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Upper Avoca River Flood Investigation

Data Review Report

001 | RevB

1 April 2020

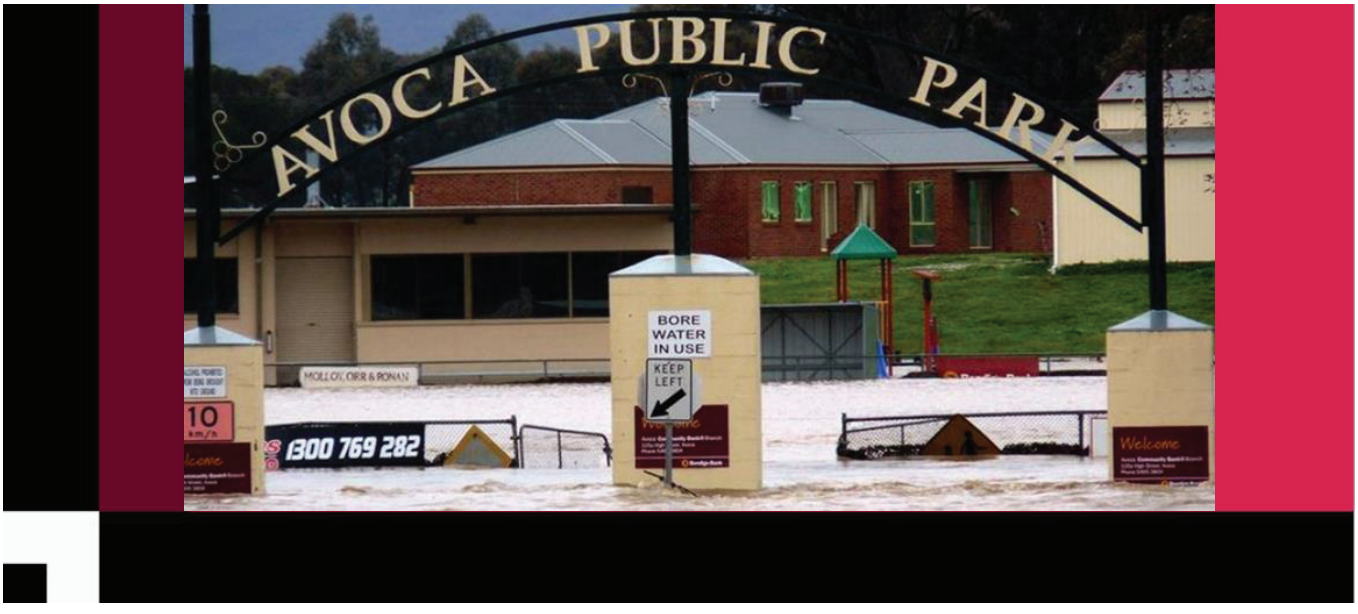
Pyrenees Shire Council

Australian Government

VICTORIA State Government

PYRENEES SHIRE

North Central CMA



Upper Avoca River Flood Investigation

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Project Manager:	Michael South
Author:	Terence Kelly, Michael South
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Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia
T +61 3 8668 3000
F +61 3 8668 3001
www.jacobs.com

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Contents

Definitions

Annual Exceedance Probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five per cent, it means that there is a five per cent chance (i.e. a 1 in 20 chance) of a peak discharge of 500 cubic metres per second being equalled or exceeded in any one year (also see average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding to about mean sea level.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, flood with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The catchment at a particular point is the area of land that drains to that point.
Design flood	A theoretical flood representing a specific likelihood of occurrence (for example the 1% AEP flood).
Flood behaviour	The pattern / characteristics / nature of a flood.
Flood depth	The height or elevation of floodwaters above ground level.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum).
Hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
LiDAR	Remote (airplane) sensing method that uses light in the form of a pulsed laser to measure distance to the Earth. This is used to generate detailed 3D topographical information across an area.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event at a particular location.
RORB	Runoff routing computer model for hydrologic analysis of catchment runoff.
TUFLOW	Fully two-dimensional and one-dimensional unsteady flow hydraulic computer modelling software.
Velocity	The speed at which the floodwaters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section if a one-dimensional solution is used; and depth average if a two-dimensional solution is used.

Abbreviations

ARR 2019	2019 release of Australian Rainfall & Runoff
BoM	Bureau of Meteorology
Council	Pyrenees Shire Council
DELWP	Department of Environment, Land, Water and Planning
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EIA	Effective Impervious Area
GSAM	Generalised Southeast Australia Storm Method
GSDM	Generalised Short-Duration Method
m AHD	meters Australian Height Datum
FFA	At-Site Flood Frequency Analysis
LiDAR	Light Detection and Ranging
m/s	Metres per second (a measure of speed / velocity).
m^3/s	Cubic metres per second (a measure of flow).
NCCMA	North Central Catchment Management Authority
NDRGS	Natural Disaster Resilience Grant Scheme
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PRG	Project Reference Group
RCP	Representative Concentration Pathway
RFFE	Regional Flood Frequency Estimate
RRV	Regional Roads Victoria
The Investigation	Upper Avoca River Flood Investigation
The Catchment	Upper Avoca River catchment to the Investigation downstream boundary
TIA	Total Impervious Area

1. Introduction

This Data Review Report provides a summary of the data collected and for the Upper Avoca River Flood Investigation (the Investigation), along with recommendations for adoption of the data in the Investigation and further verification required during the flood modelling tasks. A register of all data collected and reviewed is provided in Appendix A.

The Data Review Report has been prepared prior to finalisation of the flood modelling and community engagement tasks of the study. As result all data used during the Investigation may not be documented in this report.

1.1 Investigation Background

The Upper Avoca River area has a long history of flooding, including experiencing three significant flood events over the past decade in 2010, 2011 and 2016. However, to date, there has not been a detailed flood assessment completed for this area. To address this a flood study of the Upper Avoca River to inform flood intelligence and planning scheme maps for Amphitheatre, Avoca and Natte Yallock and the rural areas in between was identified as a high regional priority in the North Central Regional Floodplain Management Strategy 2018-2028 (NCCMA 2018).

In response the Pyrenees Shire Council (Council) has received funding from the Victorian and Commonwealth Governments through the Natural Disaster Resilience Grants Scheme (NDGRS), and in partnership with the North Central Catchment Management Authority (NCCMA) have engaged Jacobs to undertake the Upper Avoca River Flood Investigation.

The main Investigation objectives are to:

- Define flood related controls in the Pyrenees Shire Council Planning Scheme
- Develop flood intelligence products and inform emergency response planning
- Investigate opportunities for flood mitigation works and activities
- Assist in the preparation of community flood awareness and education products
- Assess feasibility for improved flood warning arrangements
- Support the assessment of flood risk for insurance purposes

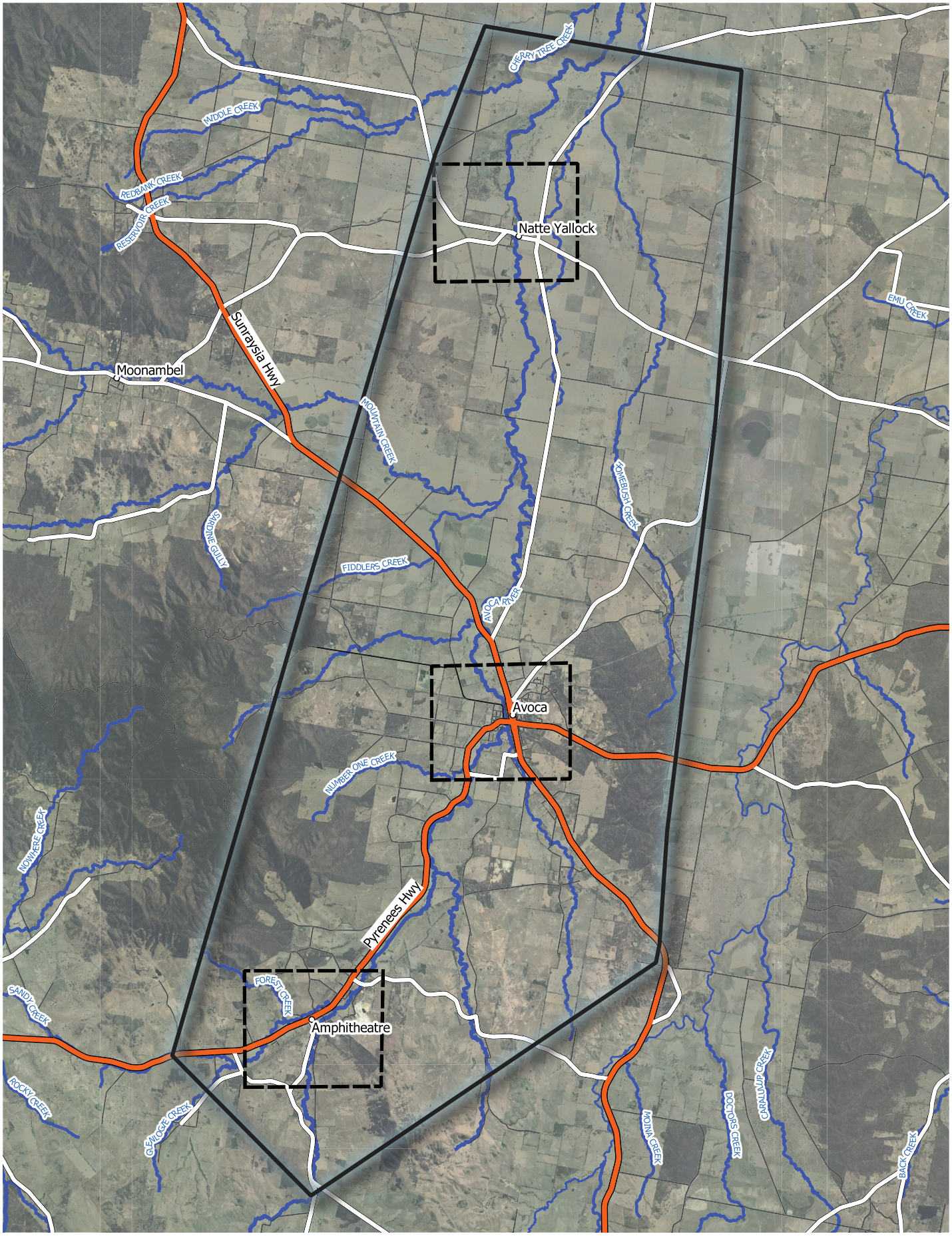
1.2 Catchment and Investigation Area Description

The Investigation area (Figure 1.1) is located in the upper reaches of the Avoca River where it flows from the hills of the Great Dividing Range ranges onto the Avoca River floodplain where it remains relatively confined until it breaks out into the wider floodplain north of Charlton. To Archdale Junction (the downstream limit of the Investigation), there is contributing catchment of approximately 1,000 km^2.

The Avoca River is the primary waterway in the catchment area, forming in the hills south of Amphitheatre and flowing north, with several tributaries that join it prior to Archdale Junction, including:

- Homebush Creek
- Brown Hill Creek
- Cherry Tree Creek
- Middle Creek
- Redbank Creek
- Mountain Creek
- Wild Dog Creek
- Sardine Gully
- Fiddlers Creek
- Number One Creek
- Number Two Creek
- Sugarloaf Creek
- Rutherford Creek
- Green-hill Creek
- Forrest Creek
- Glenlogie Creek
- Amphitheatre Creek.

In total the Investigation covers an area of approximately 300 km^2 from upstream of Amphitheatre to Archdale Junction, covering the townships of Amphitheatre, Avoca and Natte Yallock as shown in Figure 1.1. These towns have populations of 248, 1,193 and 188 respectively as of the 2016 census. High-resolution modelling is proposed for the townships (which are referred to as town models), with coarser modelling for the broader area (which is referred to as the regional model).



Upper Avoca Flood Investigation Overview

Legend

- Watercourses
- Major Roads
- Secondary Roads
- Minor Roads
- High resolution study areas
- Overall study area

0 3 6 km

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2. Data Review

2.1 Previous Studies

No previous detailed flood studies have been undertaken for the Upper Avoca River area, however the following relevant previous studies have been identified:

- **North Central Regional Floodplain Management Strategy 2018-2028** (NCCMA 2018) – Regional floodplain management strategy for the NCCMA area. Identifies regional floodplain management priorities, including actions for the Upper Avoca River area.
- **Charlton Flood and Drainage Management Plan** (BMT WBM 2013) – Flood study completed for the township of Charlton including a hydrologic assessment that encompasses the Upper Avoca River Catchment. RORB hydrologic model and historic event calibration data provides basis for the Upper Avoca River hydrologic modelling.
- **Upper Avoca River - Catchment Action Plan** (Alluvium 2007) – Catchment action plan to improve river and catchment health. Provides details of the physical characteristics of the catchment.

2.1.1 Recommendations

- This information has been used in the hydrologic and hydraulic tasks of this investigation

2.2 Historic Flood Data

In addition to the historic flood data provided by the community (refer to Section 2.8) the following historic flood information has been collected and reviewed.

2.2.1 Flood Marks

NCCMA provided the following surveyed flood marks:

- 2 x Avoca and 1 x Natte Yallock 2010 flood level marks surveyed by Tomkinson Group
- 1 x 1956, 6 x 2010 and 5 x 2011 flood level marks in Avoca surveyed by Price Merrett Consulting
- A plan of unknown source estimating the 1870, 1934 and 1956 flood levels in Avoca.

During the site visit (refer to Section 2.9) Jacobs also identified the Avoca community flood pole (Figure 2.1) located at the corner of Dundas Street and North Street identifying 1956, 2010, 2011 and 2016 flood levels.

Figure 2.1: Avoca Flood Pole

2.2.2 Flood Photography

NCCMA provided flood photography from Avoca of the 2007, 2010 and 2011 flood events along with aerial flood photography captured on 5 October 2016.

2.2.3 Newspaper Search

The National Library of Australia's Trove newspaper online library (https://trove.nla.gov.au/newspaper/) was searched with references of significant flooding in the Upper Avoca River catchment as far back as September 1867 found when the Archdale Bridge over the Avoca River was destructed by floodwaters as reported in the Avoca Mail and Pyrenees District Advertiser on September 28th , 1867.

2.2.4 Recommendations

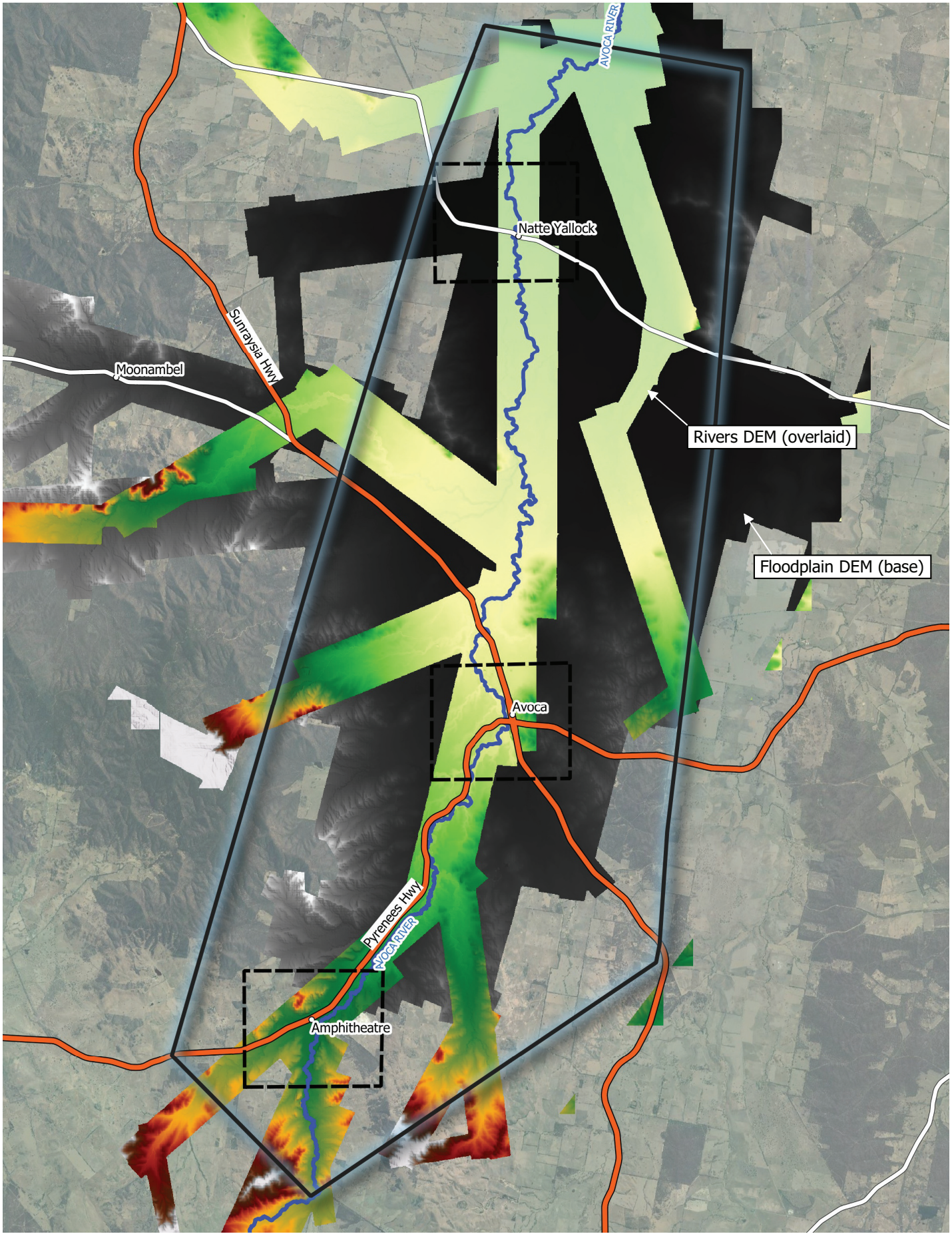
- The surveyed flood level marks were used for calibration and validation of the flood model
- Field survey of the additional flood level marks at the Avoca Flood Pole was captured
- The historic flood information (pre-recorded stream gauge data) is used as historic flood event inputs into the at-site flood frequency analysis

2.3 Topographical Data

The following topographic datasets were sourced for the investigation:

- **2009-10 Victorian State-Wide Floodplains LiDAR Project:** Captured on 30 April 2011 with a stated vertical accuracy of +/- 0.1 m provided as 1 m grid
- **2009-10 ISC Rivers LiDAR:** Captured on 10 October 2010 with a stated vertical accuracy of +/- 0.2 m provided as 1m grid
- **VicMap Elevation DTM 10m:** 10 m grid with a stated accuracy of +/- 5 m

The extents of the two LiDAR digital elevation models (DEM) are shown in Figure 2.2 while the north-west portion of the DTM 10m covers the entire catchment area



Upper Avoca Flood Investigation
LiDAR Extent

0 3 6 km

Legend

- Watercourses
- Major Roads
- Secondary Roads
- High resolution study areas
- Overall study area

Rivers DEM	Floodplain DEM
185	185
215	215
245	245
275	275
305	305
335	335
365	365
395	395
425	425
455	455
485	
500	

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2.3.1 LiDAR Verification

To verify the vertical accuracy of the two LiDAR datasets, DEM elevations were compared to those from survey control marks within the Catchment area and road centreline spot heights captured during the field survey (Section 2.10). Only survey control marks with rigorously adjusted coordinates and spirit levelled AHD heights (SCN GDA94 and SCN AHD) were used for this assessment of which there are 24 within the extent of each DEM. 206 road centreline spot heights were surveyed.

A Histogram of the difference between the surveyed levels and the LiDAR data is shown in Figure 2.3 for the 2009-10 Victorian State-Wide Floodplains LiDAR Project (Floodplains) DEM and 2009-10 ISC Rivers LiDAR (Rivers) DEM respectively. This analysis found that in comparison with the surveyed levels the accuracy of both datasets was very similar with 90% of the 230 points within +/- 0.1 m, with mean differences of 0.014 m for the Floodplains DEM and 84% of the points within +/- 0.1 m, with mean differences of 0.044 m for the Rivers DEM. When compared to road centreline spot heights which are considered more accurate as LiDAR information is able to represent hard surfaces with minimum filtering and infilling of the topography data the accuracy of the DEMs improves. 95% of the 206 road centreline spot heights are within +/- 0.1 m, with mean differences of 0.002 m for the Floodplains DEM and 89% of the points within +/- 0.1 m, with mean differences of 0.037 m for the Rivers DEM.

Both the Floodplains and Rivers DEMs are considered to have sufficient accuracy for use in the hydrologic and hydraulic models without any vertical corrections.

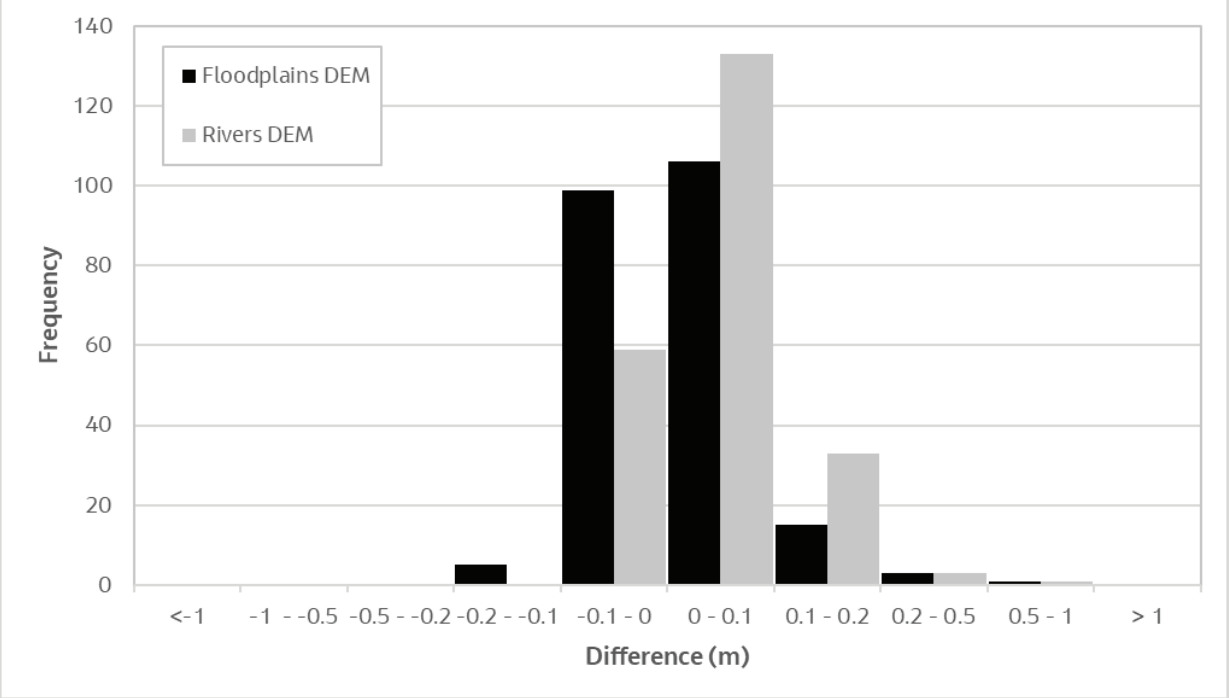


Figure 2.3: Histogram of the difference between DEM and survey levels

2.3.2 Recommendations

- DEM accuracy and coverage is appropriate and has been used in the hydrologic and hydraulic flood models

2.4 Aerial Photography

Council provided aerial photography covering the Catchment with 20 cm definition dated 15 January 2017.

2.4.1 Recommendations

- The aerial photography provides sufficient definition and has been used in the Investigation to identify floodplain characteristics and for mapping purposes

2.5 Stream and Rainfall Data

2.5.1 Stream data

Historic stream gauge level and flow data was sourced online through the online Water Measurement Information System (WMIS) for the nine sites in the catchment listed in Table 2.1 and mapped in Figure 2.4. Instantaneous and mean daily flows were extracted for these datasets and a review of the Victorian Surface Water Information to 1982 "Red Book" (State Rivers 1984) and Victorian Surface Water Information to 1987 "Blue Book" (State Rivers 1990) showed that no additional stream recordings prior to data available on the WMIS.

Prior to use of streamflow data in the hydrologic model calibration and at-site flood frequency analysis, verification of the rating curves will be undertaken using the hydraulic model. The rating verification are presented in the combined hydrologic and hydraulic modelling report.

Table 2.1: Stream gauges

Site	Record Period
Avoca River @ Amphitheatre (408202)	1966 - Current
Avoca River @ Archdale Junction (408206)	1987 - Current
Cherry Tree Creek @ Archdale Junction (408207)	1971 - 1987
Redbank Creek @ Redbank Reservoir H.G. (408218)	2012 - Current
Sugarloaf Creek @ Sugarloaf Res H.G. (408217)	2009 - Current
Forrest Creek @ Amphitheatre Res H.G. (408216)	2009 - Current
Avoca River @ Mount Lonarch (408211)	1959 - 1966
Glenlogie Creek @ Amphitheatre (408204)	1975 - 1987
Avoca River @ Coonooer (408200)	1964 - Current

2.5.2 Rainfall Data

Historic daily and sub-daily rainfall data was sourced from a number of locations listed in Table 2.2 and mapped in Figure 2.4 for sites in and near the catchment:

- Daily total rainfall records from the Bureau of Meteorology (BoM) Climate Data Online portal
- BoM sub-daily (pluviograph) rainfall records
- Sub-daily (pluviograph) rainfall records for gauges not operated by BoM accessed via the WMIS

In addition to the rainfall data available through government agencies, daily rainfall data recoded at Amphitheatre by a community member between 2015 and September 2019 has also been provided.

As part of the hydrologic model calibration and validation, verification of the rainfall data available for each selected historic event has been undertaken and will be presented in the Flood Modelling Report.

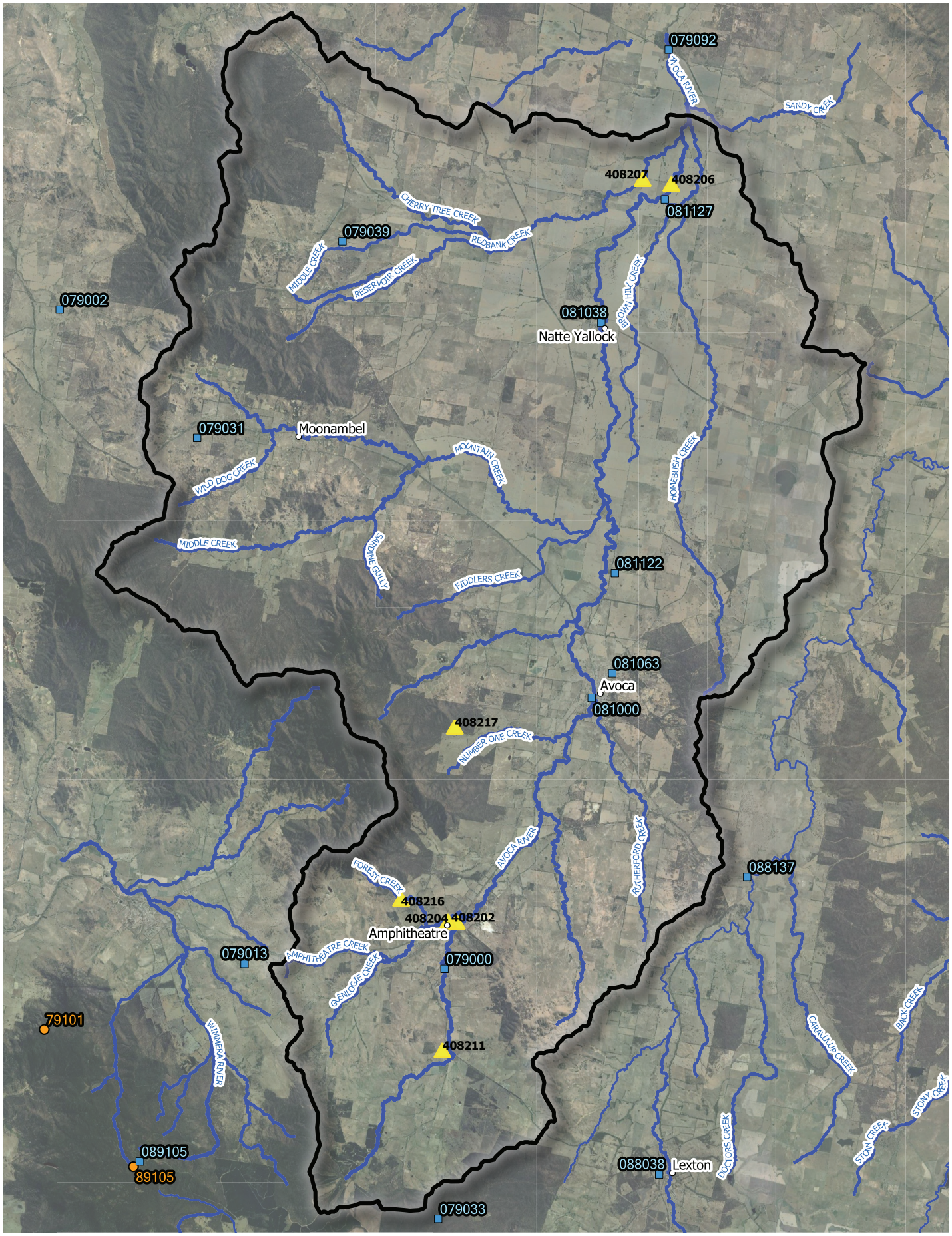
Table 2.2: Sub-daily and daily rainfall stations

Sub-daily Station	Record Period	Daily Station	Record Period
Avoca River @ Coonooer (408200)	1990 - 2019	Avoca (Post Office) (081000)	1884 - 2019
Pyrenees (Ben Nevis) (079101)	2008 - Current	Avoca (081063)	1889 - 2012
Lookout Hill (089105)	1992 - 2007	Avoca Homebush (081122)	1986 - 2018
Laanaecoorie Weir (081026)	1973 - 2004	Lillicur (088137)	2002 - 2019
Natte Yallock (081038)	1974 - 2016	Lexton (088038)	1903 - 2019
Navarre (Avon No. 3) (079086)	1973 - 2016	Moonambel (088038)	1901 - 2019
Cairn Curran Reservoir (088009)	2004 - 2016	Redbank (079039)	1897 - 2019

Sub-daily Station	Record Period	Daily Station	Record Period
Beaufort (Sheepwash) (089082)	1974 - 2016	Natte Yallock (081038)	1898 - 2017
Ararat Prison (089085)	1981 - Current	Avoca River @ Archdale Junction (081127)	2001 - 2019
Avoca Water Treatment Plant (408800)	2001 - Current	Bealiba (081002)	1891 - 2019
Avoca River @ Archdale Junction (408206)	1998 - Current	Amphitheatre (079000)	1891 -1970
Ballarat Aerodrome (089002)	2000 - 2017	Barkly (079002)	1907 - 2017
Bet Bet Creek @ Bet Bet (407211)	1990 - Current	Dunolly (081085)	1882 - Current
Bet Bet Creek @ Norwood (407220)	2013 - Current	Raglan (089107)	1993 - Current
Bung Bong (408801)	2017 - Current		
Doctors Creek @ Lexton Reservoir (407326)	2015 - Current		
Forrest Creek @ Amphitheatre Reservoir (408216)	2009 - 2019		
Franks Gully Creek @ Landsborough Reservoir (415275)	2010 - Current		
Redbank Creek @ Redbank Reservoir (408218)	2012 - 2019		
Stawell Aerodrome (079105)	1996 - 2017		
Tottington (079079)	1973 - Current		

2.5.3 Recommendations

- The rating curves used in the Investigation have been verified hydraulic model
- Verification of the rainfall data available for each selected historic event has been undertaken as part of the hydrologic model calibration



Upper Avoca Flood Investigation Climate and Streamflow Gauges

Legend

- Watercourses
- Catchment boundary
- Streamflow gauges
- Daily rainfall gauges
- Sub-daily rainfall gauges

0 4 8 km

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2.6 Hydraulic Structures

Hydraulic structures, including culverts and bridges, are located on waterway crossing throughout the Investigation area, and are managed by various government agencies:

- Regional Roads Victoria (RRV) owns and maintains road assets along declared roads. These include the Sunraysia and Pyrenees Highways, which cross at Avoca, as well as Maryborough-St Arnaud Road, which runs through Natte Yallock. RRV has provided drawings and dimensions of a number of these crossings.
- Pyrenees Shire Council owns and maintains assets for all other roads in the Investigation area. Council provided a GIS dataset of their road drainage assets.
- V/Line leases and operates the rail infrastructure in the area from VicTrack. There is one railway line that runs through the study area from west to east, with approximately 8 crossings of major and minor waterways. Data was not able to be sourced from V/Line within the Investigation time constraints.

NCCMA also provided bridge drawings of the Maryborough – Natte Yallock Road crossing. These drawings will be cross-checked against those provided by RRV.

During the site visits, Jacobs staff undertook inspections and measurements of structures along the key watercourses and roads. This includes dimensions and arrangements of approximately 50 culverts and bridges within the area.

For structures that were considered critical to the Investigation, field survey has been captured (Section 2.10).

2.6.1 Recommendations

- Available structure details have been used in the hydraulic model

2.7 GIS Data

GIS data was sourced from the Victorian spatial data online portal. The GIS data sourced includes:

- **Planning Zones and Overlays:** Used to define catchment landuse to aid in determining catchment fraction imperviousness and surface roughness
- **Property Parcels:** Used to populate flood intelligence outputs and undertake economic flood damages assessment
- **Watercourse:** Used to identify and present waterways for mapping products

2.8 Community Information

2.8.1 Project Reference Group Meetings

2.8.1.1 Meeting 1 (23 September 2019)

The first Project Reference Group (PRG) meeting was held in Avoca on 23 September 2019 with representatives from the local community, Council, NCCMA and the Department of Environment, Land, Water and Planning (DELWP). During this meeting the following datasets were provided:

- Flood photography, observations (identification of potential flood marks) and waterway management works/studies information for Avoca
- Flood photography and observations (identification of potential flood marks) for Natte Yallock

2.8.1.2 Meeting 2 (24 February 2020)

The second PRG meeting was held in Natte Yallock on 24 February 2020 with representatives from the local community, Council, NCCMA, VicSES and RRV. During this meeting the tasks up to the draft flood modelling task were presented including draft flood mapping.

2.8.2 Community Sessions

2.8.2.1 Session 1 (23 September 2019)

The first community meeting was held in Avoca on 23 September 2019. During this meeting the following datasets were provided:

- Flood photography and observations (identification of potential flood marks) for Natte Yallock

2.8.2.2 Session 2 (24 February 2020)

The second community meeting was held in Natte Yallock on 24 February 2020. During this meeting draft flood mapping and animations was presented and potential mitigation options discussed. The following feedback was provided:

- The January 2011 flood extent mapping was not representing locations of breakout flows upstream of Natte Yallock
- A permanent or temporary levee system to prevent high velocity flow down Reserve Road into the Natte Yallock Recreation Reserve
- The bermed road corner at the intersection of Moonambel – Natte Yallock Road and Cains Road is causing overland flow to be diverted in the Natte Yallock township

2.8.3 Community Surveys

To complement Community Session 1 a community flood survey was mailed out to gain a further information regarding the community's past experiences with flooding and the identification of potential mitigation options. The community survey responses are compiled in Appendix A.

In total there were 36 responses to the surveys; 19 from Avoca, seven from Amphitheatre, one from Natte Yalock, one from Lamplough and eight from unknown locations within the catchment. From these 36 respondents, 15 of them of them had experienced flooding on their property.

The respondents identified to main factors which are seen be contributing to flooding; too much debris and trees in the Avoca River and contributing creek channels and poor maintenance of local drainage assets such as culverts and minor drains along roads.

Several potential structural mitigation options were identified including:

- Channel clearing (tree and debris removal) along river and creek channels
- Reservoir or weir in the upper catchment to hold back the flow of water (could also be used as a recreation asset or irrigation water supply)
- Construction and maintenance of local drainage infrastructure such as road table drains and culverts
- Levee banks along the Avoca River
- Excavate Avoca River channel to increase flow capacity
- Silt removal (dredging) of the upper reaches of the Avoca River near Amphitheatre
- Install culvert of Barry Road so road is not closed during flood events

2.8.4 Recommendations

- Incorporate community information into the Investigation, primarily during flood model calibration and validation, and the structural mitigation option assessment
- Incorporate any additional community information provide during the remaining three community sessions in the Investigation outcomes

2.9 Site Visit

Jacobs, accompanied by Council and the NCCMA, undertook a sit visit on 15 ~~July,~~July 2019. During this site visit, areas of interest were visited including the stream gauges and hydraulic structures along key waterways and roads. These site visits allowed Jacobs to gain an understanding of the Investigation area, identify structures and obtain a photographic record.

2.10 Field Survey

Field survey was captured by Stateline Surveying and is presented in Appendix C. The following field survey was captured:

- 206 spot heights along centre lines at 5 separate long section locations
- 20 road and five railway bridges
- 10 road and seven railway culverts
- Levels and details of the Avoca River @ Amphitheatre and Avoca River @ Archdale Junction stream gauges
- Flood mark survey of the Avoca Flood Pole (Section 2.2.1)
- Crest survey of the raised garden bed in the Avoca Public Park

Following completion of 0.2% AEP flood mapping floor level survey of buildings within the flood extent will also be commissioned.

3. Summary and Recommendations

This Data Review Report provides a summary of the data collected and reviewed for the Investigation.

The data collected and reviewed to date has been used to develop the draft flood modelling. IF additional data becomes available, it will incorporated into the Investigation during the final flood modelling task and the subsequent flood mapping, risk assessment and management tasks of the Investigation.

4. References

Alluvium (2007), *Upper Avoca River – Catchment Action Plan*, Alluvium.

BMT WBM (2013), *Charlton Flood and Drainage Management Plan: Technical Report*, BMT WBM.

(NCCMA) North Central Catchment Management Authority (2018), *North Central Regional Floodplain Management Strategy*, North Central Catchment Management Authority.

(State Rivers) State Rivers and Water Supply Commission of Victoria (1984), *Victorian Surface Water Information to 1982*, Volume 4, State Rivers and Water Supply Commission of Victoria.

(State Rivers) State Rivers and Water Supply Commission of Victoria (1990), *Victorian Surface Water Information to 1987*, Volume 4, State Rivers and Water Supply Commission of Victoria