150.4961	Exist 8/7'x5' RC Culvert (skew 45 deg) - 34' along centreline of culvert, 24' square	20
Dawson Highway	-24.4086	150.4919	3/36" RC Pipe (36')	10
Dawson Highway	-24.4162	150.4673	4/54" RC Pipes (32')	10
Dawson Highway	-24.4195	150.4624	Existing 12/7'x7' RC Culvert (24')	30
Burnett Highway	-24.1753	150.3734	11/3600x1800 SLBC	40
Burnett Highway	-24.1818	150.3708	5/3600x1800 SLBC	30

Bridges

Initial testing of bridge structures indicated that clear openings between embankments without including any obstruction (i.e. bridge piers and deck) resulted in an overestimation in the volume of flow downstream.

As a result, further testing was undertaken and a selection of large bridges in sensitive locations has been included using a customised manning's 'n' vs depth curve. Each bridge has a unique curve based on manning values determined through calibration of the Dawson Highway Bridge using TUFLOW classic.

Table C-3 Summary of modelled culverts

Road / Rail Name	Latitude	Longitude	Description
Moura Rail Line	-24.2317	150.4135	6/15'x6' CBDs
Moura Rail Line	-24.2356	150.4084	2/15'x6' CBDs
Moura Rail Line	-24.2361	150.4076	2/15'x6' CBDs
Moura Rail Line	-24.2394	150.4027	6/15'x13' CBDs
Moura Rail Line	-24.2449	150.3946	5/50' Prestressed Conc. Spans - Bridge Callide Creek
Moura Rail Line	-24.2475	150.3919	3/50' Prestressed Conc. Spans - Bridge Kroombit Creek
Moura Rail Line	-24.2547	150.3885	2/15'x4' CBDs
Dawson Highway	-24.2625	150.3852	Unidentified
Moura Rail Line	-24.2646	150.3828	3/50' Prestressed Conc. Spans - Bridge Kroombit Creek
Burnett Highway	-24.3545	150.3155	Kroombit Creek Bridge - 5/15m spans
Dawson Highway	-24.2082	150.4773	Callide Creek Bridge - 7/17m spans

BOUNDARY CONDITIONS

The downstream boundary condition has been applied as a fixed water level over time. The tailwater level has been set approximately equal to the invert of Callide Creek.

Total and local inflow boundary conditions were derived from the hydrological model. Total inflow boundary conditions are used where an inflow represents a source of flow generated by sub- catchments that extend upstream of the hydraulic model boundary extent and are generally applied just within the model boundary. Local inflow boundary conditions represent a source of flow generated from a sub-catchment located within the model boundary. All inflows have been applied using a 2d_SA approach, whereby flow is equally distributed over all cells within the inflow polygon.

Calibration and verification

OVERVIEW

The following sections outline available data, methodology and results of the hydraulic model calibration and verification process.

A considerable amount of data was gathered during and after Ex-Tropical Cyclone Marcia which resulted in extensive flooding across the Callide Valley floodplain during the summer of 2015. Given the amount of available data, it was determined that the Callide Valley TUFLOW-GPU model would be calibrated to the 2015 flood event.

Validation will occur against flood events which occurred in 2013 and 2010. Considerably less data is available from these events; however a comparative analysis at known locations will serve to verify the model.

2015 TROPICAL CYCLONE MARCIA

Available data

Flood debris height data was collected following the 2015 flood event by Council in coordination with staff from KBR. Surveyed debris heights and depths were recorded at 53 locations across the Callide Valley. These points form the basis for the 2015 model calibration.

Surveyed debris data has undergone a rigorous desktop analysis. Surveyed ground levels have been cross checked against 1 m LiDAR data.

Debris heights have been cross checked against aerial imagery and photographic evidence.

Following a desktop analysis it was observed that in some locations surveyed ground and debris levels varied significantly from 1 m LiDAR data. In these locations measured debris depths were adopted to undertake model calibration. The table in Appendix C-1 at the end of this report provides a list of all points used for the 2015 calibration event. The table outlines whether calibration is based on depth or height.

As a consequence of observed differences between surveyed ground and debris levels to 1 m LiDAR and the origin of the recording (woody debris, grass debris, mudline, etc.), each calibration point has been assigned a high, medium or low confidence level. The location and confidence ratings of these points are shown in the table in Appendix C-1 at the end of this report. Model calibration was undertaken preferentially based on the confidence rating of recorded debris heights and depths, i.e. flood levels calibrated to points with a high confidence rating in preference medium and low rating points.

Flood heights recorded by the Goovigen stream gauge were included as part of calibration. The gauge has been assumed a high confidence point to match modelled flood levels.

Aerial SPOT imagery recorded after the 2015 event was also assumed a reliable source of flood extent. The imagery shows defined mud lines and flow extent. In some areas ponded water also indicates extent of flood waters. Modelled flood extents were validated against this data.

Calibration methodology

A target tolerance of ±300 mm was adopted for calibration of modelled levels to recorded data.

In locations where uncertainties exist between surveyed ground level and LiDAR (for recorded debris heights) differences in flood depth were assessed and reported.

Initially hydraulic model inflows were based on outputs from the RAFTS hydrologic model which included rainfall losses with losses calibrated to available stream gauge data. Initial hydraulic model runs indicated very large overestimation in predicted flood levels by over 1.5 m in many locations.

Model roughness was revised a number of times however the closest comparison between predicted and recorded levels (while maintaining industry accepted roughness values) varied by over 1 m.

Given the large differences between recorded and predicted water levels using this method, it was determined that a joint calibration between the hydrologic and hydraulic model would be undertaken.

Initial and continuing losses (within the hydrology model) were adjusted in an iterative process between runs of the TUFLOW-GPU model. After a number of iterations a comparatively close match was achieved between modelled water levels and recorded debris data (while maintaining loss factors within industry standard).

A final adjustment of manning roughness was undertaken in order to ‘fine tune’ final calibration. For additional details on hydrologic calibration see Section 3 of the main report.

Calibration Results

Water levels and depths from the 2015 flood event are shown in the flood maps in Volume 2. Calibration results from the 2015 Ex-Tropical Cyclone Marcia flood event show peak flows from a majority of the catchments within the Callide Valley floodplain were large enough to exceed the capacity of many ‘perched’ creeks and spill across the adjacent landform and floodplain.

Biloela

The peak flood wave from Callide Creek occurred several hours prior to the peak from Kroombit Creek and associated break out flows across Washpool Gully. The results show isolated 'break out' flows along Callide Creek in several locations upstream of Muirs Road.

Calibration results show significant overtopping of the high bank along Kroombit Creek. The model shows 'break out' flows from Kroombit Creek initially spill into washpool gully (adjacent Baileys Lane) and spill again downstream into Browns Gully.

Flows from Kroombit Creek 'break out' again further downstream adjacent to the Burnett Highway and travel in a northerly direction spreading and spilling along the highway. These flows ultimately find their way into Contact Creek and Browns Gully upstream of the Dawson Highway.

The complex nature of break out flows from Kroombit Creek is extremely sensitive to model parameters. Considerable effort was invested in adjusting model parameters in order to replicate the spread of flow and match the debris marks. Modelled flood levels were matched to almost all calibration points within 300 mm and many within 100 mm through this area.

All modelled water levels through washpool gully upstream of the Burnett Highway and adjacent to Tognalini Drive match to high confidence calibration points within 200 mm. Many of these points match within 100 mm.

Considerable effort was undertaken to match predicted flood levels at Browns gully adjacent to Council Chambers and Contact Creek upstream of the Dawson Highway. Results indicate modelled levels are approximately 300 mm higher than recorded levels at Browns Gully and 460 mm higher at Contact Creek upstream of Dawson highway. Flood levels through this area are dependent on the volume of flow to break out of Kroombit Creek at Washpool Gully and the Burnett Highway. Roughness values have been adjusted using an iterative process to balance flows between Washpool Gully, Browns Gully and Kroombit Creek in order to match levels as closely as possible.

Thangool

Flooding at Thangool is dominated by flows originating from Kariboe Creek. Results indicate significant 'break out' flow from Kariboe Creek upstream and adjacent to Thangool Airport.

Predicted flood levels match to within 70 mm of recorded debris data at this location and modelled flood extents closely match mud outlines evident in SPOT aerial imagery.

Jambin

Flood levels across the floodplain between Biloela and Jambin match recorded debris data to within 200 mm in the majority of locations.

Flood heights were recorded in three locations at Jambin. The calibration point with the highest confidence rating matches modelled levels to within 140 mm, which is within the target tolerance outlined above.

The remaining points recorded at Jambin indicate overestimated flood levels; however they have a lower confidence rating and are considered less accurate for calibration purposes. In particular the medium confidence point has been recorded adjacent to private property where significant filling has recently occurred. Consequently large differences in ground level (and recorded flood height) should be expected between LiDAR recorded in 2010 and the more recently surveyed flood height.

Goovigen

The modelled regional flood level from Callide Creek at Goovigen is below the level of the Goovigen Township. Results show the township of Goovigen is not affected by a regional flood event from Callide Creek.

It should be noted that localised flooding from Eleven Mile Creek (adjacent to Goovigen) has not been assessed as part of this study. Localised flooding may still result in inundation of private properties and roads at Goovigen. This was demonstrated in the *Goovigen Flood Hazard Mapping Study* undertaken by WRM Water and Environment for Queensland Reconstruction Authority.

The Goovigen stream gauge remained operational throughout the flood event and was assigned a high confidence rating. Modelled flood levels are shown to be 230 mm higher than the maximum recorded level during the 2015 event. This is within the target tolerance of 300 mm and considered a good match given the width the floodplain and complex nature of flow surrounding the perched channel.

On the eastern extent of the floodplain flood debris data was recorded at the Burnett Highway where flows 'break out' from Bell Creek downstream of Fiveways Mount Eugen Road and overtop Burnett Highway. Predicted flood levels are shown to be less than 100 mm higher than recorded data which is also considered a good match.

Table C-4 provides a summary of differences between recorded flood heights and modelled flood depths for the 2015 calibration event.

Table C-4 Summary of calibration results

Calibration Point Confidence Rating	Total Points	Outside 300 mm	Between 300 – 200 mm	Between 200 - 100 mm	Within 100 mm
High	19	1	2	7	9
Medium	15	4	1	3	7
Low	19	4	1	10	4
Total	53	9	4	20	20

2013 TROPICAL CYCLONE OSWALD

Available Data

Two locations are known where historic flood heights have been surveyed or recorded. The first location is the stream gauge at Goovigen which remained operational throughout the duration of the 2013 flood event. The second location is the pub at Jambin, where historic flood height and depth data have been provided by DEWS.

Verification Results

2013 Flood depth and heights are shown in the Volume 2 maps.

The modelled flood level at the Goovigen stream gauge matches the recorded level to within 190 mm. This is considered a good match and provides an excellent validation to parameters selected for the calibration event.

The modelled flood level at Jambin pub is approximately 240 mm above the recorded level which is also within the target tolerance for model calibration and validation.

Biloela

Peak flow from the Callide Dam upstream of the Dawson Highway is estimated as 1970 m^3/s. This is significantly less than the 2015 event which had a peak flow of approximately 4800 m^3/s.

The reduced peak flow from Callide dam in the 2013 flood event, results in decreased flood extent upstream of Dawson Highway. Flows break out of bank downstream of Muirs Road, and continue to break out the perched creek further down the floodplain.

Peak flow from Kroombit Dam is much less than the 2015 event. Consequently much less flow breaks out upstream of Burnett Highway and into Washpool Gully. Any flow within washpool gully is contained and does not contribute to flooding of private property.

Break out flow from Kroombit Creek overtops the Burnett Highway at multiple locations between Browns Gully and Kroombit Creek. There is currently no known reliable historic flood height data for the 2013 event at Biloela.

Thangool

Flood levels and extent at Thangool are reduced when compared to 2015 results. Peak flow from Kariboe Creek is reduced and results in significantly less break out flow at Thangool.

Jambin

The modelled peak flow across the Callide Valley at Jambin is approximately 4200 m^3/s. This is similar to the 2015 event which resulted in a peak flow of approximately 4110 m^3/s. Modelled flood levels at Jambin in the 2013 and 2015 event are very similar.

A historical flood height record was provided by DEWS at the location of the Jambin Hotel, which included a maximum level for the 2013 event. The modelled flood height at the location of the Jambin Hotel matches to within 240 mm of the recorded level and is within the target range for calibration and validation.

Goovigen

Similarly to the 2015 event, the Goovigen stream gauge was operational throughout the 2013 flood event and has been assigned a high confidence rating. Modelled flood level for the 2013 validation event is approximately 190 mm higher than the recorded gauge height which is within the target tolerance.

2010 FLOOD EVENT

Available Data

The Goovigen stream gauge again provides a reliable source of recorded level for the 2010 flood event.

Recorded flood levels for the townships of Jambin and Thangool have been extracted from reports delivered as part of the Queensland Flood Mapping Project (QFMP) commissioned by the Queensland Reconstruction Authority (QRA).

Verification Results

2010 Flood depth and heights maps are presented in Volume 2.

The modelled flood level at the Goovigen stream gauge matches the recorded level to within 110 mm. This is considered a good match and provides an excellent validation to parameters selected for the calibration event. The modelled flood level at Jambin pub is approximately 110 mm below the recorded level which is also within the target tolerance for model calibration and validation.

Biloela

The main township of Biloela remained relatively unaffected during the 2010 flood event.

The intensity and volume of rainfall upstream of Callide dam in combination with lower starting water levels within the dam resulted in flows not overtopping the spillway. As a consequence flows within Callide Creek downstream of the dam do not result in flooding.

Flows within Kroombit are large enough to result in flooding of the Burnett Highway, however the flow is reduced when compared to the 2015 event and significant breakout does not occur into washpool gully.

Thangool

Flood levels and extent at Thangool are reduced when compared to 2015 and 2013 results. Peak flow from Kariboe Creek is reduced and results in significantly less break out flow at Thangool.

Peak flood levels at Thangool aerodrome have been compared to recorded debris data published in previous flood investigations undertaken as part of the QFMP commissioned by the QRA.

The results of this study compare well to recorded values. The closest comparison occurs within the dominant overland flowpath where modelled values match to recorded data within 70 mm.

Modelled levels appear to under predict at the remaining two locations. However these points are at the extent of the flood flow and still match to within a reasonable tolerance.

Jambin

A historical flood height record was provided by DEWS at the location of the Jambin Hotel, which included a maximum level for the 2013 event. The modelled flood height at the location of the Jambin Hotel matches to within 110 mm of the recorded level and is within the target range for calibration and validation.

Other recorded levels were digitised from the recently published flood investigation of Jambin undertaken as part of the QFMP project. The recorded levels match the latest modelled levels within 200 mm in most locations.

Goovigen

Similarly to the 2015 and 2013event, the Goovigen stream gauge was operational throughout the 2013 flood event and has been assigned a high confidence rating. Modelled flood level for the 2013 validation event is approximately 110 mm higher than the recorded gauge height which is within the target tolerance.

The modelled peak flow across the Callide Valley at Goovigen is approximately 2400 m^3/s. This is considerably less than in the 2015 event which resulted in a peak flow of approximately 4060 m^3/s. Although there is a relatively large difference in peak flows across the floodplain in this location the water level at Goovigen is similar in both events. The peak water level in the 2010 event was 122.36 m AHD, while in the 2015 event the modelled water level was approximately 122.5 m AHD.

Conclusions

The majority of 2015 flood debris calibration points fall within 300 mm target range, with high percentage within 100 mm tolerance.

The Moura rail line effectively acts as a Levy across the floodplain. The rail line creates flood storage upstream with the bridge opening’s operating as a form of fixed outlet control which has been observed to equalise in the downstream sections of the floodplain between historical events.

Break out flow from Bell Creek can significantly affect water levels at the Goovigen stream gauge, and flows within the wider Callide Creek floodplain.

Results demonstrate the majority of flooding experienced at Biloela during Tropical Cyclone Marcia was a consequence of break out flow from Kroombit Creek into Washpool Gully.

The comparatively large differences in peak flows and minor change in water levels at the Goovigen stream gauge suggest the location of the stream gauge may not be effective when undertaking flood flow analysis.

Appendix C-1
Flood Calibration Points

Calibration Point ID	Confidence Rating	Surveyed Debris Depth	TUFLOW 2015 Flood Depth	Surveyed Debris Height	TUFLOW 2015 Flood Height	Difference to Surveyed Flood Data	Adopted Comparison Data Type
P_01	low	0.84	0.75	166.32	167.18	-0.09	Depth
P_02	high	0.35	0.44	167.49	168.36	0.09	Depth
P_03	high	0.62	0.48	167.46	167.32	-0.14	Height
P_04	high	0.53	0.48	167.38	167.32	-0.05	Depth
P_05	low	0.90	1.07	168.25	167.97	0.17	Depth
P_06	medium	1.37	1.04	167.68	167.82	0.14	Height
P_07	medium	0.81	0.93	167.28	167.43	0.12	Depth
P_08	low	0.84	1.28	168.08	168.48	0.40	Height
P_09	low	0.69	1.01	167.66	168.33	0.32	Depth
P_10	low	0.68	1.13	168.09	168.43	0.34	Height
P_11	high	0.40	0.72	168.22	168.37	0.15	Height
P_12	high	0.38	0.57	168.16	168.33	0.17	Height
P_13	high	0.70	0.77	169.35	169.40	0.05	Height
P_14	high	0.59	0.73	172.83	172.92	0.08	Height
P_15	high	1.01	1.16	173.04	172.86	0.15	Depth
P_16	medium	0.47	0.74	172.79	173.61	0.27	Depth
P_17	high	0.87	1.21	172.47	172.57	0.10	Height
P_18	low	0.00	0.40	176.49	176.38	-0.11	Height
P_19	high	0.71	0.79	173.47	173.23	0.08	Depth
P_20	medium	0.00	0.15	176.05	175.97	-0.08	Height
P_21	high	0.77	0.18	176.08	175.96	-0.13	Height
P_22	high	0.71	1.13	175.58	175.88	0.30	Height
P_23	low	0.50	0.35	178.80	176.67	-0.15	Depth
P_24	low	0.50	0.65	177.02	176.06	0.15	Depth
P_25	high	0.32	0.38	184.31	184.12	0.06	Depth
P_26	low	0.52	0.65	185.96	185.74	0.13	Depth
P_27	high	0.86	0.93	193.02	193.15	0.07	Depth
P_28	medium	0.67	0.72	193.10	193.16	0.05	Depth
P_29	low	0.65	0.55	191.91	191.80	-0.10	Depth
P_30	low	0.62	0.59	191.86	191.81	-0.03	Depth
P_31	low	0.51	0.13	182.79	182.67	-0.12	Height
P_32	medium	0.31	0.36	180.45	180.56	0.05	Depth
P_33	high	0.32	0.00	176.18	175.92	-0.26	Height
P_34	low	0.84	1.50	170.30	171.08	0.66	Depth
P_35	high	0.63	1.09	169.79	170.31	0.46	Depth
P_36	medium	0.25	0.09	167.79	167.57	-0.16	Depth
P_37	medium	0.81	0.86	170.42	170.26	0.05	Depth
P_38	medium	0.00	1.42	188.51	189.58	1.07	Height
P_39	high	1.41	1.73	163.87	164.19	0.32	Depth
P_40	medium	0.86	0.88	164.50	164.42	0.02	Depth
P_41	medium	1.30	1.56	157.13	157.39	0.26	Depth

Calibration Point ID	Confidence Rating	Surveyed Debris Depth	TUFLOW 2015 Flood Depth	Surveyed Debris Height	TUFLOW 2015 Flood Height	Difference to Surveyed Flood Data	Adopted Comparison Data Type
P_42	low	0.42	0.30	158.62	158.52	-0.10	Height
P_43	low	1.54	1.76	141.85	142.19	0.22	Depth
P_44	high	0.76	1.11	133.99	134.16	0.17	Height
P_45	low	0.34	1.02	133.26	133.78	0.52	Height
P_46	low	0.85	1.22	131.67	131.96	0.29	Height
P_47	medium	0.00	1.72	132.95	133.50	0.55	Height
P_48	medium	0.00	1.02	132.29	131.99	-0.30	Height
P_49	medium	0.00	0.08	129.79	129.86	0.07	Height
P_50	low	0.94	0.89	130.12	130.06	-0.05	Depth
P_51	medium	0.50	0.26	130.21	130.25	0.04	Height
P_52	low	1.47	1.49	131.40	131.53	0.02	Depth
P_53	high	10.98	9.11	122.30	122.53	0.23	Height

Appendix D

DAWSON TOWNS HYDRAULIC REPORT

Appendix D1
Taroom

Appendix D2
Theodore

Appendix D3
Moura

Appendix D4
Baralaba

Appendix D5
Dululu and Wowan

Appendix D
Dawson Towns Hydraulic Report

Introduction

Kellogg Brown & Root Pty Ltd was commissioned by Banana Shire Council (Council) to undertake a floodplain management study and plan for 10 towns within Council's Land Government Area (LGA).

The purpose of this Appendix is to describe the technical detail of the hydraulic models including assumptions, setup, and results. This report describes the hydraulic models for the towns of Taroom, Theodore, Moura, Baralaba, Dululu, and Wowan. The hydraulic model covering the towns of Biloela, Thangool, Jambin, and Goovigen are not discussed and are covered in Appendix C.

Detail specific to each model is described in the following Appendices:

- Taroom – Appendix D-1
- Theodore – Appendix D-2
- Moura – Appendix D-3
- Baralaba – Appendix D-4
- Dululu and Wowan – Appendix D-5

Data

Terrain

Terrain data was captured by Light Detection and Ranging (LiDAR) techniques as part of the QFMP. LiDAR is considered to be of high accuracy and suitable for use in hydraulic modelling. However, due to its capture techniques, it is unable to penetrate standing water, buildings, bridge decks, or dense vegetation. Algorithms are used (prior to receipt by KBR) to automatically remove most of these features from the terrain. However because these processes are automated, some features are missed, or over smoothing can occur. This point is important to remember, as terrain is the primary input into flood models and results can be sensitive.

The accuracy of the LiDAR and when it was captured for each hydraulic model is noted in the corresponding Appendix.

Calibration

Calibration data has primarily been sourced from stream gauges such as DNRM, BOM, and SunWater.

Debris survey data was collected by KBR and Council after the 2015 event and was used in the 2015 calibration in the Wowan TUFLOW model. The survey collection recorded ground level, and the corresponding water level at most locations, and rated the confidence of the level based on the flood mark. For example, debris on a fence might be rated as low confidence, and a mud mark on a wall might be rated high confidence.

The data was processed by Council and given to KBR in the form of and electronic XYZ point file. On inspection, KBR found processing errors in the data, such as flood elevations that were below ground level. KBR, using additional information provided by Council, subsequently made corrections to the data to the best ability with the data available. Despite the corrections, confidence in some of the data points was downgraded to reflect the uncertainty.

Hydraulic model setup

Model extents

Figure 1 presents the location of the hydraulic models assessed in this study. The model extents have been chosen considering a number of factors such as: available terrain data, hydraulic controls, and suitable upstream and downstream boundary locations.

Individual model extents are presented in the corresponding model Appendix. The Callide Valley TUFLOW model is not discussed in this technical report, and is detailed in Appendix C.

Roughness

Model roughness, represented as Manning's 'n', describes the hydraulic properties of the land cover and is a key input parameter to hydraulic flood modelling.

Different land covers generally have an acceptable Manning's 'n' value range, and the selected value can vary depending on the engineer. Calibration is therefore important to the selection of Manning's 'n' values, as it is the key parameter altered, and provides confidence in its selection.

The adopted Manning's 'n' values and delineated roughness maps for each model is presented in the corresponding model Appendix. The Callide Valley TUFLOW model is not discussed in this technical report, and is detailed in Appendix C.

Structures

Hydraulic structures such as bridges and culverts, can act as hydraulic controls during flood events. Structures were implemented in the hydraulic models using either One Dimensional (1D) or 2D techniques depending on the data available and the software package.

Boundary conditions

Upstream boundary

The upstream boundary inflows were sourced from the appropriate hydrologic model (Dawson model or Don-Dee model).

The inflows were applied using Source Area (SA) polygons in the TUFLOW models. SA polygons initially apply flow at the lowest elevated terrain within the polygon. Once initial wetting occurs, flow is distributed evenly to all wet grid cells within the polygon.

Downstream boundary

The adopted downstream boundary in all the hydraulic models was specified as 'HQ' type. The 'HQ' type boundary converts exiting flow to water level to satisfy the hydraulic equations.

The 'HQ' type boundary requires the input of normal water surface slope to generate a rating curve to convert flow to water level. In the Dawson catchment, the normal water surface slope is very flat due to the flat terrain. Adopting a flat slope can cause instabilities at the downstream boundary, resulting in an unhealthy model and a loss in confidence in the results. Often the slope at the downstream boundary was steepened to achieve stability, and the results were checked for the boundaries influence over water levels in the model. It was found that the downstream boundary assumptions had a limited zone of influence, and no influence in the areas of interest within the hydraulic models.

The slope value adopted at the downstream boundary in each model is stated in their corresponding Appendix.

Calibration

Calibration results are presented and discussed in the corresponding Appendices.

Design

Design results are presented and discussed in the corresponding Appendices.

Conclusion

KBR developed TUFLOW models to assess the towns of Taroom, Theodore, Moura, Baralaba, Dululu, and Wowan. The hydraulic models located along the Dawson River were calibrated to the 2010 event, and the Towns located within the Don-Dee catchment were calibrated to the 2015 event.

The Theodore TUFLOW model was verified to the 2013 event, and the Callide Valley TUFLOW GPU event was verified to the 2013, 2010, and 1978 flood events.

The calibrated hydraulic models were used to obtain design flood levels using design flows from the appropriate hydrologic model.

Appendix D1
Taroom Hydraulic Report

Introduction

This report discusses the individual setup and results of the Taroom TUFLOW model. It is intended to be read in conjunction with Appendix D, which describes the modelling methodology and assumptions.

Data

Terrain

The LiDAR data used for Baralaba was captured on 25 July and 4 November 2011. It has a quoted vertical accuracy of 0.15 m, horizontal accuracy of 0.45 m (DERM, 2012).

The elevation data was provided in Australian Height Datum (AHD), and the horizontal data was projected in Map Grid Australia Zone 55 (MGA55).

Hydraulic model setup

Roughness

Table D1-1 presents the adopted Manning's 'n' roughness values adopted in the model. Figure D1-1 presents the corresponding roughness map.

Table D1-1 Taroom land use Manning's 'n' classification

Land use type	Manning 'n' roughness value
Cropping	0.100
Intensive animal production	0.090
Irrigated Cropping	0.100
Land in transition	0.040
Livestock grazing	0.100
Manufacturing and industrial	0.300
Marsh/wetland	0.040
Other minimal use	0.070
Production forestry	0.080
Reservoir/dam	0.030
Residential	0.100

Land use type	Manning 'n' roughness value
River	0.050
Services	0.050
Transport and communication	0.040
Utilities	0.300
Dense vegetation	0.100

Downstream boundary

The downstream boundary normal water surface slope was adopted as 1%.

Culverts and bridges

Bridges and culverts were modelled in the 1D using TUFLOW's Estry engine and in 2D domain by leaving a gap in the terrain to allow water to pass through embankments. Seven major crossings were identified in the model extent; six were located on the Dawson River, four at the Leichardt Highway, and two at Dawson Street, and one on Kungay Mungay Creek at the Leichardt Highway.

Calibration

The resulting calibration flood surface is presented in Volume 2 of this report. The comparison between the modelled water level and the historic level is shown on the map, and the resulting modelled water surface is 0.18 m higher.

Through the calibration process, it was found that inflows from the hydrological model were required to be significantly higher than what the stream suggested. This indicates either that the model is under predicting water levels, or that there are inaccuracies in the gauge rating curve.

The Manning's 'n' values were increased to the upper limit of acceptable bounds, and water levels were unable to be matched using similar flows suggested by the current rating curve. It was therefore concluded through the join calibration process that the Taroom gauge rating curve was under predicting flows during the 2010 event.

A flood outline derived from aerial photographs during the flood compare well with the modelled water surface.

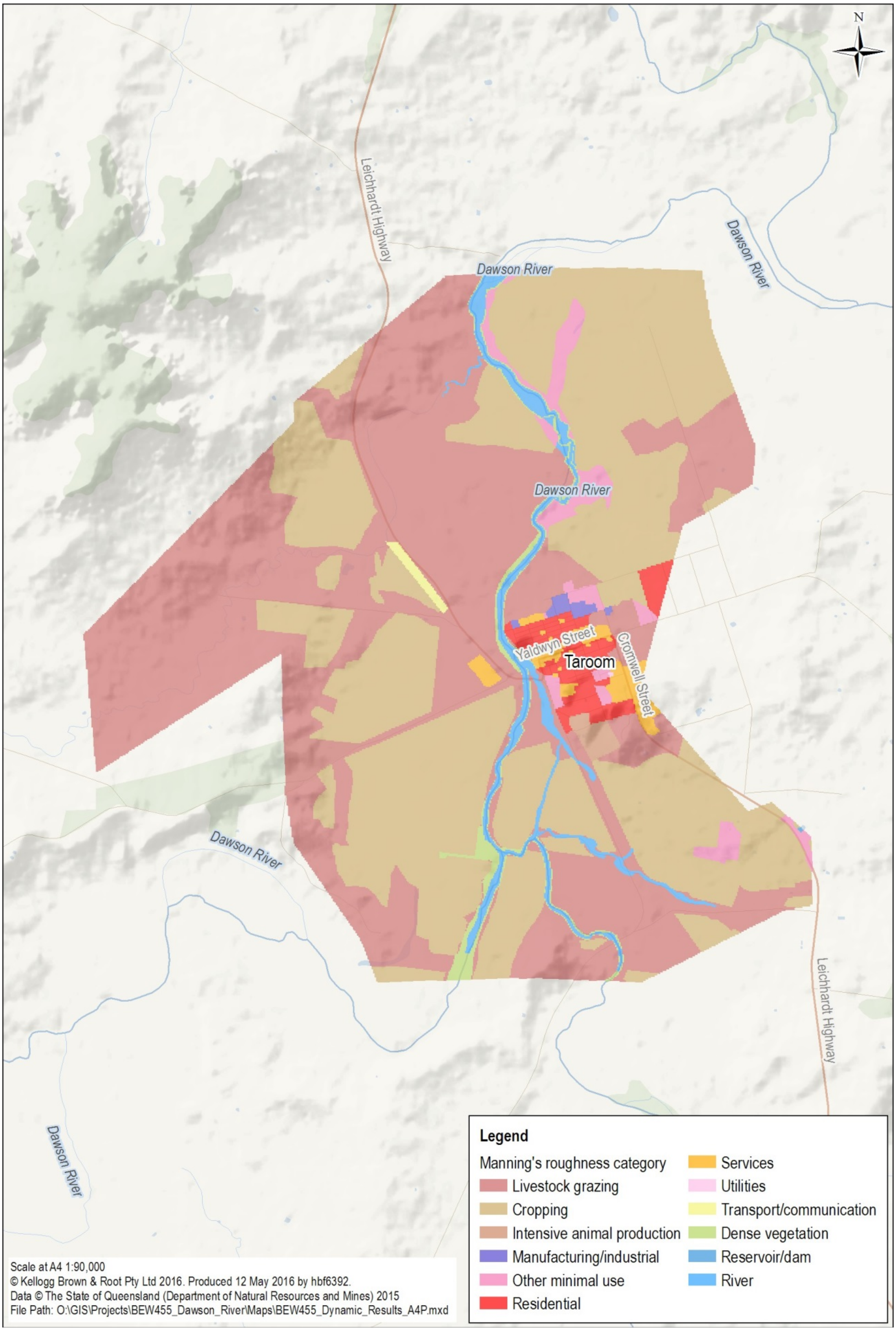

Figure D1-1
TAROOM ROUGHNESS MAP

Design

Table D1-2 presents a summary of the water level results from the Taroom TUFLOW model design runs. The water level was extracted at the Taroom stream station.

Table D1-2 Design flood level results

	Historic	Design				
	2010	5%	2%	1%	1%CC*	PMF
Water level	190.93	189.24	190.00	190.57	191.22	195.62

* *1%CC denotes the 1% AEP event with climate change sensitivity*

Conclusion

KBR developed a hydraulic model for Taroom Township. The model was calibrated to the 2010 event and showed a good comparison.

Design flows from the hydrologic model were simulated in the calibrated model to obtain design levels.

References

DERM 2012, Queensland LiDAR data (Inland towns Stage 2 Project) Banana Shire Council (LGA) - Zone 55 Published on 3 February 2012

Introduction

This report discusses the individual setup and results of the Theodore TUFLOW model. It is intended to be read in conjunction with Appendix D, which describes the modelling methodology and assumptions..

Data

Terrain

The LiDAR data used for Theodore was captured on 3 and 4 November 2011. It has a quoted vertical accuracy of 0.15 m, horizontal accuracy of 0.45 m (DERM, 2012).

The elevation data was provided in Australian Height Datum (AHD), and the horizontal data was projected in Map Grid Australia Zone 55 (MGA55).

Hydraulic model setup

Roughness

Table D2-1 presents the adopted Manning's 'n' roughness values adopted in the model. Figure D2-1 presents the corresponding roughness map.

Table D2-1 Theodore land use Manning's 'n' classification

Land use type	Manning 'n' roughness value
Cropping	0.045
Irrigated Cropping	0.065
Intensive animal production	0.090
Livestock grazing	0.050
Manufacturing and industrial	1.000
Marsh/wetland	0.040
Production forestry	0.080
Reservoir/dam	0.030
Residential	0.080
River	0.040
River Banks	0.070

Land use type	Manning ‘n’ roughness value
Transport and communication corridors	0.040
Other minimal use	0.040
Land in transition	0.060
Services	0.050
Utilities	1.000

Downstream boundary

The downstream boundary normal water surface slope was adopted as 0.5%.

Culverts and bridges

Bridges and culverts were modelled in the 2D domain by leaving a gap in the terrain to allow water to pass through embankments. Three bridges were identified in the model extent; two were located on the Dawson River at the Leichardt Highway, and one on Castle Creek at Fifth Avenue.

Calibration

The resulting calibration flood surfaces for the 2010 and 2013 events are presented in Volume 2 of this report. The comparison between the modelled water level and the historic level is shown on the maps, and the resulting modelled water surface is 0.17 m higher for the 2010 event, and 0.32 m high for the 2013 event.

During large storm events, where flood waters overtop the river banks and onto the floodplain (as is present in the 2010 event), water levels are controlled by the natural downstream constriction in the terrain. Water levels were found to not be sensitive to changes in roughness values. Theodore is therefore an excellent location for joint calibration, as hydrological inflows are the primary variable. During the calibration process, flows in the hydrological model for the 2010 event were reduced significantly through attenuation to achieve hydraulic calibration.

A larger difference in modelled water levels exists for the 2013 event between the modelled and recorded flood levels. This difference is most likely caused by the ‘false bottom’ in the creek captured by the LiDAR due to standing water behind the weir.

A flood outline derived from aerial photographs during the 2010 flood compare well with the modelled water surface.

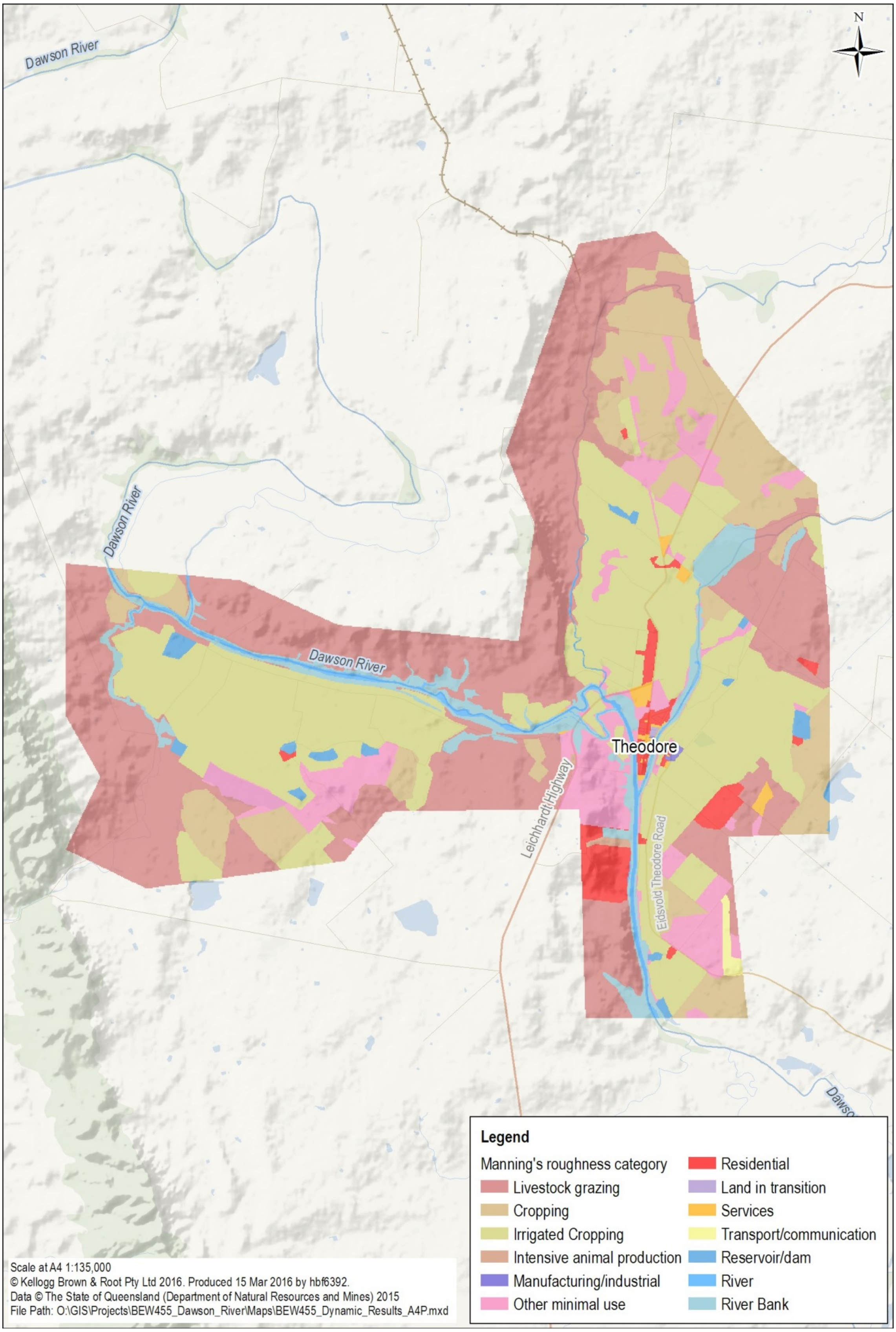

Figure D2-1
THEODORE ROUGHNESS MAP

Design

Table D2-2 presents a summary of the water level results from the Theodore TUFLOW model design runs. The water level was extracted at the Taroom stream station.

Table D2-2 Design flood level results

	Historic		Design						
	2010	2013	10%	5%	2%	1%	1%CC*	0.2%	PMF
Water level	142.05	137.61	139.07	140.16	141.46	142.19	142.92	143.13	149.83

* *1%CC denotes the 1% AEP event with climate change sensitivity*

Conclusion

KBR developed a hydraulic model for Taroom Township. The model was calibrated to the 2010 event and showed a good comparison.

Design flows from the hydrologic model were simulated in the calibrated model to obtain design levels.

References

DERM 2012, Queensland LiDAR data (Inland towns Stage 2 Project) Banana Shire Council (LGA) - Zone 55 Published on 3 February 2012

Introduction

This report discusses the individual setup and results of the Moura TUFLOW model. It is intended to be read in conjunction with Appendix D, which describes the modelling methodology and assumptions.

Data

Terrain

The LiDAR data used for Moura was captured on 12 August 2012. It has a quoted vertical accuracy of 0.15 m, horizontal accuracy of 0.45 m (DERM, 2012). The elevation data was provided in Australian Height Datum (AHD), and the horizontal data was projected in Map Grid Australia Zone 55 (MGA55).

DERM prepared background studies for the proposed Rolleston Dam which included a large photogrammetric dataset at 2 m contour intervals. This dataset extends over the Dawson River below Gyranda Weir (between Theodore and Taroom) to the Capricorn Highway. This data was utilised to extend the flood model extents where the LiDAR was insufficient.

Hydraulic model setup

Roughness

Table D3-1 presents the adopted Manning's 'n' roughness values adopted in the model. Figure D3-1 presents the corresponding roughness map.

Table D3-1 Taroom land use Manning's 'n' classification

Land use type	Manning 'n' roughness value
Cropping	0.050
Intensive animal production	0.090
Irrigated Cropping	0.050
Land in transition	0.060
Livestock grazing	0.045
Manufacturing and industrial	0.300
Marsh/wetland	0.040
Mining	0.300

Land use type	Manning ‘n’ roughness value
Other minimal use	0.060
Production forestry	0.080
Reservoir/dam	0.030
Residential	0.100
River	0.030
Services	0.050
Transport and communication	0.040
Utilities	0.300

Downstream boundary

The downstream boundary normal water surface slope was adopted as 0.5%.

Culverts and bridges

Bridges and culverts were modelled in the 2D domain by leaving a gap in the terrain to allow water to pass through embankments. One major bridge was identified in the model extent along the Dawson River located at the Dawson Highway.

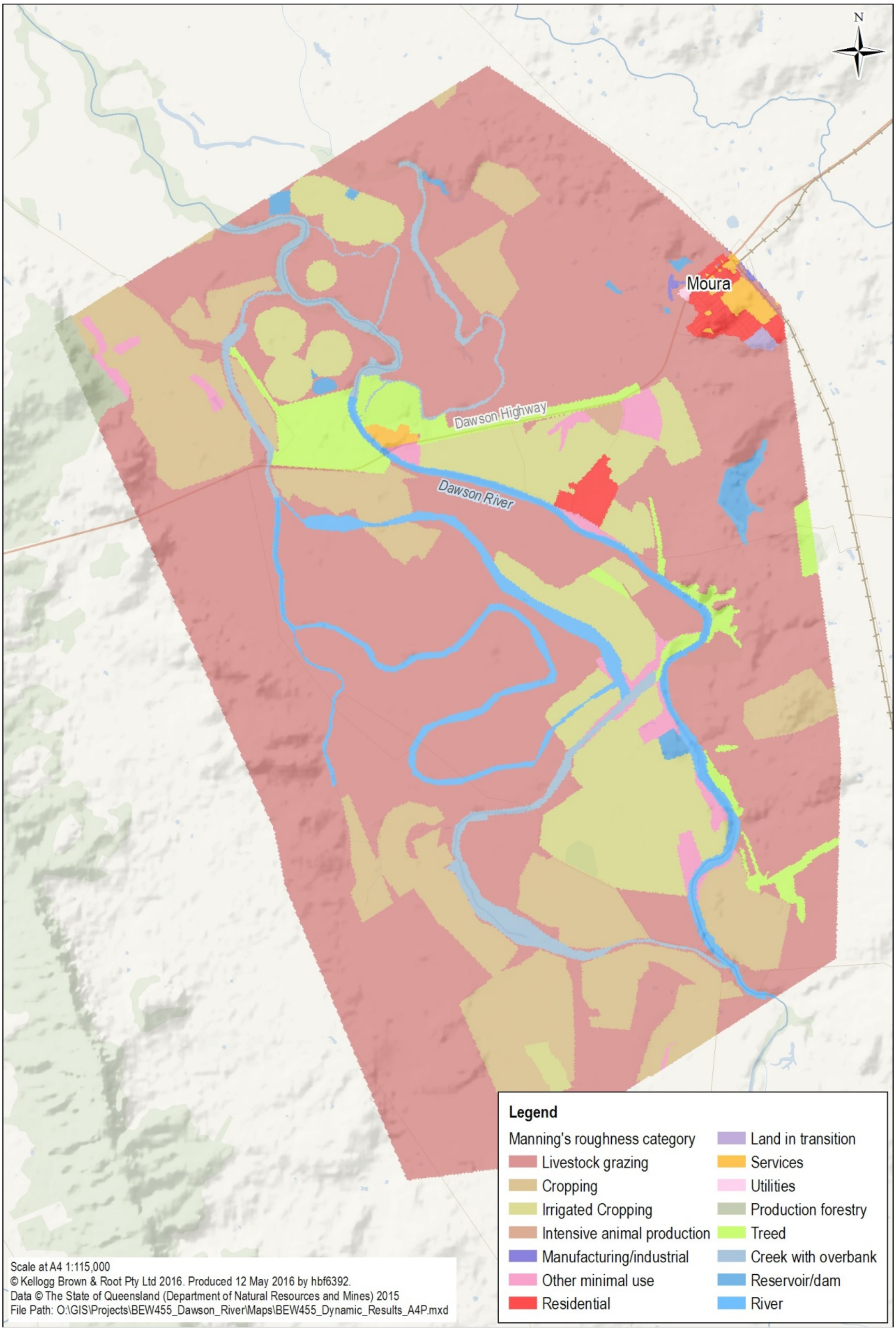

Figure D3-1
MOURA ROUGHNESS MAP

Calibration

The resulting calibration flood surface for the 2010 event is presented in Volume 2 of this report. The comparison between the modelled water level and the historic level is shown on the maps, and the resulting modelled water surface is 0.82 m lower for the 2010 event.

On further inspection of the detailed aerial imagery flown in the morning after the 2010 event there are some areas where the peak flood extent is more clearly discernible. Five points were identified that were used to assist the joint calibration process of the Dawson River RAFTS model and the Moura TUFLOW model. Three points on the Dawson Highway as the road profile rose in and out of the flood water, one point on the road to the Moura Weir and one point at the Moura and District Golf Club near the club house. The peak water level at these points was estimated using the LiDAR and compared to the model results, which showed a good match. Table D3-2 presents the comparison at these points.

Table D3-2 Comparison between extents estimated from aerial photograph and modelled water surface

Location	Historic elevation (from LiDAR) (m AHD)	Modelled water elevation (m AHD)	Difference* (m)
Dawson Highway point 1	110.31	110.52	0.21
Dawson Highway point 2	109.79	110.05	0.26
Dawson Highway point 3	109.54	109.78	0.24
Moura Weir road	109.73	110.23	0.50
Golf club	110.17	110.52	0.35

* *Positive values denote higher water levels in the modelled water surface, and negative values denote lower water modelled surface*

Design

Table D3-3 presents a summary of the water level results from the Moura TUFLOW model design runs. The water level was extracted at Moura Weir.

Table D3-3 Design flood level results

	Calibration	Design				
	2010	5%	2%	1%	1%CC*	PMF
Water level	110.84	110.39	110.70	110.86	110.99	111.86

* *1%CC denotes the 1% AEP event with climate change sensitivity*

Conclusion

KBR developed a hydraulic model for Moura Township. The model was calibrated to the 2010 event and showed a good comparison to elevations extracted from the LiDAR where extents were discernible from aerial photography.

Design flows from the hydrologic model were simulated in the calibrated model to obtain design levels.

References

DERM 2012, Queensland LiDAR data (Inland towns Stage 2 Project) Banana Shire Council (LGA) - Zone 55 Published on 3 February 2012

Appendix D4
Baralaba Hydraulic Report

Introduction

This report discusses the individual setup and results of the Baralaba TUFLOW model. It is intended to be read in conjunction with Appendix D, which describes the modelling methodology and assumptions.

Data

Terrain

The LiDAR data used for Moura was captured on 12 August 2012. It has a quoted vertical accuracy of 0.15 m, horizontal accuracy of 0.45 m (DERM, 2012). The elevation data was provided in Australian Height Datum (AHD), and the horizontal data was projected in Map Grid Australia Zone 55 (MGA55).

DERM prepared background studies for the proposed Rolleston Dam which included a large photogrammetric dataset at 2 m contour intervals. This dataset extends over the Dawson River below Gyranda Weir (between Theodore and Taroom) to the Capricorn Highway. This data was utilised to extend the flood model extents where the LiDAR was insufficient.

Hydraulic model setup

Roughness

Table D4-1 presents the adopted Manning's 'n' roughness values adopted in the model. Figure D4-1 presents the corresponding roughness map.

Table D4-1 Taroom land use Manning's 'n' classification

Land use type	Manning 'n' roughness value
Cropping	0.07
Intensive animal production	0.09
Irrigated Cropping	0.07
Land in transition	0.04
Livestock grazing	0.07
Manufacturing and industrial	0.3
Marsh/wetland	0.04
Other minimal use	0.06

Land use type	Manning ‘n’ roughness value
Production forestry	0.08
Reservoir/dam	0.03
Residential	0.1
River	0.06
Services	0.05
Transport and communication	0.04
Utilities	0.3
Anabranch	0.09
River bank	0.11
Treed	0.075
River upstream of weir (standing water)	0.03

Downstream boundary

The downstream boundary normal water surface slope was adopted as 1%.

Culverts and bridges

Bridges and culverts were modelled in the 2D domain by leaving a gap in the terrain to allow water to pass through embankments. One major bridge was identified within the model extent, located on the Dawson River at Baralaba-Woorabinda Road.

Calibration

The resulting calibration flood surface is presented in Volume 2 of this report. The comparison between the modelled water level and the historic level is shown on the map, and the resulting modelled water surface is 0.24 m higher.

The peak water level recording at Neville-Hewitt Weir was discarded as it appeared to be much higher than both the ALERT stream gauge (39143) and aerial photography suggests. The inaccuracy could be caused by inaccuracy in the instrument or local turbulence around the weir.

The modelled water surface also compares well with additional calibration points presented as part of the Baralaba North Continued Operations Project Flood Study undertaken as part of the Environmental Impact Statement (EIS) (Water Solutions, 2014).

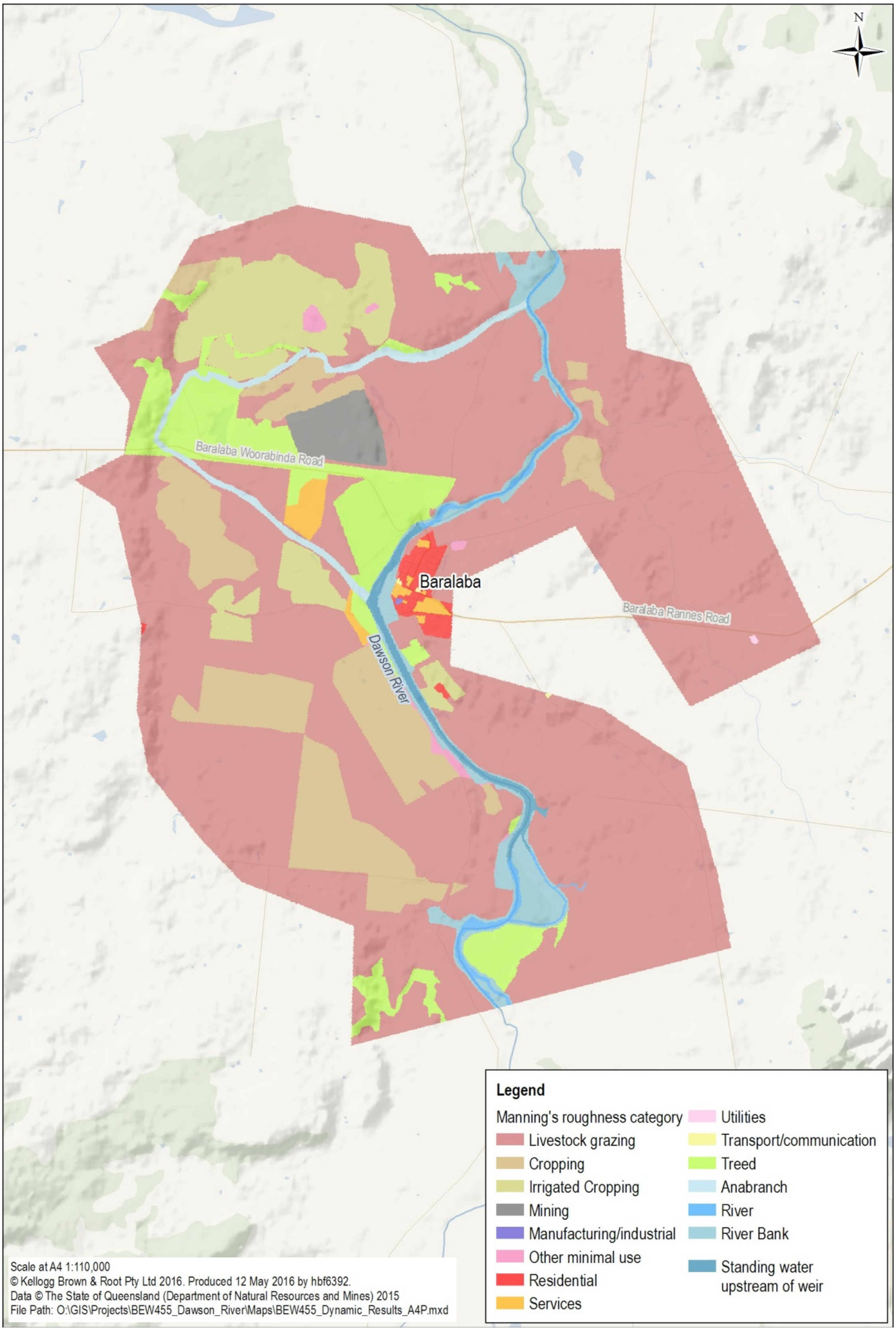

Figure 1
BARALABA ROUGHNESS MAP

Design

Table D4-2 presents a summary of the water level results from the Baralaba TUFLOW model design runs. The water level was extracted at the Baralaba ALERT stream station.

Table D4-2 Design flood level results

	Calibration	Design				
	2010	5%	2%	1%	1%CC*	PMF
Water level	86.75	85.42	86.24	86.68	87.10	90.87

* *1%CC denotes the 1% AEP event with climate change sensitivity*

Conclusion

KBR developed a hydraulic model for Baralaba Township. The model was calibrated to the 2010 event and showed a good comparison.

Design flows from the hydrologic model were simulated in the calibrated model to obtain design levels.

References

DERM 2012, Queensland LiDAR data (Inland towns Stage 2 Project) Banana Shire Council (LGA) - Zone 55 Published on 3 February 2012

Water Solutions 2014, *Baralaba North Continued Operations Project: Flood Study* (Rev 3), Issued to Cockatoo Coal Limited on 4 April 2014

Introduction

This report discusses the individual setup and results of the Wowan TUFLOW model. It is intended to be read in conjunction with Appendix D, which describes the modelling methodology and assumptions.

Data

Terrain

The LiDAR data used for Wowan and Dululu was captured on 13 August and 25 October 2011. It has a quoted vertical accuracy of 0.15 m, horizontal accuracy of 0.45 m (DERM, 2012). The elevation data was provided in Australian Height Datum (AHD), and the horizontal data was projected in Map Grid Australia Zone 55 (MGA55).

Hydraulic model setup

Roughness

Table D5-1 presents the adopted Manning's 'n' roughness values adopted in the model. Figure D5-1 presents the corresponding roughness map.

Table D5-1 Wowan and Dululu land use Manning's 'n' classification

Land use type	Manning 'n' roughness value
Cropping	0.050
Intensive animal production	0.090
Irrigated Cropping	0.050
Land in transition	0.040
Livestock grazing	0.040
Manufacturing and industrial	0.300
Marsh/wetland	0.040
Other minimal use	0.060
Production forestry	0.080
Reservoir/dam	0.030
Residential	0.070
River	0.035
Services	0.050
Transport and communication	0.040
Utilities	0.300
Overbank	0.070

Downstream boundary

The downstream boundary normal water surface slope was adopted as 0.25%.

Culverts and bridges

Bridges and culverts were modelled in the 2D domain by leaving a gap in the terrain to allow water to pass through embankments. Two major crossings were identified in the model extent, located on the Dee River at the Burnett Highway, and at Dixalea Deeford Road.

Calibration

The resulting calibration flood surfaces for the 2015 and 2013 events are presented in Volume 2 of this report. The comparison between the modelled water level and the historic level for the 2015 event is shown on the maps, and presented in Table D5-2. No historic data was available for the 2013 event.

The calibration shows a good comparison between modelled and historic flood levels. The flood survey marks were designated to be of medium confidence for both the Dululu flood survey and Wowan flood survey on Dee River, and high for the Wowan flood survey at town.

Table D5-2 2015 calibration results

Location	Historic recorded (m AHD)	Modelled (m AHD)	Difference* (m)
Dululu TM gauge (539219)	127.86	127.62	-0.24
Dululu flood survey	126.50	126.59	0.09
Wowan flood survey at town	114.07	114.01	-0.06
Wowan flood survey on Dee River	114.04	114.20	0.16

* *Positive values denote higher water levels in the modelled water surface, and negative values denote lower water modelled surface*

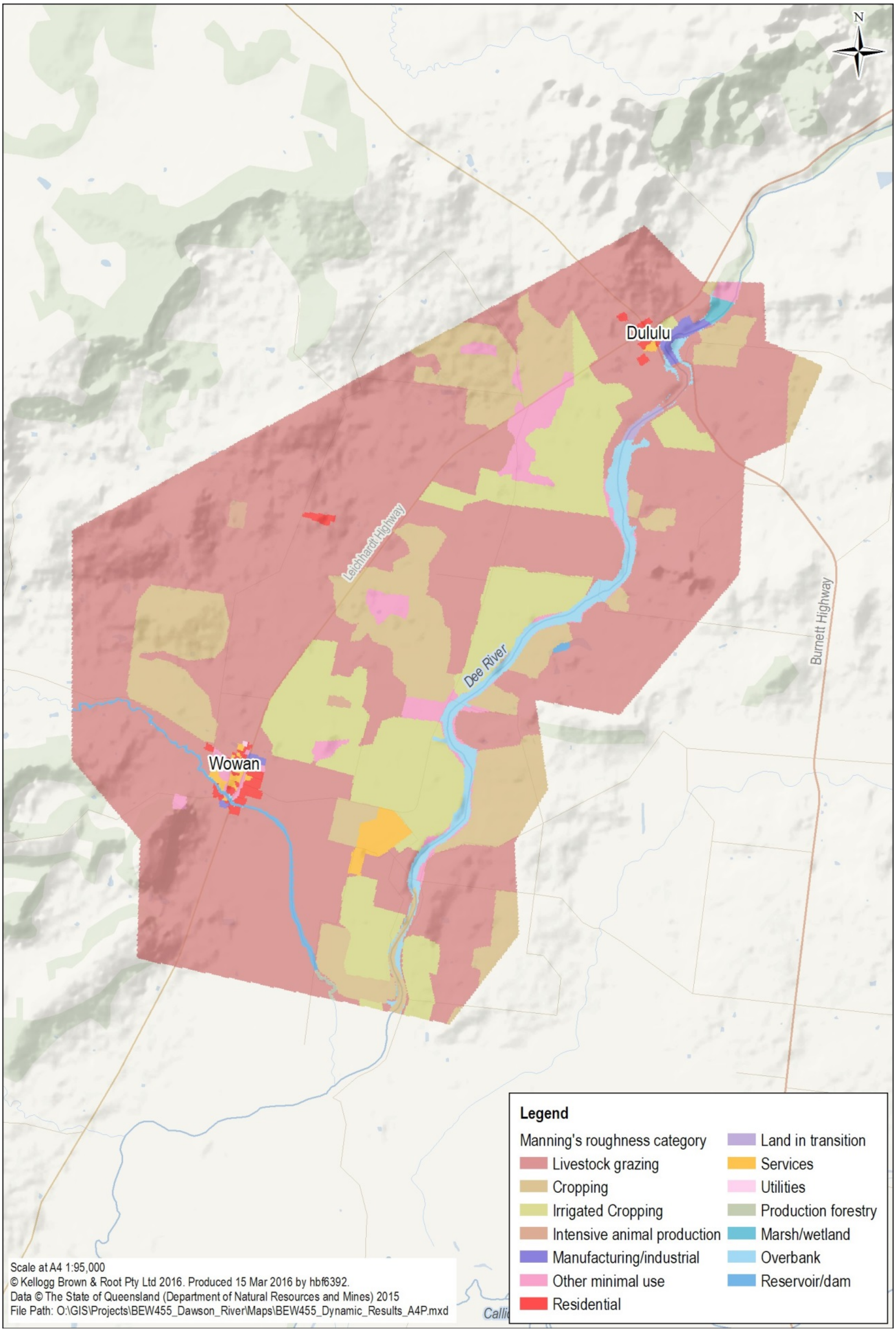

Figure 1
WOWAN AND DULULU ROUGHNESS MAP

Design

Table D5-3 presents a summary of the water level results from the Wowan TUFLOW model design runs. The water levels were extracted at the Dululu TM stream station and the Dee River adjacent to Wowan on Dixalea Deeford Road.

Table D5-3 Design flood level results

Location	Historic		Design						
	2015	2013	10%	5%	2%	1%	1%CC*	0.2%	PMF
Dululu on Dee River	125.89	125.69	122.28	123.21	125.42	125.82	126.76	127.17	129.00
Wowan on Dee River	114.10	114.08	111.29	112.50	114.08	114.11	114.15	114.17	114.34

* *1%CC denotes the 1% AEP event with climate change sensitivity*

Conclusion

KBR developed a hydraulic model for Wowan and Dululu Townships. The model was calibrated to the 2015 event and showed a good comparison. Design flows from the hydrologic model were simulated in the calibrated model to obtain design levels.

References

DERM 2012, Queensland LiDAR data (Inland towns Stage 2 Project) Banana Shire Council (LGA) - Zone 55 Published on 3 February 2012