Regional Floodplain Database:

Hydrologic and Hydraulic Modelling - Stanley River (STA)

Moreton Bay Regional Council

Emergency Management Queensland

Australian Government
Attorney-General's Department
Emergency Management Australia

Queensland Government

MORETON BAY REGIONAL COUNCIL

Regional Floodplain Database

Hydrologic and Hydraulic Modelling Report: Stanley River (STA)

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SYNOPSIS

This flood study report has been prepared by WorleyParsons for Moreton Bay Regional Council for the purposes of documenting the methodology, approach and outcomes associated with the comprehensive flood assessment works undertaken for the Stanley River (STA) minor basin as part of the MBRC Regional Floodplain Database (RFD) Stage 2 project. The study has included detailed hydrologic and hydraulic modelling to assess the flood behaviour of Stanley River for a range of design storm events from the 1 year Average Recurrence Interval (ARI) event to the Probable Maximum Flood (PMF).

Modelling software packages used in this flood study are the WBNM (Watershed Bounded Network Model) as the hydrologic modelling software and TUFLOW as the hydraulic modelling software.

The flood assessment undertaken for the STA minor basin as documented in this report has been successful in addressing the overall objectives of the study. It is considered that the associated model outputs can be adopted by MBRC for the Regional Floodplain Database to deliver seamless information about flood behaviour across the entire Moreton Bay Regional Council area.

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PROJECT 301001-01156 - REGIONAL FLOODPLAIN DATABASE

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0	Issue for use	L Cheung	K Hegerty	M Shaw	10 Aug 2012		

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1 INTRODUCTION

WorleyParsons Services Pty Ltd has been commissioned by Moreton Bay Regional Council (MBRC) to carry out detailed surface water flood modelling over six (6) regional minor basins located within the MBRC Local Government Area (LGA). The six minor basins are Upper Pine River (UPR), Sideling Creek (SID), Stanley River (STA), Neurum Creek (NEU), Mary River (MAR) and Byron Creek (BYR). This flood modelling study has been carried out as part of Stage 2 of the Regional Floodplain Database (RFD) Project. Stage 1 of the RFD Project involved a pilot study and various sub-projects that have provided the basis for the overall project methodology.

UPR and SID make up 'Package 1' and STA, NEU, MAR and BYR make up 'Package 5' of MBRC's Stage 2 RFD Project.

This report details the project methodology, results and outcomes associated with the Stanley River (STA) minor basin investigation.

1.1 Scope

The scope of this flood modelling investigation was to carry out detailed hydrologic and hydraulic modelling over the Stanley River minor basin. The results from the detailed modelling of Stanley River will provide Council with an enhanced understanding of the flood behaviour in the minor basin for a large range of flood events from the 1 year Average Recurrence Interval (ARI) event to the Probable Maximum Flood (PMF).

1.2 Objectives

The objectives of this study are:

- Development of computer based hydrologic and hydraulic modelling suite for the Stanley River minor basin based on standardised modelling procedures and modelling input parameters specific for the RFD study minor basins.
- Use of the developed models to predict where and how flooding may occur in the Stanley River minor basin.

The associated model outputs are to be included in the RFD for delivering seamless information about flood behaviour across the entire MBRC LGA.

1.3 General Approach

The detailed hydrologic and hydraulic modelling undertaking for the STA minor basin has involved the following tasks:

- Refine the broadscale WBNM2010 hydrologic model established for STA minor basin in Stage 1 RFD project.
- Establish a detailed 1D/2D coupled TUFLOW model to investigate flood behaviour for the STA minor basin utilising the topographic information, roughness values, inflow and other boundary condition information determined in previous sub-projects as detailed in Table 1-1.
- Undertake separate critical duration assessments for simulation of a range of storm durations for the 10 and 100 year ARI design events and the Probable Maximum Flood (PMF) event.
- Select three (3) critical durations for each design event from the above separate critical duration assessments as follows:
  - 1 to 10 year ARI events, determined by the 10 year ARI critical duration assessment;
  - 20 to 100 year ARI events, determined by the 100 year ARI critical duration assessment; and
  - 200 year ARI to PMF events, determined by the PMF critical duration assessment.
- Simulate 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000 year ARI and PMF events for the three (3) selected critical durations for each design event.
- Simulate the 100 year ARI 15 minutes Burst in 270 minutes envelope Embedded Design Storm (EDS);
- Assess model sensitivity to Manning's 'n' and blockage of culverts;
- Assess climate change scenarios including 20% increase of rainfall intensity and rise of tailwater boundary conditions over the STA minor basin;
- Assess future landuse scenarios by increased vegetation coverage and residential development on the floodplain; and
- Provide a concise report describing the adopted methodology, study data, model results and findings.

1.4 Related Sub-Projects (RFD Stage 1 & Stage 2 Pilot)

Table 1-1 summarises the previous related sub-projects (as part of the RFD Stage 1) for the purposes of providing input data and or methodologies to this RFD Stage 2 project:

Table 1-1 Related Previous Sub-Projects

Sub-Project	Origin	Scope
1D – Hydrologic and Hydraulic modelling (Broadscale)	BMT WBM (2010)	To define model naming conventions and model protocols to be used in the RFD project
1E – Floodplain Topography (2009 LiDAR)	WorleyParsons (2010a)	To provide the topographic information, such as model z-pts layer and digital elevation models (DEM) utilising a DEM tool developed specifically for the RFD
1G – Hydrography	MBRC	To supply the sub-catchment delineation of Burpengary minor basin including a stream line and junctions (used in the WBNM model)
1H – Floodplain Landuse	SKM (2010a)	To deliver the current percentage impervious cover (utilised in the hydrologic model) and the roughness Manning's 'n' values (utilised in the hydraulic model)
1I – Rainfall and Stream Gauges Information Summary	MBRC	To summarise available rainfall and stream gauge information for the study area
2B – Detailed modelling of the Burpengary Creek minor basin	BMT WBM (2010)	The pilot study for the RFD Stage 2. One of the key outputs of this sub project was to develop a general modelling methodology and structure as an overall guideline for all detailed modelling being undertaken in Stage 2 of the RFD
2C – Floodplain Structures (Culverts)	Aurecon (2010)	To supply a GIS layer of the culverts to be included in the hydraulic model for the RFD project
2D - Floodplain Structures (Bridges)	Aurecon (2010)	To provide a GIS layer of the major road bridges and foot bridges to be included in the hydraulic model for the RFD project
2F – Floodplain Structures (Trunk Underground Drainage)	Aurecon (2010)	To provide trunk underground drainage information for the RFD project
2G - Floodplain Structures (Basins)	Aurecon (2010)	To consolidate and survey the existing basin information for the RFD project

Sub-Project	Origin	Scope
2I - Floodplain Structures (Channels)	Aurecon (2010)	To identify channels within the minor basins
2J – Floodplain Landuse (Historic and Future)	SKM (2010a)	To define the historic and future percentage impervious cover (utilised in the hydrologic model) and the roughness (Manning's 'n') values representing landuse for the February 1999 event (utilised in the hydraulic model)
2K – Flood Information Historic Flooding	GHD (2010)	To locate and survey flood levels for the May 2009 and February 1999 historic flood events
2L – Design Rainfall and Infiltration Loss	WorleyParsons (2010b)	To develop the hydrologic models for the Burpengary Creek minor basin and provide the design rainfall hydrographs for the TUFLOW models
2M – Boundary Conditions, Joint Probability and Climate Risk Scenarios	SKM (2012b)	To define the boundary conditions and provide recommendations in regards to joint probability (i.e. occurrence of storm surge in combination with river flooding events, or river flooding in combination with local tributary flooding). This project also recommended certain sea level rise and rainfall intensity values to assess Climate Risk Scenarios
2N – Floodplain Parameterisation	SKM (2012c)	To provide recommendations of the floodplain parameters, such as a range of values for various impervious percentages for various landuse types (i.e. residential or rural landuse, dense vegetation), a range of values for various roughness types (i.e. long grass, dense vegetation) and structure losses

2 AVAILABLE DATA

The following list summarises the data available for the study:

- Floodplain Topography - DEM Tool to create 2.5m DEM and model Z-pts (model topography) The topography is based on LiDAR (Light Detection And Ranging) data collected in 2009 and provided by Department of Environment and Resource Management (DERM);
- Hydrography - hydrography dataset (sub-minor basin delineation) supplied by MBRC;
- Floodplain Landuse – polygons for nine (9) different landuse categories provided by MBRC and developed by SKM (2010a) as part of RFD Stage 1;
- Floodplain Structures – DTMR and QT structures prepared by Aurecon (2010) and provided by MBRC in TUFLOW readable format. Other structure provided by MBRC in the form of as constructed drawings and detail survey;
- Design Rainfall – amendment of WBNM models, development of design simulations and provision of design rainfall hydrographs;
- Boundary Conditions, Joint Probability and Climate Risk Scenarios – report with recommendations for boundary conditions, joint probability and climate change scenarios; and
- Floodplain Parameterisation – recommendations for impervious percentages for various landuse types, roughness types and structure losses.

2.1 Qualification to Report Findings

It is important to appreciate that the accuracy of the information presented in this report is entirely dependent on the accuracy of these available data. Therefore, the interpretation of information presented in this report should be done so with an understanding of any limitations in their accuracy.

Factors for consideration:

- All data listed above have been provided by Moreton Bay Regional Council for the purpose of developing this model. WorleyParsons have assumed the accuracy of this data and suitability of use for this study, and have not critically reviewed this information. In particular, topographic information has been provided by MBRC, and the flood assessment predictions are based on the accuracy of this data;
- Recognition that no two floods behave in exactly the same manner and the data provided for use cannot represent conditions for all possible flood scenarios. Therefore, the results presented may not exactly replicate the flooding behaviour of an actual flood event;
- Design floods are considered a best estimate of an “average” flood for their probability of occurrence. It is assumed that these data provide the best estimate of the average;

- Over time further information may become available that could impact on the outcomes of the study as presented in this report. Council should be mindful of new information that may impact the outcomes as presented in this study and consider appropriate actions to address possible changes to findings;
- Flood study analysis relies on the requirement to have a freeboard between the predicted average recurrence interval flood event and land levels used for development purposes. The freeboard accounts for variation in modelling assumptions and impacts not accounted in the analysis such as wave action. Accordingly flood levels from this study will need to be used with freeboard allowances contained in the applicable MBRC Town Planning Scheme; and
- This analysis has been carried out using industry standard software and methods considered industry best practice at the time of the study.

3 METHODOLOGY

3.1 Data Review

3.1.1 Infrastructure Data Assessment

WorleyParsons completed a report entitled "*Infrastructure Data Assessment Report Package 5*" in October 2010. The purpose of the report was to review, identify and prioritise any additional floodplain infrastructures as well as the existing data for the Stanley River (STA), Upper Mary River (MAR), Neurum Creek (NEU) and Byron Creek (BYR) minor basins that is necessary to complete the detailed modelling for the Stage 2 RFD project. The infrastructures assessed within the minor basins included:

- Structure junctions
- Hydraulic structures
- Basins and dams
- Buildings in the floodplains

A copy of the "*Infrastructure Data Assessment Report Package 5*" is included in Appendix A.

3.1.2 Calibration and Validation

WorleyParsons completed a report entitled "*Calibration and Validation Feasibility Report Package 5*" in November 2010. The purpose of the report was to assess the feasibility of carrying out historical event model calibration and validation for the Stanley River (STA), Upper Mary River (MAR), Neurum Creek (NEU) and Byron Creek (BYR) minor basins as part of the Stage 2 RFD project. The report identified two (2) river gauges within the Stanley River minor basin with potential historical data for the purpose of model calibration/validation.

A copy of the "*Calibration and Validation Feasibility Report Package 5*" is included in Appendix C.

Based on the recommendations from the feasibility study report, MBRC has decided to carry out model calibration to the January 2011 event and validation to the February 1999 event based on available data. Sections 3.4 and 4.1 provide a detailed description on the two calibration/validation modelling runs.

3.1.3 Hydrography

WorleyParsons completed a report entitled "*Hydrography Review Report Package 5*" in November 2010. The purpose of the report was to review the supplied hydrography data against other data provided for the Stage 2 RFD project including aerial imagery and a 2.5m grid aerial LiDAR digital elevation model and identify issues in the supplied data as well as make recommendations to improve the suitability of the hydrography for use in the Stage 2 RFD project. Most of the recommendations in the report have been adopted by MBRC and the sub-catchment delineation for STA minor basin was updated and re-issued.

A copy of the "*Hydrography Review Report Package 5*" is included in Appendix B of this report.

3.2 Hydrologic Model

The WBNM (Watershed Bounded Network Model) software was nominated by MBRC as the hydrologic software package to be used for the RFD to calculate inflow hydrographs for the hydraulic model described in Section 3.3 of this report.

WBNM is an event based hydrologic model that was developed at the University of Woolongong and is widely used throughout Australia. The model calculates flood flow hydrographs from storm rainfall hyetographs and can simulate the behaviour of hydraulic structures including weirs, culverts and diversion works. The model routes runoff from upstream sub-areas through the current sub-area and adds the routed flow to the excess rainfall that is routed separately through the sub-area. The model can be used for natural, partly urban and fully urbanized minor basin using different lag factors for pervious and impervious areas.

Detailed hydrologic model parameters, such as adopted losses, design gauge locations and Intensity Frequency Duration (IFD) data are described in the Regional Floodplain Database Design Rainfall - Burpengary Pilot Project Report (WorleyParsons, 2010b). Other model input data, such as landuse and minor basin delineation, was provided through other sub-projects outlined in Section 1.4 of this report. Table 3-1 below summarises the ultimate rainfall loss and model lag parameters adopted for the current STA WBNM model.

Table 3-1 Rainfall Loss and Model Lag Parameters

Loss Parameters		Sub-area Lag Parameter
Initial	Continuing	
0mm	2.5mm/hour	1.6

3.3 Hydraulic Model

3.3.1 Model Selection

Because of the complex nature of floodplain flow patterns in urban and rural minor basins, MBRC has adopted TUFLOW, a dynamically-linked 2D/1D hydrodynamic numerical model, to predict the flood behaviour of a minor basin. TUFLOW has the ability to:

- Accurately represent overland flow paths, including flow diversion and breakouts (2D modelling);
- Model the waterway structures of the entire minor basin with a relatively high level of accuracy (1D or 2D modelling);
- Dynamically link components of the 1D models (i.e. culverts) to any point in the 2D model area; and
- Produce high quality flood map output (i.e. flood extent, flood levels, depths, velocities, hazard and stream power), which are fully compatible with Geographic Information Systems (GIS).

A brief description of TUFLOW is provided in the following sections.

3.3.2 Model Geometry

The Stanley River is located in the northeast of the Brisbane River Basin and has historically provided major contributions to floods in the Brisbane River System. Somerset Dam was constructed across the Stanley River just upstream of its confluence with the Brisbane River as a major water supply and flood mitigation storage for Southeast Queensland some 60 years ago.

The STA minor basin extends over the upper portion of the Stanley River catchment, upstream of Lake Somerset and includes a number of tributary streams. The town of Woodford is the major urban centre within the STA minor basin and is located just upstream of the Monkeybong Creek junction.

Neurum Creek and Delaney Creek, which are major tributaries of the Upper Stanley River, have been investigated in the NEU minor basin study. The total study area of STA minor basin is approximately 479 km^2.

Due to the large catchment size of the STA minor basin, the TUFLOW model has been constructed in two (2) chosen model cell sizes with a horizontal grid orientation (zero rotation). The horizontal grid orientation approach was selected as part of the development of the RFD to ensure consistency of model parameters across the entire RFD study area. The two chosen model cell sizes are detailed below:

- 5m cell to carry out all the selected critical durations runs for the 1 year to 100 year ARI design events to ensure highest resolution design event flood results can be achieved for the STA minor catchment. However, the 5m cell model requires extensive model run time to complete one flood event run.
- 10m cell to carry out all the other event model runs including extreme design events, calibration/verification and model sensitivity analysis runs. Other than the cell size, all model input parameters are identical to the 5m cell model. The chosen 10m cell size is considered to be sufficiently detailed to determine flood behaviour for the extreme events, calibration and sensitivity analysis runs without extensive model run times.

The model topography was derived from the DEM tool (WorleyParsons, 2010) including the DEM modifiers utilising the 2009 ALS data developed for the RFD project. During Stage 1 RFD studies, stream and road modifiers were used in the DEM tool to ‘carve out’ streams and define road embankments in the Z-pts layer. However, in the current RFD Stage 2 studies, the DEM tool has been updated so that roads are modified after the streams, avoiding the need to further modify the topography in TUFLOW.

The combination of the above features has allowed for the development of catchment-wide flood models, providing detailed flood information across the entire STA minor basin. Figure 3-1 illustrates the STA model layout.

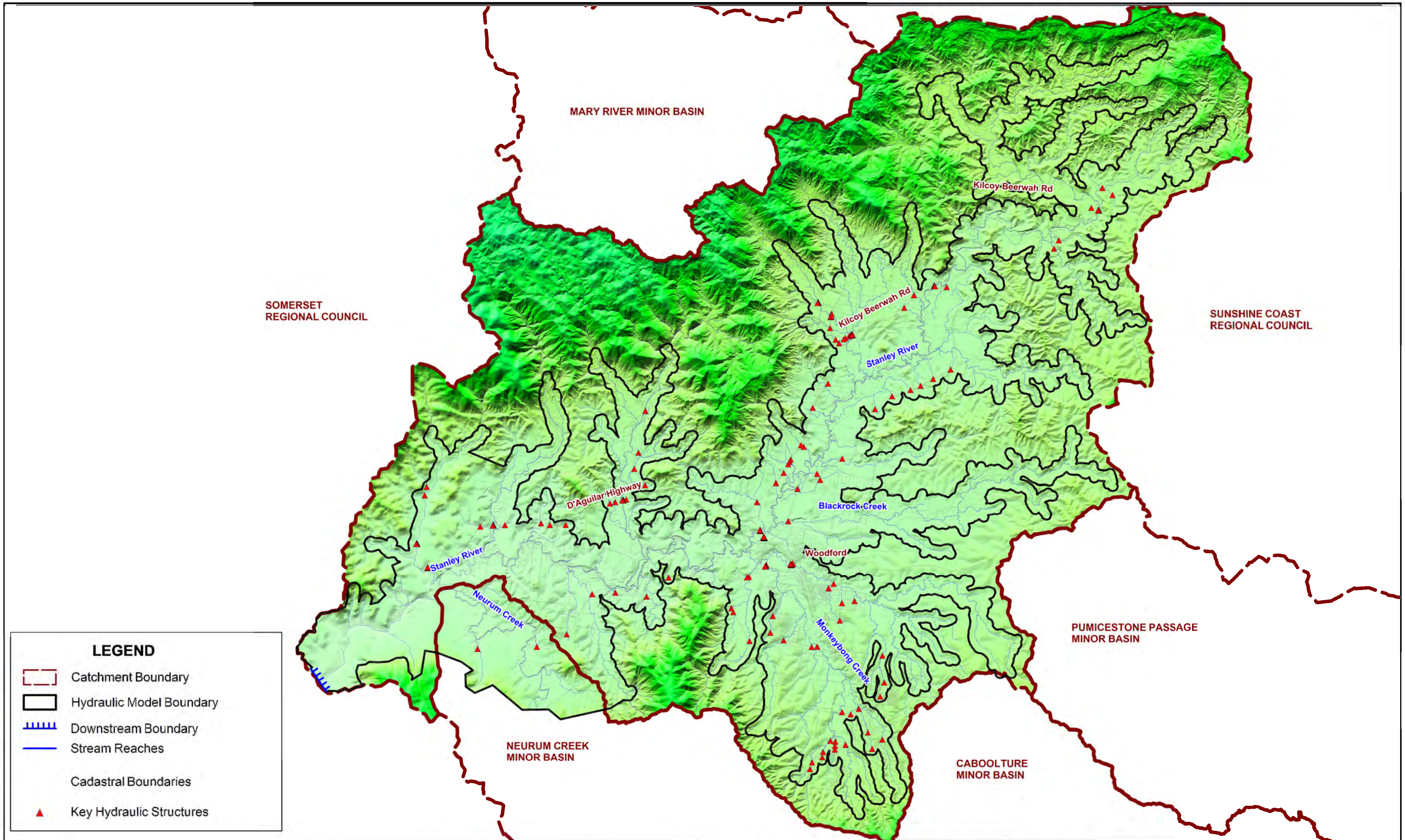

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FIGURE 3.1 - HYDRAULIC MODEL LAYOUT

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3.3.3 Model Structures

The entire STA TUFLOW model has been established in the 2D domain. A total number of some 98 culverts and 11 bridges have been included in the STA TUFLOW model. Culvert crossings were typically modelled as 1D elements. Flow over culverts was modelled within the 2D domain. Bridges and footbridges were represented in the 2D domain. Structure details were provided by MBRC in the form of as constructed drawings and detail survey.

The adopted exit and entry loss coefficients, applied to the hydraulic structures, have been based on recommendations from Sub-project 2N (SKM, 2012c).

3.3.4 Landuse Mapping

Landuse mapping was used to define the spatially varying hydraulic roughness within the hydraulic model. In total, nine (9) different types of landuse based on recommendations from Sub-project 2N (SKM, 2012c) were mapped across Stanley River minor basin, together with associated Manning's 'n' values as presented in Table 3-2 and Figure 3-2.

Table 3-2 Hydraulic Model Roughness and Landuse Categorisation

Landuse Type	Manning's 'n' Roughness Coefficient
Dense vegetation	Depth varying Mannings 'n'
Medium dense vegetation	Depth varying Mannings 'n'
Low Grass/Grazing	Depth varying Mannings 'n'
Reeds	0.080
Crops	0.040
Roads/Footpaths	0.015
Buildings	1.000
Waterbodies	0.030
Urban block	0.300

Footpaths within open space areas were excluded from the model, as these features are typically finer than the model grid resolution. In some locations where there were sudden changes in roughness across one or a few cells (e.g. narrow roads crossing dense vegetation), roughness was locally modified to resolve associated modelling instabilities.

In highly developed blocks larger than 2000m², the urban block category was used (Manning's 'n' of 0.3). In addition, an individual buildings layer (building footprint) was used for areas outside the high residential development (Manning's 'n' of 1.0).

Based on the results from the model calibration and validation runs, MBRC has adopted a depth varying Manning's 'n' approach to globally represent the hydraulic roughness for the dense, medium dense and low grass grazing vegetation landuse profiles.

The change in roughness factors with increasing depth of water represents the increased obstruction to flow caused by branches and foliage of trees, compared to individual tree trunks at lower depths and the reduction in vegetation retardance due to flattening of grasses with increasing depth of flow.

The depth varying Manning's 'n' relationships for the above vegetation profiles are summarised in Table 3-3.

Table 3-3 Depth Varying Manning's 'n'

Depth y(m)	Manning's 'n'			Depth y(m)	Manning's 'n'
	Dense Vegetation	Medium Dense Vegetation			Low Grass Grazing
0	0.090	0.075		0	0.250
1.5	0.090	0.075		0.2	0.060
3.5	0.180	0.150		0.4	0.045
99.0	0.180	0.150		0.8	0.035
				2.0	0.025
				99.0	0.025

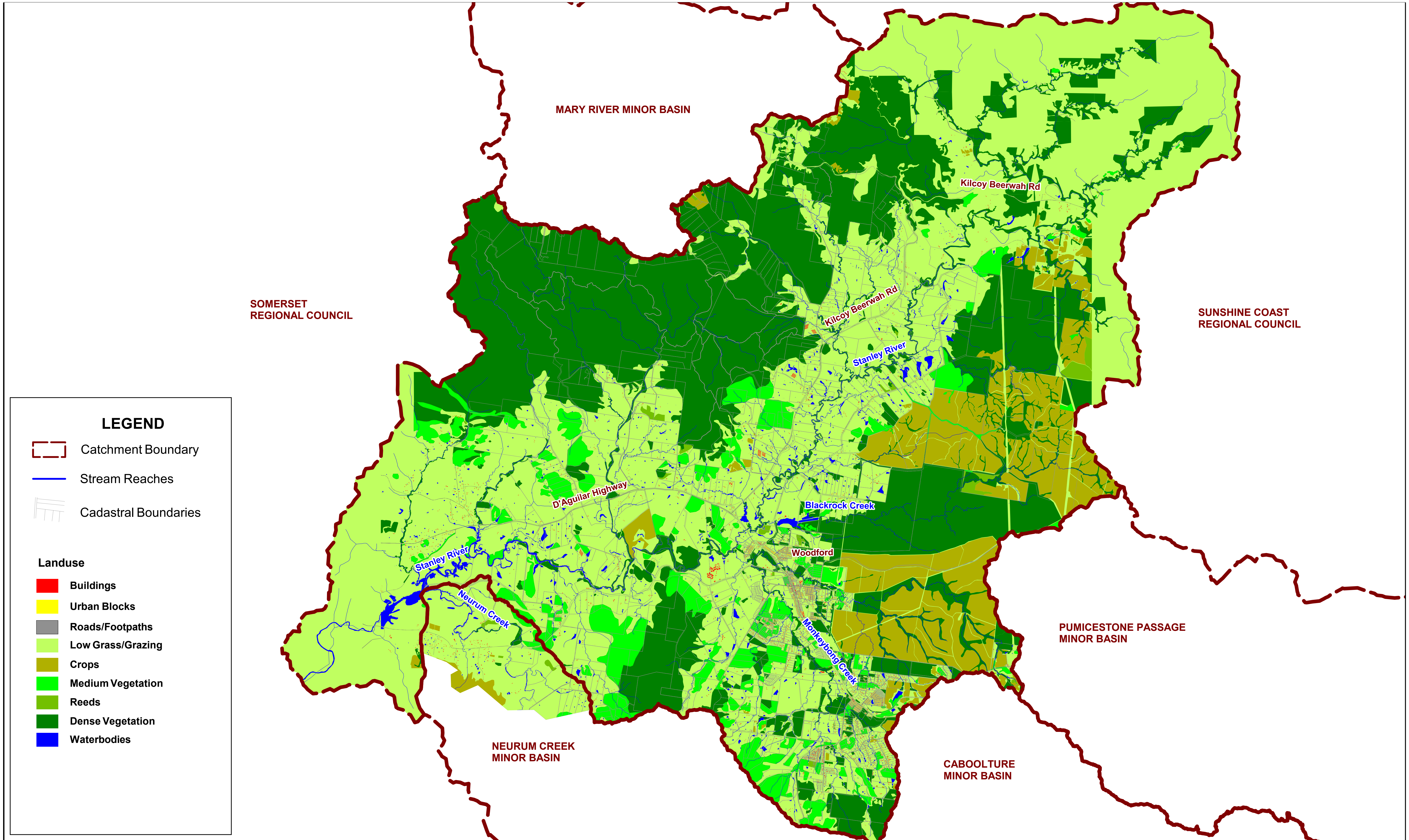

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FIGURE 3.2 - LANDUSE MAPPING - EXISTING CONDITIONS

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3.3.5 Model Boundaries

The results of the WBNM hydrologic model were used to generate inflow hydrographs for the hydraulic model for all design events, as discussed in Section 3.1. The inflows were applied to the 2D domain using a flow-time source boundary for each sub-catchment. This technique applies the inflow at the lowest grid cell in a sub-catchment initially and then subsequently to all wet cells in that sub-catchment.

The downstream boundary of STA model is located near the top of Lake Somerset; therefore, the gate operations at the dam will control water levels in the lake and the outflow of the STA model. In 2003, Sargent Consulting completed the Stanley River Flood Study for the former Caboolture Shire Council and has provided the peak dam levels for a range of design events (sourced from SEQWater) in the study report (Sargent Consulting, 2003).

Based on the Stanley River flood study report, WorleyParsons utilised the frequency relationship approach to derive a range of design event downstream water levels for the STA model. The adopted peak downstream peak levels are presented in Table 3-4.

Table 3-4 STA Downstream Water Levels

ARI Events	Design Peak Level (mAHD)
1	100.50
2	101.70
5	102.00
10	102.12
20	102.24
50	102.68
100	103.13
200	103.62
500	104.49
1000	105.19
2000	105.80
PMF	110.41

3.4 Model Calibration and Validation

The STA TUFLOW model has been calibrated and validated against the following two historical events:

- January 2011 (calibration event); and
- February 1999 (validation event).

These events were chosen by MBRC due to the availability of rainfall, river stream gauge data and the availability of flood marks. Calibration and validation outcomes are provided and discussed in the Stanley River (STA) Model Calibration Report included in Appendix C of this report.

3.5 Design Flood Events

Design storm events are hypothetical events that are used to estimate design flood conditions. They are based on a probability of occurrence, frequently specified as an Average Recurrence Interval (ARI).

3.5.1 Critical Storm Duration Assessment

Critical storm durations were selected based on the hydraulic models results, rather than hydrologic model results. This means that the critical duration was selected based upon the maximum flood levels rather than flows. Separate assessments were undertaken for the minor events (1, 2, 5 and 10 year ARI event), moderate and major events (20, 50 and 100 year ARI), very large and extreme events (200, 500, 1000, 2000 year ARI and the probable maximum flood (PMF) event).

The following methodology was adopted to determine the critical storm durations for the Stanley River model:

- WBNM hydrologic modelling of a range of 10, 100 year ARI and PMF standard storm durations (from 30 minutes to 72 hours) to calculate inflow hydrographs for the TUFLOW hydraulic model.
- TUFLOW hydraulic modelling of 10, 100 year ARI and PMF to calculate peak flood levels for all the studied storm durations.
- Mapping of the peak flood level results for the 'maximum envelope' of all the 10, 100 year ARI and PMF standard storm durations.
- Selection of three critical durations for each ARI storm event based on the storm durations generating the highest flood levels across the most widespread and developed areas.
- Mapping of the peak flood level results for the 'maximum envelope' of the selected three storm durations for each storm event.
- Difference comparison between the mapped peak flood levels for the three selected critical durations and the results accounting for all storm durations for each of the storm event.
- The critical duration storms resulting in the least difference, compared with the mapping of the full envelope of durations, were then adopted throughout the studied storm events ranging from 1 year to PMF events.

A summary of the three selected critical storm durations for STA model for all events assessed is outlined in Table 3-5. A comparison of the 10, 100 year ARI and PMF peak flood levels is illustrated in

Figure 3-3 to Figure 3-5 respectively. The figures demonstrate that the three selected critical storm durations have dominated the 10, 100 year ARI and PMF peak flood levels across the study area.

Table 3-5 Critical Duration Selection

Assessment Event	Selected Critical Durations	Adopted Event
10 year ARI	2hr, 12hr and 24hr	1, 2, 5 and 10 year ARI
100 year ARI	2hr, 12hr and 24hr	20, 50 and 100 year ARI
PMF	2hr, 6hr and 12hr	200, 500, 1000, 2000 year ARI and PMF

3.5.2 Design Event Simulations

As discussed in the previous section, the STA model was simulated for a range of Average Recurrence Intervals (ARI) and storm durations which has included:

- Minor events – 1, 2, 5 and 10 year ARI events;
- Moderate and major events – 20, 50 and 100 year ARI events; and
- Very large and extreme events – 200, 500, 1000, 2000 year ARI and PMF events.

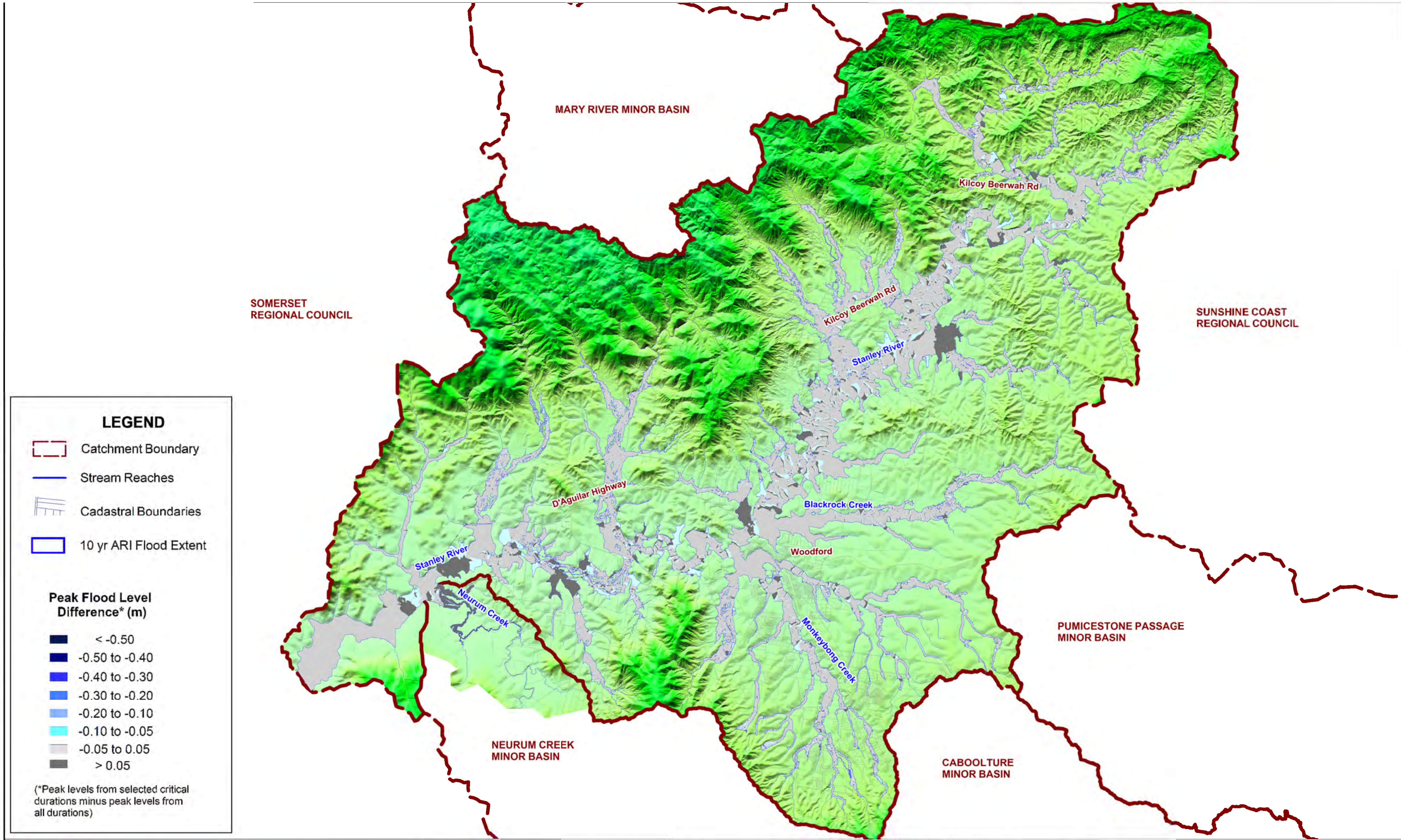

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FIGURE 3.3 - CRITICAL DURATION ASSESSMENT
PEAK FLOOD LEVEL DIFFERENCE - 10 YEAR ARI

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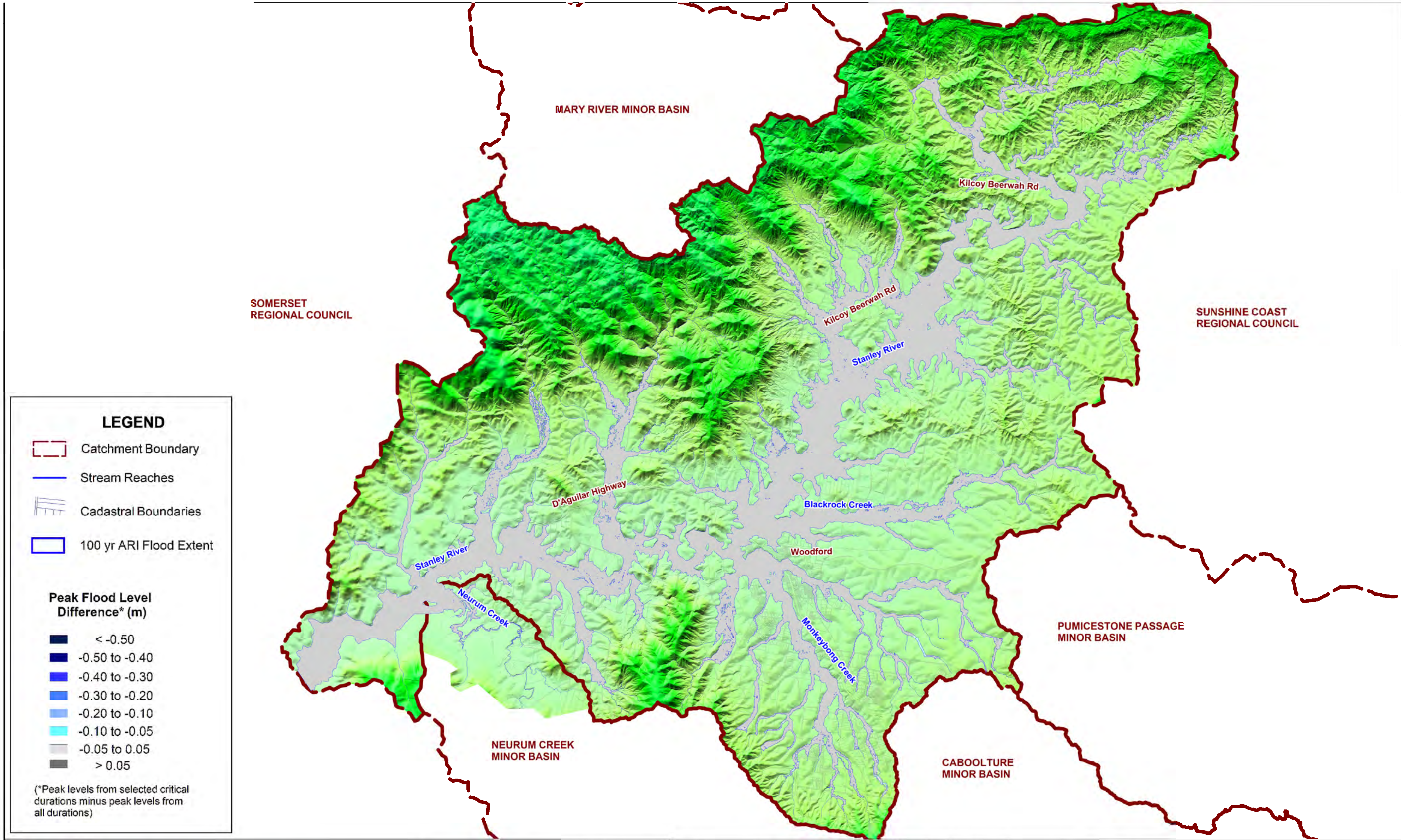

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FIGURE 3.4 - CRITICAL DURATION ASSESSMENT
PEAK FLOOD LEVEL DIFFERENCE - 100 YEAR ARI

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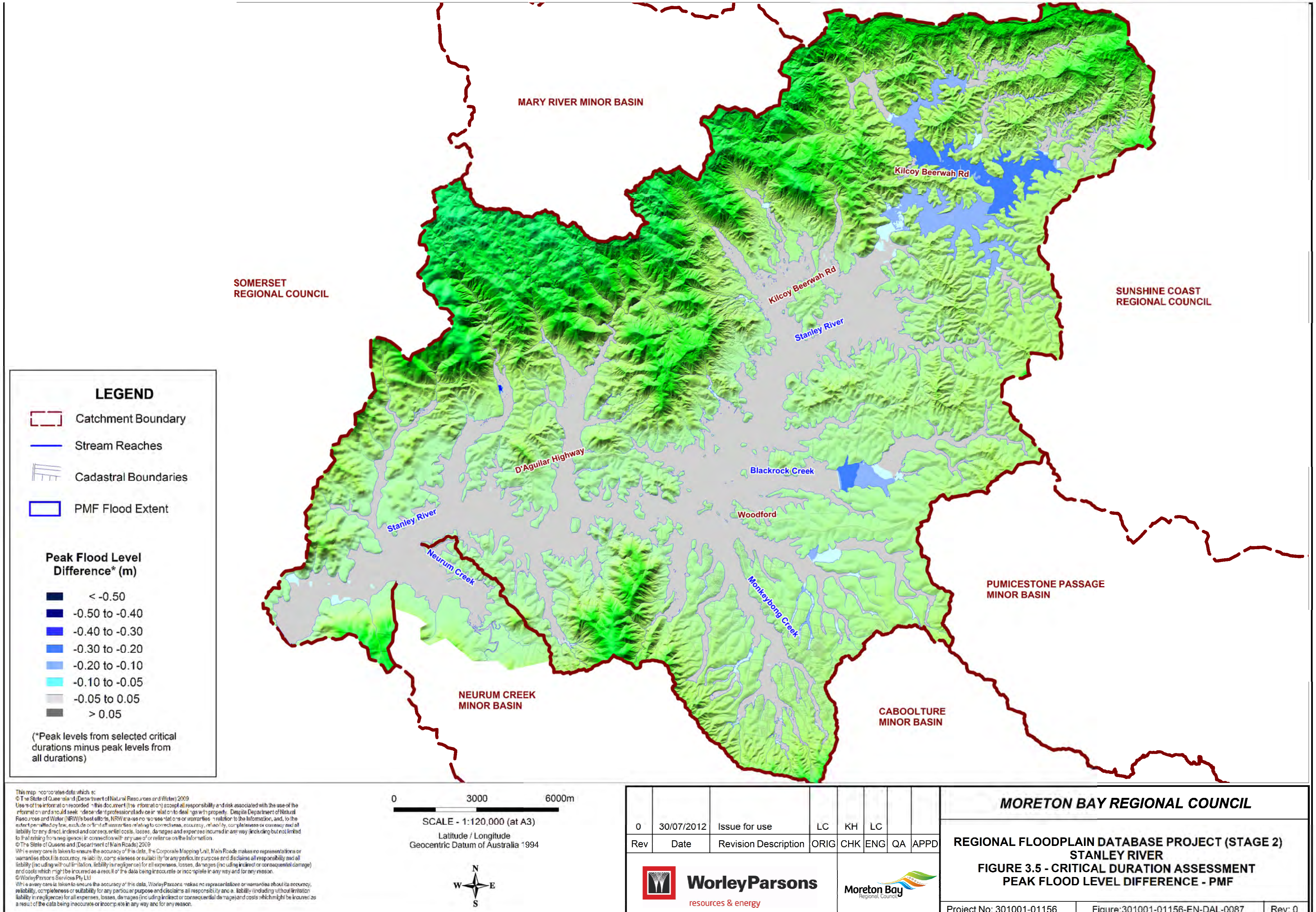

0	30/07/2012	Issue for use	LC	KH	LC		
Rev	Date	Revision Description	ORIG	CHK	ENG	QA	APPD

WorleyParsons
resources & energy

Moreton Bay Regional Council

MORETON BAY REGIONAL COUNCIL

REGIONAL FLOODPLAIN DATABASE PROJECT (STAGE 2)
STANLEY RIVER
FIGURE 3.5 - CRITICAL DURATION ASSESSMENT
PEAK FLOOD LEVEL DIFFERENCE - PMF

Project No: 301001-01156	Figure:301001-01156-EN-DAL-0087	Rev: 0

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3.6 Sensitivity Analysis

MBRC adopted the use of a single EDS which approximates the flood levels and behaviour of the 100 year ARI critical duration design events. The EDS is useful for initial investigations into changes in model parameters and catchment characteristics, as it reduces the number of model runs required.

The 15 minutes burst in a 270 minutes storm envelope duration provides the best representation across all minor basins within the MBRC LGA. Therefore, the 100 Year 15 minutes burst in a 270 minutes envelope EDS has been adopted for the STA model.

The adopted EDS storm was utilised as a base case for the assessment of model sensitivity, climate change and future landuse scenarios as discussed in the following sections below.

3.6.1 Future Landuse Analysis

Three (3) future landuse scenario model runs utilising the 100 year EDS event have been undertaken to assess the potential impact of flooding as a result of future development in the Stanley River floodplains. The three future landuse scenarios are:

- Assessment of the potential impact of increased vegetation in the Stanley River floodplains by
    - Changing medium dense vegetation to high dense vegetation; and
    - Changing low grass/grazing to medium dense vegetation through the materials layer.
- Assessment of the potential impact of increased residential development in the Stanley River floodplains by raising the impervious percentage in the WBNM hydrologic model at future residential development areas determined by MBRC to calculate inflow hydrographs for the TUFLOW model. The TUFLOW model was then run with the increased inflow hydrographs to assess the impact of future landuse as a result of increased residential development.
- A combination of increased vegetation and residential development in the Stanley River floodplains.

The results of the above scenario model runs were then compared to the 100 year EDS base case results to assess the potential flood impact to the STA minor basin as a result of future development on the floodplains.

3.6.2 Hydraulic Roughness Analysis

To check the sensitivity of the adopted model roughness values, all Manning's 'n' values were uniformly increased by 20% and applied to the 100 year EDS model. Results of the increased Manning's "n" values run were then compared to the base case run results to check how sensitive the model is to the initial selection of the roughness values.

3.6.3 Structure Blockage Analysis

A structure blockage scenario in the 100 year EDS event was run to simulate the effects of waterway crossings (culverts) becoming blocked during a flood event. This is a reasonably common occurrence and may be the result of debris being washed into the waterways during a flood. Recent storm events have shown that the blockage is generally caused by accumulated debris, or larger items such as tree stems, wood planks, shopping trolleys or even cars. Blockages reduce the capacity for water to flow through stormwater infrastructure and force the water out of the channel, often increasing overland flooding.

The sub-project 2N report provided by SKM (SKM, 2012c) compared three potential debris risk categories to the culvert opening size, to determine culvert blockage factors.

Table 3-6 summarises the blockage factors as presented in of the SKM report (Table 8-3 SKM, 2012c).

Based on the SKM blockage factors, MBRC has adopted the moderate blockage category to assess the culvert blockage sensitivity scenario in the STA model with the following blockage factors:

- 100% blockage for all culverts/pipes with culvert diameter/width less than 2.4m; and
- 15% blockage for culverts/pipes with culvert diameter/width larger than 2.4m.

Table 3-6 Blockage Categories and Factors (SKM 2012c)

Blockage Category/ Debris Potential	Culvert Blockage Condition	
	Full Blockage	Partial Blockage
High	If culvert < 6.0m diagonal	If culvert > 6.0m diagonal, apply 25%
Moderate	If culvert < 2.4m diagonal	If culvert > 2.4m diagonal, apply 15%
Low	If culvert < 1.2m diagonal	If culvert > 1.2m diagonal, apply 10%

3.6.4 Climate Change and Downstream Boundary Condition Analysis

As determined by MBRC, three (3) climate change scenario model runs have been undertaken to investigate the potential impact on flooding for the STA minor basin as a result of climate change. These climate change scenarios are:

- Increase in rainfall intensity - The rainfall intensity increase assessment used for this study is based on the sub-project 2M reports (SKM, 2012b). A 20% increase of rainfall to the 100 year EDS event was applied to the WBNM hydrologic model to calculate inflow hydrographs for the TUFLOW model. The TUFLOW model was then run with the increased inflow hydrographs to assess the impact of climate change as a result of increased rainfall.

- Increase of downstream boundary condition - To assess the potential impact of an increase downstream boundary, the peak flood level obtained from the PMF run was applied as the downstream boundary condition; and
- A combination of increased rainfall intensity and downstream boundary condition.

4 RESULTS AND OUTCOMES

4.1 Calibration and Validation

4.1.1 Overview

A model calibration and validation to two (2) historical flood events has been undertaken for the Stanley River (STA) minor basin. The calibration and validation outcomes are provided and discussed in the Stanley River (STA) Model Calibration Report included in Appendix C of this report.

Recorded rainfall data has been obtained from 11 gauging stations operated by MBRC or Bureau of Meteorology (BOM) for the period between 6th – 12th January 2011 and from 6 gauging stations for the period between 7th – 10th February 1999 for the purposes of model calibration and validation respectively.

Calibration and validation of the TUFLOW model was based on recorded flood level data collected from the January 2011 and February 1999 historical events. Surveyed levels were provided by MBRC for 37 flood marks for the January 2011 calibration event and for 34 flood marks for the February 1999 validation event. In addition, stage hydrographs were obtained from the Peachester ALERT flood warning station in the upper reach of the Stanley River for the January 2011 and February 1999 events and Woodford ALERT flood warning stations in the middle reach for the January 2011 event.

As stated in Section 3.3.3 above, the entry and exit loss coefficients at hydraulic structures adopted for the TUFLOW calibration/validation models have been based on recommendations from Sub-project 2N (SKM, 2012c). Initial runs for the February 1999 and January 2011 events were undertaken using the parameters for the Burpengary Pilot Project. Following a calibration and validation exercise for this and the adjacent minor basins, MBRC selected the final hydraulic roughness parameters as stated in Section 3.3.4. Therefore, the calibration and validation of the TUFLOW model was undertaken primarily to validate the adopted model parameters, as no refinement of parameters was required by Council. The results using the final adopted parameters are discussed below.

4.1.2 January 2011 Results

The modelled peak flood levels were compared to the recorded flood levels and the stage hydrographs obtained from the Peachester and Woodford ALERT flood warning stations.

The modelled peak flood levels were generally under-estimated with the median difference being -374mm and the range extending from -1,326mm to 1504mm. The differences distributions of the flood levels show that approximately 30% of modelled levels are within ±200mm and 40% of modelled levels are within ±300mm for the January 2011 event. The spatial results of the calibration run are presented on Figure 3 of the Model Calibration Report included in Appendix C of this report.

Comparisons of modelled and recorded stage hydrographs for the January 2011 event are presented on Figures 5 and 6 of the Model Calibration Report. The hydrograph plots show good agreement with timing at Peachester gauge, with the modelled at Woodford gauge being marginally early.

4.1.3 February 1999 Results

The modelled peak flood levels were compared to the recorded flood levels and stage hydrograph obtained from the Peachester gauge.

The modelled peak flood levels were generally under-estimated with the median difference being -207mm and the range extending from -1,207mm to 454mm. The differences distributions of the flood levels show that approximately 30% of modelled levels are within ±200mm and 40% of modelled levels are within ±300mm for the February 1999 event. The spatial results of the calibration run are presented on Figure 9 of the Model Calibration Report included in Appendix C of this report.

The stage hydrograph plots (Figure 10 of the Model Calibration Report) show that the modelled peak level is almost a meter lower than the Peachester gauge recorded level and the duration of modelled peak is about 12 hours longer than the recorded peak. The discrepancies may be due to the quality of the recorded data. The recorded hydrograph shows some discontinuity during the peak flood period.

4.1.4 Discussions and Conclusions

The January 2011 event used for model calibration was classified as a major event, based on BoM's classification system. The February 1999 event utilised for model validation was also classified as a major flood event at BoM's Woodford Flood ALERT flood gauge; for more details refer to the WorleyParsons (November 2010) *Calibration and Validation Feasibility Report Package 5*. These two events provide a good range of magnitude and in particular the January 2011 event occurred relatively recently, thus limiting the changes in the catchment of the landuse, additional waterway structures or change in topography.

The model calibration and validation model runs showed reasonable results, considering the two major factors of timing and peak flood levels; however it also highlighted that the peak flood levels in the middle reach were underestimated for both events. The anomalies are likely due to difference in the source of the levels (usage of the LiDAR versus ground survey undertaken to collect flood marks) and interpretation of flood marks/peak flood levels may have varied amongst the survey teams.

Localised model adjustments may have resulted in better "fit" between the measured and modelled results. However such a course of action would be counter to Council's objective for a regionally consistent model library. Localised model adjustments may also mask underlying modelling uncertainties and input data limitations. The adopted parameter set was therefore considered on-balance to be appropriate to this model. It is also noted that this decision was reached by Council having regard to similar calibration and validation exercises in adjoining catchments. These results therefore need to be considered in the context of a regional calibration approach across multiple model domains.

4.2 Design Flood Behaviour

Design flood event modelling of minor basin runoff events was undertaken using the STA TUFLOW model for the 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000 year ARI design events and the Probable Maximum Flood (PMF) event. For each design flood magnitude, the model was run for the three nominated storm durations (refer to Section 3.5.1).

The performance of the model was monitored throughout the simulation. Careful attention was to ensure that flows through the 1D elements in the model as well as flows over the floodplain in the 2D domain were stable. Overland flow hydrographs were checked at key locations on the Stanley River floodplains to ensure the simulation extended well beyond the peak throughout the study area. A modelling quality report of the STA model has been included in Appendix D of this report.

General patterns of flood behaviour that can be observed from the STA design run results include:

- Flooding in the upper reaches of the tributary streams is generally confined to a corridor generally less than 500m wide.
- Extensive inundation is predicted upstream of the Monkeybong Creek junction with floodwaters extending approximately 1km over the floodplain.
- Flooding in the lower reaches of the Stanley River is affected by Lake Somerset water levels and runoff from the remainder of the Stanley River catchment into the Lake.
- Velocities of floodwaters are generally less than 2.5m/s within watercourse channels and less than 0.5m/s on the floodplain.

4.2.1 Model Results

The following output types were used in the model to produce modelling results:

- Flood Levels (H flag);
- Flood Depth (D flag);
- Flood Velocity (V flag);
- Flood Velocity x Depth (Z0 flag);
- Flood Hazard based on NSW Floodplain Development Manual (DIPNR, 2005) (Z1 flag);
- Stream Power (SP flag);
- Unit Flow (q flag); and
- Inundation times (Times flag).

The model results were used to prepare a set of design flood map database, including inundation, peak flow velocity, hazard and stream power. The flood conditions for these flood map database were derived using the envelope (maximum) of the three critical storm durations for all studied events.

Typical flood maps presented in Appendix E are the 100 year ARI design event as the focus of this project is on digital data, rather than provision of hardcopy flood maps. A description of the digital data provided to MBRC for incorporation into their RFD is summarised in Section 4.2.2.

4.2.2 Digital Data Provision

The Regional Floodplain Database is focused on structuring model input and output data in a GIS database held by MBRC. Therefore, all model input and output data in digital format will be provided to MBRC at the completion of the study. The digital data includes all model files and result files for all the design events, sensitivity analysis, climate change assessment and future landuse scenarios.

4.3 Sensitivity Analysis

The 100 Year Embedded Design Storm (EDS) with a 15 minutes burst and a 270 minutes envelope storm duration was simulated to form the base case for model sensitivity runs as described previously. The sensitivity runs undertaken for the STA minor basin have included future landuse, hydraulic roughness, structure blockage and climate change scenarios.

A plot for comparing flood levels of the 100 year EDS base case run against the 100 year ARI design storm is provided in Figure F1 of Appendix F. The plot demonstrates that the predicted 100 year EDS flood levels are generally lowered than the 100 year ARI design storms. The EDS flood levels at the upper reaches of the tributaries are generally 100 to 200mm lower while the area over the floodplain around the Monkeybong Creek junction, the differences in flood levels are at the range of 500 to 1500mm. This is due to EDS is a 15minute burst in a 270 minute duration storm whereas the majority of the floodplains of Stanley River catchment are dominated by the 24 hour critical storm. Therefore, the flood volume of the EDS is much lesser than the ARI design storms resulting a lower flood level over the floodplains. It is recommended that future sensitivity analysis undertaken during model upgrades use the selected critical duration events rather than the EDS event in order to eliminate the under prediction of flooding for the STA minor basin

4.3.1 Future Landuse Analysis

The predicted difference in peak flood levels for the three (3) future landuse scenarios as described in Section 3.6.1 compared to the EDS Base Case are described as follows:

Increase of vegetation scenario

A general increase in flood levels by 100–500mm along the watercourses on the tributary streams with a maximum increase of some 700mm upstream of the Monkeybong Creek junction is observed due to significant change of vegetation profiles over these areas. Water levels have also increased in the range of 200–800mm in the lower Stanley River floodplain. However, the model has predicted a decrease in flood levels along a section of the water course immediately downstream of the Monkeybong Creek junction by 300 to 500mm due to the retardation of flood flow by the increased vegetation upstream. Figure F10 in Appendix F shows the difference in peak flood levels between the Base Case and the increase vegetation scenario.

Increase of residential development scenario

The proposed residential developments are located at Monkeybong Creek tributary. The model has predicted minimal impact on flood level as a result of increased residential development on the tributary catchment. This is due to most of the increased flow being attenuated during routing through the river channels. Figure F11 of Appendix F illustrates the difference in peak flood levels between the Base Case and the increase residential development scenario.

Combination of Increase Vegetation and Residential Development

The modelling results showed that the flood profile for the future landuse conditions is mainly affected by increase of vegetation over the STA minor basin. Cumulative impact due to increase of residential developments and increase of vegetation over the catchment is considered negligible in this future landuse scenario run. The difference in peak flood levels between the Base Case and a combination of increase vegetation and residential development conditions is shown on Figure F12 in Appendix F of this report.

4.3.2 Hydraulic Roughness Analysis

A hydraulic roughness sensitivity scenario has been simulated to assess an increase in roughness coefficients. Model results indicate that an increase in Manning's 'n' roughness coefficients by 20% generally results in a difference in peak levels of ±100mm. The difference in peak flood levels between the sensitivity run and the Base Case utilising the 100 year EDS is illustrated on Figures F2 in Appendix F.

4.3.3 Structure Blockage Analysis

A structure blockage analysis has been simulated utilising the 100 year EDS model as described in Section 3.6.3 to assess impact to the STA minor basin as a result of blockage of culverts. The flood impact on the major waterways and floodplains of STA minor basin as a result of structure blockage is generally considered minimal. This is due to most of the culvert crossings already being overtopped during the flood event in the base case scenario. However, three culverts located along Kilcoy Beerwah Road with 100% culvert blockage have caused some local flood impacts. An increase in flood levels by approximately 700mm on the upstream side and a reduction in flood levels by 200mm on the downstream side of the culverts were observed. Figures F3 in Appendix F illustrates the difference in peak flood levels between the Structure Blockage run and the Base Case utilising the 100 year EDS.

4.3.4 Climate Change and Downstream Boundary Condition Analysis

The predicted differences in peak flood levels for the three (3) climate change and downstream boundary condition analysis scenarios as described in Section 3.6.4 compared to the EDS Base Case are described as follows:

Increase of rainfall intensities by 20%

A global increase of the 100 year EDS event rainfall intensities by 20% was applied to the WBNM hydrologic model to calculate inflow hydrographs for the TUFLOW model. An increase of rainfall results in higher flood levels throughout the STA minor basin. Figure F4 in Appendix F indicates the difference in peak flood levels for the increased rainfall scenario compared to the EDS Base Case is generally an increase within the range of 200 to 500mm along the upper reaches of the tributary streams across the STA minor basin. An increase of some 800mm flood levels is observed over the floodplain at the vicinity of the Monkeybong Creek junction. A 100 to 300mm increase in flood levels is also observed on the lower floodplains at the vicinity of the Neurum Creek junction.

Increase of downstream boundary condition

To assess the impact of an increased downstream boundary, the peak flood level obtained from the PMF run was applied to the downstream boundary condition of the STA EDS model. The PMF downstream level is 110.41m compared to the 100yr ARI level of 103.13m, an increase of 7.28m at the downstream boundary. The increased downstream boundary condition has caused significant expansion of the flood extent over the lower Stanley River floodplain up to a distance of some 15km from the downstream boundary. Figure F5 of Appendix F illustrates the difference in peak flood levels between the EDS Base Case and the increased downstream boundary condition scenario.

Combination of increase rainfall and downstream boundary condition

To assess the cumulative impact of the increased rainfall and downstream boundary scenarios, the inflow hydrographs with 20% increased of rainfall and PMF downstream water levels were applied to the STA model. The modelling results showed that the downstream area of the STA minor basin is mainly controlled by the downstream boundary conditions. The cumulative effect of increased rainfall and downstream boundary is observed on a section of the Stanley River some 14km upstream from the downstream boundary. The cumulative effect of increased rainfall and raised downstream boundary water level was predicted to be an increase in peak flood levels up to a maximum of 500mm over and above the changes predicted for the individual change scenarios. The differences in peak flood levels between EDS Base Case and the combined increase of rainfall and downstream flood level conditions are shown on Figure F6 in Appendix F.

4.4 Model Limitations

The topography of creeks in the STA minor basin is defined using LiDAR data due to the absence of surveyed cross-sections or bathymetry. LiDAR data are unable to pick up ground levels below the water surface, and therefore the bed levels of creeks are not precisely represented in detail. This approach means that the flood levels, particularly for small flood events where a greater proportion of the flow is typically conveyed within bank (e.g. the 1 to 10 year ARI), may be overestimated. The extent of this over-estimation will vary according to local topographic factors.

Watercourses have also been represented in the 2D domain, for which the grid resolution is limited to 5m up to major design event runs and 10m for the very large and extreme event runs. In addition, for the narrower upstream reaches, a waterway landuse layer has not been incorporated. This may not allow adequate representation of the channel conveyance, particularly for the narrower upper reaches. In some instances this limitation may lead to the model over or underestimating conveyance in the watercourses for small flood events.

5 CONCLUSIONS AND RECOMMENDATIONS

The hydrologic modelling works undertaken in this study have utilised the WBNM (Watershed Bounded Network Model) software to calculate flood flow hydrographs for a range of design storm events to be used as inflows to the hydraulic model developed for the STA minor basin.

The hydraulic assessment under this project has included the development of a detailed 5m grid TUFLOW hydraulic model, a dynamically-linked 2D/1D hydrodynamic numerical model for the STA minor basin to run all the selected critical durations for the 1, 2, 5, 10, 20, 50 and 100 ARI design events to achieve the highest resolution design event flood results for the Stanley River minor basin.

A detailed 10m grid TUFLOW hydraulic model has also been developed for the STA minor basin to run the very large and extreme flood events including the 200, 500, 1000, 2000 year ARI and the PMF events as well as the calibration/validation and model sensitivity analysis runs. The chosen 10m cell size is considered to be sufficiently detailed to determine flood behaviour for the extreme large events, calibration/validation and sensitivity analysis runs without extensive model run times.

A model calibration and validation to two (2) historical flood events has been undertaken for the STA model. The January 2011 event was selected for model calibration due to the flood event being the largest flood on record within the Stanley River catchment. The February 1999 event was chosen for model validation for consistency with other catchments included in the RFD.

Separate critical storm duration assessments have been undertaken for the minor events (1, 2, 5 and 10 year ARI event), moderate and major events (20, 50 and 100 year ARI), very large and extreme events (200, 500, 1000, 2000 year ARI and the probable maximum flood (PMF) event) to determine three (3) critical storm durations for each design flood event for the purpose of predicting the peak flood behaviour of the STA minor basin.

Based on the critical duration assessments, the STA TUFLOW model has been utilised to run for the following three (3) nominated storm durations for each design flood event:

- Minor events (1, 2, 5 and 10 year ARI) - 2hr, 12hr and 24hr;
- Moderate and major events (20, 50 and 100 year ARI) - 2hr, 12hr and 24hr; and
- Very large and extreme events – 2hr, 6hr and 12hr.

The 15 minutes burst in a 270 minutes 100 year Embedded Design Storm (EDS) has been adopted and applied to the TUFLOW model. The EDS is useful for initial investigations into changes in model parameters and minor basin characteristics, as it reduces the number of model runs required. The adopted EDS storm was utilised as a base case for the comparison to model sensitivity, climate change and future landuse scenarios.

The Regional Floodplain Database is focused on structuring model input and output data in a GIS database held by MBRC. Therefore, all model input and output data in digital format will be provided to MBRC at the completion of the study. The data includes all model files for all the design events, sensitivity analysis, climate change assessment and future landuse scenarios.

The flood assessment undertaken for the STA minor basin as documented in this report has been successful in addressing the overall objectives of the study. It is recommended that this study report be accepted by MBRC and the associated model outputs be included in RFD for delivering seamless information about flood behaviour across the entire Moreton Bay Regional Council area.

6 REFERENCES

Aurecon, July 2010, "Data Standard - Culverts, Regional Floodplain Database - Stage 2, Moreton Bay Regional MBRC"

Aurecon, July 2010, “Data Standard - Bridges, Regional Floodplain Database - Stage 2, Moreton Bay Regional MBRC”

Aurecon, July 2010, “Data Standard - Detention Basins, Regional Floodplain Database - Stage 2, Moreton Bay Regional MBRC”

Aurecon, July 2010, “Data Standard – Trunk Underground Drainage, Regional Floodplain Database - Stage 2, Moreton Bay Regional MBRC”

Aurecon, July 2010, “Floodplain Structures - Regional Floodplain Database Moreton Bay Regional MBRC”

BMT WBM, 2009: TUFLOW Build 2009-07-AA Release Notes (http://www.tuflow.com/Downloads/Releases/TUFLOW%20Release%20Notes.2009-07-AA.001.pdf)

BMT WBM (2010), “TUFLOW User Manual”

BMT WBM (July 2010), “Hydraulic Modelling (Broadscale) - Regional Floodplain Database Stage 1 Sub-Project 1D”

Brisbane City MBRC, December 2003, “*Natural Channel Design Guidelines”*

Bureau of Meteorology, September 2009 (last website update), “FLOOD WARNING SYSTEM for the UPPER BRISBANE RIVER ABOVE WIVENHOE DAM” (http://www.bom.gov.au/hydro/flood/qld /brochures/brisbane_upper/brisbane_upper_above_wivenhoe_dam.shtml)

Commonwealth Bureau of Meteorology (June 2003), *“The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method”*

Commonwealth Bureau of Meteorology (November 2003), *“Guidebook To The Estimation Of Probable Maximum Precipitation: Generalised Tropical Storm Method”*

GHD, June 2010, ‘Moreton Bay Regional MBRC - Regional Floodplain Database - Sub-project 2K Historic Flood Information’

http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml (BoM IFD Application)

Institution of Engineers Australia, 2001, “*Australian Rainfall and Runoff”*

JWP (For Pine Rivers Shire MBRC), December 2004, “Terrors Creek Dayboro, Flood Study, Extreme Event Analysis”

JWP (For Pine Rivers Shire MBRC), May 2005, “North Pine River Hydrology Final Report”

Michael Boyd et al, January 2007, *“WBNM User Guide”*

QLD Department of Natural Resources & Water, et al, 2007, *"Queensland Urban Drainage Manual (QUDM), Volume 1, Second Edition 2007"*

QLD DNRW (2005), Rainfall IFD v1.0 CRC-Forge-ARF (Computer Application)

Sargent Consulting (2003), "Caboolture Shire Council, Stanley River Flood Study Final Report"

Sinclair Knight Merz, 2010a, "MBRC Regional Floodplain Database - Existing, Historic and Future Floodplain Land Use"

Sinclair Knight Merz, 2012b, "MBRC Regional Floodplain Database - Boundary Conditions, Joint Probability & Climate Change"

Sinclair Knight Merz, 2012c, "MBRC Regional Floodplain Database - Floodplain Parameterisation"

Water Assessment and Planning, Water Assessment Group, Gary Hargraves (2005), *'Final Report, Extreme Rainfall Estimation Project, Crcforge and (Crc) Arf Techniques, Queensland and Border Locations, Development and Application'*

WorleyParsons, 2010a "Regional Floodplain Database - Floodplain Terrain"

WorleyParsons, 2010b "Moreton Bay Regional MBRC - Regional Floodplain Database - Design Rainfall - Burpengary Pilot Project"

WorleyParsons, October 2010 "Moreton Bay Regional MBRC – Infrastructure Data Assessment Reprot Package 5"

WorleyParsons, November 2010 "Moreton Bay Regional MBRC – Calibration and Validation Feasibility Report Package 5"

WorleyParsons, November 2010 "Moreton Bay Regional MBRC - Hydrography Review Report Package 5"