Upper Wimmera Flood Investigation Final Report

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Upper Wimmera Flood Investigation Final Report

Prepared for:	Wimmera Catchment Management Authority
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies) In association with Michael Cawood and Associates

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Synopsis:	**This report documents the tasks undertaken as part of the Upper Wimmera Flood Investigation.**	

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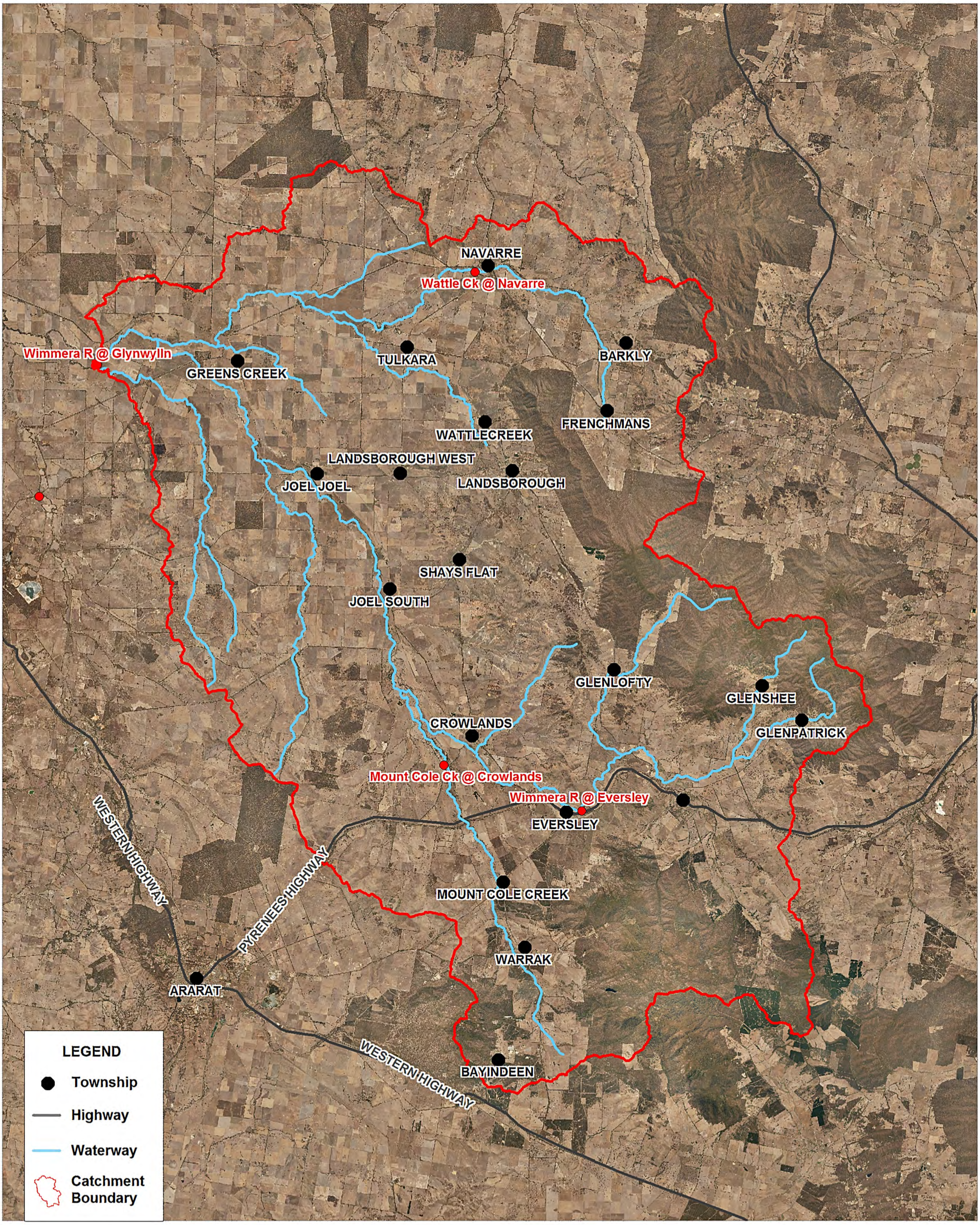
Executive Summary

This Executive Summary outlines the objectives, methodology and key outcomes of the Upper Wimmera Flood Investigation. Detailed reporting and mapping undertaken as part of the Upper Wimmera Flood Investigation are contained within the main report.

Study Background

Following the widespread flooding across Victoria in September 2010 and January 2011 the Minister for Water on the 19th September 2011 announced funding for the Upper Wimmera Flood Investigation. The Wimmera Catchment Management Authority (Wimmera CMA), in partnership with the Department of Environment and Primary Industries (DEPI), Northern Grampians Shire Council (NGSC), Pyrenees Shire Council (PSC) and, Ararat Rural City Council (ARCC) have commissioned this investigation.

The Upper Wimmera Catchment has an area of 1,500 km2 and is located in Central West Victoria. The catchment includes a number of waterways, namely, the Wimmera River and a number of its tributaries, including Mount Cole Creek, Wattle Creek (also known as Heifer Station Creek), Howard Creek and Seven Mile Creek. The majority of the catchment is used for agricultural purposes, predominately grazing. There are several townships within the catchment including Navarre, Landsborough, Elmhurst, Eversley, Crowlands, Joel Joel, Greens Creek and Campbells Bridge (Figure 1). The catchment was subject to flooding on three separate occasions between September 2010 and January 2011, which emphasised the need for improved understanding of the flood behaviour. The WCMA engaged BMT WBM Pty Ltd (BMT WBM) to undertake the flood investigation of the catchment.



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Upper Wimmera Flood Study
Study Catchment

Figure: 1

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Approx. Scale

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Key Objectives

The key objectives of this study are to:

- Review available data and historic flood information;
- Engage with the community and stakeholders in order to understand their experiences of flooding and desired outcomes - data collected from the community will be potentially used as inputs (rainfall) and model outputs and verification (flood behaviour matching event observations);
- Determination and documentation of flood levels, extents, velocities and depths (and thus flood risk) for a range of flood events;
- A review of Ararat Rural City Council, Northern Grampians Shire Council and the Pyrenees Shire Council Planning Scheme's current Land Subject to Inundation Overlay (LSIO) and Flood Overlay (FO) overlay in the existing planning scheme. Prepare draft documentation for recommended (if any) amendments for council review;
- Preparation of digital and hard copy floodplain maps for design 1% AEP and other flood events, showing both floodplain and floodway extents, suitable for incorporation into municipal planning schemes should council deem appropriate;
- Assessment of flood damages;
- Identification and assessment of structural and non-structural mitigation measures to alleviate intolerable flooding risk;
- Costing and assessment of preferred structural mitigation measures;
- Preparation of flood intelligence and consequence information, including maps, for various flood frequency return periods;
- Review and update Northern Grampians Shire Council and the Pyrenees Shire Council Flood Response under the Municipal Emergency Management Plan;
- Delivery of all flood related data and outputs including fully attributed Victorian Flood Database (VFD) compliant datasets;
- Transparently reporting the outcome of the study together with the process followed and the findings;
- Engage the community in all stages of the flood investigation to ensure that most appropriate outcomes are achieved; and
- Recommend improvements to the existing flood warning network to reduce the impact upon potentially flooded persons and properties.

Data Collection

As part of the Upper Wimmera Flood Investigation, datasets and information were obtained from a variety of organisations. The datasets obtained included:

- **Topographic Data** – Including LiDAR and Permanent Survey Marks.
- **GIS Data** – Including: aerial photography, flood overlays, historical flood extents, cadastral information, planning zones and other government zones.

- **Infrastructure Data** – Including: drainage network details and floodplain control structure details.
- **Rainfall and Streamflow Data** – Including: daily rainfall, pluviograph, stream stage and stream flow records.
- **Historic Flood Levels** – Including: surveyed flood levels and surveyed floor levels.

In addition to collecting data from external sources, site inspections and community surveys were also undertaken as part of the Upper Wimmera Flood Investigation.

Stakeholder Engagement

Community consultation was undertaken throughout the development of the Upper Wimmera Flood Investigation. The consultation included a series of public meetings and through community surveys.

The WCMA formed a Steering Committee for the project which consisted of key stakeholders from WCMA, DEPI, Council, VicSES and the local community. The steering committee provided governance and management of the Investigation and ensured that issues important to the Upper Wimmera community were properly considered. Throughout the study, regular meetings were with the Steering Committee at which the interim reports and presentations were discussed and issues were resolved.

Flood Model Development

The fully calibrated flood model developed for the Upper Wimmera Flood Investigation, to define flood behaviour within the study area and assess mitigation options, incorporates both hydrologic and hydraulic modelling techniques. Flood frequency analyses was undertaken using the FLIKE package to determine the magnitude of predicted peak discharges for a given level of risk or probability. Hydrologic modelling was undertaken using the RORB hydrologic modelling package to determine the rainfall-runoff characteristics of the catchment.

The catchment flows derived from the hydrologic modelling were then used as input flow boundaries for the TUFLOW hydraulic model. The TUFLOW hydraulic model was used to generate the required flood mapping and define the flooding characteristics of the study area.

The flood model was calibrated to the January 2011 flood event and validated against the September 2010 flood event. To assess the impacts of flooding on the Upper Wimmera, the flood model was run for the following Annual Exceedance Probability (AEP) events: 20%, 10%, 5%, 2%, 1% and 0.5% along with the Probable Maximum Flood (PMF) event.

Hydrologic Modelling

Flood Frequency Analysis

Flood frequency analysis (FFA) has been undertaken using the methods outlined in the draft version of Australian Rainfall and Runoff (ARR) Book IV Peak Flow Estimation. FFA of the four gauges within the catchment has been undertaken using the FLIKE software. The results of the FFA for the Glynwylln gauge provided peak flow estimates for a given AEP event for the Wimmera River. The resulting peak flows verses return period at Glynwylln gauge are shown in Table 1-1.

Table 1-1 Wimmera River at Glynwylln: Flood Frequency Analysis Results

AEP	Expected Quantile (m^3/s)	90% Quantile Probability Limits	
20%	153	118	201
10%	247	183	353
5%	364	254	606
2%	559	352	1168
1%	743	424	1879

Hydrologic Modelling

The purpose of the hydrologic modelling was to characterise the catchment's runoff response to rainfall. This modelling produces time-series of discharge data (i.e. hydrographs) and was undertaken using the RORB hydrologic modelling software. The RORB model covered the entire Wimmera River catchment to downstream Glynwylln Gauge; an area of approximately 1,465 km^2.

To establish a degree of confidence that the hydrologic modelling was suitably representing the runoff behaviour of the catchment, model calibration and validation was undertaken at the four stream gauges within the catchment. The RORB model was calibrated against two flood events and summary statistics were reviewed to assess the fit of the model. The model was then validated against a further two flood events using the calibrated parameters. The RORB model was then used to derive flow hydrographs to provide inputs into the TUFLOW hydraulic model for the required flood events.

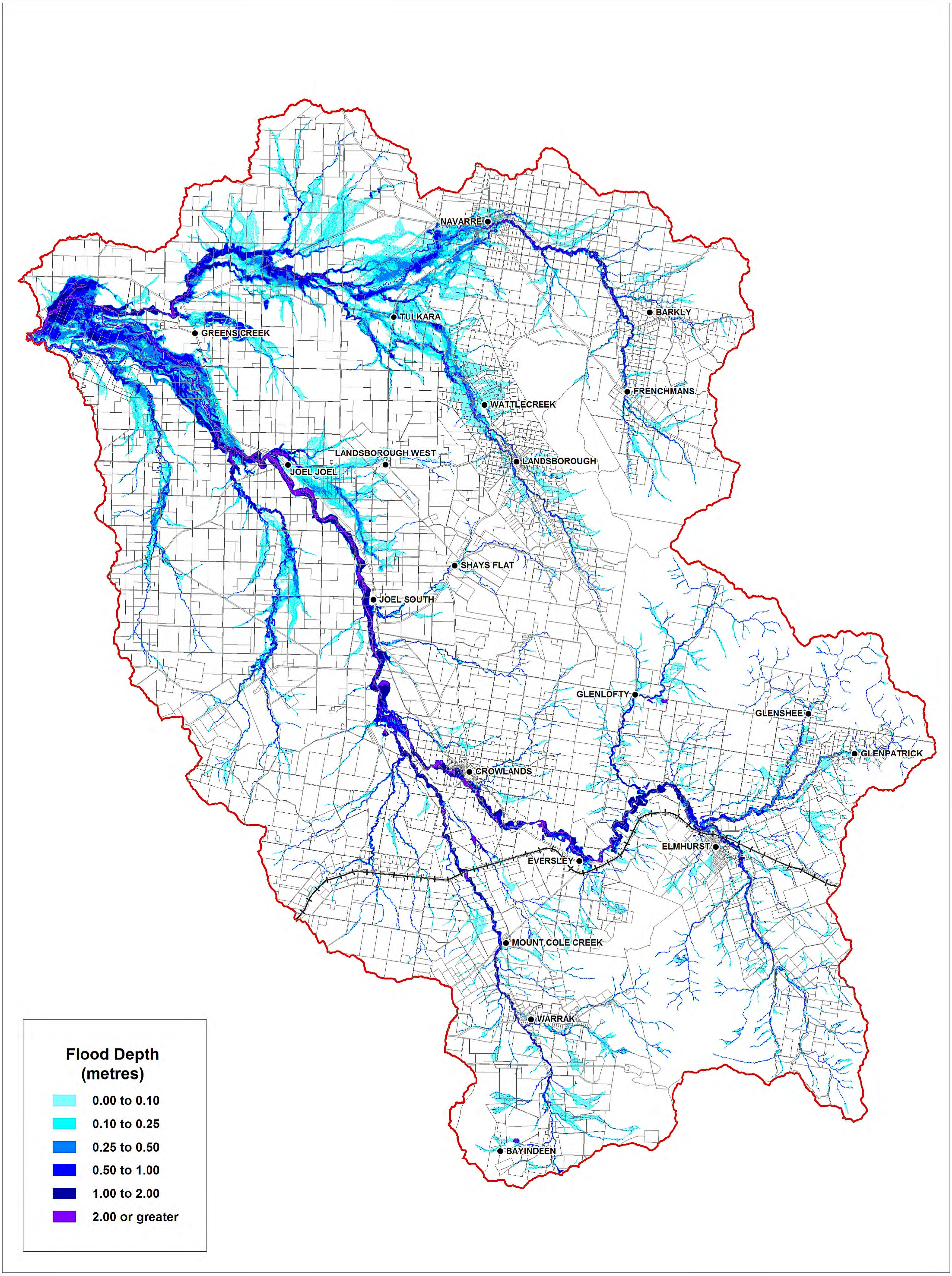
Hydraulic Modelling

In order to produce flood extents, depths, velocities and other hydraulic properties for the study area a 1D/2D linked hydraulic model was developed using TUFLOW. The floodplain was represented in the 2D domain with drainage and hydraulic structures modelled as 1D elements as required. The townships of Navarre and Landsborough were modelled at a higher resolution than the surrounding floodplain by incorporating a fine grid 2D domain into the model. The model covers the entire Upper Wimmera catchment.

The Upper Wimmera TUFLOW model underwent a calibration process to fit the model to the observed data. The TUFLOW model was calibrated to the September 2010 flood event and validated against the January 2011 flood event. The hydraulic model was successfully calibrated to the September 2010 and validated to the January 2011 flood events. The results demonstrated that the flood model has been effectively calibrated and is suitable for undertaking modelling of existing conditions and flood mitigation scenarios.

Existing Conditions Flood Mapping and Results

The flood model was run for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP design flood events (existing conditions) along with the PMF event. For each of these design flood events a suite of flood mapping outputs was generated including: flood depth, flood level, flood velocity, flood hazard and flood affected properties and buildings. Existing conditions peak flood depth for the 1% AEP event is presented in Figure 2.



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Upper Wimmera Flood Investigation
1% AEP Design Flood Depths - Catchment

Figure: **2**

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Existing Conditions Flood Damages Assessment

The existing conditions flood damages were assessed using a combination of the Rapid Appraisal Method (RAM) and ANUFLOOD methods, both widely adopted throughout Victoria. The ANUFLOOD method was adopted to estimate potential building damages while the RAM method was used to estimate potential agricultural and infrastructure damages.

Flood damages assessments enable floodplain managers and decision makers to gain an understanding of the monetary magnitude of assets under threat from flooding. The information determined in the damages assessment is also used to inform the selection of mitigation measures via a benefit cost analysis. The results of the flood modelling indicated that during the 1% AEP event, only 3 properties experience above floor flooding, as shown in Table 1-2. The existing conditions Average Annual Damages for the Upper Wimmera catchment were calculated to be $2,926,300. However, agricultural damage and road infrastructure damage account for 77% and 22% of the total damage respectively.

Table 1-2 Properties flooded and above floor flooding against AEP event

Event AEP	No of Properties Inundated	No. of properties with Above Floor Flooding
PMF	53	37
0.5%	33	7
1%	20	3
2%	12	2
5%	7	0
10%	3	0
20%	2	0

Flood Management Options Assessment

Through consultation with the community, emergency management authorities and other stakeholders, an understanding of the major factors that influence flood risk in the Upper Wimmera were identified. This understanding was further enhanced through computer flood modelling and mapping undertaken as part of the investigation. These factors relate to the physical characteristics of the floodplain that contribute to flood risk in the Upper Wimmera and the factors that hamper the community's ability to manage the impact of flooding. The major factors are:

- The locations of many of the towns, including Navarre and Landsborough, are on the banks of multiple waterways subject to flooding;
- Limited road access through the majority of the Upper Wimmera catchment during times of flood;
- The steep upper catchment resulting in fast flood responses from heavy rainfall. Flooding is generally fast flowing but confined to recognised flow paths

- The flat lower catchment results in widespread flooding (flood extents are wide), floodwaters are generally slower in velocity and more likely to simply 'pond' on the floodplain.
- The limited rain and streamflow gauges within the catchment limit the ability for the community and emergency services to respond to a flood event. Flood warning is designed more for the towns downstream on the Wimmera River, rather than the Upper Wimmera Catchment. Flood warning in the upper reaches of any catchment is challenging due to the rapid response of the upper catchment.

In order to address and manage these factors that contribute to the flood risk in the Upper Wimmera, a comprehensive flood management options assessment was undertaken, including both structural and non-structural management options.

Management Option Screening

The screening was undertaken by the Technical Working Group. The Technical Working Group screened all management options collated as part of this investigation based on the knowledge of the members and the results of the flood modelling and analysis completed by BMT. The screening considered the feasibility of each potential management option in terms of;

- The option's likelihood of delivering the required flood alleviation to the communities of the Upper Wimmera; and
- The economic, social and environmental costs.

In total 27 structural and eight non-structural management options were screened resulting in three structural and six non-structural management options were recommended for further assessment.

Structural Management Options Assessment

The three management schemes that were assessed were:

- **Scheme 1: Removal of Vegetation** – The creek alignments through Navarre and Landsborough are heavily vegetated and this scheme was used to determine the impact on flood levels through the removal of this vegetation.
- **Scheme 2: Town Levee around Navarre** - The design of a levee(s) to prevent flow from entering the Navarre for all flood events up to and including the 100 year ARI flood event.
- **Scheme 3: Whole of Catchment Access** - The design of upgraded roads to ensure safe road access between townships during all flood events up to and including the 100 year ARI flood event.

Hydraulic modelling of the range of design events; that is the 20%, 10%, 5%, 2%, 1% and 0.5% AEP and the PMF events; were used to undertake flood impact and damages assessments. Additionally, a benefit-cost ratio, which is an economic assessment based on preliminary cost estimates, was undertaken.

The resulting reductions in flood risk and Average Annual Damages (AAD) for the four schemes assessed was similar. As a result, the benefit-cost ratios were most heavily influenced by the cost of each scheme, as shown in Table 1-3.

Table 1-3 Structural Management Scheme Benefit-Cost Ratios

Structural Management Scheme	AAD	Capital Cost	Total Scheme Cost	BCR
Existing	$2,914,700			
Scheme 1	$2,912,500	$850,000	$1,165,000	0.03
Scheme 2	$2,912,200	$1,500,000	$2,067,000	0.02
Scheme 3	$2,821,500	$37,320,000	$51,443,000	0.03

Recommended Structural Management Scheme

All three modelled structural mitigation schemes provide minimal reductions to the Annual Average Damages and consequently result in very low Benefit-Cost Ratios. This is not unexpected due to the majority of the flood damages being incurred through damages to agricultural land and roads, and the schemes one and two having very little (if any) difference to these values. Whilst there is a noticeable reduction in the damages for Scheme 3, it comes at a significant capital cost; hence the BCR is still very low.

Consequently, there is no preferred structural mitigation scheme recommended by the Steering Committee for the Upper Wimmera Catchment. However, mitigation works should still be considered for protection of individual properties where deemed appropriate. A series of non-structural mitigation works will also be implemented across the catchment, including recommendations for improving the flood warning system and amendments to the planning scheme overlays.

Recommended Non-Structural Management Options

A number of non-structural management options identified during options screening were recommended for implementation in the Upper Wimmera Flood Investigation. These were:

- Declaration of flood levels;
- Amendments to planning schemes, including Planning Overlays;
- Flood response plan, including flood intelligence and consequence information.
- Flood warning system; and
- Community education.

List of Abbreviations, Acronyms & Glossary

1D/2D Model	1D hydraulic models rely on cross-sections taken at select location as representative of the floodplain or controls. A 2D model is (typically) a grid built from a DEM which allows for better representation of floodplains and allows superior modelling of complex flow patterns.
AEP	Annual Exceedance Probability – The % probability of an event occurring within any one year, as it is a probability it is possible to have two (or more) events that exceed this level within the space of a single year.
AEMI	Australian Emergency Management Institute
AHD	Australian Height Datum – The datum to which all vertical control mapping would be referred Australia wide. The datum (zero level) is set at the mean sea level around Australia.
ARCC	Ararat Rural City Council
ARI	Average Recurrence Interval – The probable recurrence interval of any event occurring, i.e. 100 year event is probable only to occur once every 100 years. The inverse of ARI is AEP, i.e. 50 year ARI = 2% AEP and is therefore possible to have two (or more) 100 year ARI storm events within the space of any 100 year period.
AWS	Automatic Weather Station
BoM	Bureau of Meteorology
CMA	Catchment Management Authority
Critical Duration	The design event that results in the peak discharge for any given AEP
DEM	Digital Elevation Model – Three dimensional computer representation of terrain
DEPI	Department of Environment and Primary Industries
DoTARS	Department of Transport and Regional Services
DSE	Department of Sustainability and Environment (now known as Department of Environment and Primary Industries)
EA	Emergency Alert
EMA	Emergency Management Australia
EMMV	Emergency Management Manual Victoria
ERTS	Event Report Radio Telemetry System
FFA	Flood Frequency Analysis, whereby historic data is used to determine design flood estimations.
FFWS	Flash Flood Warning System
FI	Fraction Imperviousness – The fraction of the catchment that is impervious, that is, land which does not allow infiltration of water

FLIKE	A software package for performing the FFA, includes many standard statistical distributions
FO	Flood Overlay
IC	Incident Controller
ICC	Incident Control Centre
LGA	Local Government Area
LiDAR	Light Detection and Ranging – Ground survey taken from an aeroplane typically using a laser. Using the laser pulse properties the ranging and reflectivity is used to determine properties of the laser strike, soil type/tree/building/road/etc. It is usual to filter non-ground strikes (trees/buildings/etc) from the LiDAR before it is used to generate a DEM.
LSIO	Land Subject to Inundation Overlay
Manning's n	Hydraulic roughness due to ground conditions, typically averaged over an area of relative homogeneity, e.g. it's harder for water to flow through an area of heavy brush and trees than maintained grass.
MEMPC	Municipal Emergency Management Planning Committee
MERO	Municipal Emergency Resource Officer
MFEP	Municipal Flood Emergency Plan
NGSC	Northern Grampians Shire Council
OESC	Office of the Emergency Services Commissioner
PMF	Probable Maximum Flood – the flood resulting from the PMP (see below).
PMP	Probable Maximum Precipitation – Largest probable rainfall event. These typically have an ARI beyond 1,000,000 years, or alternatively a 0.000001% AEP.
PSC	Pyrenees Shire Council
PSM	Permanent Survey Mark
QA	Quality Assure
RDO	Regional Duty Officer
RORB	A node and link runoff and routing hydrologic modelling program
TFWS	Total Flood Warning System
TUFLOW	A 1D and 2D hydraulic modelling package developed by BMT WBM and is the most widely used 1D/2D flood modelling software in Australia.
VFD	Victorian Flood Database
VICPOL	Victoria Police
VICSES	Victoria State Emergency Service

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