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# BAKERS CREEK / WALKERSTON FLOOD STUDY

**Mackay Regional Council**
May 2013

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**WRM Water & Environment Pty Ltd**

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**Director**

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# 1 INTRODUCTION

Mackay Regional Council (MRC) has engaged WRM Water & Environment Pty Ltd (WRM) to prepare a flood study of Bakers Creek. The Bakers Creek catchment includes the township of Walkerston and Bakers Creek and is shown in Figure 1.1.

The purpose of the study is to develop hydrologic and hydraulic modelling tools to determine the flood risk along Bakers Creek through the township of Walkerston that will assist MRC in land use planning and development assessment. Design flood discharges, flood levels and flood extents were determined for the 5 year, 50 year, 100 year, 200 year and 500 year Average Recurrence Interval (ARI) events, and the Probable Maximum Flood (PMF). The potential impacts of climate change on flooding along Bakers Creek based on Queensland Government (2010) recommendations have also been assessed.

The report is structured as follows:

- Section 2 describes the Bakers Creek catchment including the channel and floodplain characteristics and typical land use. The previous investigations undertaken for the catchment as well as the adopted method of assessment is also described;
- Section 3 describes the data available for the calibration of the hydrologic and hydraulic models;
- Section 4 outlines the development and calibration of the hydrologic and hydraulic models;
- Section 5 presents the design discharge estimates for the Bakers Creek catchments;
- Section 6 presents the design flood levels and extents,
- Section 7 gives flood levels for the future climate change conditions;
- Section 8 summarises the findings of the study;
- Section 9 is a list of references;
- Appendix A shows the locations and details of the road and rail culverts within the Bakers Creek catchment; and
- Appendix B presents the flood maps for Case 1.
- Appendix C presents the flood maps for climate change conditions.

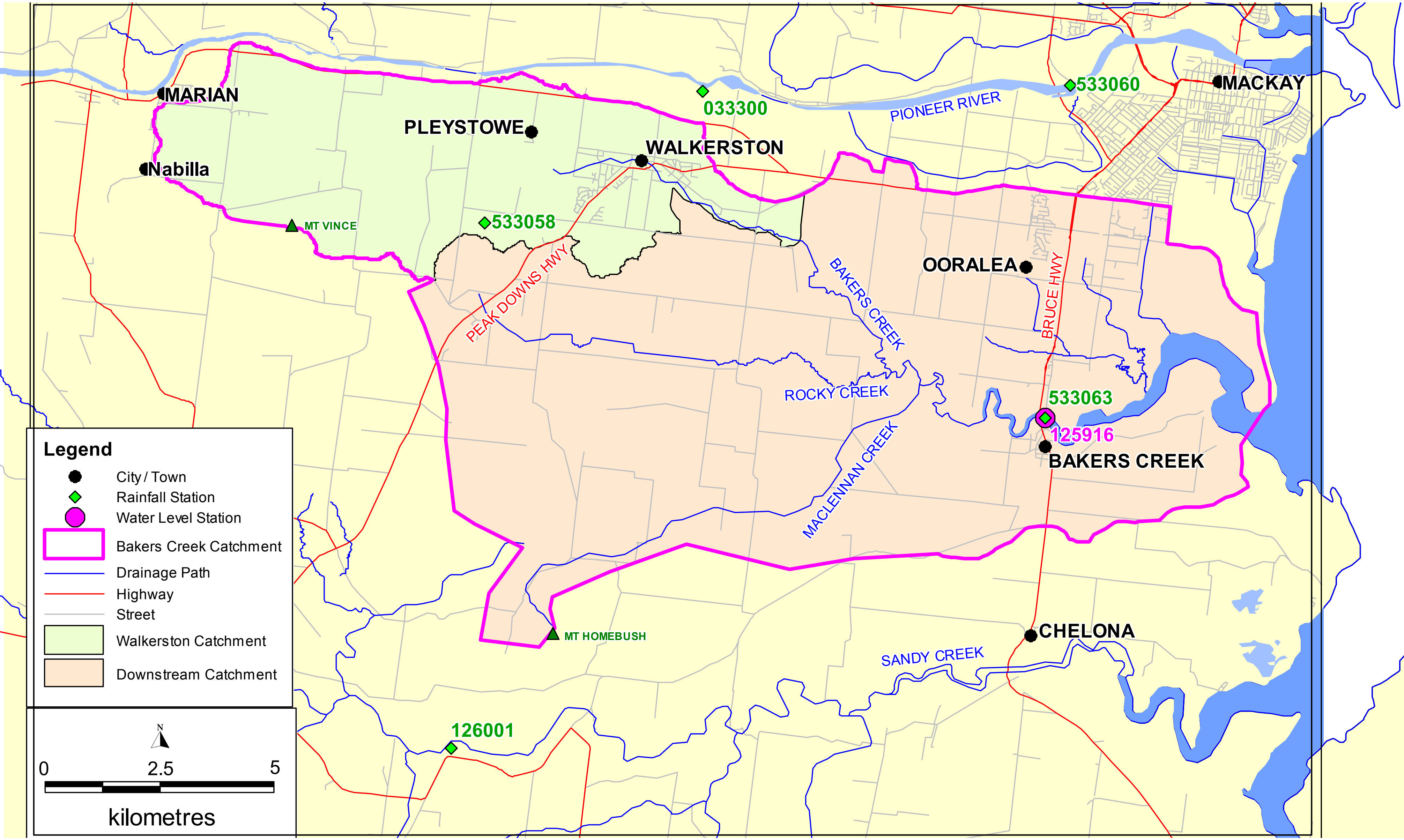


Figure 1.1 Bakers Creek Catchment and Drainage Characteristics

# 2 BACKGROUND

## 2.1 CATCHMENT CHARACTERISTICS

Bakers Creek drains the southern floodplain of the Pioneer River through the townships of Walkerston and Bakers Creek to the South Pacific Ocean about 8 km south of the Pioneer River mouth. Figure 1.1 shows the drainage network within the Bakers Creek catchment. The catchment is bordered by the Pioneer River catchment to the north and Sandy Creek catchment to the west and south. The catchment area of Bakers Creek to Pugsley Street at Walkerston is approximately 36 $km^2$. The total catchment area of Bakers Creek is approximately 190 $km^2$.

The Bakers Creek catchment is topographically flat except for the areas in the vicinity of Mt Vince and Greenmount. The topographically flat sections of the Bakers Creek catchment are cropped for sugarcane area.

## 2.2 DRAINAGE CHARACTERISTICS

The Bakers Creek catchment consists of predominantly agricultural land used for sugarcane farming and is topographically flat. Sugarcane crops usually take 12-16 months to mature and before harvesting can stand over 2 metres tall. Sugarcane is usually harvested between June and December when rainfall is less frequent and the crop's sugar content is at its highest. Once harvested, the cane paddocks are left to fallow and as such, have significantly different runoff characteristics. Numerous irrigation channels traverse the floodplain to provide water to farms.

The main channel of Bakers Creek in the vicinity of Walkerston is narrow and typically between 20 m and 30 m wide. As the creek nears the ocean, the channel widens to between 100 m and 600 m. Two tributaries, Rocky Creek and MacLennan Creek, drain into Bakers Creek between the townships of Walkerston and Bakers Creek. The overall longitudinal slope of Bakers Creek channel from Nabilla to Walkerston is approximately 0.15%.

The vegetation characteristics of the Bakers Creek channel banks varies considerably from completely denuded of vegetation through the sugarcane areas upstream of Walkerston to heavily vegetated between Walkerston to its mouth where it discharges into the Coral Sea. The banks within the estuarine areas consist mainly of mangroves.

## 2.3 PREVIOUS INVESTIGATIONS

### 2.3.1 Ullman & Nolan (1996)

Ullman & Nolan developed a flood study of Bakers Creek in the vicinity of the township of Walkerston on behalf of Mackay City Council (now Mackay Regional Council) in 1996. Design discharges were estimated using three methods, the Rational Formula, the Clarke Synthetic Unit hydrograph method and from a RORB rainfall runoff routing model. Design flood levels through Walkerston were estimated from an assessment of historical flood levels and the development of a one-dimensional backwater model. Calibration data was limited to peak flood levels at the western end of Fadden St in Walkerston for several historical floods. The approach taken was relatively robust, given the lack of calibration data, and provided conservative estimates of design flood levels in Walkerston for use in development assessment.

#### 2.3.2 Chaseling McGiffin (2004)

Chaseling McGiffin (2004) prepared a flood study of the Pioneer River, which also included an assessment of Bakers Creek flooding at Walkerston. Design discharges were estimated from an URBS rainfall runoff routing model of the Pioneer River and a RORB rainfall runoff routing model of Bakers Creek. A NEX-1 quasi two dimensional hydraulic model was developed to estimate design flood levels. The primary focus of this study was to estimate peak flood levels along the Pioneer River in the vicinity of Mackay as well as Bakers Creek at Walkerston. The model was calibrated to surveyed flood marks in and around Walkerston for the 1970 and 1979 historical floods. Of note, Chaseling McGiffin estimated that the Pioneer River would overflow during the 50 year Average Recurrence Interval (ARI) event to impact on the township of Walkerston.

#### 2.3.3 WRM (2011)

WRM (2011) estimated flood levels along Bakers Creek as part of the Pioneer River Flood Study. An URBS rainfall runoff routing model was developed to estimate design discharges and a TUFLOW two dimensional hydrodynamic model was developed to estimate design flood levels. The TUFLOW model covered both the Pioneer and Bakers Creek floodplains to allow design discharges and flood levels to be estimated along Bakers Creek when the Pioneer River overflowed. The models were calibrated to recorded water levels in Bakers Creek at the Bakers Creek gauge for two historical floods and design discharges were estimated for Bakers Creek to the Bakers Creek township.

Peak discharges and flood levels at Walkerston were based on a relatively coarse URBS model configuration (two sub areas) and design rainfalls were based on the total catchment to Bakers Creek and as such the design flood level estimates at Walkerston were not reliable. In addition, the modelling found that the flat topography and extent of sugar cane development in the catchment significantly impacted on the predicted flood discharges and flood levels. Extensive sugar cane growth tended to increase the available flood storage and reduce downstream peak discharges. This phenomenon was particularly evident in the upper Bakers Creek catchment where the main channel carries only a small proportion of the total catchment flow and the remainder is conveyed through the sugar cane areas.

## 2.4 METHOD OF ASSESSMENT

This investigation attempts to update all previous investigations of Bakers Creek with particular emphasis on the Walkerston Area using more rigorous hydrological and hydraulic assessments and the most up to date calibration data. A RAFTS rainfall-runoff-routing model (XP Software, 2009) was developed of the Bakers Creek catchment to estimate design discharges. The model includes 23 sub-areas upstream of Walkerston and extends to the Coral Sea. A TUFLOW two dimensional hydrodynamic model (WBM, 2010) was used to estimate design flood levels. The TUFLOW model covers the majority of the sugarcane growing areas both upstream and downstream of Walkerston to allow an effective assessment of the impact of sugarcane growth on flood storage and design flood levels.

The TUFLOW model was run for three scenarios as follows:

- Case 1: Sugarcane growth at 2008/9 levels of development (Existing Conditions).
- Case 2: Cleared land or low sugarcane land use catchment conditions; and
- Case 3: Bakers Creek catchment flooding coinciding with Pioneer River overflows.

Given the significant overbank flood storage in the catchment, design flood discharges were estimated using both the RAFTS and TUFLOW models. The RAFTS model was used to estimate inflow hydrographs for each sub-area, which were then routed through the TUFLOW model to estimate design flood discharges and flood levels.

The RAFTS and TUFLOW models were calibrated to the February 2007 and February 2008 historical flood events. The calibrated model was adopted for Case 1 and Case 3. The adopted roughness values of the sugar cane growing areas were lowered for Case 2. For Case 3, the Pioneer River overflows were obtained from the Pioneer River Flood Study model. Note that the Pioneer River only overflows for events greater than the 50 year ARI event.

# 3 AVAILABLE DATA

## 3.1 GENERAL

The February 2007 and February 2008 historical floods were used to calibrate the hydrologic and hydraulic models. Available data for model calibration consisted of:

- Recorded rainfalls (pluviometer records);
- Recorded water levels at the Bakers Creek stream gauge at Bakers Creek (GS 125916);
- Topographic data; and
- Surveyed peak flood levels throughout the floodplain for February 2008 flood event.

A summary of the available data is provided in the following sections.

## 3.2 RAINFALL DATA

### 3.2.1 Pluviometer Data

Table 3.1 provides details of the available rainfall stations within and in the vicinity of the Bakers Creek catchments for the 2007 and 2008 flood events. The rainfall data was obtained from the Commonwealth Bureau of Meteorology (BOM) and the Department of Natural Resources and Mines (DNRM). Figure 3.1 and Figure 3.2 and show the recorded cumulative rainfalls at selected stations for the two flood events. Locations of the rainfall stations are shown in Figure 1.1.

**Table 3.1 Rainfall Data Availability for Calibration Events**

| Station No. | Station Name | Observation Interval | Total Rainfall (mm) | |
|---|---|---|---|---|
| | | | Feb 2007[a] | Feb 2008[b] |
| 33300 | Dumbleton Rocks Alert | Continuous | 388 | 517 |
| 533058 | Greenmount Alert | Continuous | 351 | 469 |
| 533060 | Hospital Br Alert | Continuous | 434 | 692 |
| 533063 | Bakers Ck Alert | Continuous | 403 | 531 |
| 126001 | Sandy Creek at Homebush GS | Continuous | 267 | 286 |

[a] 9am 30 January to 4pm 2 February
[b] 12am 14 February to 11pm 15 February

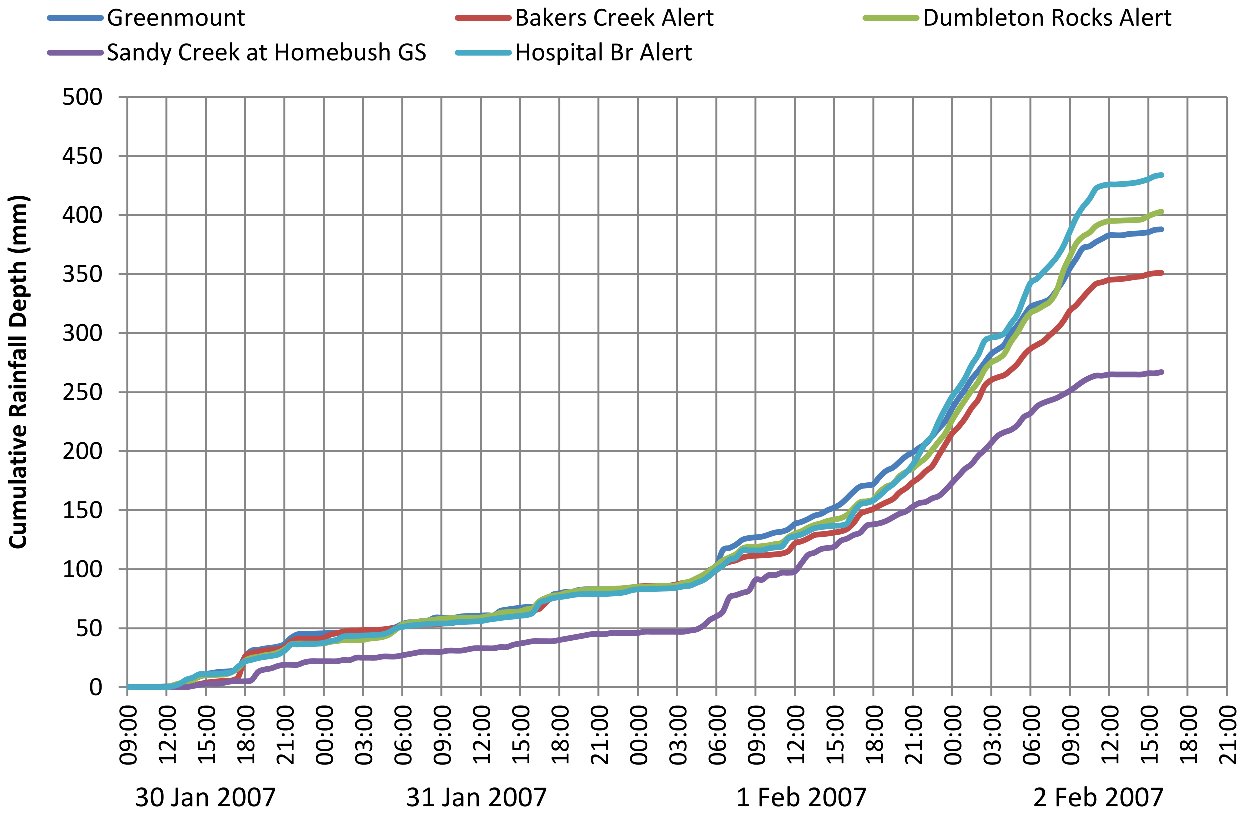


Figure 3.1 Cumulative Rainfall at Selected Rainfall Stations, February 2007 Flood Event

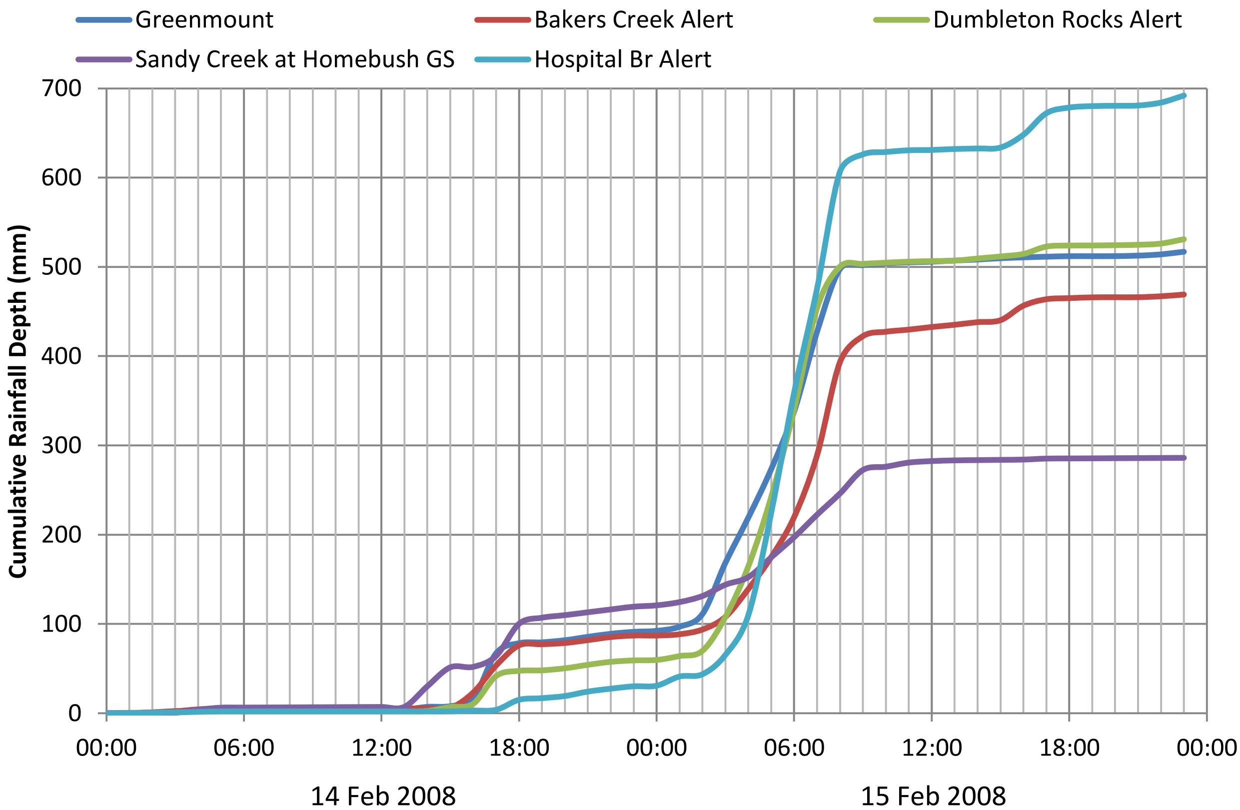


Figure 3.2 Cumulative Rainfall at Selected Rainfall Stations, February 2008 Flood Event

### 3.2.2 Historical Rainfall Analysis – January 2007

The Bakers Creek catchment experienced a minor flood event on January/February 2007. Figure 3.1 shows the cumulative rainfall at Dumbleton Rocks Alert, Greenmount Alert, Hospital Br Alert, Bakers Creek Alert and Sandy Creek at Homebush GS for the 2007 event. Table 3.2 shows the maximum 1 hour, 2 hour, 3 hour, 6 hour, 12 hour, 24 hour, 48 hour and 72 hour recorded rainfall depths and approximate ARI's at selected rainfall stations.

In general, the recorded rainfalls were more severe at the northern stations (Dumbleton Rocks and Hospital Bridge Alert Stations) compared with the southern stations (Greenmount, Bakers Creek and Sandy Creek Alert Stations). Short duration storms (less than 6 hours) had ARI's of less than 2 years, while longer duration storms (greater than 12 hours) ARI's were up to between 5 to 10 years.

### 3.2.3 Historical Rainfall Analysis – February 2008

The Bakers Creek catchment experienced a major flood event on 15 February 2008. Figure 3.2 shows the cumulative rainfall at selected Dumbleton Rocks Alert, Greenmount Alert, Hospital Br Alert, Bakers Creek Alert and Sandy Creek at Homebush GS, for the February 2008 event. Table 3.3 shows the maximum 1 hour, 2 hour, 3 hour, 6 hour, 12 hour and 24 hour recorded rainfall depths and approximate ARI's at selected rainfall stations. The following is of note:

- The estimated ARI of rainfalls recorded in the catchment upstream of the Walkerston, based on Greenmount and Dumbleton Rocks Alert Stations, were:
  - between 50 to 100 years at Dumbleton Rocks Alert and 10 to 20 years at Greenmount Alert for a 1 hour storm duration ;
  - generally greater than 100 years for storm durations between 2 and 12 hours at both stations; and
  - between 50 to 100 years at Dumbleton Rocks Alert and 20 to 50 years at Greenmount Alert for a 24 hour storm duration;
- The estimated ARI of rainfalls recorded at Hospital Br Alert Stations were all greater than a 100 years for all storm durations;
- The estimated ARI of rainfalls recorded at Bakers Creek Alert Station were:
  - between 20 to 50 years for a 1 hour storm duration;
  - greater than a 100 years for storm durations between 2 and 6 hours; and
  - between 50 to 100 years for a 12 hour storm duration; and
  - between 20 to 50 years for a 24 hour storm duration.
- The estimated ARI of rainfalls recorded at Sandy Creek at Homebush GS were much lower than rainfalls recorded at other stations, and generally less than 5 years for all storm durations up to 24 hours.

Table 3.2 Rainfall Depths and Estimated ARI's at Selected Rainfall Stations, January 2007 Event

| Storm Duration (hrs) | Dumbleton Rocks Alert | | Greenmount Alert | | Hospital Br Alert | | Bakers Creek Alert | | Sandy Creek at Homebush GS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI |
| 1 | 26 | <1 | 20 | <1 | 25 | <1 | 19 | <1 | 14 | <1 |
| 2 | 49 | <1 | 35 | <1 | 40 | <1 | 35 | <1 | 24 | <1 |
| 3 | 56 | <1 | 50 | <1 | 57 | <1 | 49 | <1 | 34 | <1 |
| 6 | 98 | 1 to 2 | 87 | 1 to 2 | 111 | 2 to 5 | 89 | 1 to 2 | 62 | <1 |
| 12 | 186 | 2 to 5 | 149 | 2 to 5 | 200 | 5 to 10 | 160 | 2 to 5 | 106 | <1 |
| 24 | 266 | 5 to 10 | 228 | 2 to 5 | 299 | 5 to 10 | 246 | 2 to 5 | 174 | 1 to 2 |
| 48 | 335 | 2 to 5 | 288 | 2 to 5 | 369 | 5 to 10 | 320 | 2 to 5 | 232 | 1 to 2 |
| 72 | 394 | 2 to 5 | 346 | 2 to 5 | 422 | 5 to 10 | 382 | 2 to 5 | 265 | 1 to 2 |

Table 3.3 Rainfall Depths and Estimated ARI's at Selected Rainfall Stations, February 2008 Event

| Storm Duration (hrs) | Dumbleton Rocks Alert | | Greenmount Alert | | Hospital Br Alert | | Bakers Creek Alert | | Sandy Creek at Homebush GS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI | Max. Rainfall Depth (mm) | Estimated ARI |
| 1 | 46 | 50 to 100 | 89 | 10 to 20 | 116 | >100 | 29 | 20 to 50 | 36 | <1 |
| 2 | 160 | >100 | 160 | 50 to 100 | 247 | >100 | 133 | >100 | 50 | <1 |
| 3 | 258 | >100 | 224 | >100 | 267 | >100 | 203 | >100 | 75 | 1 to 2 |
| 6 | 396 | >100 | 386 | >100 | 561 | >100 | 288 | >100 | 129 | 1 to 2 |
| 12 | 447 | >100 | 416 | >100 | 601 | >100 | 344 | 50 to 100 | 159 | 2 to 5 |
| 24 | 505 | 50 to 100 | 503 | 20 to 50 | 664 | >100 | 433 | 20 to 50 | 276 | 2 to 5 |

## 3.3 STREAMFLOW DATA

Recorded water level data for the Bakers Creek Alert stream gauging station (No. 125916) was obtained from BOM. The location of the streamflow gauging station is shown in Figure 1.1. This streamflow gauging station is tidally influenced and has not been gauged to derive a water level height to discharge rating. Figure 3.3 shows the theoretical rating curve adopted for the Bakers Creek Alert gauge. This curve was derived using the TUFLOW hydraulic model, described in Section 4.

A potential flood level anomaly was identified at the Bakers Creek Alert for the 2008 flood event. A peak flood level of 4.15m AHD was recorded at the gauge, whereas the surveyed flood marks indicate that the peak may have reached a height of over 4.6m AHD. In this study, the recorded flood levels at the gauge for the 2008 event were adjusted to match the surveyed flood level.

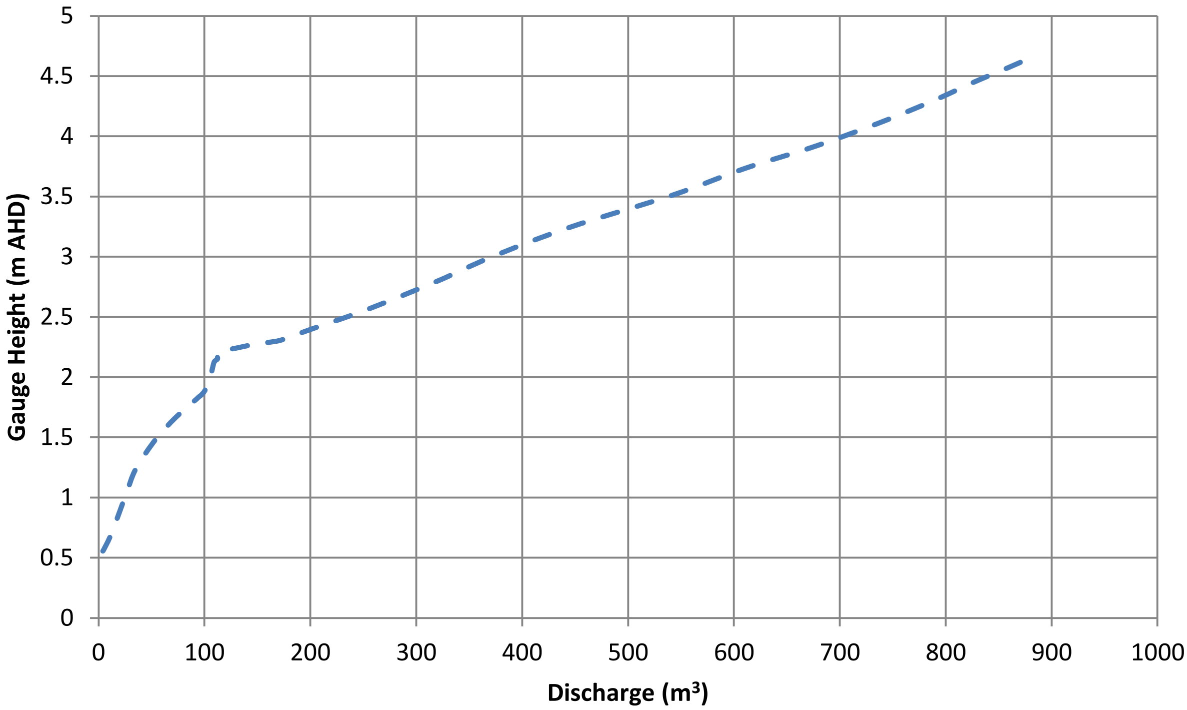


**Figure 3.3 Theoretical Bakers Creek Alert Rating Curve, 2008 Flood TUFLOW model**

## 3.4 TOPOGRAPHIC DATA

A digital terrain model (DTM) of the Bakers Creek catchment was provided by Fugro Spatial Solutions Pty Ltd via MRC. The ground surface model was obtained by LiDAR capture in July and December 2009. RPS Group Australia provided bathymetry survey for the tidal reach of Bakers Creek (downstream of the Bruce Highway crossing). The survey was captured during the first half of 2010.

The LiDAR data and the bathymetry data were combined to create the DTM used as the ground surface for the hydraulic model. The LiDAR DTM was supplemented with ground survey provided Mackay Regional Council of the existing road and rail infrastructure.

# 4 HYDROLOGIC AND HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

## 4.1 OVERVIEW

Flood discharges within the Bakers Creek catchment were estimated using the RAFTS runoff-routing model (XP Software, 2009). The RAFTS model extends from the eastern side of Marian to the ocean, covering the townships of Walkerston and Bakers Creek. The TUFLOW hydrodynamic model (WBM, 2010) was used to simulate the flow behaviour of Bakers Creek from the eastern side of Marian to the mouth of the creek. TUFLOW estimates flood levels and velocities on a fixed grid pattern by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. It also incorporates a one-dimensional or quasi two-dimensional modelling system (ESTRY). The one-dimensional (ESTRY) and two-dimensional (TUFLOW) schemes are solved independently, but are dynamically linked at the boundary to ensure continuity (mass) is conserved.

The RAFTS and TUFLOW models were calibrated to the January 2007 and February 2008 flood events. The purpose of model calibration is to achieve the best possible fit between the predicted and recorded discharge hydrographs at the Bakers Creek Alert gauge, as well as match as close as possible to the surveyed flood marks at Walkerston. Due to the fact that only one stream flow station is located within the catchment and this station is unrated, the parameters of RAFTS model were refined through a joint calibration with the hydraulic model.

## 4.2 RAFTS MODEL CONFIGURATION

### 4.2.1 Model Sub-catchments

Figure 4.1 shows the Bakers Creek RAFTS model configuration, which consists of 52 sub-catchment areas totalling 190 km$^2$ (18,987 ha). The model also incorporates the Bakers One catchment, which drains into Bakers Creek downstream of the Bakers Creek streamflow gauging station. Figure 4.2 shows the Bakers One catchment RAFTS model configuration. Note that this study does not consider flooding within the Bakers One catchment.

### 4.2.2 Model Parameters

Table 4.3 and Table 4.4 show the adopted RAFTS sub-catchment parameters for the Bakers Creek catchment and Bakers One catchment respectively. The rainfall station data adopted for each sub-catchment for model calibration is also shown. The following is of note:

- The average catchment slope was determined from the 0.5m contours.
- A global storage 'Bx' factor of 1 was adopted for the model.

  The RAFTS percentage impervious in each subcatchment was assumed to vary linearly with percentage urbanisation, between 3% impervious for undeveloped (impervious fraction of 0.0) and 80% impervious for a commercial centre (impervious fraction of 1.0).

- The nearest recorded rainfall and temporal pattern was assigned to each sub-catchment. Figure 4.1 shows the model sub-catchments and the available pluviograph rainfall stations.
- Sub-catchment Manning's 'n' was used at the primary calibration parameter in the model. Table 4.1 shows the adopted Manning's 'n' values for different landuses within the catchment. These RAFTS catchment Manning's 'n' values were adopted for all three scenarios.

**Table 4.1 Adopted RAFTS Catchment Manning's 'n' Values**

| Sub-Catchment Type | Adopted Manning's 'n' |
|---|---|
| Sugarcane Cropped Areas | 0.11 |
| Heavily Vegetated Areas | 0.09 |
| Partly Developed or Moderate Vegetated Areas | 0.07 |
| Fully Developed Areas | 0.05 |

#### 4.2.3 Initial and Continuing Losses

Table 4.2 shows the adopted initial loss and continuing loss for each of the calibration events.

**Table 4.2 Adopted Initial and Continuing Losses for Calibration Events**

| Calibration Event | Initial Loss (mm) | Continuing Loss (mm/hr) |
|---|---|---|
| January 2007 | 10 | 1.0 |
| February 2008 | 15 | 2.0 |

## 4.3 HYDRAULIC MODEL CONFIGURATION

#### 4.3.1 Model Extent

Figure 4.3 shows the extent of the Bakers Creek TUFLOW model. Due to the large floodplain within the 2D model, two nested domains (coarse and fine grid size) were used in the hydraulic model. A fine 5m grid size and a 2 second time step were adopted from Pleystowe School Road to Walkerston Homebush Road, including the township of Walkerston. The fine grid size domain provides a more reliable estimate of flood levels in Walkerston. A coarse 20m grid size and 8 second time step were adopted for the upstream and downstream areas.

#### 4.3.2 Adopted Manning's 'n' Values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). Discrete regions of continuous vegetation types and land uses were mapped, and appropriate roughness values assigned to each region.

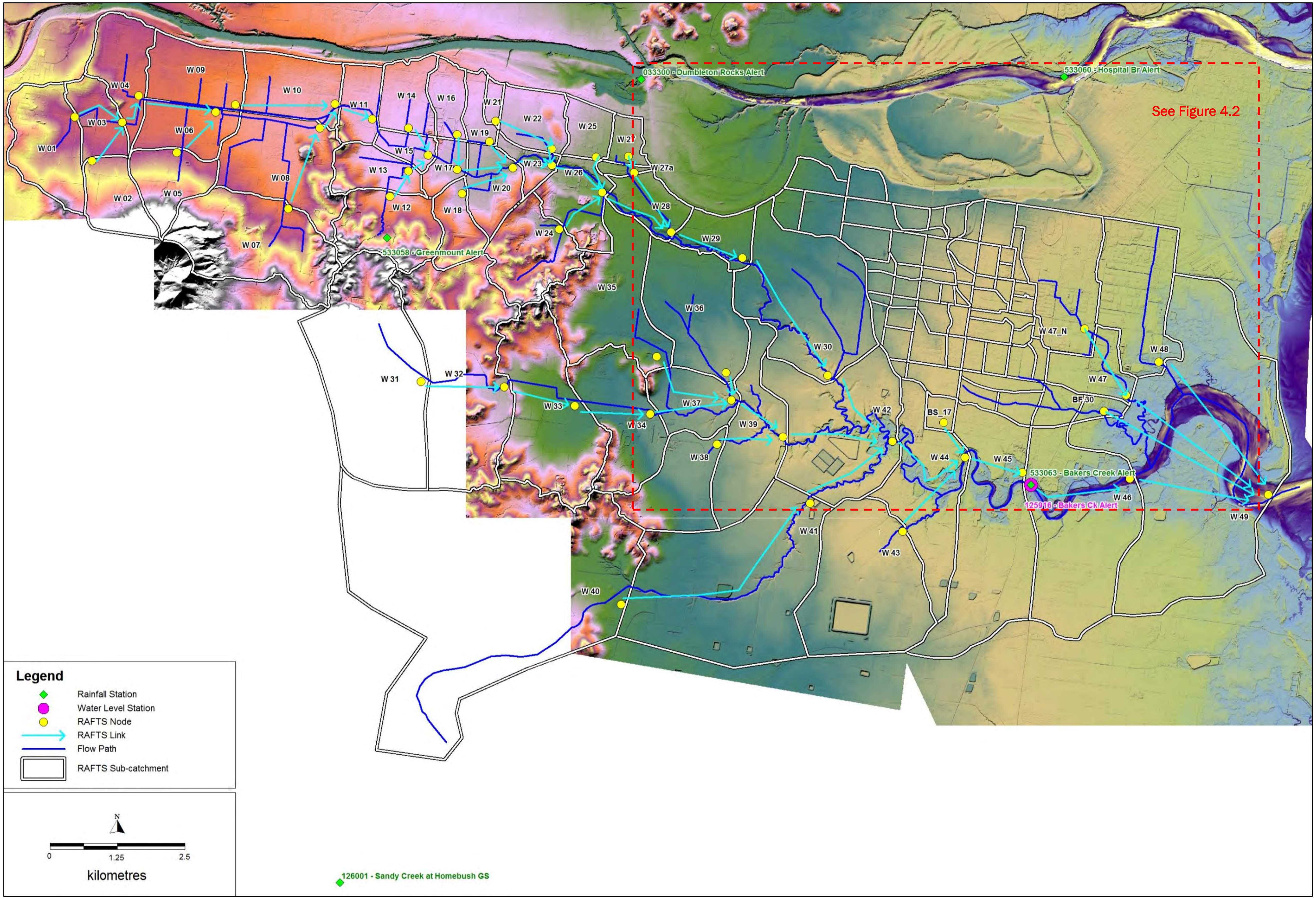


Figure 4.1 Adopted RAFTS Model Configuration, Bakers Creek

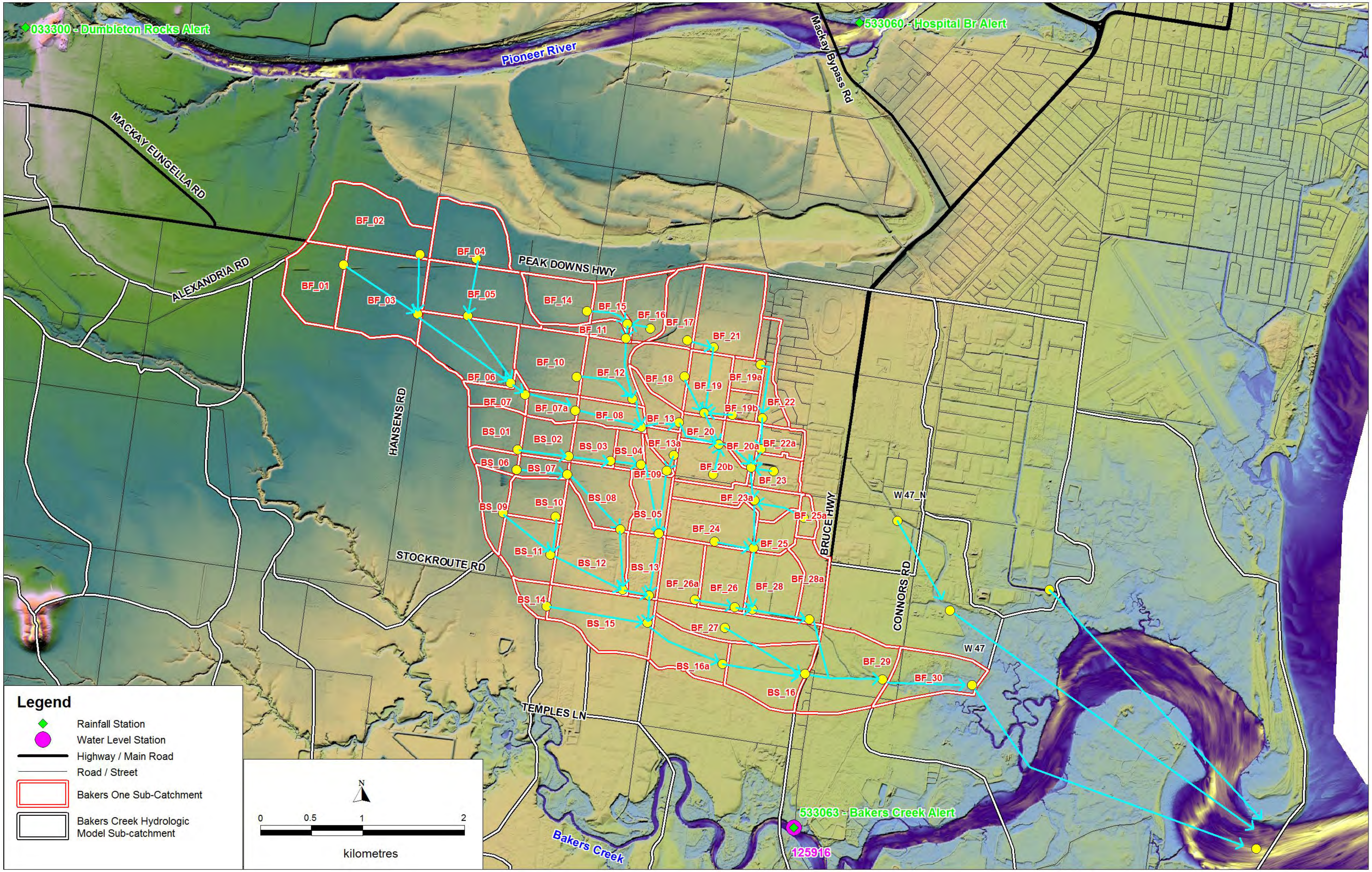


Figure 4.2 Adopted RAFTS Model Configuration, Bakers One Catchment

Table 4.3 Adopted RAFTS Model Sub-Catchment (Bakers Creek Catchment)

| Sub-Catchment ID | Catchment Area (ha) | Catchment Slope (%) | Percentage Impervious (%) | Adopted Rainfall Station | Sub-Catchment ID | Catchment Area (ha) | Catchment Slope (%) | Percentage Impervious (%) | Adopted Rainfall Station |
|---|---|---|---|---|---|---|---|---|---|
| W 01 | 272.7 | 1.5 | 17.0 | Greenmount Alert | W 27 | 58.7 | 0.3 | 3.0 | Dumbleton Rocks Alert |
| W 02 | 157.6 | 10.0 | 3.0 | Greenmount Alert | W 27a | 21.3 | 0.1 | 38.8 | Dumbleton Rocks Alert |
| W 03 | 130.0 | 1.4 | 3.0 | Greenmount Alert | W 28 | 128.1 | 0.7 | 3.8 | Dumbleton Rocks Alert |
| W 04 | 194.7 | 0.5 | 3.0 | Greenmount Alert | W 29 | 124.0 | 0.5 | 3.0 | Dumbleton Rocks Alert |
| W 05 | 172.3 | 9.8 | 3.0 | Greenmount Alert | W 30 | 592.2 | 0.4 | 3.0 | Bakers Creek Alert |
| W 06 | 165.3 | 0.4 | 3.0 | Greenmount Alert | W 31 | 765.5 | 1.5 | 3.0 | Greenmount Alert |
| W 07 | 467.5 | 6.7 | 3.0 | Greenmount Alert | W 32 | 709.3 | 0.8 | 3.0 | Greenmount Alert |
| W 08 | 375.1 | 1.2 | 3.0 | Greenmount Alert | W 33 | 529.7 | 0.7 | 3.0 | Greenmount Alert |
| W 09 | 222.2 | 0.3 | 3.0 | Greenmount Alert | W 34 | 328.5 | 0.8 | 3.0 | Greenmount Alert |
| W 10 | 222.4 | 0.3 | 3.0 | Greenmount Alert | W 35 | 423.0 | 1.0 | 3.0 | Dumbleton Rocks Alert |
| W 11 | 114.5 | 1.5 | 3.0 | Greenmount Alert | W 36 | 395.2 | 0.4 | 3.0 | Bakers Creek Alert |
| W 12 | 250.3 | 2.8 | 3.0 | Greenmount Alert | W 37 | 181.3 | 0.7 | 3.0 | Dumbleton Rocks Alert |
| W 13 | 132.0 | 3.5 | 3.0 | Greenmount Alert | W 38 | 260.5 | 0.8 | 3.0 | Bakers Creek Alert |
| W 14 | 140.2 | 0.5 | 3.0 | Greenmount Alert | W 39 | 322.4 | 0.3 | 3.0 | Bakers Creek Alert |
| W 15 | 62.2 | 0.2 | 3.0 | Greenmount Alert | W 40 | 1956.0 | 1.5 | 3.0 | Sandy Creek at Homebush GS |
| W 16 | 92.9 | 0.3 | 8.9 | Greenmount Alert | W 41 | 951.7 | 0.8 | 3.0 | Sandy Creek at Homebush GS |
| W 17 | 67.6 | 0.8 | 3.0 | Greenmount Alert | W 42 | 566.6 | 0.2 | 3.0 | Bakers Creek Alert |
| W 18 | 114.8 | 2.6 | 3.0 | Greenmount Alert | W 43 | 594.6 | 0.2 | 3.0 | Bakers Creek Alert |
| W 19 | 62.3 | 0.3 | 3.0 | Dumbleton Rocks Alert | W 44 | 406.7 | 0.3 | 3.0 | Bakers Creek Alert |
| W 20 | 147.0 | 1.0 | 16.6 | Dumbleton Rocks Alert | W 45 | 634.6 | 0.2 | 5.3 | Bakers Creek Alert |
| W 21 | 27.3 | 0.2 | 3.0 | Dumbleton Rocks Alert | W 46 | 671.7 | 0.2 | 4.3 | Bakers Creek Alert |
| W 22 | 143.7 | 1.2 | 3.0 | Dumbleton Rocks Alert | W 47 | 142.8 | 0.3 | 12.9 | Bakers Creek Alert |
| W 23 | 59.1 | 0.9 | 28.7 | Dumbleton Rocks Alert | W 47_N | 362.9 | 0.3 | 28.0 | Hospital Br Alert |
| W 24 | 252.7 | 6.2 | 8.6 | Greenmount Alert | W 48 | 376.9 | 0.2 | 45.0 | Bakers Creek Alert |
| W 25 | 92.2 | 0.3 | 6.6 | Dumbleton Rocks Alert | W 49 | 1537.0 | 0.1 | 3.0 | Bakers Creek Alert |
| W 26 | 182.1 | 0.9 | 17.1 | Dumbleton Rocks Alert | | | | | |

Table 4.4 Adopted RAFTS Model Sub-Catchment (Bakers One Catchment)

| Sub-Catchment ID | Catchment Area (ha) | Catchment Slope (%) | Percentage Impervious (%) | Adopted Rainfall Station for Calibration | Sub-Catchment ID | Catchment Area (ha) | Catchment Slope (%) | Percentage Impervious (%) | Adopted Rainfall Station for Calibration |
|---|---|---|---|---|---|---|---|---|---|
| BF_01 | 40.1 | 0.9 | 3.0 | Dumbleton Rocks Alert | BF_23a | 25.9 | 0.3 | 3.0 | Bakers Creek Alert |
| BF_02 | 56.5 | 0.8 | 3.0 | Dumbleton Rocks Alert | BF_24 | 35.2 | 0.3 | 3.0 | Bakers Creek Alert |
| BF_03 | 65.3 | 0.7 | 3.0 | Dumbleton Rocks Alert | BF_25 | 13.6 | 0.3 | 3.0 | Bakers Creek Alert |
| BF_04 | 42.2 | 0.5 | 3.4 | Hospital Br Alert | BF_25a | 6.5 | 0.8 | 3.0 | Bakers Creek Alert |
| BF_05 | 52.2 | 0.4 | 3.2 | Hospital Br Alert | BF_26 | 28.1 | 0.2 | 3.0 | Bakers Creek Alert |
| BF_06 | 52.6 | 0.5 | 3.2 | Hospital Br Alert | BF_26a | 25.3 | 0.5 | 3.0 | Bakers Creek Alert |
| BF_07 | 13.7 | 0.5 | 3.5 | Bakers Creek Alert | BF_27 | 40.3 | 0.3 | 3.0 | Bakers Creek Alert |
| BF_07a | 13.0 | 0.9 | 3.5 | Bakers Creek Alert | BF_28 | 32.3 | 0.3 | 3.0 | Bakers Creek Alert |
| BF_08 | 16.0 | 1.0 | 3.0 | Bakers Creek Alert | BF_28a | 20.8 | 0.3 | 4.6 | Bakers Creek Alert |
| BF_09 | 5.5 | 0.4 | 3.0 | Bakers Creek Alert | BF_29 (Sub-catchment 1) | 51.8 | 0.5 | 3.0 | Bakers Creek Alert |
| BF_10 | 39.2 | 0.7 | 3.0 | Hospital Br Alert | BF_29 (Sub-catchment 2) | 8.0 | 1.0 | 60.0 | Bakers Creek Alert |
| BF_11 | 9.7 | 0.4 | 3.0 | Hospital Br Alert | BF_30 | 36.5 | 0.8 | 3.0 | Bakers Creek Alert |
| BF_12 | 30.9 | 0.4 | 3.0 | Hospital Br Alert | BS_01 | 22.0 | 0.6 | 3.0 | Bakers Creek Alert |
| BF_13 | 12.9 | 0.3 | 3.0 | Bakers Creek Alert | BS_02 | 18.4 | 0.4 | 3.2 | Bakers Creek Alert |
| BF_13a | 8.9 | 0.1 | 3.0 | Bakers Creek Alert | BS_03 | 16.7 | 0.4 | 3.0 | Bakers Creek Alert |
| BF_14 | 28.4 | 0.8 | 3.5 | Bakers Creek Alert | BS_04 | 10.9 | 0.6 | 3.0 | Bakers Creek Alert |
| BF_15 | 12.6 | 0.7 | 3.0 | Bakers Creek Alert | BS_05 | 21.4 | 0.5 | 3.0 | Bakers Creek Alert |
| BF_16 | 24.7 | 0.6 | 5.7 | Hospital Br Alert | BS_06 | 8.8 | 0.7 | 3.0 | Bakers Creek Alert |
| BF_17 | 25.0 | 0.8 | 6.3 | Hospital Br Alert | BS_07 | 9.7 | 0.4 | 3.0 | Bakers Creek Alert |
| BF_18 | 26.3 | 0.4 | 3.0 | Hospital Br Alert | BS_08 | 32.3 | 0.6 | 3.0 | Bakers Creek Alert |
| BF_19 | 25.6 | 0.6 | 3.0 | Hospital Br Alert | BS_09 | 18.4 | 0.8 | 3.8 | Bakers Creek Alert |
| BF_19a | 9.7 | 0.3 | 13.2 | Hospital Br Alert | BS_10 | 21.9 | 0.9 | 3.4 | Bakers Creek Alert |
| BF_19b | 9.0 | 0.2 | 31.9 | Hospital Br Alert | BS_11 | 31.4 | 0.9 | 3.0 | Bakers Creek Alert |
| BF_20 | 10.4 | 0.5 | 4.3 | Bakers Creek Alert | BS_12 | 50.1 | 0.4 | 3.0 | Bakers Creek Alert |
| BF_20a | 13.7 | 0.1 | 3.0 | Bakers Creek Alert | BS_13 | 20.1 | 0.1 | 3.0 | Bakers Creek Alert |
| BF_20b | 25.7 | 0.8 | 3.5 | Bakers Creek Alert | BS_14 | 9.2 | 0.7 | 3.0 | Bakers Creek Alert |
| BF_21 | 52.3 | 0.5 | 5.3 | Hospital Br Alert | BS_15 | 51.1 | 0.4 | 3.0 | Bakers Creek Alert |
| BF_22 | 20.0 | 1.0 | 50.0 | Hospital Br Alert | BS_16 | 44.2 | 0.4 | 3.0 | Bakers Creek Alert |
| BF_22a | 12.4 | 1.0 | 42.4 | Bakers Creek Alert | BS_16a | 32.2 | 0.6 | 3.0 | Bakers Creek Alert |
| BF_23 | 15.8 | 0.3 | 3.0 | Bakers Creek Alert | BS_17 | 36.5 | 0.6 | 3.0 | Bakers Creek Alert |

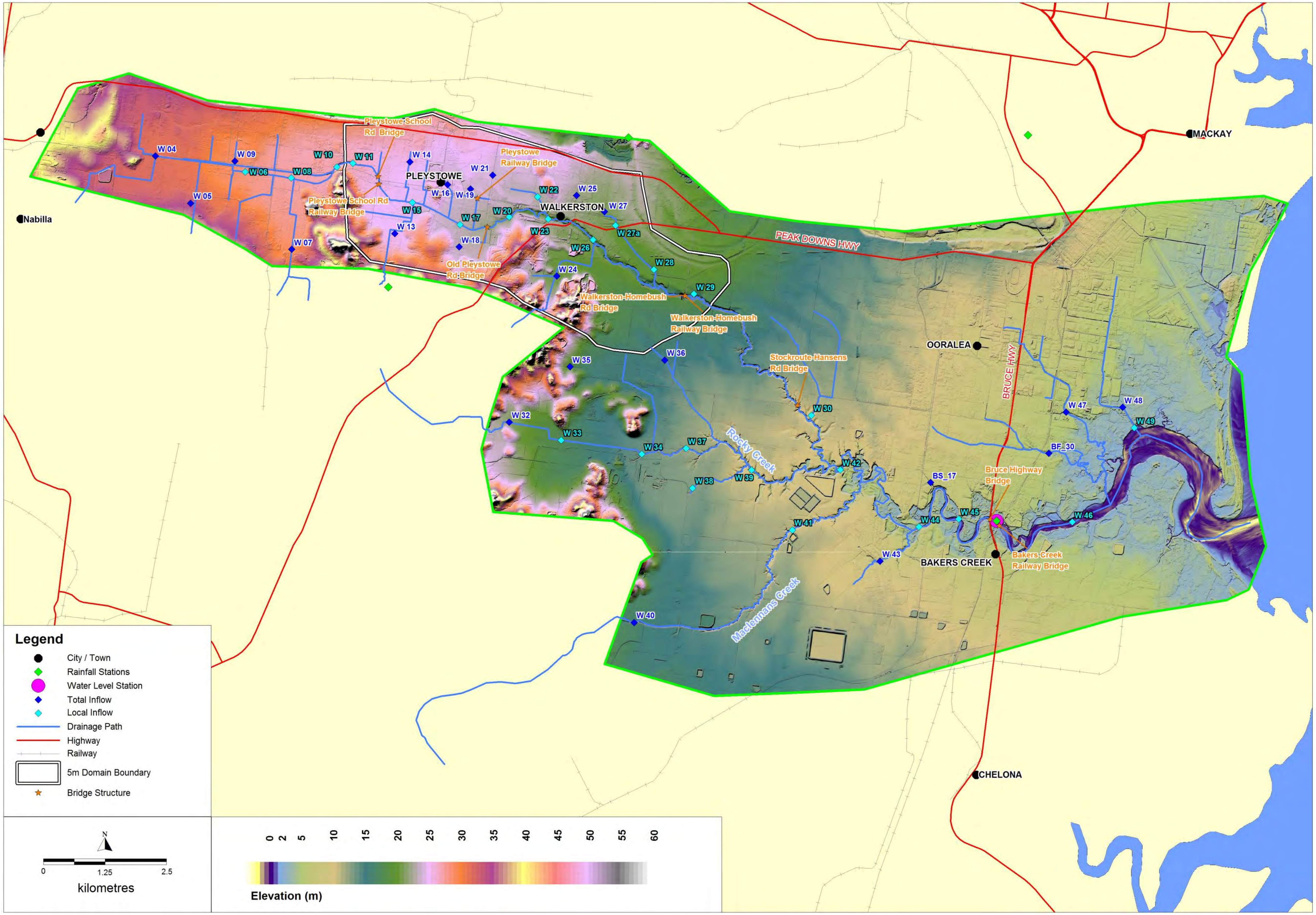


Figure 4.3 Bakers Creek TUFLOW Model Configuration

Vegetation and land use mapping was undertaken using an orthophotograph of the area captured in December 2009 (provided by MRC). The Manning's 'n' values were selected during model calibration and were applied to all model scenarios, except for Case 2 which used a Manning's 'n' value of 0.05 for all sugarcane area. Table 4.5 shows the adopted Manning's 'n' values for different material types.

**Table 4.5 Adopted Manning's 'n' values, Case 1 and Case 3**

| Location | Adopted Manning's 'n' |
|---|---|
| Sugarcane | 0.150 (to 0.5m deep)<br>0.050 (to 1.5m deep) |
| Heavily Vegetated Overbank | 0.125 |
| Urban Areas | 0.100 |
| Roads | 0.020 |
| Open Drains | 0.035 |
| Bakers Creek - Channel | 0.060 |
| Clear Area, Low Density Rural Residential Area and Railway | 0.050 |
| Mangrove Overbank | 0.070 |
| Southern Tributaries | 0.045 |
| Bakers Creek Tidal zone | 0.030 |

### 4.3.1 Inflow and Outflow Boundaries

Figure 4.3 shows the locations of the inflow boundaries used in the TUFLOW model. Inflow boundaries have been obtained from the RAFTS model with names corresponding to the RAFTS node numbers (See Figure 4.1). Inflows have been delineated into 'total' and 'local' inflows, with total inflows including runoff from the entire catchment draining to that point and local inflows representing runoff from the single sub-area only.

The Mackay Outer Harbour tidal gauge record was adopted as the downstream boundary for Bakers Creek for the calibration runs.

### 4.3.2 Hydraulic Structures

Nine bridge structures within the catchment were added as layered flow constrictions within the 2D domain. Figure 4.3 shows the locations of the bridge structures included in the TUFLOW model. Table A1 in Appendix A shows the adopted bridge characteristics at each crossing. Table A2 in Appendix A shows the adopted blockage factor and form loss co-efficient (FLC) within each layer at each structure. Four layers represent the flow across a bridge structure:

- Layer 1 represents the waterway area beneath the bridge deck;
- Layer 2 represents the bridge deck;
- Layer 3 represents the guard rail; and
- Layer 4 represents flow above the bridge (assumed to be unimpeded).

#### 4.3.3 Culvert Structures

Major road and rail stormwater culverts were embedded within the 2D domain of the TUFLOW model. The ESTURY 1D hydraulic model, a built-in feature of TUFLOW, was used to undertake the hydraulic calculations of structures within the 1D domain.

Details of culvert structures were obtained from detailed survey provided by Mackay Regional Council. Table A3 in Appendix A shows the hydraulic characteristics for each culvert in the model. Figure A1 in Appendix A shows the locations of the 1D culverts in the TUFLOW model. In general, minor stormwater pipes such as driveway crossings were not included in the model.

### 4.4 MODEL CALIBRATION RESULTS

#### 4.4.1 January 2007

Figure 4.4 shows comparisons of predicted and recorded water level hydrographs at the Bakers Creek Alert gauge for the January 2007 event. There is a good agreement between recorded and predicted water levels at Bakers Creek Alert. The peak water level predicted by TUFLOW model is some 0.17m lower than the recorded water level. It is of note that no adjustment was made to the Bakers Creek (recorded) water levels for this event. The January 2007 event was much smaller than the February 2008 event and the flood levels were highly influenced by tides. Overall, calibration is considered to be acceptable.

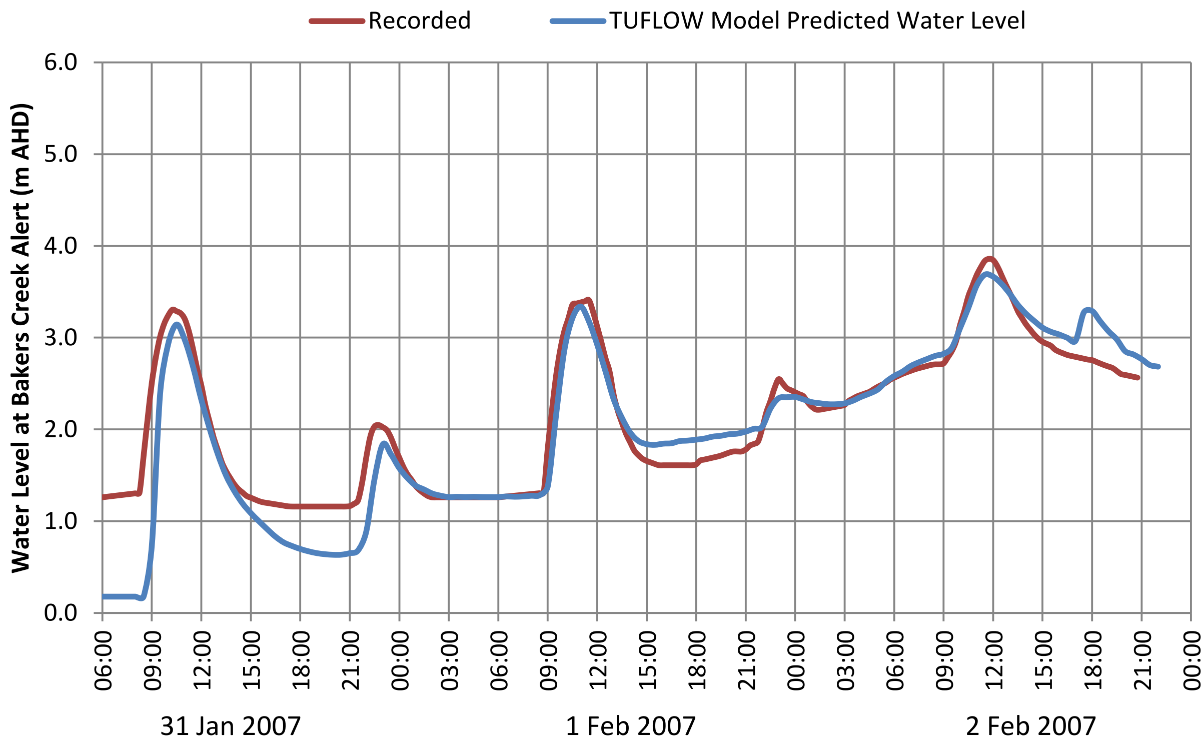


Figure 4.4 Comparison of Predicted and Recorded Water Level Hydrographs, Bakers Creek Alert, Jan/Feb 2007 Event

### 4.4.1 February 2008

The February 2008 event was calibrated to both the recorded water levels at the Bakers Creek Alert gauge and the surveyed flood marks in and around Walkerston.

Figure 4.5 shows the recorded and predicted water levels at the Bakers Creek Alert gauge for the February 2008 event. A comparison of surveyed and predicted peak flood levels throughout Walkerston and within the Bakers Creek floodplain is shown in Table 4.6. The locations of the surveyed flood marks, as well as the predicted flood extent for this event, are shown in Figure 4.6.

The adjusted (recorded) water level hydrograph to achieve a peak that is consistent with the surveyed water levels at Bakers Creek was adopted. The recorded water levels were multiplied by 1.11 to achieve a peak level consistent with the local surveyed data. The predicted peak level at the gauge is some 0.35m higher than the adjusted recorded value. With this adjustment, an acceptable calibration was achieved at Bakers Creek for this event. The peak discharge at the Bakers Creek Alert gauge for this event is 930m$^3$/s.

At Walkerston, the predicted flood levels for the 2008 event are generally in agreement with the surveyed levels, as are the levels in the overbank area downstream of Walkerston. Peak flood levels along the Bakers Creek channel downstream of Walkerston are underestimated by 0.4 to 0.5m, which may be due to local influences. On the basis of the 2008 calibration, it is expected that the TUFLOW model would represent flooding conditions at Walkerston along Bakers Creek adequately.

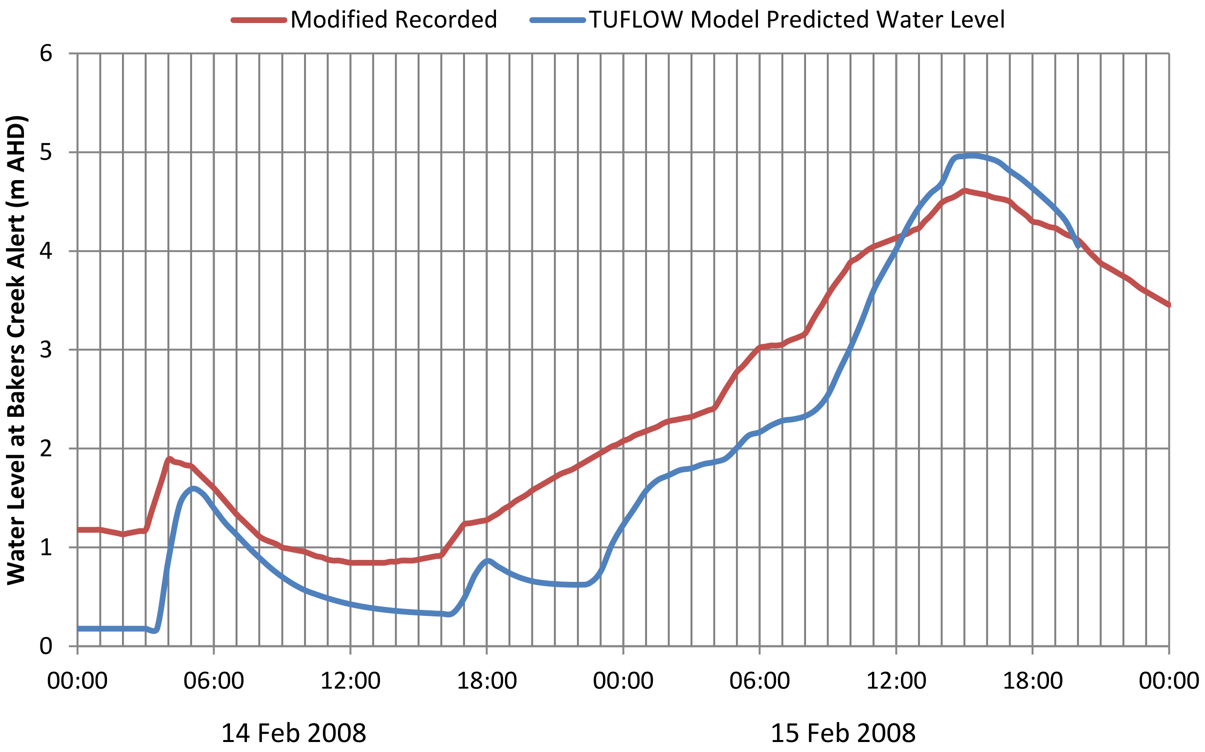


**Figure 4.5 Comparison of Predicted and Recorded Water Level Hydrographs and Predicted Discharge Hydrograph, Bakers Creek Alert, Feb 2008 Event**

Table 4.6 Surveyed and Predicted Peak Water Levels, February 2008 Event

| Location ID (see ) | Surveyed Level (m AHD) | Predicted Level (m AHD) | Difference (Predicted - Surveyed) |
|---|---|---|---|
| 1 | 24.42 | 24.19 | -0.23 |
| 2 | 24.68 | 24.24 | -0.44 |
| 3 | 24.39 | 24.24 | -0.15 |
| 4 | 24.60 | 24.12 | -0.47 |
| 5 | 23.56 | 24.04 | 0.48 |
| 6 | 23.64 | 23.97 | 0.33 |
| 7 | 23.77 | 23.85 | 0.08 |
| 8 | 22.67 | 22.97 | 0.30 |
| 9 | 22.79 | 22.96 | 0.18 |
| 10 | 22.76 | 22.99 | 0.24 |
| 11 | 22.76 | 22.96 | 0.20 |
| 12 | 22.82 | 22.85 | 0.03 |
| 13 | 22.02 | 22.36 | 0.33 |
| 14 | 22.11 | 22.21 | 0.09 |
| 15 | 22.35 | 22.32 | -0.03 |
| 16 | 21.80 | 22.14 | 0.34 |
| 17 | 21.93 | 22.08 | 0.15 |
| 18 | 21.42 | 21.63 | 0.21 |
| 19 | 22.19 | 22.11 | -0.08 |
| 20 | 21.83 | 22.00 | 0.17 |
| 21 | 21.61 | 21.86 | 0.25 |
| 22 | 21.47 | 21.77 | 0.30 |
| 23 | 21.70 | 21.65 | -0.05 |
| 24 | 21.42 | 21.55 | 0.13 |
| 25 | 21.50 | 21.39 | -0.11 |
| 26 | 21.22 | 21.15 | -0.07 |
| 27 | 21.34 | 20.93 | -0.40 |
| 28 | 21.34 | 21.21 | -0.13 |
| 29 | 21.03 | 20.98 | -0.05 |
| 30 | 21.14 | 20.79 | -0.36 |
| 31 | 20.95 | 20.43 | -0.52 |
| 33 | 22.26 | 21.88 | -0.38 |
| 34 | 18.39 | 17.95 | -0.44 |
| 35 | 11.75 | 11.17 | -0.58 |
| 36 | 4.61 | 4.96 | 0.35 |
| 37 | 18.98 | 18.72 | -0.26 |
| 38 | 16.09 | 16.01 | -0.08 |
| 39 | 15.24 | 15.13 | -0.11 |
| 40 | 16.69 | 16.51 | -0.18 |
| 41 | 16.42 | 16.44 | 0.02 |
| 42 | 16.26 | 16.05 | -0.21 |
| 43 | 15.99 | 15.92 | -0.07 |
| 44 | 14.69 | 14.63 | -0.06 |
| 45 | 13.46 | 13.23 | -0.23 |
| 46 | 26.17 | 26.82 | 0.65 |
| 47 | 26.46 | 26.03 | -0.42 |

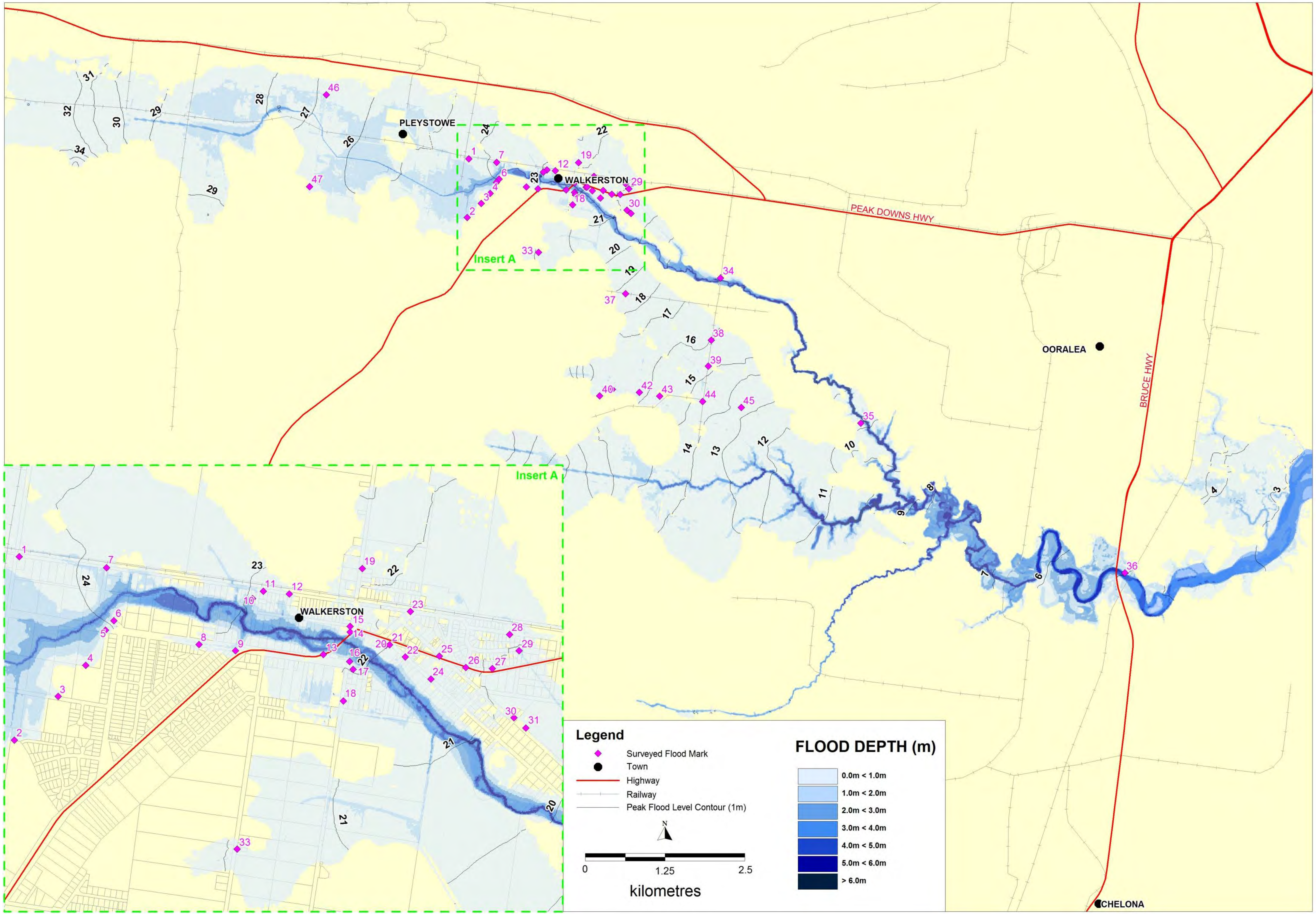


Figure 4.6 Predicted Flood Depths, Levels and Extent, February 2008 Event

# 5 DESIGN DISCHARGE ESTIMATION

## 5.1 GENERAL

Design discharges for the 5, 50, 100, 200 and 500 year ARI and the Probable Maximum Flood (PMF) events were estimated at both Walkerston and Bakers Creek using the calibrated RAFTS and TUFLOW models for the following three scenarios:

- Case 1: Sugarcane growth at 2008/9 levels of development (Existing Conditions).
- Case 2: Cleared land or low sugarcane land use catchment conditions; and
- Case 3: Bakers Creek catchment flooding coinciding with Pioneer River overflows.

For each case, the calibrated RAFTS runoff-routing model, described in Section 4, was used to estimate design flood discharges for each sub area. The RAFTS model inflows were then routed through the TUFLOW model to estimate design discharges and flood levels.

The design discharges have also been compared to the previous estimates made by Ullman & Nolan (1996), Chaseling McGiffin (2004) and WRM (2011).

## 5.2 DESIGN RAINFALLS

### 5.2.1 Overview

Given that the primary focus of this study is Walkerston, design discharges for the catchment were estimated using catchment averaged design rainfalls to Walkerston. Design rainfalls for the residual catchment downstream of Walkerston were factored so that the combined upper and lower Bakers Creek rainfall depth multiplied by their respective catchment areas was equivalent to total catchment rainfall depth multiplied by the total catchment to ensure mass is conserved. This is expressed using the formula:

$$R_w \times A_w + R_r \times A_r = R_b \times A_b$$

where R is the rainfall depth, A is the catchment area and subscript w, r and b denote the Walkerston catchment, residual catchment and Bakers Creek catchment respectively. Figure 1.1 shows the Walkerston catchment and lower Bakers Creek catchment.

For Case 3, where outflows from the Pioneer River were included, the model was run using Bakers Creek catchment rainfall depths.

### 5.2.2 Design Rainfall Depths

Table 5.1 shows the catchment based design rainfall depths to Walkerston and for the entire catchment as well as for the residual catchment downstream of Walkerston for the 5 year, 50 year, 100 year, 200 year and 500 year ARI events. Design rainfall depths were estimated for a range of storm durations using the CRC-Forge method (Hargraves, c2004). The Areal Reduction

Table 5.1 Walkerston and Bakers Creek Catchment Design Rainfall Depths

| Storm Duration (hours) | Design Rainfall Depth (mm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | To Walkerston | | | | | Downstream of Walkerston [a] | | | | | Bakers Creek Catchment | | | | |
| | 5 Yr ARI | 50 Yr ARI | 100 Yr ARI | 200 Yr ARI | 500 Yr ARI | 5 Yr ARI | 50 Yr ARI | 100 Yr ARI | 200 Yr ARI | 500 Yr ARI | 5 Yr ARI | 50 Yr ARI | 100 Yr ARI | 200 Yr ARI | 500 Yr ARI |
| 12 | 221 | 380 | 442 | 510 | 608 | 211 | 360 | 419 | 483 | 576 | 213 | 365 | 425 | 489 | 584 |
| 18 | 267 | 469 | 546 | 629 | 751 | 255 | 448 | 521 | 600 | 716 | 258 | 453 | 527 | 607 | 725 |
| 24 | 305 | 544 | 633 | 729 | 870 | 291 | 522 | 607 | 699 | 834 | 294 | 527 | 613 | 706 | 843 |
| 36 | 374 | 654 | 758 | 882 | 1048 | 358 | 633 | 740 | 841 | 999 | 362 | 638 | 745 | 851 | 1011 |
| 48 | 425 | 758 | 879 | 1008 | 1192 | 404 | 725 | 840 | 964 | 1142 | 409 | 733 | 850 | 975 | 1154 |
| 72 | 487 | 870 | 1012 | 1165 | 1391 | 462 | 829 | 967 | 1117 | 1337 | 468 | 839 | 978 | 1129 | 1351 |

[a] residual catchment rainfalls determined based on catchment averaged difference between the Bakers Creek catchment rainfall and Walkerston Catchment Rainfall

Factors (ARFs) applied to the 5, 50, 100, 200 and 500 year ARI rainfall depths are given in Table 5.2.

**Table 5.2 Adopted Areal Reduction Factors**

| Storm Duration (hours) | ARF | |
|---|---|---|
| | Walkerston Catchment | Bakers Creek Catchment |
| 12 | 0.95 | 0.93 |
| 18 | 0.95 | 0.93 |
| 24 | 0.95 | 0.93 |
| 36 | 0.96 | 0.94 |
| 48 | 0.98 | 0.96 |
| 72 | 0.99 | 0.97 |

Table 5.3 shows the adopted Probable Maximum Precipitation (PMP) rainfall depths for the entire Bakers Creek catchment for various storm durations. PMP rainfall intensities and patterns were estimated using the Generalised Short-Duration Method (GSDM) (BOM, 2003a) and Generalised Tropical Storm Method (GTSMR) (BOM, 2003b). GSDM was used to estimate the 6 hour duration storm and GSTMR was used to estimate long duration storms from 24 hours to 120 hours. The rainfall depth of a 12 hour storm was interpolated between the GSDM and GTSMR estimates. The spatial distribution of PMP rainfall across the catchment was determined in accordance with the methodology outlined in BOM (2003a, 2003b).

**Table 5.3 Adopted PMP Rainfall Depths**

| Storm Event Duration (Hours) | PMP Rainfall Depth (mm) |
|---|---|
| 6 | 650 |
| 12 | 1,040 |
| 24 | 1,820 |
| 36 | 2,210 |
| 48 | 2,570 |

### 5.2.1 Temporal Patterns

The temporal patterns given in Australian Rainfall and Runoff (ARR) (IEAust, 1987) were applied to the 5, 50 and 100 year ARI design events. The temporal patterns given in the BOM GSDM and GTSMR were applied to the 200 and 500 year ARI design events and the PMF events as recommended in ARR (IEAust, 1987).

### 5.2.2 Rainfall Losses

An initial loss of 15 mm and a continuing loss of 1.0 mm/hour were adopted for to 5 year, 50 year, 100 year, 200 year and 500 year ARI events. Zero losses were adopted for the PMF.

## 5.3 DESIGN DISCHARGES

### 5.3.1 Bakers Creek at Walkerston

Table 5.4 shows the Bakers Creek design discharges at Walkerston (Peak Downs Highway) for the three scenarios estimated by the RAFTS and TUFLOW models. The following is of note:

- The critical duration for all events was between 12 and 24 hours.
- The 5 year, 50 year, 100 year, 200 year and 500 year ARI design discharges, estimated by the TUFLOW model, are 19% to 35% lower than the RAFTS model estimates for Case 1. The RAFTS model is unable to adequately model the overbank flood storage in the catchment and as such is likely to overpredict peak flows.
- The 5 year, 50 year, 100 year, 200 year and 500 year ARI design discharge estimated by TUFLOW for cleared land/low sugarcane catchment landuse conditions (Case 2) are 4% to 20% higher than for the calibrated model (Case 1). It appears that the sugarcane slows catchment flows and increases levels within the sugar cane areas to increase flood storage, particularly for the lower ARI design events.
- Based on the Pioneer River Flood Study (WRM, 2011), the peak discharges of the Pioneer River overflow into Bakers Creek catchment downstream of the Peak Downs Highway are about 243m$^3$/s, 669m$^3$/s and 1109m$^3$/s respectively for the 100 year, 200 year and 500 year ARI 12 hour storm events.
- The 100 year ARI design discharges at Walkerston for Case 3 are the same as for Case 1 because the Pioneer River overflows downstream of the Peak Downs Highway. The 200 year and 500 year ARI design discharges at Walkerston for Case 3 are 2% to 13% higher than for Case 1. The increase in discharges for the 200 year and 500 year ARI design events is caused by some Pioneer River overflows draining into Bakers Creek upstream of the Peak Downs Highway.
- The PMF estimate for Case 3 was not estimated because the Pioneer River PMF has not been estimated.

**Table 5.4 Bakers Creek at Walkerston Design Discharges, RAFTS and TUFLOW Model estimates**

| Design Storm Event (ARI) | Peak Discharge (m$^3$/s) | | | |
|---|---|---|---|---|
| | RAFTS Model | TUFLOW Model | | |
| | | Calibration Model (Case 1) | Reduced Sugarcane (Case 2) | Pioneer River Overflows (Case 3) |
| 5 year | 168 | 108 | 135 | 108 |
| 50 year | 312 | 223 | 252 | 223 |
| 100 year | 373 | 270 | 293 | 270* |
| 200 year | 441 | 358 | 372 | 366* |
| 500 year | 534 | 433 | 453 | 497* |
| PMF | 1,195 | | | - |

* Includes Pioneer River overflows

### 5.3.2 Bakers Creek at Bakers Creek

Table 5.5 shows the Bakers Creek design discharges at the Bakers Creek Alert Gauge for the three scenarios estimated by the RAFTS and TUFLOW models. A comparison of the 100 year ARI

12 hour discharge hydrographs immediately downstream of Walkerston (Homebush Road) and at Bakers Creek is shown in Figure 5.1. The following is of note:

- The RAFTS model discharges are some 4% to 15% higher than the TUFLOW model estimates for Case 1.
- Case 2 discharges are about 5% to 10% higher than for Case 1 for all five design events. Figure 5.1 shows that the Case 2 discharges peak several hours earlier than for Case 1.
- Case 3 discharges for the 5 year and 50 year ARI events are the same as for Case 1 (because the Pioneer River does not overflow). The 100 year ARI discharges are only marginally higher.
- Figure 5.1 shows that for the 100 year ARI 12 hour event, the overflows from the Pioneer River (243m$^3$/s) increase peak discharges at Homebush Road by only 100m$^3$/s and by 11m$^3$/s at Bakers Creek. The modelling suggests that the overbank flood storage between the Pioneer River and Bakers Creek significantly mitigates the flood peak.
- The 200 year ARI and 500 year ARI discharges for Case 3 are 149m$^3$/s (11%) and 524m$^3$/s (27%) higher than for Case 1 respectively.

**Table 5.5 Bakers Creek at Bakers Creek Design Discharges, RAFTS and TUFLOW Model estimates**

| Design Storm Event (ARI) | Peak Discharge (m$^3$/s) | | | |
|---|---|---|---|---|
| | RAFTS Model | TUFLOW Model | | |
| | | Calibration Model (Case 1) | Reduced Sugarcane (Case 2) | Pioneer River Overflows (Case 3) |
| 5 year | 451 | 384 | 422 | 384 |
| 50 year | 864 | 755 | 824 | 755 |
| 100 year | 1,021 | 890 | 987 | 900* |
| 200 year | 1,248 | 1,184 | 1,259 | 1,333* |
| 500 year | 1,498 | 1,436 | 1,514 | 1,960* |
| PMF | 3,643 | 3,195 | - | - |

* Includes Pioneer River overflows

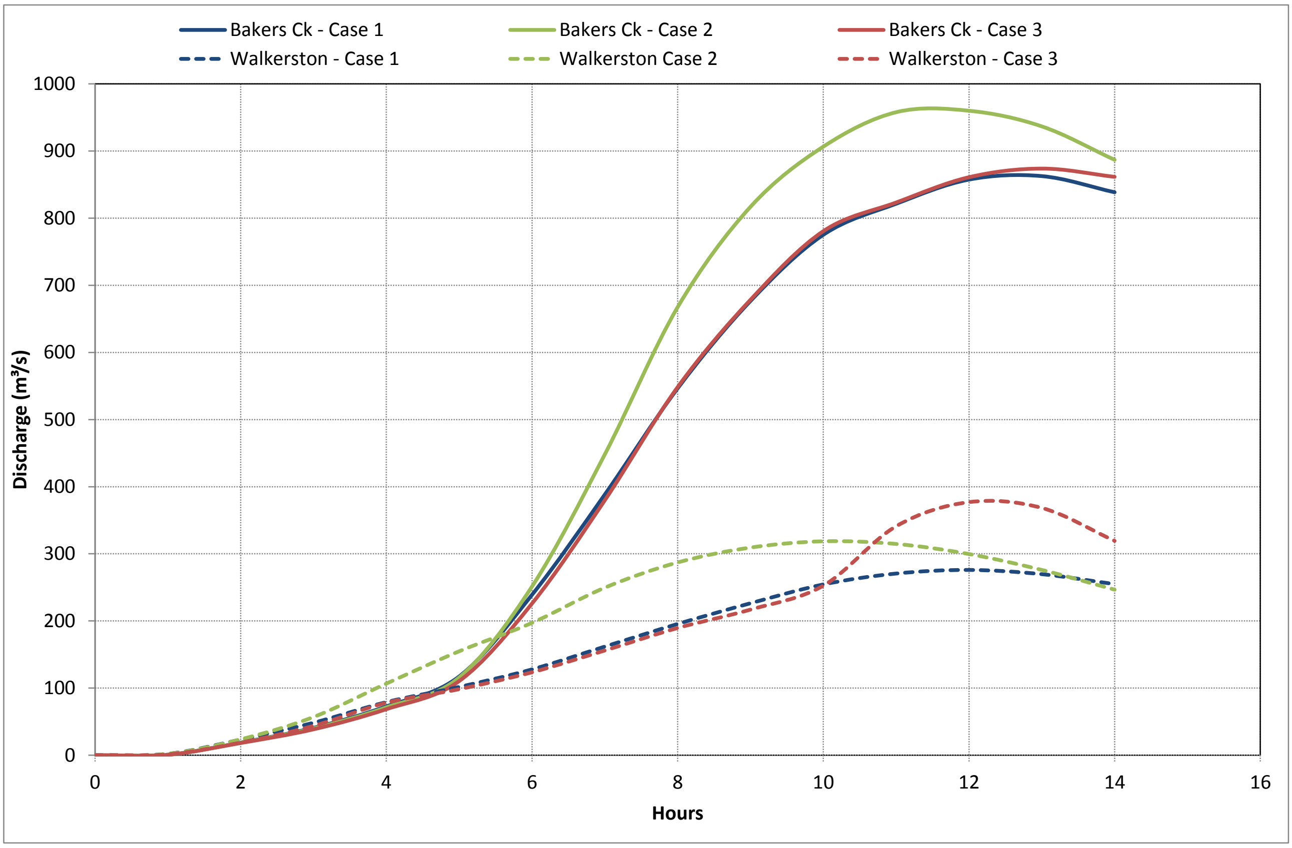


Figure 5.1 Bakers Creek Discharge Hydrographs At Walkerston (Homebush Rd) and Bakers Creek (Gauge), 100 year ARI 12 hour Event

## 5.4 COMPARISON TO PREVIOUS ESTIMATES

### 5.4.1 Ullman & Nolan (1996)

Table 5.6 shows the design discharges at Walkerston estimated by Ullman & Nolan (1996) and compares them to the RAFTS model estimates. Ullman & Nolan (1996) estimated design discharges using three methods: the Rational Method, Synthetic Unit Hydrograph and RORB Model. Limited calibration data was available for the study.

Table 5.6 Comparison of Bakers Creek Design Discharges at Walkerston - RAFTS Model and Previous Ullman & Nolan (1996) Estimates

| Design Storm Event (ARI) | Design Discharge ($m^3/s$) | | | |
|---|---|---|---|---|
| | WRM (2013) RAFTS Model | Ullman & Nolan (1996) | | |
| | | Rational Method | Synthetic Unit Hydrograph | RORB Model |
| 5 Year | 164 | - | - | - |
| 50 Year | 306 | 260 | 345 | 360 |
| 100 Year | 366 | - | 400 | 425 |

The Ullman & Nolan discharge estimates are comparable to the RAFTS model estimate but much higher than the TUFLOW estimate. As stated, neither the RAFTS model nor the Ullman &

Nolan (1996) estimates fully consider the available flood storage within the catchment and as such, the TUFLOW model estimates have been adopted for this study.

### 5.4.2 Chaseling McGiffin (2004)

The design discharges estimated by the TUFLOW model are very similar to the Chaseling McGiffin (2004) estimates at both Walkerston and Bakers Creek but are again, lower than the RAFTS and Ullman & Nolan estimates. The Chaseling McGiffin discharge estimates have been determined using the NEX-1 hydraulic model in a similar manner to the TUFLOW model, which take into consideration effective channel routing and flood storage.

Overall, the RAFTS and TUFLOW model discharges are comparable to the previous estimates when derived using the similar methodologies and as such have been adopted in this report.

### 5.4.3 WRM (2011)

The design discharge estimates for all design events at both Walkerston and Bakers Creek are substantially higher than the previous estimates made by WRM (2011) using the Pioneer River TUFLOW model. The design discharges are some 70% higher at Walkerston and 23% higher at Bakers Creek. The Walkerston discharges have increased for several reasons, mostly due to the availability of peak flood level data for the February 2008 event, which wasn't available for the Pioneer River study. The use of the Walkerston catchment design rainfalls rather than Bakers Creek catchment design rainfalls also increased discharges. At Bakers Creek, minor modifications were made to the channel roughness and configuration of the North Coast Railway bridge to account for the higher discharges originating from the upper catchment.

# 6 DESIGN FLOOD DEPTHS, LEVELS AND EXTENTS

## 6.1 OVERVIEW

The calibrated TUFLOW model described in Section 4 was used to estimate the levels, extent and depth of flooding for the 5 year, 50 year, 100 year, 200 year and 500 year ARI design flood and PMF. Design flood hydrographs predicted by the calibrated RAFTS model were used as inflows into the TUFLOW model. Three different cases were investigated:

- Case 1: Sugarcane growth at 2008/9 levels of development (Existing Conditions).
- Case 2: Cleared land or low sugarcane land use catchment conditions; and
- Case 3: Bakers Creek catchment flooding coinciding with Pioneer River overflows.

The highest predicted flood level from each event was adopted as the design level.

## 6.2 ADOPTED TAILWATER CONDITIONS

The Highest Astronomical Tide (HAT) level of 3.64mAHD was adopted as the downstream boundary for all design events. Although not AEP neutral, it provides conservative flood level estimates at the downstream end of Bakers Creek.

Note that flood levels in Walkerston are not affected by the adopted tailwater level.

## 6.3 SCENARIO MODEL RESULTS

### 6.3.1 Case 1 – Existing Conditions.

Figure B1 to B5 in Appendix B show the 5 year, 50 year, 100 year, 200 year and 500 year ARI design flood depths, flood extents and 1m flood contours for the Case 1. Figure B6 in Appendix B shows the PMF extents and flood contours for Case 1. The TUFLOW model was run for storm durations ranging from 12 to 36 hours to determine the maximum level at all locations along Bakers Creek. Table 6.1 shows peak flood heights at key reporting locations (see Figure B1 in Appendix B) along Bakers Creek for the 5 year, 50 year, 100 year, 200 year, 500 year ARI and PMF events.

The following is of note:

- For the 5 year ARI design flood:
  - Bakers Creek flood waters inundates significant areas of sugarcane farmland upstream of Walkerston with flood extents varying from 600m to 1,600m.

- Just upstream of Walkerston at the Old Pleystowe Road crossing, Bakers Creek flows become confined within well-defined bed and banks as it flows towards Walkerston.
- Bakers Creek floodwaters through Walkerston are generally confined within the waterway with flood widths of between 90m and 120m.
- Some Bakers Creek floodwaters overflow around the northern side of McColl Street upstream of Walkerston in an easterly direction before overflowing McColl Street at two locations at its intersections with Pugsley Street and Fadden Street to re-enter the Bakers Creek main channel.
- Localised flooding of extensive areas of sugarcane occurs on the northern side of Walkerston to the east of Branscombe Road. Local runoff from this area sheet flows through sugarcane area in a south-easterly direction towards a set of culverts along the railway and McColl Street before discharging into a concrete-lined constructed drain that flows through an urban residential subdivision to the south of McColl Street. It appears that some localised minor inundation (depths less than 0.3m) of road and properties within this subdivision would occur for an event of this magnitude. Local stormwater runoff would continue to drain in a south easterly direction through stormwater culvert crossings at Ford Street and the Peak Downs Highway before discharging into Bakers Creek about 1.4km to the south-east.
- Localised stormwater inundation also occurs on the sugarcane farms on the southern side of Walkerston, which crosses Kellys Road and Bold Street. It appears that residential properties on the eastern (downstream) side of Kellys Road may be affected by flooding by local runoff during an event of this magnitude. Local stormwater runoff would continue to drain in a south easterly direction before discharging into Rocky Creek about 4.7km to the south-east of the Bold Street crossing. Flood depths along this stormwater flowpath are typically less than 0.5m.
- Bakers Creek floodwaters downstream of Walkerston are mainly confined to Bakers Creek main channel to its confluence with Rocky Creek and MacLennan Creek.

- For the 50 year ARI design flood:
  - Bakers Creek flood water inundates significant areas of sugarcane farmland upstream of Walkerston.
  - On the southern side of the Bakers Creek floodplain, some floodwaters inundate the western side of Kennedy Street with flood depths up to 1.3m.
  - On the northern side of the floodplain, floodwaters from Bakers Creek inundate the road and some properties near the intersection of McColl Street with Pugsley Street and Fadden Street.
  - Localised flooding of extensive areas of sugarcane occurs on the northern side of Walkerston to the east of Branscombe Road. Some properties would be inundated with flood depths up to 0.6m. Local stormwater runoff from this area (not Bakers Creek floodwater) flows as overland flows through sugarcane area in a south-easterly direction towards a set of culverts along the railway and McColl Street and potentially overflows the top of the railway and McColl Street before discharging into a concrete-line constructed drain that flows through an urban residential subdivision to the south of McColl Street. It appears that some localised inundation (depths less than 0.5m) of road and properties within this subdivision would occur for an event of this magnitude.
  - Localised stormwater runoff from the sugarcane farms on the southern side of Walkerston (Kellys Road and Bold Street) joins overflows from Bakers Creek to drain in a south easterly discharging into Rocky Creek about 4.7 km to the south-east of the Bold Street. Flood depths along this stormwater flowpath are typically less than 0.8m.

- Bakers Creek floodwaters downstream of Walkerston are mainly confined to Bakers Creek main channel to its confluence with Rocky Creek and MacLennan Creek (other than along the southern stormwater flow path).

- For the 100 year ARI design flood:
  - The western side of Kennedy Street upstream of Walkerston would be inundated with flood depths up to 1.4m.
  - Significant areas of the northern floodplain upstream of Walkerston would be inundated with several properties along McColl Street impacted.
  - Downstream of the Peak Downs Highway crossing, floodwaters from Bakers Creek break out to inundate properties to the east of Bold Street and along Creek Street.
  - The 100 year ARI design flood level at the Peak Downs Highway bridge on Bakers Creek is 21.99m, which is slightly lower than 2008 recorded flood level.
  - Localised flooding of extensive areas of sugarcane occurs on the northern side of Walkerston to the east of Branscombe Road. A small portion of floodwaters from this area flows along Branscombe Road in a southerly direction through a set of culverts at its intersections with the railway and McColl Street before flowing into Bakers Creek or along McColl Street in an easterly direction. The majority of local runoff from this area sheet flows through sugarcane area in a south-easterly and inundate the large part of the urban residential area to the south of McColl Street.
  - Bakers Creek floodwater also overflows downstream of Walkerston into the southern stormwater channel that drains into Rocky Creek.

- For the 200 year and 500 year ARI design floods:
  - The western side of Kennedy Street upstream of Walkerston would be inundated with flood depths up to 2.3m and 2.5m respectively.
  - Much of the northern and eastern sections of Walkerston would be inundated by these events. Most of the properties in these areas would be impacted by these events.
  - Floodwaters from Bakers Creek overtop the Peak Downs Highway near Pugsley Street and inundate significant areas to the south of the Peak Downs Highway. Several properties along Pugsley Street would be impacted by these events.
  - The 200 year and 500 year ARI design flood levels at the Peak Downs Highway bridge on Bakers Creek are 22.30m and 22.47m respectively, which are higher than 2008 recorded flood level.
  - Floodwaters break out from Bakers Creek and inundate significant area of sugarcane farmland downstream of Walkerston-Homebush Road.
  - The 200 year and 500 year ARI design flood levels at Bakers Creek Alert gauge are 5.53m and 5.88m respectively, which are significantly higher than 2008 recorded flood level of 4.61m.

- For the PMF design flood:
  - The predicted extent of flooding for the PMF design flood is significantly larger than 100 year ARI design flood extent. Large overflow from upstream of Walkerston flows back into Bakers Creek from the northern side of McColl Street.
  - Significant overbank inundation occurs through the town of Walkerston. All properties in Walkerston on the northern side of Bakers Creek are inundated during a PMF event.
  - Floodwaters also overflow across Pugsley Street and the Peak Downs Highway in a south-easterly direction.

- The PMF design flood level at Peak Downs Highway on Bakers Creek is 23.14m, which is approximately 1m and 1.1m higher than 2008 recorded flood level and 100 year ARI design flood level respectively.
- Bakers Creek overflows to inundate the sugarcane farms on the southern side of Walkerston before flowing into Rocky Creek and MacLennan Creek.

### 6.3.2 Case 2 – Cleared Land or Low Sugarcane Catchment Land Use Conditions

Table 6.1 shows the Bakers Creek 5 year, 50 year, 100 year, 200 year and 500 year ARI design flood levels at various locations throughout Walkerston as well as key reporting locations along Bakers Creek for Case 2. Figure 6.1 shows the water level differences in Walkerston during a 100 year ARI event for Case 2 when compared with Case 1.

The following is of note:

- The critical storm duration for Case 2 is the 12 hour storm.
- Flood levels are significantly reduced along the floodplain in sugarcane areas as a result of the low surface roughness (Manning's 'n').
- For a 100 year ARI design flood, the peak flood levels along Bakers Creek increase by up to 0.1m upstream of the Pugsley Street crossing and up to 0.2m between the Pugsley Street and the Peak Downs Highway crossings.
- The peak 100 year ARI flood level at the Bakers Creek gauge at Bakers Creek for Case 2 is 5.24m, which is approximately 0.14m higher than for Case 1 at this location.
- The peak 200 year and 500 year ARI flood levels both increase by 0.01m at the Peak Downs Highway crossing in Walkerston compared with Case 1.
- The peak 200 year and 500 year ARI flood levels both increase by 0.09m at the Bakers Creek gauge at Baker compared with Case 1.
- The cleared land or low sugarcane catchment land use conditions have less impact on peak flood levels for extreme design events.

### 6.3.3 Case 3 – 100 year, 200 year and 500 year ARI Flooding with Pioneer River Overflows

During the 100 year, 200 year and 500 year ARI design flood events in Pioneer River Catchment, Pioneer River floodwaters overflow upstream of Dumbleton Rocks Weir towards Bakers Creek via a drainage path through the north-east of Walkerston (WRM, 2011). The estimated peak discharge of overflows from the Pioneer River for the 100 year, 200 year and 500 year ARI design events are about 223 $m^3/s$, 669 $m^3/s$ and 1109 $m^3/s$ respectively, for the 12 hour duration storm events (WRM, 2011). The overflow hydrograph from Pioneer River was extracted from the Pioneer River TUFLOW model developed by WRM (2011) and added to the Bakers Creek TUFLOW model as 2D QT (discharge vs time) boundary.

Table 6.1 shows the peak flood heights at various locations throughout Walkerston as well as some key locations on Bakers Creek for Case 3. Figure 6.2 shows the increase in the 100 year ARI design flood levels for the Case 3 compared to Case 1.

The following is of note:

- The north-eastern part of Walkerston is significantly influenced by Pioneer River overflows. The peak flood levels in this area are increased by up to 0.7m, 1.3m and 1.5m in places for the 100 year, 200 year and 500 year ARI design flood events respectively.
- For the 100 year ARI design flood event, Pioneer River overflows drain in a south-easterly direction through Walkerston mainly to the north east of High Street before discharging into Bakers Creek upstream of Walkerston-Homebush Road.

- For the 100 year ARI design flood event, increases in peak flood levels caused by Pioneer River overflows are generally confined to the Bakers Creek reach immediately downstream of Walkerston to its confluence with Rocky Creek. The 100 year ARI flood levels along Bakers Creek through Walkerston are not impacted by Pioneer River overflows.
- For the 200 year and 500 year ARI design flood events, significant portion of overflows from Pioneer River drains in a southerly direction across the Peak Downs Highway and into Bakers Creek. Peak flood levels in parts of Walkerston to the south of Bakers Creek are also influenced by Pioneer River overflows. For example, peak flood levels at the properties to the east of Bold Street increase by up to 0.32m and 0.51m respectively compared with Case 1.
- For the 200 year and 500 year ARI design flood events, Pioneer River overflows drain to the sugarcane farms and Rocky Creek on the southern side of Walkerston before flowing back into Bakers Creek. The peak flood levels along Bakers Creek downstream of Walkerston are significantly influenced by the Pioneer River overflows for these events. The 200 year and 500 year ARI design flood levels at Bakers Creek Gauge increase by 0.14m and 0.51m respectively.

#### 6.3.4 Design Flood Levels

Figure 6.3 to Figure 6.7 show the 5 year, 50 year, 100 year, 200 year and 500 year ARI design flood depths, flood extents and 1m flood contours adopted for this study. The design flood depths, levels and extents were obtained from the highest predicted flood levels from Case 1, 2 and 3.

- Case 1 dominates flood levels upstream of Walkerston.
- Case 2 dominates flood levels through Walkerston for the 5 year, 50 year and 100 year ARI events, downstream of Walkerston along the Bakers Creek channel for the 5 year and 50 year ARI events and upstream of Fadden Street in Walkerston for the 200 year and 500 year ARI events, and
- Case 3 dominates flood levels to the north east of Walkerston along the Bakers Creek channel to Stockroute Road/Hansens Road for the 100 year ARI event. For the 200 year and 500 year ARI events, Case 3 dominates flood levels from downstream of Fadden Street in Walkerston to the mouth of Bakers Creek.

The maximum of these flood levels should supersede all previous design flood levels along Bakers Creek at Walkerston.

Table 6.1 Case 1, 2 and 3 Design Flood Levels at Key locations, 5, 50, 100, 200 and 500 year ARI and PMF events

| Point ID | Location | Design Flood Level (m AHD) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Case 1 | | | | | | Case 2 | | | | | Case 3 | | |
| | | 5 Year ARI | 50 Year ARI | 100 Year ARI | 200 Year ARI | 500 Year ARI | PMF | 5 Year ARI | 50 Year ARI | 100 Year ARI | 200 Year ARI | 500 Year ARI | 100 Year ARI | 200 Year ARI | 500 Year ARI |
| 1 | Kennedy Street | 23.18 | 23.77 | 23.95 | 24.26 | 24.46 | 25.23 | 23.23 | 23.83 | 23.99 | 24.19 | 24.38 | 23.84 | 24.12 | 24.34 |
| 2 | Pugsley Street | 22.55 | 23.36 | 23.59 | 23.97 | 24.21 | 25.05 | 22.80 | 23.52 | 23.73 | 23.97 | 24.17 | 23.45 | 23.80 | 24.08 |
| 3 | Fadden Street | 21.38 | 22.35 | 22.61 | 23.00 | 23.23 | 24.14 | 21.70 | 22.55 | 22.77 | 23.04 | 23.27 | 22.44 | 22.92 | 23.22 |
| 4 | 3-21 Kellys Road | - | - | - | 22.21 | 22.47 | 23.37 | - | - | 21.75 | 22.24 | 22.50 | - | 22.32 | 22.72 |
| 5 | Peak Downs HWY | 20.71 | 21.73 | 21.99 | 22.30 | 22.47 | 23.14 | 21.05 | 21.92 | 22.11 | 22.31 | 22.48 | 21.84 | 22.44 | 22.78 |
| 6 | Bold Street | - | - | 21.88 | 22.16 | 22.32 | 23.05 | - | 21.82 | 21.97 | 22.17 | 22.32 | 21.75 | 22.31 | 22.68 |
| 7 | Anne Street | 20.06 | 21.04 | 21.27 | 21.58 | 21.75 | 22.37 | 20.39 | 21.17 | 21.32 | 21.52 | 21.67 | 21.17 | 21.92 | 22.27 |
| 8 | Pound Street | 19.55 | 20.52 | 20.74 | 21.01 | 21.16 | 21.64 | 19.88 | 20.63 | 20.77 | 20.92 | 21.03 | 20.68 | 21.38 | 21.66 |
| 9 | Walkerston-Homebush Road | 16.22 | 17.49 | 17.74 | 18.14 | 18.40 | 19.05 | 16.81 | 17.62 | 17.78 | 18.05 | 18.19 | 18.25 | 19.05 | 19.22 |
| 10 | Hansens Road | 8.95 | 10.52 | 10.78 | 11.07 | 11.29 | 12.00 | 9.48 | 10.58 | 10.79 | 11.00 | 11.13 | 10.95 | 11.48 | 11.71 |
| 11 | Baker Creek Gauge | 3.97 | 4.70 | 5.10 | 5.53 | 5.88 | 7.31 | 4.03 | 4.94 | 5.24 | 5.62 | 5.97 | 5.06 | 5.66 | 6.39 |

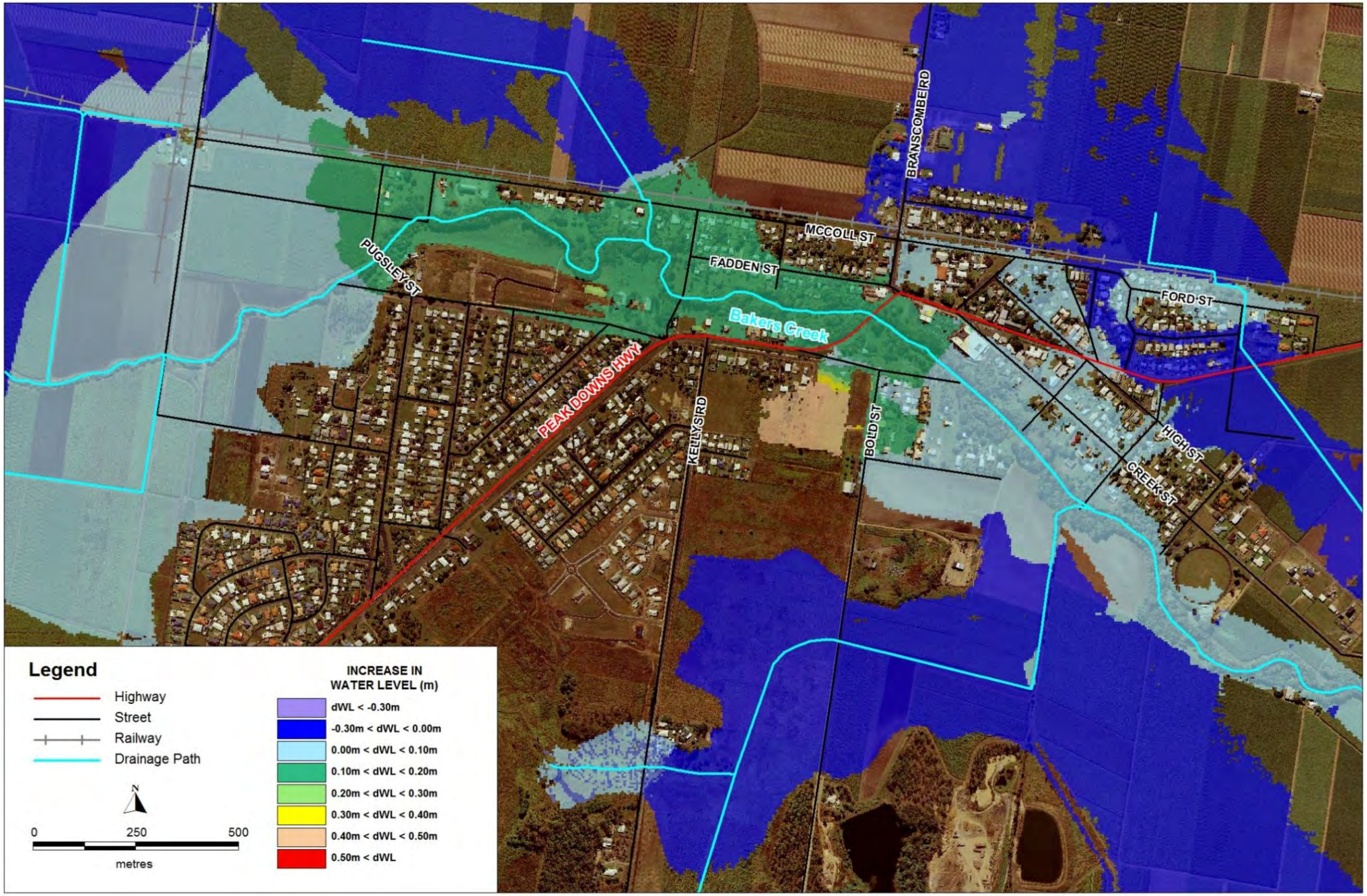


Figure 6.1 Increase in Peak Flood Levels in Case 2 when Compared with Case 1, 100 Year ARI Design Flood at Walkerston

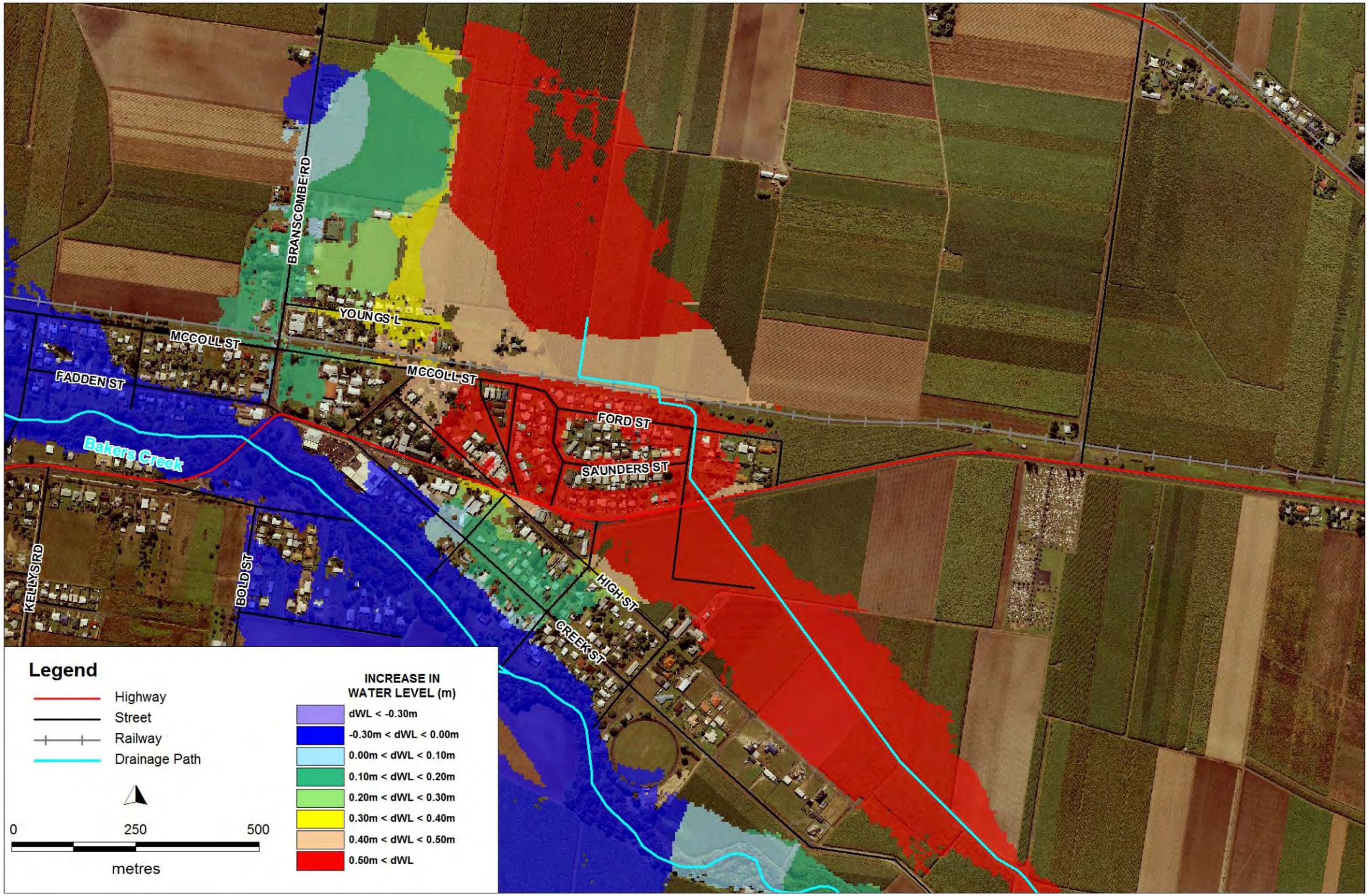


Figure 6.2 Increase in Peak Flood Levels in Case 3 when Compared with Case 1, Walkerston

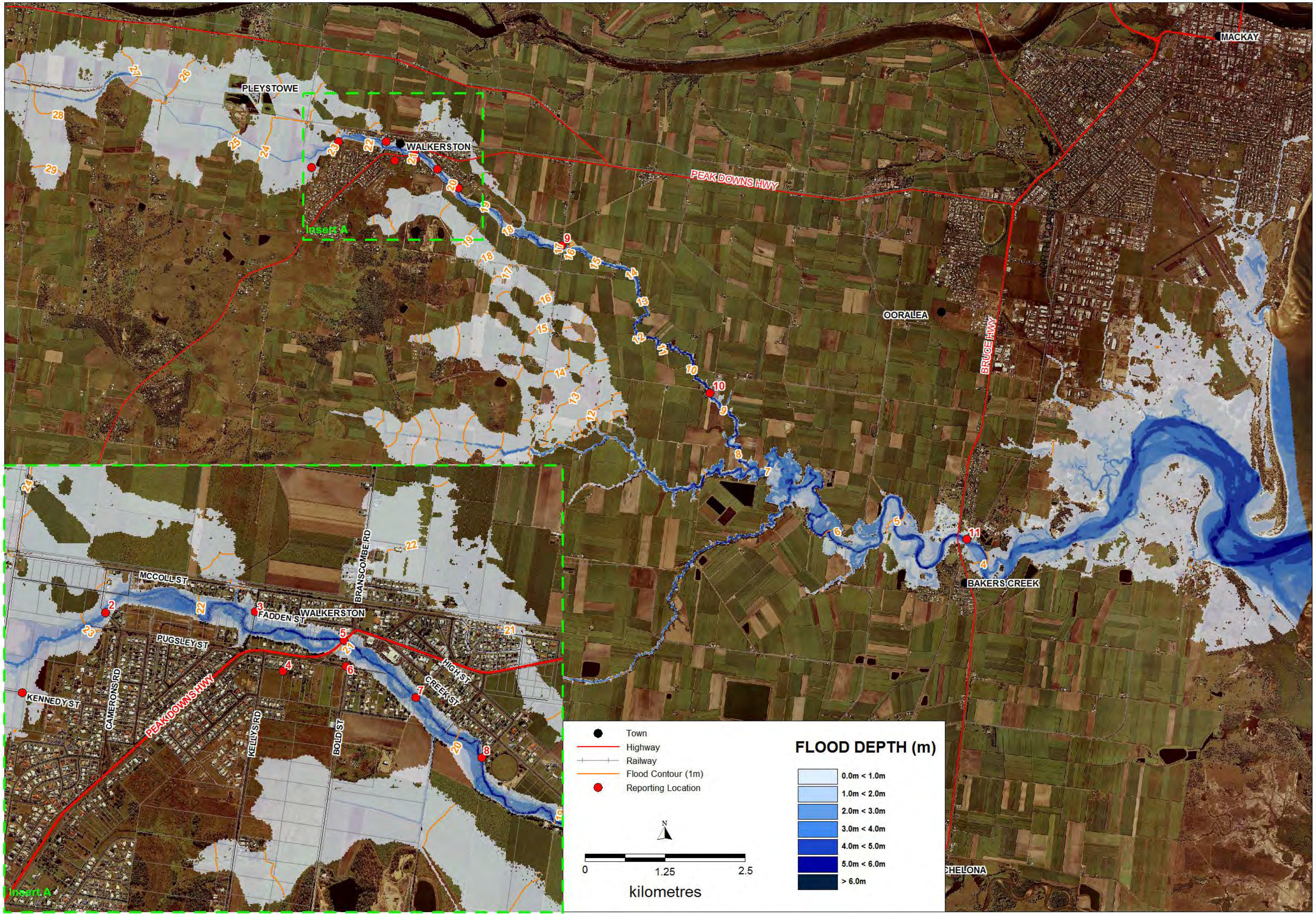


Figure 6.3 5 year ARI Flood Depths, Levels and Extent, Bakers Creek

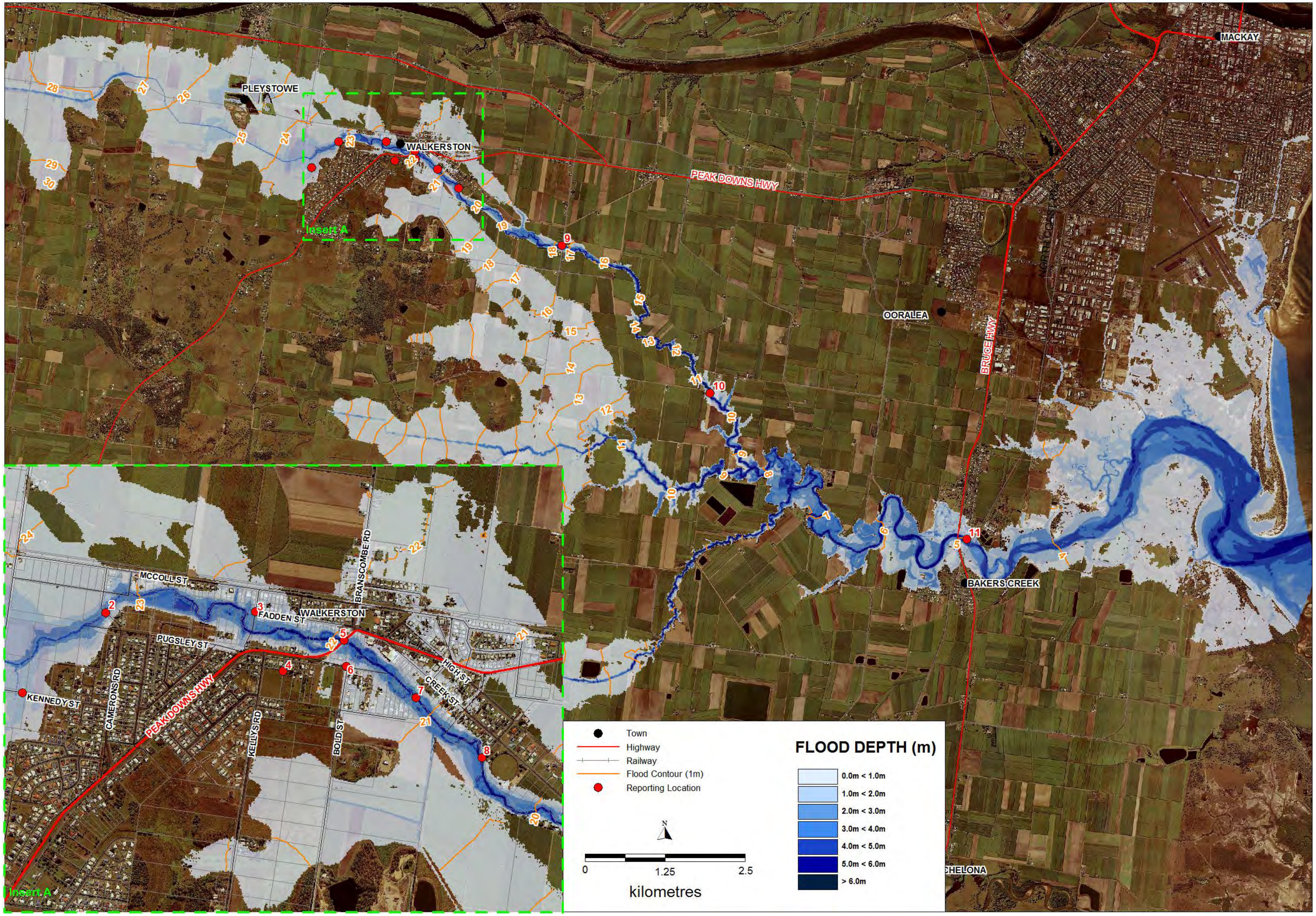


Figure 6.4 50 year ARI Flood Depths, Levels and Extent, Bakers Creek

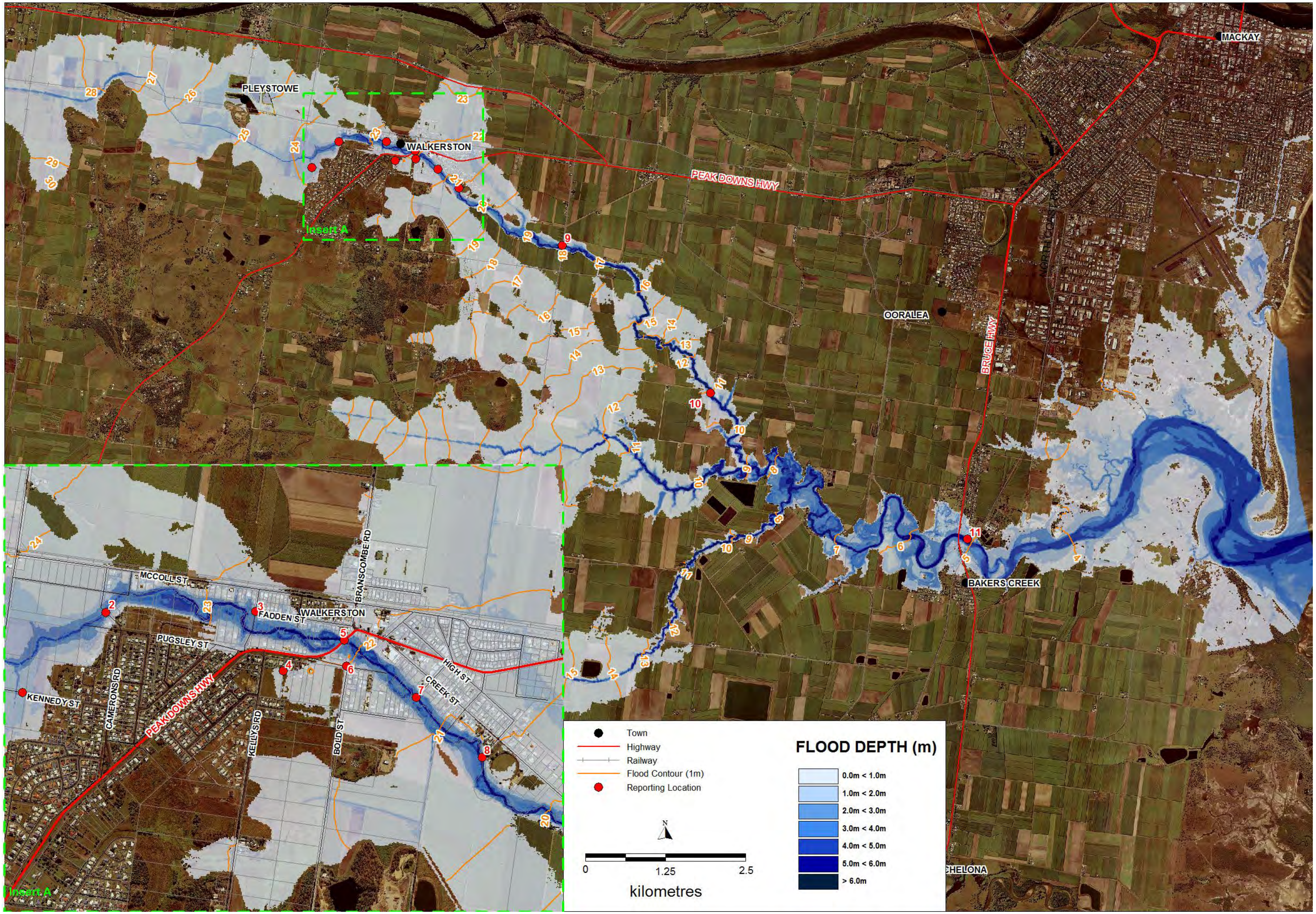


Figure 6.5 100 year ARI Flood Extent, Bakers Creek Catchment

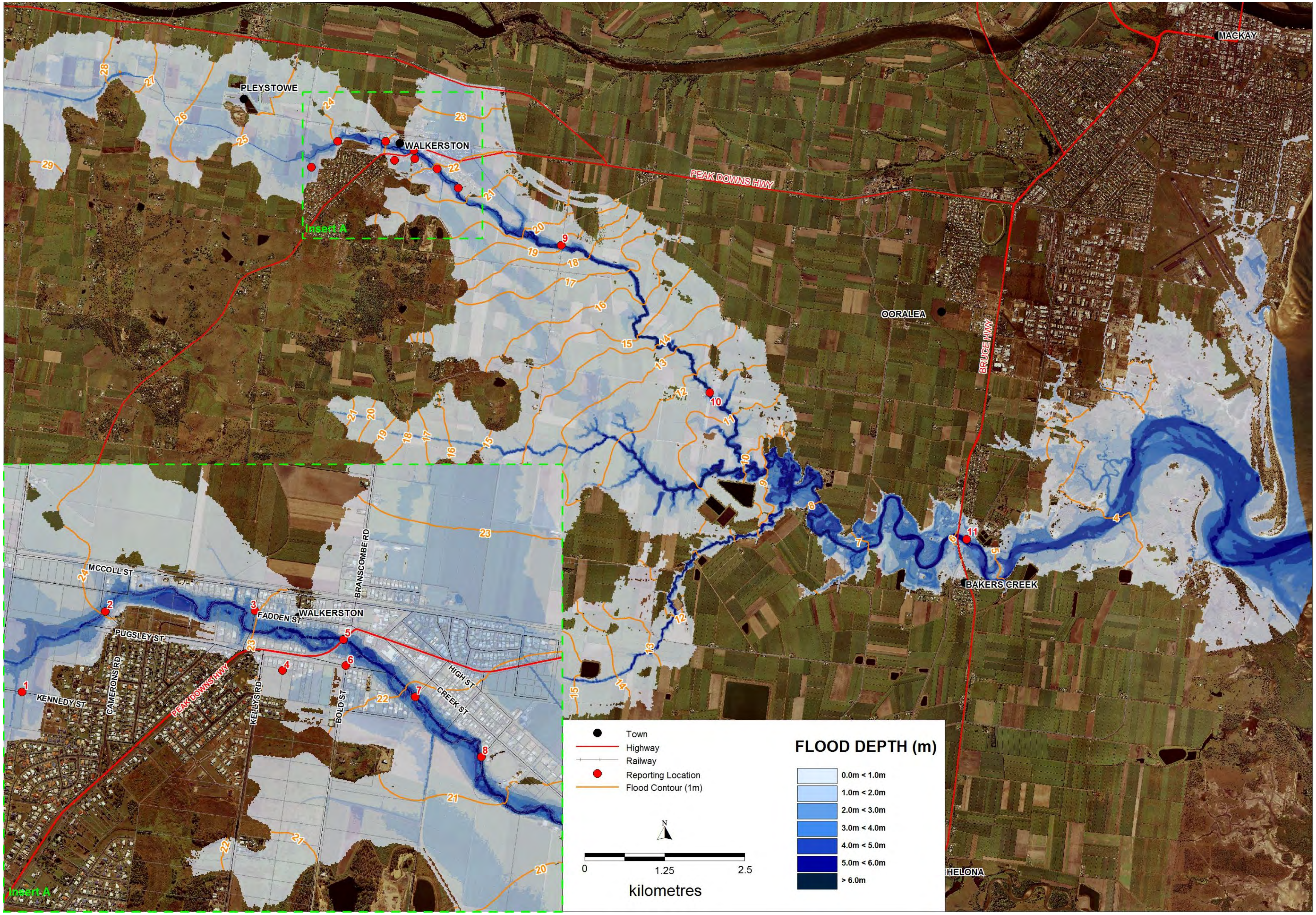


Figure 6.6 200 year ARI Flood Extent, Bakers Creek Catchment

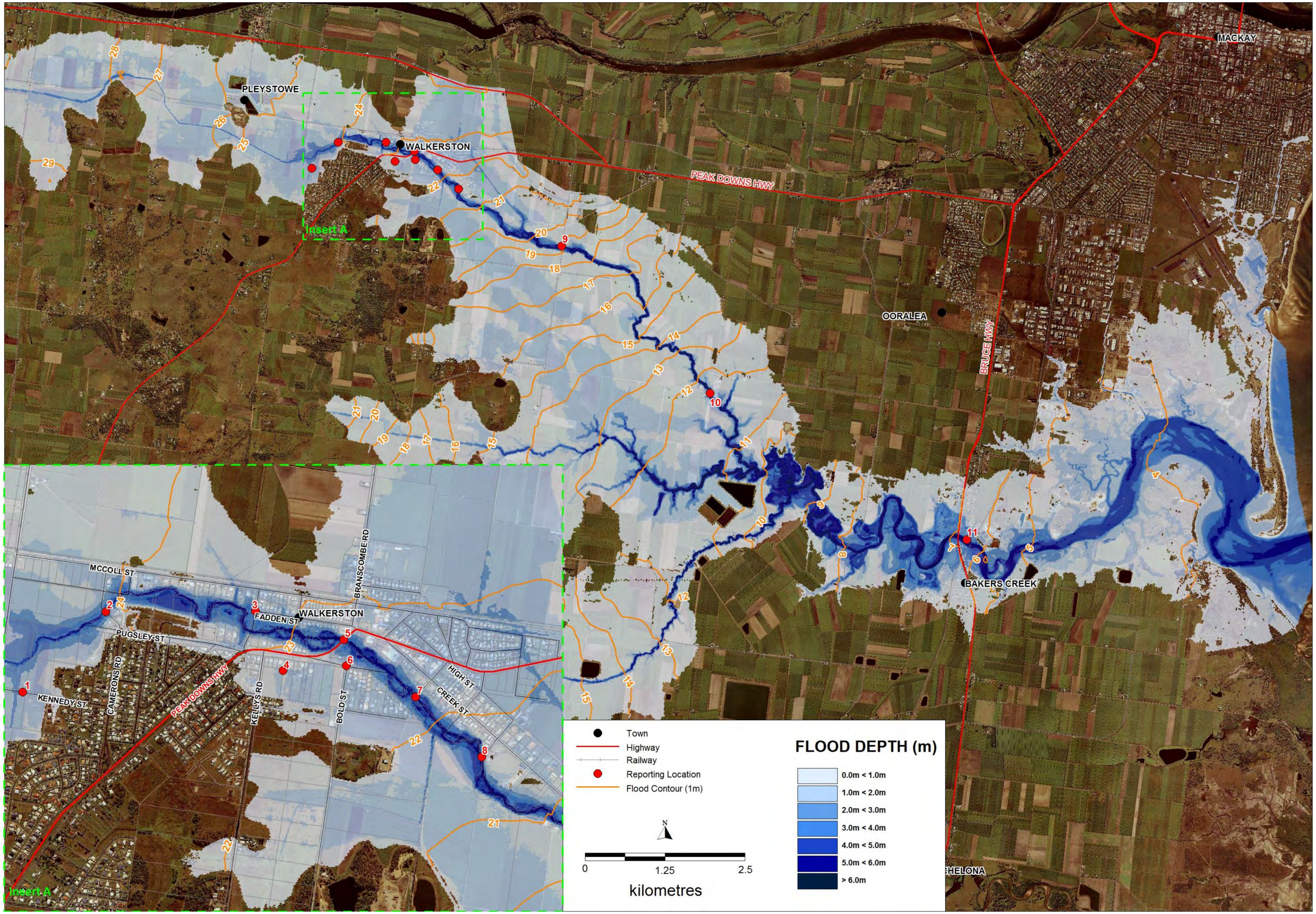


Figure 6.7 500 year ARI Flood Extent, Bakers Creek Catchment

# 7 THE EFFECT OF CLIMATE CHANGE

## 7.1 GENERAL

The Local Government Association of Queensland (LGAQ) and the Queensland Government have undertaken a study (Qld Govt, 2010) to establish a framework to provide Queensland local governments with advice on how to account for climate change in assessing flood risk. The study recommends a 'climate change factor' be included into flood studies in the form of a 5% increase in rainfall per degree of global warming. For the purposes of applying the climate change factor, the study outlines the following temperature increases and planning horizons:

- 2°Celsius by 2050;
- 3°Celsius by 2070; and
- 4°Celsius by 2100.

These increases in temperature equate to a 10% increase in rainfall depth by 2050, and 15% increase in rainfall depth by 2070 and a 20% increase in rainfall depth by 2100 (Qld Govt, 2010). Following discussions with Mackay Regional Council, the hydrologic and hydraulic models have been used to assess the impact of climate change that would be expected to occur in 2100 on 5 year, 50 year, 100 year, 200 year and 500 year ARI design events.

In addition to increased rainfall, climate change has the potential to increase sea levels. A sea level rise of 0.8m is expected by 2100. The HAT level at the downstream boundary has been increased by 0.8m to 4.44m AHD for the three design events.

## 7.2 DESIGN RAINFALLS

The rainfall depths in Table 5.1 were factored up by 1.2 to be the adopted climate change rainfall depths for the 5 year, 50 year, 100 year, 200 year and 500 year ARI design events.

## 7.3 TUFLOW MODEL RESULTS

Table 7.1 shows a comparison of peak water levels at the 11 reporting locations throughout the study area (see Figure 6.3) for the 5 year, 50 year, 100 year, 200 year and 500 year ARI events for Case 1 (Existing Conditions) and 2100 climate change conditions. The 5 year, 50 year, 100 year, 200 year and 500 year ARI flood extents for the 2100 climate change conditions are given in Appendix C.

The following is of note:

- For the 5 year ARI climate change event:
  - The peak flood level at the Peak Downs Highway is increased by 0.31 m.
  - The flood depths are increased by no more than 0.1m along the northern side of Walkerston.

  - The year 2100 climate change scenario remains within the Bakers Creek channel from Walkerston to its confluence with Rocky Creek. The peak flood levels in this section of Bakers Creek are increased by up to 0.8m, due to the very confined channel.
- For the 50 year ARI climate change event:
  - The predicted flood extent is considerably larger than for the Case 1 scenario at Walkerston.
  - The peak flood level at the Peak Downs Highway is 22.03m, which is higher than the 100 year ARI design flood level for the Case 1 conditions.
  - The Bakers Creek floodwater remains within the banks of the Bakers Creek from Walkerston to its confluence with Rocky Creek, with some overbank inundation near the confluence. The peak flood levels in this section of Bakers Creek are increased by up to 0.6m.
- For the 100 year ARI climate change event:
  - The predicted flood extent is considerably larger than the Case 1 scenario at Walkerston.
  - The peak flood level at the Peak Downs Highway is increased by 0.23m from existing conditions.
- For the 200 year and 500 year ARI climate change events:
  - The predicted flood extent is considerably larger than the Case 1 scenario at Walkerston.
  - The peak flood levels at the Peak Downs Highway are increased by 0.17m and 0.15m respectively from existing conditions.
  - The peak flood levels at the Bakers Creek gauge are increased by 0.46m and 0.41m respectively from existing conditions.

Table 7.1 Case 1 Conditions and Year 2100 Climate Change Scenario Peak Water Level Comparison, 5, 50, 100, 200 and 500 year ARI Events

| | | Design Flood Level (m AHD) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Point ID | Location | 5 Year ARI | | 50 Year ARI | | 100 Year ARI | | 200 Year ARI | | 500 Year ARI | |
| | | Case 1 | 2100 | Case 1 | 2100 | Case 1 | 2100 | Case 1 | 2100 | Case 1 | 2100 |
| 1 | Kennedy Street | 23.18 | 23.35 | 23.77 | 23.99 | 23.95 | 24.2 | 24.26 | 24.47 | 24.46 | 24.65 |
| 2 | Pugsley Street | 22.55 | 22.79 | 23.36 | 23.64 | 23.59 | 23.9 | 23.97 | 24.22 | 24.21 | 24.44 |
| 3 | Fadden Street | 21.38 | 21.66 | 22.35 | 22.67 | 22.61 | 22.90 | 23.00 | 23.24 | 23.23 | 23.46 |
| 4 | 3-21 Kellys Road | - | - | - | - | - | 22.1 | 22.21 | 22.48 | 22.47 | 22.70 |
| 5 | Peak Downs HWY | 20.71 | 21.02 | 21.73 | 22.03 | 21.99 | 22.2 | 22.30 | 22.47 | 22.47 | 22.62 |
| 6 | Bold Street | - | - | - | 21.91 | 21.88 | 22.1 | 22.16 | 22.33 | 22.32 | 22.49 |
| 7 | Anne Street | 20.06 | 20.37 | 21.04 | 21.31 | 21.27 | 21.50 | 21.58 | 21.76 | 21.75 | 21.91 |
| 8 | Pound Street | 19.55 | 19.88 | 20.52 | 20.78 | 20.74 | 20.9 | 21.01 | 21.16 | 21.16 | 21.29 |
| 9 | Walkerston-Homebush Road | 16.22 | 16.81 | 17.49 | 17.78 | 17.74 | 18 | 18.14 | 18.42 | 18.40 | 18.67 |
| 10 | Hansens Road | 8.95 | 9.58 | 10.52 | 10.85 | 10.78 | 11 | 11.07 | 11.30 | 11.29 | 11.45 |
| 11 | Baker Creek Gauge | 3.97 | 4.73 | 4.70 | 5.34 | 5.10 | 5.57 | 5.53 | 5.99 | 5.88 | 6.29 |

# 8 SUMMARY

A flood study of the Bakers Creek / Walkerston has been undertaken to assist MRC in land use planning and development assessment in and around Walkerston. A RAFTS runoff-routing hydrologic model was developed for the Bakers Creek catchments and a TUFLOW two dimensional hydraulic model was developed of the Bakers Creek channel and floodplain. The RAFTS and TUFLOW models were jointly calibrated to recorded stream flows at the Bakers Creek Alert gauge and surveyed peak flood levels in Walkerston for the 2007 and 2008 historical flood events.

Design flood discharges, flood levels and flood extents were determined for the 5 year, 50 year, 100 year, 200 year and 500 year Average Recurrence Interval (ARI) events, and the Probable Maximum Flood. The study also included an assessment of the impact of climate change based on recommendations from the Queensland Government (2010).

The flood levels were estimated for three cases.

- Case 1: Sugarcane growth at 2008/9 levels of development (Existing Conditions).
- Case 2: Cleared land or low sugarcane land use catchment conditions; and
- Case 3: Bakers Creek catchment flooding coinciding with Pioneer River overflows.

The highest predicted flood levels for Case 1, 2 and 3 were adopted as the design flood levels for the catchment.

The following is of note:

- Case 1 dominates flood levels upstream of Walkerston.
- Case 2 dominates flood levels through Walkerston for the 5 year, 50 year and 100 year ARI events, downstream of Walkerston along the Bakers Creek channel for the 5 year and 50 year ARI events and upstream of Fadden Street in Walkerston for the 200 year and 500 year ARI events.
- Case 3 dominates flood levels to the north east of Walkerston along the Bakers Creek channel to Stockroute Road/Hansens Road for the 100 year ARI event. For the 200 year and 500 year ARI events, Case 3 dominates flood levels from downstream of Fadden Street in Walkerston to the mouth of Bakers Creek.
- The model predicts that lower sugar cane growth in the catchment could increase peak 100 year ARI flood levels up to 0.2m along Bakers Creek when compared with Case 1.
- During the 100 year, 200 year and 500 year ARI design flood events in the Pioneer River, the north-eastern part of Walkerston is significantly impacted by Pioneer River overflows. The peak 100 year, 200 year and 500 year ARI flood levels in this area are increased by up to 0.7m 1.3m and 1.5m in places when the Pioneer River overflows.
- The potential impact due to 2100 climate change conditions could result in 100 year, 200 year and 500 year ARI flood level increases of up to 0.5m along Bakers Creek when compared with Case 1.

# 9 REFERENCES


| | |
|---|---|
| BOM (2003) | *Guidebook to Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method*, Prepared by the Hydrometeorological Advisory Services, November 2003. |
| Chaseling McGiffin (2004) | *Pioneer River Flood Study*, Prepared for Mackay City Council, Chaseling McGiffin Pty. Ltd, November 2004 |
| IEAust (1987) | *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Institution of Engineers, Australia |
| Hargraves, c.2004 | *'Final Report, Extreme Rainfall Estimation Project, CRCFORGE and (CRC) ARF Techniques, Queensland and Border Locations, Development and Application'*, Report prepared by Gary Hargraves, Water Assessment Group, Water Assessment and Planning, Resource Sciences Centre, undated, circa 2004. |
| Ullman & Nolan (1996) | *Flood Study of Bakers Creek – Walkerston Reach,* Report prepared for Mackay City Council by Ullman & Nolan Pty. Ltd., April 1996 |
| WBM (2010) | *Tuflow User Manual, GIS Based 2D/1D Hydrodynamic Modelling,* Build 2010-10-Ab BMT WBM 2010 |
| WRM (2011) | *Pioneer River Flood Study. Report prepared for Mackay Regional Council by WRM Water & Environment Pty Ltd, October 2011.* |
| XP Software (2009) | XP-RAFTS, XP Software, Florida, USA |

# APPENDIX A

## TUFLOW HYDRAULIC STRUCTURES AND 1D NETWORK

Table A1 Adopted Bridge Crossing Properties

| Property | Pleystowe School Rd Bridge | Pleystowe School Rd Railway Bridge | Pleystowe Railway Bridge | Old Pleystowe Rd Bridge | Walkerston-Homebush Rd Bridge | Walkerston-Homebush Railway Bridge | Stockroute-Hansens Rd Bridge | Bruce Highway Bridge | Bakers Creek Railway Bridge |
|---|---|---|---|---|---|---|---|---|---|
| Bridge Deck Level (m AHD) | 25.35 | 25.15 | 23.7 | 21.69 | 16.93 | 15.53 | 8.075 | 6 | 3.87 |
| Deck Depth (m) | 0.45 | 0.55 | 0.75 | 0.74 | 0.5 | 0.87 | 0.7 | 1.5 | 0.99 |
| Approximate Bed Level (m AHD) | 24.05 | 23.64 | 22.29 | 19.58 | 11.41 | 11.61 | 3.002 | -1 | -0.618 |
| Guard Rail Height (m) | - | - | - | 1.5 | 0.5 | - | 0.7 | 0.5 | 0.47 |
| Approximate Bridge Length (m) | 24 | 42 | 23.3 | 9.9 | 45 | 24 | 40 | 167.6 | 120.65 |
| Number of Piers | 5 | 6 | 3 | - | 2 | 2 | 2 | 6 | 7 |
| Pier Width or Diameter (m) | 0.22 | 0.4 | 0.4 | - | 0.56 | 0.3 | 0.56 | 0.53 | 1 |
| Approximate Distance between piers (m) | 4 | 6 | 5.8 | - | 15 | 8 | 12 | 24 | 15 |

Table A2 Layered Flow Constriction Properties

| Description | Pleystowe School Rd Bridge | Pleystowe School Rd Railway Bridge | Pleystowe Railway Bridge | Old Pleystowe Rd Bridge | Walkerston-Homebush Rd Bridge | Walkerston-Homebush Railway Bridge | Stockroute-Hansens Rd Bridge | Bruce Highway Bridge | Bakers Creek Railway Bridge |
|---|---|---|---|---|---|---|---|---|---|
| Layer 1 Blockage | 8 | 8 | 10 | 5 | 6 | 8 | 6 | 5 | 7.5 |
| Layer 1 FLCa | 0.5 | 0.5 | 0.3 | 0.5 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 |
| Layer 2 Blockage | 100 | 90 | 90 | 100 | 100 | 100 | 100 | 100 | 100 |
| Layer 2 FLCa | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0.5 | 1 |
| Layer 3 Blockage | - | - | | 5 | 50 | - | 10 | 5 | 100 |
| Layer 3 FLCa | - | - | | 0.5 | 0.5 | - | 0.5 | 0.1 | 0.2 |

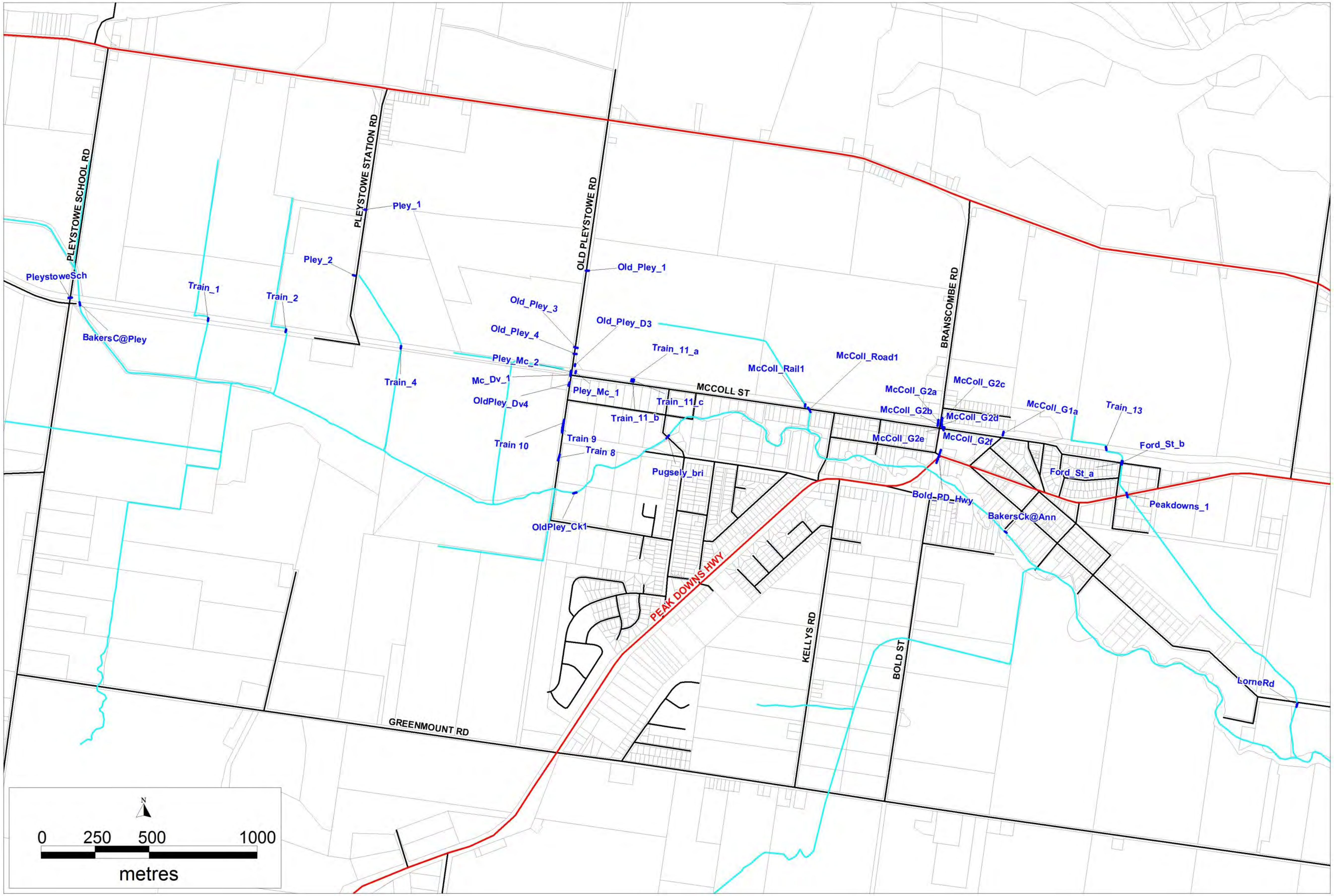


Figure A1 TUFLOW 1D Culvert Locations

Table A3 Details of 1D Hydraulic Structures in the TUFLOW model

| ID | Channel Type | Ignore | Channel Storage at Nodes | Length or ANA | Manning's n | U/S Invert | D/S Invert | Form or Bend Loss | Blockage | Branch | Topo_ID | Xsect ID or Chainage | Diameter or Width | Weir Factor or Height | No of Culverts | Culv H Contraction Coeff | Culv W Contraction Coeff | Culvert Entry Loss | Culvert Exit Loss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PleystoweSch | R | F | T | 10.9 | 0.015 | 25.114 | 25.071 | 0 | 0 | | | 0 | 0.6 | 0.3 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| BakersC@Pley | C | F | T | 4 | 0.015 | 23.888 | 23.584 | 0 | 0 | | | 0 | 0.45 | 0 | 3 | 0 | 1 | 0.5 | 1 |
| BakersCk@Ann | C | F | T | 3.8 | 0.015 | 15.833 | 15.800 | 0 | 0 | | | 0 | 0.9 | 0 | 2 | 0 | 1 | 0.5 | 1 |
| LorneRd | C | F | T | 9.4 | 0.015 | 15.413 | 15.318 | 0 | 0 | | | 0 | 1.37 | 0 | 4 | 0 | 1 | 0.5 | 1 |
| Train_1 | R | F | T | 6.8 | 0.015 | 23.697 | 23.712 | 0 | 0 | | | 0 | 2.4 | 1.25 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Train_2 | R | F | T | 7.3 | 0.03 | 24.059 | 24.058 | 0 | 0 | | | 0 | 1.2 | 0.6 | 8 | 0.6 | 0.9 | 0.5 | 1 |
| Train_4 | R | F | T | 6.5 | 0.03 | 22.612 | 22.553 | 0 | 0 | | | 0 | 1.54 | 1.54 | 2 | 0.6 | 0.9 | 0.5 | 1 |
| Train_13 | R | F | T | 6.6 | 0.015 | 19.661 | 19.610 | 0 | 0 | | | 0 | 2.4 | 1.2 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Peakdowns_1 | R | F | T | 12.3 | 0.015 | 19.366 | 19.214 | 0 | 0 | | | 0 | 1.52 | 0.7 | 4 | 0.6 | 0.9 | 0.5 | 1 |
| Pley_1 | C | F | T | 10.4 | 0.015 | 23.936 | 23.985 | 0 | 0 | | | 0 | 0.525 | 0 | 3 | 0 | 1 | 0.5 | 1 |
| Pley_2 | R | F | T | 3.8 | 0.015 | 23.736 | 23.730 | 0 | 0 | | | 0 | 1.2 | 0.75 | 7 | 0.6 | 0.9 | 0.5 | 1 |
| Old_Pley_1 | R | F | T | 8.7 | 0.015 | 23.240 | 23.296 | 0 | 0 | | | 0 | 0.6 | 0.5 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Old_Pley_3 | R | F | T | 10 | 0.015 | 23.167 | 23.172 | 0 | 0 | | | 0 | 0.6 | 0.4 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Old_Pley_4 | R | F | T | 10 | 0.015 | 23.157 | 23.162 | 0 | 0 | | | 0 | 0.6 | 0.4 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Old_Pley_D3 | R | F | T | 6.1 | 0.015 | 23.362 | 22.911 | 0 | 0 | | | 0 | 0.9 | 0.475 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Pley_Mc_2 | R | F | T | 4 | 0.015 | 22.843 | 22.778 | 0 | 0 | | | 0 | 1.2 | 0.6 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Mc_Dv_1 | C | F | T | 5.1 | 0.015 | 22.762 | 22.678 | 0 | 0 | | | 0 | 0.9 | 0 | 1 | 0 | 1 | 0.5 | 1 |
| Pley_Mc_1 | R | F | T | 6.1 | 0.015 | 23.278 | 23.280 | 0 | 0 | | | 0 | 1.2 | 0.3 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Train_11_a | R | F | T | 6.2 | 0.015 | 22.540 | 22.540 | 0 | 0 | | | 0 | 0.3 | 0.45 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Train_11_b | R | F | T | 6.2 | 0.015 | 22.544 | 22.544 | 0 | 0 | | | 0 | 0.6 | 0.3 | 3 | 0.6 | 0.9 | 0.5 | 1 |
| Train_11_c | R | F | T | 6.2 | 0.015 | 22.546 | 22.535 | 0 | 0 | | | 0 | 1.2 | 0.3 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| McColl_G2a | C | F | T | 4.9 | 0.015 | 21.102 | 21.113 | 0 | 0 | | | 0 | 0.6 | 0 | 5 | 0 | 1 | 0.5 | 1 |
| McColl_G2b | R | F | T | 6.1 | 0.015 | 21.115 | 21.124 | 0 | 0 | | | 0 | 1.2 | 0.6 | 3 | 0.6 | 0.9 | 0.5 | 1 |
| McColl_G2c | C | F | T | 18.3 | 0.015 | 21.249 | 21.195 | 0 | 0 | | | 0 | 0.6 | 0 | 3 | 0 | 1 | 0.5 | 1 |
| McColl_G2d | R | F | T | 5.9 | 0.015 | 21.186 | 21.228 | 0 | 0 | | | 0 | 1.2 | 0.6 | 2 | 0.6 | 0.9 | 0.5 | 1 |
| McColl_G2e | C | F | T | 17.3 | 0.015 | 21.008 | 20.997 | 0 | 0 | | | 0 | 0.6 | 0 | 3 | 0 | 1 | 0.5 | 1 |
| McColl_G2f | C | F | T | 6.9 | 0.015 | 21.457 | 21.420 | 0 | 0 | | | 0 | 0.375 | 0 | 1 | 0 | 1 | 0.5 | 1 |
| McColl_G1a | R | F | T | 9.3 | 0.015 | 20.584 | 20.570 | 0 | 0 | | | 0 | 1.8 | 0.7 | 2 | 0.6 | 0.9 | 0.5 | 1 |
| Ford_St_a | R | F | T | 10.9 | 0.015 | 19.587 | 19.561 | 0 | 0 | | | 0 | 1.8 | 1 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Ford_St_b | R | F | T | 10.9 | 0.015 | 19.716 | 19.561 | 0 | 0 | | | 0 | 1.8 | 0.75 | 2 | 0.6 | 0.9 | 0.5 | 1 |
| Train 10 | R | F | T | 14.8 | 0.015 | 22.163 | 22.052 | 0 | 0 | | | 0 | 0.6 | 0.35 | 1 | 0.6 | 0.9 | 0.5 | 1 |
| Train 9 | C | F | T | 9.9 | 0.015 | 22.019 | 22.023 | 0 | 0 | | | 0 | 0.375 | 0 | 2 | 0 | 1 | 0.5 | 1 |
| Train 8 | C | F | T | 17.3 | 0.015 | 21.935 | 21.925 | 0 | 0 | | | 0 | 0.45 | 0 | 2 | 0 | 1 | 0.5 | 1 |
| McColl_Rail1 | R | F | T | 6.6 | 0.015 | 19.842 | 19.858 | 0 | 0 | | | 0 | 3 | 1.8 | 3 | 0.6 | 0.9 | 0.5 | 1 |
| McColl_Road1 | C | F | T | 16.7 | 0.015 | 19.538 | 19.357 | 0 | 0 | | | 0 | 1.2 | 0 | 3 | 0 | 1 | 0.5 | 1 |
| Bold_PD_Hwy | C | F | T | 60 | 0.015 | 20.618 | 19.398 | 0 | 0 | | | 0 | 0.6 | 0 | 3 | 0 | 1 | 0.5 | 1 |
| OldPley_Dv4 | C | F | T | 4.2 | 0.015 | 22.744 | 22.864 | 0 | 0 | | | 0 | 0.75 | 0 | 1 | 0 | 1 | 0.5 | 1 |
| OldPley_Ck1 | R | F | T | 4.9 | 0.015 | 19.603 | 19.477 | 0 | 0 | | | 0 | 1.2 | 0.445 | 2 | 0.6 | 0.9 | 0.5 | 1 |
| Pugsely_bri | R | F | T | 6.8 | 0.015 | 18.991 | 18.943 | 0 | 0 | | | 0 | 2 | 1.4 | 3 | 0.6 | 0.9 | 0.5 | 1 |

# APPENDIX B

## CASE 1 FLOOD MAPS

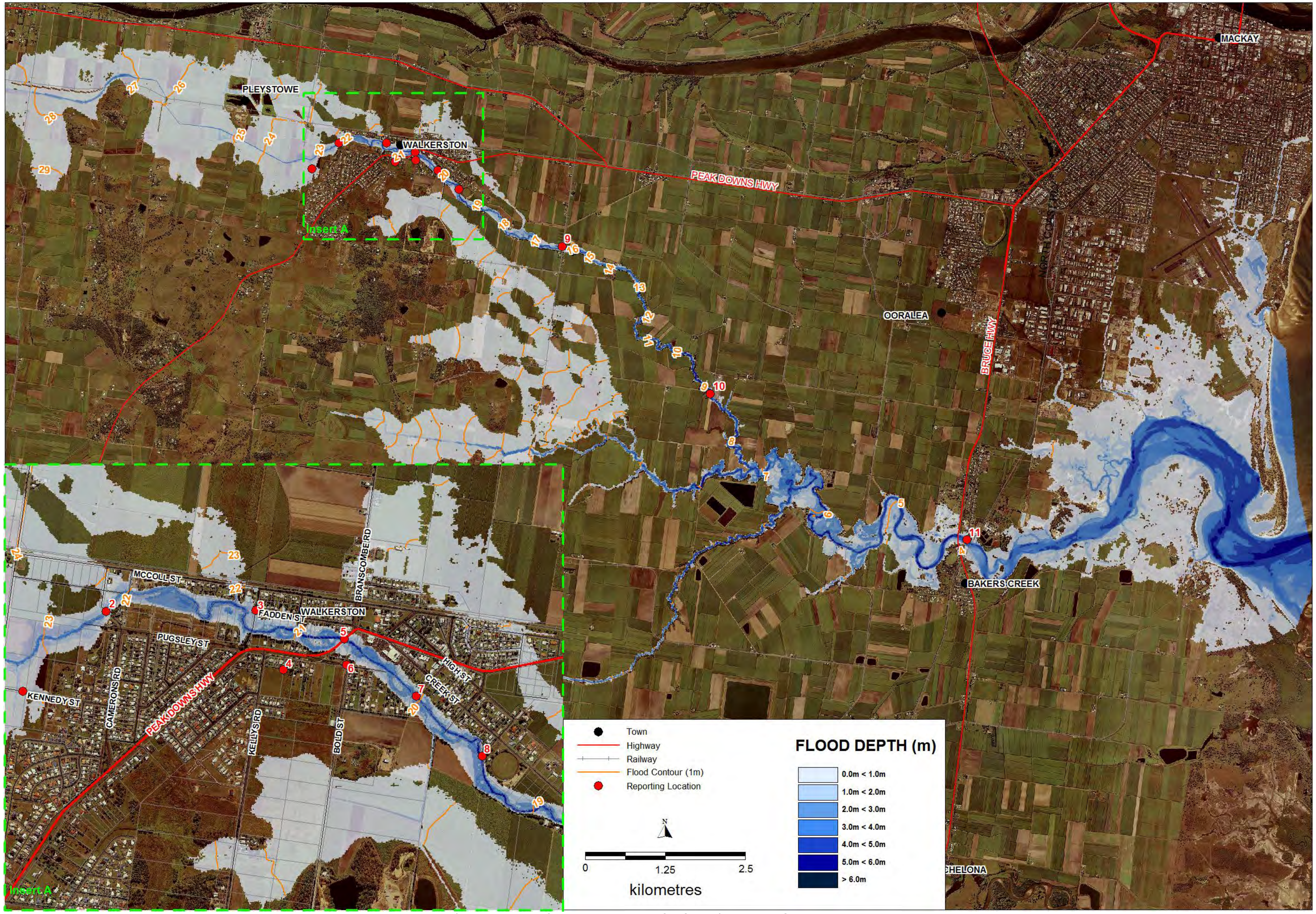


Figure B1 Bakers Creek Flood Extent for Case 1 (Existing Conditions), 5 year ARI

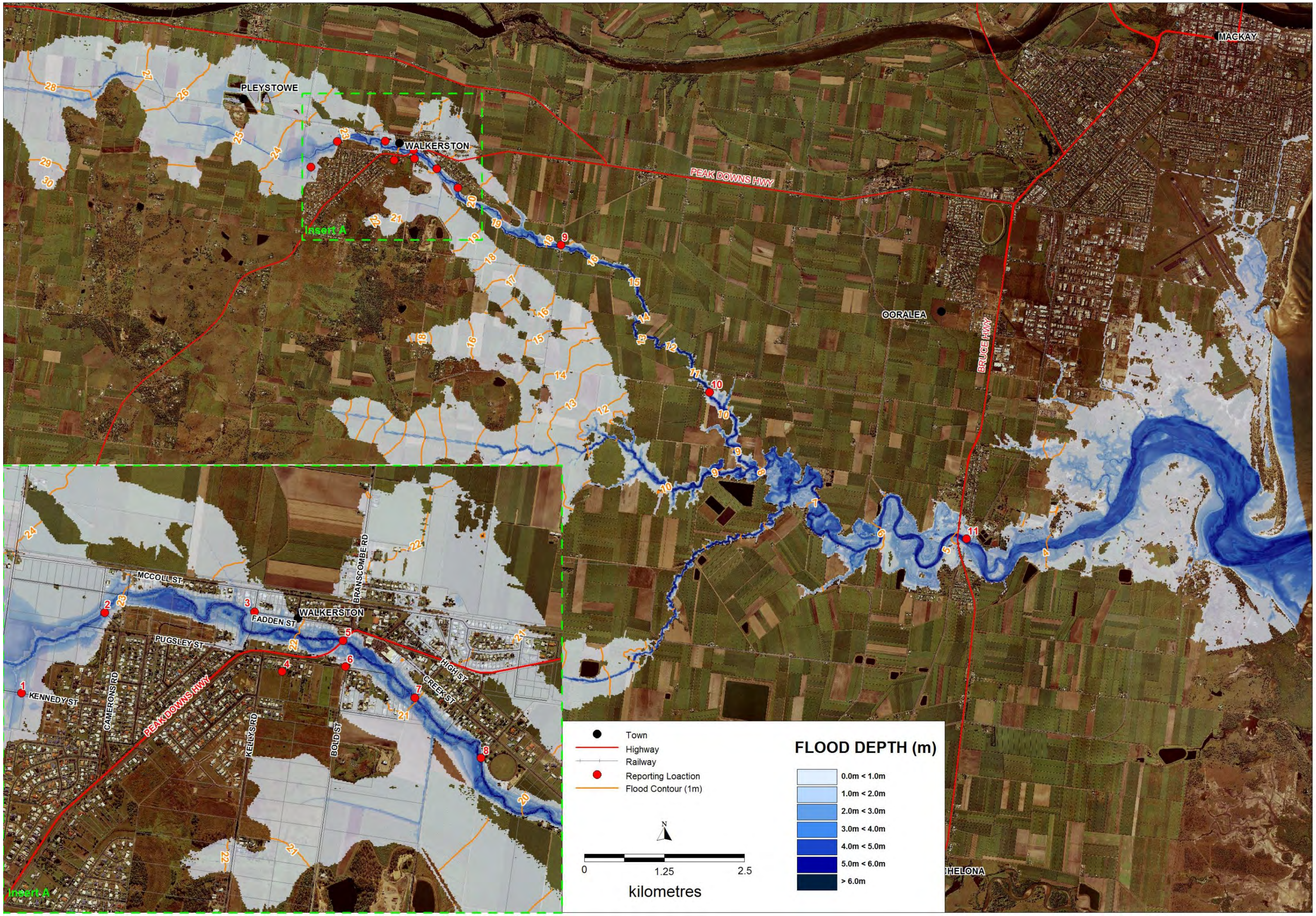


Figure B2 Bakers Creek Flood Extent for Case 1 (Existing Conditions), 50 year ARI

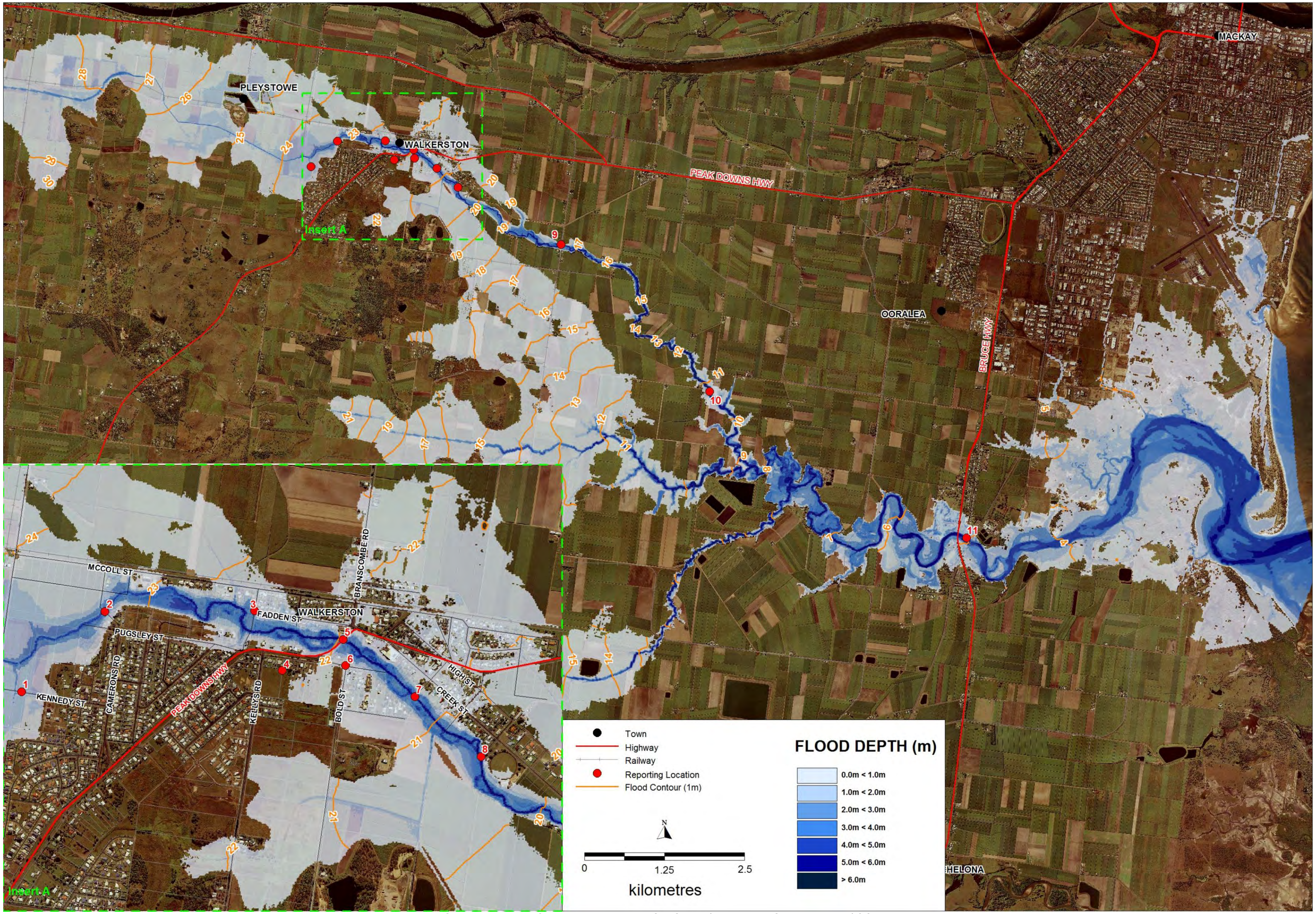


Figure B3 Bakers Creek Flood Extent for Case 1 (Existing Conditions), 100 year ARI

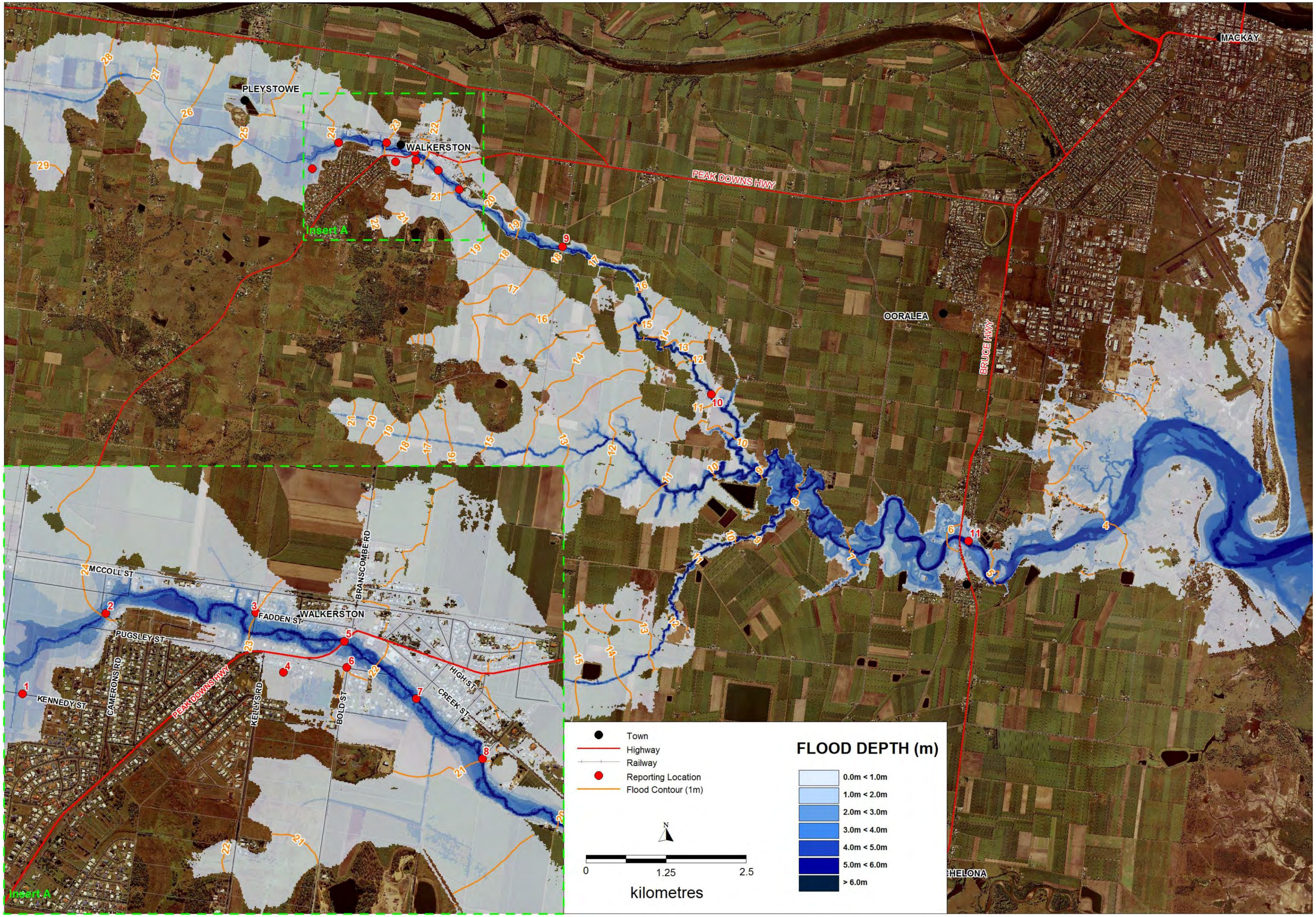


Figure B4 Bakers Creek Flood Extent for Case 1 (Existing Conditions), 200 year ARI

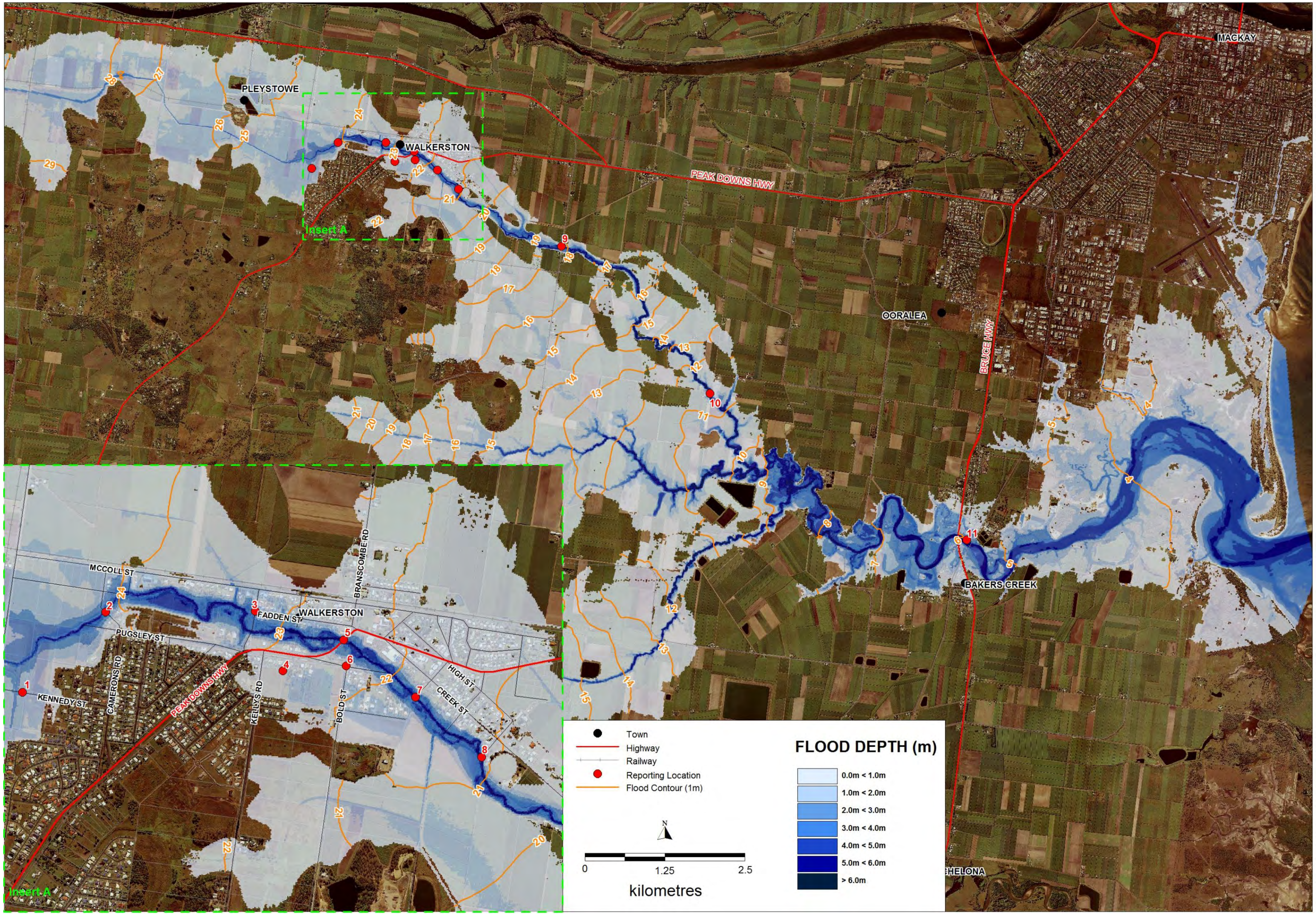


Figure B5 Bakers Creek Flood Extent for Case 1 (Existing Conditions), 500 year ARI

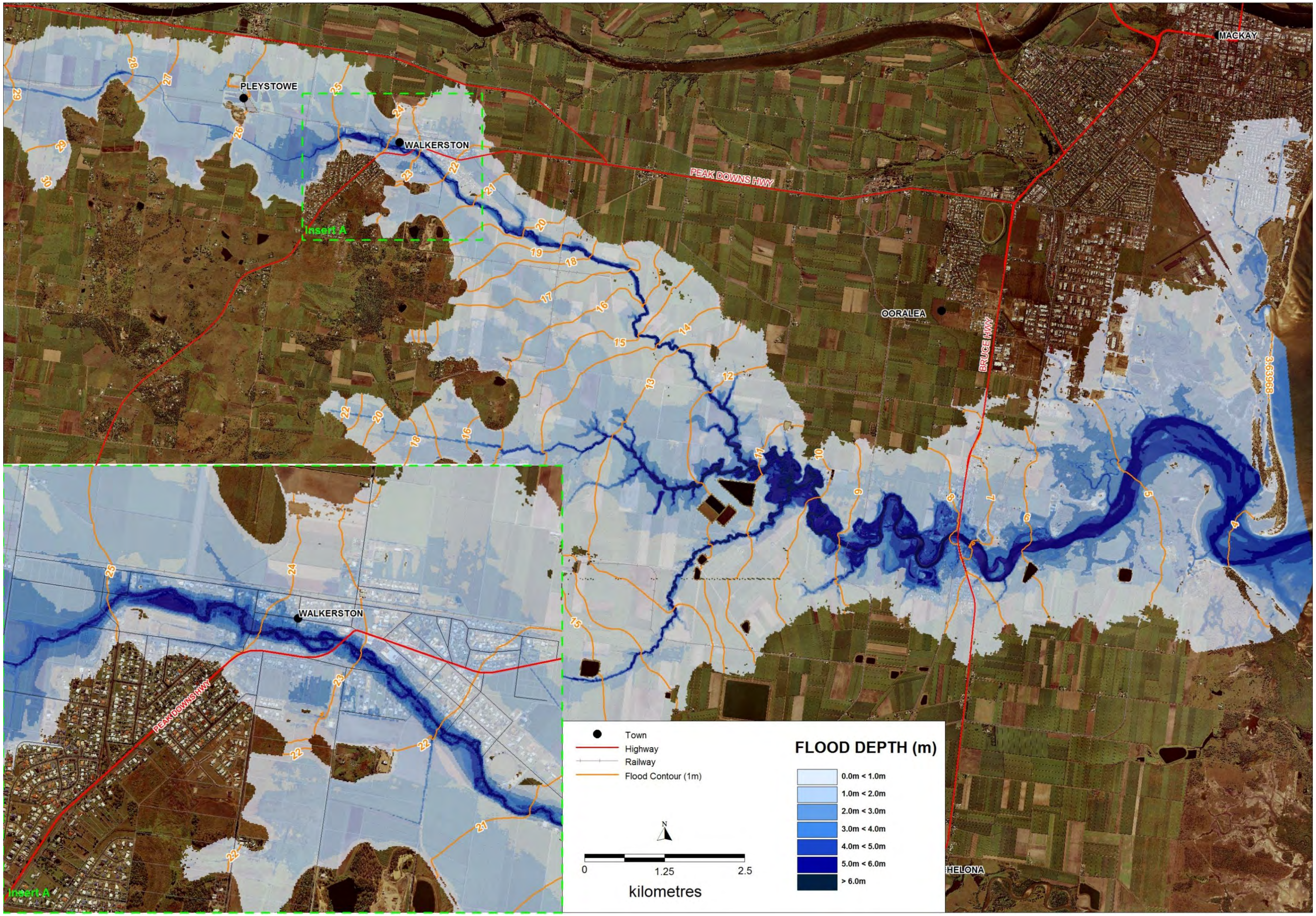


Figure B6 Bakers Creek Flood Extent for Case 1 (Existing Conditions), PMF

# APPENDIX C

## CLIMATE CHANGE CONDITIONS FLOOD MAPS

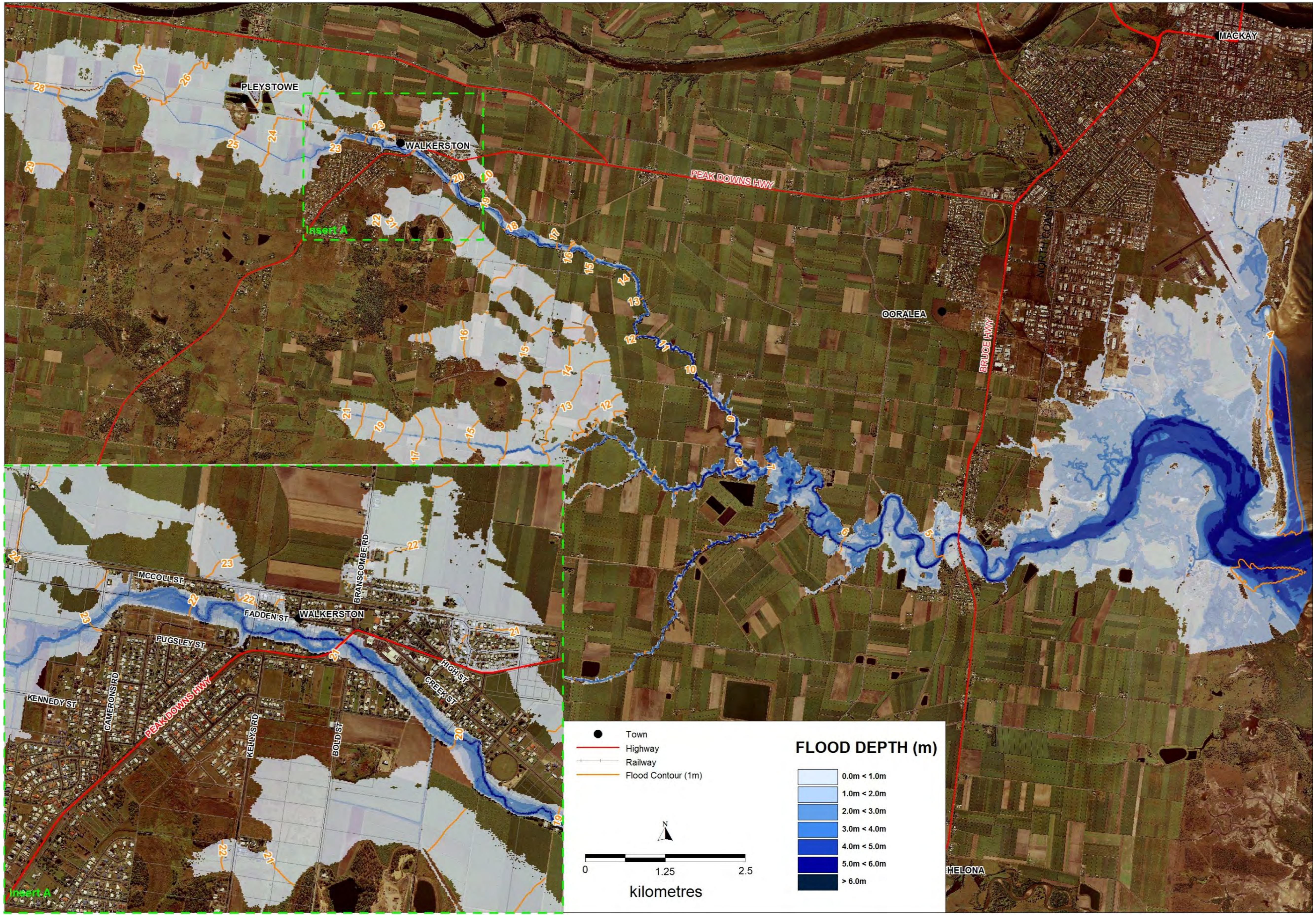


Figure C1 Year 2100 Climate Change Scenario Flood Extent, 5 year ARI Event

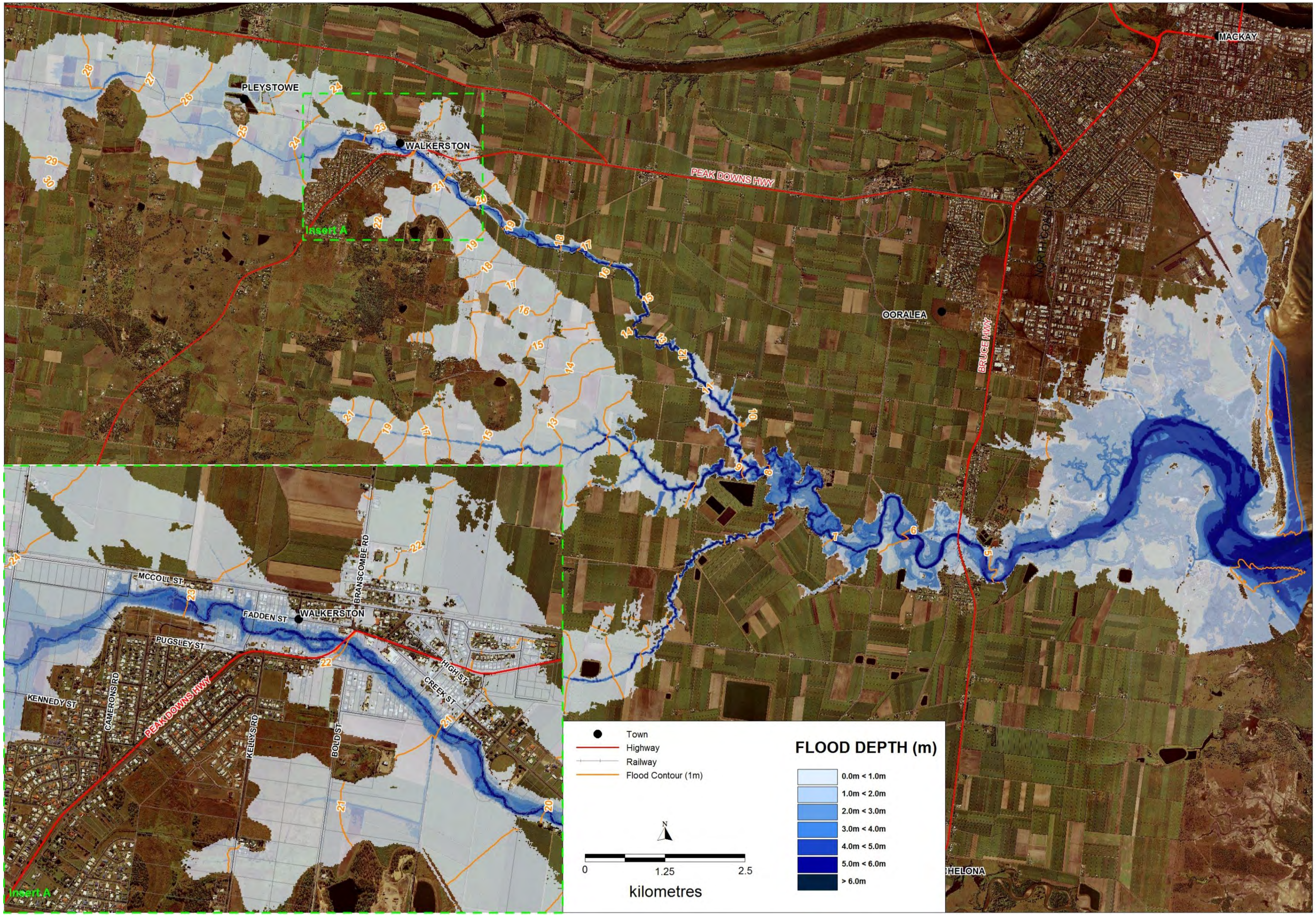


Figure C2 Year 2100 Climate Change Scenario Flood Extent, 50 year ARI Event

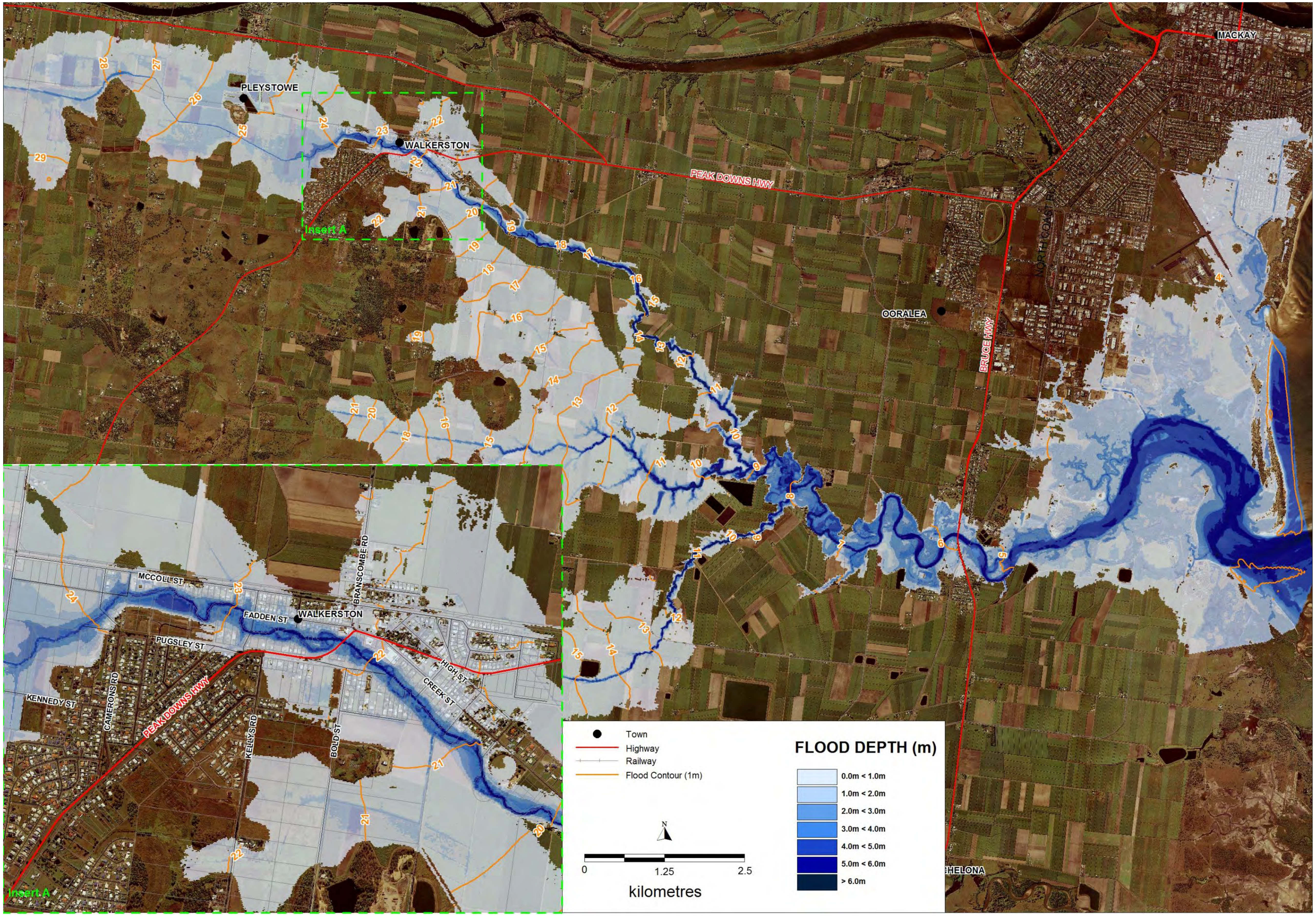


Figure C3 Year 2100 Climate Change Scenario Flood Extent, 100 year ARI Event

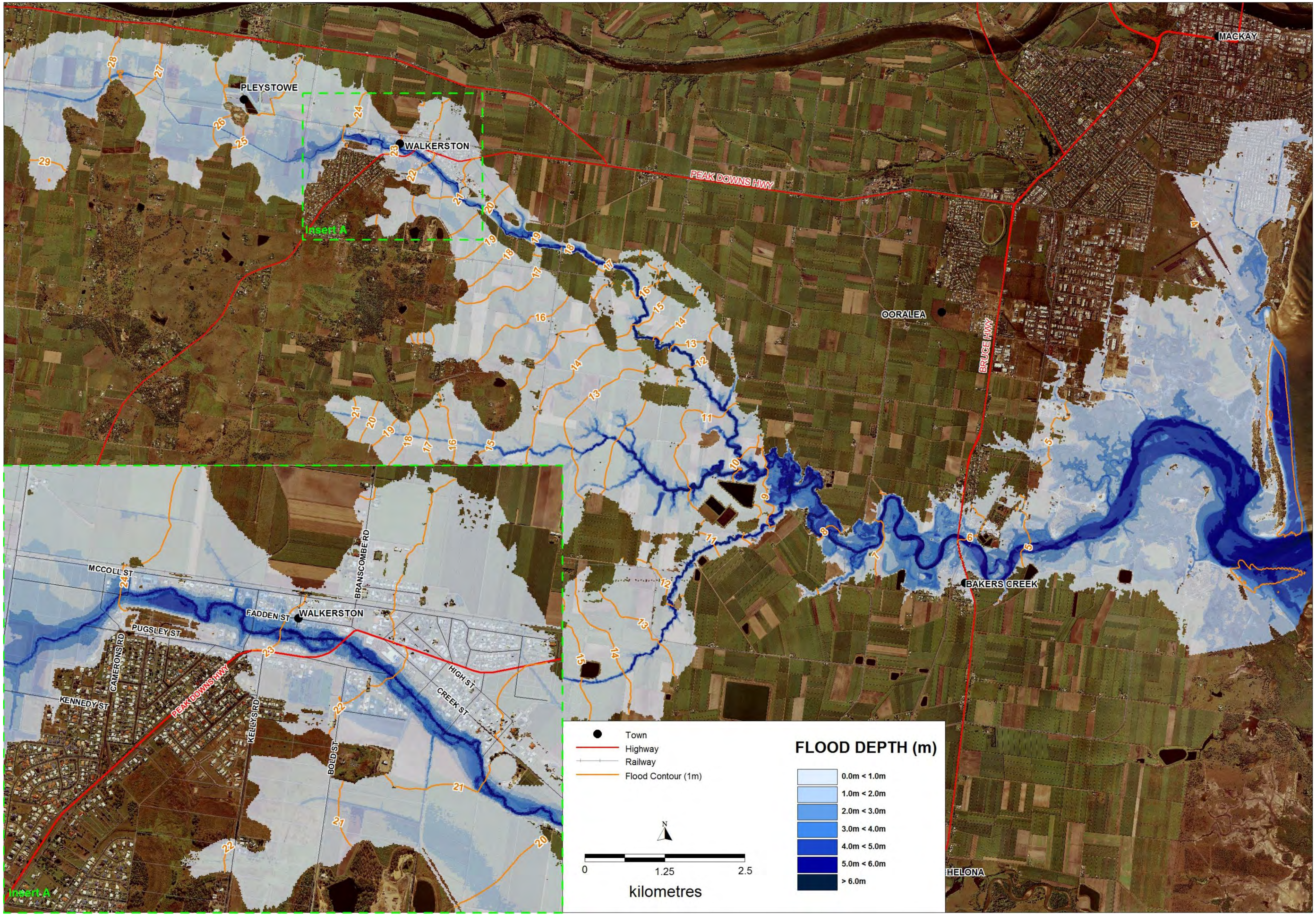


Figure C4 Year 2100 Climate Change Scenario Flood Extent, 200 year ARI Event

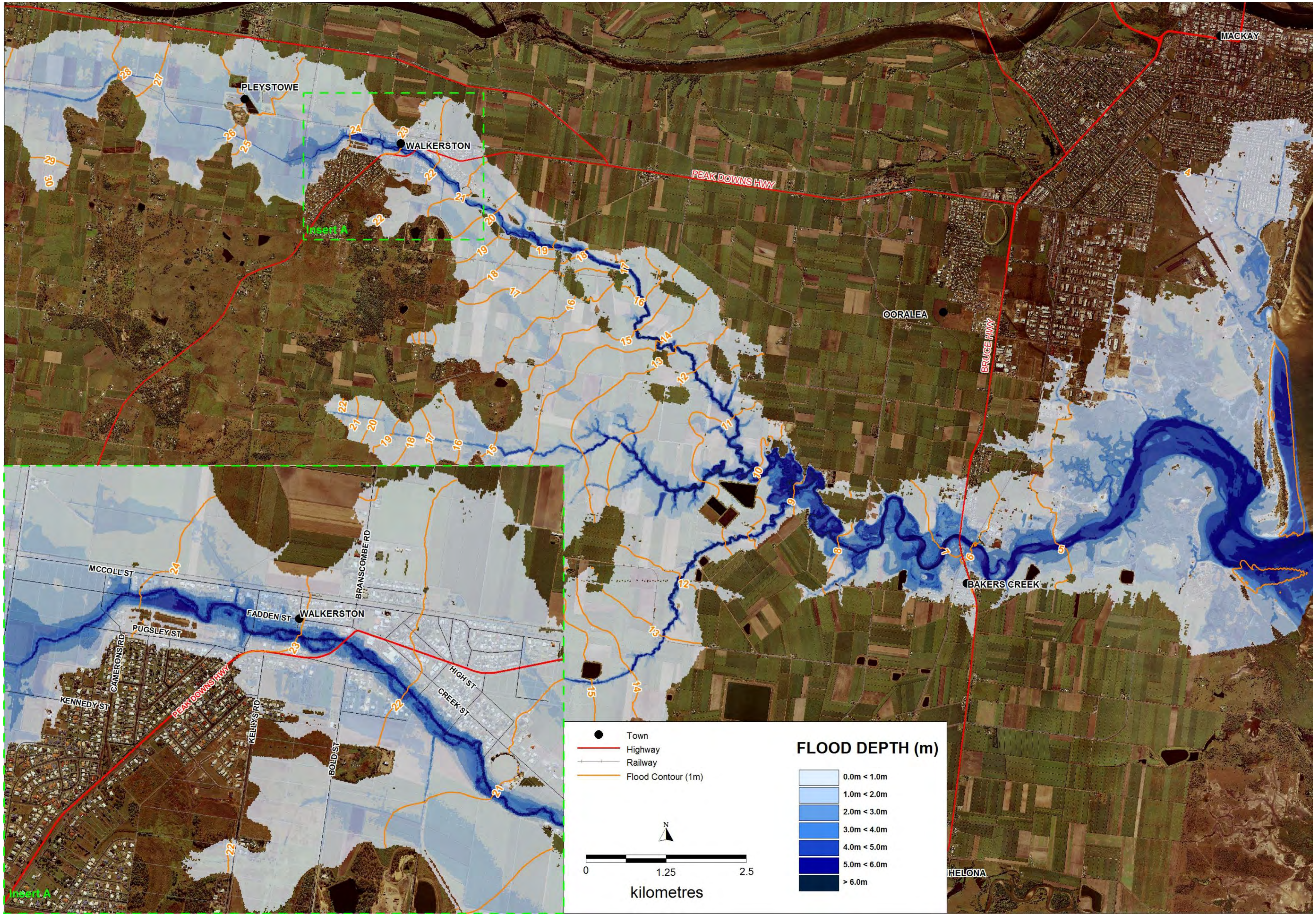


Figure C5 Year 2100 Climate Change Scenario Flood Extent, 500 year ARI Event