1. REPORT OF THE NARROMINE FLOODPLAIN MANAGEMENT COMMITTEE

Author	Director Infrastructure and Engineering Services
Responsible Officer	Director Infrastructure and Engineering Services

Executive Summary

This report provides the attachment referred to in the minutes of the Narromine Floodplain Management Committee.

Report

The attachment referred to in the Floodplain Management Committee minutes as referenced in Item No. 2 of the Reports of Committees Report is attached for consideration (***See Attachment No. 1***).

Andre Pretorius
Director Infrastructure and Engineering Services

PROGRESS REPORT No. 1

Following is a brief summary of progress up until the end of June 2020.

Inception Meeting and Site Inspection

- The Inception Meeting was held at Council Chambers on Monday 3 February 2020. Site inspections were also undertaken on 3 February 2020.

Data Collection

- A review has been undertaken of the following studies:
  - *Narromine Flood Behaviour Study* (Bewsher, 1998)
  - *Narromine Flood Study* (Lyall & Associates, 2009a)
  - *Narromine Floodplain Risk Management Study and Plan* (Lyall & Associates, 2009b)
  - *Narromine River Bank Levee Feasibility Study* (Lyall & Associates, 2012) Draft Report
  - *Narromine River Bank Levee Feasibility Study* (Lyall & Associates, 2013)
  - *Review of Narromine Flood Studies* (BMT WBM, 2018)
  - *Narromine Town Levee Concept Design* (SMEC, 2019)
- Council provided GIS data on the current land zoning in Narromine, as well as information on sewer and water infrastructure.
- Annual maximum stream flow and water level data for both the *Macquarie River at Narromine* (Gauging Station (**GS**) 421006) and *Macquarie River at Baroona* (GS 421127) stream gauges (**Narromine and Baroona stream gauges**) were extracted from the WaterNSW's Pinneena database, as well as from its website. Peak flow and water level data presented in Bewsher, 1998 were also relied upon in part for the present study. **Table A1** in **Annexure A** of this progress report lists the available annual maximum stream flow and water level data for the period 1901 to 1919.
- A review of BMT WBM, 2018 shows that the Narromine stream gauge was originally located a distance of about 970 m upstream of the Eumungarie Road bridge adjacent to Rotary Park (**Town gauge**) and was later shifted about 2.1 km downstream to the weir in about 1942 (**Weir gauge**). The current stream gauge was installed on the right (eastern) abutment of the Eumungarie Road bridge in about 1953 (**Bridge gauge**).
- A review of Bewsher, 1998 identified that there is a discrepancy between the nominated peak flood levels for the April 1950 and February 1955 floods, as contemporaneous newspaper articles quote the official gauge reader at the time as stating that the recorded gauge heights for the two floods were 47 feet 10 inches (or 14.58 m) and 51 feet 4.5 inches (or 15.66 m). The peak flood level given by the official gauge reader at the time is almost identical to the time-based peak flood level data which is contained on Pinneena, a copy of which is contained in **Annexure B** of this progress report. It is noted that BMT WBM, 2018 attributes the gauge reading of 15.66 m for the February 1955 flood to the Town gauge.

Community Consultation

- Council distributed approximately 1,672 *Community Newsletters* and *Questionnaires* to residents and business owners in April 2020.
- A total of 143 responses were received (a response rate of about 9 per cent), 133 were residents, several of whom also run businesses in Narromine.
- **Appendix A** attached to this progress report deals with the responses to the *Community Questionnaire*.

Updated Hydraulic Model

- The two-dimensional (in plan) hydraulic model that was developed as part of Lyall & Associates, 2013 was updated to include additional LiDAR survey data that extended further to the south and east of Narromine.
- The blocking effects of individual buildings were taken into account by assigning an artificially high Manning's n value to each structure.
- The updated hydraulic model was recalibrated to flood marks that were recorded during the August 1990 and December 2010 flood events.
- The recalibrated hydraulic model was also run for conditions that are thought to be representative of those at the time of the February 1955 flood (e.g. a peak flow of 5,600 m^3/s, the Main Western Railway lowered by 300 mm and the river in its "hydraulically smooth" condition).
- **Figures 2.4**, **2.5** and **2.6** show the indicative extent and depth of the February 1955, August 1990 and December 2010 floods as derived by the recalibrated hydraulic model, respectively while **Figure 2.7** shows the water surface profiles along the Macquarie River for the three historic floods. Included on **Figure 2.7** is the Town, Weir and Bridge gauges, noting that the gauge zero on the two historic gauges has been derived based on the *Water Datum*, the conversion to Australian Height Datum for which is as follows:

  Gauge Zero (m AHD) = (Gauge Zero (feet/inches) + 1.7') x 0.3048 – 0.05

  WaterNSW has been attempting to identify the correct datum conversion as the information contained on Pinneena states that the datum in 1907 was surveyed to "WCDatum" (which is assumed to mean *Water Conservation Datum*) and in 1949 to "NWWCD" (which is understood to mean *North-West Water Conservation Datum*). By inspection of the modelled water surface profile for the February 1955 flood it would appear that the adopted *Water Datum* may be the same or similar to the *Water Conservation Datum* and *North-West Conservation Datum* as the modelled February 1955 flood level is close to the official gauge reading of 15.66 m on the Town gauge.
- **Table C1** in **Annexure C** of this progress report provides a comparison of recorded versus modelled peak flood levels for the February 1955, August 1990 and December 2010 floods.

Updated Flood Frequency Analysis

- The flood frequency analysis that was undertaken as part of Lyall & Associates, 2013 was updated to include an additional seven years of peak flow data. The latest approach to undertaking flood frequency analyses was implemented, with the result that information relating to the two large floods that occurred in 1955 and 1956 (i.e. prior to the construction of Burrendong Dam) were able to be taken into account. **Figure 2.8** shows the lines of best fit that were fitted to the available stream flow record.

- **Table 1** provides a comparison of design peak flows that were derived for Narromine as part of previous studies, as well as the present study.
- The key finding of the updated flood frequency analysis was that the design peak flow estimates for Narromine are largely unchanged to those derived as part of Lyall & Associates, 2013.

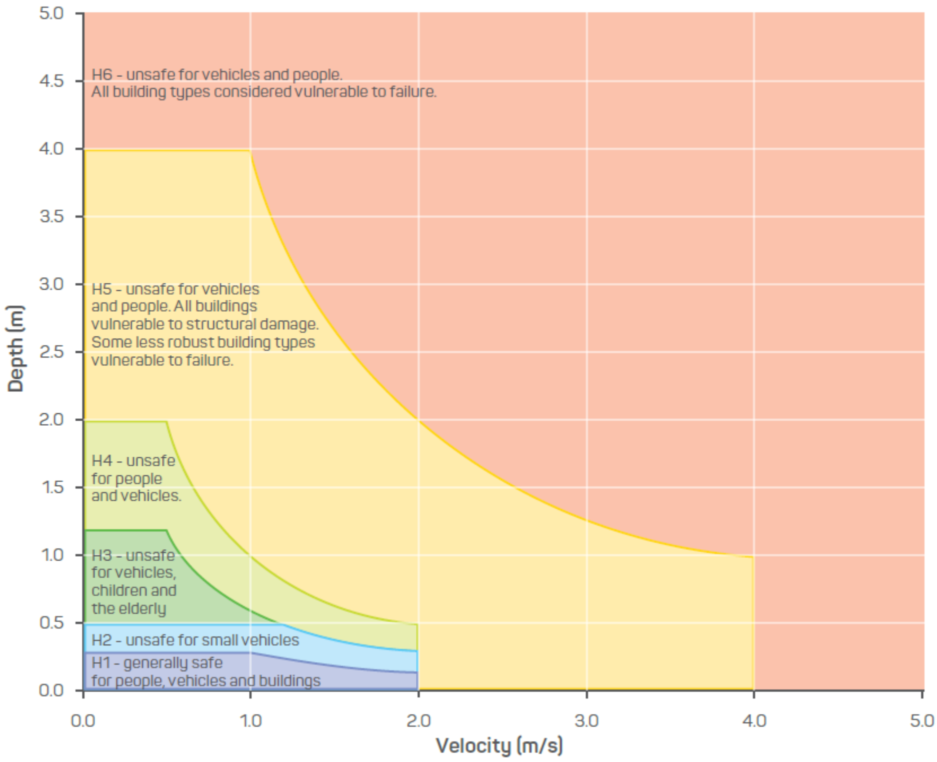
TABLE 1
FLOOD FREQUENCY DERIVED DESIGN PEAK FLOWS AT NARROMINE(3)
(m^3/s)

Annual Exceedance Probability (% AEP)	Bewsher, 1998	Lyall & Associates, 2013	Present Study
20	-	-	600
10	1,000	-	1,000
5	1,500	1,600	1,600
2	2,600	2,700	2,700
1	3,800	3,900	3,900
0.5	5,600	5,800	5,600
0.2	-	-	9,000

1. Values have been rounded to the nearest 100 m^3/s.

Updated Design Flood Modelling – Present Day Floodplain Conditions

- The updated hydraulic model was run for floods with Annual Exceedance Probabilities (**AEPs**) of 5%, 2%, 1% and 0.5%, as well as the Extreme Flood which was assumed to have a peak flow five (5) times the peak 1% AEP flood event (i.e. 5 x 3,900 = 19,500 m^3/s).
- **Figures 2.9** to **2.13** show the indicative extent and depth of inundation for the five modelled design flood events, while **Figure 2.14** shows design water surface profiles along the Macquarie River at Narromine.
- **Figure 2.15** shows the indicative extent of inundation relating to the abovementioned five design flood events, as well as the location of vulnerable development and critical infrastructure in Narromine.
- **Figure 2.16** shows the potential impact an increase in the peak 1% AEP flow associated with future climate change could have on flood behaviour in Narromine.
- **Figure 2.17** shows the flood hazard vulnerability classification for Narromine based on a 1% AEP flood event and the definitions contained in the document entitled "*Managing the Floodplain: A Guide to Best practice in Flood Risk Management in Australia"* (Australian Institute for Disaster Resilience (**AIDR**), 2017). The illustration over the page is taken from AIDR, 2017 and shows the relationship between depth and flow velocity that has been used to define the six flood hazard vulnerability zones for Narromine. The flood hazard vulnerability classifications will form the basis for updating Council's current flood policy for Narromine.
- **Figure 2.18** shows the extent of floodway, flood storage and flood fringe areas in Narromine based on the 1% AEP flood event.



Updated Flood Damages

- The damages that would be experienced in Narromine for floods of varying magnitude were first assessed as part of Lyall & Associates, 2009b and later updated as part of the present study. **Table 2** over sets out the total flood damages that would be experienced in Narromine for floods ranging between 20% AEP and the Extreme Flood.[1]
- The key findings of the flood damages assessment were as follows:
    - While the threshold of above-floor flooding for residential type development is a 2% AEP flood, large-scale flood damages are not experienced in Narromine until the southern bank of the river is overtopped during a slightly larger flood event.
    - The maximum depth of above-floor inundation in the worst affected properties would increase from about 1.3 m during a 1% AEP flood event, increasing to about 4 m in the Extreme Flood.
    - The *Present Worth Value* of damages for all flood events up to the 1% AEP flood based on the nominal set of peak flood levels is about $3.5 Million for a discount rate of 7% pa and an economic life of 50 years. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Narromine for all flood events up to this level.[2] While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.
- **Appendix B** attached to this progress report provides background to the flood damages assessment that was undertaken as part of the present study.

[1] Flood damages are based on the nominal design flood levels that have been derived as part of the present study and do not include any allowance for freeboard.

[2] The *Present Worth Value* of damages saved by the construction of a river-bank levee would be greater due to it preventing damages from being incurred during floods larger than 1% AEP.

TABLE 2
FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Residential			Commercial/ Industrial			Public			Total Damages ($ Million)
	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)	Number of Properties		Damages ($ Million)	
	Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		Flood Affected	Flood Above Floor Level		
20%	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0
5%	0	0	0	0	0	0	0	0	0	0
2%	10	2	0.27	0	0	0	0	0	0	0.27
1%	747	449	43.32	111	72	3.30	10	7	3.07	49.69
0.5%	1310	1126	108.31	153	138	11.93	24	17	5.71	125.95
0.2%	1512	1446	201.94	168	159	30.10	26	26	12.25	244.29
Extreme	1659	1655	314.53	176	175	78.46	27	27	23.77	416.76

Updated River Bank Levee Assessment

- Details of Levee Option B which was progressed to concept design stage as part of SMEC, 2019 were incorporated in the updated hydraulic model, as were three alternative alignments which have been denoted B1, B2 and Ha. **Figure 3.1** shows the alignment of the four levee options which were assessed as part of the present study, while **Figure 3.2** is a long section along each.
- **Figures 3.3** to **3.6** show the impact that the construction of the four alternative levee options would have on flood behaviour for a 1% AEP flood event.
- The third-party related impacts associated with the construction of the river bank levee was of major concern to the owners of residential properties that are located on Warren Road. The Chairman of the *Narromine Irrigation Board of Management* also raised concerns regarding the impact that the change in flow regime would have on its infrastructure.

  As the Main Western Railway presently obstructs floodwater which naturally breaks out of the Macquarie River at the location of Webbs Siding from discharging to the south of Narromine, an assessment was undertaken to determine whether reinstating the natural flow path at this location would offset the third-party related impacts associated with the construction of the river bank levee.

  Figures 3.7 to **3.10** show that the impact that the construction of the river bank levee in combination with the upgrade of the railway culverts at Webb Siding would have on flood behaviour in Narromine.

  The investigation found that only Option B1 in combination with the rail culvert upgrade would remove the third-party related impacts associated with the construction of the river bank levee. While impacts are shown to occur along the Backwater Cowal, these are relative to what would happen during a 1% AEP flood under current floodplain conditions.

ANNEXURE A

TABLE A1
ANNUAL SERIES OF MAXIMUM GAUGE HEIGHTS AND PEAK FLOWS
MACQUARIE RIVER AT NARROMINE 1901-2019

Year	Gauge Height (m)		Gauge	Peak Flow (m^3/s)	
	Bewsher, 1998	Pinneena		Bewsher, 1998	Pinneena
1901	5.69		Unknown	399	No Record
1902	2.64		Unknown	116	No Record
1903	5.11		Unknown	479	No Record
1904	4.88		Unknown	319	No Record
1905	4.42		Unknown	299	No Record
1906			Unknown	9.6	No Record
1907			Unknown	181	No Record
1908			Unknown	156	No Record
1909			Unknown	227	No Record
1910	9.14		Unknown	906	No Record
1911			Unknown	841	No Record
1912	5.89		Unknown	488	No Record
1913	4.11		Unknown	133	No Record
1914	3.35	3.35	Town	181	No Record
1915	5.18	5.21	Town	354	No Record
1916	9.75	9.75	Town	894	No Record
1917	7.16	7.16	Town	580	No Record
1918	2.67	4.88	Town	319	No Record
1919	2.13	2.13	Town	90	No Record
1920	14.17	14.17	Town	2211	No Record
1921	10.36	10.36	Town	991	1331
1922	9.45	9.45	Town	1133	1136
1923	7.01	6.78	Town	563	653
1924	8.08	7.72	Town	609	812
1925	4.65	4.72	Town	252	356
1926	14.15	14.16	Town	2211	1628
1927	No Record	4.83	Town	No Record	370
1928	9.04	9.04	Town	1058	1057
1929	2.90	2.90	Town	164	164
1930	6.71	6.71	Town	640	640
1931	12.19	13.41	Town	1736	1600
1932	3.38	3.38	Town	206	206
1933	3.20	3.20	Town	190	190
1934	10.87	11.35	Town	1124	1564
1935	4.11	4.12	Town	284	283
1936	7.92	8.23	Town	906	906
1937	2.21	2.74	Town	145	144

Cont'd Over

TABLE A1 (CONT'D)
ANNUAL SERIES PEAK FLOWS
MACQUARIE RIVER AT NARROMINE 1901-2019

Year	Gauge Height (m)		Gauge	Peak Flow (m^3/s)	
	Bewsher, 1998	Pinneena		Bewsher, 1998	Pinneena
1938	1.80	1.80	Town	72	72
1939	3.96	3.96	Town	266	266
1940	1.57	1.60	Town	58	57
1941	12.22	No Record	Town	1296	No Record
1942	11.89	11.89	Weir	1505	1620
1943	6.86	6.86	Weir	666	664
1944	0.66	2.16	Weir	23	9
1945	7.14	9.17	Weir	994	1081
1946	0.91	2.36	Weir	62	29
1947	3.45	No Record	Weir	376	No Record
1948	No Record	No Record	Weir	No Record	No Record
1949	4.52	No Record	Weir	541	No Record
1950	14.86(1)	No Record	Weir	2314	No Record
1951	9.75	9.75	Town	1084	1158
1952	13.23	13.23	Town	1644	2148
1953	4.80	4.80	Bridge	278	278
1954	8.53	8.59	Bridge	784	754
1955	14.94(2)	15.65	Bridge	5800	No Record
1956	14.66	14.66	Bridge	4444	3369
1957	2.26	2.26	Bridge	37	48
1958	6.53	6.53	Bridge	512	507
1959	12.78	12.78	Bridge	1609	1479
1960	11.18	11.18	Bridge	1133	1151
1961	6.43	6.43	Bridge	499	495
1962	6.27	6.27	Bridge	481	478
1963	5.46	5.46	Bridge	385	388
1964	7.54	7.54	Bridge	649	622
1965	No Record	2.64	Bridge	No Record	84
1966	3.38	3.38	Bridge	145	165
1967	3.18	3.18	Bridge	82	143
1968	3.38	3.38	Bridge	145	165
1969	10.29	10.29	Bridge	1032	1001
1970	6.10	6.10	Bridge	464	459
1971	13.16	13.08	Bridge	1829	1574
1972	5.08	4.78	Bridge	311	314
1973	8.84	8.84	Bridge	838	787
1974	7.16	7.16	Bridge	633	630

Cont'd Over

TABLE A1 (CONT'D)
ANNUAL SERIES PEAK FLOWS
MACQUARIE RIVER AT NARROMINE 1901-2019

Year	Gauge Height (m)		Gauge	Peak Flow (m^3/s)	
	Bewsher, 1998	Pinneena		Bewsher, 1998	Pinneena
1975	3.04	3.02	Bridge	123	126
1976	8.40	8.40	Bridge	778	783
1977	3.00	3.01	Bridge	117	114
1978	No Record	4.86	Bridge	663	358
1979	No Record	No Record	Bridge	117	No Record
1980	No Record	No Record	Bridge	51	No Record
1981	5.84	No Record	Bridge	475	No Record
1982	3.62	No Record	Bridge	207	No Record
1983	No Record	No Record	Bridge	156	No Record
1984	7.72	No Record	Bridge	697	No Record
1985	No Record	No Record	Bridge	211	No Record
1986	No Record	No Record	Bridge	161(3)	No Record
1987	No Record	No Record	Bridge	122(3)	No Record
1988	No Record	No Record	Bridge	198(3)	No Record
1989	No Record	No Record	Bridge	281(3)	No Record
1990	13.48	No Record	Bridge	2078(3)	No Record
1991	No Record	No Record	Bridge	148(3)	No Record
1992	No Record	No Record	Bridge	514(3)	No Record
1993	No Record	No Record	Bridge	373(3)	No Record
1994	No Record	No Record	Bridge	76(3)	No Record
1995	No Record	No Record	Bridge	286(3)	No Record
1996	No Record	No Record	Bridge	453(3)	No Record
1997	Post-Dates Study	No Record	Bridge	Post-Dates Study	62(3,4)
1998		No Record	Bridge		989(3,4)
1999		No Record	Bridge		206(3,4)
2000		No Record	Bridge		1094(3,4)
2001		No Record	Bridge		106(3,4)
2002		No Record	Bridge		85(3,4)
2003		No Record	Bridge		171(3,4)
2004		No Record	Bridge		37(3,4)
2005		No Record	Bridge		261(3,4)
2006		No Record	Bridge		38(3,4)
2007		No Record	Bridge		192(3,4)
2008		No Record	Bridge		35(3,4)
2009		No Record	Bridge		255(3,4)
2010		14.07(5)	Bridge		2200(3,4)
2011		No Record	Bridge		19(3,4)

Cont'd Over

TABLE A1 (CONT'D)
ANNUAL SERIES PEAK FLOWS
MACQUARIE RIVER AT NARROMINE 1901-2019

Year	Gauge Height (m)		Gauge	Peak Flow (m^3/s)	
	Bewsher, 1998	Pinneena		Bewsher, 1998	Pinneena
2012	Post-Dates Study	No Record	Bridge	Post-Dates Study	426(3,4)
2013		No Record	Bridge		153(3,4)
2014		No Record	Bridge		126(3,4)
2015		No Record	Bridge		16(3,4)
2016		No Record	Bridge		76(3,4)
2017		No Record	Bridge		861(3,4)
2018		No Record	Bridge		58(3,4)
2019		No Record	Bridge		45(3,4)

1. Gauge height is not consistent with contemporaneous newspaper articles that are reproduced in Appendix C of Bewsher, 1998 which state that the official gauge height was 47 feet 10 inches (or 14.58 m on what is assumed to have been the weir gauge).
2. Gauge height is not consistent with contemporaneous newspaper articles that are reproduced in Appendix C of Bewsher, 1998 which state that the official gauge height was 3 feet 6.5 inches higher than the April 1950 flood (or 15.66 m on what is assumed to have been the weir gauge).
3. Derived by reference to Baroona stream gauge
4. Source: WaterNSW website
5. NSW SES

ANNEXURE B

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"Time","421006","421006"
"and",141.01,100.00
"Date","Max","Max"

18:00:00 24/02/1955,    338000.0,""
19:00:00 24/02/1955,    338000.0,""
20:00:00 24/02/1955,    338000.0,""
21:00:00 24/02/1955,    338000.0,     12.591
22:00:00 24/02/1955,    338000.0,     12.762
23:00:00 24/02/1955,    338000.0,     12.933
00:00:00 25/02/1955,    338000.0,     13.104
01:00:00 25/02/1955,    338000.0,     13.275
02:00:00 25/02/1955,    338000.0,     13.446
03:00:00 25/02/1955,    338000.0,     13.617
04:00:00 25/02/1955,    338000.0,     13.788
05:00:00 25/02/1955,    338000.0,     13.958
06:00:00 25/02/1955,    338000.0,     14.129
07:00:00 25/02/1955,    338000.0,     14.300
08:00:00 25/02/1955,    338000.0,     14.317
09:00:00 25/02/1955,    338000.0,     14.402
10:00:00 25/02/1955,    338000.0,     14.546
11:00:00 25/02/1955,    338000.0,     14.681
12:00:00 25/02/1955,    338000.0,     14.846
13:00:00 25/02/1955,    338000.0,     15.011
14:00:00 25/02/1955,    338000.0,     15.246
15:00:00 25/02/1955,    338000.0,     15.283
16:00:00 25/02/1955,    338000.0,     15.319
17:00:00 25/02/1955,    338000.0,     15.355
18:00:00 25/02/1955,    338000.0,     15.392
19:00:00 25/02/1955,    338000.0,     15.428
20:00:00 25/02/1955,    338000.0,     15.465
21:00:00 25/02/1955,    338000.0,     15.501
22:00:00 25/02/1955,    338000.0,     15.537
23:00:00 25/02/1955,    338000.0,     15.574
00:00:00 26/02/1955,    338000.0,     15.610
01:00:00 26/02/1955,    338000.0,     15.646
02:00:00 26/02/1955,    338000.0,""
03:00:00 26/02/1955,    338000.0,""
04:00:00 26/02/1955,    338000.0,""
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ANNEXURE C

TABLE C1
COMPARISON OF RECORDED VERSUS MODELLED PEAK FLOOD LEVELS

Flood Event	Flood Mark Identifier	Source	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference[3] (m)
February 1955[2]	FM_1955.1	Bewsher, 1998	238.60	239.05	0.45
	FM_1955.2		239.77	239.09	-0.68
	FM_1955.3		239.11	239.08	-0.03
	FM_1955.4		239.50	239.57	0.07
	FM_1955.5		239.78	239.49	-0.29
	FM_1955.6		240.60	240.15	-0.45
	FM_1955.7		239.40	239.38	-0.02
	FM_1955.8		239.50	239.49	-0.01
	FM_1955.9		239.35	239.43	0.08
	FM_1955.10		239.50	239.71	0.21
	FM_1955.11		239.60	239.52	-0.08
	FM_1955.12		239.10	239.22	0.12
	FM_1955.13		239.40	239.45	0.05
	FM_1955.14		239.05	239.95	0.90
	FM_1955.15		240.05	239.94	-0.11
	FM_1955.16		239.10	239.11	0.01
	FM_1955.17		239.99	239.92	-0.07
	FM_1955.18		240.03	239.92	-0.11
	FM_1955.19		239.44	239.50	0.06
	FM_1955.20		239.07	239.10	0.03
	FM_1955.21		239.30	239.05	-0.25
	FM_1955.22		239.39	239.11	-0.28
	FM_1955.23		238.72	239.14	0.42
	FM_1955.24		238.90	239.12	0.22
	FM_1955.25		238.90	239.14	0.24
	FM_1955.26		238.88	239.24	0.36
	FM_1955.27		239.25	239.26	0.01
	FM_1955.28		239.80	239.92	0.12
	FM_1955.29		239.10	239.37	0.27
	FM_1955.30		237.70	236.69	-1.01
	FM_1955.31		242.42	243.25	0.83
	FM_1955.32		238.93	239.03	0.10
	FM_1955.33		239.02	238.99	-0.03
	FM_1955.34		238.90	238.87	-0.03
	FM_1955.35		242.79	243.26	0.47
	FM_1955.36		242.96	243.29	0.33
	FM_1955.37	Community Questionnaire	239.30[5]	239.19	-0.11
	FM_1955.38		239.90[5]	240.27	0.37
	FM_1955.39		239.40[5]	239.26	-0.14
	FM_1955.40		240.16[5]	239.65	-0.51
	FM_1955.41		239.85[5]	239.76	-0.09
	FM_1955.42		239.20[5]	239.07	-0.13
	FM_1955.43		238.60[5]	239.07	0.47

Cont'd Over

TABLE C1 (Cont'd)
COMPARISON OF RECORDED VERSUS MODELLED PEAK FLOOD LEVELS

Flood Event	Flood Mark Identifier	Source	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference(3) (m)
August 1990(3)	FM_1990.1	Bewsher, 1998	239.16	239.16	0.00
	FM_1990.2		239.30	239.47	0.17
	FM_1990.3		237.02	237.00	-0.02
December 2010(4)	FM_2010.1	NSW SES	239.78	239.64	-0.14
	FM_2010.2		239.71	239.66	-0.05
	FM_2010.3		239.71	239.84	0.13
	FM_2010.4		239.48	239.89	0.41
	FM_2010.5		238.40	238.79	0.39
	FM_2010.6		238.64	238.78	0.14
	FM_2010.7		238.84	238.78	-0.06
	FM_2010.8		239.55	239.64	0.09
	FM_2010.9		238.38	238.38	0.00
	FM_2010.10		237.54	237.56	0.02
	FM_2010.11		237.18	237.55	0.37

1. A positive value indicates that the modelled peak flood level is higher, and conversely a negative value indicates that the modelled peak flood level is lower than the recorded peak flood level.
2. Refer **Figure 2.4** which shows the plan location of the flood mark.
3. Refer **Figure 2.5** which shows the plan location of the flood mark.
4. Refer **Figure 2.6** which shows the plan location of the flood mark.
5. Recorded flood level derived by assuming floor level of dwelling is located 0.3 m above natural surface level.

APPENDIX A

COMMUNITY CONSULTATION

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ATTACHMENT 1 Community Newsletter and Questionnaire

ATTACHMENT 2 Responses to Community Questionnaire

A1. INTRODUCTION

At the commencement of the *FRMS,* the Consultants prepared a *Community Newsletter* and a *Community Questionnaire*, both of which were distributed by Council to the residents and business owners in Narromine (refer to **Attachment 1**). The questionnaire was also able to be completed online via Council's website.

The purpose of the *Community Newsletter* was to introduce the objectives of the study and set the scene on flooding conditions so that the community would be better able to respond to the *Community Questionnaire* and contribute to the study process.

The *Newsletter* contained the following information:

- A statement of the objectives of the *FRMS&P*; namely the development of a strategy for reducing the flood risk and minimising the long-term impact of flooding on the community.
- A list of the floodplain risk management measures which comprised the *Narromine Floodplain Risk Management Plan 2009.*
- A plan showing the extent of the study area.

The *Community Questionnaire* was structured with the objectives of:

- Determining residents' and business owners' attitudes to controls over future development in flood liable areas.
- Inviting community views on possible flood management options which could be considered for further investigation in the *FRMS* and possible inclusion in the resulting *FRMP*.
- Obtaining feedback on any other flood related issues and concerns which the residents and business owners cared to raise.

This **Appendix** to the *FRMS&P* report discusses the responses to the nine questions that were included in the *Community Questionnaire* and comments made by respondents.

Chapter A2 deals with the residents' and business owners' views on the relative importance of classes of development over which flood-related controls should be imposed by Council.

Chapter A3 identifies residents' and business owners' views on the suitability of the various options which could be considered in more detail in the *FRMS.*

Chapter A4 discusses the best methods by which the community could provide feedback to the consultants over the course of the study.

Chapter A5 summarises the findings of the community consultation process.

A2 RESIDENT PROFILE AND FLOOD AWARENESS

A2.1 General

Residents were requested to complete the *Community Questionnaire* and return it to the Consultants by 15 May 2020. The deadline was extended to include any submissions that were received after this date. The Consultants received 143 responses in total out of the 1,672 that had been distributed.

The Consultants have collated the responses, which are shown in graphical format in **Attachment 2**.

A2.2 Respondent Profile

The first four questions of the *Community Questionnaire* canvassed resident information such as whether the respondent was a resident or business owner, length of time at the property, the type of property (e.g. house, unit/flat).

Of the 143 responses, 133 were residents, several of whom also run businesses in Narromine (**Question 2**).

The majority of respondents occupied residential type property (**Question 3**), which included houses (79 respondents), units/flats/apartments (1), villas/townhouses (2) and vacant lots (2). Nine (9) respondents owned non-residential type property, which included shops/commercial premises (4 respondents), industrial units (2), and warehouse or factory (3). Note that some responses were included in more than one property classification type, while a large number of respondents did not provide a response to this question.

The length of time respondents had been at the address was found to be varied, with approximately 12% of respondents having lived at the residence for between ‘1-5 years’, 41% for ‘5 to 20 years’, and 47% for ‘more than 20 years’ (**Question 4**).

A2.3 Flood Experience

Twenty-six (26) respondents said they had information of flooding at their property, the sources of which included personal experience (25 respondents), flood levels from Council (3), information from NSW SES (1) and photographs (7) (**Question 5**).

Twenty-one (21) respondents had experienced flooding at their property as a result of floodwater which broke out of the Macquarie River, while another nine had been impacted by major overland flow. Twelve (12) respondents said their property was impacted by the February 1955 flood, while six (6) nominated the August 1990 flood and twelve (12) the December 2010 flood as impacting their property. (**Question 6**)

Twelve (12) respondents said that their property had been above-floor flooded, eleven (11) of which related to the February 1955 flood and one (1) to the August 1990 flood (**Question 7**). Several respondents advised the depth of above-floor flooding that was experienced in the dwelling.

Twenty (20) respondents advised that parts of their dwelling was damaged during the biggest flood that they had experienced, in addition to damage that was experienced elsewhere on the property (**Question 8**).

Thirty-five (35) respondents advised that they had not experienced any problems as a result of the biggest flood, while other advised that they had experienced a loss of trade (5), restricted access (15) and higher insurance premiums (21). Two (2) others advised that they had considered moving as a result of flooding (**Question 9**).

One respondent advised that they had incurred $10,000 of damages as a result of the biggest flood that they had experienced (event not nominated by the respondent), while a second advised that they had incurred $8,500 as a result of the August 1990 flood. Several others advised that they had incurred up to $5,000 of damages as a result of flooding in Narromine (**Question 10**).

During the biggest flood to have been experienced by respondents, most received some form of warning of the approaching flood, with only ten (10) stating that they had not received any warning (**Question 11**).

A2.4 Controls over Development in Flood Prone Areas

The respondents were asked to rank from 1 to 4 the classes of development which they consider should receive protection from flooding (**Question 12**). Rank 1 was the most important and rank 4 the least.

The classes in decreasing order of importance to respondents ranged from:

- essential services (e.g. sewer, water, electricity);
- residential property;
- vulnerable residential (e.g. aged persons accommodation); and
- essential community facilities (e.g. schools, evacuation centres residential property;
- commercial/business type development.

These results gave a guide to the Consultants as to the appropriate location of future development of the various classes within the floodplain. For example, on the basis of community views, essential services would receive the highest level of protection by locating future development of this nature outside the floodplain.

In **Question 13**, respondents were asked what notifications Council should give about the flood affectation of individual properties. The community was strongly in favour of advising existing residents (93) and prospective purchasers (83) of the known potential flood threat, while eighteen (18) respondents favoured only advising those who enquire to Council about the known potential flood risk. Seven (7) respondents favoured not providing any notification.

Respondents were also asked in **Question 14** about the level of control Council should place on new development to minimise flood-related risks. The most popular response was to advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks (73 respondents). The next most favoured response was to prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties (31 respondents). Twenty-five (25) respondents felt Council should place restrictions on developments to reduce the potential for flood damage (e.g. minimum floor level controls or the use of compatible building materials) and prohibit all development on land with any potential to flood, while seventeen (17) respondents felt that Council should prohibit all new development only in those locations that would be extremely hazardous to persons or property during floods.

A3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were asked for their opinion on potential flood management measures which could be evaluated in the *FRMS* (and if found to be feasible included in the *FRMP*), by ticking a “yes” or “no” to the eleven potential options identified in **Question 15**.

The options comprised a range of *structural flood management measures* (e.g. programs by Council to manage vegetation in the river system to maintain hydraulic capacity; widening of watercourses; removal of floodplain obstructions; improving the stormwater system within the town; levees to contain floodwaters; upgrade of existing railway culverts, as well as various *non-structural management measures* (e.g. voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; flood related controls over new developments; improvements to flood warning and evacuation procedures; community education on flooding; flood advice certificates). The options were not mutually exclusive, as the adopted *FRMP* could, in theory, include all of the options set out in the *Community Questionnaire*, or indeed, other measures nominated by the respondents or the FRMC.

The most popular structural measures were improvements to the stormwater system within the town area, followed in descending order of preference by the removal of floodplain obstructions, the upgrade of existing railway culverts and management of riparian vegetation.

Of the non-structural measures, provision of a Planning Certificate to purchasers in flood prone areas, improvement of flood warning and evacuation procedures and specifying controls on future development in flood-prone areas.

A mostly negative response was given to the widening of watercourses and the construction of permanent levees. Providing subsidies for raising the floor level of properties and the implementation of a residential Voluntary Purchase scheme were also unpopular.

A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY

In **Question 16,** residents were asked for their view on the best methods of their providing input to the Study and feedback to the Consultants over the course of the investigation. Council's website and social media pages were the most popular methods, followed by articles in the local newspaper. Other suggestions raised by respondents include:

- Circular or newsletter either posted or emailed from Council
- Face-to-face interaction through community meetings.

Thirty (30) respondents advised that they would like Council to contact them in order to provide further information (**Question 17**).

A5 SUMMARY

One-hundred and forty three (143) responses were received to the *Community Questionnaire* which was distributed by Council to residents and business owners in Narromine. The responses amounted to about nine (9) per cent of the total number of questionnaires that were distributed to the community.

The issues identified by the responses to the *Community Questionnaire* support the objectives of the study as nominated in the attached *Community Newsletter,* and the activities nominated in the Study Brief. While over ten percent of the respondents to the questionnaire were in favour of prohibiting all new development on land with any potential to flood, the majority of respondents were in favour of Council advising of the flood risks, but allowing the individual a choice to develop so long as potential flood risks are minimised.

Of the *structural measures* which could be incorporated in the *FRMP*, the most popular were improvements to the stormwater system within the town area and the removal of floodplain obstructions. While the construction of permanent levees was one of the least favoured of the options, a large number of respondents felt it was necessary to either upgrade the existing levee bank or build the new river-bank levee as they believed the degree of flood affectation within the town was holding back development and also leading to increased insurance premiums.

The provision of a Planning Certificate to purchasers in flood prone areas, improvements to flood warning and evacuation procedures, and specifying controls on future development in flood-prone areas were the most popular of the potential *non-structural measures* set out in the *Community Questionnaire*.

ATTACHMENT A1

COMMUNITY NEWSLETTER
AND QUESTIONNAIRE

YOUR ATTITUDES TO COUNCIL'S DEVELOPMENT CONTROLS

12. Please rank the following development types according to which you think are the most important to protect from floods
(1= highest priority to 4= least priority)

Development Type	Rank
Commercial/Business	
Residential	
Vulnerable residential development (e.g. aged persons accommodation)	
Essential community facilities (e.g. schools, evacuation centres)	
Essential services (e.g. sewer, water, electricity etc.)	

13. What notifications do you consider Council should give about the potential flood affectation of individual properties? *(Tick one or more boxes)*

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the known potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat.
- ☐ Provide no notifications
- ☐ Other

14. What level of control do you consider Council should place on new development to minimise flood-related risks? *(Tick only one box)*

(In addition to being favoured by the Community, these options would also need to comply with legislation)

- ☐ Prohibit all new development on land with any potential to flood
- ☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
- ☐ Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or the use of flood compatible building materials)
- ☐ Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks
- ☐ Provide no advice regarding the potential flood risks or measures that could minimise those risks

YOUR OPINIONS ON FLOODPLAIN RISK MANAGEMENT MEASURES

15. Below is a list of other possible options that may be looked at to try to minimise the effects of flooding in the study area.
This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No
Management of riparian vegetation to provide flood mitigation, stability, aesthetic and habitat benefits.		
Widening of watercourses.		
Removal of floodplain obstructions.		
Improve the stormwater system within the town area.		
Construction of urban levees		
Upgrade of the existing railway culverts		
Voluntary scheme to purchase residential property in high hazard areas.		
Provide funding or subsidies to raise houses above major flood level in low hazard areas.		
Specify additional controls on future development in flood-liable areas.		
Improve flood warning and evacuation procedures both before and during a flood.		
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.		

OTHER INFORMATION

16. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?
(Tick one or more boxes)

- ☐ Council's website
- ☐ Articles in local newspaper
- ☐ Through Council's Floodplain Management Committee
- ☐ Other

17. If you wish us to contact you so you can provide further information, please provide your details below:

Name:

Phone: Best time to call is

Email:

ADDITIONAL COMMENTS

REVIEW OF THE NARROMINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Narromine SHIRE COUNCIL

TO RESIDENTS & BUSINESS OWNERS OF NARROMINE:

Narromine Shire Council has engaged consultants to undertake a review of the Narromine Floodplain Risk Management Study and Plan which was prepared for the township in 2009. The purpose of the review is to assist Council in refining strategic plans for mitigating and managing the effects of existing flood risk (associated with existing development on flood prone land), future flood risk (associated with any new development on flood prone land) and continuing flood risk (the risk remaining in both existing and future development areas after floodplain risk management measures are implemented).

The review is jointly funded by Council and the NSW Department of Planning, Industry and Environment and aims to build community resilience towards flooding through informing better planning of development, emergency management and community awareness. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The review will utilise the results of the Narromine River Bank Levee Feasibility Study which was completed in 2013. Figure 1 overleaf shows the indicative extent of the 1 in 100 year flood on the Macquarie River at Narromine under present day conditions as defined by this study.

A brief summary of the floodplain risk management measures which form the Narromine Floodplain Risk Management Plan (2009), including their estimated cost is provided overleaf, while an electronic copy of the Narromine Floodplain Risk Management Study and Plan (2009) and Narromine River Bank Levee Feasibility Study (2013) can be found on Council's website at www.narromine.nsw.gov.au.

ABOUT THE QUESTIONNAIRE

This Questionnaire is part of the Review of the Narromine Floodplain Risk Management Study and Plan, which is currently being undertaken by Narromine Shire Council with the financial support of the NSW Department of Planning, Industry and Environment. Your responses to the questionnaire will help us determine the flood issues that are important to you.

Please return your completed Questionnaire in the reply paid envelope provided by Friday 15 May 2020. No postage stamp is required. All information provided will remain confidential and for use in this study only. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 85163
NORTH SYDNEY NSW 2060

HAVE YOUR SAY

An important first step in the review process is to re-appraise what flood related issues are important to the community. The attached questionnaire has been provided to residents and businesses to assist the Consultants in gathering this important information.

The questionnaire may also be completed online via Council's website at www.narromine.nsw.gov.au.

All information provided will remain confidential and for use in this study only. Please return the completed questionnaire in the reply paid envelope provided by Friday 15 May 2020.

FOR MORE INFORMATION CONTACT

Narromine Shire Council
Sarah Masonwells, Executive Assistant
Infrastructure and Engineering
P: (02) 6889 9999
M: mail@narromine.nsw.gov.au
W: www.narromine.nsw.gov.au

FLOODPLAIN MANAGEMENT MEASURES FORMING THE NARROMINE FLOODPLAIN RISK MANAGEMENT PLAN (2009)

The table below is a brief summary of the floodplain risk management measures which form the Narromine Floodplain Risk Management Plan (2009), including their estimated costs.

Option	Estimated Cost	Priority	Status of Measure
PM1 - Implement the recommended development controls based on draft Flood Policy for Narromine.	Council staff's Cost	High	✓
RM1 - Ensure flood data in this Floodplain Risk Management Study and draft Plan is available to NSW SES for inclusion in flood emergency response.	Council and NSW SES Costs	High	✓
RM2 - Implement flood awareness and education program for residents and owners of commercial and industrial developments.	NSW SES and Property/ Business Owner Costs	High	✓
FM1 - Feasibility Study of river bank levee.(1,2)	$80,000 (1)	High	✓
FM2 - Preparation of detailed design and construction of levee (dependent on the results of the above study).	$1.6 Million (3)	Medium	Yet to commence
FM3 - Feasibility Study of upgrading the hydraulic capacity of culverts beneath the Parkes Narromine Railway.(4)	$50,000 (3)	Medium	Yet to commence
FM4 - Prepare detailed design and construct culvert works (scheme is dependent on the results of the above study and whether river bank levee scheme is implemented. The river levee would reduce ponding upstream of the railway and possibly reduce the need for improved culverts).(4)	$0.8 Million (3)	Medium	Yet to commence
Total Cost of Implementing Flood Mitigation Measures FM1, FM2, FM3 and FM4	$2.53 Million (3)		

1. FM1 was completed in 2013. The results of the study are presented in Narromine River Bank Levee Feasibility Study (2013)

2. Scope of floodplain risk management measure refined as part of Narromine River Bank Levee Feasibility Study (2013) and the Narromine Town Levee Concept Design (2016). Figure 1 shows the currently proposed alignment of the river bank levee.

3. Following the adoption of the revised Plan, Narromine Shire Council can seek funding from the NSW State Government under its Floodplain Management Program to cover the majority of the cost of implementing the recommended set of measures.

4. Refer Figure 1 for location of the proposed upgraded culverts

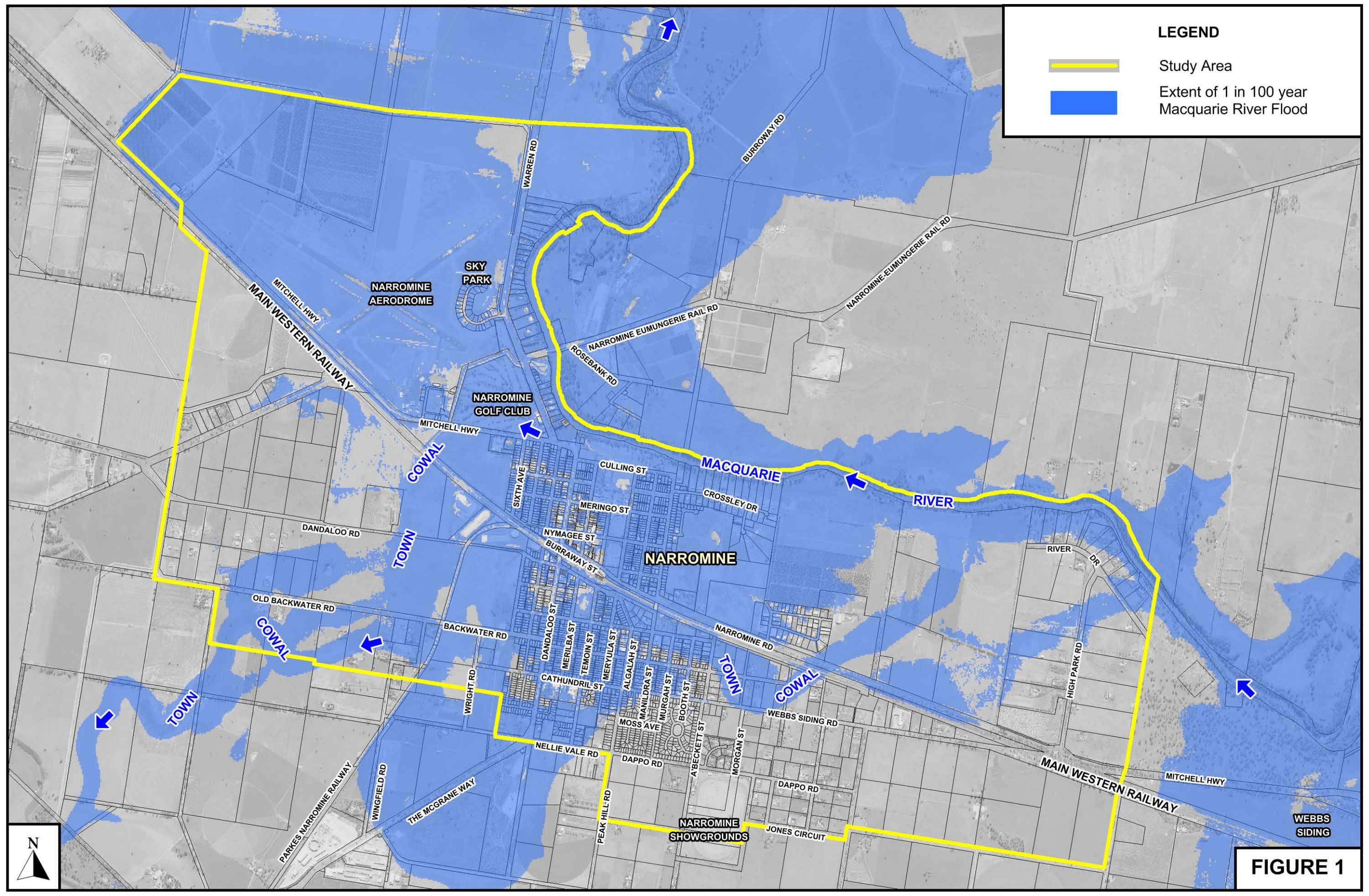


FIGURE 1

COMMUNITY QUESTIONNAIRE

Your name (optional):

Address:

ABOUT YOUR PROPERTY

2. Please tick as appropriate:

- ☐ I am a resident
- ☐ I am a business owner
- ☐ Other

3. How long have you been at this address?

- ☐ 1 year to 5 years
- ☐ 5 years to 20 years
- ☐ More than 20 years (years)

4. What is your property?

- ☐ House
- ☐ Villa/Townhouse
- ☐ Unit/Flat/Apartment
- ☐ Vacant land
- ☐ Industrial unit in larger complex
- ☐ Stand alone warehouse or factory
- ☐ Shop
- ☐ Community building
- ☐ Other

YOUR FLOOD EXPERIENCE

If flooding has affected your property - Go to Q5

If not, but flooding has affected you in other ways - Go to Q9

If you have not been affected by flooding - Go to Q12

5. Do you have any information about flooding at the property?

☐ Yes ☐ No

If yes, what information do you have?

- ☐ Own experience
- ☐ Flood levels from Council
- ☐ Information from NSW SES
- ☐ Photographs
- ☐ Other

6. Have you ever experienced flooding, either as a result of the river breaking its banks or due to shallow overland flow through the property?

- ☐ Yes - River break out ☐ Yes - Shallow overland flow
- ☐ No

If yes, which floods?

- ☐ December 2010 ☐ August 1990
- ☐ Other

7. In the biggest flood you have experienced, was the property flooded above floor level of the main building?

☐ Yes ☐ No ☐ Not applicable

☐ If yes, what was the depth of water over the floor?

What year?

8. During the biggest flood, what was damaged by floodwaters?

(Tick one or more boxes)

- ☐ No damage occurred
- ☐ Vehicles
- ☐ Garden, yard, paddocks
- ☐ Garage, shed
- ☐ Electrical equipment, machinery, tools
- ☐ Stock and other goods
- ☐ Carpet, furniture, fittings and/or office equipment
- ☐ Your premises (paint, structurally, etc)
- ☐ Other

9. As a result of the biggest flood, did you experience any problems during or after the flood?

(Tick one or more boxes)

- ☐ No problems experienced
- ☐ Loss of business / trade
- ☐ Restricted access / can't get to work
- ☐ Higher insurance premiums
- ☐ Considered selling/moving

10. During the biggest flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

$

11. In this biggest flood, did you receive any warning, and if so, from where?

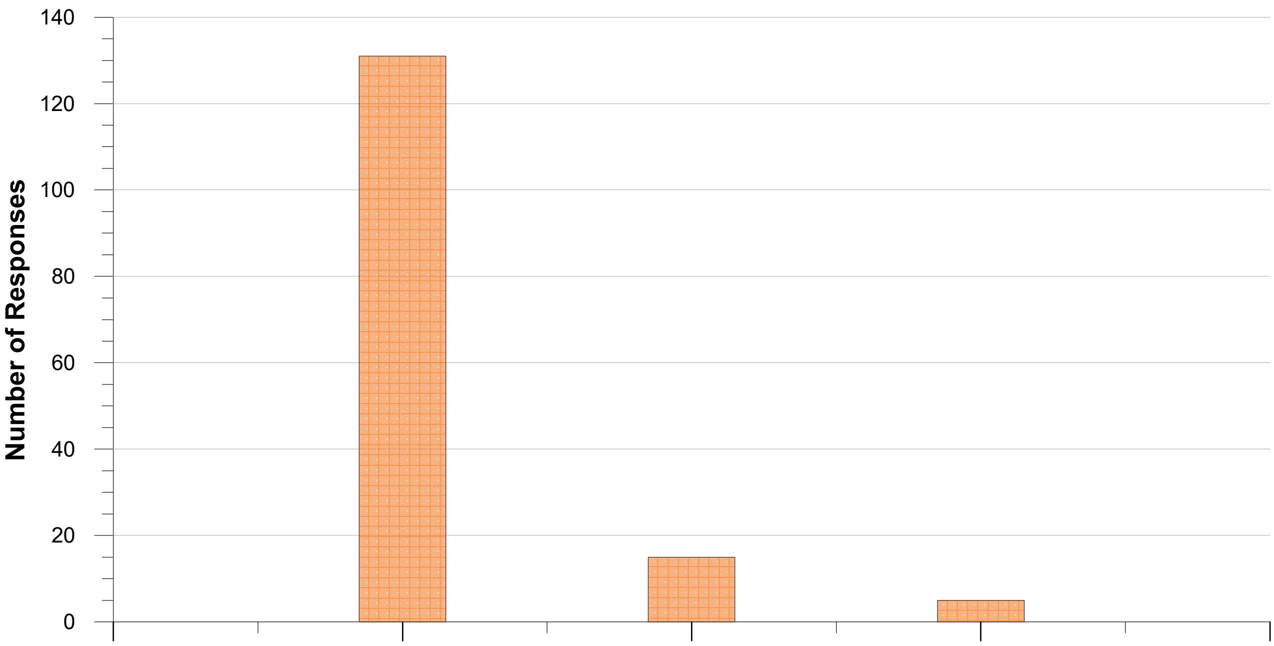
(Tick one or more boxes)

- ☐ No warning whatsoever
- ☐ TV
- ☐ Radio
- ☐ Own observations
- ☐ Police
- ☐ NSW SES
- ☐ Neighbours, relatives or friends
- ☐ Other

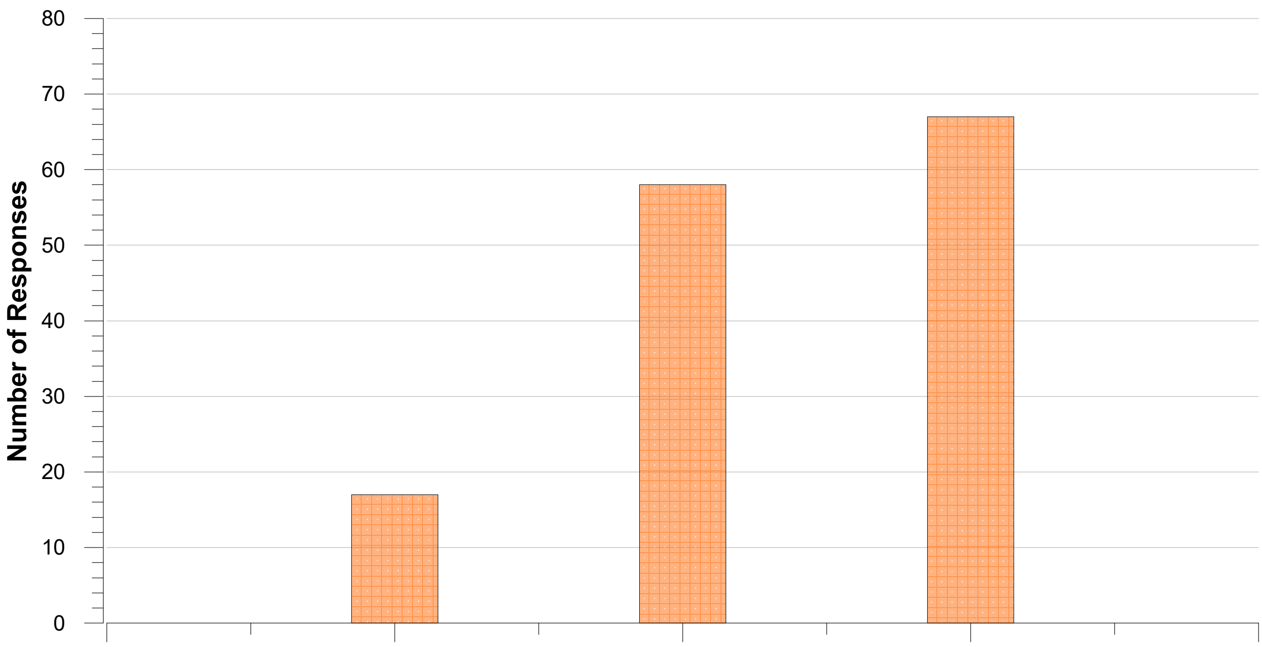
ATTACHMENT A2

RESPONSES TO COMMUNITY QUESTIONNAIRE

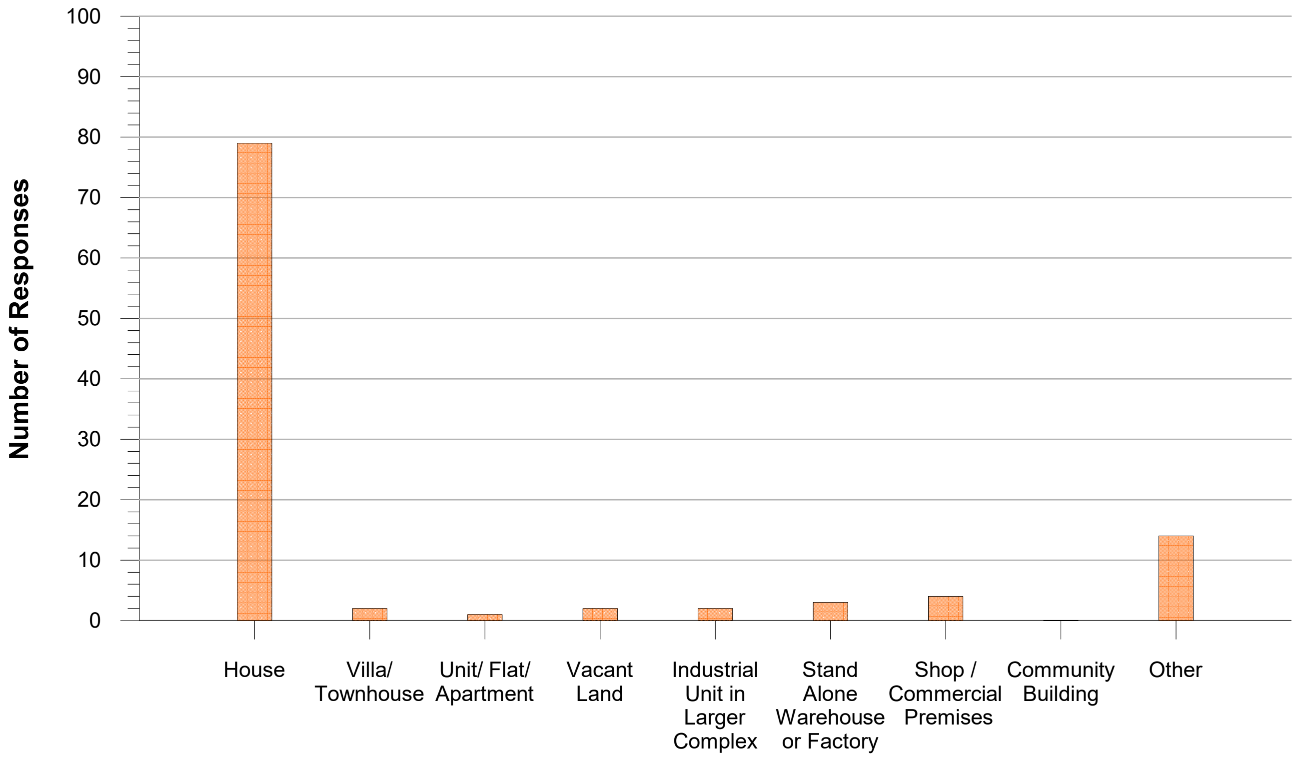
Q2. Residential Status



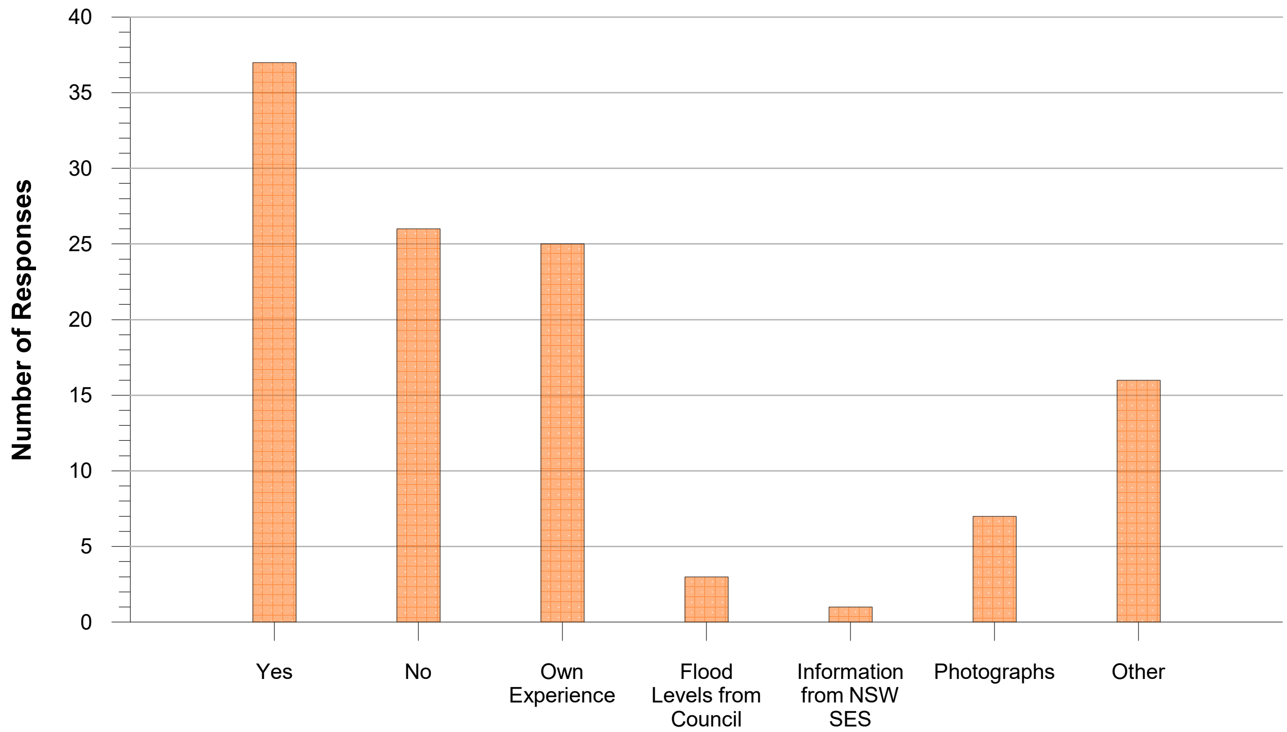
Q3. How long have you been at this address?



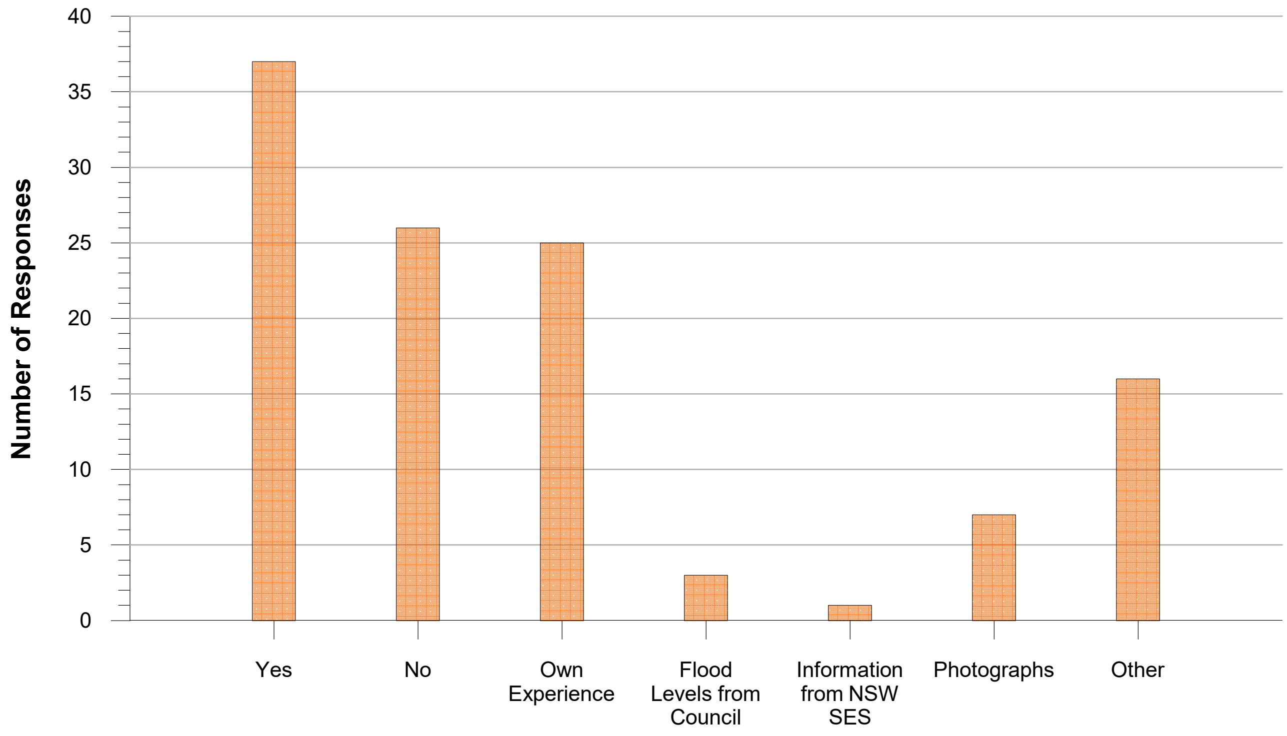
Q4. Type of Property



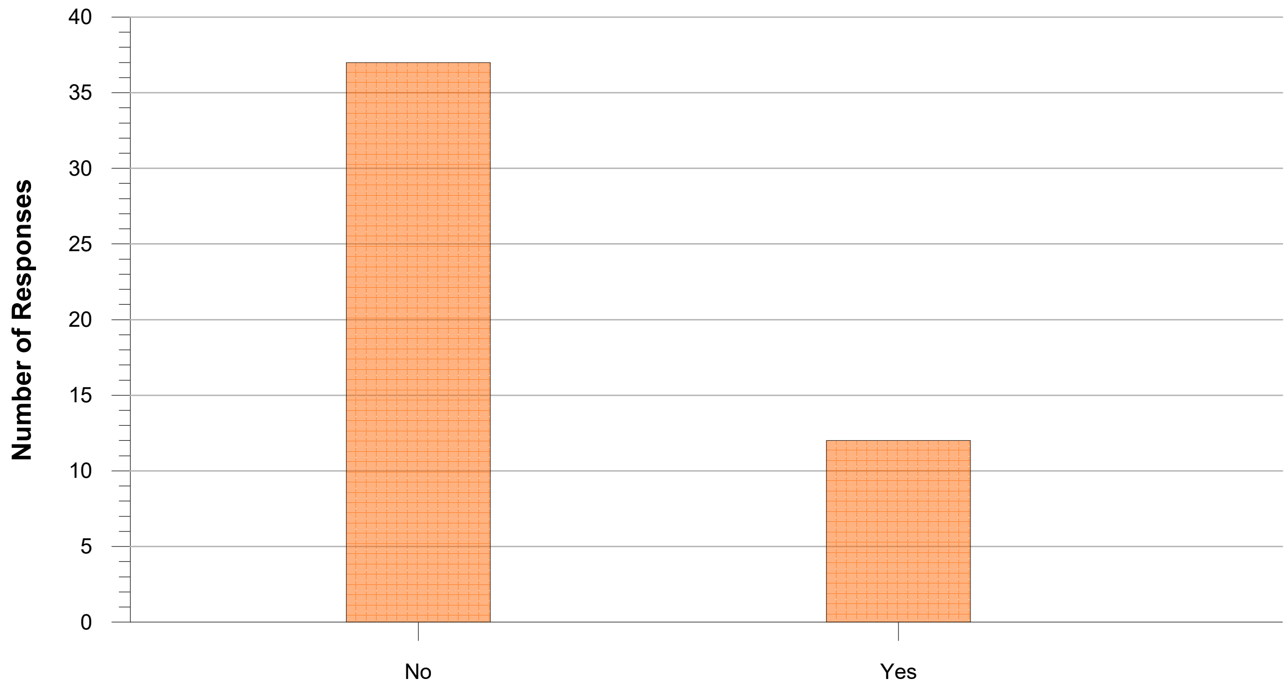
Q5. Do you have any information about flooding at your property?



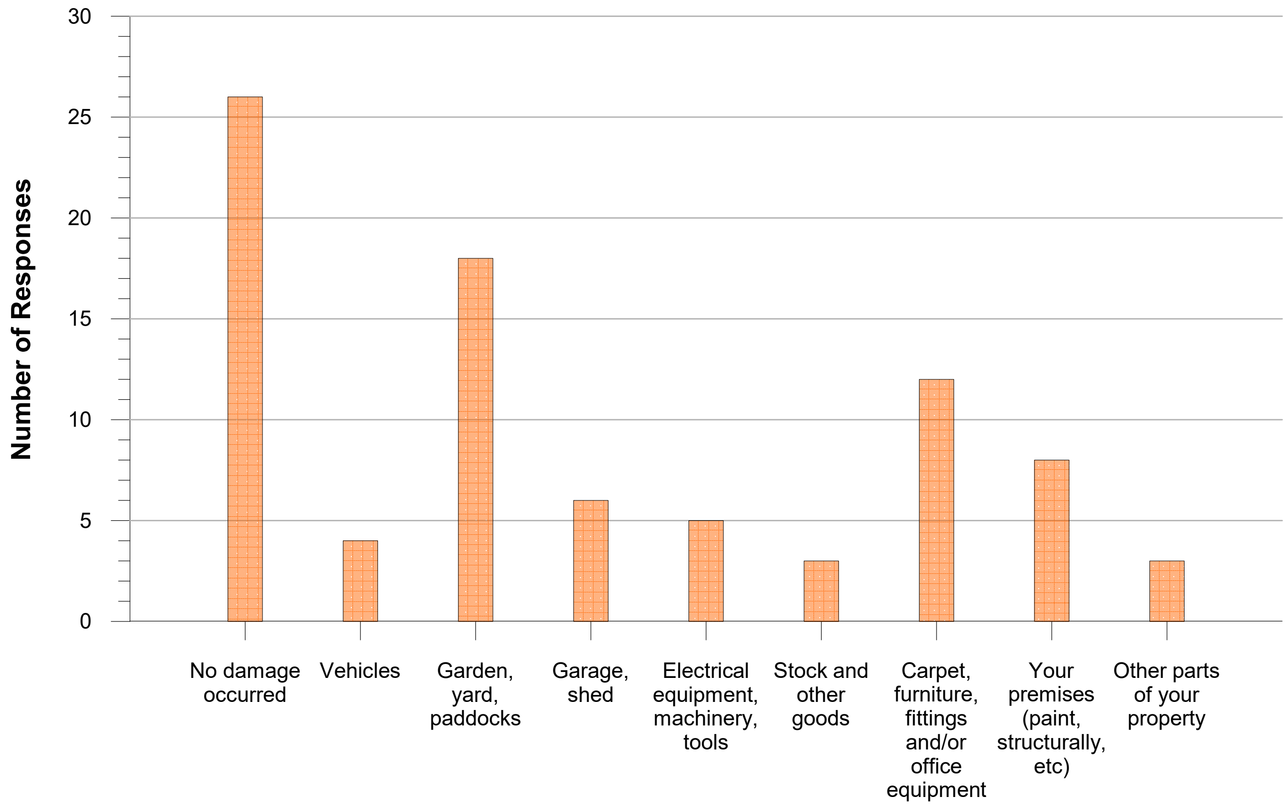
Q6. Have you experienced flooding?



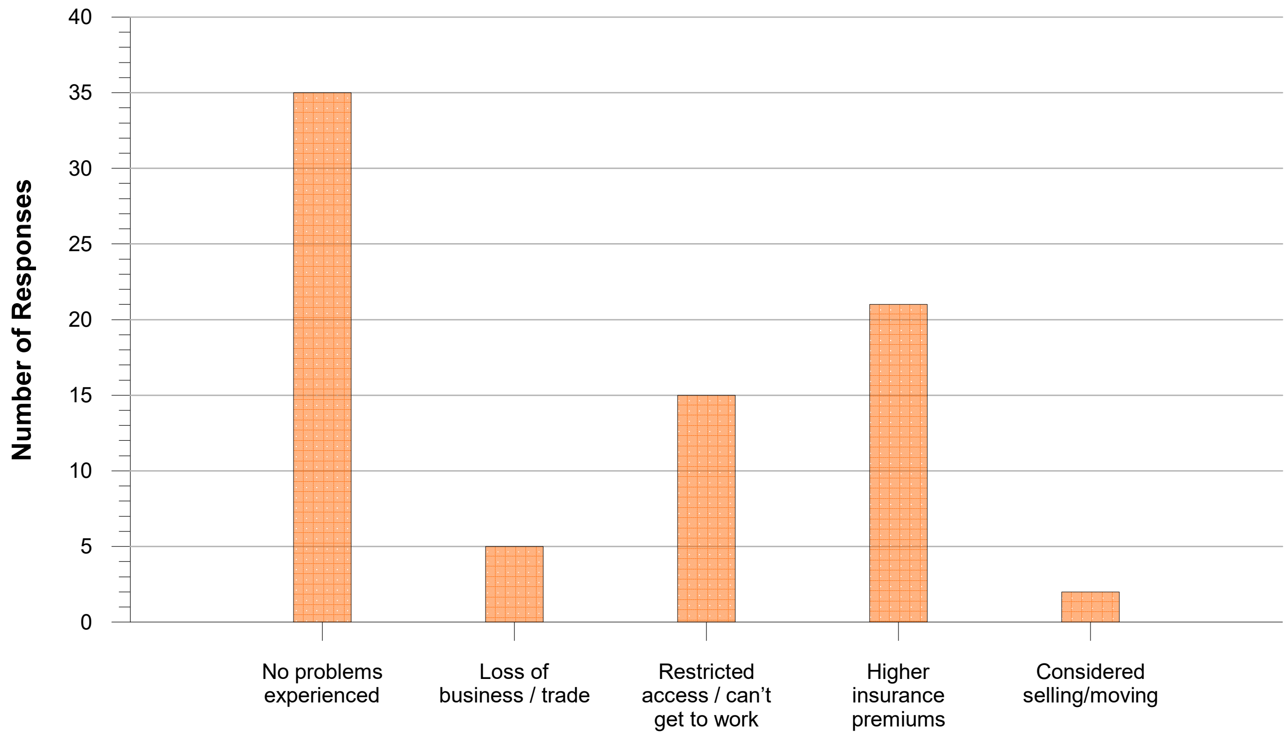
Q7. Was the main building of your property flooded above floor level?



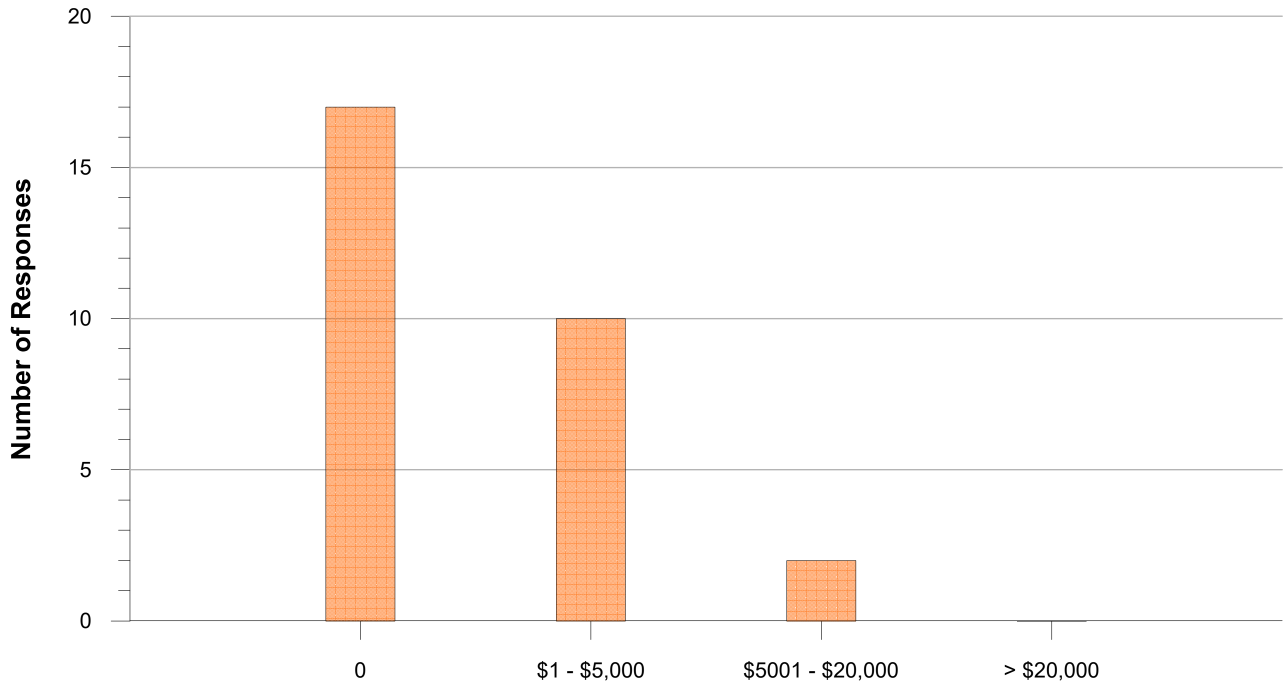
Q8. What was damaged by floodwaters?



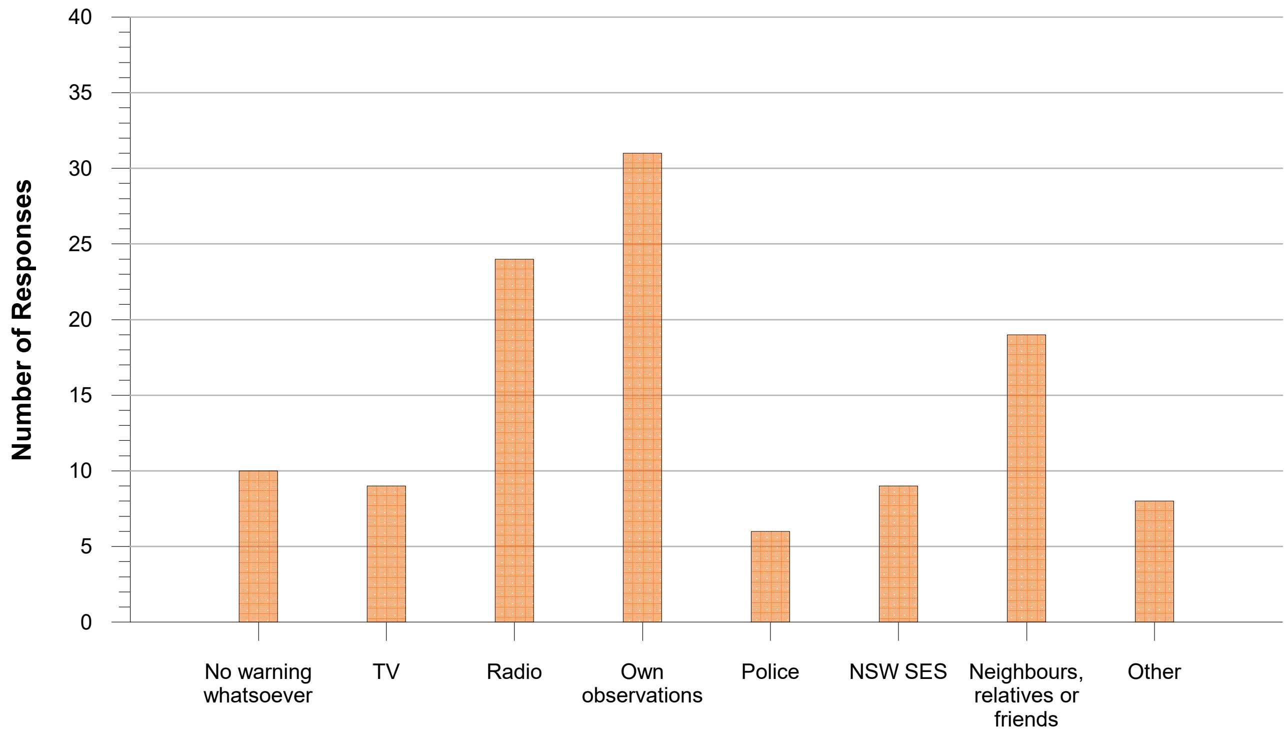
Q9. Did you experience any problems due to flooding?

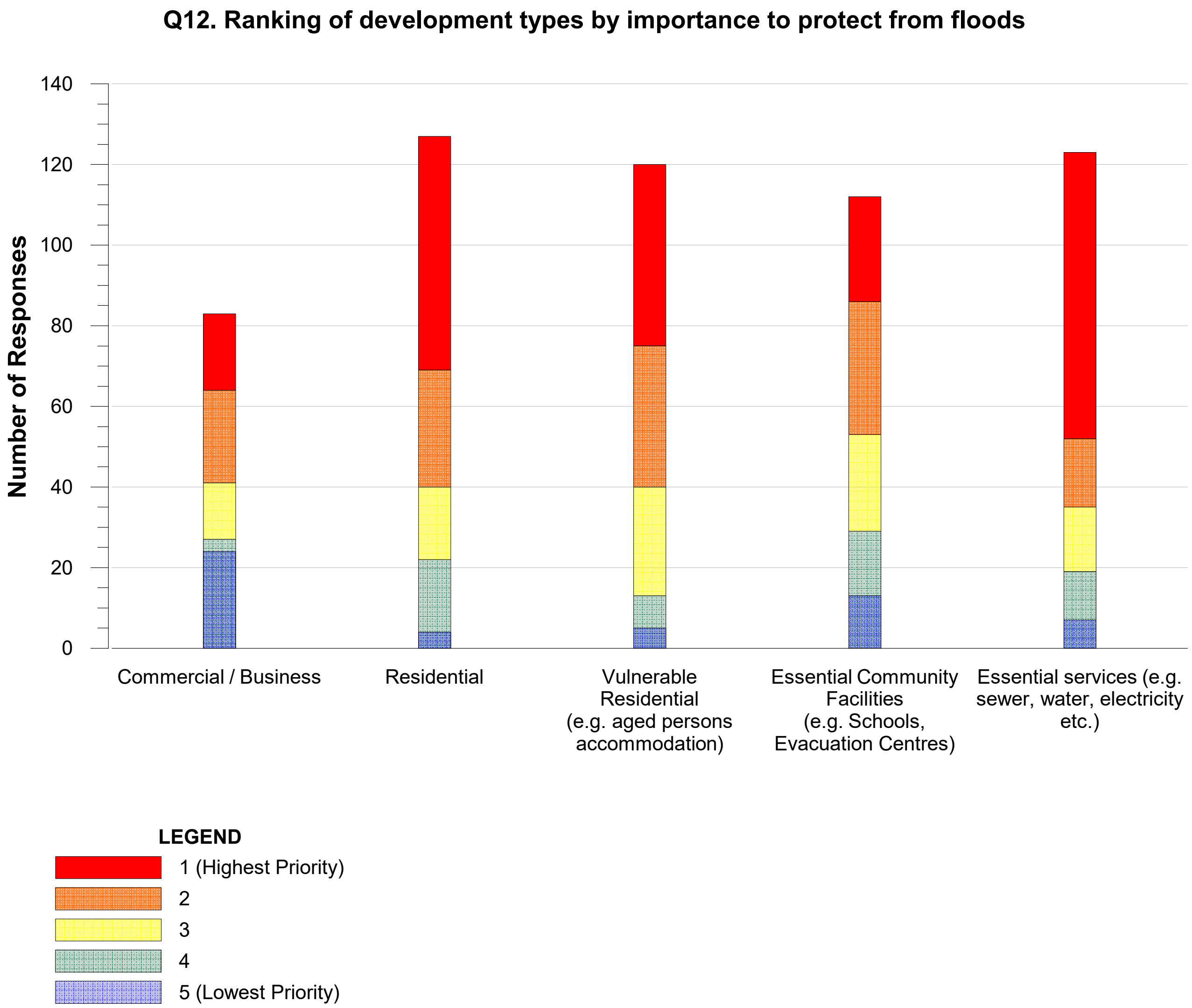


Q10. What was the cost of the damage?

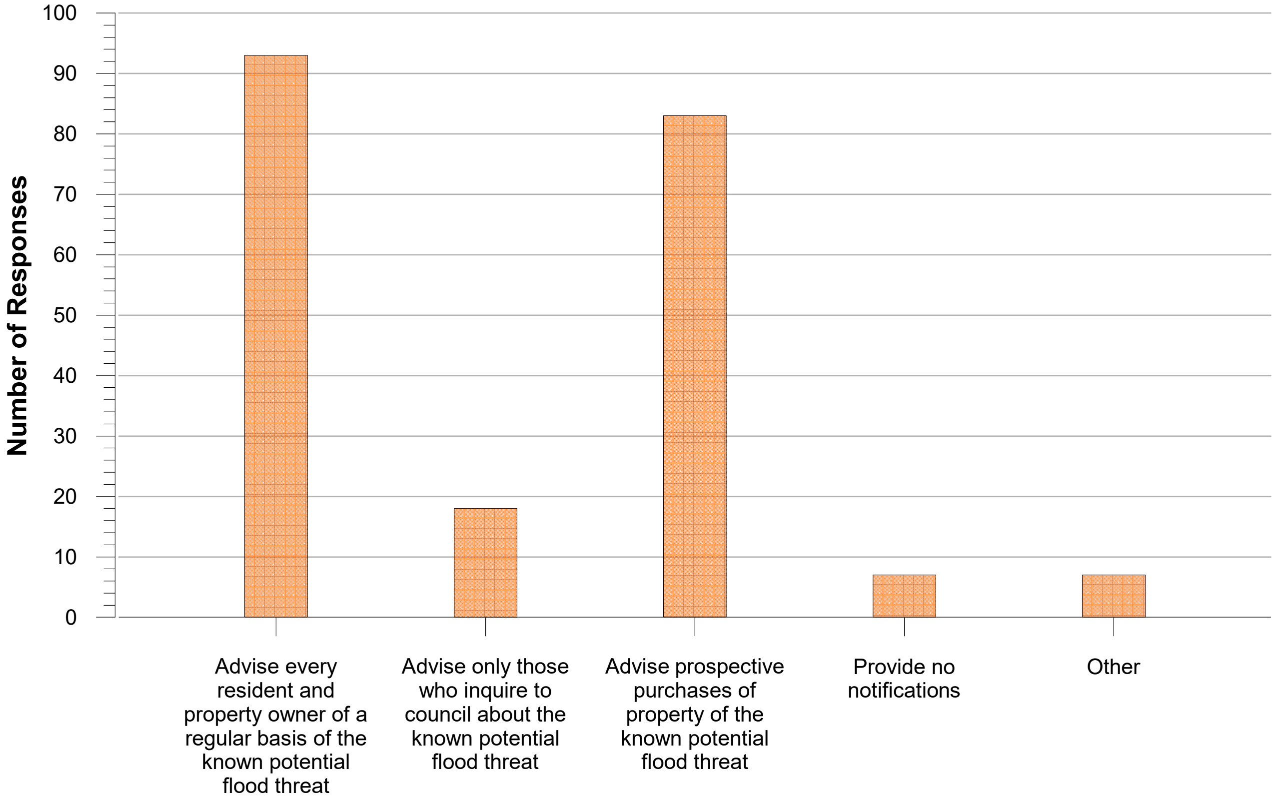


Q11. Where did the flood warning come from?

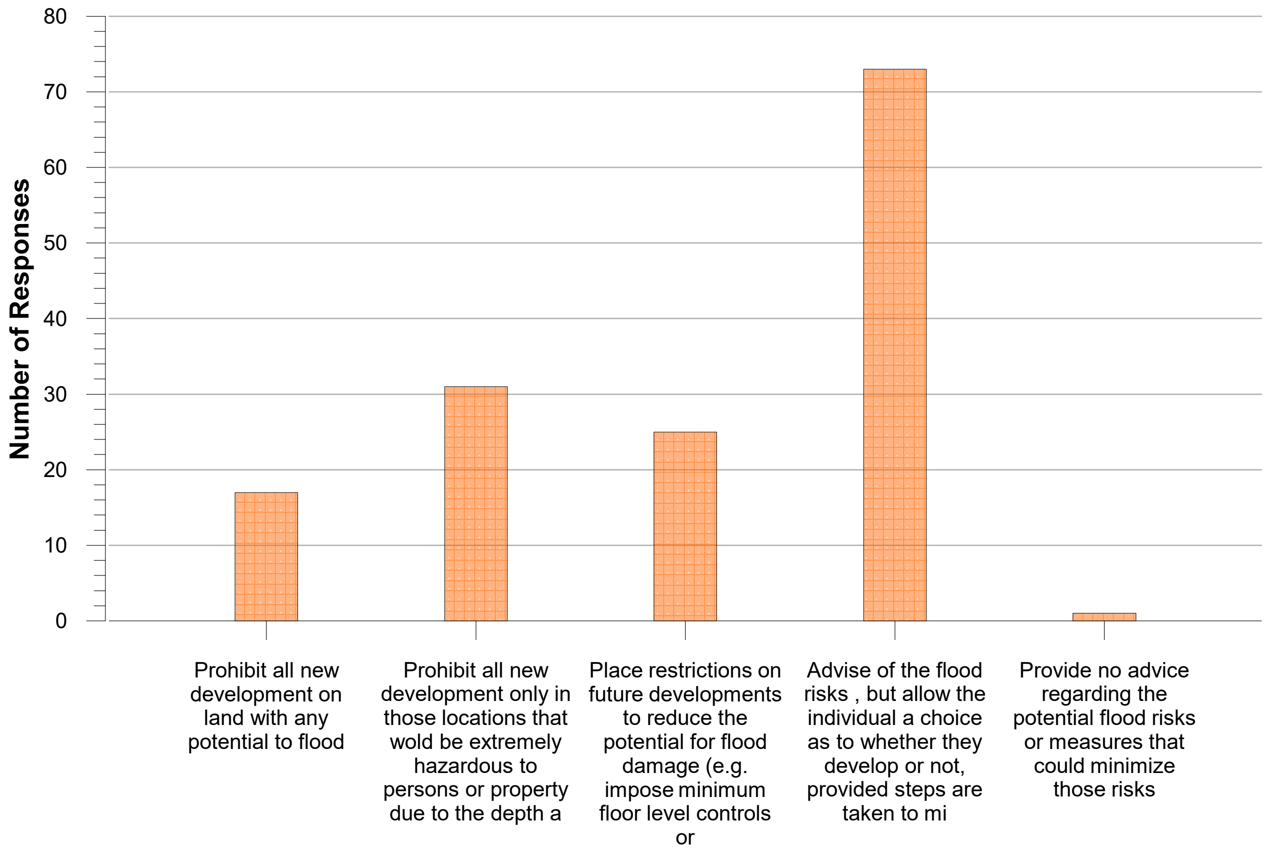



Q12. Ranking of development types by importance to protect from floods
Number of Responses
0
20
40
60
80
100
120
140
Commercial / Business
Residential
Vulnerable Residential (e.g. aged persons accommodation)
Essential Community Facilities (e.g. Schools, Evacuation Centres)
Essential services (e.g. sewer, water, electricity etc.)
LEGEND
1 (Highest Priority)
2
3
4
5 (Lowest Priority)

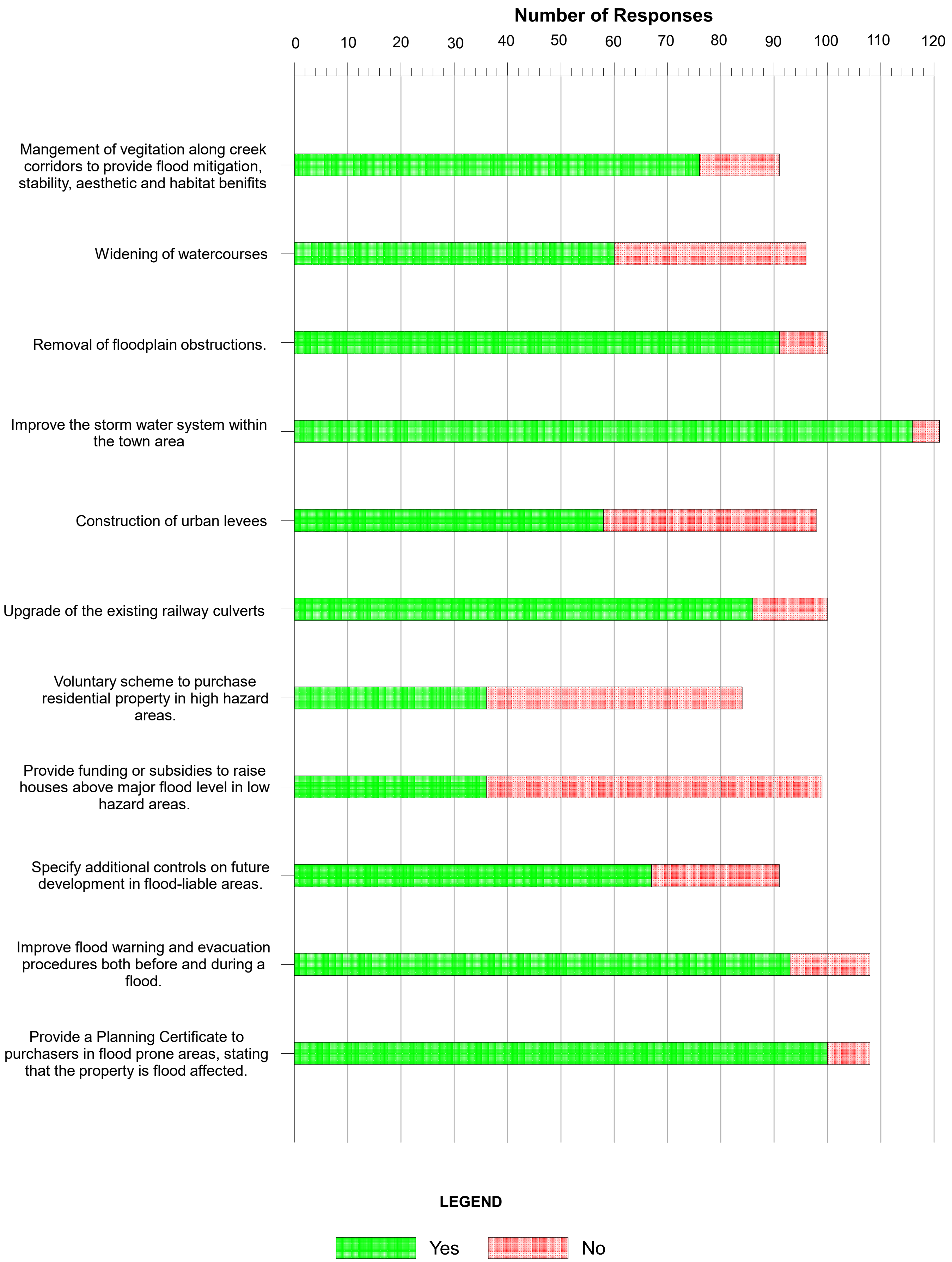
Q13. What notifications should Council give about the potential flood affectation of properties?



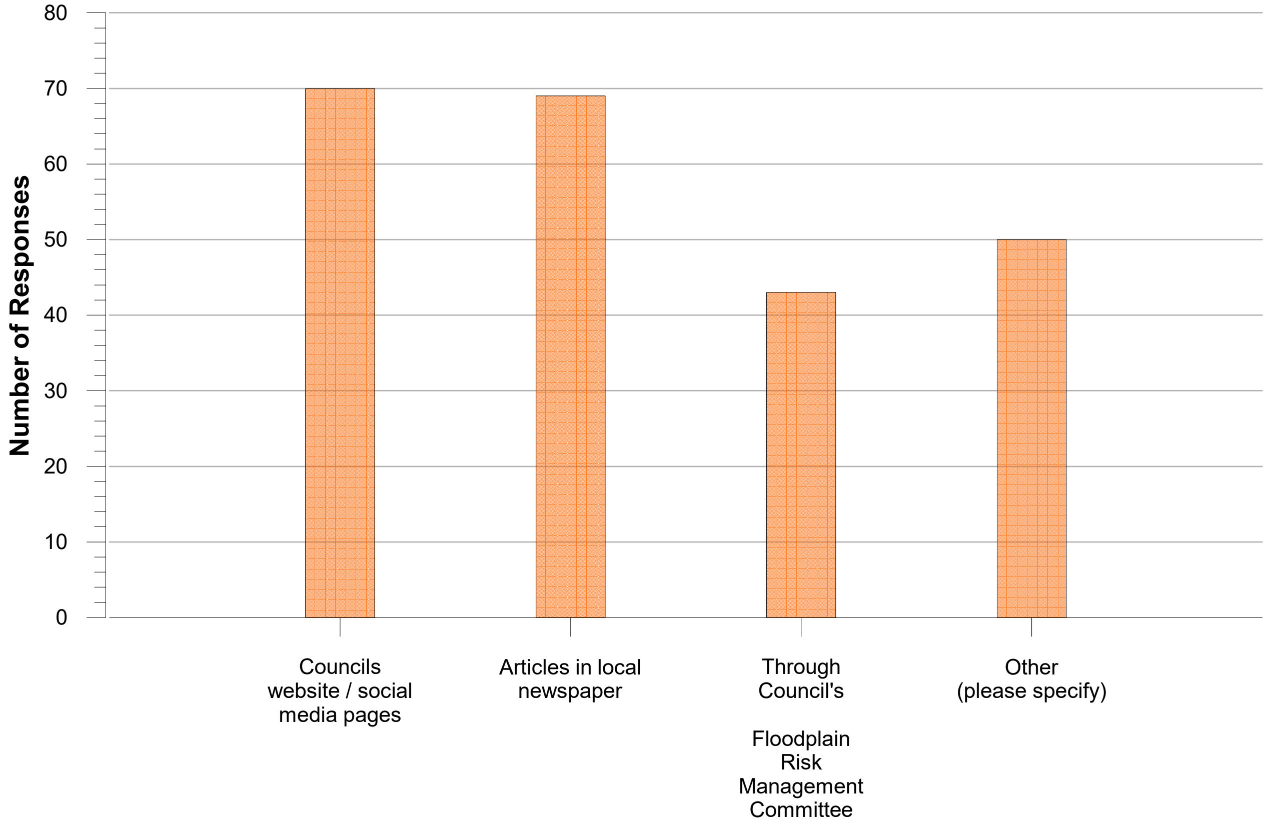
Q14. What level of control should Council place on new development to minimise flood-related risks?



Q15. Possible Floodplain Management Measures



Q16. Best methods to get input and feedback from the local community



APPENDIX B

FLOOD DAMAGES

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B1. INTRODUCTION AND SCOPE

B1.1. Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and industrial and residential building structures and contents, as well as damages to infrastructure services such as electricity and water supply. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

B1.2. Scope of Investigation

In the following sections, tangible damages to residential, commercial / industrial and public properties have been estimated resulting from flooding in Narromine. Intangible damages have not been quantified. The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there is no data available to allow a quantitative assessment of damages to be made to this category.

B1.3. Terminology

Definitions of the terms used in this Appendix are presented in **Chapter B8** which also summarises the value of Tangible Flood Damages.

B2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of inundation above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. A spreadsheet model which has been developed by DPIE for estimating residential damages and an in-house spreadsheet model which has been developed for previous investigations of this nature for estimating commercial, industrial and public building damages were used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the updated flood modelling, a peak flood elevation for each event was derived at each property. The property flood levels were input to the spreadsheet models which also contained property characteristics and depth-damage relationships. The depth of above-floor inundation was computed as the difference between the interpolated flood level and the floor elevation at each property. The elevations of building floors were assessed by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey data. The type of structure and potential for property damage were also assessed during the visual inspection.

The depth-damage curves for residential damages were determined using procedures described in *Guideline No. 4*. Damage curves for other categories of development (commercial and industrial, public buildings) were derived from previous floodplain management investigations.

Damages to the non-residential sector depend on the nature of the enterprise, the depth of inundation over the floor area and the time available for owners to take action to mitigate losses to contents. A spreadsheet model was used which was similar to the residential model in terms of estimation of depths of inundation, but used typical unit damage data which had been adopted in similar studies in NSW in recent years.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the value of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors to convert *potential damages* to *actual flood damages* experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

For the above reasons, the information contained in the spreadsheets used to prepare the estimates of flood damages for the catchments should not be used to provide information on the depths of above-floor inundation of individual properties.

B3. SOURCES OF DATA

B3.1. General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e. of different frequencies, and then to integrate the area beneath the damage – frequency curve computed over the whole range of frequencies up to the PMF. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach would not be practicable at Narromine given the limited data that are available on historic flood damages.
- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for the present investigation.
- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). These kinds of data are considered to be suitable for generalised studies, such as broad regional studies. They are not considered to be suitable for use in specific areas, unless none of the other approaches can be satisfactorily applied.
- The fourth way is to adapt or transpose data from other flood liable areas. This was the approach used for the present study. As mentioned, the *Guideline No 4* procedure was adopted for the assessment of residential damages. The approach was based on data collected following major flooding in Katherine in 1998, with adjustments to account for changes in values due to inflation, and after taking into account the nature of development and flooding patterns in the study area. The data collected during site inspection in the flood liable areas assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations of a similar nature to the present study.

B3.2. Property Data

The properties were divided into three categories: residential, commercial / industrial, and public buildings.

For residential properties, the data used in the damages estimation included:

- the location/address of each property
- an assessment of the type of structure
- natural surface level
- floor level

For commercial / industrial and public properties, the required data included:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- natural surface level
- floor level

The property descriptions were used to classify the commercial and public developments into categories (i.e. high, medium or low value properties) which relate to the magnitude of likely flood damages.

The total number of residential properties, commercial / industrial and public buildings is shown in **Table B3.1**.

TABLE B3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties
Residential[(1)]	1,683
Commercial / Industrial	176
Public	27
Total	**1,886**

1. Includes individual residential units

B3.3. Flood Levels Used in the Analysis

Damages were computed for the design flood levels determined from the hydraulic model that was developed as part of the present investigation. The design levels assume that the drainage system is operating at optimum capacity. They do not allow for any increase in levels resulting from wave action, debris build-ups in the channels which may cause a partial blockage of bridges and which may result in conversions of flow from the supercritical to the subcritical flow regime, as well as other local hydraulic effects. These factors are usually taken into account by adding a factor of safety (freeboard) to the "nominal" flood level when assessing the "level of protection" against flooding of a particular property. Freeboard could also include an allowance for the future effects of climate change.

B4. RESIDENTIAL DAMAGES

B4.1. Damage Functions

The procedures identified in *Guideline No 4* allow for the preparation of a depth versus damage relationship which incorporates structural damage to the building, damage to internals and contents, external damages and clean-up costs. In addition, there is the facility for including allowance for accommodation costs and loss of rent. Separate curves are computed for three residential categories:

- Single storey slab on ground construction
- Single storey elevated floor
- Two storey residence

The level of flood awareness and available warning time are taken into account by factors which are used to reduce "potential" damages to contents to "actual" damages. "Potential" damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean-up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (BoM and NSW SES).

Water levels in the Macquarie River at Narromine generally rise over a period of several days. There is also a well-tested flood warning system operated by BoM and specific flood response procedures are incorporated in the *Narromine Shire Local Flood Plan 2014*. Consequently, there would be considerable time in advance of a flood event in which to warn residents and for them to take action to mitigate flood losses. Provided warning is available, house contents may be raised above flood level to about 0.9 m, which corresponds with the height of a typical table/bench height. The spreadsheet provides two factors, one for above and one for below the typical bench height. The reduction in damages is also dependent on the likely duration of inundation of contents, which in the case of Narromine extend for several days.

Table B4.1 over shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 1.0 m (The maximum depth of above-floor inundation in Narromine is about 3.9 m at the 1% AEP level of flooding). A typical ground floor area of 240 m^2 was adopted for the assessment. The values in **Table B4.1** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

B4.2. Total Residential Damages

Table B4.2 over summarises residential damages for the range of floods in Narromine. The damage estimates were carried out for floods between the 20% AEP and the PMF, which were modelled hydraulically as part of the present study.

TABLE B4.1
DAMAGES TO RESIDENTIAL PROPERTIES

Type of Residential Construction	0.3 m Depth of Inundation Above Floor Level	1.0 m Depth of Inundation Above Floor Level
Single Storey Slab on Ground	$110,365	$149,814
Single Storey High Set	$73,305	$131,385
Double Storey	$51,313	$91,969

Note: These values allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

While the threshold of above-floor flooding for residential type development in Narromine is a 2% AEP flood, when two dwellings, one of which is located on River Drive and the other on Warren Road would be inundated by a maximum of 150 mm, large-scale flood damages are not experienced in Narromine until the southern bank of the river is overtopped during a slightly larger flood event. For example, the total number of dwellings that would experience above-floor inundation at the 1% AEP level of flooding would be 449, increasing to 1, during a 0.5% AEP flood event. Almost all of the existing dwellings in Narromine would experience above-floor flooding in an extreme flood event.

The maximum depth of above-floor inundation in the worst affected dwelling would increase from about 1.3 m during a 1% AEP flood event, increasing to about 1.7 during a 0.5% AEP flood event and about 4 m in the Extreme Flood.

The total residential damages in Narromine would increase from about $43.3 Million at the 1% AEP level of flooding to about $315 Million at the upper limit of flooding.

TABLE B4.2
RESIDENTIAL FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20%	0	0	0
10%	0	0	0
5%	0	0	0
2%	10	2	0.27
1%	747	449	43.32
0.5%	1310	1126	108.31
0.2%	1512	1446	201.94
Extreme	1659	1655	314.53

B5. COMMERCIAL / INDUSTRIAL DAMAGES

B5.1. Direct Commercial / Industrial Damages

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category
- floor area
- floor elevation

The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages also depend on the floor area.

It has recently been recognised following the 1998 flood in Katherine that previous investigations using stage-damage curves contained in proprietary software tends to seriously underestimate true damage costs. DPIE are currently researching appropriate damage functions which could be adopted in the estimation of commercial and industrial categories as they have already done with residential damages. However, these data were not available for the present study.

On the basis of previous investigations the following typical damage rates are considered appropriate for potential external and internal damages and clean-up costs for both commercial and industrial properties. They are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur:

Low value enterprise	$280/m^2	(e.g. Commercial: small shops, cafes, joinery, public halls. Industrial: auto workshop with concrete floor and minimal goods at floor level, Council or Government Depots, storage areas.)
Medium value enterprise	$420/m^2	(e.g. Commercial: food shops, hardware, banks, professional offices, retail enterprises, with furniture/fixtures at floor level which would suffer damage if inundated. Industrial: warehouses, equipment hire.)
High value enterprise	$650/m^2	(e.g. Commercial : electrical shops, clothing stores, bookshops, newsagents, restaurants, schools, showrooms and retailers with goods and furniture, or other high value items at ground or lower floor level. Industrial: service stations, vehicle showrooms, smash repairs.)

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time, a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

For the present study, the potential damages described above were converted to actual damages using a multiplier which ranged from between 0.5 and 0.8 depending on the depth of above-floor inundation.

B5.2. Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.
- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e. turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages. A clean-up cost of \$15/m^2 of floor area of each flooded property was also included.

B5.3. Total Commercial and Industrial Damages

Table B5.1 over summarises estimated commercial and industrial damages in Narromine.

The threshold of above-floor flooding in commercial and industrial type development in Narromine is a flood which is slightly larger than 2% AEP, when flood water would surcharge the southern bank of the Macquarie River and enter the town.

A total of 72 commercial/industrial type development would experience above-floor inundation at the 1% AEP level of flooding, increasing to 138 at the 0.5% AEP level of flooding. Almost all of the commercial and industrial type properties in Narromine would experience above-floor inundation during an extreme flood event.

The maximum depth of above-floor inundation in the worst affected property would increase from about 1 m during a 1% AEP flood event, increasing to about 1.3 m during a 0.5% AEP flood event and about 4 m in the Extreme Flood.

The total commercial/industrial damages in Narromine would increase from about \$3.3 Million at the 1% AEP level of flooding to about \$78 Million at the upper limit of flooding.

TABLE C5.1
COMMERCIAL AND INDUSTRIAL FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20%	0	0	0
10%	0	0	0
5%	0	0	0
2%	0	0	0
1%	111	72	3.30
0.5%	153	138	11.93
0.2%	168	159	30.10
PMF	176	175	78.46

B6. DAMAGES TO PUBLIC BUILDINGS

B6.1. Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an area basis according to the perceived value of the property. Potential internal damages were indexed to a depth of above-floor inundation of 2 m as shown below. At floor level and 1.2 m depth of inundation, zero and 70% of these values respectively were assumed to occur.

Low value	$280/m^2	
Medium value	$420/m^2	(e.g. council buildings, NSW SES HQ, fire station)
High value	$650/m^2	(e.g. schools)

These values were obtained from the Nyngan Study (DWR, 1990), as well as commercial data presented in the Forbes Water Studies report (WS, 1992) and adjusted for inflation. External and structural damages were taken as 4 and 10% of internal damages respectively.

B6.2. Indirect Damages – Public Buildings

A value of $15/m^2 was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs.

B6.3. Total Damages – Public Buildings

Table B6.1 over summarises estimated damages to public buildings in Narromine.

Similar to the findings for commercial/industrial type development, the threshold of above-floor flooding for public buildings in Narromine is equivalent to a flood which is slightly larger than 2% AEP. The number of public buildings in Narromine that are above-floor inundated increases from 7 at the 1% AEP level of flooding to 17 during a 0.5% AEP flood event. All of the public buildings in Narromine would experience above-floor flooding during an extreme flood event.

The maximum depth of above-floor inundation in the worst affected property would increase from about 1 m during a 1% AEP flood event, increasing to about 1.3 m during a 0.5% AEP flood event and about 3.6 m in the Extreme Flood.

The total public building damages in Narromine would increase from about $3.1 Million at the 1% AEP level of flooding to about $24 Million at the upper limit of flooding.

TABLE B6.1
PUBLIC FLOOD DAMAGES IN NARROMINE

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20%	0	0	0
10%	0	0	0
5%	0	0	0
2%	0	0	0
1%	10	7	3.07
0.5%	24	17	5.71
0.2%	26	26	12.25
PMF	27	27	23.77

B7. DAMAGES TO INFRASTUCTURE AND COMMUNITY ASSETS

No data are available on damages experienced to infrastructure and community assets during historic flood events. However, a qualitative matrix of the effects of flooding on critical assets in Narromine is presented in **Table 2.4** of the Main Report.

B8. SUMMARY OF TANGIBLE DAMAGES

B8.1. Tangible Damages

Floods have been computed for a range of flood frequencies from 20% AEP up to the Extreme Flood. From **Table B8.1**, the threshold for flood damages is the 2% AEP flood event. **Figure B8.1** shows the damage-frequency curves and cumulative distribution of above-floor depths of inundation at the 1% AEP flood level for residential, commercial and industrial and public buildings in Narromine.

TABLE B8.1
TOTAL FLOOD DAMAGES IN NARROMINE
$ MILLION

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total
20%	0	0	0	0
10%	0	0	0	0
5%	0	0	0	0
2%	0.27	0	0	0.27
1%	43.32	3.30	3.07	49.69
0.5%	108.31	11.93	5.71	125.95
0.2%	201.94	30.10	12.25	244.29
PMF	314.53	78.46	23.77	416.76

B8.2. Definition of Terms

Average Annual Damages (also termed “expected damages”) are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent “*Present Worth Value”* of damages and used in the economic analysis of potential flood management measures.

A flood management scheme which has a design 1% AEP level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods then these damages represent the benefits of the scheme expressed on an average annual basis and converted to the *Present Worth Value* via the discount rate.

Using the procedures outlined in *Guideline No. 4*, as well as current NSW Treasury guidelines, economic analyses were carried out assuming a 50 year economic life for projects and discount rates of 7% pa. (best estimate) and 11% and 4% pa. (sensitivity analyses).

B8.3. Average Annual Damages

The average annual damages for all flood events up to the PMF are shown below in **Table B8.2**. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages.

TABLE B8.2
AVERAGE ANNUAL DAMAGES IN NARROMINE
$ MILLION

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total
20%	0	0	0	0
10%	0	0	0	0
5%	0	0	0	0
2%	0.004	0	0	0.004
1%	0.22	0.02	0.02	0.25
0.5%	0.60	0.06	0.04	0.69
0.2%	1.36	0.16	0.08	1.60
PMF	1.36	0.16	0.08	1.60

B8.4. Present Worth of Damages at Narromine

The *Present Worth Value* of damages likely to be experienced for all flood events up to the 1% AEP and PMF, for a 50 year economic life and discount rates of 4, 7 and 11 per cent are shown in **Table B8.3**.

For a discount rate of 7% pa, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $3.5 Million, for a 50 year economic life. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Narromine for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility. Flood management measures are considered on a multi-objective basis in **Chapter 4** of the Main Report.

TABLE B8.3
PRESENT WORTH VALUE OF DAMAGES IN NARROMINE
$ MILLION

Discount Rate (%)	All Floods up to 1% AEP	All Floods up to PMF
4	5.4	34.4
7	3.5	22.1
11	2.3	14.4

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NARROMINE SHIRE COUNCIL

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

JUNE 2020

VOLUME 2 – FIGURES

PROGRESS REPORT

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3.11 Local Drainage Patterns in Narromine – Flood Gates Fully Open – Post-River Bank Levee Option B Conditions – 1% AEP (2 Sheets)
3.12 Impact of Elevated River Levels on Local Drainage Patterns in Narromine – Post-River Bank Levee Option B Conditions – 1% AEP (2 Sheets)
3.13 Flood Emergency Response Planning Classifications – 1% AEP
3.14 Flood Emergency Response Planning Classifications – Extreme Flood

600 0 600 1200 1800 m

Scale: 1:60,000

LEGEND

- Stream Gauge
- Existing Town Levee
- Weir

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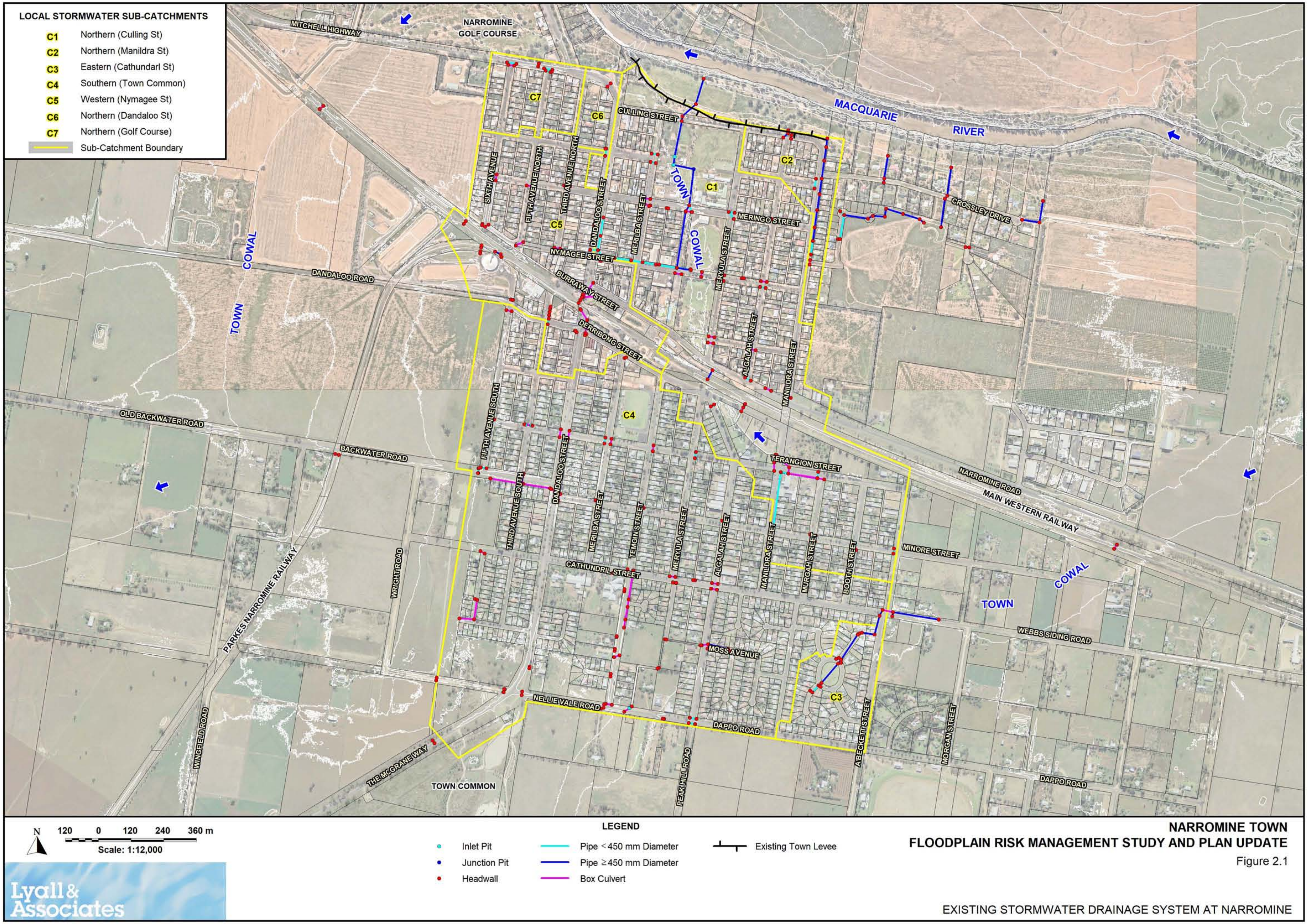
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 1.1

LOCATION PLAN



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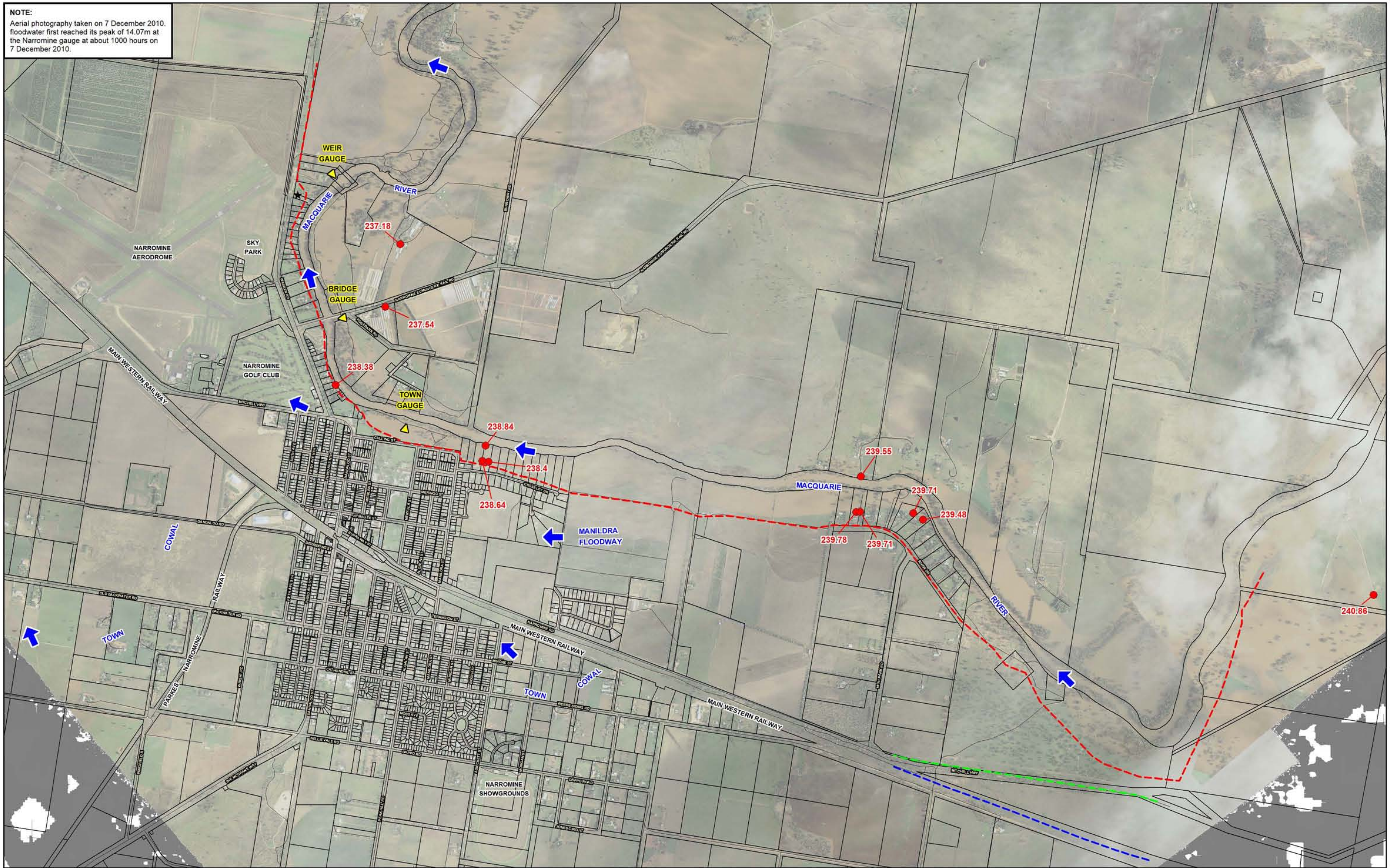
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.1

EXISTING STORMWATER DRAINAGE SYSTEM AT NARROMINE

NOTE:
Aerial photography taken on 7 December 2010. floodwater first reached its peak of 14.07m at the Narromine gauge at about 1000 hours on 7 December 2010.



N
250 0 250 500 750 m
Scale: 1:25,000

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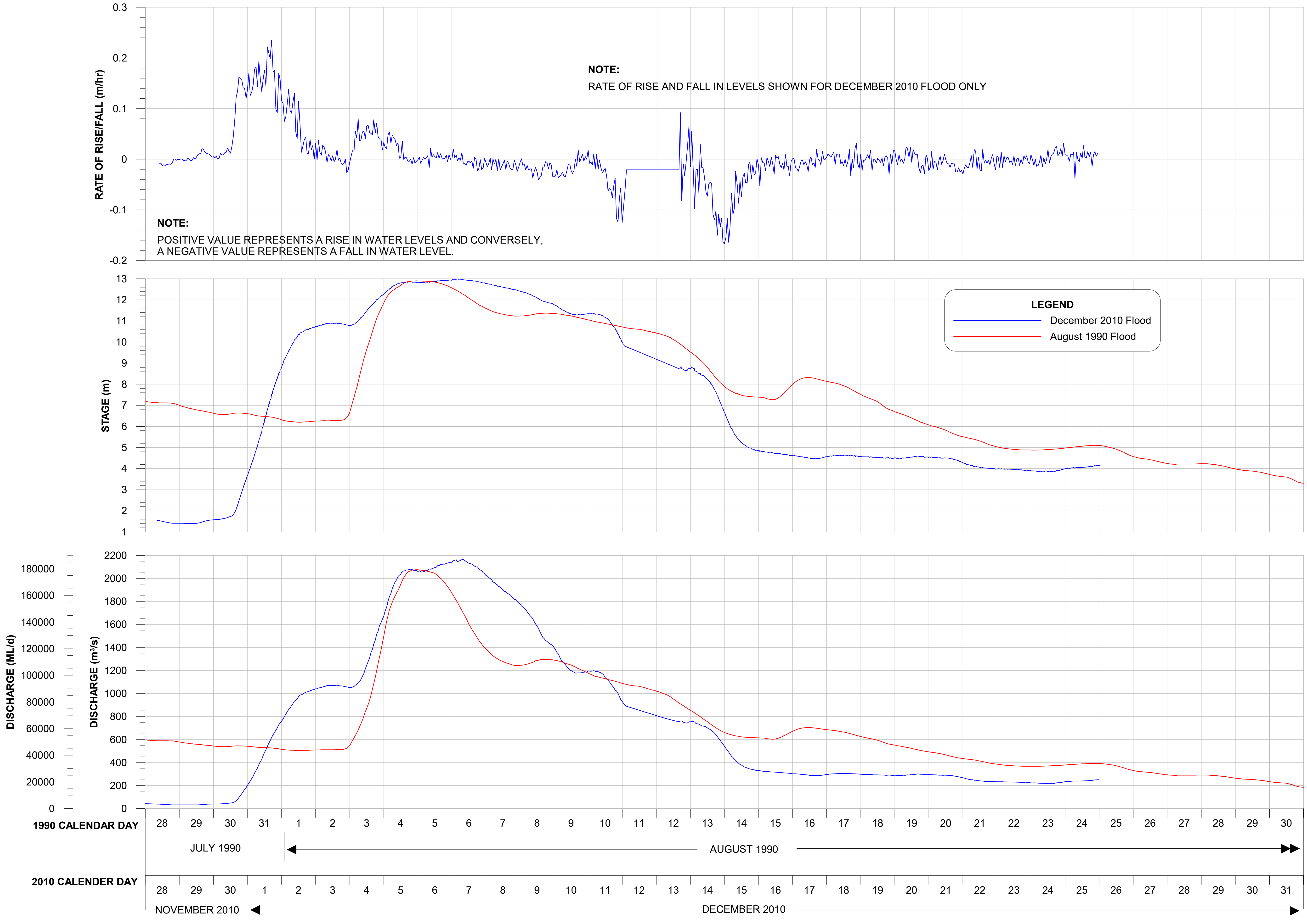
LEGEND

Alignment of LiDAR Survey Data Levels Along Southern Bank of Macquarie River
Alignment of LiDAR Survey Data Levels Along Mitchell Highway
Alignment of LiDAR Survey Data Levels Along Main Western Railway
238.27 Surveyed December 2010 Flood Mark (m AHD)
Stream Gauge

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE
Figure 2.2

AERIAL PHOTOGRAPH SHOWING HISTORIC FLOODING AT NARROMINE
DECEMBER 2010 FLOOD



NOTE : TIME ZERO ON CALENDAR DAY AXIS = 0000 HOURS ON 28 JULY 1990
0000 HOURS ON 28 NOVEMBER 2010

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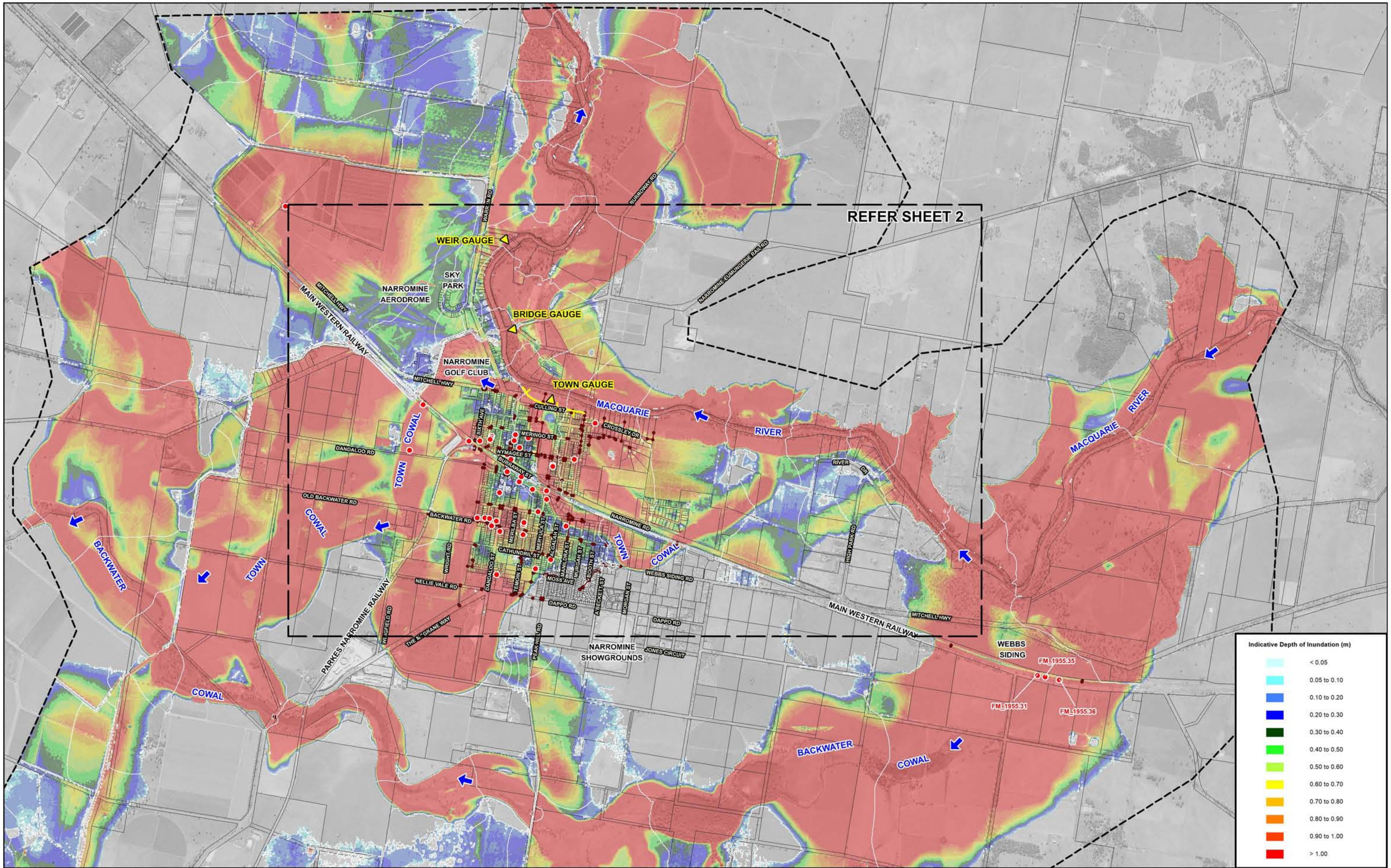
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.3

STREAM GAUGE DATA
MACQUARIE RIVER AT BAROONA (GS 421127)



N

400 0 400 800 1200 m

Scale: 1:40,000

NOTE:
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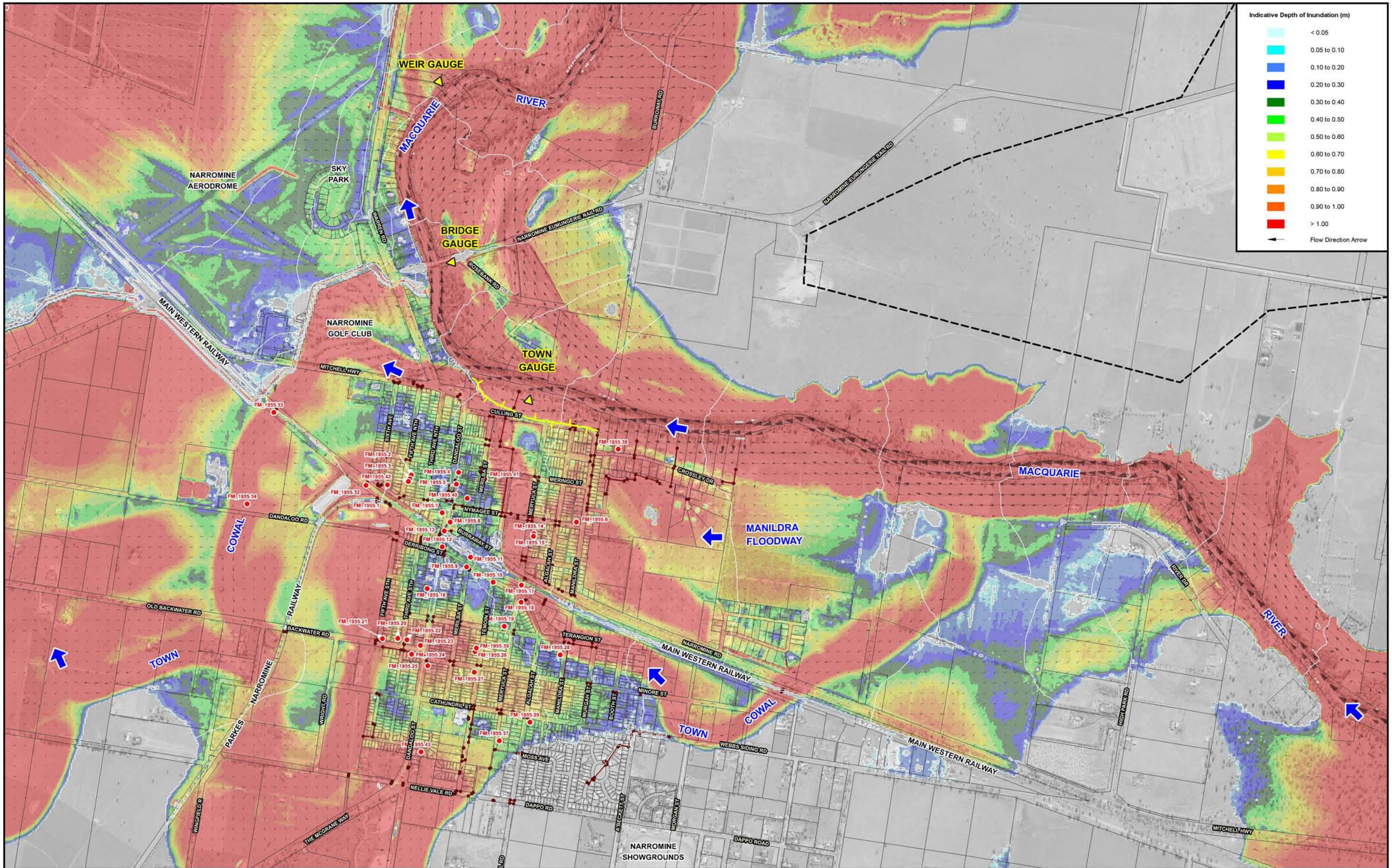
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)
- FM_1955.15 Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.4
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
FEBRUARY 1955 FLOOD



Scale: 1:20,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Water Surface Elevation Contour (m AHD) (238.5)
- Historical Flood Mark and Identifier (FM_1955.15) (Source of Flood Marks: Bewsher, 1998)

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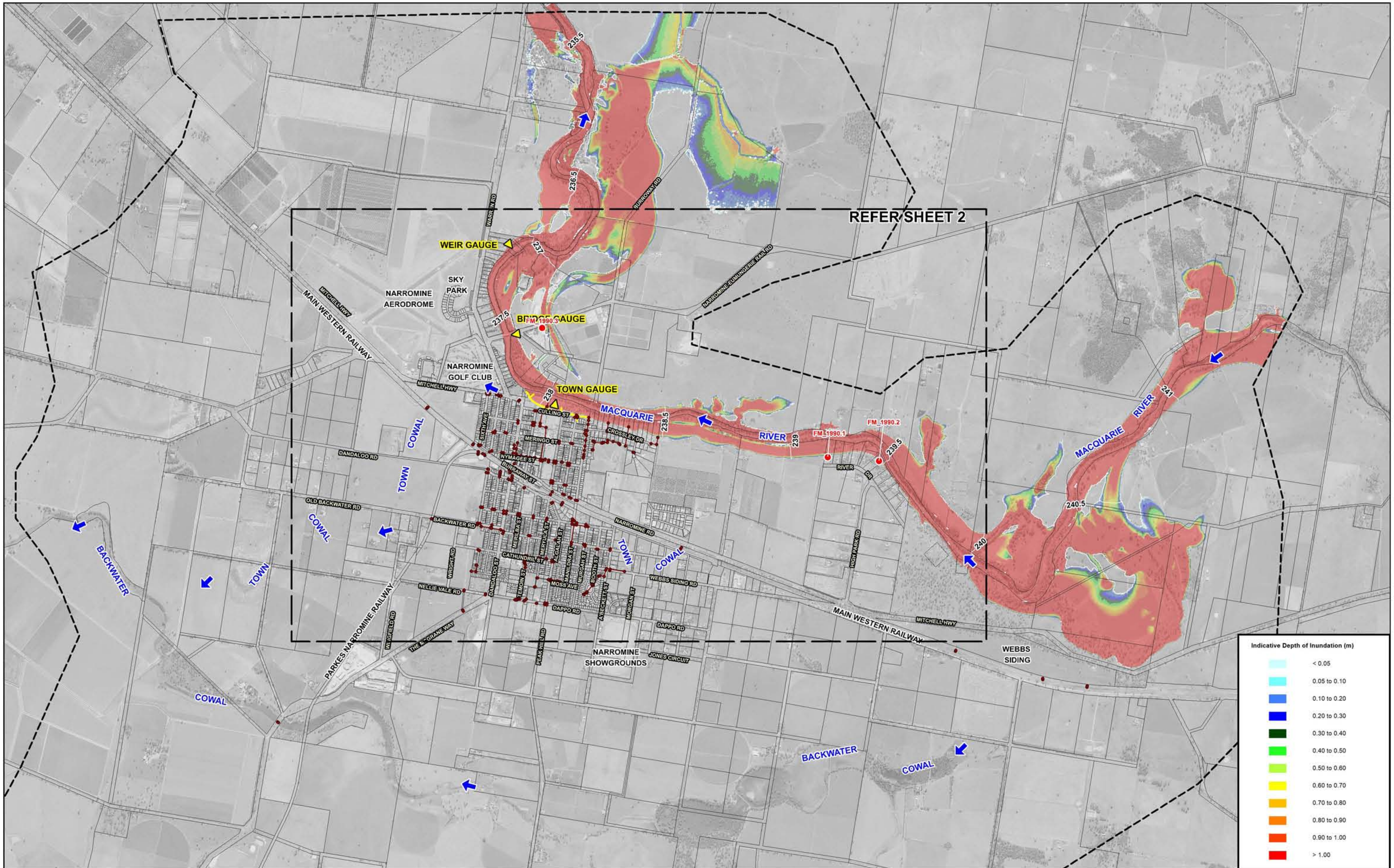
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.4
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
FEBRUARY 1955 FLOOD



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)
- FM_1990.1 Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998)

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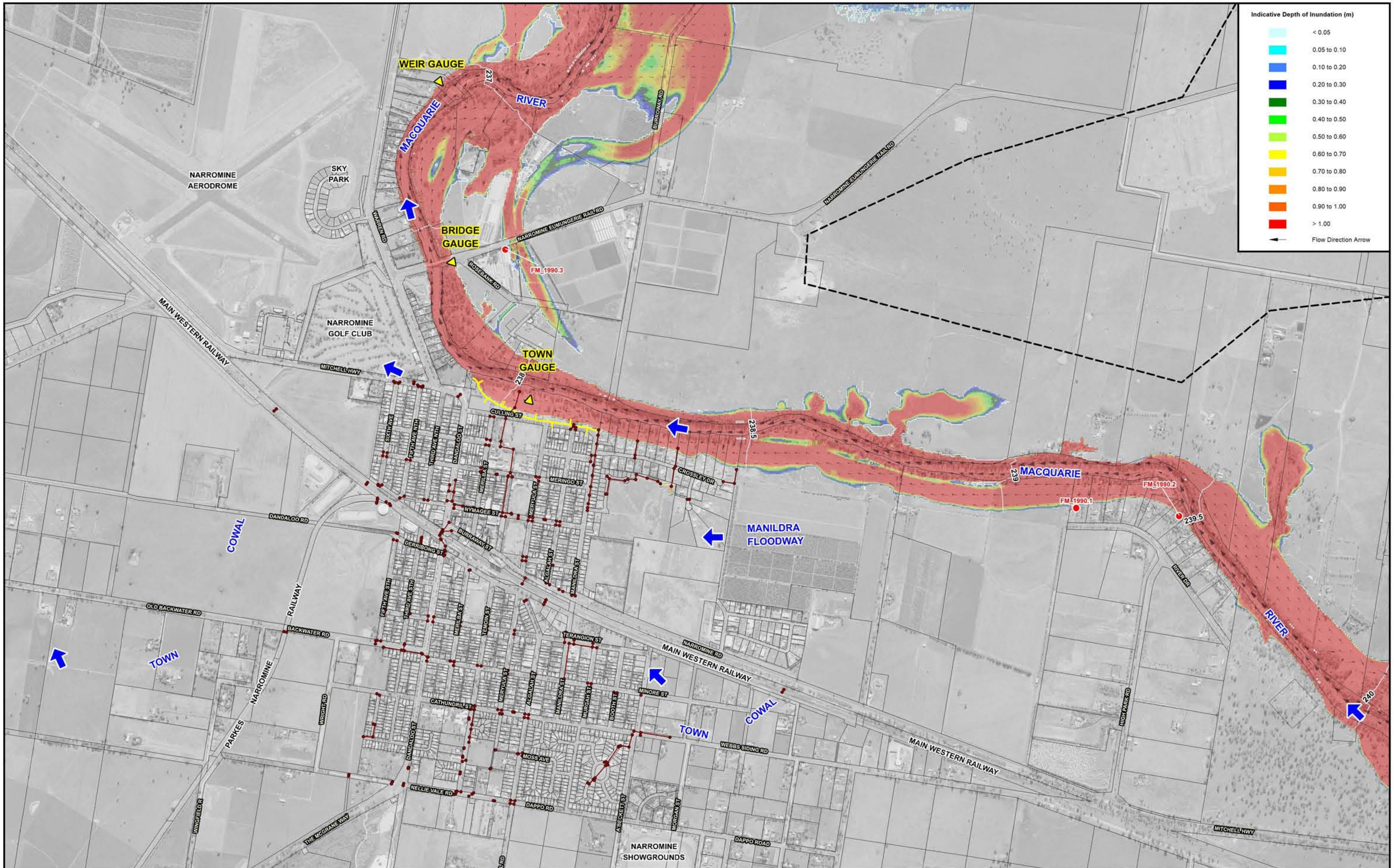
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.5
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
AUGUST 1990 FLOOD



N

200 0 200 400 600 m

Scale: 1:20,000

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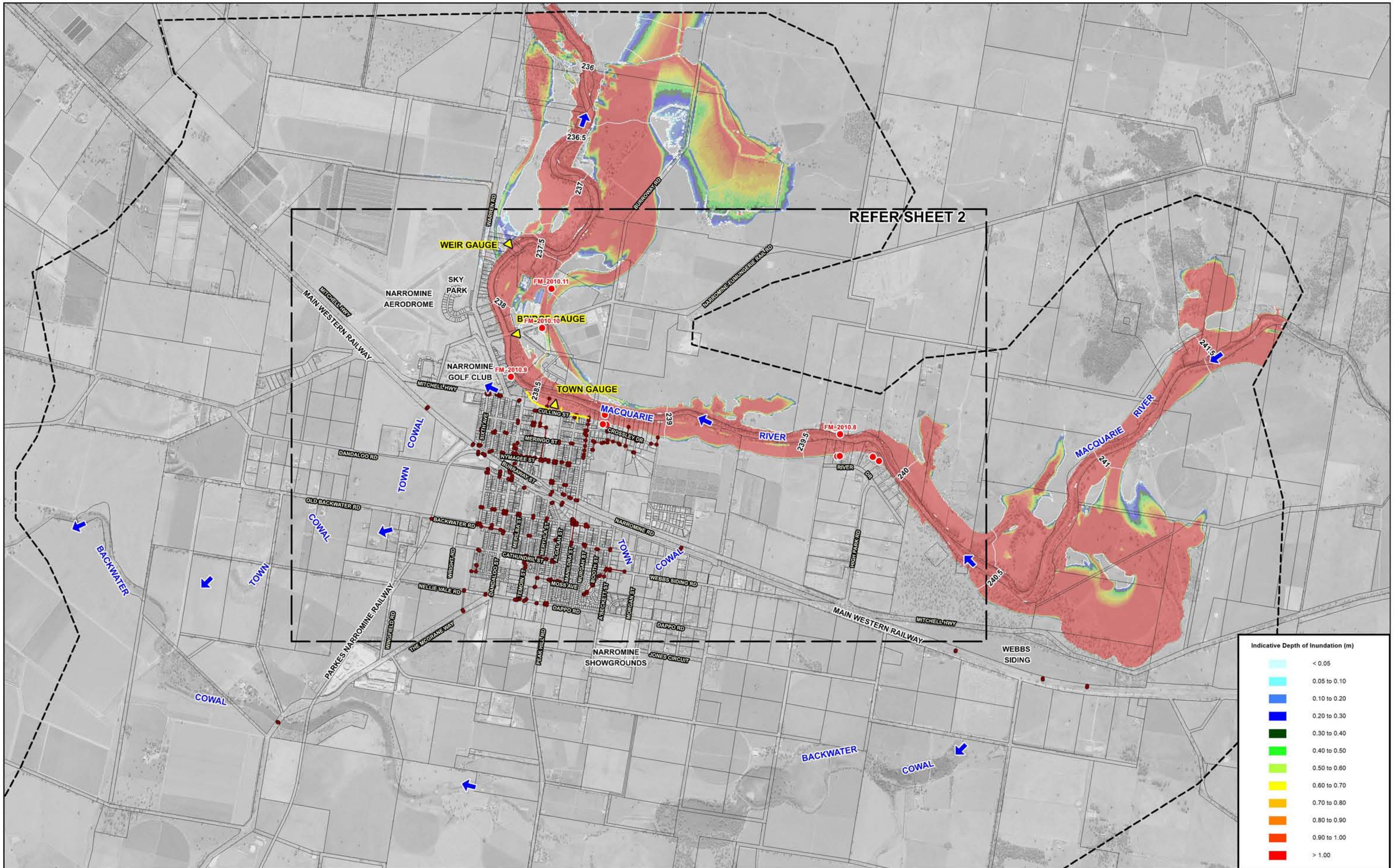
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)
- FM_1990.1 Historical Flood Mark and Identifier (Source of Flood Marks: Bewsher, 1998)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.5
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
AUGUST 1990 FLOOD



N
400 0 400 800 1200 m
Scale: 1:40,000

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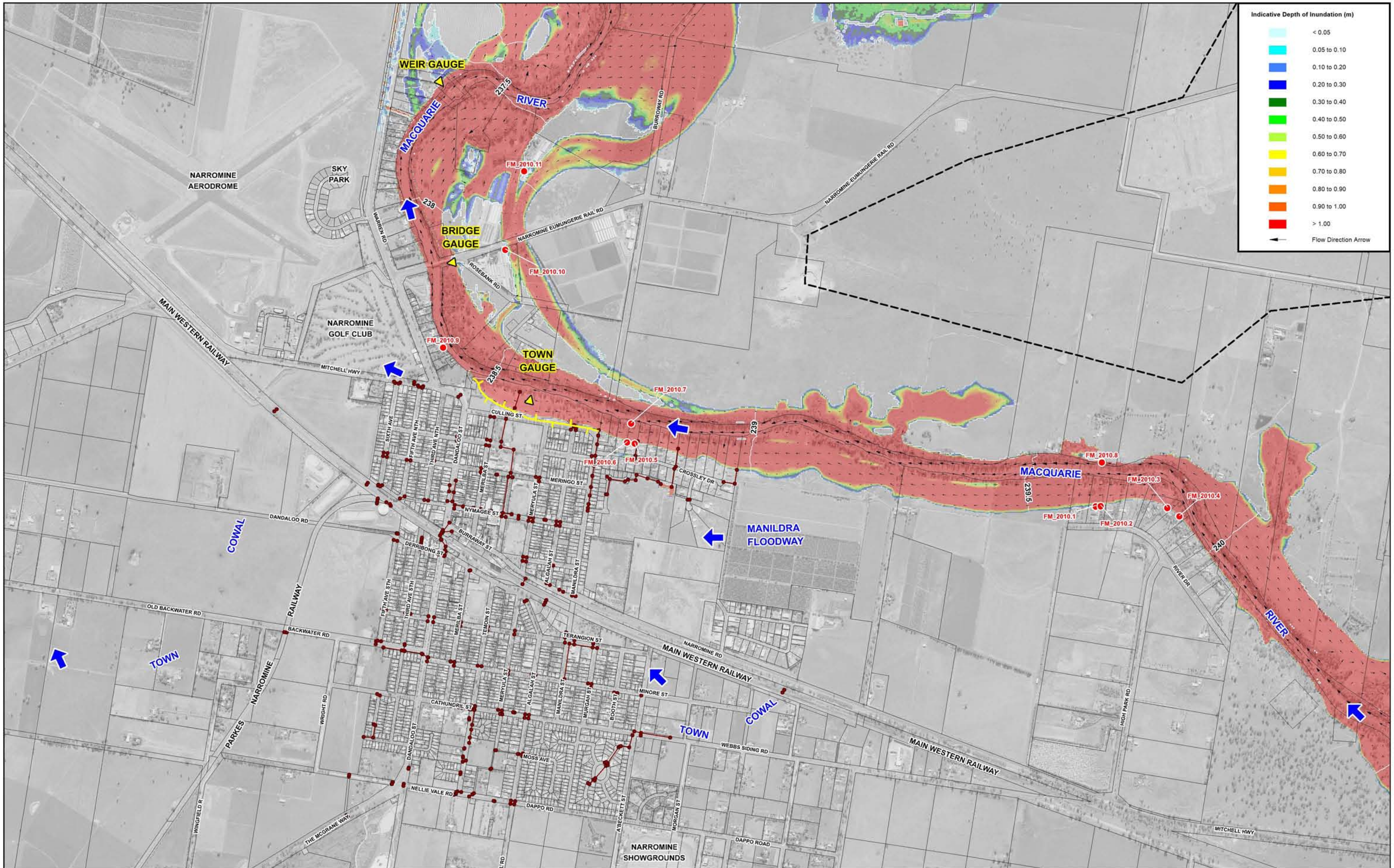
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Water Surface Elevation Contour (m AHD) (238.5)
- Historical Flood Mark and Identifier (FM_2010.5) (Source of Flood Marks: NSW SES)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.6
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
DECEMBER 2010 FLOOD



200 0 200 400 600 m

Scale: 1:20,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Water Surface Elevation Contour (m AHD) (238.5)
- Historical Flood Mark and Identifier (FM_2010.5) (Source of Flood Marks: NSW SES)

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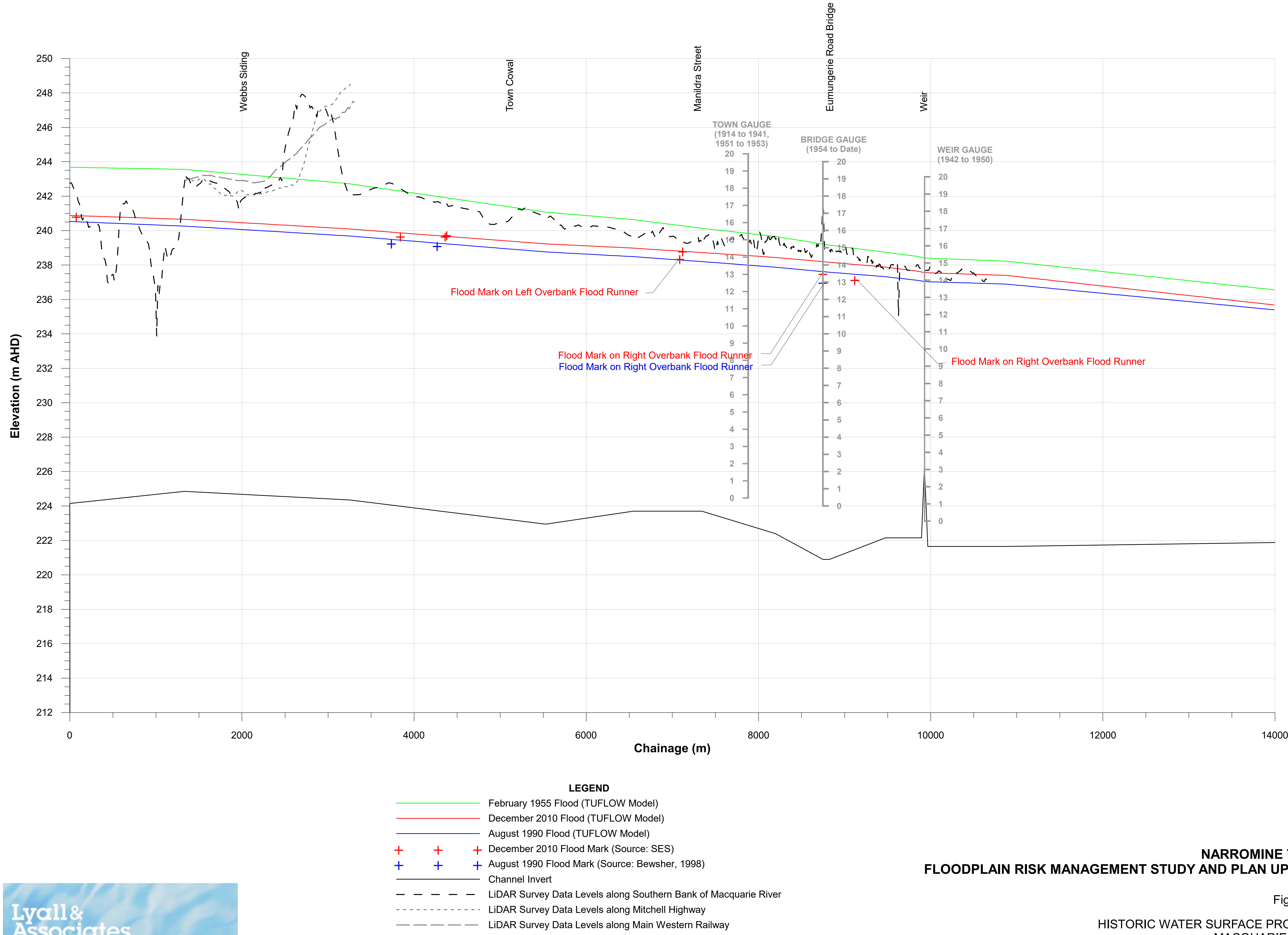
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.6
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
DECEMBER 2010 FLOOD



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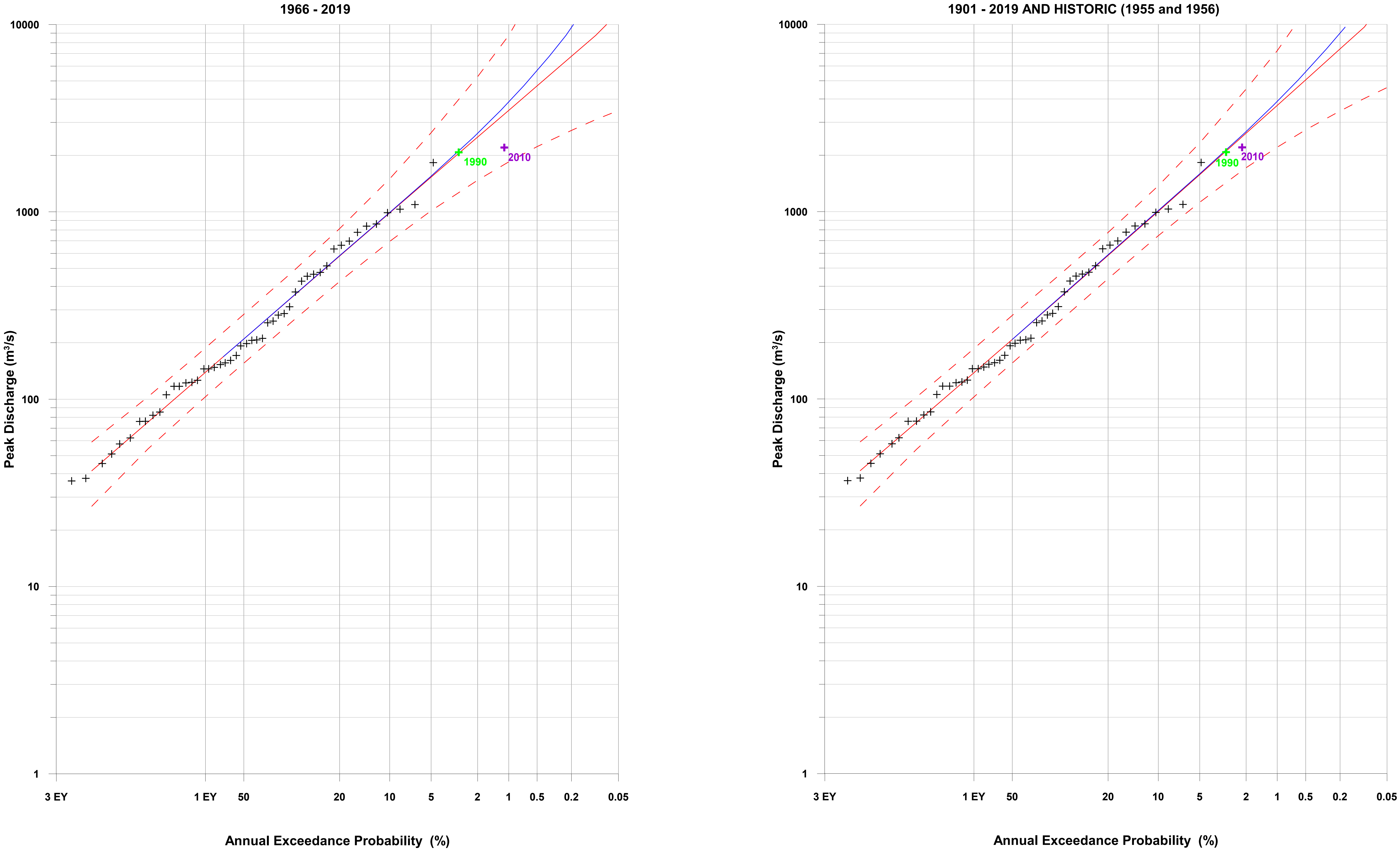
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.7

HISTORIC WATER SURFACE PROFILES
MACQUARIE RIVER



LEGEND

Blue solid line	Expected Probability Adjustment
Red dashed line	Log-Pearson III 5% Confidence Limits
Red solid line	Log-Pearson III Fit
+	Recorded Annual Maximum Discharge

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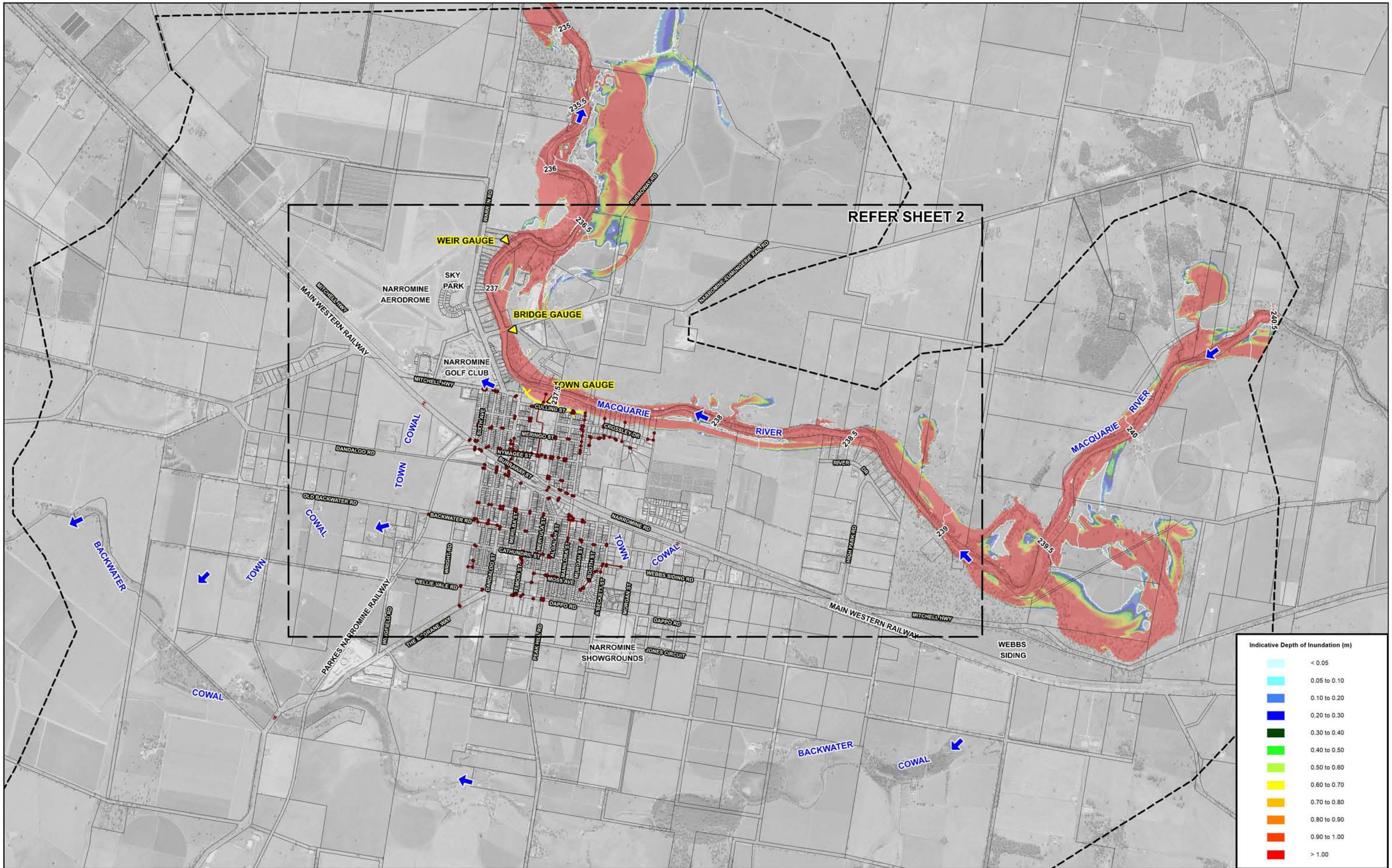
UPDATE OF THE NARROMINE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.8

UPDATED FLOOD FREQUENCY ANALYSIS
MACQUARIE RIVER AT BAROONA STREAM GAUGE (GS 421127)



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

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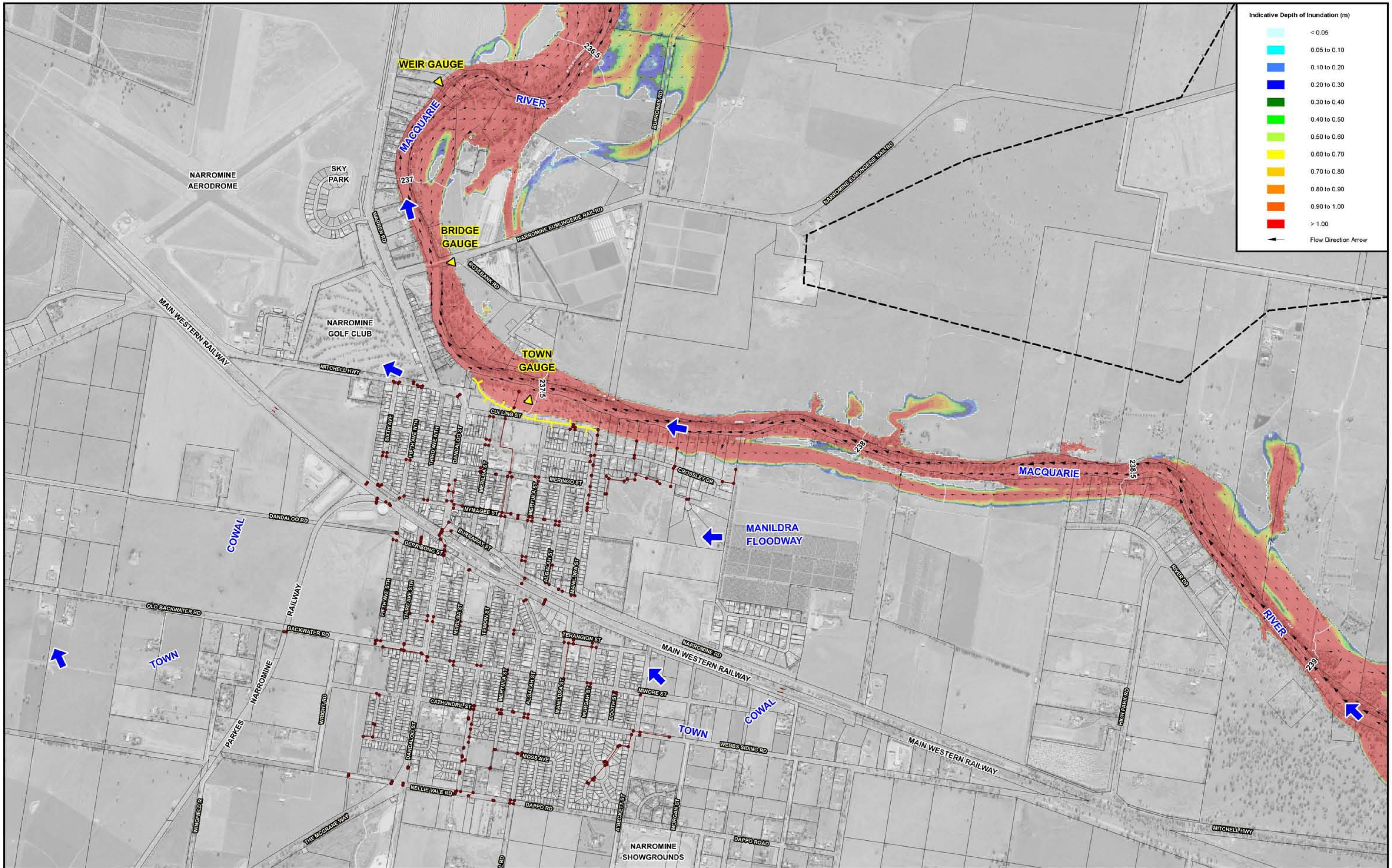
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.9
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
5% AEP



N
200 0 200 400 600 m
Scale: 1:20,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

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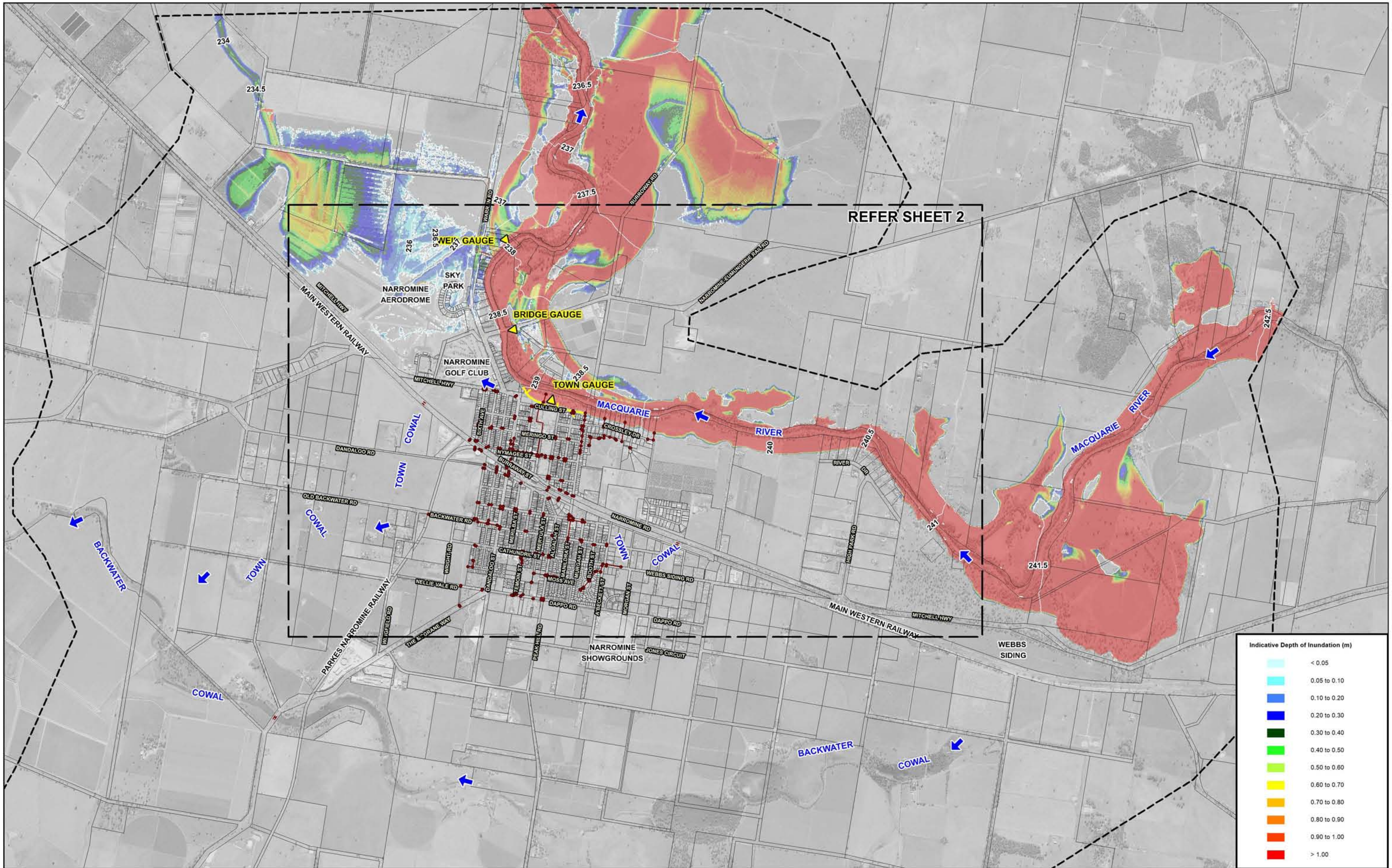
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.9
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
5% AEP



400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Water Surface Elevation Contour (m AHD)

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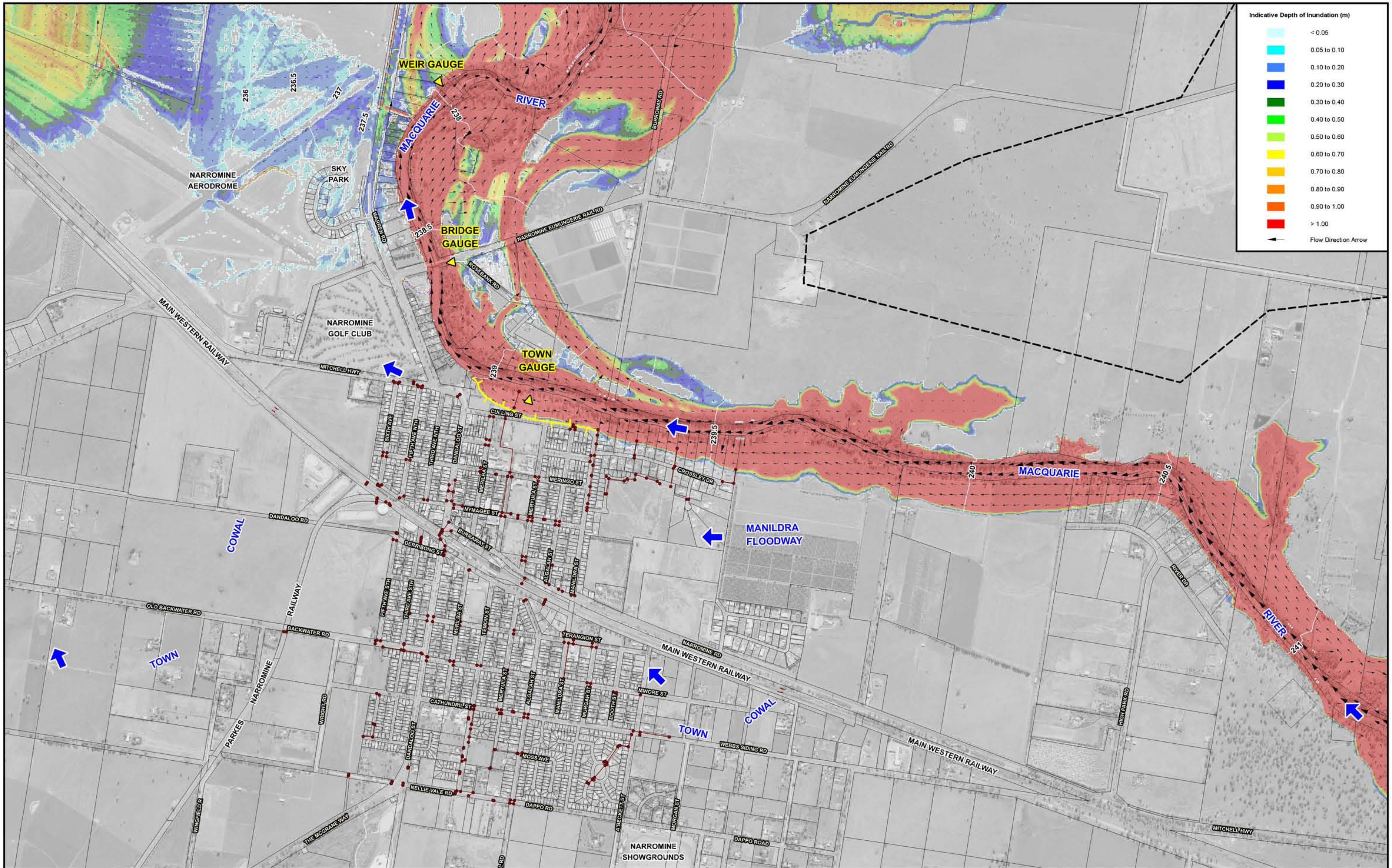
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.10
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
2% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

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LEGEND

Two-Dimensional Model Boundary

Modelled Stormwater Drainage System

Stream Gauge

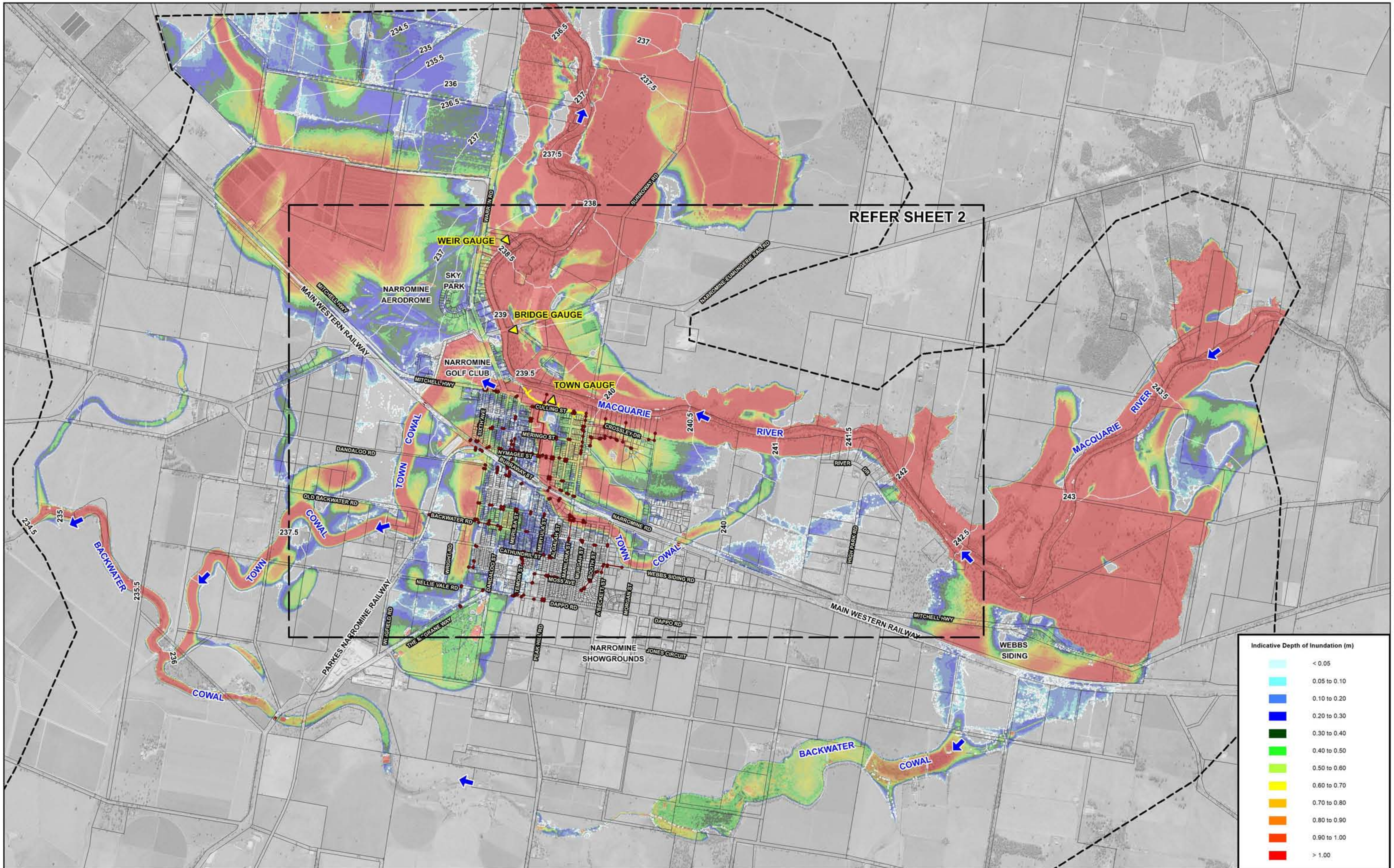
Existing Town Levee

Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.10
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
2% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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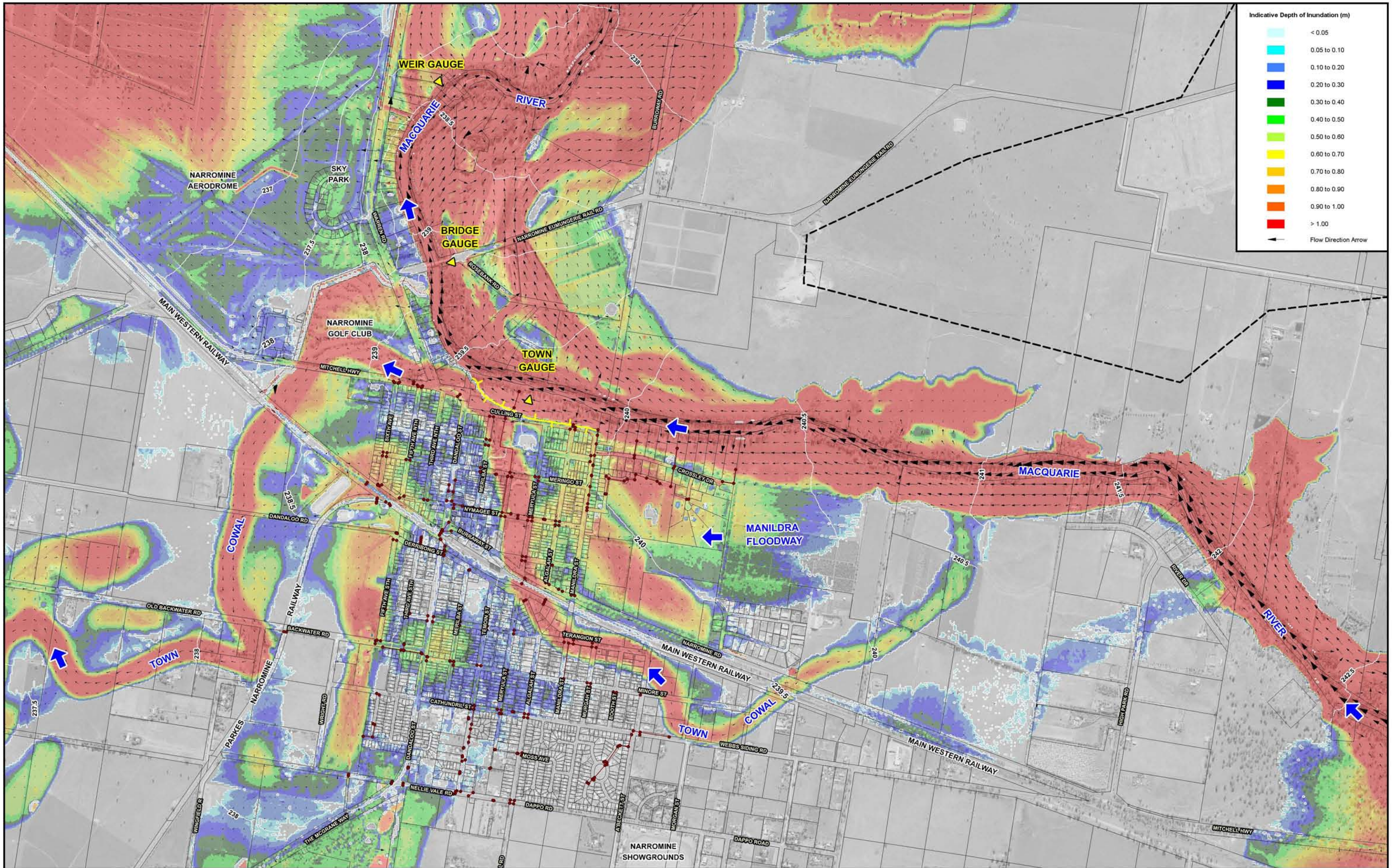
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.11
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
1% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

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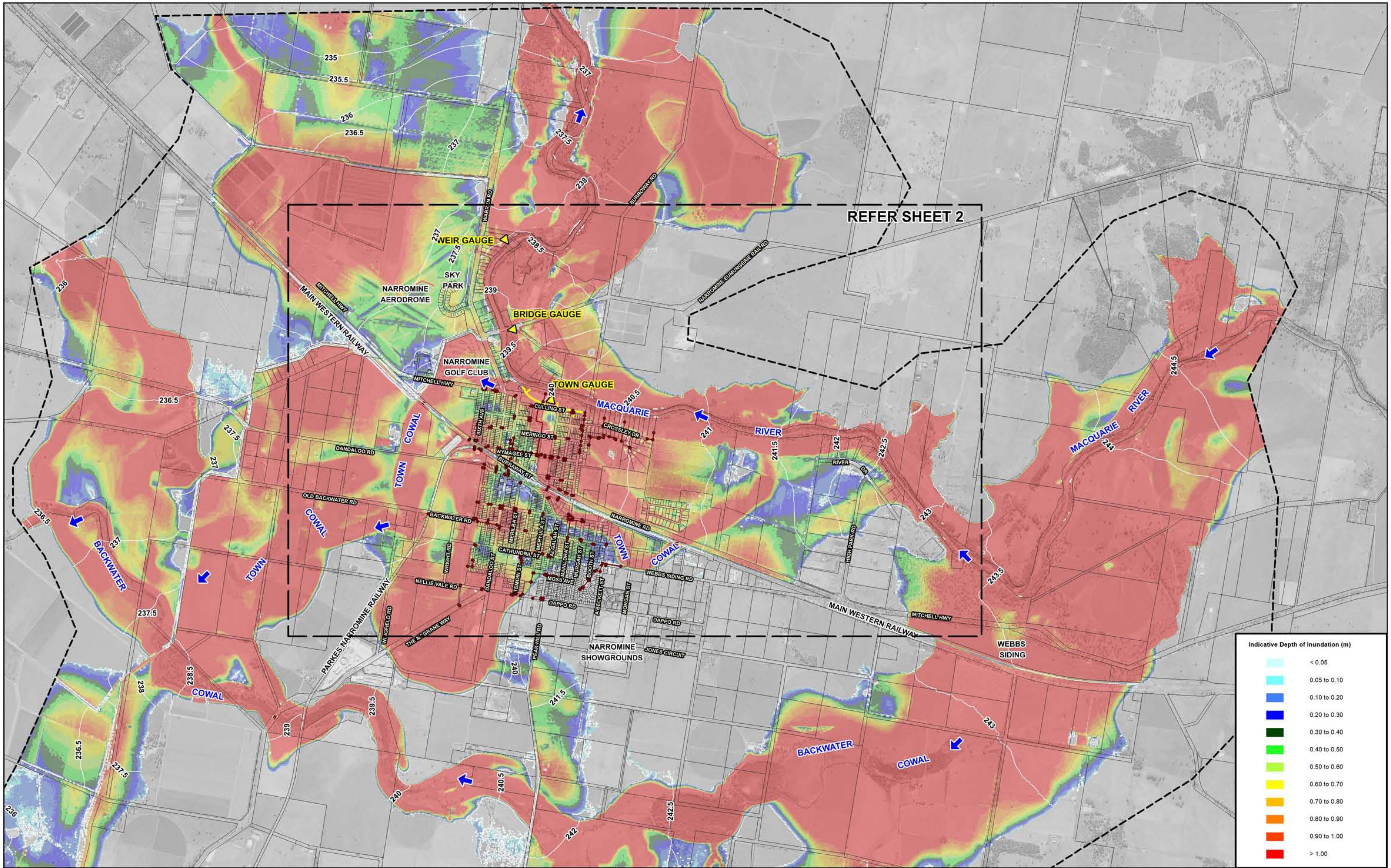
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.11
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
1% AEP



N
400 0 400 800 1200 m
Scale: 1:40,000

Lyall & Associates

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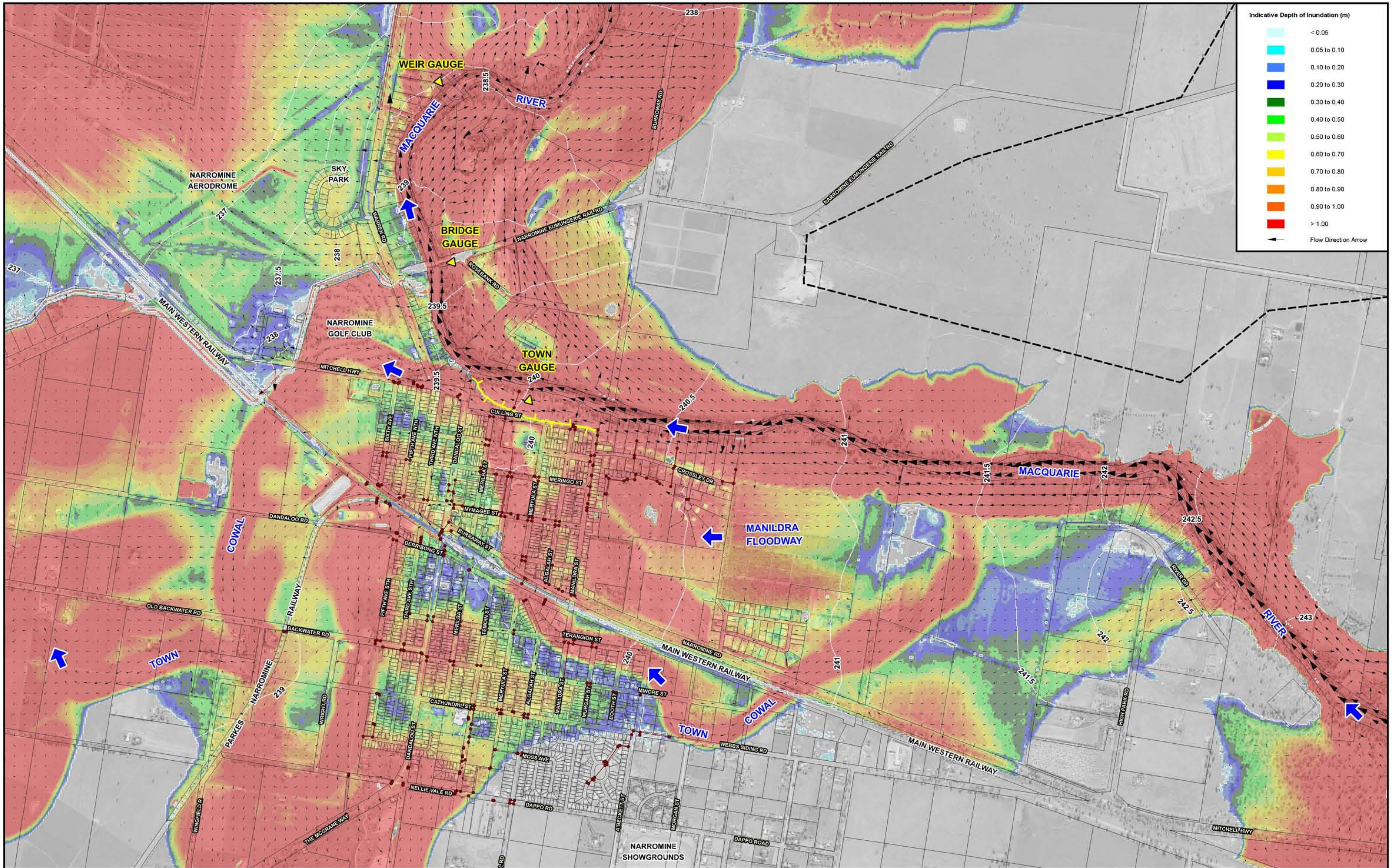
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.12
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
0.5% AEP



LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Water Surface Elevation Contour (m AHD)

200 0 200 400 600 m

Scale: 1:20,000

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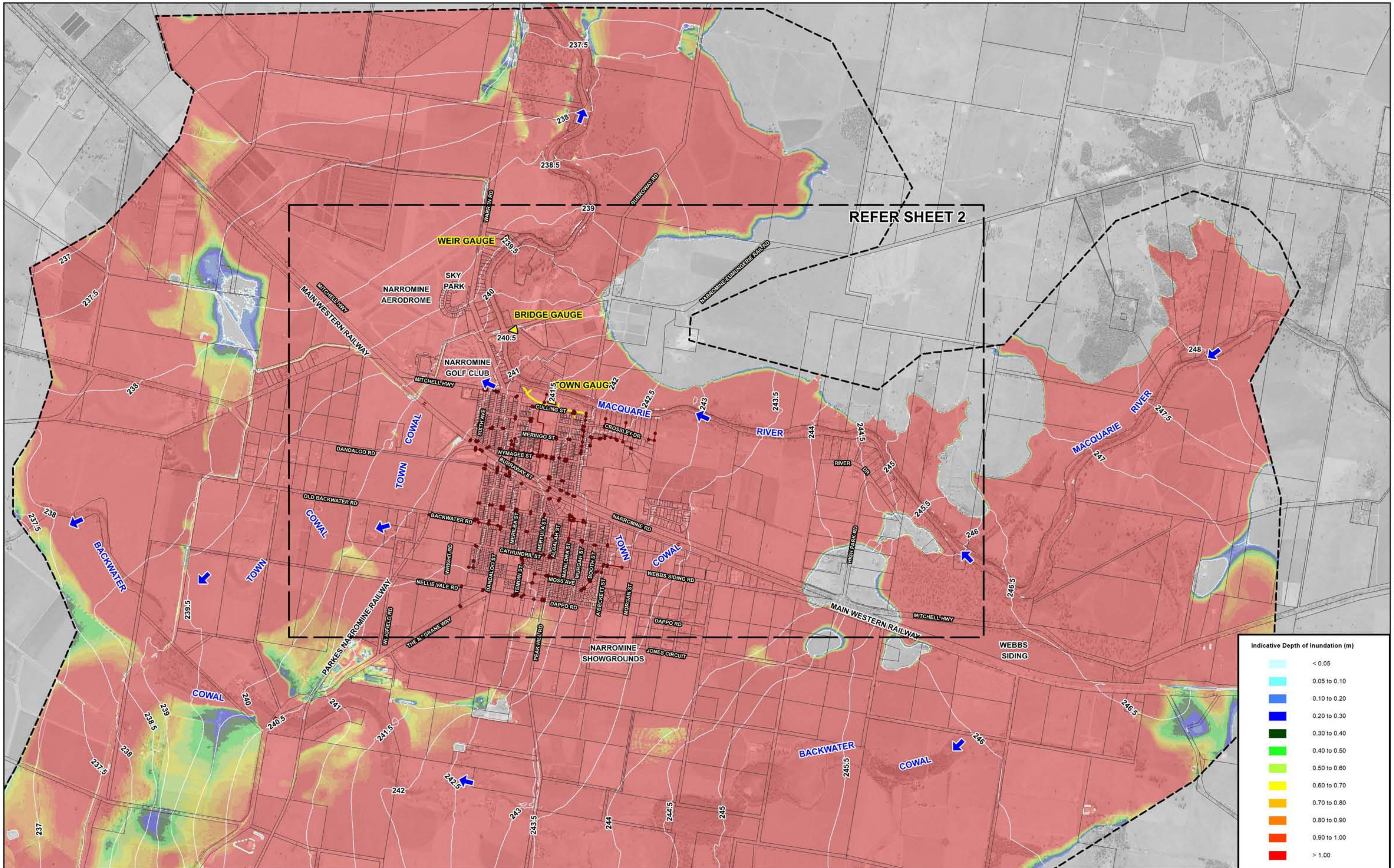
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.12
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
0.5% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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LEGEND

Two-Dimensional Model Boundary

Modelled Stormwater Drainage System

Stream Gauge

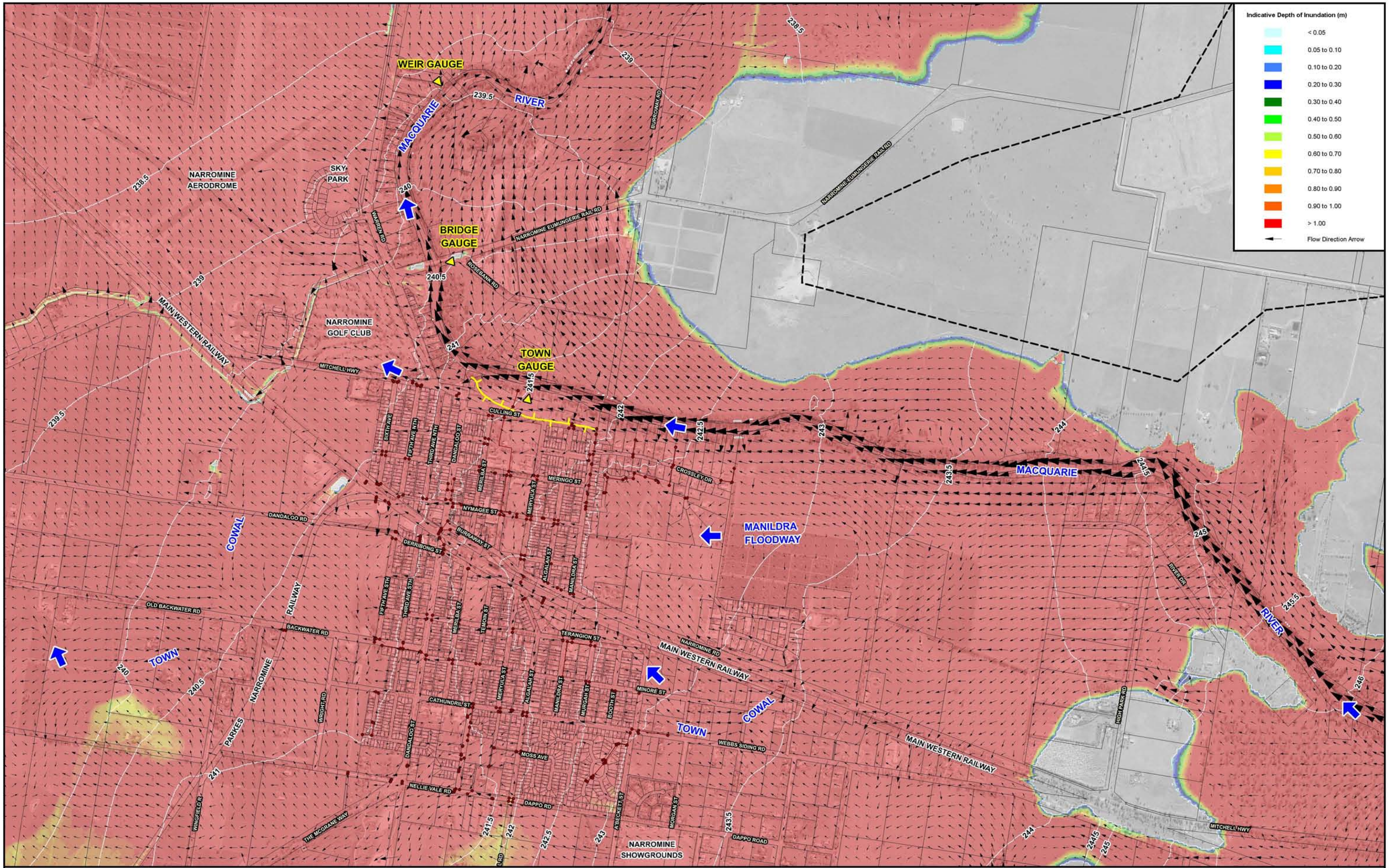
Existing Town Levee

238.5 Water Surface Elevation Contour (m AHD)

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.13
(Sheet 1 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
EXTREME FLOOD



N

200 0 200 400 600 m

Scale: 1:20,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- 238.5 Water Surface Elevation Contour (m AHD)

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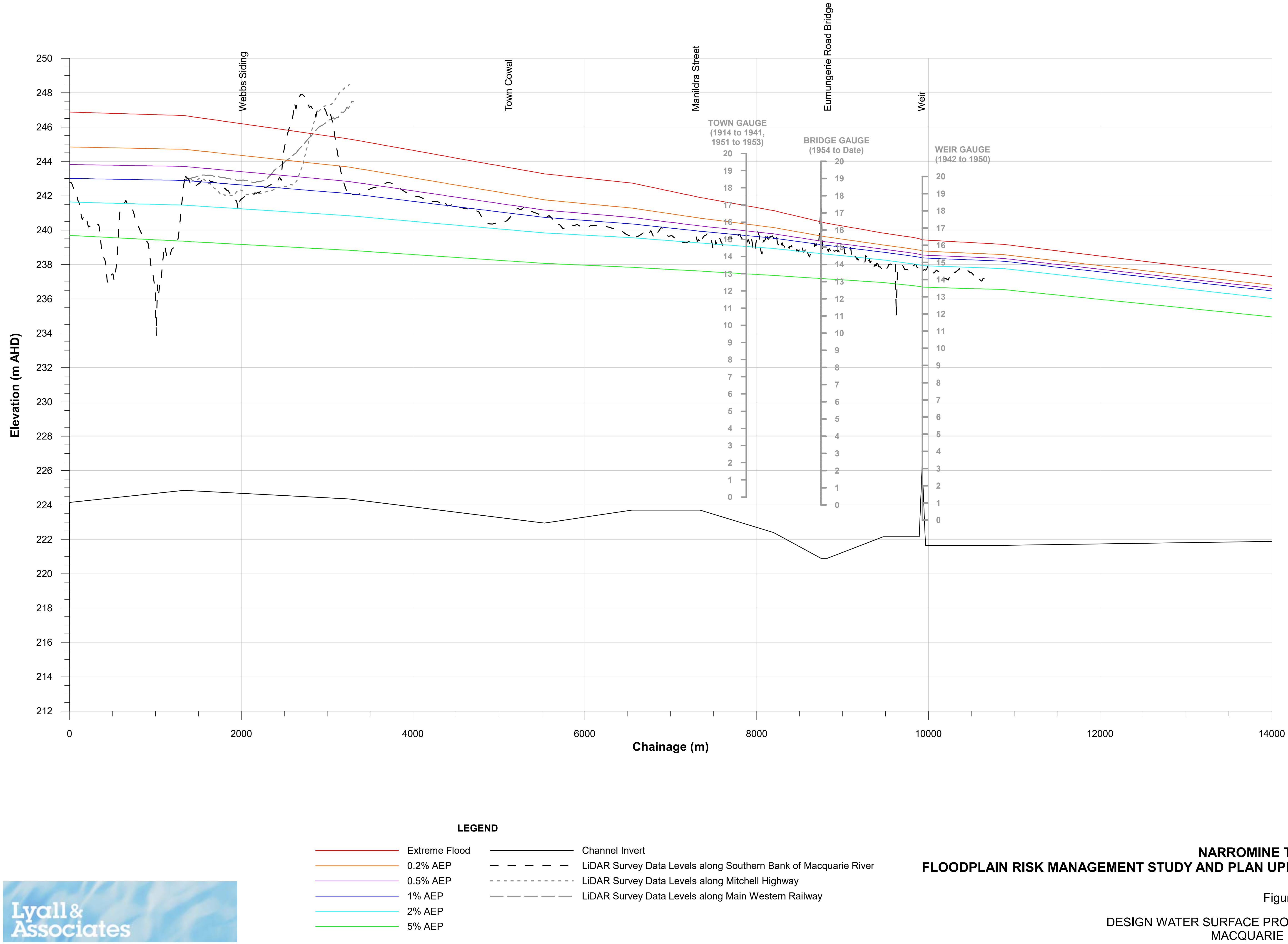
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.13
(Sheet 2 of 2)

INDICATIVE EXTENT AND DEPTHS OF INUNDATION
EXTREME FLOOD



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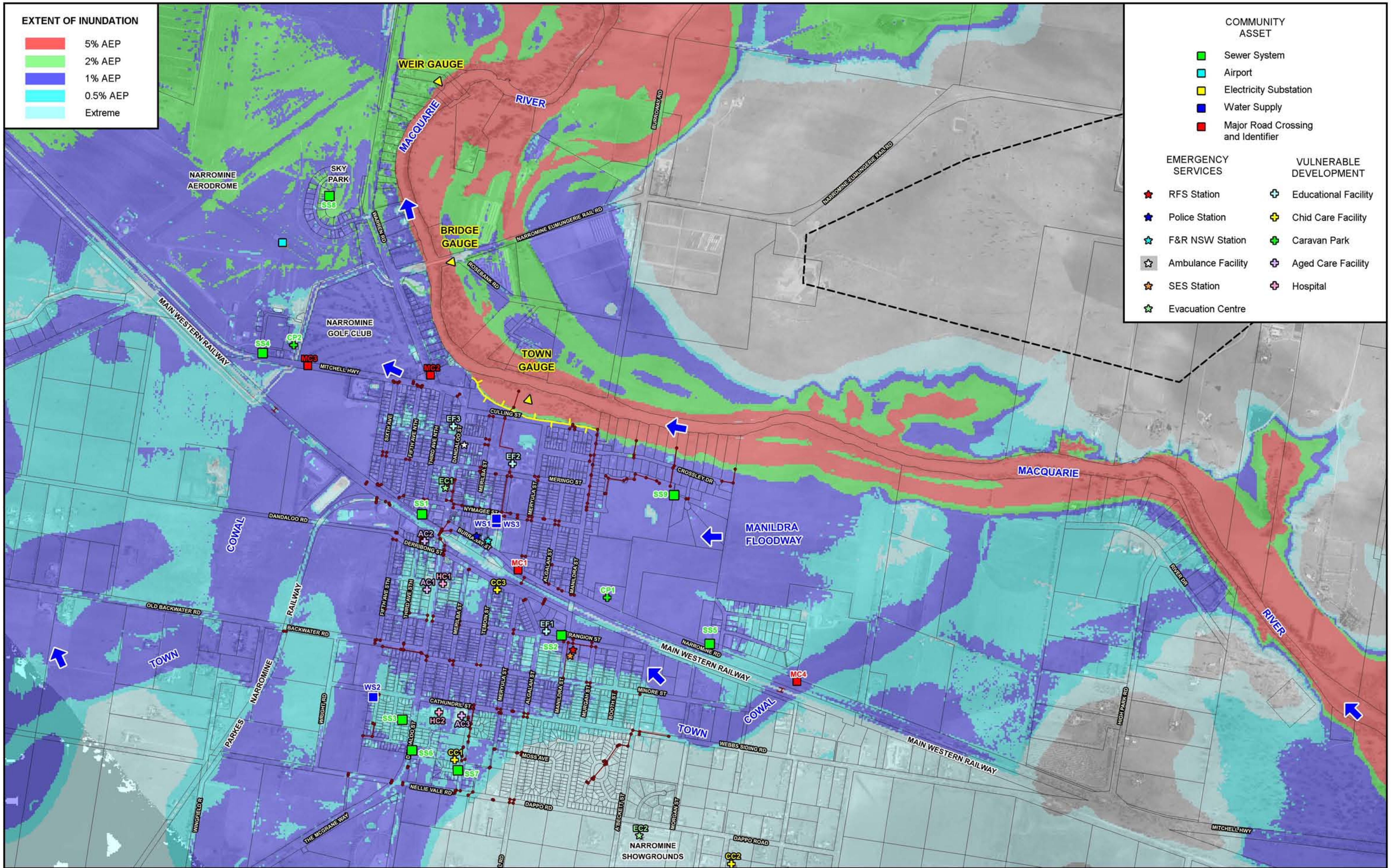
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.14

DESIGN WATER SURFACE PROFILES
MACQUARIE RIVER



N
200 0 200 400 600 m
Scale: 1:20,000

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LEGEND
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee

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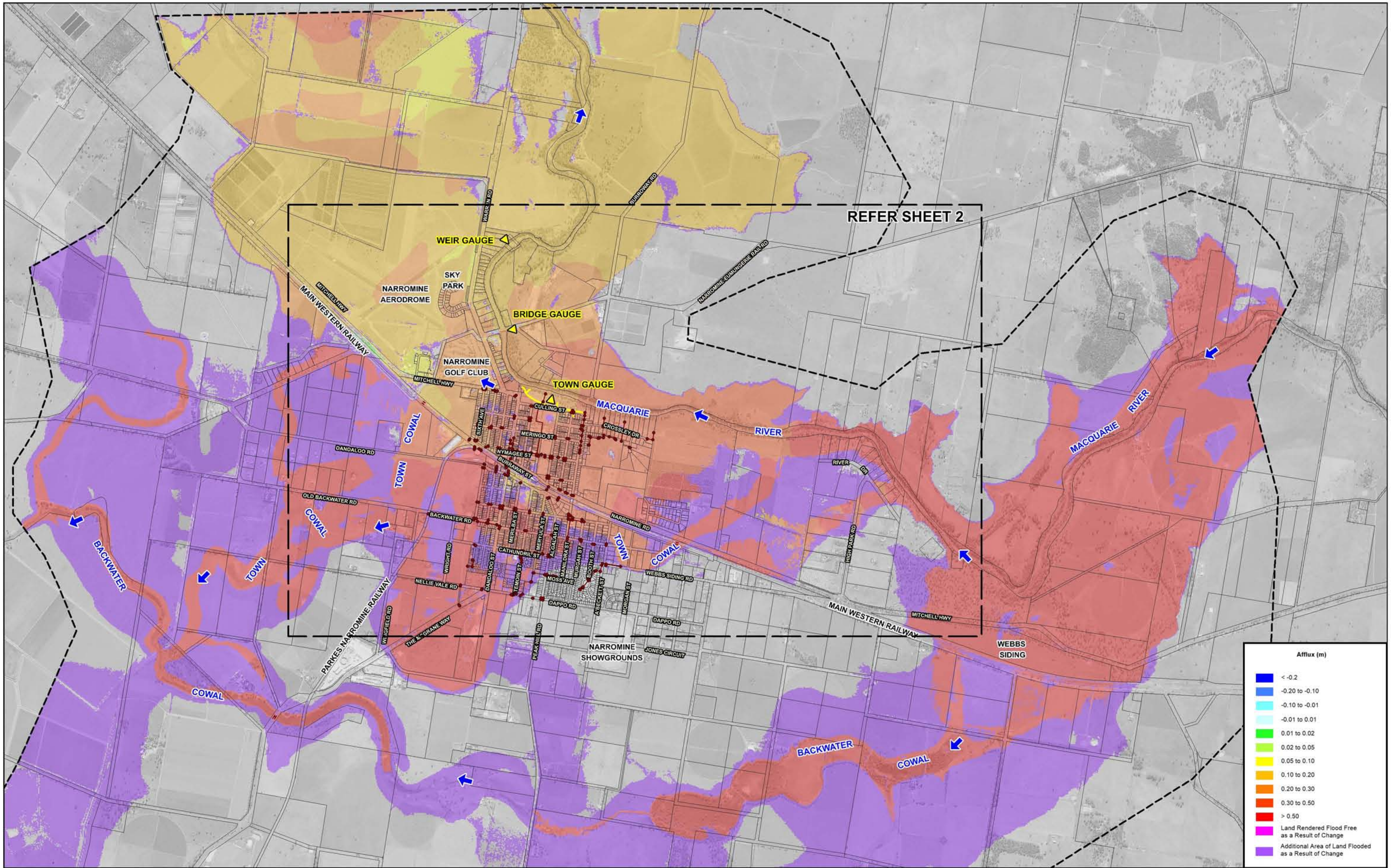
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.15

INDICATIVE EXTENT OF INUNDATION AND LOCATION OF VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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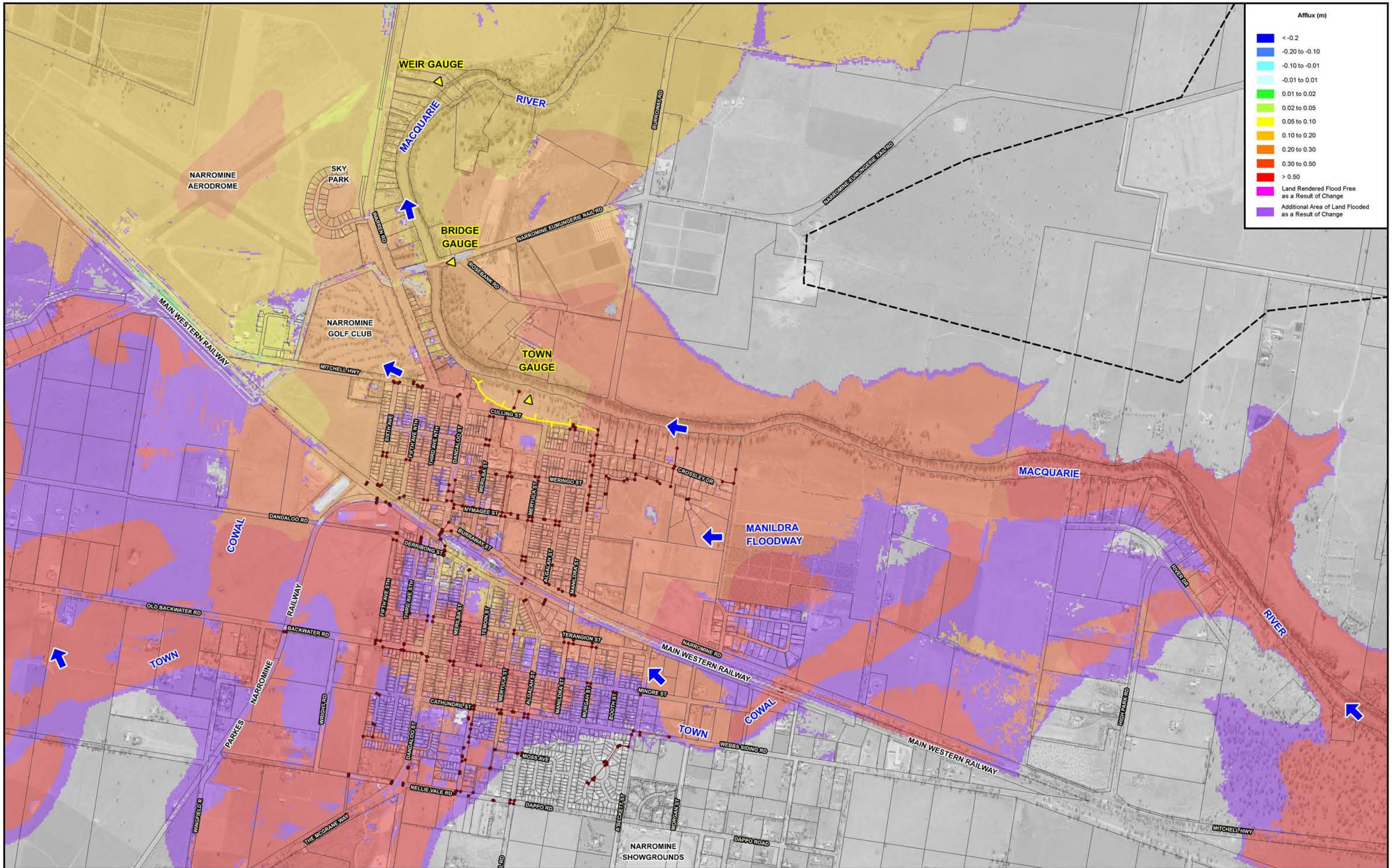
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.16
(Sheet 1 of 2)

POTENTIAL IMPACT OF CLIMATE CHANGE ON FLOODING AND DRAINAGE PATTERNS
1% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

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LEGEND

Two-Dimensional Model Boundary

Modelled Stormwater Drainage System

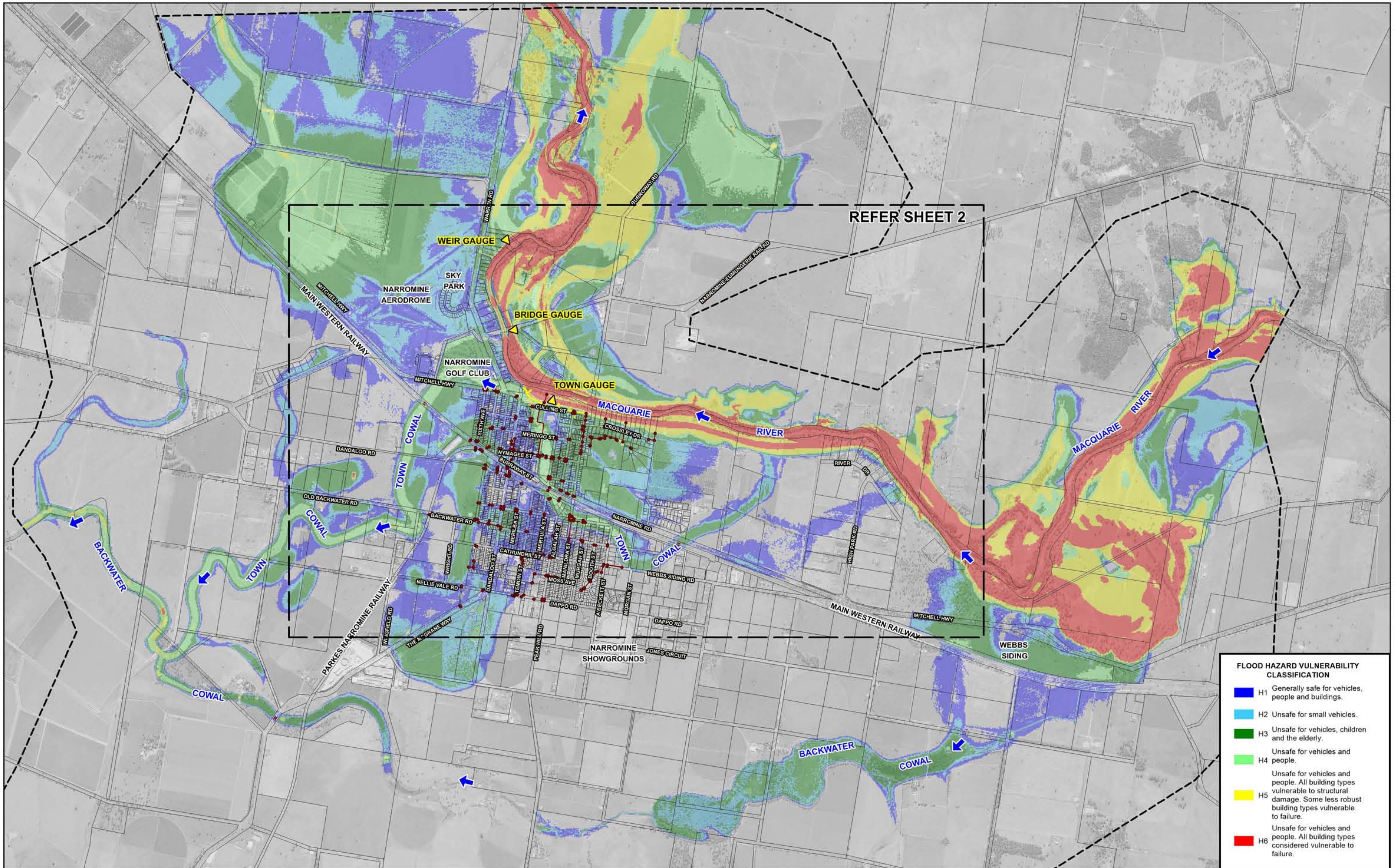
Stream Gauge

Existing Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.16
(Sheet 2 of 2)

POTENTIAL IMPACT OF CLIMATE CHANGE ON FLOODING AND DRAINAGE PATTERNS
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

NOTE:
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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

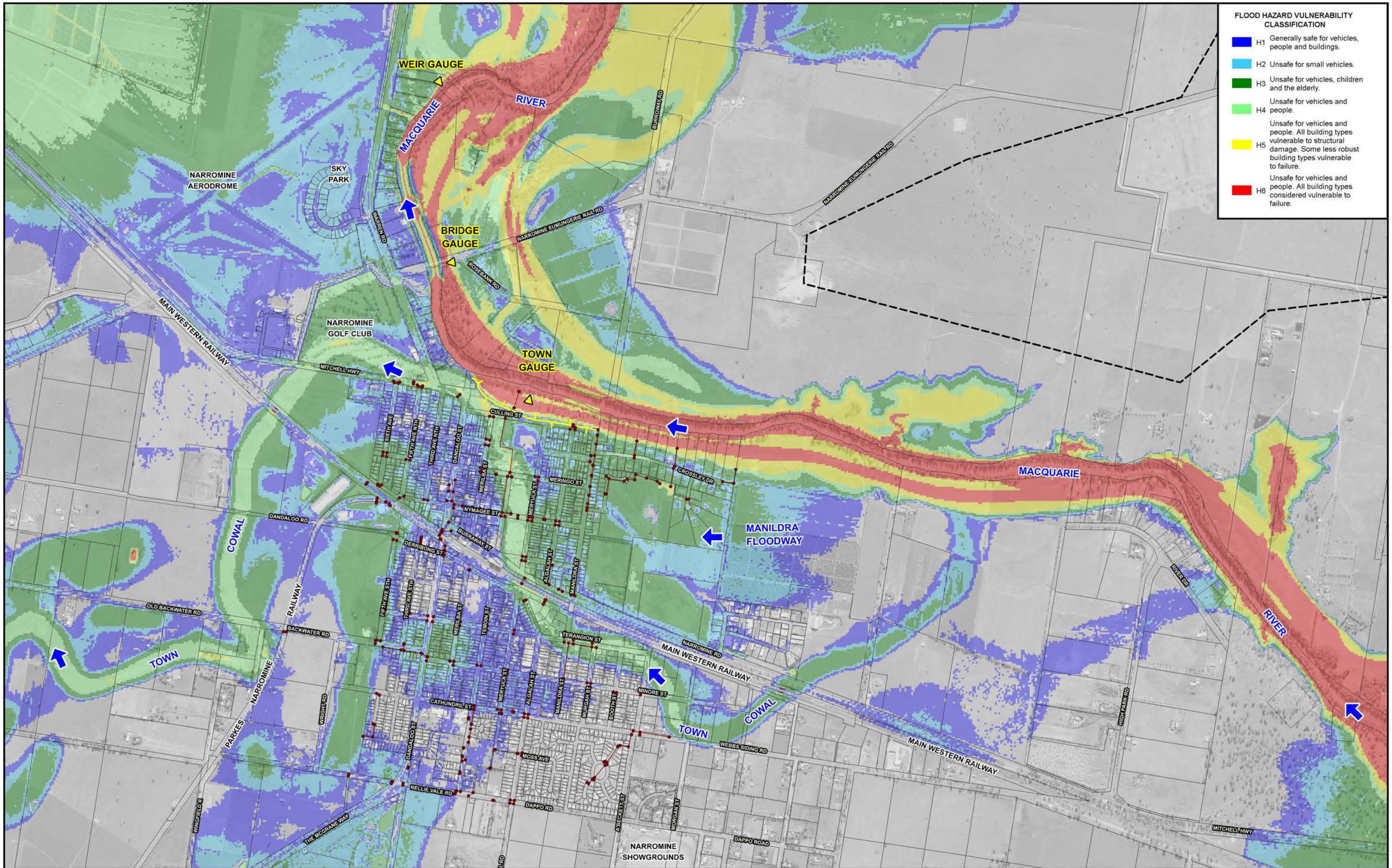
- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee

Lyall & Associates

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.17
(Sheet 1 of 2)

FLOOD HAZARD VULNERABILITY CLASSIFICATION
1% AEP



N

200 0 200 400 600 m

Scale: 1:20,000

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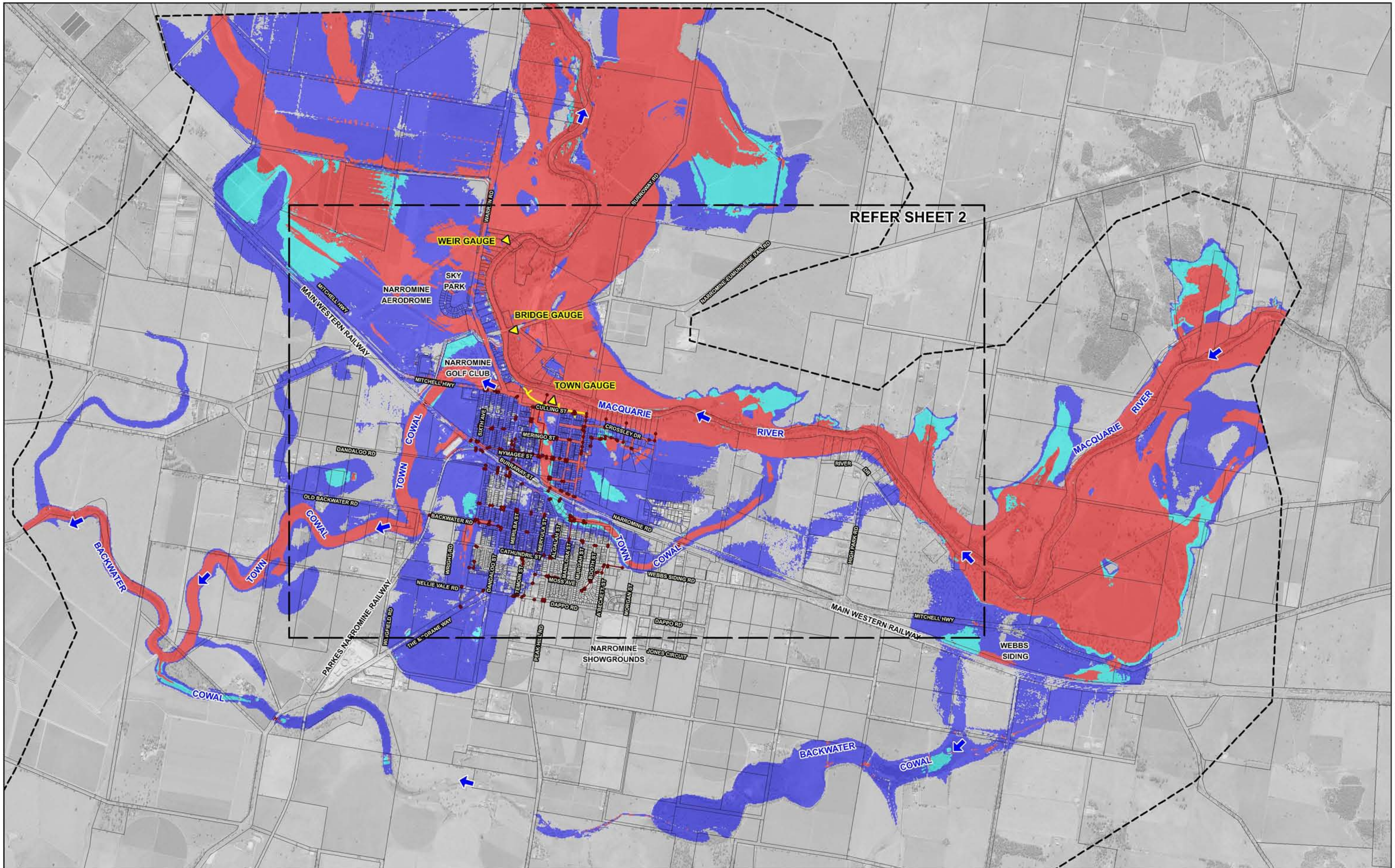
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.17
(Sheet 2 of 2)

FLOOD HAZARD VULNERABILITY CLASSIFICATION
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Floodway
- Flood Storage
- Flood Fringe

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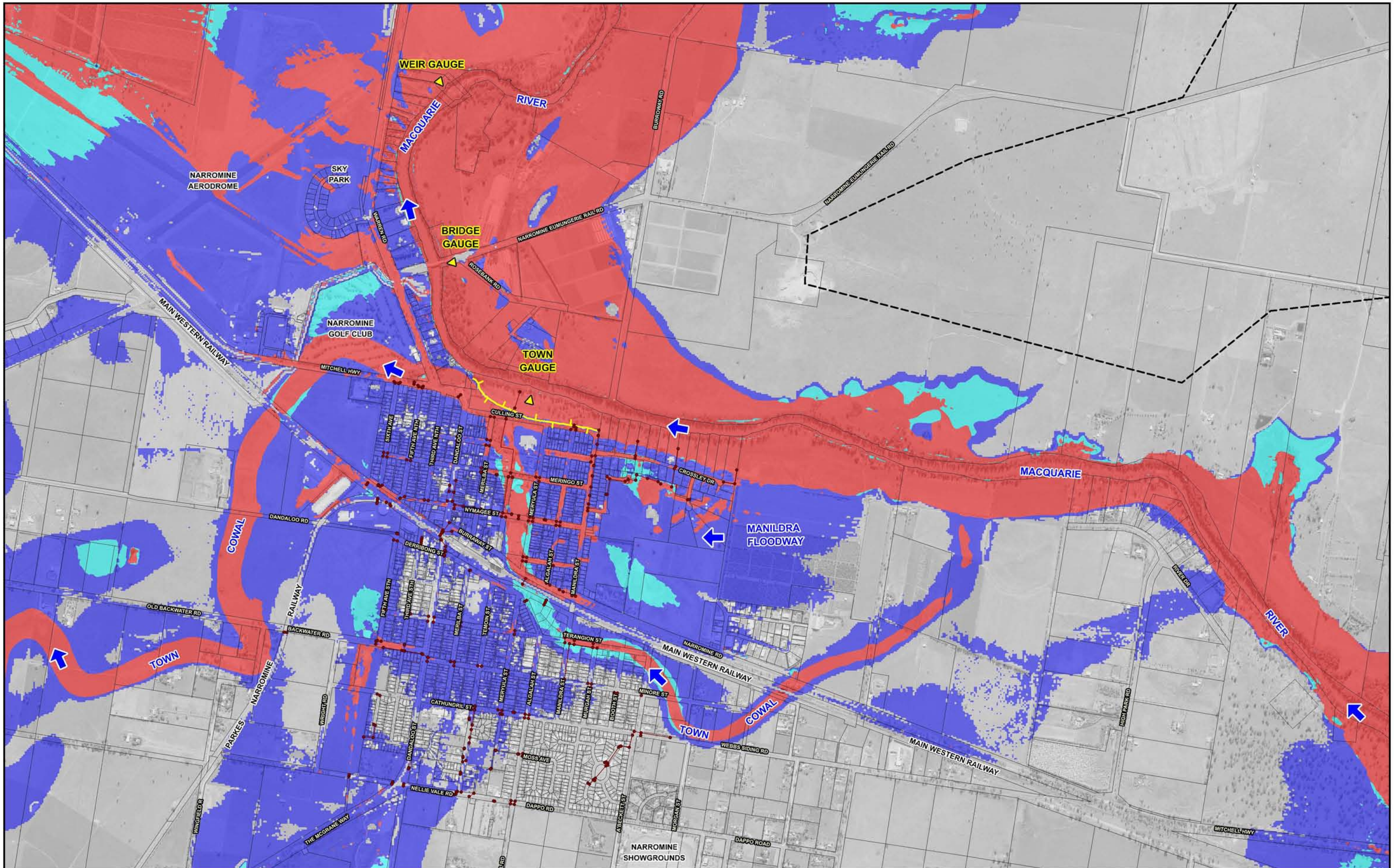
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.18
(Sheet 1 of 2)

HYDRAULIC CATEGORISATION OF FLOODPLAIN
1% AEP



200 0 200 400 600 m

Scale: 1:20,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Existing Town Levee
- Floodway
- Flood Storage
- Flood Fringe

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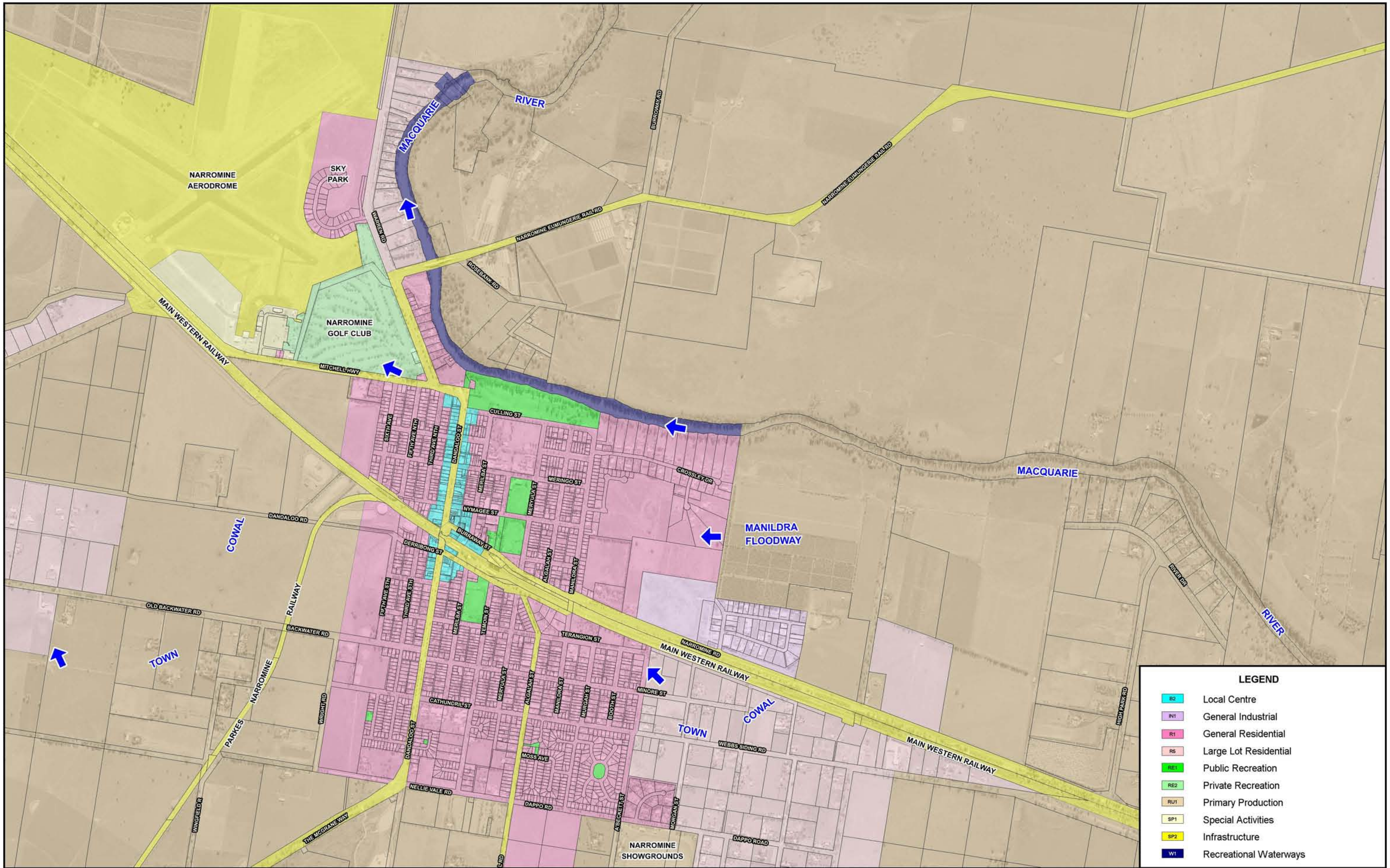
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.18
(Sheet 2 of 2)

HYDRAULIC CATEGORISATION OF FLOODPLAIN
1% AEP



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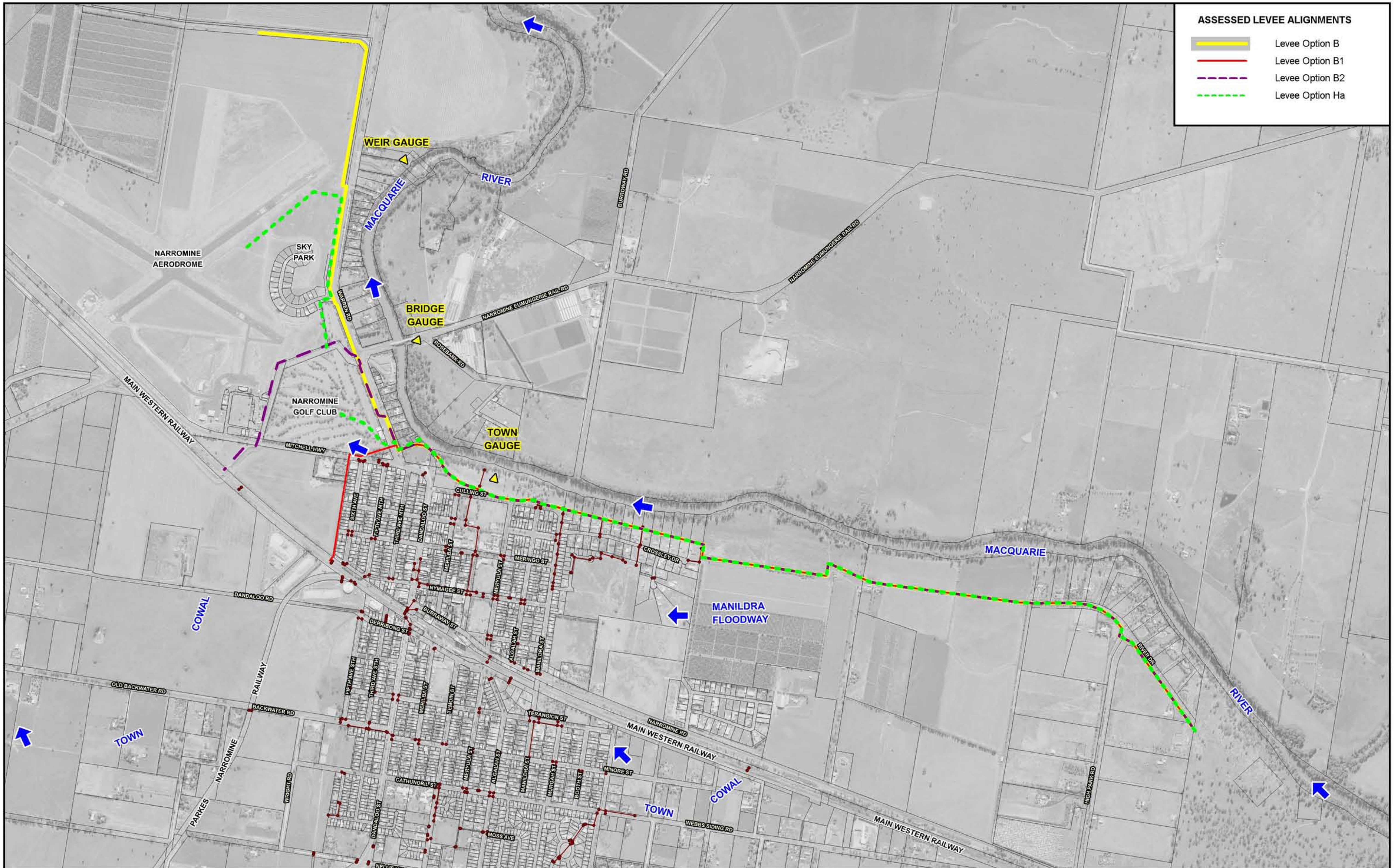
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 2.19

NARROMINE LEP 2011 ZONING



N

200 0 200 400 600 m

Scale: 1:20,000

LEGEND

Modelled Stormwater Drainage System

Stream Gauge

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.1

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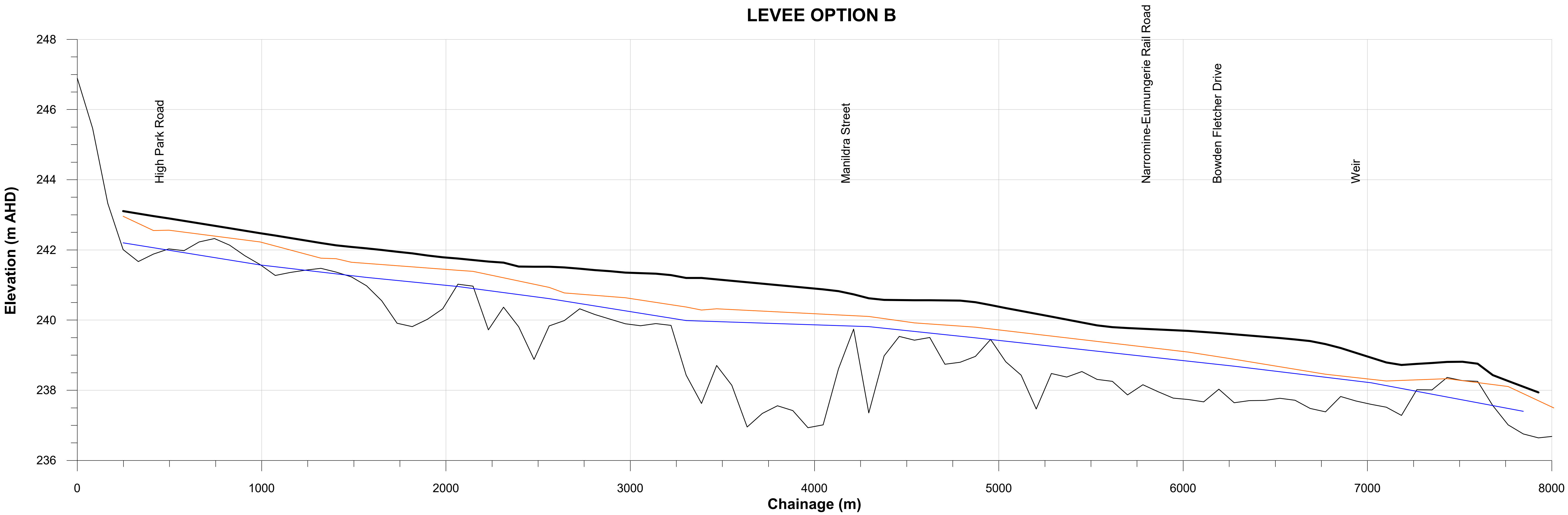
ASSESSED RIVER BANK LEVEE ALIGNMENTS

LEVEE OPTION B



LEGEND

- Crest Level (SMEC, 2019)
- 0.5% AEP Peak Flood Level
- 1% AEP Peak Flood Level
- Existing Natural Surface Level

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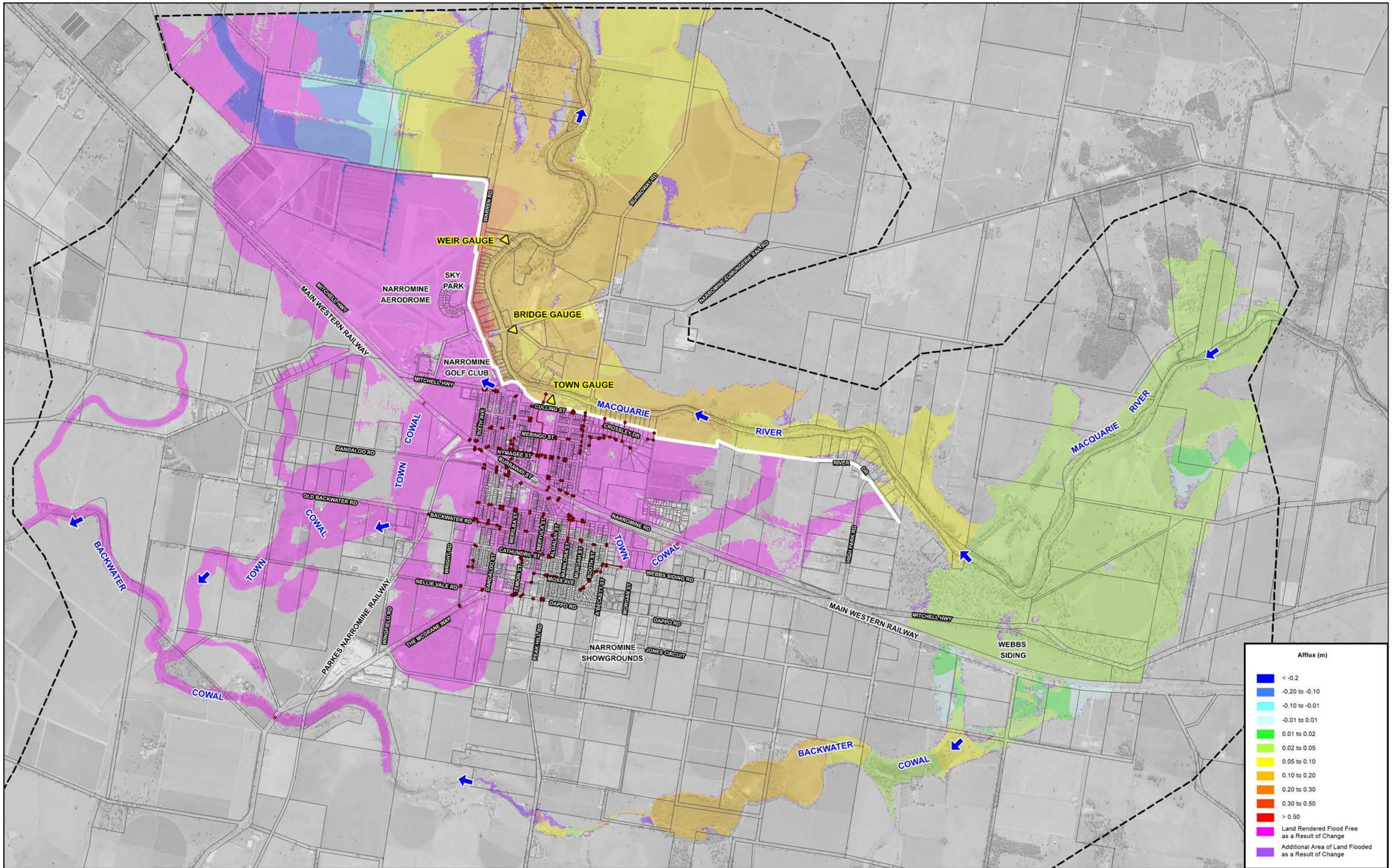
NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.2
(Sheet 1 of 2)

LONG SECTIONS OF ASSESSED RIVER BANK LEVEE OPTIONS



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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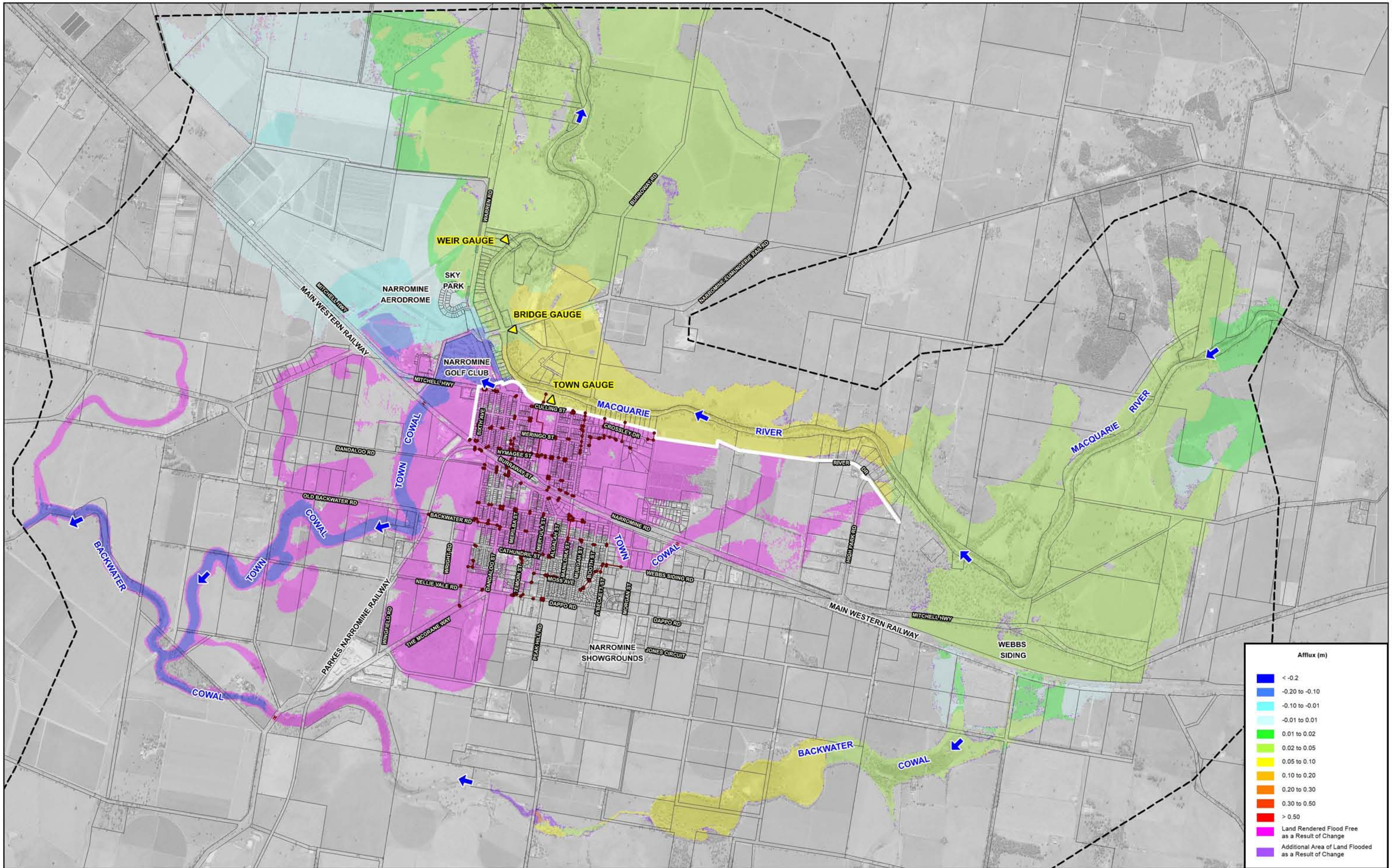
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.3

IMPACT OF LEVEE OPTION B ON FLOOD BEHAVIOUR
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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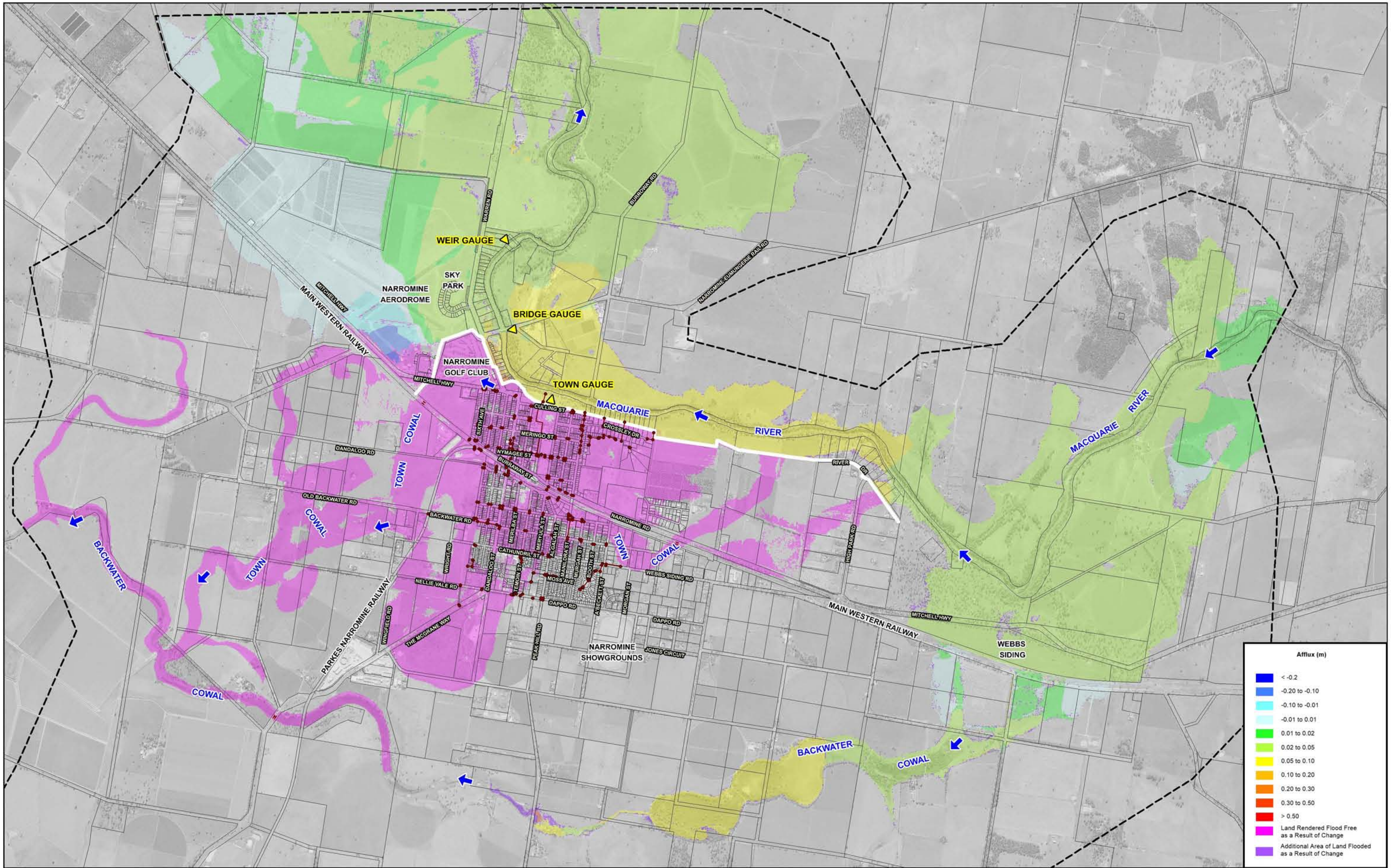
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.4

IMPACT OF LEVEE OPTION B1 ON FLOOD BEHAVIOUR
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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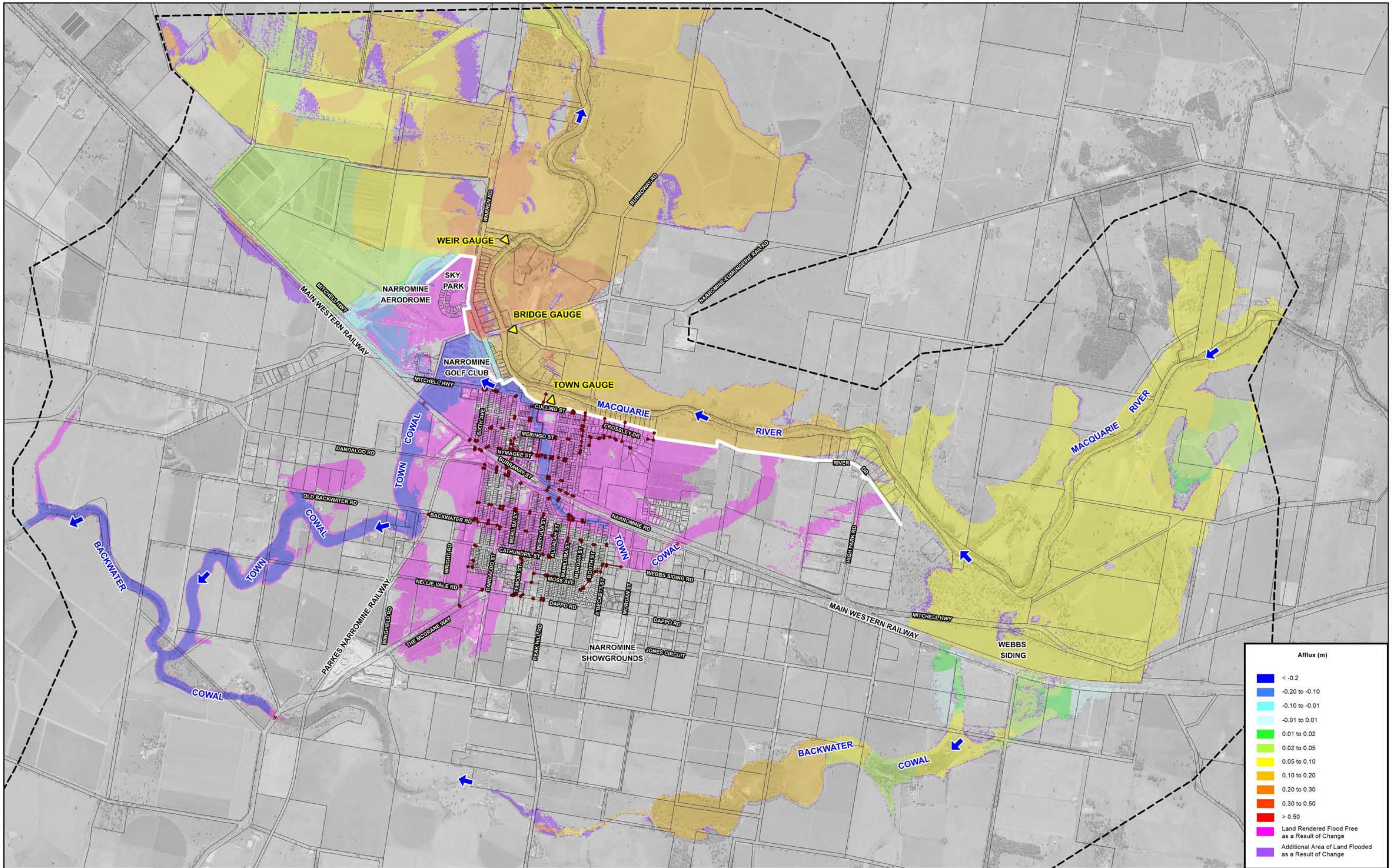
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.5

IMPACT OF LEVEE OPTION B2 ON FLOOD BEHAVIOUR
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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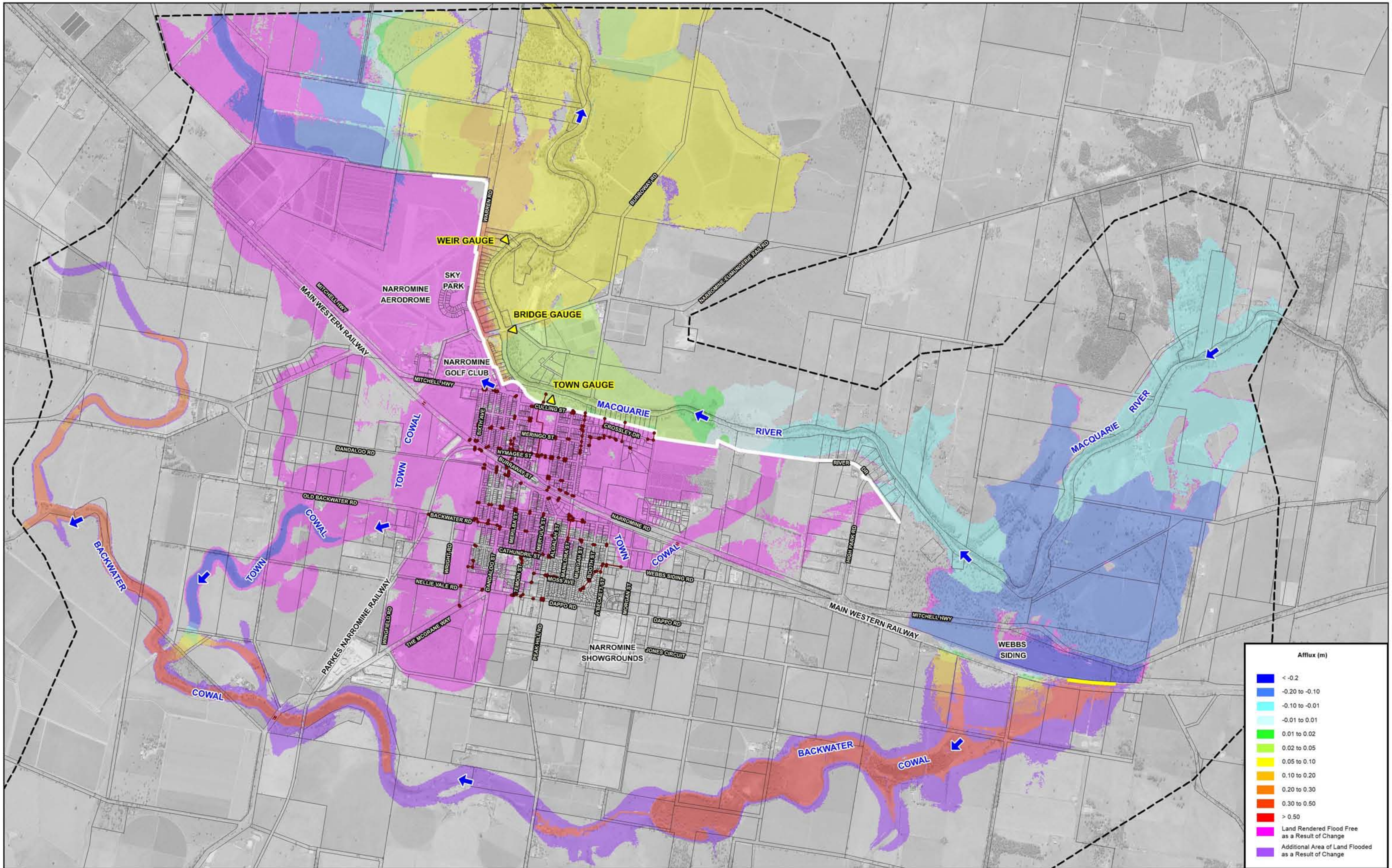
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.6

IMPACT OF LEVEE OPTION Ha ON FLOOD BEHAVIOUR
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

Lyall & Associates

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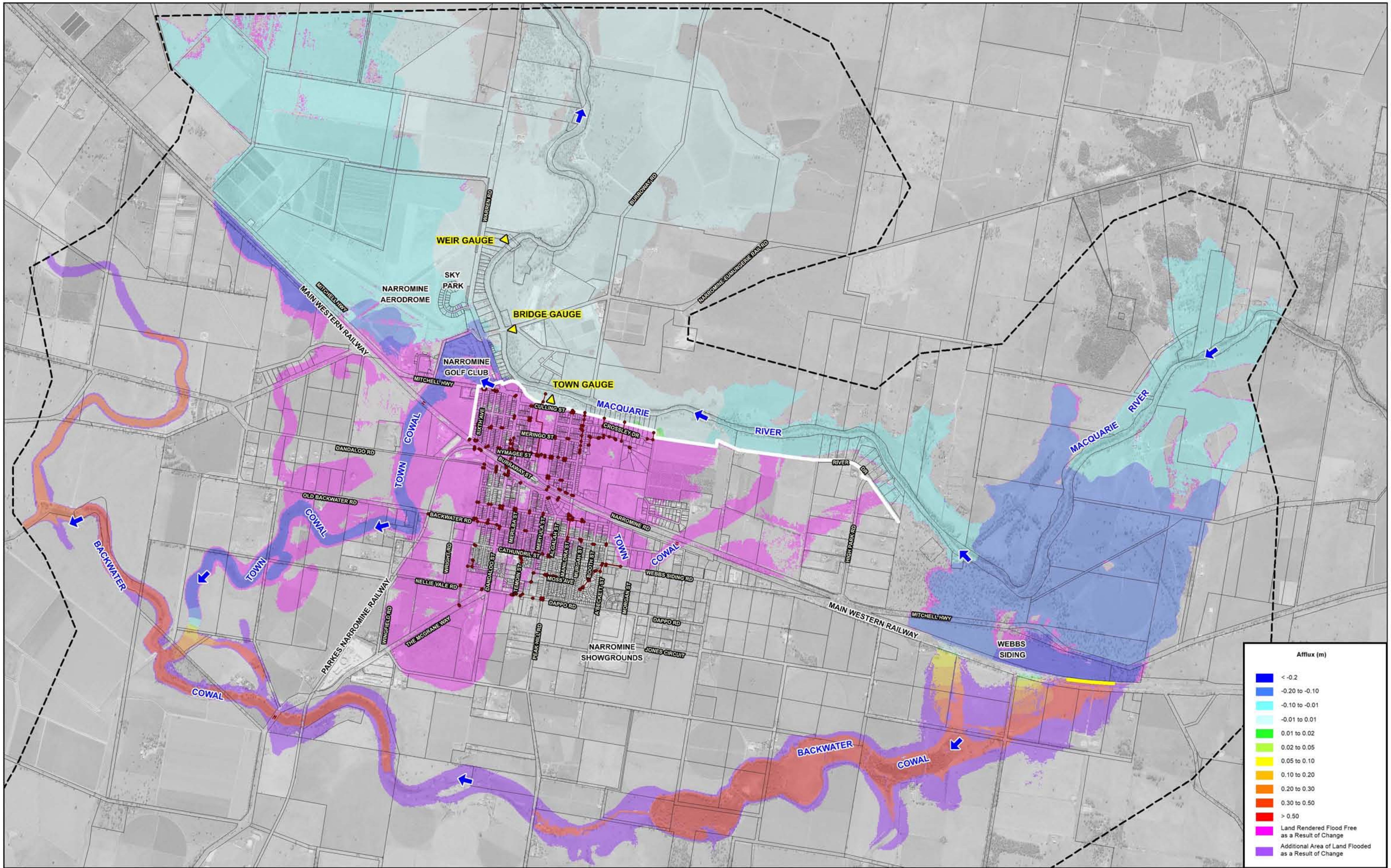
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.7

IMPACT OF LEVEE OPTION B WITH RAILWAY CULVERT UPGRADE ON FLOOD BEHAVIOUR
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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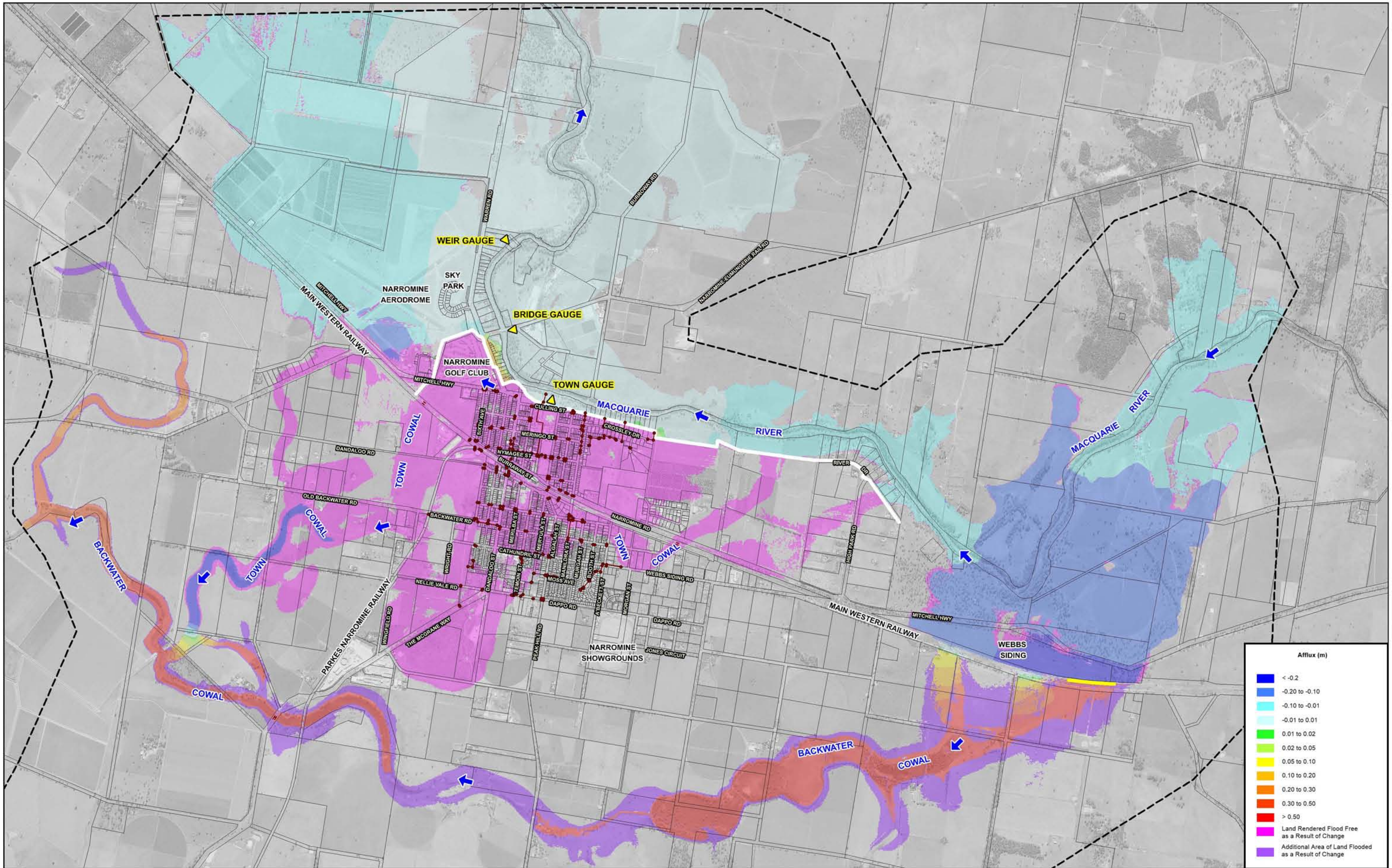
LEGEND

Two-Dimensional Model Boundary
Modelled Stormwater Drainage System
Stream Gauge
Proposed Levee Alignment
Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.8

IMPACT OF LEVEE OPTION B1 WITH RAILWAY CULVERT UPGRADE ON FLOOD BEHAVIOUR
1% AEP



N
400 0 400 800 1200 m
Scale: 1:40,000

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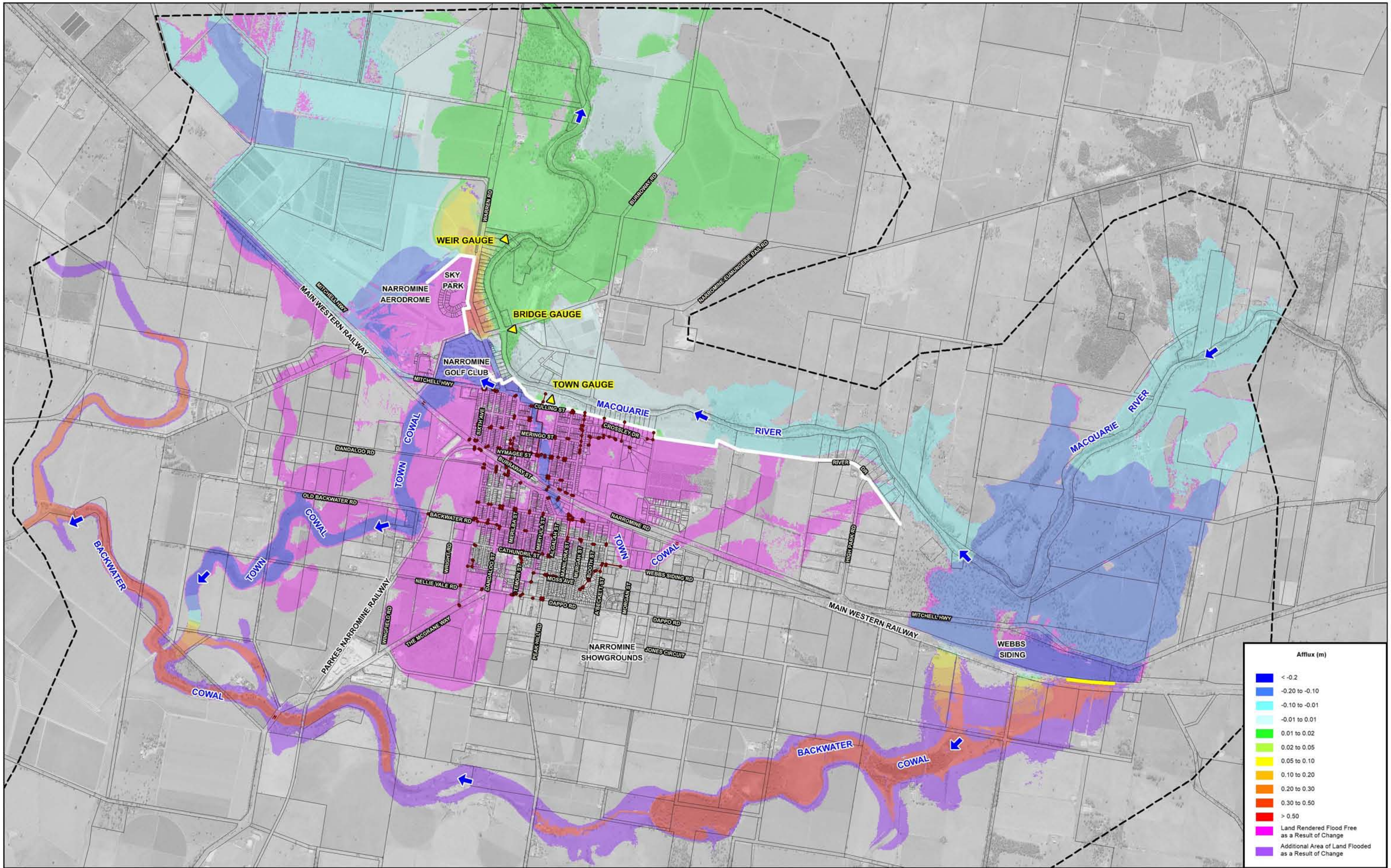
LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.9

IMPACT OF LEVEE OPTION B2 WITH RAILWAY CULVERT UPGRADE ON FLOOD BEHAVIOUR
1% AEP



N

400 0 400 800 1200 m

Scale: 1:40,000

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LEGEND

- Two-Dimensional Model Boundary
- Modelled Stormwater Drainage System
- Stream Gauge
- Proposed Levee Alignment
- Proposed Railway Culvert Upgrade

NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure 3.10

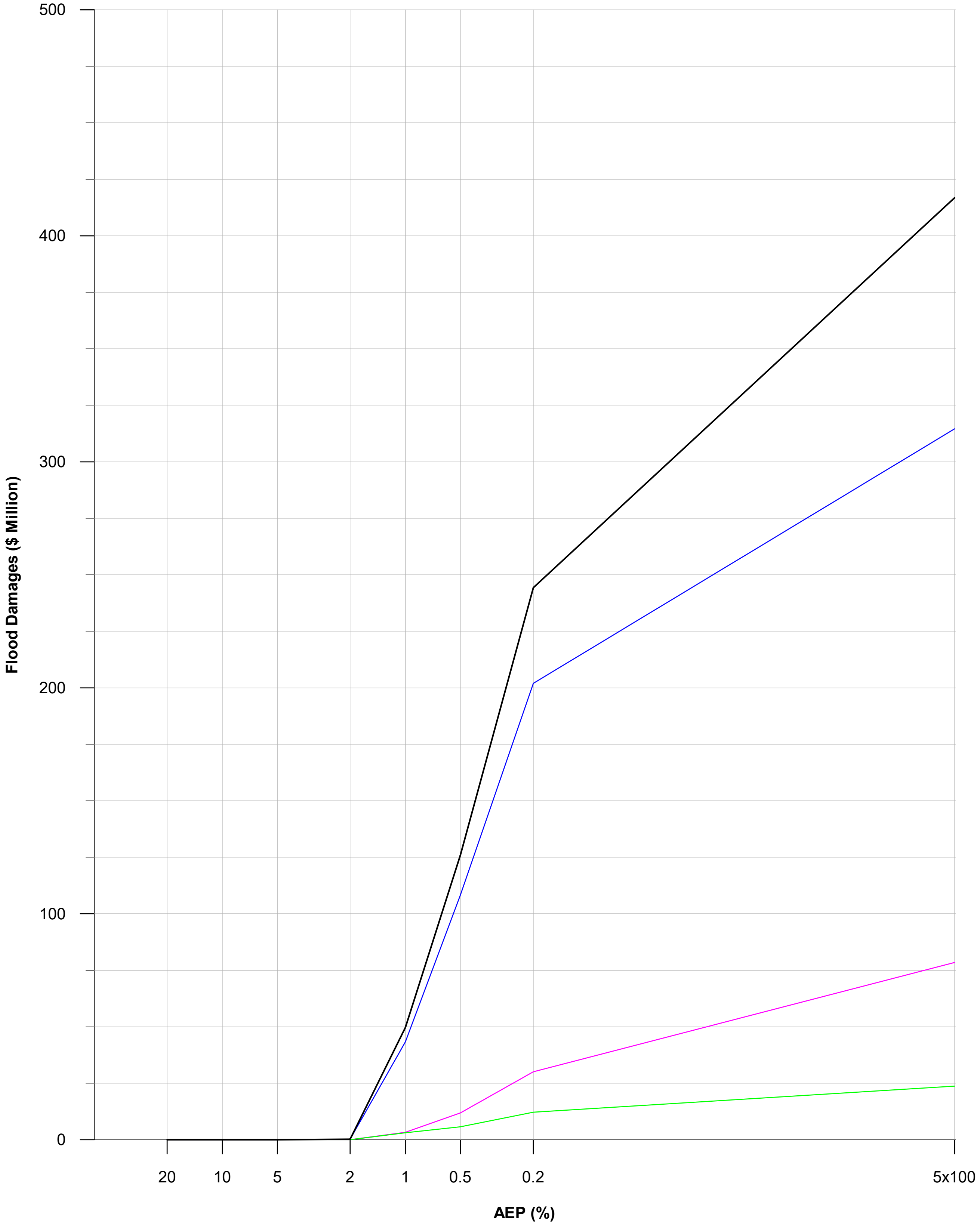
IMPACT OF LEVEE OPTION Ha WITH RAILWAY CULVERT UPGRADE ON FLOOD BEHAVIOUR
1% AEP

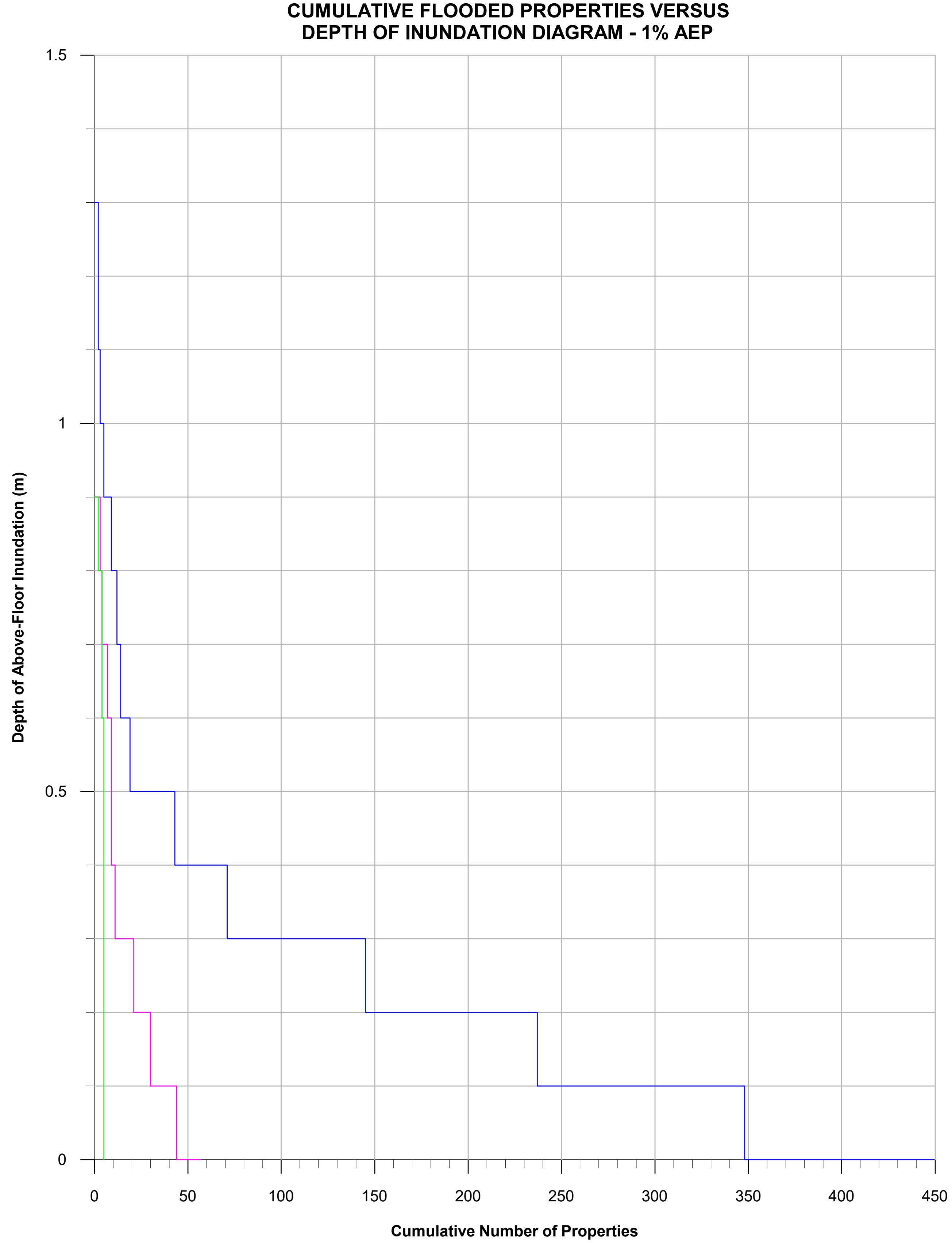
APPENDIX B

FLOOD DAMAGES

LIST OF FIGURES (APPENDIX B)

B8.1 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP





LEGEND

- Total
- Residential
- Commercial
- Public

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NARROMINE TOWN
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN UPDATE

Figure B8.1

DAMAGE - FREQUENCY CURVES AND
CUMULATIVE FLOODED PROPERTIES VERSUS DEPTH OF INUNDATION DIAGRAM
1% AEP