Warracknabeal and Brim Flood Investigation – Levee Design Report

March 2017

DOCUMENT STATUS

Version	Doc type	Reviewed by	Approved by	Distributed to	Date issued
v01	Draft	Ben Tate	Ben Tate	Clare Wilson	12/01/2017
v02	Final	Ben Hughes	Ben Hughes	Paul Fennell	31/03/2017

PROJECT DETAILS

Project Name	Warracknabeal and Brim Flood Investigation
Client	Wimmera CMA
Client Project Manager	Clare Wilson
Water Technology Project Manager	Ben Hughes
Report Authors	Ben Hughes
Job Number	3532-01
Report Number	R05
Document Name	Levee Design Report

Cover Photo: January 2011 Inundation in Warracknabeal, showing the levee constructed immediately prior to the event (Source: Yarriambiack Shire Council)

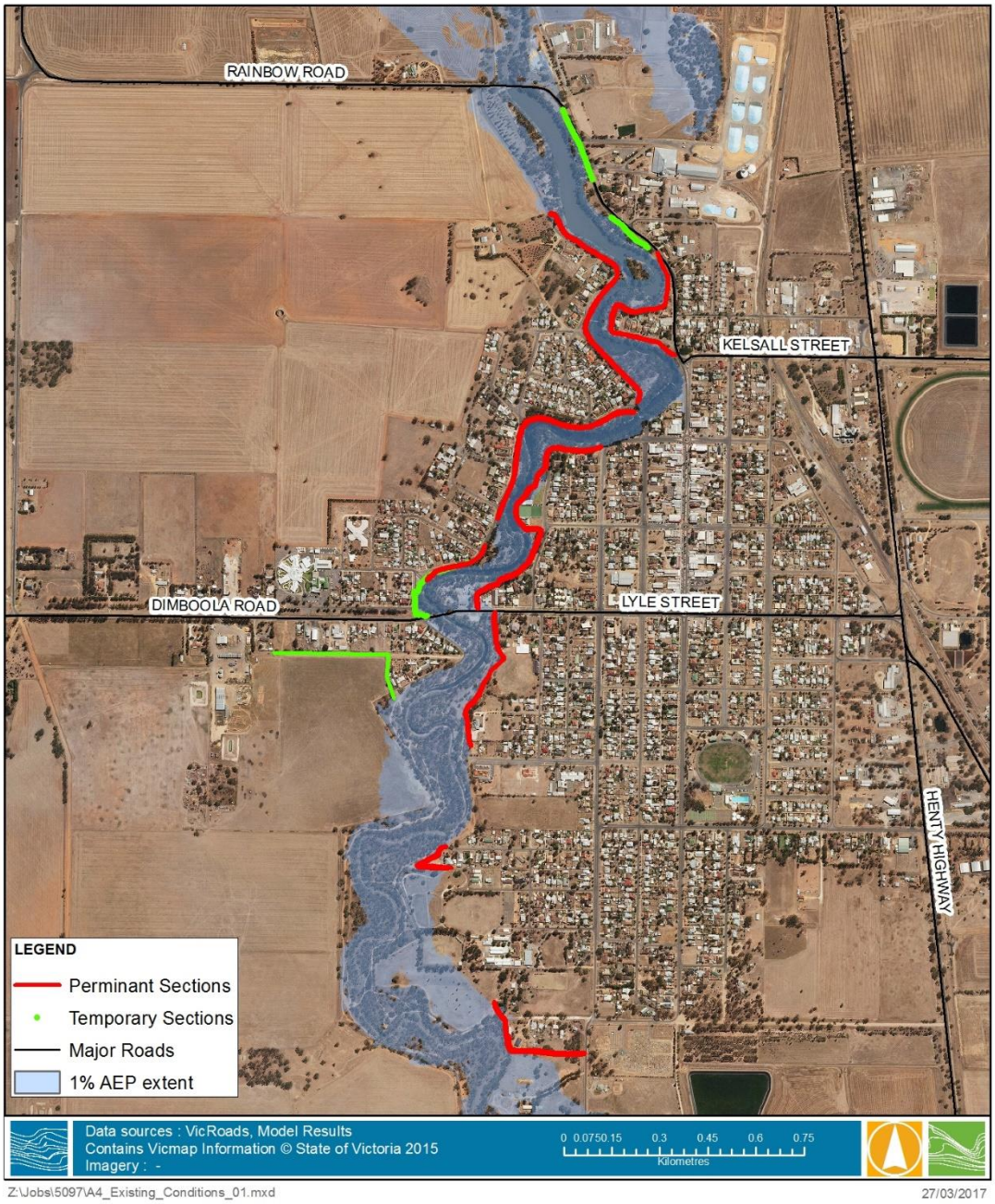
15 Business Park Drive
Notting Hill VIC 3168

Telephone (03) 8526 0800
Fax (03) 9558 9365

ACN No. 093 377 283
ABN No. 60 093 377 283

TABLE OF CONTENTS

LIST OF FIGURES



LIST OF TABLES

1. BACKGROUND

The township of Warracknabeal is in western Victoria on Yarriambiack Creek, within the Wimmera River catchment and Wimmera CMA management area. During high flows in the Wimmera River, flow is distributed to Yarriambiack Creek between Glenorchy and Horsham, near Longerenong.

The distribution of flood flows to Yarriambiack Creek has caused several large floods along the waterway and in the townships of Warracknabeal. The most recent of these was during January 2011. Other events large enough to cause flooding include 1909, 1981 and 1983. The January 2011 event was the largest historic event in living memory.

Prior to the January 2011 floodwaters arriving at Warracknabeal and Brim significant effort was put into the construction of earthen levees and sandbagging. These levees prevented significant damage to both townships, particularly in Warracknabeal where a large number of properties were protected from above floor inundation. Some of the levees constructed during January 2011 in both Warracknabeal and Brim remain in place; some have been moved and formally constructed and maintained by Yarriambiack Shire Council.

2. REPORT PURPOSE

The Warracknabeal and Brim Flood Investigation[1] was commissioned to increase the flood understanding and resilience for Warracknabeal and Brim and the Yarriambiack Creek floodplain. The investigations primary purpose was to ensure the community and government agencies are aware and prepared for future flood events. This involves improvements to flood intelligence and planning, recommendations to improved flood warning, and design of a levee system for the Warracknabeal township.

This report provides all the information required for a funding application to be submitted for finalising the final design and construction of the Warracknabeal levee.

3. FLOOD INVESTIGATION OVERVEIW

The Warracknabeal and Brim Flood Investigation was commissioned by Wimmera CMA and awarded to Water Technology, the study had numerous components and was thoroughly reviewed by Wimmera CMA, a project steering committee, the Warracknabeal community and the DELWP Technical Review Panel.

The project contained the following key outputs, each output has a short summary of key information:

- Site Visit, Inception and Data Collation Report – Detailing previous projects, available survey information, data gaps and any additional information required to complete the project.
- LiDAR Verification Memo – Assessment of the LiDAR datasets available, comparison to feature survey and determination of base topography data.
- Design Modelling - Remnant Levee Memo – Assessment of the remnant levee and design modelling intent.
- Hydrology and Hydraulics Report – Details of the base hydrology methodology (FFA at the Wimmera River at Glenorchy gauge and hydraulic model distribution), model calibration (January 2011 and September 2010) and design modelling.
- Flood Warning Assessment Report (Molino Stewart) – Assessment of existing flood warning arrangements and potential areas for improvement.

[1] Water Technology (2016), Warracknabeal and Brim Flood Investigation (Commissioned by Wimmera CMA)

- Flood Mitigation Report – Assessment of the proposed mitigation options, a proposed levee alignment, existing and mitigated damages assessment, approximate levee costs and a benefit cost analysis.
- Levee Engineering Design and Costing Memo (Price Merrett) – A detailed design and detailed costing of the Warracknabeal levee.
- Flood Intelligence Report – Flood response information ready for insertion to the Yarriambiack Shire Council MFEP.
- Planning Scheme Amendment Report (Planning and Environmental Design) – Information supporting a planning scheme amendment for Yarriambiack Shire Council along Yarriambiack Creek.

4. PROJECT CONSULTATION

A key element in the development of the Warracknabeal and Brim Flood Investigation was the active engagement of residents in the study area. This was also key to ensuring success in the final design and construction process. Extensive community engagement was undertaken throughout the project, including:

- Six community meetings, three in each of Warracknabeal and Brim.
- Newspaper articles and press releases before every community meeting
- Social media campaign, including a Facebook page to allowed residents to comment on proposed levee alignments.
- All project maps, draft reports and final reports were put on the Wimmera CMA and the Yarriambiack Shire Council web sites for the community to view and comment on throughout the project.
- Signs and pegs were placed along the levee alignment to advertising the height and location of the levee

The project team was supported by a steering committee comprised of members of the community, VicSES, Wimmera CMA, Yarriambiack Shire Council, Water Technology, the Victorian Water Monitoring Partnership and Bureau of Meteorology. Four steering committee meetings were held over the course of the project to communicate project progress, review outputs and receive guidance regarding mitigation options and community consultation.

Throughout the later stages of the project an additional the project steering committee and community group leaders where taken on a bus tour of the proposed levee alignment to discuss the height and possible construction arrangements of the levee.

In addition to advertising community meetings in local papers and on local radio, the project team constructed a Facebook site for this project, initially asking Warracknabeal if they want a levee, then later asking Warracknabeal if they approve the proposed Warracknabeal design. There was a significant number of community members commented on this site. There was a significant community response on the Facebook site. It was useful to see comments made by the community, they were pleased that a levee was constructed during the January 2011 flood event and were very supportive of building a levee in Warracknabeal.

All community meetings were supported by media releases to local papers and meeting notices advertising meetings well in advance. The following community meetings were held as part of the consultation process:

- Initial community meetings held in Brim on 3rd November 2014 and Warracknabeal on 20th November 2014. The first public meeting was held to outline the objectives of the study to

the community, communicate what the community can expect from the study and gather input from the community regarding observed inundation and potential mitigation solutions;

- Second community meetings held in Brim on 29th July 2015 and Warracknabeal on 30th July 2015. The second community meeting presented calibration results for the January 2011 and September 2010 events and outlined a list of potential flood mitigation options identified to date. Community feedback was sought on the flood modelling results and their preference/suggestions for additional flood mitigation options; and
- Third community meetings held in Brim on 11th July 2016 and Warracknabeal on 11th July 2016. The final public meeting presented the flood warning recommendations, planning scheme layers, Warracknabeal final levee design and project outcomes. Community feedback was sought on the levee design, location and appearance.

Additional to the formal community meetings, Yarriambiack Shire Council held informal 'drop in' sessions for members of the community to express their views on the levee in a more private setting. These were held on the 29th June 2016 and 6th July 2016 from 4-5pm.

In general, the Yarriambiack Creek community was very pleased with the rigour and outcomes of the Warracknabeal and Brim Flood Investigation. The Warracknabeal community was largely the focus of the proposed structural mitigation works due to the high flood consequence in the township. Wimmera CMA and Yarriambiack Shire Council provided extensive information on Facebook prior to the community meetings along with "drop in" sessions. During the final community meeting the only concerns raised were to do with the finer design features of the levee, colouring of concrete walls, gardens to make the levee look more natural etc.

A lot of effort and time was put into engaging the Yarriambiack Creek community about the proposed Warracknabeal levee. The Warracknabeal and Brim Flood Investigation project team were highly commended for the Floodplain Management Australia 2016 Excellence Award for the Flood Risk Management Project of the year for their extensive community consultation activities. The Warracknabeal and Brim Flood Investigation project extensive community consultation activities increased awareness of, and resilience to flood risks in the Yarriambiack community.

5. DESIGN FLOOD MODELLING

Design flood modelling was completed for events ranging from 0.5% AEP to 20% AEP. The 1% AEP flood event in event in Warracknabeal impacts 14 buildings above floor and 163 allotments with a building on them are inundated to some extent but are flooded below the floor level.

Figure 5-1 shows the 1% AEP extent of inundation and properties flooded above and below floor. Table 5-1 shows the number of buildings flooded above and below floor for the range of modelled flood events.

Table 5-1 Existing conditions damages over the Warracknabeal township

ARI (years) / AEP	200yr 0.5%	100yr 1%	50yr 2%	20yr 5%	10yr 10%	5yr 20%
Residential Buildings Flooded Above Floor	46	11	4	0	0	0
Commercial Buildings Flooded Above Floor	9	3	1	0	0	0
Properties flooded with a building on them	238	163	73	8	3	3
Total Properties Flooded	**293**	**177**	**78**	**8**	**3**	**3**

Figure 5-1 Yarriambiack Creek 1% AEP flood extent and impacted buildings at Warracknabeal

6. MITIGATION ASSESSMENT

6.1 Overview

During the Warracknabeal and Brim Flood Investigation[1] a broad range of structural mitigation options were developed during community meetings, Project Steering Committee meetings and general discussion with the study team. A prefeasibility assessment was conducted on the list of mitigation options, which narrowed down the options to be tested further in the hydraulic model. The mitigation options suggested were focused on reducing flood damages in Warracknabeal.

Given the number of mitigation options suggested the mitigation assessment was separated into four stages, these were as follows:

- Prefeasibility Assessment - to determine the potential for a mitigation option to reduce flood damage at reasonable cost and feasibility.
- Detailed Hydraulic Modelling Assessment - to determine what reduction in flood levels and extents could be achieved.
- Damages Assessment – to determine the reduction in damages that could be achieved by the chosen mitigation options.
- Benefit Cost Analysis – to compare the reduction in flood damage and costs of the chosen mitigation options over a period of time to assess the economic performance of the options.
- Concept design of the recommended mitigation option.

Based on the pre-feasibility assessment and conversations with the local community it was determined a levee system in Warracknabeal was the most feasible option to reduce flood damages in the township.

6.2 Concept Design

6.2.1 Overview

During concept design of the levee a range of variations were trialled before the optimum design was achieved. This option aimed to not negatively impact any private built assets in Warracknabeal while reducing the number of properties flooded above and below floor to as low as possible.

The combined mitigation package included levees in similar alignments to the temporary levees constructed during January 2011 with the following modifications:

- A levee protecting the industrial area north of Warracknabeal
- Modification to the levee protecting the Bowling Club
- Two private levees protecting the areas south of Warracknabeal

The concept levee design scenario and 1% AEP inundation extent is shown in Figure 6-1 with a comparison of the combined mitigation package and existing conditions water levels shown in Figure 6-2.

A water level comparison in Figure 6-2 was calculated by subtracting the existing conditions water level from the developed conditions water level as follows:

Difference = Modelled concept design water levels – Existing water levels

This results in positive values where the concept design modelled water levels are higher than existing (an increase in water levels), and negative values when the concept design modelled water levels are lower than existing (a decrease in water levels).

It is important to note under the adopted concept levee design no buildings are flooded above or below floor for a 1% AEP flood event

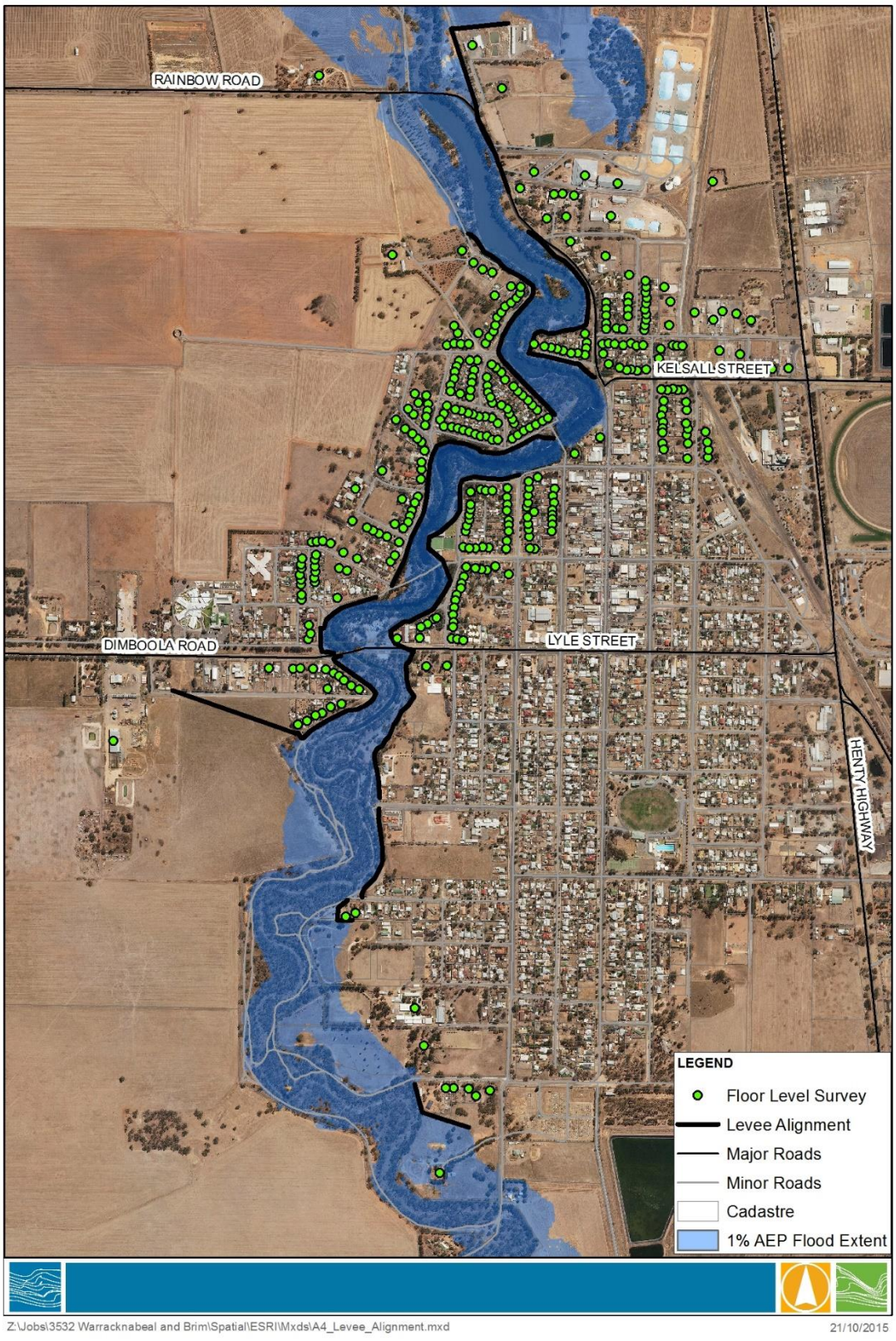


Figure 6-1 Inundation extent and levee alignments for the combined mitigation package

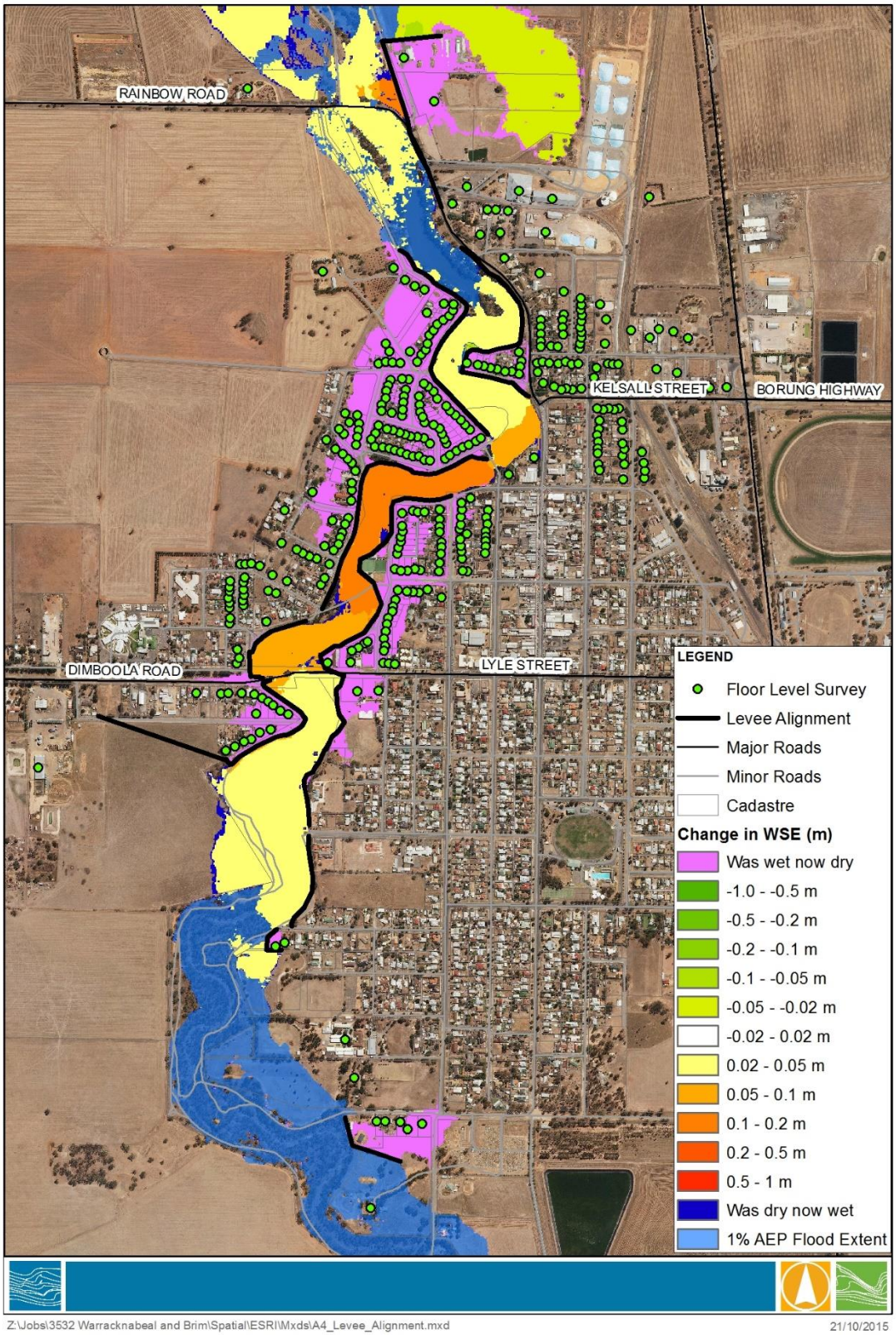


Figure 6-2 Change in water levels – Combined mitigation package vs existing conditions

6.2.2 Temporary and Permanent Levees

The Warracknabeal Levee comprises of 14 sections, 9 permanent sections and 5 temporary sections. As discussed previously, the sections of permanent levee were set at the 1% AEP flood level plus 0.1 m freeboard. The temporary sections of levee protect against a 0.5% AEP flood with the level of their construction preceding a flood dependent on the flood height predictions for Warracknabeal. Additionally, the permanent sections of levee would be increased to increase freeboard or design height if required with temporary measures such as sandbags or tipped earth on top of the levee. These actions are included will be included in the Yarriambiack Shire Council Municipal Flood Emergency Plan (MFEP)) on completion of the levee.

In sections of temporary levee it is suggested colour coded posts be installed indicating the height at which the levee should be constructed.

Details around each of the 14 levee sections are shown in Table 6-1, the temporary levee sections are highlighted in green. These sections are also mapped in Section

Table 6-1 Levee details

Levee Number	Length (m)	Max. Height (m) (including 100 mm freeboard on permanent sections)	Average Height (m)	Notes
1	230	0.9	0.5	Permanent earthen levee protecting 2 properties from below floor inundation
2	117	0.7	0.50	Permanent earthen levee protecting one shed from above floor inundation, township levees increase inundation at this location without protection
4	512	0.7	0.40	Permanent earthen levee, school levee exists at a sufficient height
5	825	1.0	0.5	Permanent earthen levee, potential for road level increases, very narrow at the rear of the bowling club
6	830	0.7	0.3	Permanent earthen levee, potential to build into existing road shoulder
7	150	0.3	0.2	Temporary earthen levee, only required for events greater than 1% AEP
8	237	0.5	0.20	Temporary earthen levee, only required for events greater than 1% AEP
9	445	1.2	0.5	Permanent earthen levee, currently partially constructed
10	727	0.8	0.5	Earthen levee/walking track

11	694	0.9	0.5	Permanent earthen levee, potential to use road median strip
12	450	1.0	0.5	Temporary earthen levee, only required for events greater than 1% AEP
13	470	0.8	0.4	Permanent earthen levee
14	541	0.4	0.1	Temporary earthen levee, only required for events greater than 1% AEP
Total Length of 6,228 m (4,123 m permanent/2,105 m temporary)				

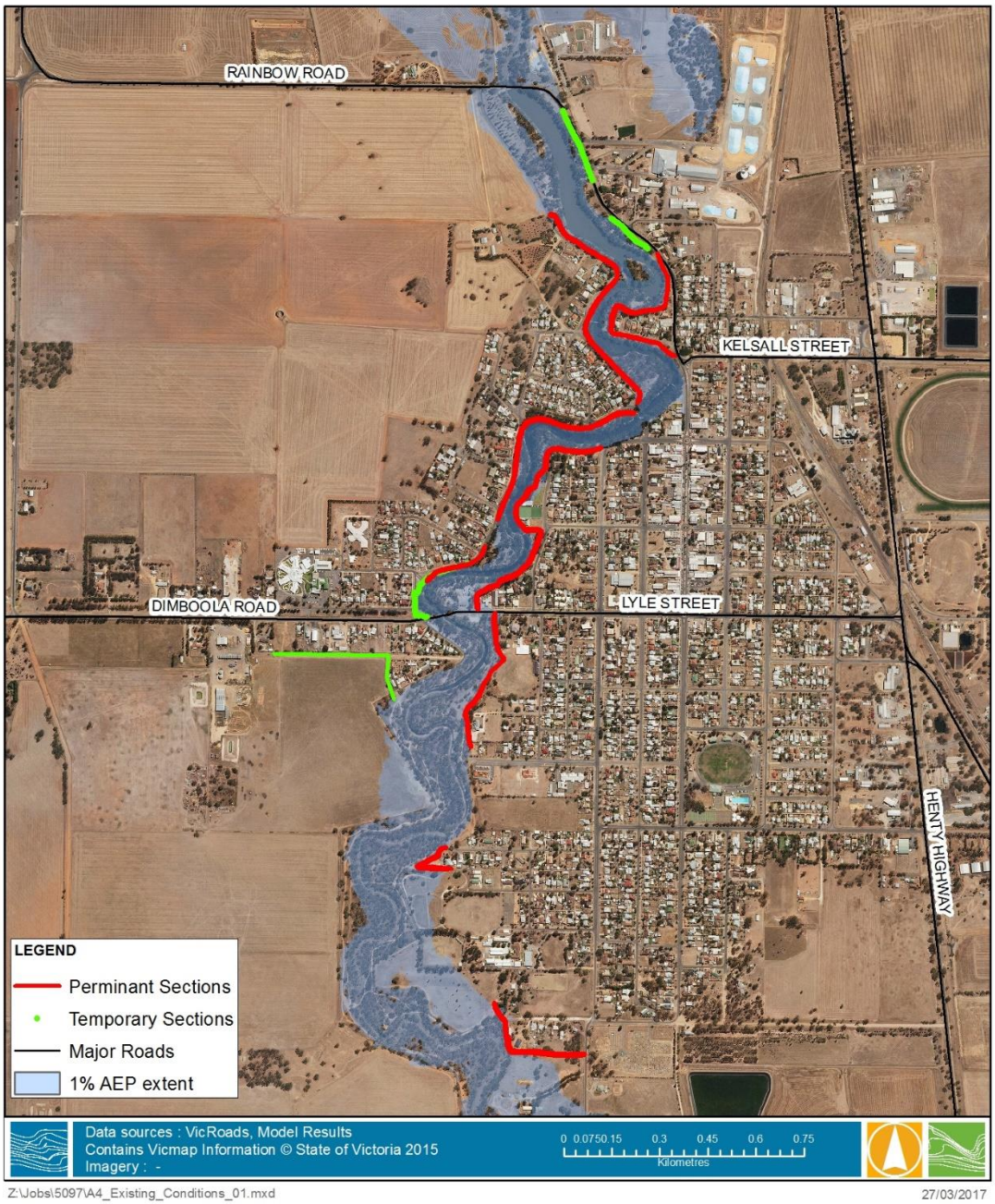


Figure 6-3 Detailed Design Components

Even if a 1% AEP flood event is expected, increasing the levee height to increase the available freeboard to above 0.1 m is recommended, an additional 0.2 m would increase the freeboard to 0.3 m.

The 0.5% AEP flood level is typically 0.2m higher than the 1% AEP flood level, therefore a 0.1 m increase to the levee height would correspond with the 0.5% AEP flood level, and a 0.4m increase would protect against the 0.5% AEP event with 0.3 m freeboard.

In areas where the levee is a concrete barrier, fill would be required behind the levee to increase its level of freeboard.

6.2.3 Assumptions and Design Constraints

The Warracknabeal Levee was designed using the Victorian Levee Management Guidelines[2]. However, during the levee design there were several design constraints that restricted the levee from meeting some items set out in the guidelines. These include:

- Freeboard – The Levee Management Guidelines specify a "General engineering practice is to provide a minimum freeboard allowance in urban areas of 600 mm". However, during community consultation it became apparent the community would not accept this level of freeboard due to the potential aesthetic impact the levee may cause and the reduction in waterway view residents along Yarriambiack Creek may have. Numerous options were discussed and proposed and a 100mm freeboard on the 1% AEP flood level was determined as the design level, with additional fill provision in the levee embankments that could be used to increase the levee height (and freeboard) when required.
- Temporary Levees – While the levee is designed to protect against a 1% AEP flood event, temporary increases in levee height and temporary sections of levee are also included in the design for a 0.5% AEP flood event. These sections are to be constructed prior to the flood event occurring (there is significant accurate warning time) and constructed as close as practically possible to the construction requirements outlined in the Levee Management Guidelines. All temporary sections of levee are on roads or paths allowing for easy construction.

[2] DELWP (2015), Victorian Levee Management Guildlines

6.3 Detailed design and costing

The permanent sections of the concept design were progressed to a detailed design by Price Merrett Consulting. During the detailed design process the levee was separated into several components, these included:

- Cemetery Road South (Levee 1) – Earthen levee
- Wood St (Levee 2) – Earthen levee
- School Levee (Levee 4) - Earthen levee
- Fong Tong Avenue (Levee 5) – Earthen levee, potential for road level increases
- Asquith Avenue (Levee 6) – Earthen levee, potential for road level increases
- Craig Avenue 01 (Levee 10) - Earthen levee
- Craig Avenue 02 (Levee 11) – Earth wall, potential for road level increases
- Craig Avenue 03 (Levee 12) – Earth wall, potential for road level increases
- McIntyre Street South (Levee 14) - Earthen levee
- McIntyre Street North (Levee 13) - Earthen levee
- The sections of levee are shown in Figure 6-4 describing the construction type and further detail around each component can be seen in the final levee design supplied with this report as a standalone design.

The detailed design has taken the following details into account:

- Vegetation removal requirements – The required vegetation removal has been factored into the design and is outlined in the design drawings. The cost of vegetation removal has also been included in the costing.
- Cultural Heritage – The levee is to be located on already disturbed ground with the excavation for the levee core considered relatively minor. A full Cultural Heritage Management Plan is not considered necessary given the low risk, however Yarriambiack Shire Council are advised to consider their own level of risk in consultation with Aboriginal Victoria using their Heritage Tools[3].
- Local drainage – Localised drainage has been allowed in the levee design through the use of one way valves, preventing backflow through the stormwater system, and the provision of sandbagging around any required drainage pits.
- Services – During the levee design feature survey was completed ensuring all services were avoided or the interaction between the levee and the services was minimised.
- Vehicle access – Vehicle access through the levee during non-flood times has been allowed by using temporary sections of levee. These temporary sections will be filled prior to a flood event and with recommendations to be included in the Yarriambiack Shire Council Municipal Flood Emergency Plan (MFEP).

[3] http://www.vic.gov.au/aboriginalvictoria/heritage/heritage-tools-and-publications/heritage-tools.html

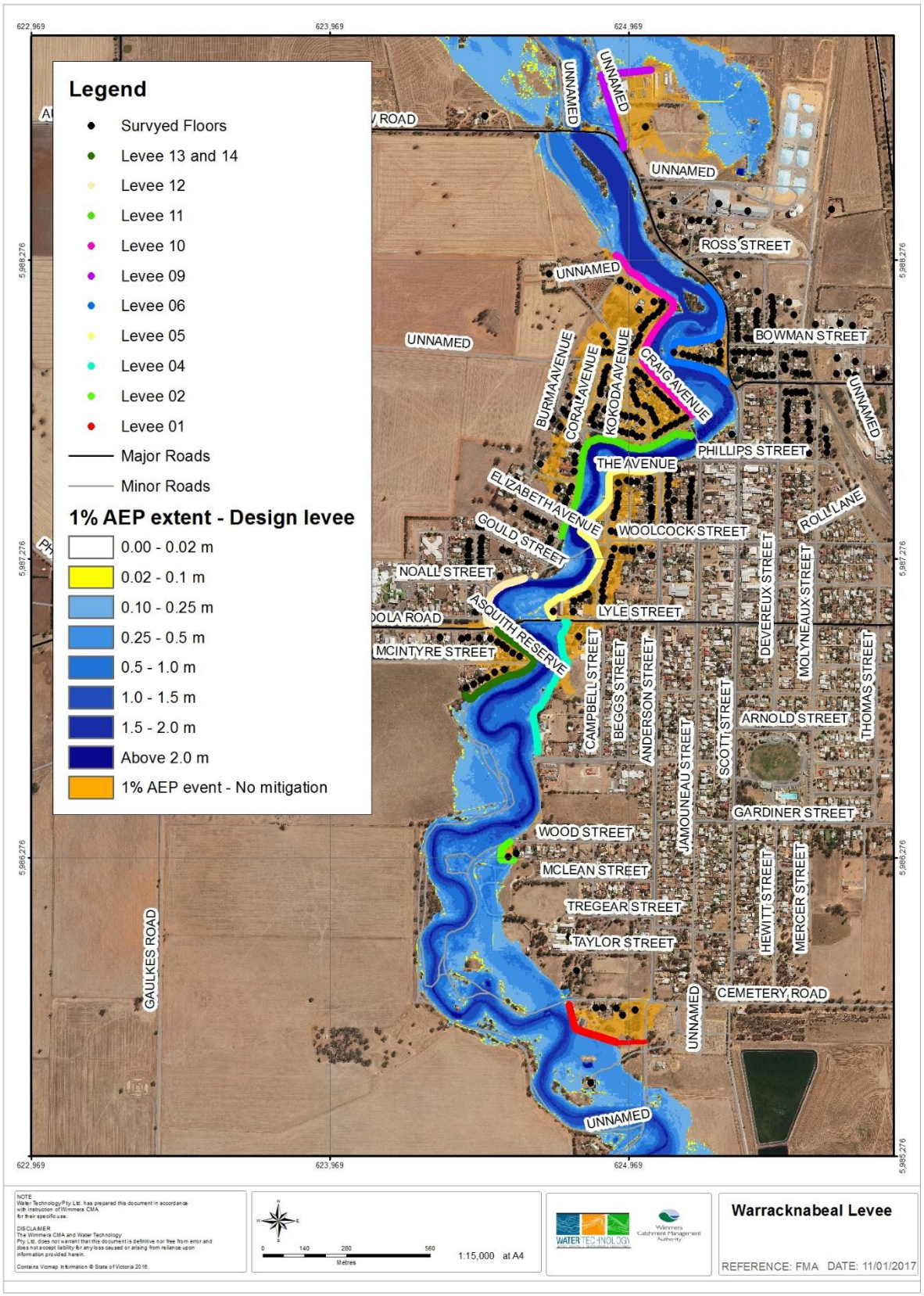


Figure 6-4 Detailed Design Components

The cost of each of these sections was determined by Price Merrett Consulting and is outlined in Table 6-2, Yarriambiack Shire Council have expressed interest in increasing the height of Craig Avenue, the potential costs have been added to the McIntyre Street, Lyle Street North and Craig Avenue and Gould St North levees in a separate column in Table 6-2.

The total cost of the levee is estimated at $596,000 without road level increases and $841,000 including these costs.

Table 6-2 Detailed design costing

Levee section/cost description	Levee Cost	Levee cost with road level increases
General site establishment, management survey	$43,000	$43,000
Cemetery Road South (Levee 1)	$99,000	$99,000
Wood St (Levee 2)	$13,000	$13,000
School Levee (Levee 4)	$37,000	$37,000
Fong Tong Avenue (Levee 5)	$133,000	$228,000
Asquith Avenue (Levee 6)	$74,000	$74,000
Craig Avenue 01 (Levee 10)	$98,000	$98,000
Craig Avenue 02 (Levee 11)	$58,000	$172,000
Craig Avenue 03 (Levee 12)	$10,000	$46,000
McIntyre Street South (Levee 14)	$16,000	$16,000
McIntyre Street North (Levee 13)	$15,000	$15,000
Total	**$596,000**	**$841,000**

With the inclusion of a 9% administration fee and 20% contingency the estimated cost without road level increases is $768,000, with the inclusion of road level increases this reaches $1,084,000, Table 6-3.

The cost of levee maintenance was calculated based on the current parks and gardens maintenance budget with a small increase of $3,000 for the standard levee and $2,000 with road level increases, due to the reduction in levee to be maintained.

Table 6-3 Additional levee costs

Cost Description	Standard Levee	Road Level increases
Estimated cost	$596,000	$841,000
Cost x Administration Fee @ 9%	$54,000	$76,000
Sub-total	$649,000	$916,000
Cost x Contingencies @ 20%	$119,000	$168,000
FORECAST CAPITAL EXPENDITURE	**$768,000**	**$1,084,000**
ANNUAL MAINTENANCE ALLOWANCE	**$3,000**	**$2,000**

7. FLOOD DAMAGES

7.1 Overview

A flood damage assessment for the study area was undertaken using the range of design events modelled (20%, 10%, 5%, 2%, 1% and 0.5% AEP design events) for existing conditions (i.e. with current remnant levees). The damage assessment was used to determine the monetary flood damage for the design floods.

The flood damage assessment was also undertaken for Combined Option 01, the recommended mitigation package.

Water Technology has developed an industry best practice flood damage assessment methodology that has been previously utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD and other relevant flood damage literature. The NSW Office of Environment and Heritage stage damage curves are utilised, which represent far superior damage estimates at low depths above floor and below floor than earlier stage damage curves. Water Technology utilises WaterRide to undertake the property inspection and apply the appropriate stage damage curves.

The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. In addition to the flood affected properties, lengths and damages of flood affected roads and bridges for each event were also calculated.

The Average Annual Damage (AAD) was determined as part of the flood damage assessment. The AAD is a measure of the flood damage per year averaged over an extended period. This is effectively a measure of the amount of money that must be put aside each year in readiness for when a flood may happen in the future.

The AAD was calculated for the entire study area and within Warracknabeal township alone. This enables the modelled mitigation options for Warracknabeal to be compared to the existing conditions damages in the township alone rather than including the broader study area agricultural damages etc.

The damages assessment shows a slightly different number of buildings flooded above and below floor to that documented in the Flood Intelligence Report and previous discussion of the number of buildings flooded above floor. This is due to the removal of sheds (unless commercial) and the counting of multiple buildings on one allotment. The damages estimates are an assessment of the average monetary damage with ancillary buildings included in these averages. The Flood Intelligence Report includes these buildings because they are significant for flood response.

7.2 Existing conditions

The flood damage assessment for existing conditions within the Warracknabeal township is shown below in Table 7-1. The Average Annual Damages (AAD) for existing conditions is estimated at approximately **$45,000.**

Table 7-1 Existing conditions damages over the Warracknabeal township

ARI (years) AEP	200yr 0.5%	100yr 1%	50yr 2%	20yr 5%	10yr 10%	5yr 20%
Residential Buildings Flooded Above Floor	46	11	4	0	0	0
Commercial Buildings Flooded Above Floor	9	3	1	0	0	0
Properties Flooded Below Floor	238	163	73	8	3	3
Total Properties Flooded	**293**	**177**	**78**	**8**	**3**	**3**
Direct Potential External Damage Cost	$857,000	$455,000	$148,000	$13,000	$5,000	$3,000
Direct Potential Residential Damage Cost	$2,365,000	$560,000	$181,000	$0	$0	$0
Direct Potential Commercial Damage Cost	$441,000	$15,000	$1,000	$0	$0	$0
Total Direct Potential Damage Cost	**$3,663,000**	**$1,030,000**	**$331,000**	**$13,000**	**$5,000**	**$3,000**
Total Actual Damage Cost *(0.8*Potential)*	**$2,930,000**	**$824,000**	**$265,000**	**$10,000**	**$4,000**	**$2,000**
Infrastructure Damage Cost	**$441,000**	**$298,000**	**$195,000**	**$73,000**	**$58,000**	**$50,000**
Total Cost	**$3,371,872**	**$1,121,845**	**$459,806**	**$83,641**	**$62,308**	**$52,449**

Average Annual Damage (AAD)	**$45,000**

7.3 Mitigation Design

The Warracknabeal levee comprises of a series of levees either side of Yarriambiack Creek ensuring water is held within the waterway. The levees prevent all above floor and below floor inundation within the township during the 1% AEP event.

The flood damage assessment for the Combined Mitigation Package within the Warracknabeal township is shown below in Table 7-2. The Average Annual Damages (AAD) for existing conditions is estimated at approximately **$9,000.** The number of properties flooded below floor is indicative of properties with inundation within their property boundaries, during this assessment damage is attributed to property if it is inundated without regard to the slope or size of the allotment.

Table 7-2 Combined Mitigation Package damages over the Warracknabeal township

ARI (years) AEP	200yr 0.5%	100yr 1%	50yr 2%	20yr 5%	10yr 10%	5yr 20%
Residential Buildings Flooded Above Floor	0	0	0	0	0	0
Commercial Buildings Flooded Above Floor	1	1	0	0	0	0
Properties Flooded Below Floor	24	19	15	5	0	0
Total Properties Flooded	**25**	**20**	**15**	**5**	**0**	**0**
Direct Potential External Damage Cost	$93,000	$47,000	$29,000	$0	$0	$0
Direct Potential Residential Damage Cost	$0	$0	$0	$0	$0	$0
Direct Potential Commercial Damage Cost	$19,555	$7,452	$0	$0	$0	$0
Total Direct Potential Damage Cost	**$112,594**	**$54,743**	**$28,000**	**$00**	**$0**	**$0**
Total Actual Damage Cost *(0.8*Potential)*	**$90,000**	**$44,000**	**$22,000**	**$0**	**$0**	**$0**
Infrastructure Damage Cost	**$221,000**	**$175,000**	**$137,000**	**$77,000**	**$0**	**$0**
Total Cost	**$311,000**	**$219,000**	**$159,000**	**$77,004**	**$0**	**$0**

Average Annual Damage (AAD)	**$9,000**

8. BENEFIT-COST ANALYSIS

A benefit-cost analysis was undertaken to assess the economic viability of the levee design. An indicative benefit-cost ratio was based on the detailed design construction cost estimates, Average Annual Damages calculated above and the annual maintenance cost.

The results of the benefit-cost analysis are shown below in Table 8-1 for both a standard levee option and the alternative option to raise the height of Craig Avenue. For this analysis, a net present value model was used, applying a 6% discount rate over a 30 year project life. The benefit-cost ratio should ideally be equal to or greater than 1, meaning that the long term benefit of flood mitigation equals or exceeds the long term costs.

Table 8-1 Benefit Cost Analysis – Including temporary levee

	Existing Conditions	Standard levee	Standard levee plus road level increases
Average Annual Damage	$45,000	$9,000	$9,000
Annual Maintenance Cost	-	$3,000	$2,000
Annual Cost Savings	-	$33,000	$34,000
Net Present Value	-	$464,059	$478,122
Cost of permanent mitigation		$768,051	$1,084,000
Benefit-Cost Ratio	**-**	**0.60**	**0.44**

9. SUMMARY

During January 2011 the Warracknabeal community prevented inundation of their township through extraordinary effort and single minded determination. The community constructed more than 6 km of earthen levee to protect their township working 24 hours a day with largely volunteer labour. There were numerous risks associated with construction of the levee including the potential for over topping and the quality of construction and materials, however the levee withstood the flood and protected the township.

A permanent levee, appropriately designed and constructed, will provide the Warracknabeal community with peace of mind that they will not be forced to construct a similar temporary levee again and it will significantly reduce the risk of failure. The community are overwhelmingly supportive of a permanent solution and allowing the responsibility for protection to be managed by government authorities.

Funding the standard levee has a benefit-cost ratio of 0.6, with the addition of raising a road to form part of the levee (which is Council's preference) reducing the benefit-cost ratio to 0.44. While these ratios are not above 1, they do not reflect the potential emotional damage caused by flooding on individual and community levels. They probably do not reflect the level of community volunteer labour and material cost that would be incurred if a permanent solution is not built and community intervention is again required.

Several townships in regional Victoria suffered inundation during January 2011 and they have struggled to cope on both a financial and emotional level. The Warracknabeal community were able to save their township and as a result there is a sense of resilience and strength. Funding a permanent levee would provide them with piece of mind they have protection without the need for a huge amount of temporary work and verification their effort and input to the permanent design has been taken seriously by government.

If a similar size flood was to occur again without a permanent levee, it is highly likely temporary levees would be constructed and the Warracknabeal community would be faced with a similar risk of levee failure, and Government would be left with the cost of removing the temporary levee which is also not included in the benefit-cost analysis.

Construction of a permanent levee in Warracknabeal will significantly reduce the flood risk for a community which is united in its support for this levee to be implemented.

Great report. Did you have any references? Can there be some discussion about what council can do if there is a flood over a 1% AEP? Are there works that can be done to ensure the Temp levee sections are less likely to fail. Within the report can you mention policy for vegetation offset requirements and cultural heritage assessment requirements. Has the levee design been completed in accordance with DELWP Levee Management Guidelines? Please mention standards used.