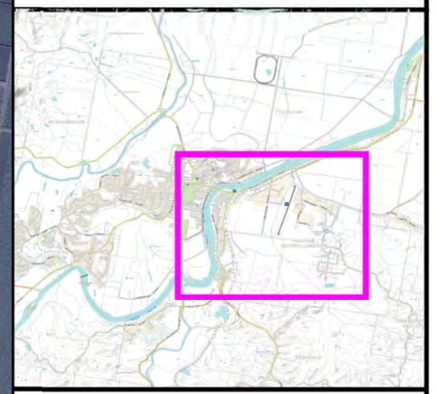
TWEED SHIRE COUNCIL



LEGEND

- Simulated 2017 Flood Extent

Q3 - How were you affected by flooding?

- Flooding Over Main Building
- Flooding of Garages / Sheds
- Sewage System Was Not Working at Our Property
- Water Supply Lost
- Lost Access Due to Flooding of Roads
- Not Flood Affected

Notes:

Aerial photograph date: 2016

N
W E
S

0 0.35 0.70

Km

Figure A1: Spatial Distribution of Historic Flood Impacts

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

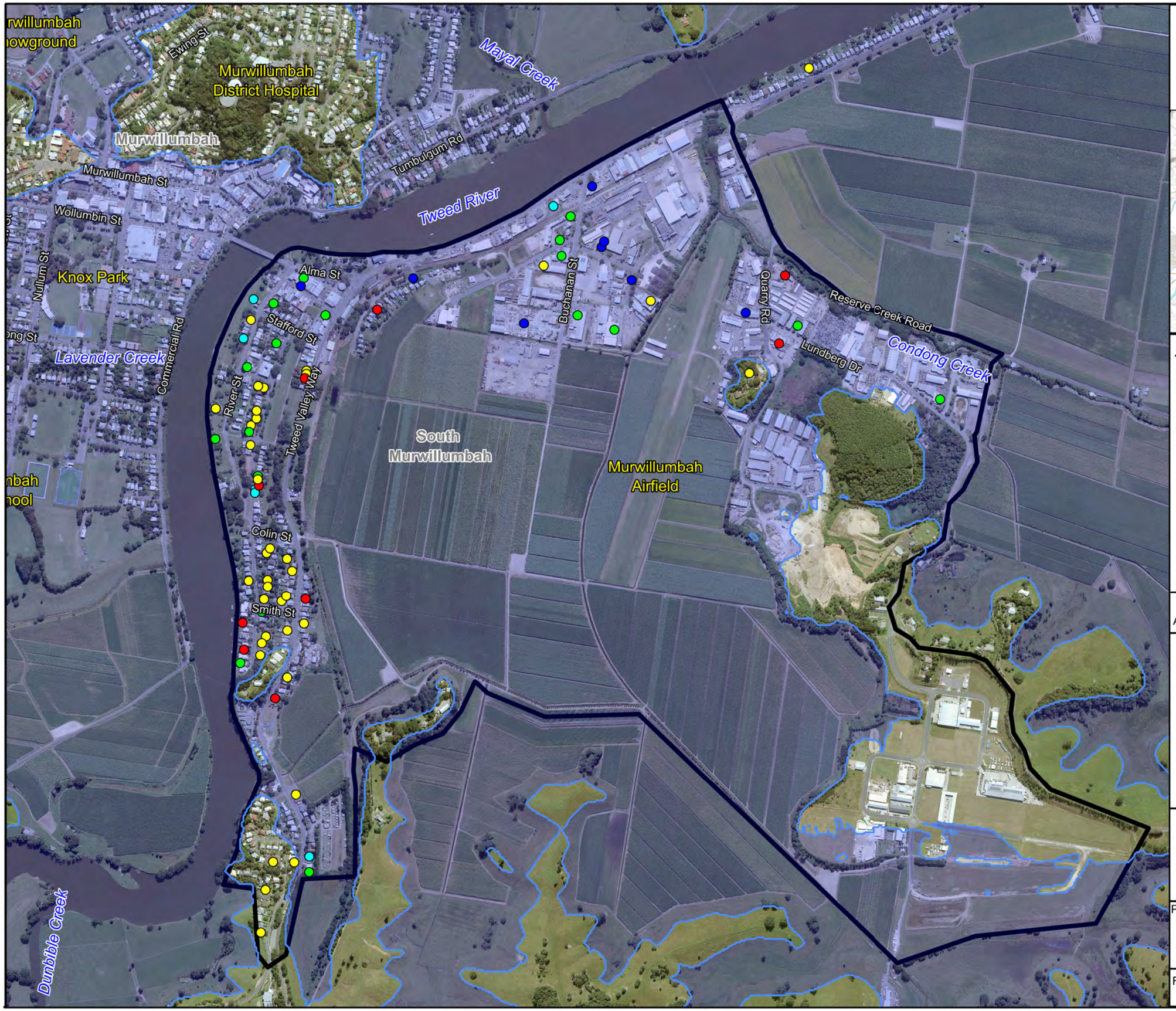
File Name: FigA1 - Historic Flood Impacts.wor

Table A1 - Property Types and Historic Flood Impacts

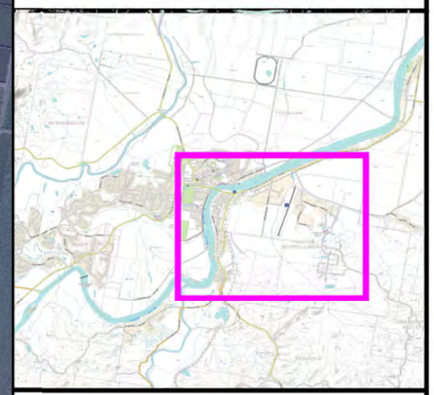
#	What type of property do you have?					Have you experienced previous floods in this area?		How were you affected by flooding?					
								Type of Flood Impact					
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes – what years?	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage system was not working at our property	Water supply lost	Other
1	X				53	1974, 1989, 2001, 2017			X	X			
2	X				4		X						
3	X				15 Months		X						
4			X		10	2017		X	X	X			
5			X		35	1989 ,2017				X			
6	X				4	2000 , 2017		X	X	X			
7	X				20	2017			X				X
8		X			5		X						
9	X				63	1954 , 1973				X		X	
10	X				24	1989 , 2017			X	X	X	X	
11		X			32	1974, 1978,1987 , 1989, 2017		X		X			
12			X		5		X						
13		X			-		X						
14	X				12.5		X						
15	X	X				2017		X	X	X			X
16	X				10		X						
17	X				4	2017		X	X	X	X		
18			X		11	2016		X	X	X	X	X	X
19	X				9	2012 , 2010,2014,2017			X	X			
20	X				25	1988		X	X	X			
21	X				10	2017		X	X	X			
22	X				29.5	2017		X	X	X			
23			X		23	2012 , 2013 ,2017		X		X	X		
24	X				29		X						
25	X				35	6-8 Floods Over 35 Years							
26	X				15	2009		X	X	X	X	X	X
27			X		38		X						
28		X			69	1954, 1956, 1961, 1967, 1974, 1989x2, 2017		X	X	X	X	X	X
29	X					2008, 2009, 2011, 2010		X	X				
30	X				2	1978, 2017		X	X	X			
31	X				16	2013 , 2017		X	X	X			
32	X						X						
33	X				38		X						
34	X					1954, 1956 1974 1989,2017			X	X			
35	X				59	54,56, 74,2017							
36			X		18	2017		X	X	X	X	X	
37			X		3	2017		X	X	X			
38	X				3	2016, 2017			X	X	X		X
39	X				29	89,1990, 2017		X	X	X		X	X

#	What type of property do you have?					Have you experienced previous floods in this area?		How were you affected by flooding?					
								Type of Flood Impact					
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes – what years?	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage system was not working at our property	Water supply lost	Other
40	X				10	2015 , 2013, 2017		X	X	X			
41	X				30	2018				X		X	
42	X				28	2017 and others		X	X	X	X	X	X
43	X				51		X						
44	X				4.5	2017		X	X	X			X
45	X				48	1974, 1976, 1989, 2017			X	X			
46			X		-	2017		X		X		X	
47	X				-	2017		X	X	X			X
48	X				9	2017		X	X	X	X		
49	X				20	1989, 2001,2017			X	X			
50	X				2		X						
51	X				75	1945 To 2017		X	X	X		X	X
52		X			10	2017		X	X	X	X		
53	X				46	1974, 1980's ,2017				X			
54	X				55	1980		X	X	X	X		
55		X	X			1998 to 2018		X	X	X	X		
56	X				4		X						
57	X				4.5	2017			X	X			
58	X				70	all from 1948 to 2018			X	X			
59		X			10.5	31-3-2017		X		X			
60	X				51	1974-2017		X	X	X	X	X	
61			X		37	Many Various		X		X			
62	X				1.5	2017			X	X			
63	X				8	2017			X	X	X		
64	X				2	2017			X	X			
65	X				4	2017			X	X			
66	X				4		X						
67			X		10	2017		X	X	X			
68	X				2.5	March 2017			X	X			X
69				Second property	13		X						
70	X					2008, 2013, 2017		X	X	X			
71	X				13								
72			X			March 2017		X	X	X	X		
73			X		28	March 2017		X		X			
74													
75	X				4	March 2017		X	X	X	X	X	
76					12	March 2017		X					
77	X					March 2017			X				
78			X		37	1989, 1987, 2001, 2004				X			
79		X			9		X	X	X	X	X	X	

#	What type of property do you have?					Have you experienced previous floods in this area?		How were you affected by flooding?					
								Type of Flood Impact					
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes – what years?	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage system was not working at our property	Water supply lost	Other
80	X				40	All floods years past 40 years				X			
81	X				5		X						
82		X			10		X						
83	X				45	1974, 1989, 2017		X	X	X	X		
84	X				12	2013, 2012, 2007		X	X	X	X		X
85	X				2	2017		X	X	X			
86		X			14			X	X	X	X	X	
87	X				2.5		X						
88	X						X						
89			X		8	42824		X	X	X			
90		X			3.5		X	X	X	X	X		
91	X				16	2017			X	X			
92	X				4.5	1973 All Flood 2008			X	X			
93	X						X						



TWEED SHIRE COUNCIL



LEGEND

- PMF Flood Extent

Q5 - How do you anticipate you would respond in a future flood in this area?

- Don't Know / Not Sure
- Remain at My House
- Evacuate Elsewhere
- Evacuate Early to an Official Evacuation Centre
- Other

Notes:

Aerial photograph date: 2016

N W E S

0 0.35 0.70 Km

Figure A2: Spatial Distribution of Preferred Flood Response

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigA2 - Preferred Flood Response.wor

Table A2 - Preferred Flood Response

#	How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you?					If you are likely to remain at your house, what factors are most important to you?					
	Evacuate early to an official evacuation centre	Remain at my house	Don't know / not sure	Evacuate elsewhere	Other	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Not applicable (I intend to remain at my house)	Other	Discomfort / inconvenience / cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for security of my property if I evacuate	Not applicable (I intend to evacuate from my house)	Other
1				X				X						X		
2		X														X
3				X		X		X								
4				X		X		X		X	X		X			
5		X			X				X		X			X		X
6		X							X			X		X		
7			X		X				X			X		X		
8					X	X		X					X	X		
9		X							X				X			
10				X						X						
11				X	X					X						X
12				X		X				X						
13				X	X	X				X	X			X		
14		X									X	X		X		
15	X			X		X		X		X		X		X	X	
16		X							X				X			
17			X			X	X	X			X	X		X		
18		X			X				X		X					X
19			X			X		X						X		X
20		X							X					X		X
21			X							X	X		X			
22		X						X	X		X			X		
23					X	X		X		X	X	X		X		X
24		X											X			X
25		X											X			
26	X					X										
27					X											
28					X	X					X			X		
29	X					X		X			X			X		
30		X				X			X		X				X	
31		X						X					X			
32			X			X		X			X	X				
33		X											X			
34		X							X							
35		X							X				X			
36				X		X		X		X					X	
37					X					X					X	
38		X							X		X			X		
39				X			X	X								

#	How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you?					If you are likely to remain at your house, what factors are most important to you?					
	Evacuate early to an official evacuation centre	Remain at my house	Don't know / not sure	Evacuate elsewhere	Other	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Not applicable (I intend to remain at my house)	Other	Discomfort / inconvenience / cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for security of my property if I evacuate	Not applicable (I intend to evacuate from my house)	Other
40		X							X		X	X		X		
41		X					X		X				X			
42		X	X									X		X		
43		X				X							X			
44				X		X		X		X						
45		X				X			X				X			
46					X											
47			X					X								
48			X		X			X			X	X		X		X
49		X						X	X					X		
50					X		X	X				X	X			
51		X							X			X	X	X		
52			X							X						X
53		X							X		X	X	X	X		
54		X	X			X	X							X		
55					X	X								X		X
56		X							X				X			
57		X										X	X	X		
58		X				X		X	X				X			
59				X				X							X	
60		X									X	X	X	X		X
61					X	X								X		
62				X				X								X
63	X							X								
64				X				X								
65	X					X		X			X	X				
66		X		X		X						X	X			
67	X							X								
68				X								X				
69								X								
70				X				X								
71																
72			X		X			X			X					
73				X												
74								X			X					
75			X					X			X					
76		X						X				X				
77		X						X						X		
78	X									X						
79				X	X	X										

#	How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you?					If you are likely to remain at your house, what factors are most important to you?					
	Evacuate early to an official evacuation centre	Remain at my house	Don't know / not sure	Evacuate elsewhere	Other	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Not applicable (I intend to remain at my house)	Other	Discomfort / inconvenience / cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for security of my property if I evacuate	Not applicable (I intend to evacuate from my house)	Other
80		X							X				X			
81		X							X							X
82		X		X					X					X		
83					X	X					X	X				
84				X		X	X	X			X	X		X		
85		X										X		X		X
86				X												
87		X							X		X					
88			X					X			X					
89				X	X	X				X					X	
90				X		X		X		X	X					
91		X							X			X	X	X		
92		X							X					X		
93				X				X							X	

Table A3 - Feedback on Potential Flood Risk Mitigation Measures

#	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?																
	Flood modification options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.								Property modification options: Refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings to flooding.				Response modification options: Are options aimed at improving the way emergency services and the general public responds before, during and after a flood.				
	Raising existing levees	New levees	Bypass floodways	Modify flow obstructions (e.g. road / rail embankments)	Enlarging / dredging river and / or creek channels	Maintenance and clearing of rivers and creeks	Culvert / bridge upgrades	New / upgraded floodgates	Voluntary house raising	Voluntary flood proofing	Voluntary house purchase	Updated development / planning controls	Updated flood warning system	SES local flood plan updates	Community education	Boom gates / signs at roadway overtopping points	Upgrade flood evacuation routes
1	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support
2	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Support	Support	Support	Support	Neutral	Support	Support	Support	Support
3	Strongly Against	Strongly Against	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
4	Support	Strongly Support	Neutral	Support	Neutral	Neutral	Strongly Support	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Support
5	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Support	Neutral	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support
6	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Neutral	Neutral	Neutral
7	Strongly Support	Strongly Support	Neutral	Support	Strongly Support	Strongly Support	Support	Strongly Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
8	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Against	Against	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
9	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Strongly Against
10	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Strongly Support	Strongly Support	Support	Unsure	Unsure
11	Strongly Against	Unsure	Neutral	Against	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support
12	Support	Support	Support	Support	Support	Support	Support	Support	Against	Against	Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Neutral
13	Against	Against	Neutral	Neutral	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support
14	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Support	Neutral	Support	Neutral	Support	Support	Support	Support	Neutral	Neutral
15	Against	Against	Strongly Support	Support	Neutral	Support	Support	Strongly Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Support
16	Unsure	Unsure	Unsure	Unsure	Neutral	Neutral	Support	Support	Support	Support	Neutral	Strongly Support	Support	Support	Strongly Support	Unsure	Support
17	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Neutral	Support	Support	Support	Strongly Support	Support	Support	Support	Support
18	Strongly Support	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral
19	Strongly Against	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Against	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
20	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Neutral	Neutral	Neutral
21	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Support	Unsure	Support	Support	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support
22					Strongly Support	Strongly Support	Support						Support	Support			
23	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Against	Neutral	Against	Neutral	Neutral	Strongly Against	Strongly Against	Strongly Support
24	Neutral	Neutral	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Against	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
25	Unsure	Unsure	Support	Support	Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure
26	Support	Support	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Support	Against	Against	Strongly Support	Neutral	Support	Support	Support	Support	Support
27	Strongly Support	Strongly Support	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support					Strongly Support				
28	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
29	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Support	Strongly Support	Strongly Against	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Unsure
30	Unsure	Against	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Unsure	Unsure	Support	Strongly Support	Strongly Support	Neutral	Unsure	Unsure
31	Support	Neutral	Neutral	Support	Neutral		Neutral	Support	Unsure	Support	Support		Support	Support	Neutral	Strongly Support	Strongly Support
32	Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support
33					Strongly Support	Strongly Support			Strongly Support						Strongly Support		
34	Strongly Support		Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
35	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support				Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support
36	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
37	Against	Against	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Support
38					Strongly Support	Strongly Support						Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
39	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support

#	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?																
	Flood modification options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.								Property modification options: Refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings to flooding.				Response modification options: Are options aimed at improving the way emergency services and the general public responds before, during and after a flood.				
	Raising existing levees	New levees	Bypass floodways	Modify flow obstructions (e.g. road / rail embankments)	Enlarging / dredging river and / or creek channels	Maintenance and clearing of rivers and creeks	Culvert / bridge upgrades	New / upgraded floodgates	Voluntary house raising	Voluntary flood proofing	Voluntary house purchase	Updated development / planning controls	Updated flood warning system	SES local flood plan updates	Community education	Boom gates / signs at roadway overtopping points	Upgrade flood evacuation routes
40	Against	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support
41	Support				Support	Support			Support		Support		Strongly Support	Strongly Support			Strongly Support
42	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support					Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
43	Strongly Support	Against	Against	Strongly Support	Support	Support	Strongly Support	Strongly Support				Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
44	Against	Neutral	Unsure	Support	Strongly Support	Strongly Support	Support	Unsure	Strongly Support	Neutral	Strongly Support	Support	Support	Support	Strongly Support	Support	Strongly Support
45	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Support	Strongly Support	Unsure	Strongly Support	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure
46	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral
47	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Against	Against	Against	Neutral	Neutral	Neutral	Neutral	Neutral
48	Unsure	Unsure	Support	Support		Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Unsure
49	Strongly Support	Strongly Support	Unsure	Unsure	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
50																	
51	Against	Against		Support	Neurtal	Support	Support	Support	Strongly Support	Strongly Support	Strongly Against	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support
52	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support				Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
53	Strongly Against	Against	Support	Support	Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support
54				Support	Strongly Support			Strongly Support	Against	Against	Against	Support	Strongly Support	Support	Unsure	Unsure	Support
55	Strongly Support	Against	Support	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Unsure	Strongly Support
56	Support	Neutral	Neutral	Support	Support	Support	Support	Support	Support	Against	Against	Against	Support	Support	Against	Support	Neutral
57	Strongly Support	Strongly Support	Neutral	Neutral	Strongly Against	Strongly Support	Strongly Support	Neutral	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
58	Support	Support	Neutral		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
59	Neutral	Neutral	Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Unsure	Support	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
60	Strongly Against	Strongly Against			Strongly Support	Strongly Support	Strongly Support	Strongly Support				Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
61	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Support	Unsure	Unsure
62	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
63	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Against	Against	Strongly Support	Strongly Support	Support	Neutral	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
64	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
65	Strongly Support	Strongly Support	Strongly Support					Strongly Support	Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support	Strongly Support		Strongly Support
66	Against	Against	Support	Support	Against	Strongly Against	Strongly Support	Strongly Against	Neutral	Neutral	Strongly Support	Strongly Support	Support	Support	Neutral	Neutral	Support
67	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
68	Unsure	Unsure	Unsure	Neutral	Strongly Support	Strongly Support	Strongly Support	Unsure	Neutral	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
69		Strongly Support		Strongly Support	Strongly Support	Strongly Support		Strongly Support				Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
70	Neutral	Against	Strongly Support	Strongly Support	Support	Support	Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Neutral	Support
71																	
72	Support	Support	Support	Support	Support	Support	Support	Support	Against	Support	Support	Support	Neutral	Neutral	Neutral	Neutral	Neutral
73	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
74																	
75	Strongly Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support	Support	Neutral	Neutral
76	Against	Neutral	Support	Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
77	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
78	Strongly Support	Strongly Support			Strongly Support	Strongly Support		Strongly Support					Strongly Support	Strongly Support			
79	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Support	Support	Strongly Support	Support	Support

#	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?																
	Flood modification options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.								Property modification options: Refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings to flooding.				Response modification options: Are options aimed at improving the way emergency services and the general public responds before, during and after a flood.				
	Raising existing levees	New levees	Bypass floodways	Modify flow obstructions (e.g. road / rail embankments)	Enlarging / dredging river and / or creek channels	Maintenance and clearing of rivers and creeks	Culvert / bridge upgrades	New / upgraded floodgates	Voluntary house raising	Voluntary flood proofing	Voluntary house purchase	Updated development / planning controls	Updated flood warning system	SES local flood plan updates	Community education	Boom gates / signs at roadway overtopping points	Upgrade flood evacuation routes
80	Neutral	Neutral	Neutral	Support	Against	Support	Support	Support	Neutral	Neutral	Neutral	Against	Strongly Support	Support	Neutral	Support	Neutral
81	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Support	Unsure	Strongly Support	Unsure	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
82	Neutral	Against	Neutral	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Support	Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Against	Strongly Support
83	Unsure	Unsure			Strongly Support	Strongly Support		Strongly Support	Strongly Support				Strongly Support	Strongly Support	Strongly Support		
84	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
85	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Support	Neutral	Strongly Support	Neutral	Strongly Support
86	Neutral	Neutral	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
87	Unsure	Unsure	Unsure	Unsure	Unsure	Support	Unsure	Support	Support	Support	Support	Unsure	Support	Support	Support	Support	Support
88	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
89	Neutral	Neutral	Neutral	Neutral	Strongly Against	Strongly Against	Support	Neutral	Unsure	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support
90	Neutral	Neutral	Neutral	Strongly Against	Support	Support	Support	Support	Neutral	Neutral	Neutral	Strongly Against	Support	Support	Neutral	Neutral	Support
91		Strongly Support		Strongly Support									Strongly Support	Support			
92	Unsure				Strongly Support	Strongly Support							Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
93	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Support	Support	Support	Strongly Support	Support

STAGE 2

South Murwillumbah Floodplain Risk Management Study

TWEED SHIRE COUNCIL

Feedback on potential flood risk mitigation measures

Tweed Shire Council is preparing a floodplain risk management study for South Murwillumbah. The primary goal of the study is to identify and evaluate options that aim to reduce the impact that flooding has on people and property across the area.

As part of the study, Council and its specialist flood consultants have identified a preliminary list of potential flood risk mitigation measures to be evaluated in detail. The goal of this evaluation is to determine which of the preliminary list of options is likely to be feasible for better managing the flood risk across the residential, commercial and industrial areas of South Murwillumbah.

One of the criteria that will be used to evaluate the options is community feedback. In this regard, residents and business owners are encouraged to provide feedback on the preliminary list of mitigation measures included in the following questionnaire. Alternatively, an online version of the questionnaire can be completed by visiting **https://southmurwillumbah.fprms.com.au**

Anyone wanting more information about the study can contact Tweed Shire Council Flood Engineer Leon McLean on (02) 6670 2400 or email **LMcLean@tweed.nsw.gov.au**.

Feedback form

Please complete all sections of the following form, marking your support of the option from 'Strongly support' to 'Strongly against' or 'Unsure' and return in the reply-paid envelope by Friday 30 November 2018.

Your feedback will be used to help prioritise the options for mitigating the potential flood risk in South Murwillumbah.

Potential flood modification options

Flood modification options are options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwaters across populated areas.

Description of option	Strongly support	Support	Neutral	Against	Strongly against	Unsure
Lower ground elevations near the western end of Durrington Street to provide additional flow path towards Tweed River	☐	☐	☐	☐	☐	☐
Purchase existing properties in vicinity of Colin Street, between River Street and Tweed Valley Way, and reshape terrain to create additional flow path between Tweed River and railway	☐	☐	☐	☐	☐	☐
Elevate low point in Alma Street to reduce frequency of overtopping and provide additional evacuation time from South Murwillumbah into town	☐	☐	☐	☐	☐	☐
Provide additional openings in existing railway embankment to allow floodwaters to move more readily from the residential area of South Murwillumbah	☐	☐	☐	☐	☐	☐
Elevate Tweed Valley Way at Blacks Drain to reduce frequency of overtopping and provide additional evacuation time	☐	☐	☐	☐	☐	☐
Reshape and maintain Condong Creek channel to reduce vegetation density and improve flow capacity	☐	☐	☐	☐	☐	☐
Create high flow bench across eastern section of Boral site to carry additional flows into Tweed River when capacity of Condong Creek channel is exceeded	☐	☐	☐	☐	☐	☐
Provide additional set of high-level floodgate-protected outlets at flood gate 17L (Condong Creek) to allow area behind flood gates to begin draining sooner	☐	☐	☐	☐	☐	☐

Continued overleaf ...

Potential flood modification options (continued)

Description of option	Strongly support	Support	Neutral	Against	Strongly against	Unsure
Enlarge Blacks Drain channel to allow additional water to bypass the residential and commercial areas of South Murwillumbah	☐	☐	☐	☐	☐	☐
Lower existing ground surface elevations across Lot 4 DP 591604 Quarry Road to allow floodwater to more readily escape from Murwillumbah airfield	☐	☐	☐	☐	☐	☐
Dredge the Tweed River channel adjacent to South Murwillumbah to provide additional flow carrying capacity	☐	☐	☐	☐	☐	☐

Potential property modification options

Property modification options refer to options that reduce the potential for flooding of individual properties or improve the resilience of buildings to flooding.

Description of option	Strongly support	Support	Neutral	Against	Strongly against	Unsure
Review Council's existing voluntary house purchase program	☐	☐	☐	☐	☐	☐
Temporary flood barriers to reduce the potential for ingress of floodwaters into commercial properties	☐	☐	☐	☐	☐	☐
Relocate industrial properties from existing low-lying industrial area to Industry Central (industrial land swap project)	☐	☐	☐	☐	☐	☐
Consolidate existing residential lots to reduce potential for additional dwellings/additional people to be introduced to the flood problem areas	☐	☐	☐	☐	☐	☐

Potential response modification options

Response modification options refer to options that improve the way emergency services and the general public responds before, during and after a flood.

Description of option	Strongly support	Support	Neutral	Against	Strongly against	Unsure
Various community education activities to raise flood awareness and allow residents and business owners to be more self-sufficient during future floods	☐	☐	☐	☐	☐	☐
Preparation of flood plans by residential property occupiers to identify actions to be taken before during and after a flood	☐	☐	☐	☐	☐	☐
Preparation of flood plans by business owners to identify actions to be taken before during and after a flood	☐	☐	☐	☐	☐	☐
Update SES local flood plan to take advantage of updated flood information generated as part of the current study	☐	☐	☐	☐	☐	☐
Update existing flood warning system to improve the dissemination of flood information	☐	☐	☐	☐	☐	☐

Catchment Simulation Solutions | TWEED SHIRE COUNCIL

Table A4 - Feedback on Specific Flood Risk Mitigation Measures

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																			
	Potential flood modification options											Potential property modification options				Potential response modification options				
	Lower ground elevations near the western end of Durrington Street to provide additional flow path towards Tweed River	Purchase existing properties in vicinity of Colin Street, between River Street and Tweed Valley Way, and reshape terrain to create additional flow path between Tweed River and railway	Elevate low point in Alma Street to reduce frequency of overtopping and provide additional evacuation time from South Murwillumbah into town	Provide additional opening(s) in existing railway embankment to allow floodwaters to move more readily from the residential area of South Murwillumbah	Elevate Tweed Valley Way at Blacks Drain to reduce frequency of overtopping and provide additional evacuation time	Reshape and maintain Condong Creek channel to reduce vegetation density and improve flow capacity	Create high flow bench across eastern section of Boral site to carry additional flows into Tweed River when capacity of Condong Creek channel is exceeded	Provide additional set of high-level floodgate-protected outlets at flood gate 17L to allow area behind flood gates to begin draining sooner	Enlarge Blacks Drain channel to allow additional water to bypass the residential and commercial areas of South Murwillumbah	Lower existing ground surface elevations across Lot 4 DP 591604 Quarry Road to allow floodwater to more readily escape from Murwillumbah airfield	Dredge the Tweed River channel adjacent to South Murwillumbah to provide additional flow carrying capacity	Review Council's existing voluntary house purchase program	Temporary flood barriers to reduce the potential for ingress of floodwaters into commercial properties	Relocate industrial properties from existing low-lying industrial area to Industry Central (industrial land swap project)	Consolidation of existing residential lots to reduce potential for additional dwellings / additional people to be introduced to the flood problem areas	Various community education activities to raise flood awareness and allow residents and business owners to be more self-sufficient during future floods	Preparation of flood plans by residential property occupiers to identify actions to be taken before during and after a flood	Preparation of flood plans by business owners to identify actions to be taken before during and after a flood	Update SES local flood plan to take advantage of updated flood information generated as part of the current study	Update existing flood warning system to improve the dissemination of flood information
1	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Support	Strongly support	Neutral	Support	Neutral	Support	Neutral	Against	Support	Support	Support	Unsure	Support
2	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
3	Against	Against	Support	Neutral	Strongly support	Strongly support	Neutral	Strongly support	Against	Against	Neutral	Neutral	Against	Neutral	Against	Neutral	Support	Neutral	Support	Support
4	Support	Neutral	Support	Strongly support	Against	Support	Neutral	Support	Support	Support	Strongly support	Support	Against	Support	Neutral	Support	Strongly support	Support	Strongly support	Strongly support
5	Neutral	Neutral	Strongly support	Neutral	Strongly support	Neutral	Strongly support	Neutral	Strongly support	Support	Strongly support	Neutral	Neutral	Neutral	Neutral	Strongly support	Support	Strongly support	Strongly support	Support
6	Support	Against	Against	Neutral	Support	Strongly support	Support	Support	Neutral	Support	Neutral	Neutral	Against	Neutral	Neutral	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
7	Support	Support	Support	Support	Strongly support	Support	Support	Support	Strongly support	Support	Strongly support	Strongly support	Strongly support	Support	Support	Support	Support	Support	Support	Support
8	Support	Support	Support	Support	Strongly support	Support	Support	Support	Support	Support	Strongly support	Support	Neutral	Neutral	Support	Support	Support	Support	Support	Support
9		Unsure	Strongly support	Strongly support			Unsure	Support	Strongly support	Unsure	Strongly support	Strongly support	Unsure	Strongly support		Strongly support	Unsure	Unsure	Strongly support	Strongly support
10	Strongly support	Unsure	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support					Strongly support	Strongly support	Unsure				Unsure	Support
11	Support	Support	Support	Support	Unsure	Unsure	Unsure	Support	Support	Unsure	Strongly support	Support	Unsure	Support	Support	Support	Support	Support	Support	Unsure
12																				
13	Support	Unsure	Strongly support	Strongly support	Strongly support	Support	Support	Support	Strongly support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly support	Strongly support
14	Neutral	Support	Support	Support	Support	Support	Neutral	Neutral	Strongly support	Support	Strongly support	Support	Support	Neutral	Support	Support	Support	Support	Support	Strongly support
15	Strongly support	Strongly against	Against	Unsure	Strongly against	Strongly support	Strongly support	Strongly support	Against	Support	Strongly against	Strongly against	Strongly against	Strongly support	Unsure	Strongly support	Support	Support	Support	Support
16	Support	Support	Strongly support	Support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
17	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Support	Strongly support	Strongly support
18	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Support	Strongly support	Strongly support
19	Support	Support	Strongly support	Strongly support	Support	Support	Support	Support	Strongly support	Support	Strongly support	Neutral	Neutral	Support	Support	Support	Support	Support	Support	Strongly support
20	Unsure	Neutral	Support	Unsure	Unsure	Unsure	Unsure	Unsure	Support	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
21		Strongly support	Strongly support	Strongly support	Strongly support		Strongly support	Strongly support	Against	Strongly support	Strongly support	Strongly support		Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
22	Against	Against	Strongly support	Against	Strongly support	Strongly support	Support	Strongly support	Strongly support	Strongly support	Neutral	Neutral	Against	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																			
	Potential flood modification options											Potential property modification options				Potential response modification options				
	Lower ground elevations near the western end of Durrington Street to provide additional flow path towards Tweed River	Purchase existing properties in vicinity of Colin Street, between River Street and Tweed Valley Way, and reshape terrain to create additional flow path between Tweed River and railway	Elevate low point in Alma Street to reduce frequency of overtopping and provide additional evacuation time from South Murwillumbah into town	Provide additional opening(s) in existing railway embankment to allow floodwaters to move more readily from the residential area of South Murwillumbah	Elevate Tweed Valley Way at Blacks Drain to reduce frequency of overtopping and provide additional evacuation time	Reshape and maintain Condong Creek channel to reduce vegetation density and improve flow capacity	Create high flow bench across eastern section of Boral site to carry additional flows into Tweed River when capacity of Condong Creek channel is exceeded	Provide additional set of high-level floodgate-protected outlets at flood gate 17L to allow area behind flood gates to begin draining sooner	Enlarge Blacks Drain channel to allow additional water to bypass the residential and commercial areas of South Murwillumbah	Lower existing ground surface elevations across Lot 4 DP 591604 Quarry Road to allow floodwater to more readily escape from Murwillumbah airfield	Dredge the Tweed River channel adjacent to South Murwillumbah to provide additional flow carrying capacity	Review Council's existing voluntary house purchase program	Temporary flood barriers to reduce the potential for ingress of floodwaters into commercial properties	Relocate industrial properties from existing low-lying industrial area to Industry Central (industrial land swap project)	Consolidation of existing residential lots to reduce potential for additional dwellings / additional people to be introduced to the flood problem areas	Various community education activities to raise flood awareness and allow residents and business owners to be more self-sufficient during future floods	Preparation of flood plans by residential property occupiers to identify actions to be taken before during and after a flood	Preparation of flood plans by business owners to identify actions to be taken before during and after a flood	Update SES local flood plan to take advantage of updated flood information generated as part of the current study	Update existing flood warning system to improve the dissemination of flood information
23		Strongly support		Strongly support		Strongly support			Strongly support	Strongly support	Strongly support	Strongly support								
24	Unsure	Unsure	Strongly support	Against	Strongly support	Support	Unsure	Support	Neutral	Unsure	Strongly support	Support	Support	Support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
25	Neutral	Neutral	Strongly against	Strongly support	Strongly support	Strongly support	Support	Support	Strongly support	Neutral	Strongly support	Neutral	Neutral	Neutral	Strongly against	Neutral	Neutral	Neutral	Neutral	Strongly support
26	Strongly against	Strongly against	Support	Strongly against	Strongly support	Strongly support	Strongly support	Strongly support	Strongly against	Against	Strongly support	Against	Neutral	Strongly against	Neutral	Support	Support	Neutral	Strongly support	Strongly support
27	Strongly against	Strongly against	Strongly support	Against	Strongly support	Strongly support	Support	Strongly support	Strongly against	Strongly against	Strongly support	Strongly against		Strongly against	Strongly against	Support	Support	Neutral	Support	Support
28	Strongly support	Against	Against	Support	Against	Against	Unsure	Neutral	Support		Support	Unsure	Strongly support	Unsure	Strongly support	Strongly against	Strongly against	Strongly against	Strongly against	Strongly against
29	Support	Support	Strongly support	Strongly support	Support	Strongly support	Support	Strongly support	Strongly support	Support	Strongly support	Support	Support	Support	Support	Support	Support	Support	Strongly support	Strongly support
30	Neutral	Strongly support	Support	Against	Support	Neutral	Unsure	Unsure	Unsure	Unsure	Support	Strongly support	Unsure	Strongly support	Strongly support	Support	Neutral	Neutral	Support	Neutral
31	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
32	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Neutral	Against	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
33	Unsure	Strongly support	Support	Strongly support	Neutral	Neutral	Neutral	Neutral	Strongly support	Neutral	Support	Strongly support	Support	Neutral	Strongly support	Support	Strongly support	Neutral	Support	Support
34	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
35	Support	Support	Strongly support	Strongly support	Support	Strongly support	Support	Support	Strongly support	Neutral	Strongly support	Strongly support	Support	Neutral	Strongly support	Strongly support	Strongly support	Support	Strongly support	Strongly support
36	Unsure	Neutral	Neutral	Support	Support	Support	Neutral	Support	Strongly support	Support	Support	Neutral	Neutral	Against	Neutral	Neutral	Neutral	Neutral	Support	Support
37	Unsure	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Unsure	Unsure	Strongly support	Unsure
38												Strongly support		Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
39	Support	Neutral	Support	Strongly support	Support	Strongly support	Support	Support	Strongly support	Neutral	Strongly support	Support	Support	Neutral	Neutral	Support	Support	Support	Strongly support	Strongly support
40	Neutral	Strongly support	Strongly support	Support		Support	Neutral	Strongly support		Neutral	Support	Strongly support	Neutral	Strongly support	Strongly support	Strongly support	Support	Strongly support	Strongly support	Strongly support
41	Unsure	Neutral	Support	Support	Support	Neutral	Support	Support	Strongly support	Neutral	Strongly support					Support	Support	Neutral	Support	Support
42	Support	Support	Strongly support	Strongly support	Strongly support	Support	Support	Neutral	Strongly support	Support	Strongly support	Neutral	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
43	Unsure	Support	Support	Strongly support	Strongly support	Support	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly support	Support	Strongly support	Unsure	Neutral	Support	Support	Support	Support
44	Neutral	Strongly support	Neutral	Strongly support	Against	Support	Neutral	Neutral	Neutral	Support	Strongly support	Strongly support	Neutral	Against	Strongly support	Neutral	Support	Support	Support	Strongly support

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																			
	Potential flood modification options											Potential property modification options				Potential response modification options				
	Lower ground elevations near the western end of Durrington Street to provide additional flow path towards Tweed River	Purchase existing properties in vicinity of Colin Street, between River Street and Tweed Valley Way, and reshape terrain to create additional flow path between Tweed River and railway	Elevate low point in Alma Street to reduce frequency of overtopping and provide additional evacuation time from South Murwillumbah into town	Provide additional opening(s) in existing railway embankment to allow floodwaters to move more readily from the residential area of South Murwillumbah	Elevate Tweed Valley Way at Blacks Drain to reduce frequency of overtopping and provide additional evacuation time	Reshape and maintain Condong Creek channel to reduce vegetation density and improve flow capacity	Create high flow bench across eastern section of Boral site to carry additional flows into Tweed River when capacity of Condong Creek channel is exceeded	Provide additional set of high-level floodgate-protected outlets at flood gate 17L to allow area behind flood gates to begin draining sooner	Enlarge Blacks Drain channel to allow additional water to bypass the residential and commercial areas of South Murwillumbah	Lower existing ground surface elevations across Lot 4 DP 591604 Quarry Road to allow floodwater to more readily escape from Murwillumbah airfield	Dredge the Tweed River channel adjacent to South Murwillumbah to provide additional flow carrying capacity	Review Council's existing voluntary house purchase program	Temporary flood barriers to reduce the potential for ingress of floodwaters into commercial properties	Relocate industrial properties from existing low-lying industrial area to Industry Central (industrial land swap project)	Consolidation of existing residential lots to reduce potential for additional dwellings / additional people to be introduced to the flood problem areas	Various community education activities to raise flood awareness and allow residents and business owners to be more self-sufficient during future floods	Preparation of flood plans by residential property occupiers to identify actions to be taken before during and after a flood	Preparation of flood plans by business owners to identify actions to be taken before during and after a flood	Update SES local flood plan to take advantage of updated flood information generated as part of the current study	Update existing flood warning system to improve the dissemination of flood information
45	Neutral	Strongly support	Strongly support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Strongly support	Support	Support	Strongly support	Strongly support	Strongly support	Strongly support
46	Unsure	Unsure	Strongly support	Unsure		Strongly support	Strongly support	Strongly support	Unsure	Unsure	Strongly support	Against	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
47	Strongly support	Strongly against	Neutral	Strongly against	Strongly against	Neutral	Neutral	Neutral	Strongly against	Strongly against	Strongly against	Neutral	Strongly support	Strongly support	Neutral	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
48	Unsure	Unsure	Unsure	Unsure	Neutral	Support	Unsure	Neutral	Unsure	Unsure	Unsure	Strongly support	Against	Unsure	Unsure	Neutral	Support	Support	Support	Support
49	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
50	Neutral	Support	Against	Support	Against	Support	Support	Support	Support	Neutral	Against	Support	Support	Neutral	Support	Support	Support	Support	Support	Support
51	Neutral	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Neutral	Neutral	Strongly support	Support	Strongly support	Strongly against	Unsure	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
52	Neutral	Neutral	Neutral	Neutral	Strongly against	Neutral	Neutral	Neutral	Strongly against	Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Neutral	Support	Support
53	Support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Support	Support	Strongly support	Strongly support
54	Strongly support	Strongly support	Support	Support	Support	Strongly support	Strongly support	Support	Strongly against	Strongly support	Strongly support	Support		Support	Support	Strongly support	Support	Support	Support	Support
55	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
56	Neutral	Support	Neutral	Strongly against	Support	Neutral	Support	Support	Strongly against	Support	Support	Strongly support	Against	Strongly support	Support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
57	Support		Strongly support	Strongly support	Strongly against	Support	Strongly against	Strongly support	Strongly support	Strongly against	Support	Strongly support	Strongly against	Strongly against	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support
58	Strongly support	Neutral	Neutral	Strongly support	Strongly support	Neutral	Neutral	Strongly support	Strongly support	Neutral	Strongly support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly support	Strongly support
59				Strongly support							Strongly support									
60	Support	Neutral	Support	Neutral	Support	Support	Support	Support	Strongly support	Strongly support	Strongly support	Neutral	Strongly support	Strongly against	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support	Strongly support

Strongly support	15	19	29	30	28	26	19	25	32	17	38	22	15	23	23	26	23	22	34	35
Support	15	13	15	12	13	18	18	19	6	15	10	16	16	10	12	20	24	20	18	17
Neutral	11	10	6	5	2	8	10	9	4	10	3	12	9	13	9	8	5	10	1	1
Against	2	4	4	4	4	1	0	0	3	2	1	2	6	2	3	0	0	0	0	0
Strongly against	2	4	1	3	4	0	1	0	6	3	2	2	2	5	2	1	1	1	1	1
Unsure	9	6	1	4	2	2	8	3	4	8	3	2	4	3	6	1	3	3	3	3
sum	54	56	56	58	53	55	56	56	55	55	57	56	52	56	55	56	56	56	57	57

In Percentage

Strongly support	27.78	33.93	51.79	51.72	52.83	47.27	33.93	44.64	58.18	30.91	66.67	39.29	28.85	41.07	41.82	46.43	41.07	39.29	59.65	61.40

#	To assist us in developing a short list of potential flood risk reduction measures, please rate the following options. Which of these options do you support/not support?																		
	Potential flood modification options											Potential property modification options				Potential response modification options				
	Lower ground elevations near the western end of Durrington Street to provide additional flow path towards Tweed River	Purchase existing properties in vicinity of Colin Street, between River Street and Tweed Valley Way, and reshape terrain to create additional flow path between Tweed River and railway	Elevate low point in Alma Street to reduce frequency of overtopping and provide additional evacuation time from South Murwillumbah into town	Provide additional opening(s) in existing railway embankment to allow floodwaters to move more readily from the residential area of South Murwillumbah	Elevate Tweed Valley Way at Blacks Drain to reduce frequency of overtopping and provide additional evacuation time	Reshape and maintain Condong Creek channel to reduce vegetation density and improve flow capacity	Create high flow bench across eastern section of Boral site to carry additional flows into Tweed River when capacity of Condong Creek channel is exceeded	Provide additional set of high-level floodgate-protected outlets at flood gate 17L to allow area behind flood gates to begin draining sooner	Enlarge Blacks Drain channel to allow additional water to bypass the residential and commercial areas of South Murwillumbah	Lower existing ground surface elevations across Lot 4 DP 591604 Quarry Road to allow floodwater to more readily escape from Murwillumbah airfield	Dredge the Tweed River channel adjacent to South Murwillumbah to provide additional flow carrying capacity	Review Council's existing voluntary house purchase program	Temporary flood barriers to reduce the potential for ingress of floodwaters into commercial properties	Relocate industrial properties from existing low-lying industrial area to Industry Central (industrial land swap project)	Consolidation of existing residential lots to reduce potential for additional dwellings / additional people to be introduced to the flood problem areas	Various community education activities to raise flood awareness and allow residents and business owners to be more self-sufficient during future floods	Preparation of flood plans by residential property occupiers to identify actions to be taken before during and after a flood	Preparation of flood plans by business owners to identify actions to be taken before during and after a flood	Update SES local flood plan to take advantage of updated flood information generated as part of the current study	Update existing flood warning system to improve the dissemination of flood information
Support	27.78	23.21	26.79	20.69	24.53	32.73	32.14	33.93	10.91	27.27	17.54	28.57	30.77	17.86	21.82	35.71	42.86	35.71	31.58	29.82
Neutral	20.37	17.86	10.71	8.62	3.77	14.55	17.86	16.07	7.27	18.18	5.26	21.43	17.31	23.21	16.36	14.29	8.93	17.86	1.75	1.75
Against	3.70	7.14	7.14	6.90	7.55	1.82	0.00	0.00	5.45	3.64	1.75	3.57	11.54	3.57	5.45	0.00	0.00	0.00	0.00	0.00
Strongly against	3.70	7.14	1.79	5.17	7.55	0.00	1.79	0.00	10.91	5.45	3.51	3.57	3.85	8.93	3.64	1.79	1.79	1.79	1.75	1.75
Unsure	16.67	10.71	1.79	6.90	3.77	3.64	14.29	5.36	7.27	14.55	5.26	3.57	7.69	5.36	10.91	1.79	5.36	5.36	5.26	5.26

APPENDIX B

HISTORIC FLOOD PHOTOS

1989 Flood Photos

Looking south east from Lions Lookout towards South Murwillumbah

Looking towards Budd Park, South Murwillumbah from Tumbulgum Road

Looking south east from Tumbulgum Road towards South Murwillumbah

2013 Flood Photos

Drain behind 76 River Street, South Murwillumbah

Drain behind 76 River Street, South Murwillumbah

Looking north east at Tumbulgum

Looking east at Tumbulgum

Fawcett St, Tumbulgum

Fawcett St, Tumbulgum

2017 Flood Photos

Alma St, South Murwillumbah (taken 4:10pm on 31/3/2017)

Tweed Valley Way near Greenhills Caravan Park (taken 7:30am on 31/3/2017)

Tweed Valley Way at Blacks Drain (taken 4:00pm on 30/3/2017)

Tweed Valley Way at Blacks Drain (taken 1:50pm on 31/3/2017)

76 River Street, South Murwillumbah (taken 6:30pm on 30/3/2017)

76 River Street, South Murwillumbah (taken 7:00am on 31/3/2017)

76 River Street, South Murwillumbah (taken 7:00am on 31/3/2017)

127 River Street, South Murwillumbah (taken 5:30pm on 30/3/2017)

Looking north along Tweed Valley Way (taken from Colin St intersection at 1:30pm on 31/3/2017)

Condong Creek looing upstream from Tweed Valley Way (taken at 6:00pm on 31/3/2017)

APPENDIX C

TUFLOW MODEL UPDATES & CALIBRATION

1 COMPUTER FLOOD MODEL

1.1 General

Design flood characteristics across the Tweed River catchment were originally defined using a WBNM hydrologic model and a TUFLOW hydraulic model that was developed as part of the 'Tweed Valley Flood Study Update' (BMT WBM, 2009). The models developed for this previous study were subsequently refined as part of the 'Murwillumbah CBD Levee & Drainage Study' (Catchment Simulation Solutions, 2018) to provide a more detailed assessment of flood and drainage behaviour in the vicinity of the Murwillumbah CBD.

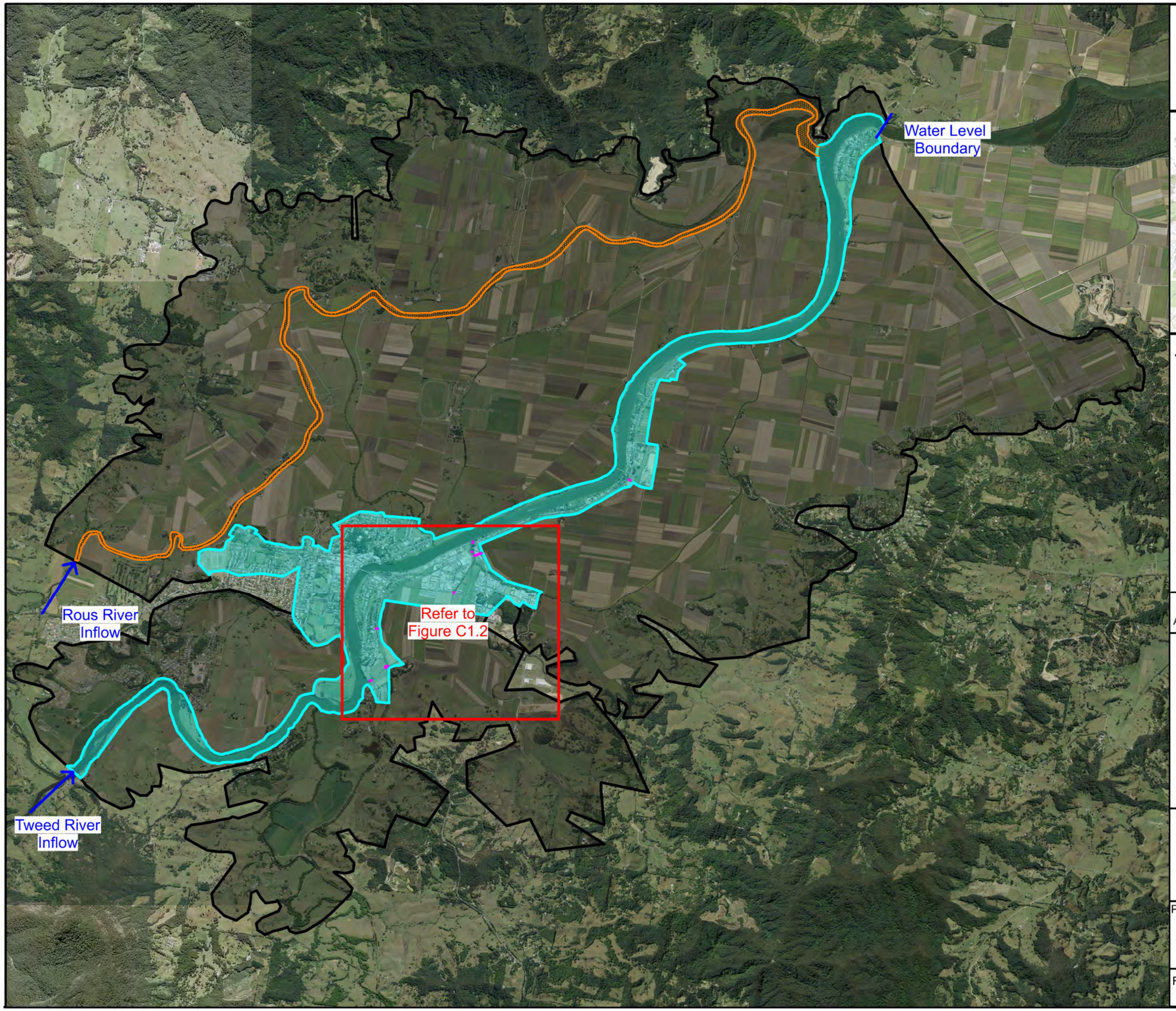
These models were also considered to provide the best contemporary description of flood behaviour across South Murwillumbah. However, several updates to the TUFLOW model were considered necessary to ensure the best possible description of flood behaviour was being provided by the model across South Murwillumbah.

The following chapter provides an overview of the updates that were completed to the TUFLOW model along with the outcomes of the calibration of the updated model.

1.2 Hydraulic Model Updates

As discussed, the TUFLOW hydraulic computer model that was developed as part 'Murwillumbah CBD Levee & Drainage Study' was also used as the basis for the hydraulic modelling completed as part of the current assessment. However, several updates were completed to the model to ensure a reliable representation of flood behaviour was being provided across South Murwillumbah. The model updates are described below.

- Model Extent: The 'Murwillumbah CBD Levee & Drainage Study' model extended downstream to Condong. However, it was considered necessary to extend the model downstream to Tumbulgum to ensure any uncertainties associated with the downstream boundary definition did not impact on flood behaviour across South Murwillumbah. The model was also extended upstream from Bray Park to Byangum. This resulted in the TUFLOW model extent roughly doubling from approximately 39 km^2 to 91 km2. The extent of the updated TUFLOW model is shown in **Figure C1**.
- Tweed River Channel: The original TUFLOW model represented each of the main river channels (e.g., Tweed and Rous Rivers) using a 1-dimensional domain. However, investigations completed as part of the 'Murwillumbah CBD Levee & Drainage Study' indicate a notable water level gradient across some bends in the Tweed River (most notably downstream of the Murwillumbah bridge). Therefore, it was considered advantageous to change the 1-dimensional representation of the Tweed River channel to a fully 2-dimensional representation. The geometry of the river channel was defined based upon the hydrosurvey collected by OEH in August 2018.
- Grid Size: As outlined above, the TUFLOW model extent was more than doubled as part of the current study. It was considered desirable to retain the 5 metre grid size that was adopted in the original model to ensure a suitably detailed description of hydraulic



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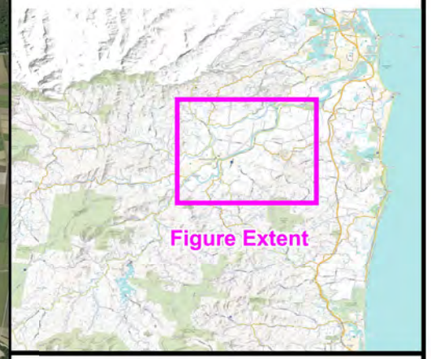

LEGEND

- Hydraulic Structure
- 1D Domain
- 5m 2D Domain
- 10m 2D Domain

Notes:

Aerial photograph date: 2016

N
W E
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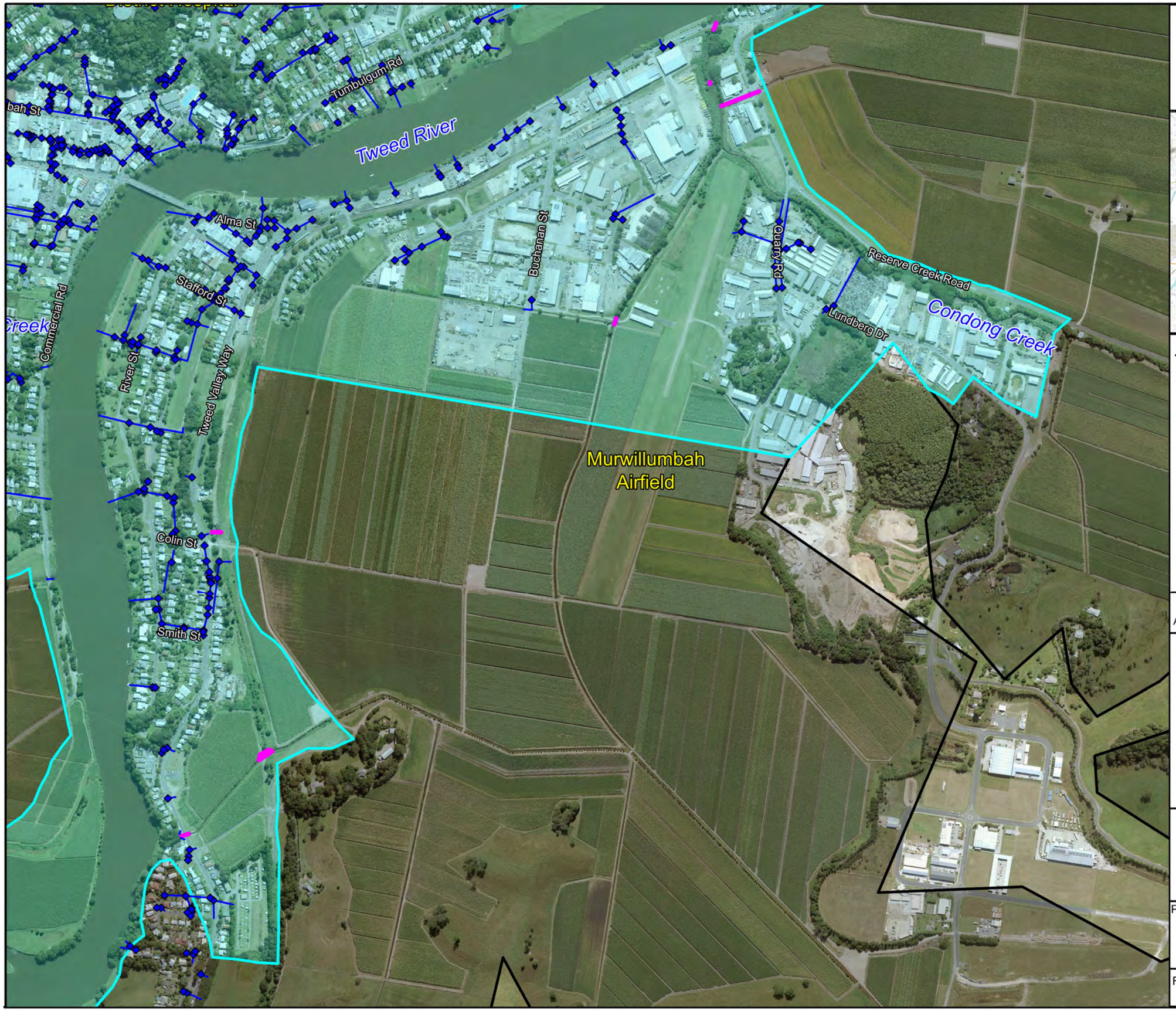
0 1.50 3.00
Km

Figure C1.1: TUFLOW Model Layout

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigC1.1 - TUFLOW Model Layout.wor



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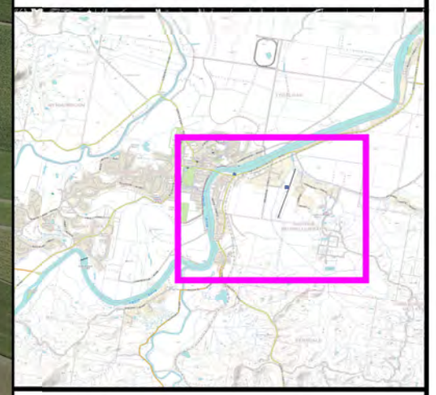

LEGEND

- Hydraulic Structure
- Stormwater Pipes and Pits
- 5m 2D Domain
- 10m 2D Domain

Notes:

Aerial photograph date: 2016

N
W E
S

0 0.25 0.50

Km

Figure C1.2: TUFLOW Model Layout

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Sydney, NSW 2000

File Name: FigC1.2 - TUFLOW Model Layout.wor

properties could be provided across South Murwillumbah. However, the significantly larger model extent made this unfeasible from a model run-time perspective. Therefore, a multi-domain TUFLOW model was developed which enables a variable grid size to be adopted across the model area. A 5 metre grid size was retained across the urban sections of the study area including Murwillumbah as well as most of the South Murwillumbah study area (in addition to the downstream villages of Condong and Tumbulgum). The Tweed River channel was also represented using a 5 metre grid size. The balance of the model area was represented using a larger 10 metre grid size. This generally encompassed the flatter floodplain areas (typically sugar cane fields). The extent of the 5 metre and 10 metre domains is shown in **Figure C1.1** and **C1.2**.

- Topography: The bathymetry along the Rous River channel was defined using river cross-sections used in the original TUFLOW model. The topography across the floodplain areas was typically defined using 2014 LiDAR information. However, this was supplemented with more detailed ground survey, where available. This included:
  - South Murwillumbah levee from near southern end of River Street to near Stafford Street
  - Tweed Valley Way between Alma Street and Condong Creek
  - Tweed Valley Way extending ~70 metres either side of Blacks Drain
  - Quarry Road from Tweed Valley Way to Airfield Ave (including Lot 4 DP591604)
  - Railway line extending from near the Tweed Regional Gallery to the Murwillumbah Visitor Information Centre
  - Murwillumbah Airfield
- Materials/Manning's "n": Manning's "n" roughness coefficients were assigned to the original TUFLOW model based upon a detailed remote sensing land use analysis. The remote sensing outputs were also used in the updated model. However, the remote sensing analysis was expanded to cover the full extent of the TUFLOW model domain. The final land use information that was used in the model is shown in **Figure C2** and the adopted Manning's "n" values for each land use are summarised in the table below.

Land Use Description		Manning's 'n' Value
River Channel	Tweed River	0.033
	Rous River	0.040
Impervious (concrete, roads)		0.015
Grass		0.040
Trees		0.100
Water		0.025
Sugar Cane		0.300
Buildings		1.000

- Hydraulic Structures: Major hydraulic structures (i.e., bridges and culverts) were generally extracted from the original TUFLOW model. However, it was noted that not all structures were represented. Therefore, it was necessary to update the model to include the following additional hydraulic structures:
  - Tweed Valley Way crossing of Blacks Drain.

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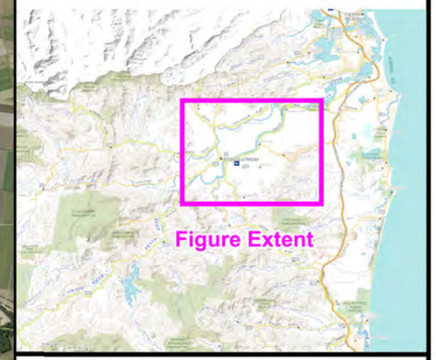

LEGEND

TUFLOW Model Extent

Material Types

- Buildings
- Water
- Trees
- Grass
- Impervious
- Crops / Sugarcane

Notes:

Aerial photograph date: 2016

N
W E
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0 1.50 3.00
Km

Figure C2: Remote Sensing

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Sydney, NSW 2000

File Name: FigC2 - Remote Sensing.wor

- Condong Creek flood gates (the flood gates were incorporated into the Tweed Valley Bridge crossing of Condong Creek in the original model).
- Tweed Valley Way culvert crossing of unnamed creek (located about 60 metres south-west of the Cane Road intersection near Condong).

The location of all hydraulic structures included in the TUFLOW model is shown in **Figure C1.2**.

- Stormwater System: The TUFLOW model included a full representation of the stormwater pit and pipe system across Murwillumbah CBD. The stormwater system representation was expanded as part of the current study to also cover the South Murwillumbah study area. The location of all stormwater pits and pipes included in the TUFLOW model is shown in **Figure C1.2**.

1.3 Computer Model Calibration

Once the model was updated, calibration was attempted. Calibration is typically completed by routing recorded rainfall from historic floods through a hydrologic computer model of the catchment. The flow hydrographs are then routed through the hydraulic model and simulated flood levels are extracted from the model results at locations where recorded/surveyed flood level data is available. Calibration is completed by iteratively adjusting the model parameters within reasonable bounds to achieve the best possible match between simulated and recorded flood flows and flood marks.

The following floods were selected for the calibration:

- March 2017;
- January 2013; and,
- April 1989.

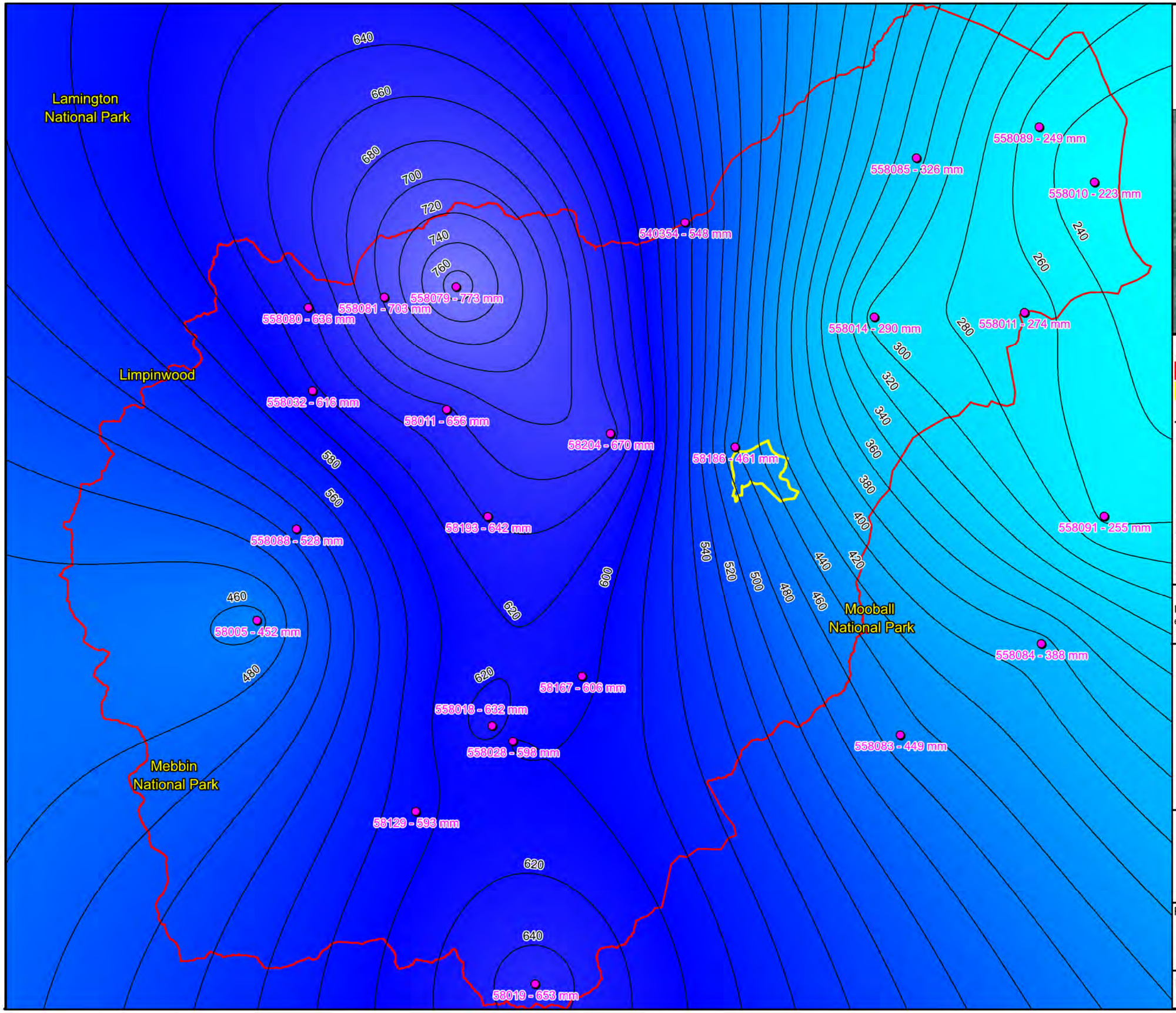
It was noted that a satisfactory calibration of the WBNM model was completed as part of the *'Tweed Valley Flood Study'* (BMT WMB, 2009). As the model remains unchanged as part of the current study, re-calibration of the WBNM model was not attempted. That is, the calibration focussed only on the TUFLOW model.

1.3.1 March 2017 Flood

Rainfall & Inflow Boundary Conditions

The March 2017 flood is the largest contemporary flood on report. It was generated as a result of ex-Tropical Cyclone Debbie and resulted in tens of millions of dollars of damage across the Tweed River valley, including South Murwillumbah. This included the failure of parts of Tweed Valley Way (most notably at Blacks Drain) and a part section of the South Murwillumbah levee.

Accumulated rainfall totals for each rainfall gauge that was operational during the 2017 event were used to develop a rainfall isohyet map for the event, which is shown in **Figure C3**. **Figure C3** shows that in excess of 750 mm of rain fell over a 24 hour period across some parts of the upper catchment during the 2017 event. **Figure C3** also shows significant spatial variation in rainfall across the catchment with rainfall depths across the coastal areas being less than half of rainfall depths across the upper catchment areas. Due to the significant spatial variation in rainfall during this event the isohyet map shown in **Figure C3** was used to describe the spatial variation in rainfall within the WBNM model.



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LEGEND

- Catchment Boundary
- Study Area
- Gauge Number - Rainfall (mm)
- Rainfall Isohyet (mm)

Rainfall Depth (mm)

- 0
- 200
- 400
- 600
- 800
- 1000

Notes:

Isohyets are calculated based on total rainfall for the entire duration of the storm.

N
W E
S

0 5 10
Km

Figure C3:
Isohyet Map for 2017 Storm

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Sydney, NSW 2000

File Name: Fig C3 - Isohyet Map for 2017 Storm.wor

The WBNM model was used to route the rainfall excess across the Tweed River catchment and produce discharge hydrographs at various locations. This included the upstream boundaries of the TUFLOW model. Accordingly, the flow hydrographs from the WBNM model were extracted and used to define inflows for the Tweed and Rous Rivers in the TUFLOW model.

Downstream Boundary Conditions

Hydraulic computer models also require the adoption of a suitable downstream boundary condition in order to reliably define flood behaviour throughout the area of interest. The downstream boundary condition is typically defined as a known water surface elevation (i.e., stage).

The downstream boundary of the computer model is located at Tumbulgum. There is a stream gauge located on the Tweed River at Tumbulgum that recorded the time variation in water level throughout the 2017 event. Accordingly, recorded water level information for the Tumbulgum gauge was used to define the time variation in water levels at the downstream boundary of the TUFLOW model throughout the 2017 flood simulation.

Results

Calibration of the TUFLOW hydraulic model was attempted using surveyed flood marks for the 2017 event. The calibration was undertaken by routing the discharge hydrographs generated by the WBNM model for the 2017 event through the TUFLOW model and comparing reported and simulated flood levels at each flood mark location.

Peak floodwater depths were extracted from the results of the 2017 flood simulation and are included on **Figure C4**. A comparison between the peak flood levels generated by the TUFLOW model and the surveyed flood mark elevations is also provided in **Figure C4**.

The flood level comparison provided in **Figure C4** shows that the 2017 flood mark elevations are generally well reproduced by the TUFLOW model (the average difference between simulated flood levels and surveyed flood mark elevations is 0.02 metres). There are some more significant differences between simulated levels and surveyed flood mark elevation at isolated locations, but this appears to be associated with flood mark discrepancies (i.e., flood mark elevations that differ significantly from nearby flood mark elevations). For example, the flood mark located on Quarry Road near Lot 4 DP 591604 is up to 1 metre lower than surrounding flood mark elevations. However, with the exception of these potentially erroneous flood mark elevations, the TUFLOW model is typically reproducing the surveyed flood mark elevations to within 0.15 metres.

The time variation in simulated flood water levels were also extracted at the location of the Tweed River at Murwillumbah and the Tweed River at Murwillumbah Bridge stream gauges and are shown in **Figures C5.1** and **C5.2**. The recorded stage hydrographs at each stream gauge were also extracted and are included on **Figures C5.1** and **C5.2** for comparison.

Figures C5.1 and **C5.2** shows that TUFLOW model provides a reasonable reproduction of the overall shape of the recorded stage hydrographs at Murwillumbah and Murwillumbah Bridge. More specifically, the timing and magnitude of the peak stages are generally reproduced by the TUFLOW model. It is noted that the TUFLOW model is producing higher peak flood levels (typically ~0.1m higher than recorded) and the simulated peak stage occurs about 1 hour later than the recorded peak stage).

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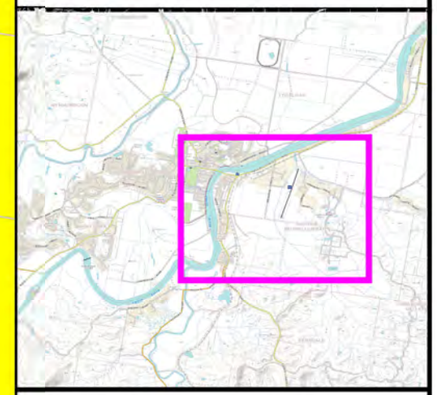

LEGEND

Survey Flood Mark Elevation (mAHD)

Simulated Water Level (mAHD)

Depths (m)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- > 6.0

Notes:

Aerial photograph date: 2016

N W E S

0 0.35 0.70 Km

Figure C4: Peak Floodwater Depths for 2017 Calibration Event for Existing

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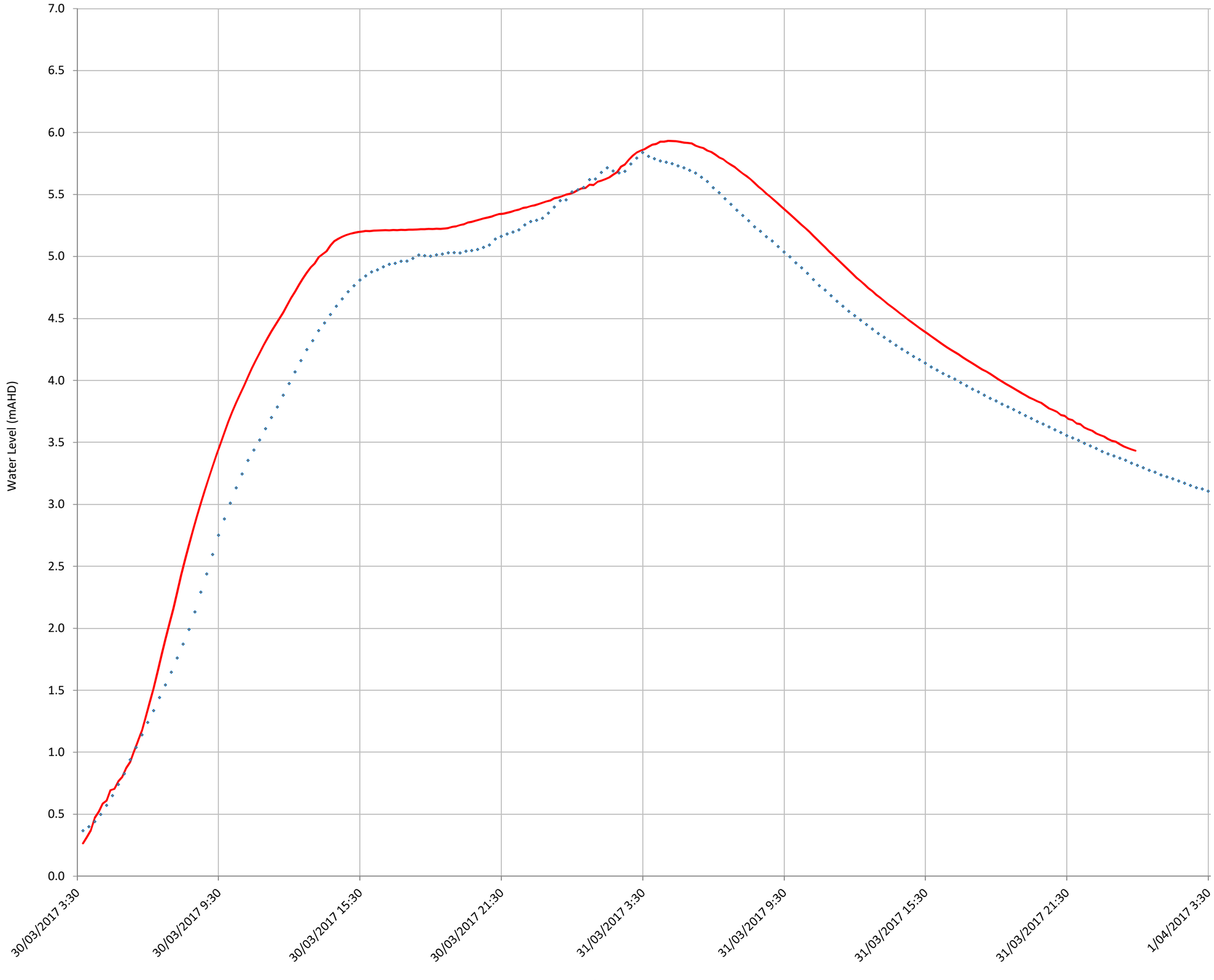
Sydney, NSW 2000

File Name: FigC4 - Cal2017 Existing Depth Results.wor



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LEGEND:

- Recorded 2017 Water Levels
- Simulated 2017 Water Levels

Notes:
- MHL Station Number 201465
- Recorded data provided by MHL NSW Office of Environnment and Heritage.

Figure C5.1: Recorded and Simulated Water Level Hydrographs for Tweed River at Murwillumbah Bridge Gauge for 2017 Flood

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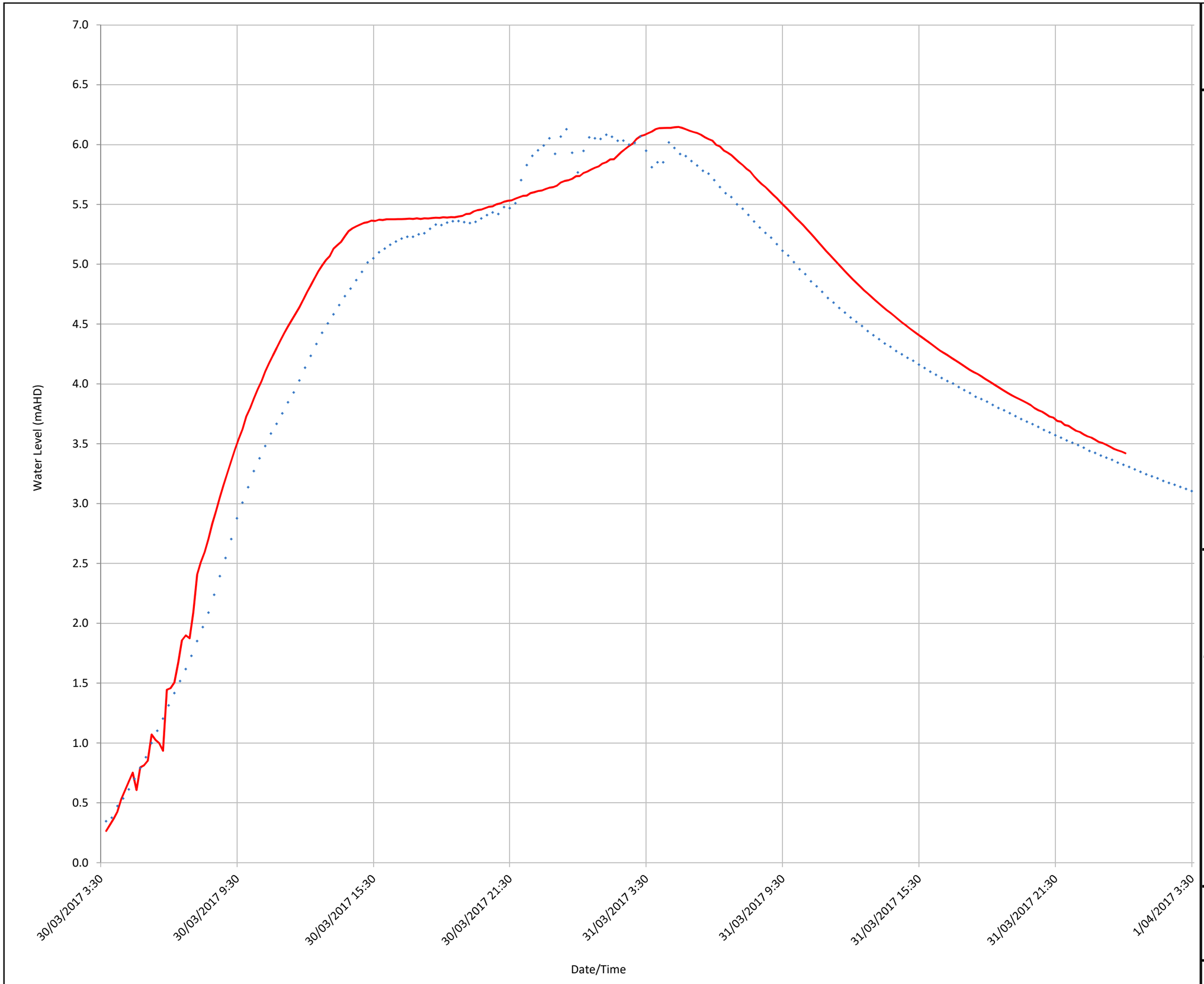
Sydney, NSW, 2000

File Name: SMurHydrographs.xlsx



TWEED SHIRE COUNCIL

LEGEND:

- Recorded 2017 Water Levels
- Simulated 2017 Water Levels

Notes:
- MHL Station Number 201420
- Recorded data provided by MHL NSW Office of Environnment and Heritage.

Figure C5.2: Recorded and Simulated Water Level Hydrographs for Tweed River at Murwillumbah Town Gauge for 2017 Flood

Prepared By:
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Sydney, NSW, 2000

File Name: SMurHydrographs.xlsx

It is noted that the recorded water levels at the Murwillumbah town gauge show considerable "noise" around the peak of the flood that is not reproduced by the TUFLOW model. It is also noted that this "noise" is not evident in the hydrograph at the nearby bridge gauge indicating that this may be associated with localised anomalies (e.g., wave action) in the vicinity of the gauge that cannot be represented in a 5-metre grid size model. Despite this difference, it is considered that the TUFLOW model is providing a good reproduction of the flood behaviour in the vicinity of South Murwillumbah during the 2017 event.

It was noted that the above results assume a "static" terrain representation. However, as noted in the preceding sections, part sections of Tweed Valley Way and the South Murwillumbah levee failed during the 2017 flood. Therefore, an additional 2017 flood simulation was completed to include a representation of the failure of these two structures.

The precise timing of the failures is not known as they occurred in the early hours of 31st March. However, anecdotal information suggests that both failures commenced at about 2am on 31st March. The amount of time it took for failure to occur is also not known. However, for the purposes of this simulation, it was assumed that the failure occurred over a period of 15 minutes. The "failed" terrain representation was included in the model based upon detailed surveyed collected at each location following the 2017 flood.

Peak floodwater depths were extracted from the results of the 2017 flood simulation, with the topographic modifications associated with the failures, on **Figure C6**. A comparison between the peak flood levels generated by the TUFLOW model and the surveyed flood mark elevations is also provided in **Figure C6**.

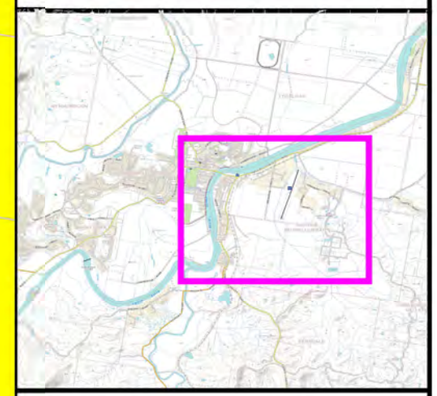
A comparison between **Figure C4** and **Figure C6** shows that there are generally minimal differences in simulated peak flood levels at each flood mark location between the "failure" and "no failure" simulations (differences are generally less than 0.05 metres with the average difference being 0.01 metres). This was also confirmed by reviewing the stage hydrographs at the Murwillumbah town and Murwillumbah Bridge gauges, which also showed negligible changes in flood level at the gauge locations associated with the failures. Accordingly, the failure of Tweed Valley Way and the South Murwillumbah levee does not appear to have had a significant impact on peak flood levels in the vicinity of South Murwillumbah.

However, several community members reported a very rapid increase in flood level over a short period of time during the 2017 flood (some community members referring to it as a "flood wave"). To provide an understanding of whether the failures increased the rate of rise of floodwaters across South Murwillumbah, stage hydrographs (showing the change in water level with respect to time) were extracted from both of the 2017 flood simulations at the following locations:

- Immediately east of the Tweed Valley Way crossing of Blacks Drain
- River Street immediately east of South Murwillumbah levee failure location
- Murwillumbah airfield (near hangers)
- Condong Creek, upstream of flood gates

The resulting stage hydrographs are presented in **Plates C1** to **C4.**

TWEED SHIRE COUNCIL



LEGEND

Survey Flood Mark Elevation (mAHD)

Simulated Water Level (mAHD)

Depths (m)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- > 6.0

Notes:

Aerial photograph date: 2016

N W E S

0 0.35 0.70 Km

Figure C6:
Peak Floodwater Depths for 2017 Calibration Event with Failure

Prepared By:
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File Name: FigC5 - Cal2017 Failure Depth Results.wor

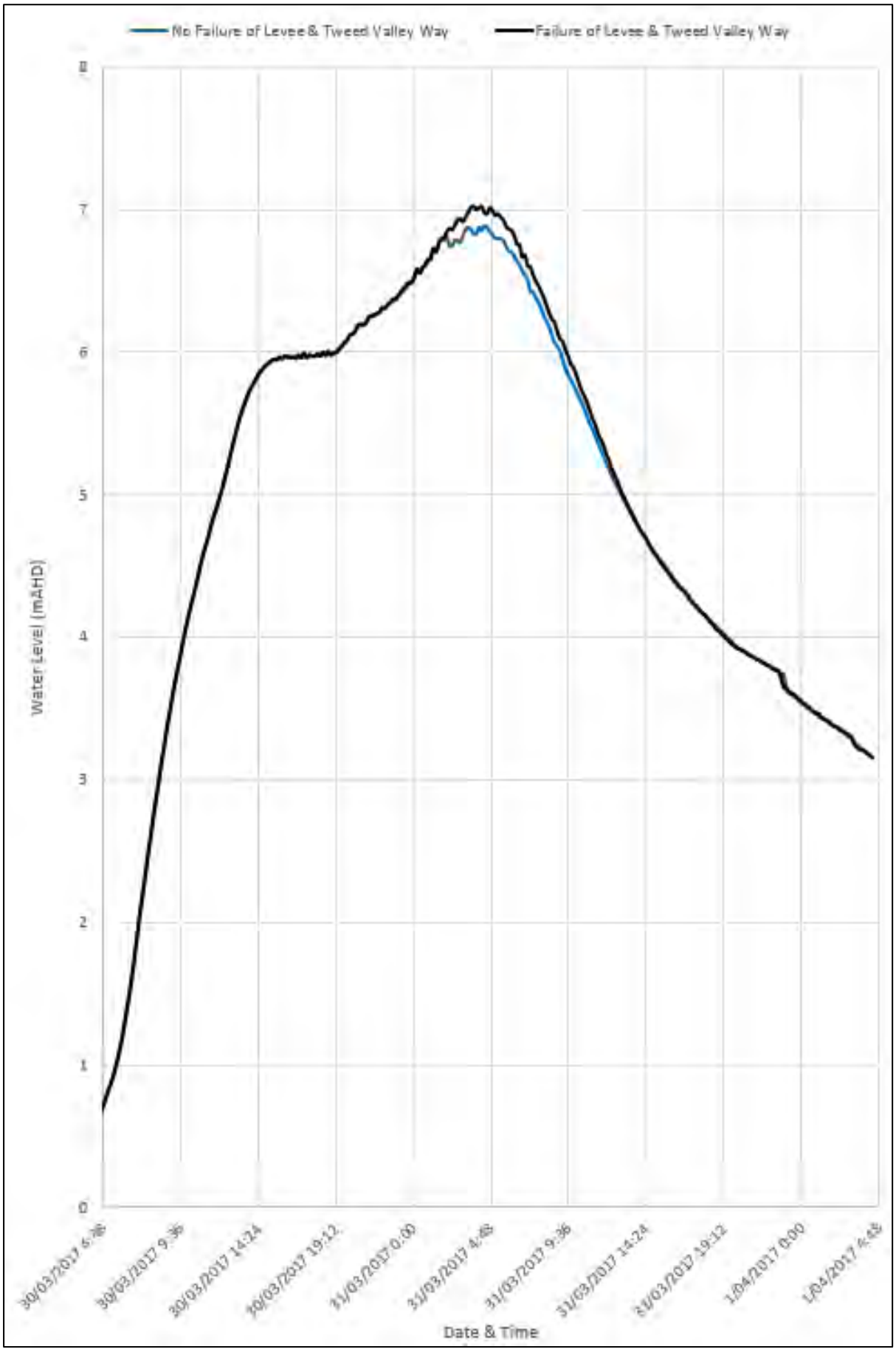


Plate C1 2017 Stage Hydrograph at Blacks Drain crossing of Tweed Valley Way

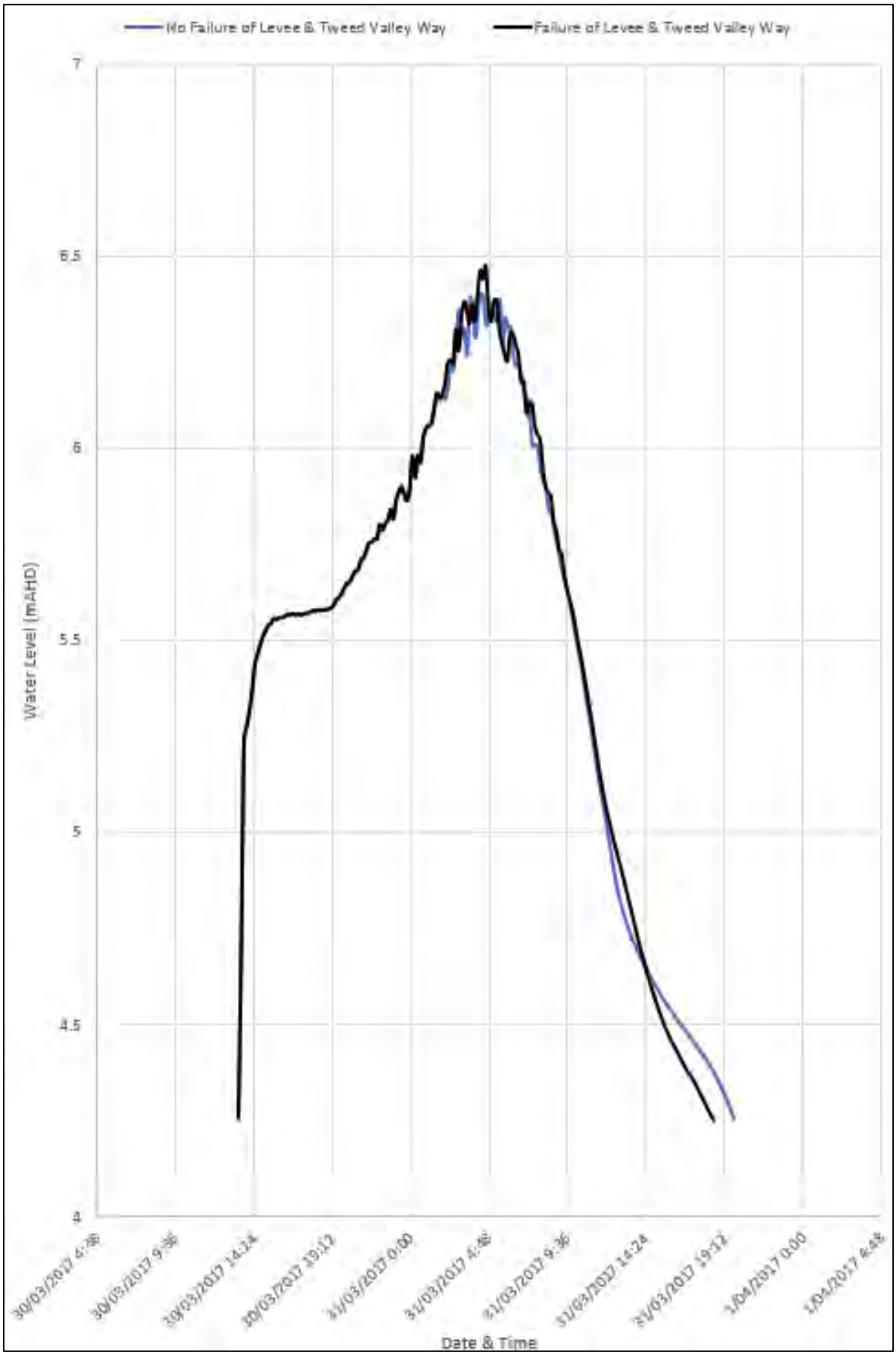


Plate C2 2017 Stage Hydrograph at River Street

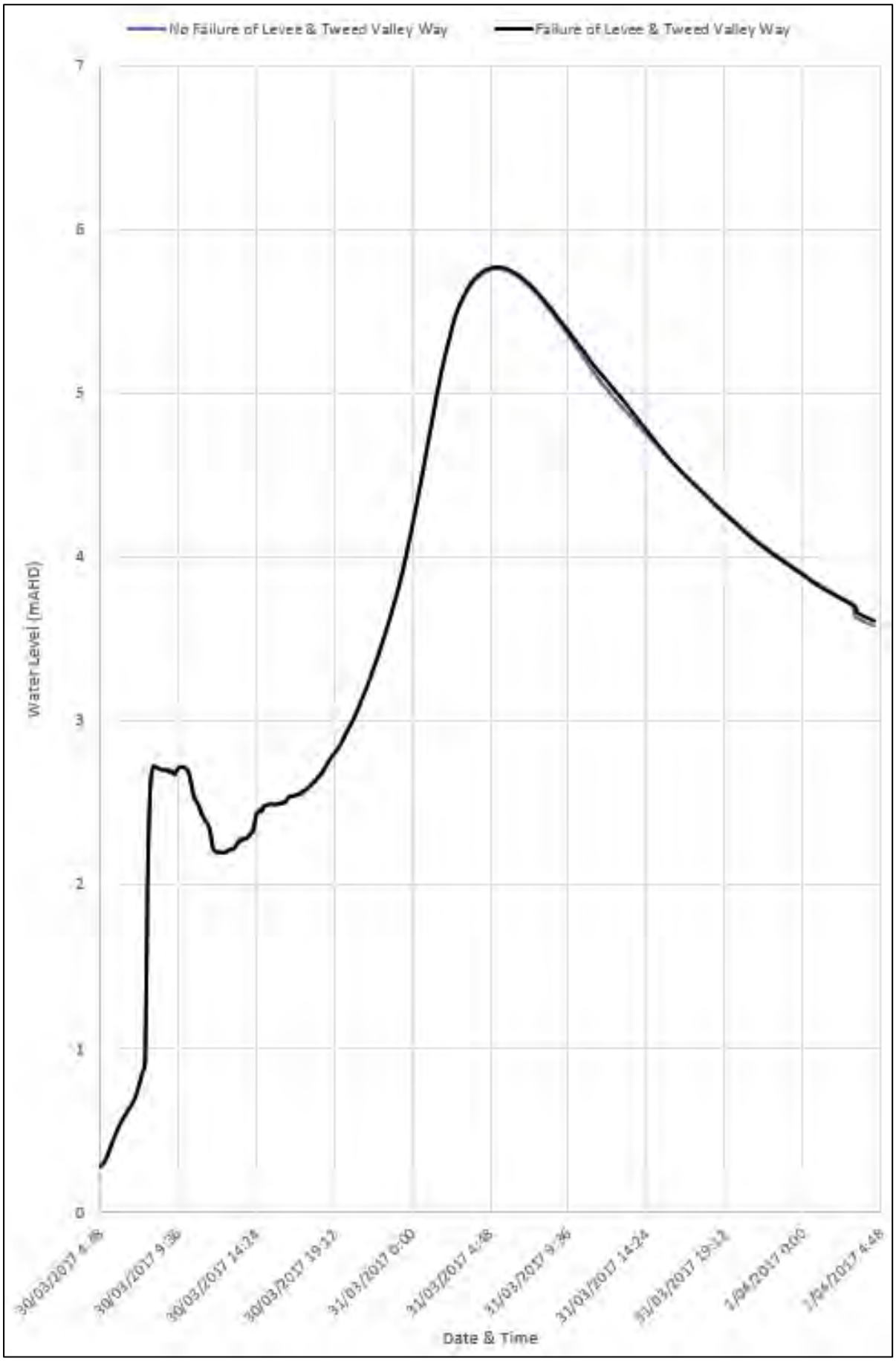


Plate C3 2017 Stage Hydrograph at Murwillumbah Airfield

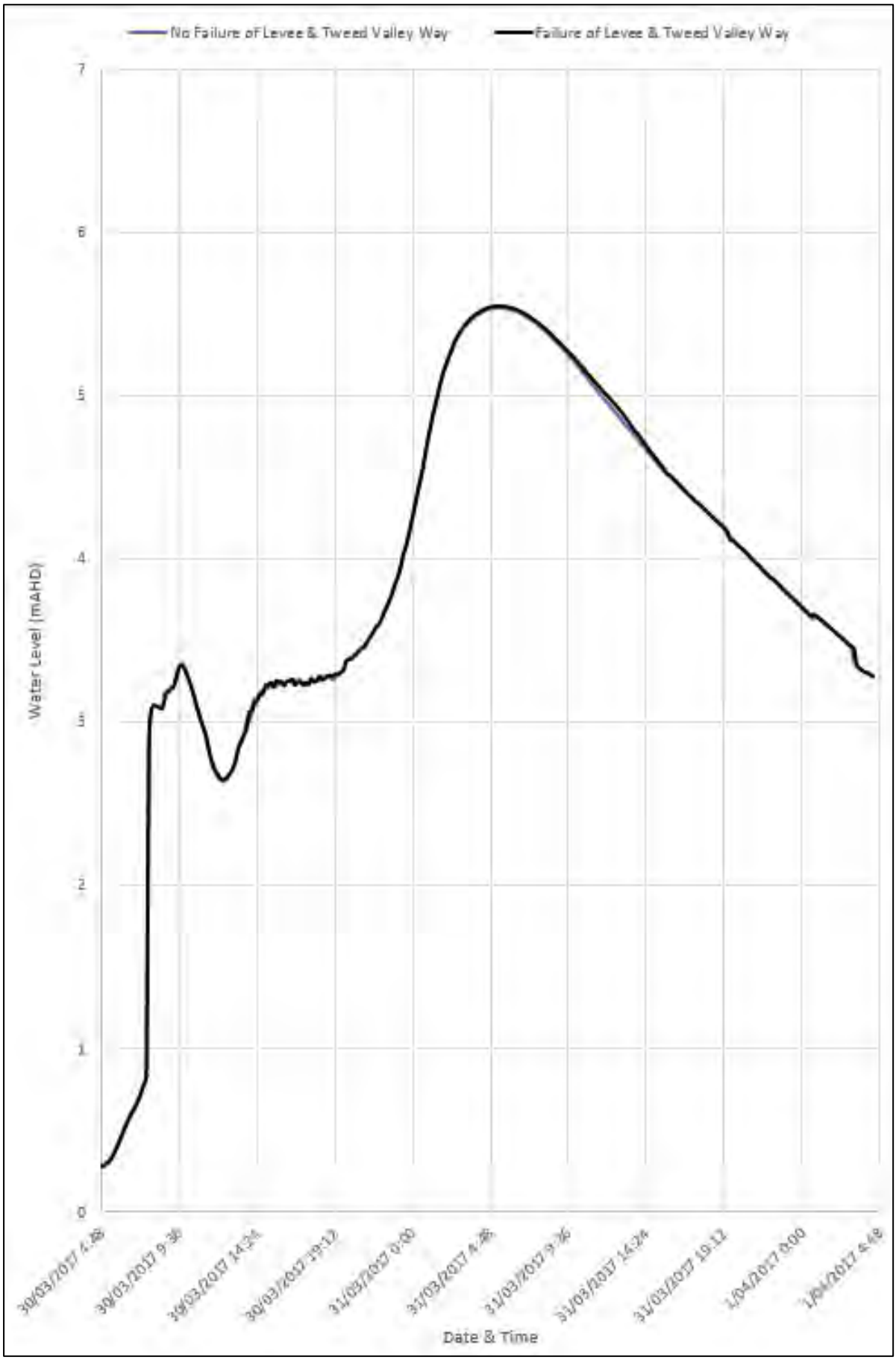


Plate C4 2017 Stage Hydrograph at Condong Creek flood gates

The stage hydrographs presented in **Plates C1** and **C2** show that failure of the levee and Tweed Valley Way did produce some localised changes to water levels in the immediate vicinity of the failure location. However, the failures do not appear to have changed the rate of rise of floodwaters. Furthermore, **Plates C3** and **C4** shows that the failures produced negligible changes in peak flood levels or the rate of rise around the airfield and Condong Creek. This is associated with the "attenuation" effects afforded by the South Murwillumbah basin.

However, **Plates C3** and **C4** do show two distinct "peaks" in the stage hydrographs with the second peak much higher than the first. The rate of rise of the second peak is also significant, with the water level rising in the vicinity of the South Murwillumbah industrial area by more than 3 metres over a 6-hour period. Therefore, it is likely that the "wall of water" that was reported by the community was the rapid rise in floodwaters associated with this second peak.

1.3.2 January 2013 Flood

Rainfall & Inflow Boundary Conditions

The 2013 flood was produced by an extended period of rain falling between the 24th and 29th January (with most rain falling over the 27th and 28th January). Accumulated daily rainfall totals for each rain gauge that was operational during the 2013 event were used to develop a rainfall isohyet map for the Tweed River catchment, which is shown in **Figure C7**.

Figure C7 shows significant spatial variation in rainfall across the catchment with rainfall depths across the coastal areas being typically less than 200 mm, while the north-western sections of the catchment recorded over 800 mm. Due to the significant spatial variation in rainfall during this event the isohyet map shown in **Figure C7** was used to describe the spatial variation in rainfall within the WBNM model.

The WBNM model was used to route the rainfall excess across the Tweed River catchment and produce discharge hydrographs at various locations. This included the upstream boundaries of the TUFLOW model. Accordingly, the flow hydrographs from the WBNM model were extracted and used to define inflows for the Tweed and Rous Rivers in the TUFLOW model.

Downstream Boundary Conditions

As with the 2017 flood simulation, the downstream boundary condition was defined using recorded water level information for the Tumbulgum stream gauge.

Results

The modified TUFLOW hydraulic model was used to simulate the 2013 flood by routing the discharge hydrographs generated by the WBNM through the TUFLOW model.

Peak floodwater depths were extracted from the results of the 2013 flood simulation and are included on **Figure C8**. A comparison between the peak flood levels generated by the TUFLOW model and the surveyed flood mark elevations is also provided in **Figure C8**.

The flood level comparison provided in **Figure C8** shows that the TUFLOW model provides a good reproduction of the surveyed flood marks at most locations. In particular, the TUFLOW model reproduces most of the surveyed floods marks to within 0.15 metres (with most levels in the immediate vicinity of the Tweed River agreeing to within 0.05 metres).

Lamington
National Park

Limpinwood

Mebbin
National Park

Mooball
National Park

558089-220 mm
558085-325 mm
558010-189 mm
558090-229 mm
558011-158 mm
558014-323 mm
540354-603 mm
558079-874 mm
558080-805 mm
558081-833 mm
558032-659 mm
58011-671 mm
58204-556 mm
558093-321 mm
58186-397 mm
558092-361 mm
558082-372 mm
58193-599 mm
558088-387 mm
58005-310 mm
58167-525 mm
558018-497 mm
558028-551 mm
58129-430 mm
58148-314 mm
58019-467 mm

TWEED
SHIRE COUNCIL

LEGEND

- Catchment Boundary
- Study Area
- Gauge Number - Rainfall (mm)
- Rainfall Isohyet (mm)

Rainfall Depth (mm)

- 0
- 200
- 400
- 600
- 800
- 1000

Notes:

Isohyets are calculated based on total rainfall for the entire duration of the storm.

N
W E
S

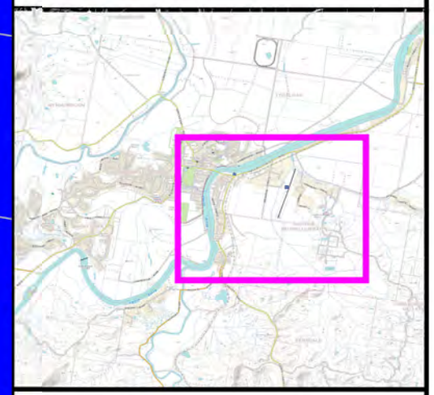
0 5 10
Km

Figure C7:
Isohyet Map for
2013 Storm

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: Fig C7 - Isohyet Map for 2013 Storm.wor

TWEED SHIRE COUNCIL



LEGEND

Survey Flood Mark Elevation (mAHD)

Simulated Water Level (mAHD)

Depths (m)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- > 6.0

Notes:

Aerial photograph date: 2016

N W E S

0 0.35 0.70 Km

Figure C8:
Peak Floodwater Depths for 2013 Calibration Event

Prepared By:

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Sydney, NSW 2000

File Name: FigC8 - Cal2013 Existing Depth Results.wor

The time variation in simulated flood water levels were also extracted at the location of the Tweed River at Murwillumbah and the Tweed River at Murwillumbah Bridge stream gauges and are shown in **Figures C9.1** and **C9.2**. The recorded stage hydrographs at each stream gauge were also extracted and are included on **Figures C9.1** and **C9.2** for comparison.

Figures C9.1 and **C9.2** shows that TUFLOW model provides a good reproduction of the overall shape of the recorded stage hydrographs at Murwillumbah North and Murwillumbah Bridge. More specifically, the timing and magnitude of the stages are well reproduced by the TUFLOW model. This confirms that mainstream flood behaviour is being well reproduced by the model for the 2013 flood.

Overall, the flood mark and stage hydrograph comparisons indicate that the TUFLOW model is providing a reasonable representation of flood behaviour in the vicinity of South Murwillumbah for the 2013 flood.

1.3.3 April 1989 Flood

Rainfall & Inflow Boundary Conditions

The 1989 flood was produced by an extended period of rain falling between the 31st March and 4th April (with the most intense downpour occurring on 1st April). Accumulated rainfall totals for each rainfall gauge that was operational during the 1989 event were used to develop a rainfall isohyet map for the event, which is shown in **Figure C10**. The isohyet map shows that over 500 mm of rain fell across the upper catchment areas during this event. Conversely, the coastal areas of the catchment received less than 100 mm of rainfall. Due to the significant spatial variation in rainfall during this event, the isohyet map was used as the basis for describing the spatial variation in rainfall within the WBNM model.

The WBNM model was used to route the rainfall excess across the Tweed River catchment and produce discharge hydrographs at various locations. This included the upstream boundaries of the TUFLOW model. Accordingly, the flow hydrographs from the WBNM model were extracted and used to define inflows in the TUFLOW model.

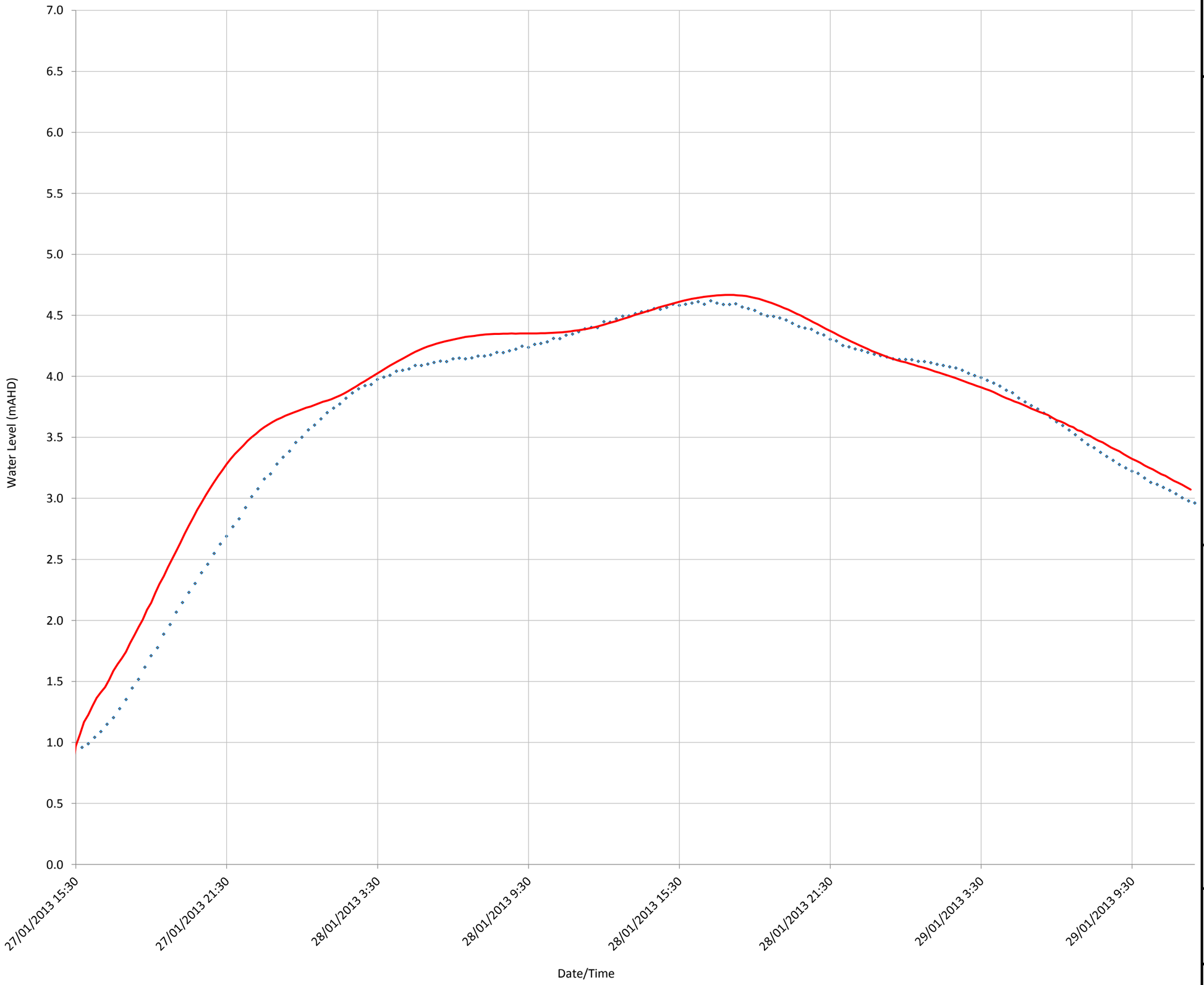
Downstream Boundary Conditions

As with the 2013 and 2017 flood simulations, the downstream boundary condition was defined as a stage hydrograph based on the recorded stage hydrograph at the Tumbulgum stream gauge.

Model Modifications

Since the 1989 flood, several significant topographic changes have occurred in the vicinity of Murwillumbah that will influence flood behaviour (most notably levee modifications). Therefore, it was considered necessary to update the TUFLOW model (which reflects contemporary topographic conditions) to be more representative of topographic conditions at the time the 1989 flood occurred.

The modifications were based on information contained in levee plans as well as the original TUFLOW model developed for the 'Tweed Valley Flood Study Update' (BMT WBM, 2009), which included a representation of topographic conditions during the 1989 flood (the 1989 flood was one of the calibration events used as part of this study). The modifications involved lowering the elevation of the South Murwillumbah, Commercial Road and East Murwillumbah levees.



TWEED SHIRE COUNCIL

LEGEND:

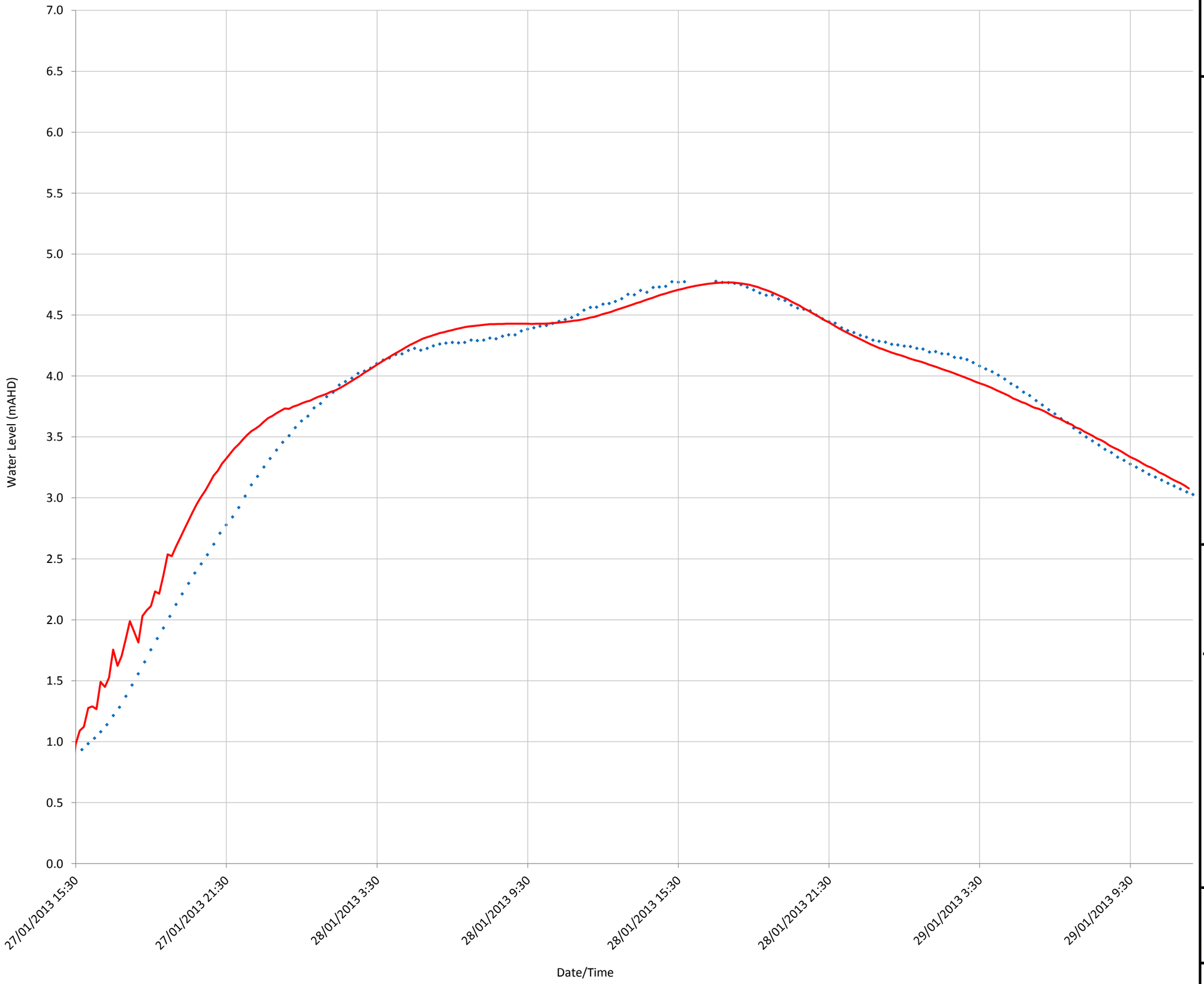
- Recorded 2013 Water Levels
- Simulated 2013 Water Levels

Notes:
- MHL Station Number 201465
- Recorded data provided by MHL NSW Office of Environnment and Heritage.

Figure C9.1: Recorded and Simulated Water Level Hydrographs for Tweed River at Murwillumbah Bridge Gauge for 2013 Flood

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George Street
Sydney, NSW, 2000

File Name: SMurHydrographs.xlsx



TWEED SHIRE COUNCIL

LEGEND:

- Recorded 2013 Water Levels
- Simulated 2013 Water Levels

Notes:
- MHL Station Number 201420
- Recorded data provided by MHL NSW Office of Environnment and Heritage.

Figure C9.2: Recorded and Simulated Water Level Hydrographs for Tweed River at Murwillumbah Town Gauge for 2013 Flood

Prepared By:
Catchment Simulation Solutions
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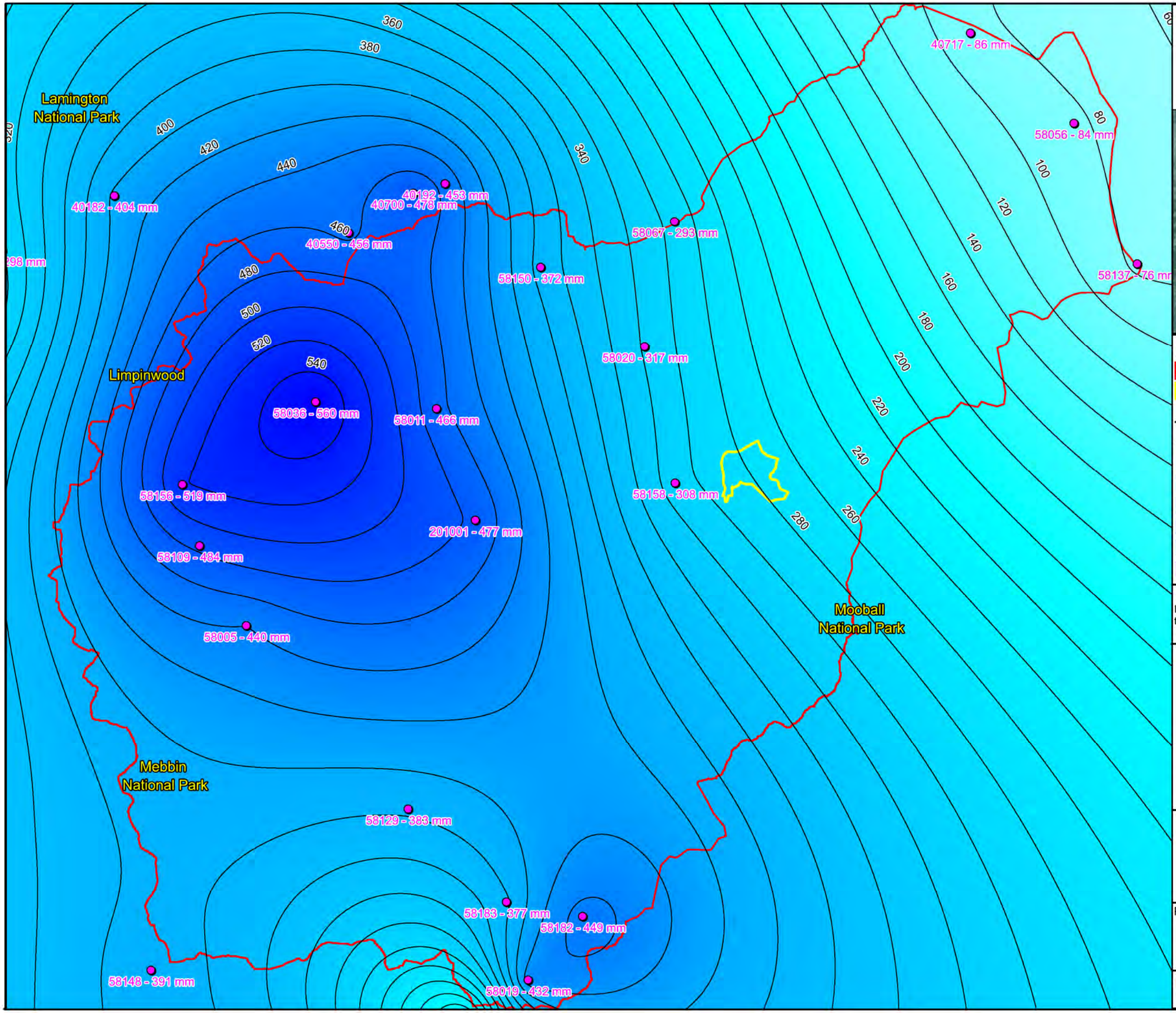
Sydney, NSW, 2000

File Name: SMurHydrographs.xlsx



TWEED SHIRE COUNCIL

LEGEND

- Catchment Boundary
- Study Area
- Gauge Number - Rainfall (mm)
- Rainfall Isohyet (mm)

Rainfall Depth (mm)

- 0
- 200
- 400
- 600
- 800
- 1000

Notes:

Isohyets are calculated based on total rainfall for the entire duration of the storm.

N W E S

0 5 10 Km

Figure C10: Isohyet Map for 1989 Storm

Prepared By:

Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: Fig C10 - Isohyet Map for 1989 Storm.wor

Results

The modified TUFLOW hydraulic model was used to simulate the 1989 flood by routing the discharge hydrographs generated by the WBNM through the TUFLOW model.

Peak floodwater depths were extracted from the results of the 1989 flood simulation and are included on **Figure C11**. A comparison between the peak flood levels generated by the TUFLOW model and the surveyed flood mark elevations is also provided in **Figure C11**.

The time variation in simulated flood water levels were also extracted at the location of the Tweed River at Murwillumbah stream gauge and are shown in **Figure C12**. The recorded stage hydrographs at this stream gauge was also provided by BMT WBM as part of the work that they completed for the '*Tweed Valley Flood Study (2009 Update)'* and is also included on **Figures C12**. The Murwillumbah Bridge gauge was not installed at the time of the 1989 flood and, therefore, a recorded hydrograph is not available for this event.

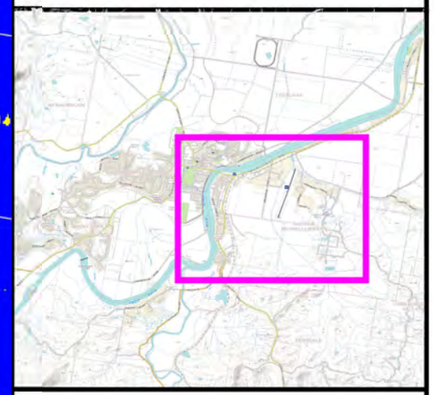
As shown in **Figure C11** and **C12**, the TUFLOW model provides a good reproduction of the flood mark elevation in Prospero Street as well as the time variation in water level at the town gauge. This includes a reasonable reproduction of the peak water level at the gauge as well as the overall shape of the hydrograph.

However, it is noted that the TUFLOW model is not able to provide as good a reproduction of the surveyed flood mark elevations in River Street. The surveyed flood mark elevations indicate a relatively level "pool" of water across South Murwillumbah (all flood mark elevations are located between 5.4 and 5.5 mAHD), while the TUFLOW model is showing a notable flood gradient (i.e., flood levels are higher in River Street relative to Prospero Street).

It is noted that calibration simulations completed as part of the 'Tweed Valley Flood Study Update' (BMT WBM, 2009) was also unable to reproduce the recorded flood levels. The simulated levels, in this instance, were approximately 0.3 metres higher than the gauge level. The inability of the 2009 models to reproduce the gauged levels were put down to potential differences in the local levee/river bank heights. As the current study has drawn on information contained in the 2009 models (particularly for the representation of the South Murwillumbah levee), it is likely that any uncertainties in the terrain representation would be carried across to the current model.

Nevertheless, as the model was able to provide a reasonable reproduction of the 2013 and 2017 floods where the topographic representation is known with more certainty, it indicates that the model is performing well in describing contemporary flood behaviour.

TWEED SHIRE COUNCIL



LEGEND

Survey Flood Mark Elevation (mAHD)

Simulated Water Level (mAHD)

Depths (m)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- > 6.0

Notes:

Aerial photograph date: 2016

N

W E

S

0 0.35 0.70

Km

Figure C11:
Peak Floodwater Depths for 1989 Calibration Event

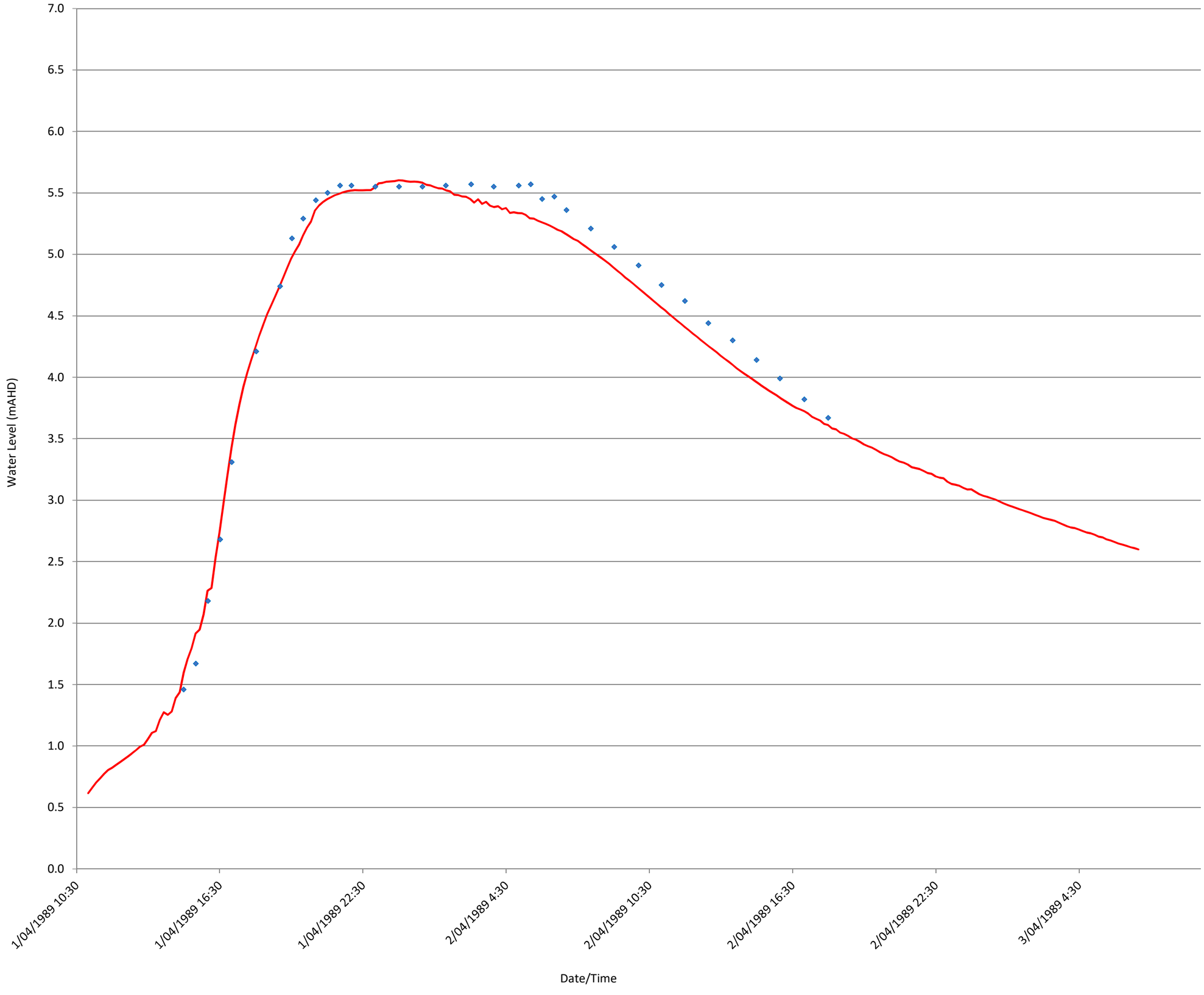
Prepared By:

Catchment Simulation Solutions

Suite 2.01, 210 George St

Sydney, NSW 2000

File Name: FigC11 - Cal1989 Topo Depth Results.wor



TWEED SHIRE COUNCIL

LEGEND:

- Recorded 1989 Water Levels
- Simulated 1989 Water Levels

Notes:
- Recorded data provided by BMT as part of the 2009 Tweed Flood Study.

Figure C12: Recorded and Simulated Water Level Hydrographs for Tweed River at Murwillumbah Town Gauge for 1989 Flood

Prepared By:
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File Name: SMurHydrographs.xlsx

APPENDIX D

FLOOD FREQUENCY ASSESSMENT

FLOOD FREQUENCY ANALYSIS

Overview

The *'Tweed Valley Flood Study'* (BMT WBM, 2005) undertook a Flood Frequency Analysis (FFA) for the Murwillumbah town gauge. Since publication of this study, 13 years of additional flood records are available, including a major flood in 2017 and a revised version of Australian Rainfall and Runoff (referred to herein as ARR2016) was released that provides additional guidance on undertaking FFA. Therefore, a revised FFA for the Murwillumbah gauge was completed as part of the study to include the latest data and utilise the latest techniques from ARR2016.

Council also requested that an FFA be completed for the Tumbulgum gauge, which has not been subject to any previous FFA. Therefore, a FFA for this gauge was also completed as part of this assessment.

2005 Flood Frequency Analysis

The FFA completed as part of the *'Tweed Valley Flood Study'* (BMT WBM, 2005) was undertaken using a 118 year series of gauge data (1887 – 2004) that was collated from a range of data sources at the Murwillumbah gauge. Earlier records are typically incomplete and so there is no complete annual maximum dataset or daily timeseries of flows for the full length of record. To account for missing data, the 2005 FFA assumed that during years of no data, that no significant flow occurred, and the maximum gauge height was set to 2.9 metres. Overall there were 32 years out of 118 years where a level of 2.9 metres was applied.

The 2005 FFA was undertaken using the HydroFreq 1.0 software developed by "HydroTools", a Canadian based company. The FFA tested both the Generalised Extreme Value (GEV) and Log-Pearson III (LP3) distributions. The final 1% AEP flow rate reported by BMT WBM (2005) is:

- WBM (2005) GEV = 3,540 m^3/s
- WBM (2005) LP3 = 3,240 m^3/s

Rating Curve

The Murwillumbah gauge includes recorded flood level information only. To convert the flood level information to flows/discharges (which are required for the FFA), a rating curve (preferably a "gauged" curve) is required. There is no gauged rating curve available for the Murwillumbah gauge as it is tidally influenced. Therefore, BMT WBM developed a synthetic rating curve as part of the 2005 flood study based on their hydraulic model results.

This rating curve was developed by averaging a number of different model extracted rating curves from different model scenarios, particularly before and after the town levee was built/upgraded. **Plate 1** shows the range of rating curves that were derived including the "representative" rating that formed the basis for the BMT WBM (2005) FFA. The synthetic rating curves show a significant "hysteresis" (i.e., equivalent gauge heights providing different flow estimates depending on whether they occur on the rising or falling limb of the hydrograph). The 2005 study ignored the "low flow" sections of the rating curves and noted that the "high flow" section generally agreed closely. A synthetic rating curve was then fitted to the historic rating curves, which is shown in **Plate 1**. This "representative" rating curve was also adopted during the initial stages of the current study.

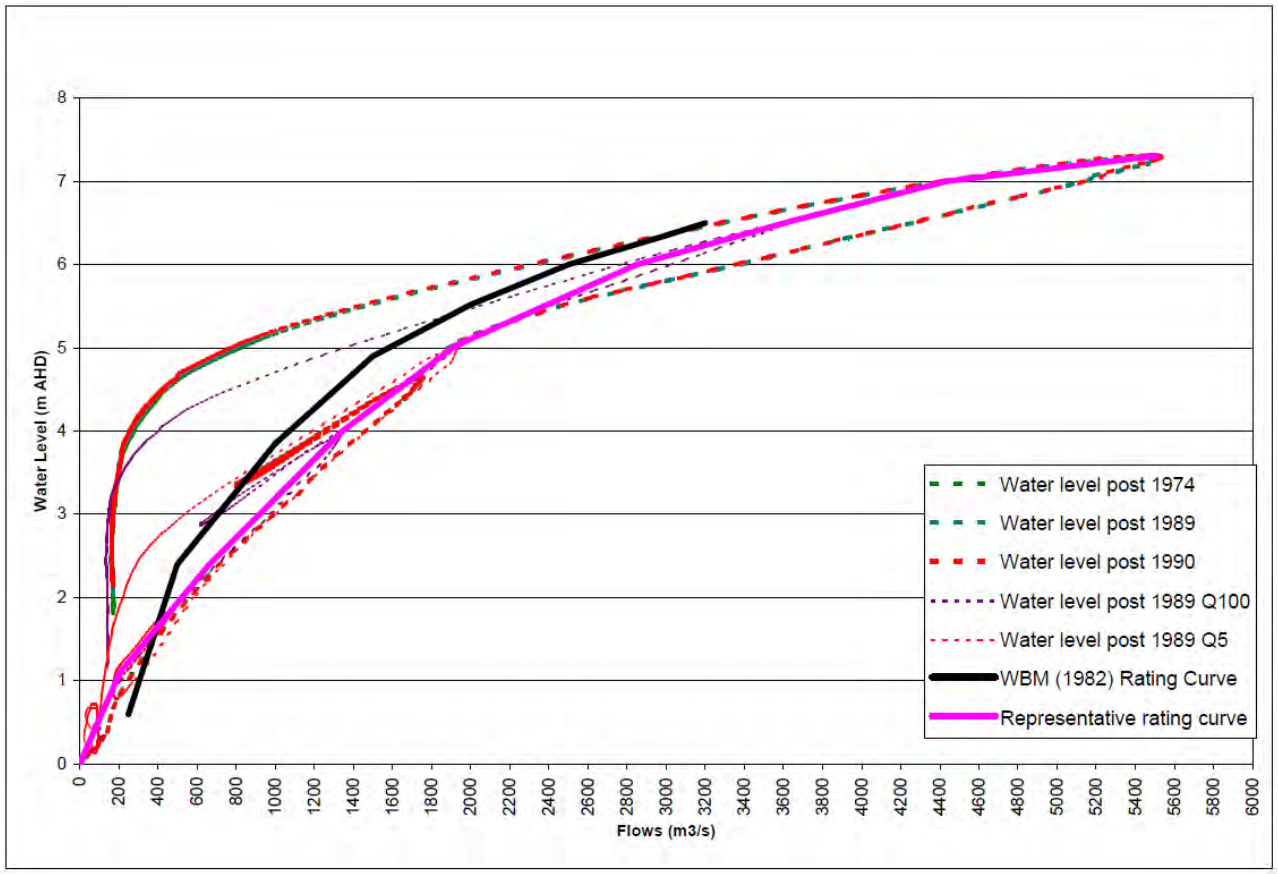


Plate 1 BMT WBM (2005) rating curves

Updated Flood Frequency Analysis for Murwillumbah

Comparison to 2005 Flood Frequency

The current study utilised the FLIKE software to undertake the FFA. As different software was to be employed relative to the 2005 FFA, a comparison was made between the BMT WBM (2005) study and this analysis. The comparison used the same assumptions (distribution, uncensored flows) and period of record (i.e., the only different was the software used). **Table 1** shows that the differences for the 1 in 10 Year and 1 in 100 Year ARI flows are relatively minor (i.re., generally within 2%). Accordingly, it was considered that the FLIKE software was generating reasonable FFA results

Table 1 Comparison of Flows between BMT WBM (2005) and CSS

Flood Frequency Analysis		Estimated Flows (m^3/s)		Difference (%)
		BMT WBM (2005)	CSS (2018)	
10% AEP	GEV	2,050	2,087	1.8
	LPIII	2,070	2,101	1.5
1% AEP	GEV	3,540	3,445	2.7
	LPIII	3,240	3,272	1.0

Censored Flows

Censoring flows (i.e., removing low flows from the analysis) is typically undertaken as part of a FFA. This is usually done to improve the fit of the observed data to the probability distribution.

The BMT WBM (2005) study did not censor any low flows, however as part of their sensitivity analysis they found that changes in their adopted low flows had a notable impact on the results. This suggests that the FFA can be improved by censoring the low flows.

As part of this study, the ARR2016 recommended Grubbs-Beck test was used to censor low flows. This removed 51 low flows that fell below approximately 850 m^3/s. **Plate 2** shows the probability distribution plot for the Generalised Extreme Value (GEV) probability distribution with the low flows censored as well as uncensored. It shows that the censored flows fit the distribution much better, with all plotting positions between the 90% limits in the censored flow distribution. In the uncensored flow distribution, both the low flows and the very high flows do not fit the distribution well, and there would be a significant difference between the flows for the estimated return period and plotting positions for similar floods. This is also seen in the BMT WBM (2005) analysis, where the distribution estimates that the 1954 event is a 1 in 45 Year ARI but the plotting position suggests that it is a 1 in 149 year ARI.

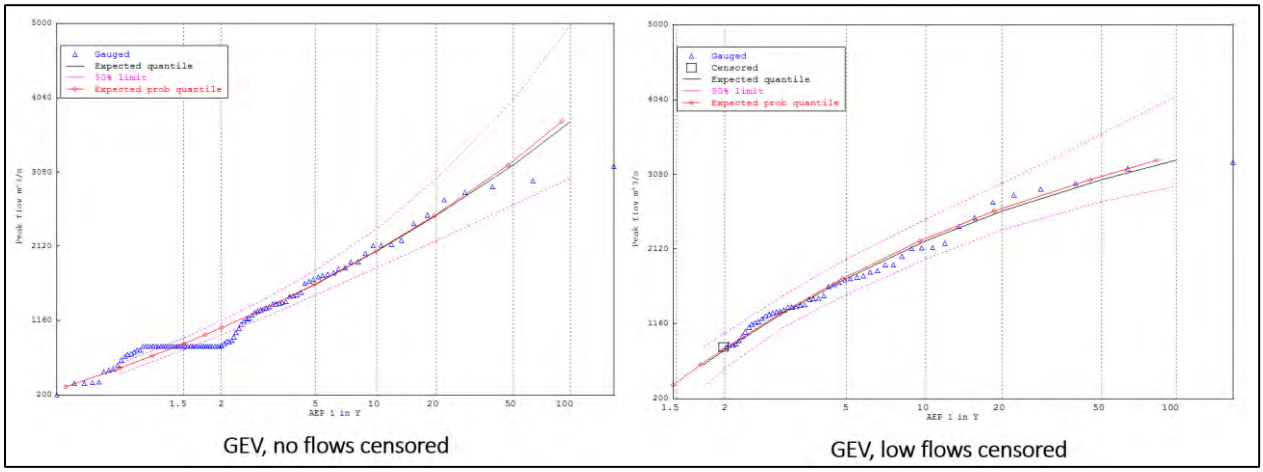


Plate 2 Censored vs Non-Censored Distributions

Review of Rating Curve

As noted in the previous sections, a synthetic rating curves was developed for the 2005 FFA and formed the basis for converting the historic peak stages at the Murwillumbah gauge to peak discharges. A review of the rating curve was completed as part of the study using the revised TUFLOW model developed for the current study, which takes advtange of more detailed hydrosurvey as well as a 2-dimensional representation of the river channel near the stream gauge. The rating curves comparison is provided in **Plate 3** and the extent of the cross-section used to derive the synthetic rating curve is shown in **Plate 4**. Also include in **Plate 3** is an alternate rating curve provided by Council that is being utilised as part of a Bureau of Meteorology (BoM) flood warning system. This curve is based upon TUFLOW model results for a range of design events.

The comparison in **Plate 3** shows a relatively good correlation between the 2005 rating curve and the synthetic rating curve developed for the current study. However, the correlation with the BoM rating curve is not as good. Furthermore, the BoM rating curve does not provide any information for events less than the 20% AEP flood (i.e., most of the annual would fall below this event). Therefore, the BoM curve was excluded from the analysis.

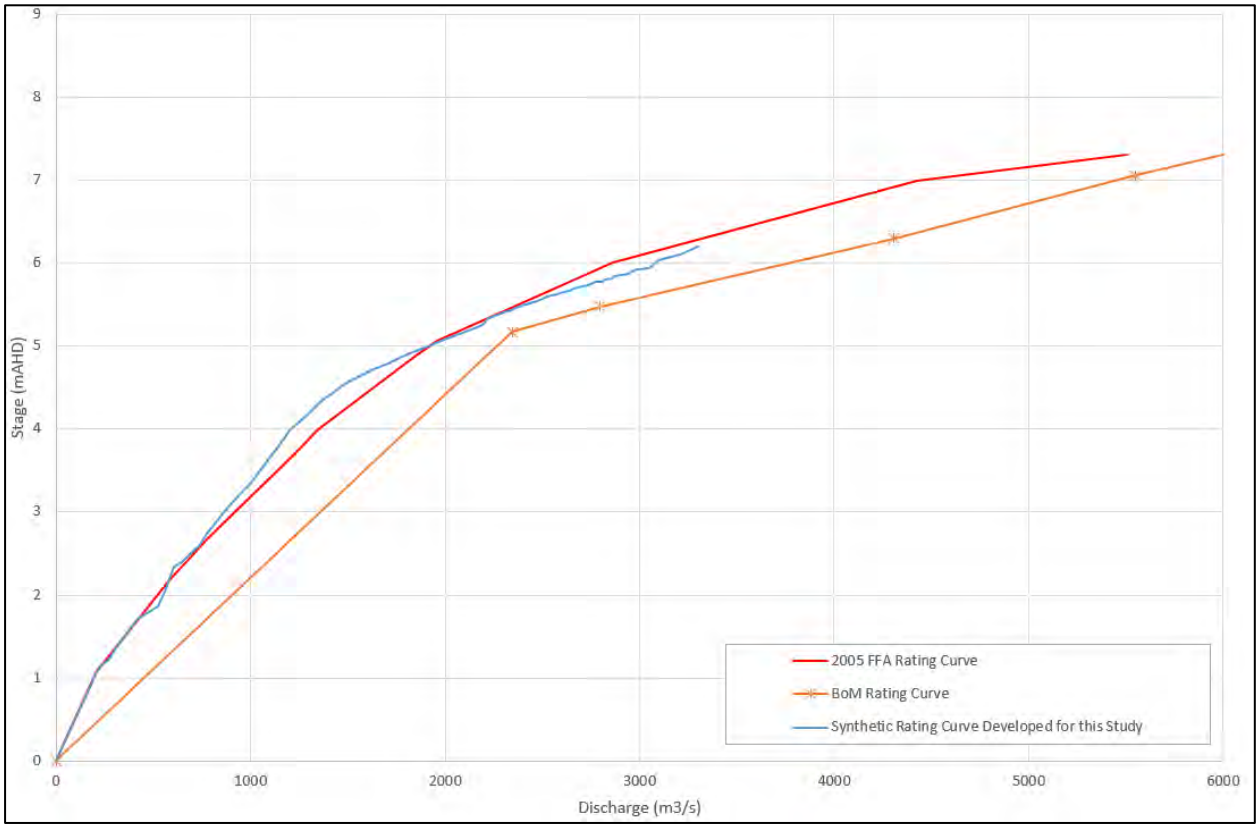


Plate 3 **Rating Curves for the Murwillumbah Gauge**

Plate 4 **Extent of cross-section (yellow) used to derive synthetic Murwillumbah rating curve for current study**

The synthetic rating curve developed for the current study was ultimately selected to use as part of the FFA for the Murwillumbah gauge as it was considered to be based upon the latest available

survey information and provided a more detailed description of flood behaviour in the vicinity of the gauge.

Probability Distribution

A range of probability distributions were tested using the FLIKE software against the recorded data to determine the distribution that provided the best fit. The probability distributions investigated included:

- Generalised Extreme Value (GEV)
- Log Pearson Type III (LP3)
- Gumbel
- Log Normal

Plates 5 to **8** show the probability plots for all of these distributions based upon the censored flow series. A qualitative assessment was undertaken by observing the plotting positions against the expected peak quantile and it was found that LP3 and GEV tended to best fit the data. The Log Normal and Gumbel distribution produced plotting positions that fell outside the 90% limits.

Given the 2005 FFA applied LP3 and GEV, and they tend to best fit the data here, these distributions were also retained for the current study.

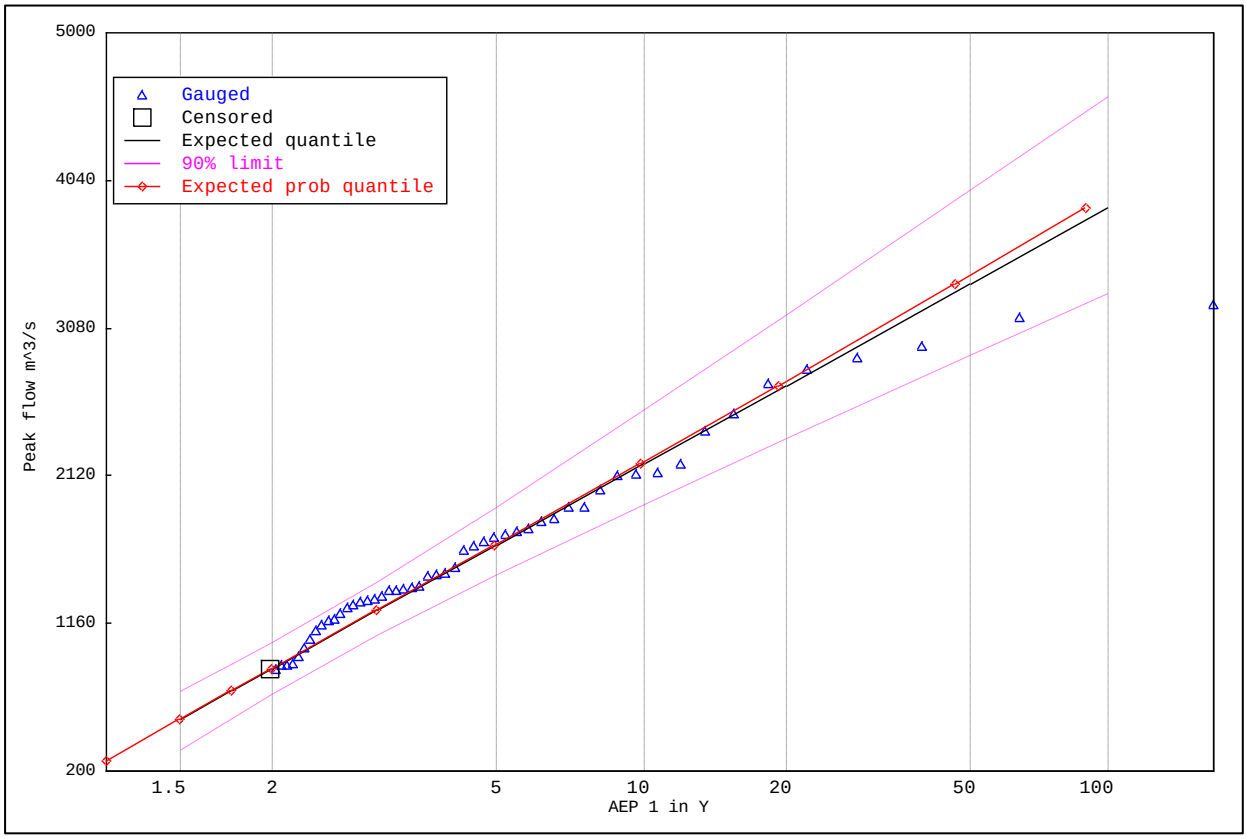


Plate 5 Gumbel Probability Plot (Censored)

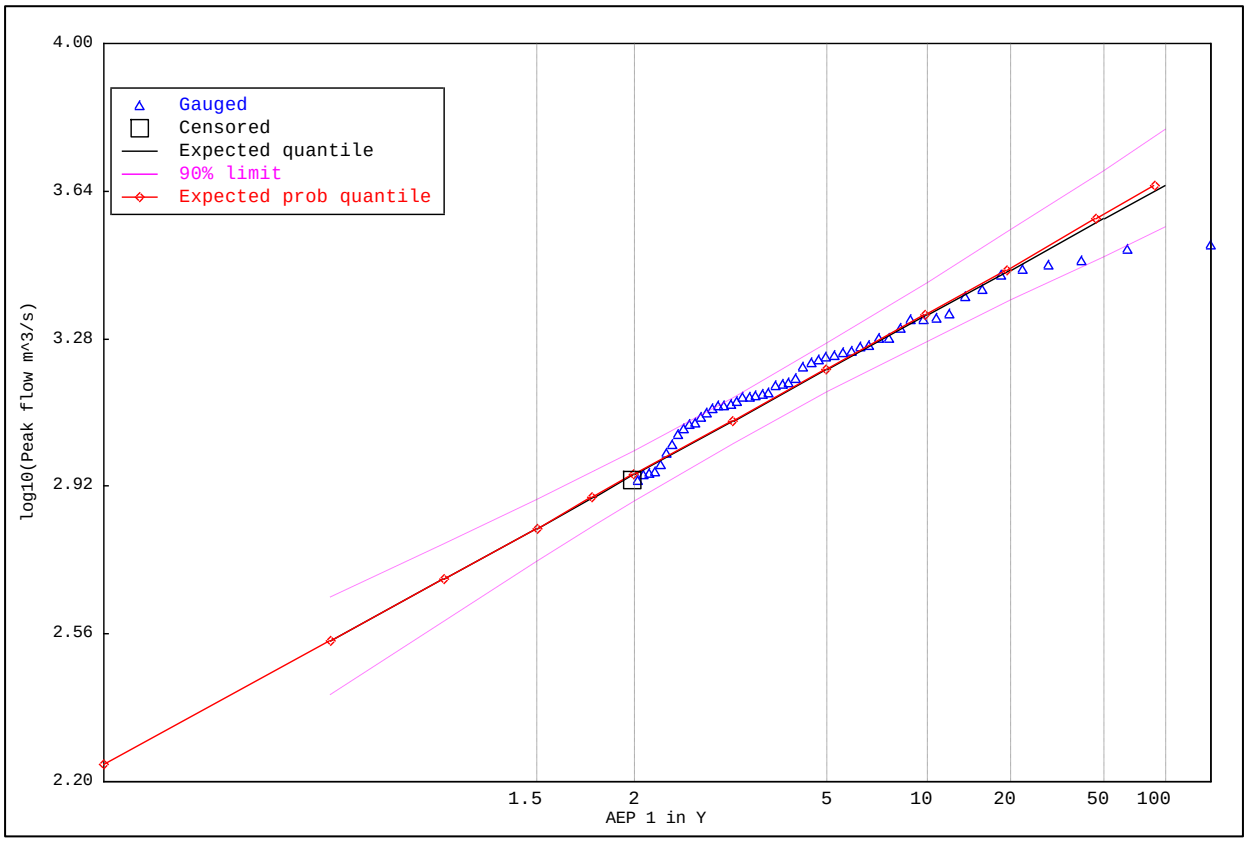


Plate 6 **Log Normal Probability Plot (Censored)**

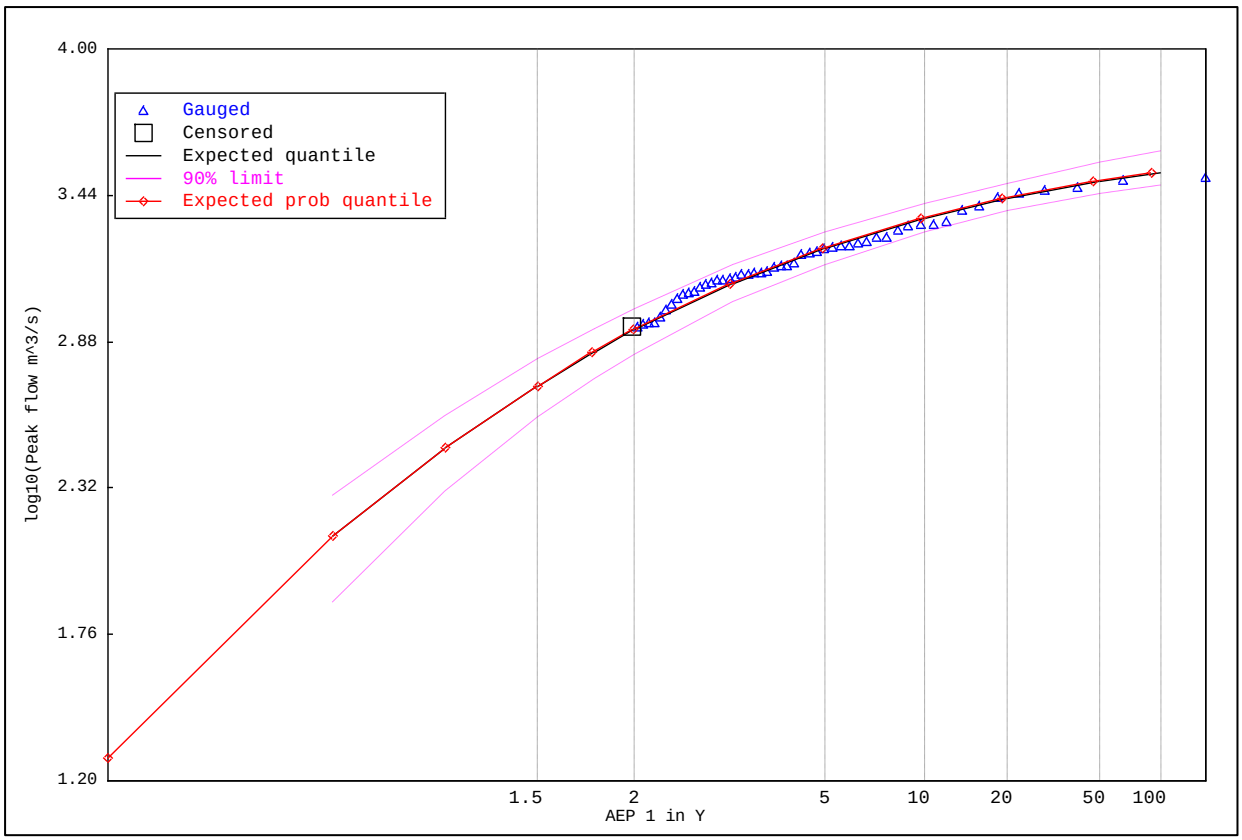


Plate 7 LP3 Probability Plot (Censored)

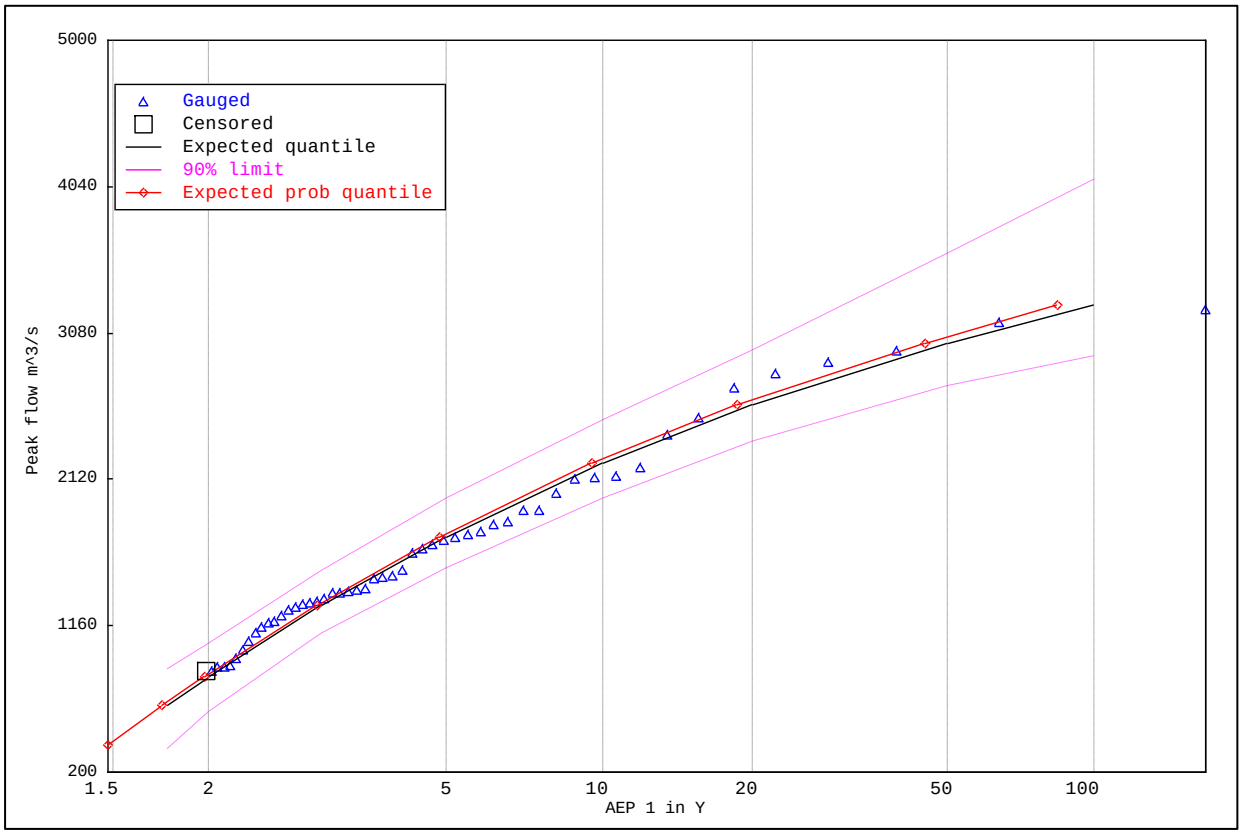


Plate 8 GEV Probability Plot (Censored)

Updated Flood Frequency

The record was subsequently extended to include the additional gauge information collected since 2004. The calculated flood frequency for the two probability distributions is shown in **Table 2** (based on censored flow records). The peak flows from the 2005 FFA are also included.

Table 2 Adopted Flood Frequency Distributions

AEP	Current Study Peak Flow (m^3/s)		2005 Study Peak Flow (m^3/s)	
	LP3 Distribution	GEV Distribution	LP3 Distribution	GEV Distribution
20%	1,728	1,742	1,700	-
10%	2,258	2,222	2,070	2,050
5%	2,683	2,606	2,430	-
1%	3,357	3,263	3,240	3,540
0.2%	3,739	3,700	4,070	4,850

The comparison shows that the revised FFA typically provides higher peak discharge estimate relative to the 2005 FFA for floods up to and including the 1% AEP flood. However, the revised FFA produced a lower peak design discharge estimate

Flood Frequency Analysis for Tumbulgum

As part of this study, a FFA was completed for the Tumbulgum gauge. The FFA was undertaken using a 33 year series of gauge data (1985-2017).

Rating Curve

As discussed, a rating curve is required to convert recorded flood heights to peak discharges for each historic flood. No rating was available for the Tumbulgum gauge at the time the study was completed.

However, Tweed Shire Council provided design discharge versus flow information that is being utilised as part of a Bureau of Meteorology (BoM) flood warning system. In addition, a synthetic rating curve was developed as part current study using results from the revised TUFLOW model. Both ratings curves are provided in **Plate 9**. The extent of the cross-section used to derive the synthetic rating curve is shown in **Plate 10**.

Like the Murwillumbah rating curves, **Plate 9** shows that there are notable differences between the BoM and synthetic rating curves at Tumbulgum. More specifically, the BoM curves doe not provide a detailed description of flows at low gauge heights. Although there is some uncertainty regarding the synthetic rating curves, the synthetic rating curves was adopted for the FFA as it appears to provide a better agreement at Murwillumbah (relative to the BoM data), it was developed using an updated and more detailed flood model and it will ensure consistency with the approach that was employed at the Murwillumbah gauge.

Censored Flows

As for the Murwillumbah gauge, flows were censured at the Tumbulgum gauge based upon the Grubbs-Beck test. This removed 15 low flows (out of 33 years of data). This corresponds to a minimum flow of approximately 800 m^3/s.

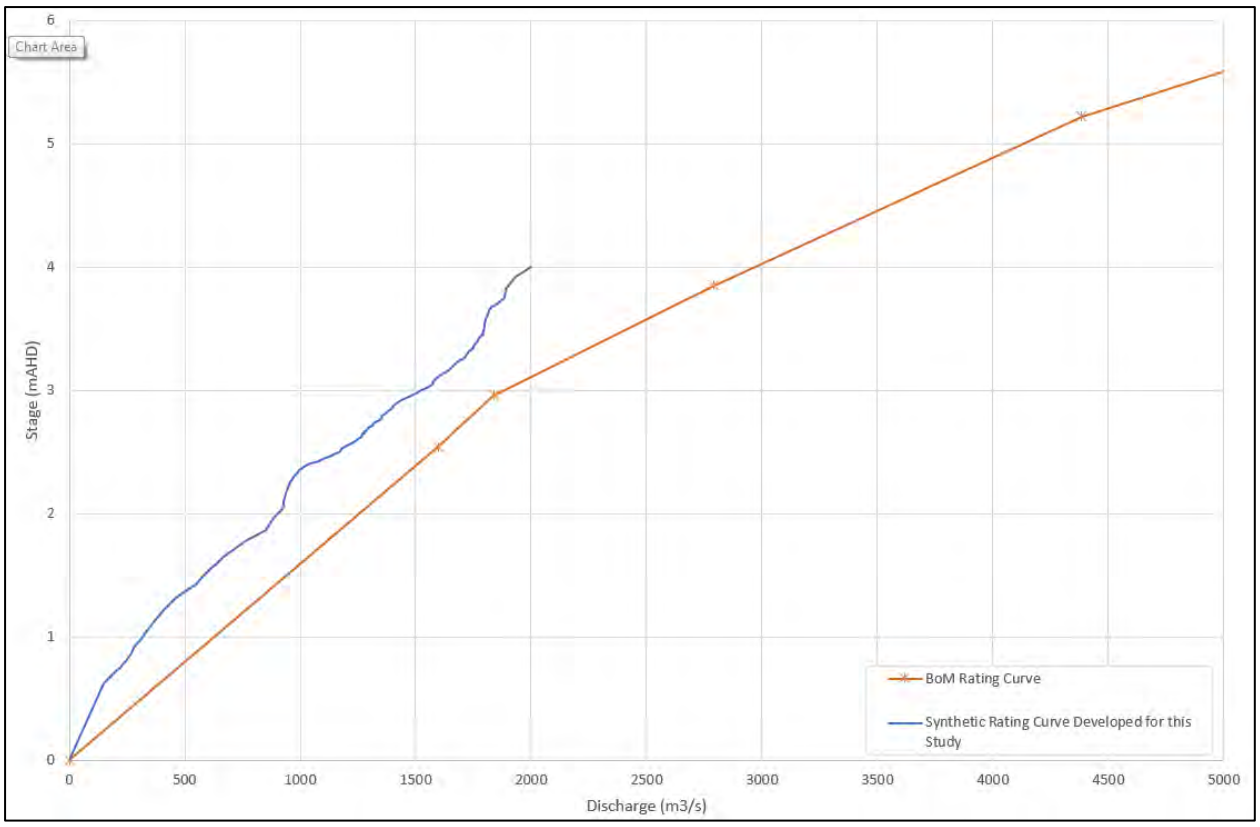


Plate 9 **Rating Curves for the Tumbulgum Gauge**

Plate 10 Extent of cross-section (yellow) used to derive synthetic Tumbulgum rating curve for current study

Plate 11 shows the probability distribution plot for the Generalised Extreme Value (GEV) with the low flows censored and uncensored. It can be seen that the censored flows fit the distribution much better and the 90% confidence limits exhibit a much smaller range.

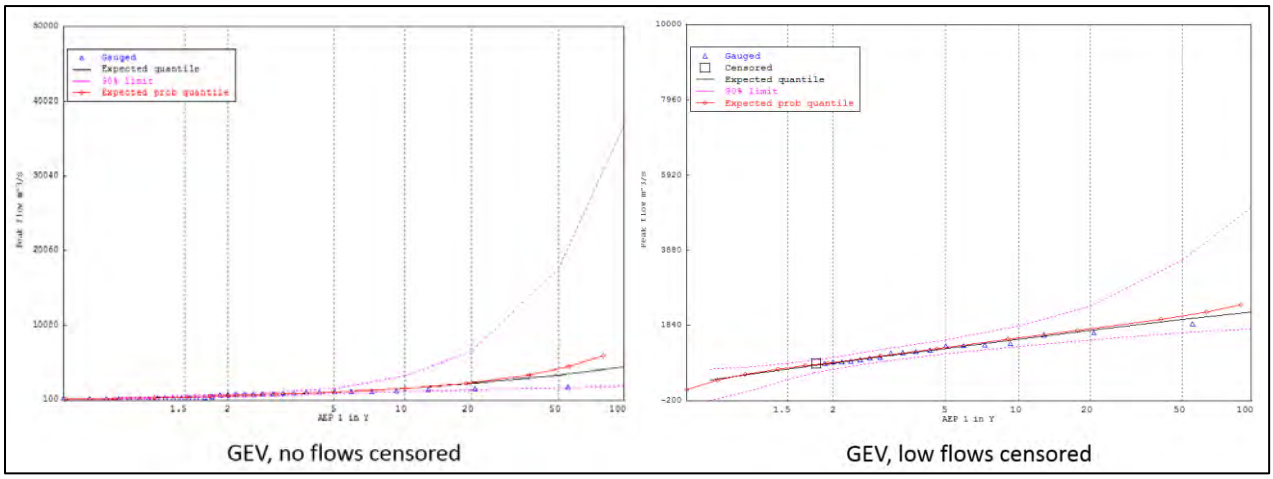


Plate 11 Censored vs Non-Censored Distributions

Probability Distribution

A range of probability distributions was tested against the data to determine the best fit. The FLIKE software was used for this purpose. The probability distributions investigated included:

- Generalised Extreme Value (GEV)
- Log Pearson Type III (LP3)
- Gumbel
- Log Normal

Plates 12 to 15 show the probability plots for all of these distributions.

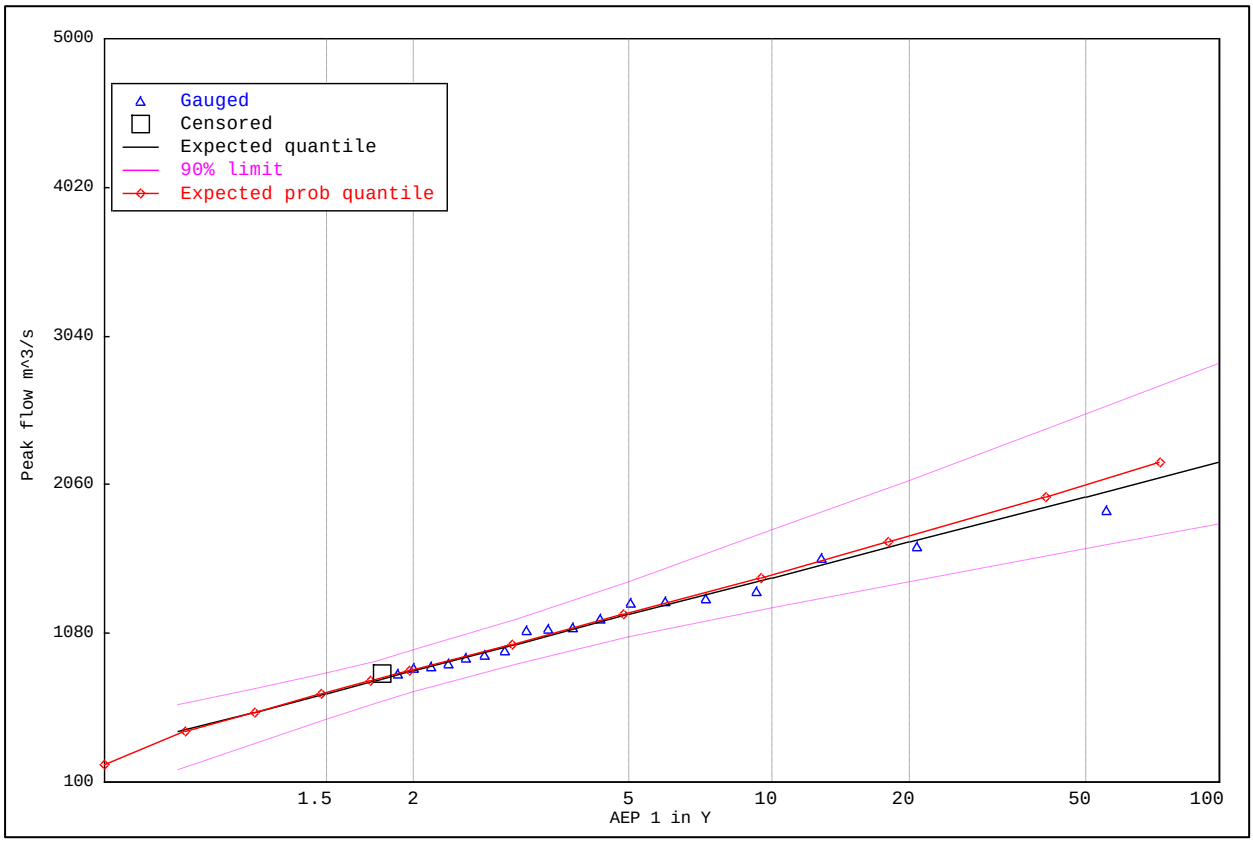


Plate 12 Gumbel Probability Plot (Censored)

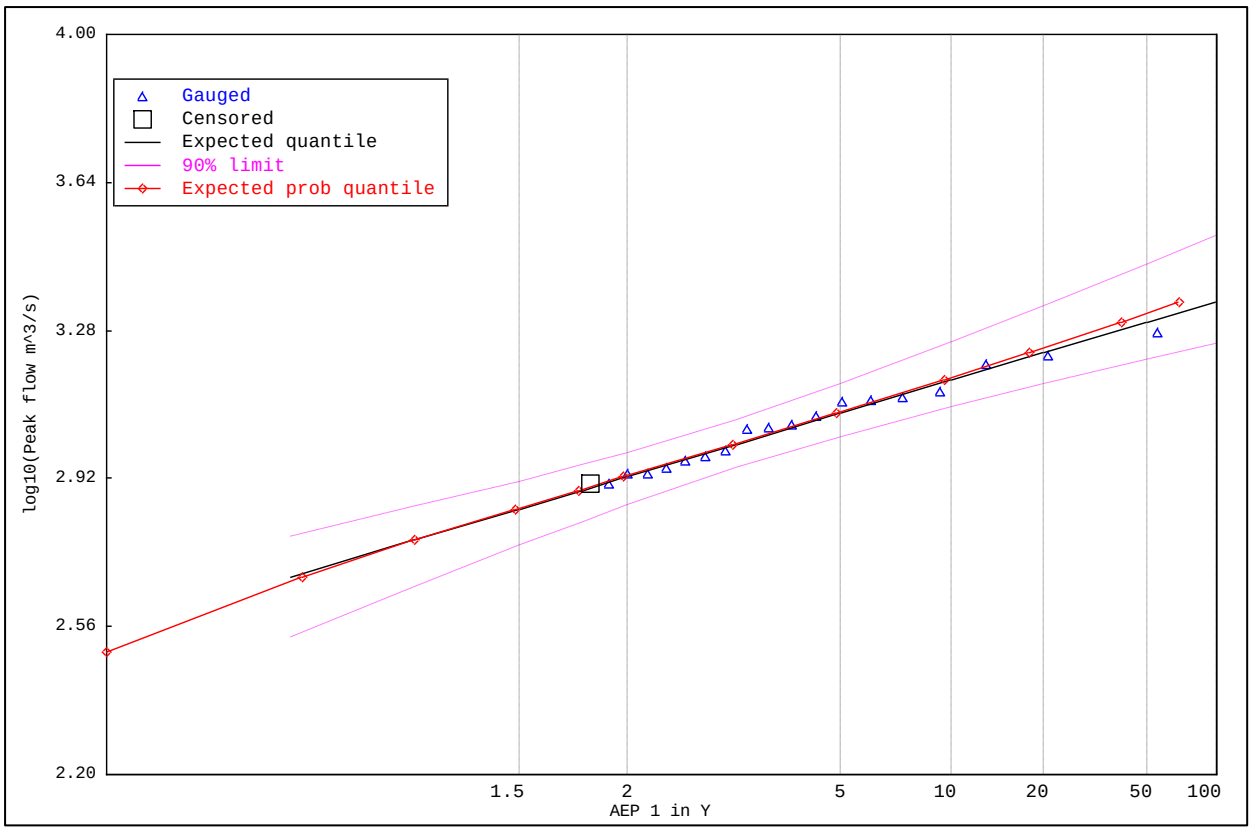


Plate 13 Log Normal Probability Plot (Censored)

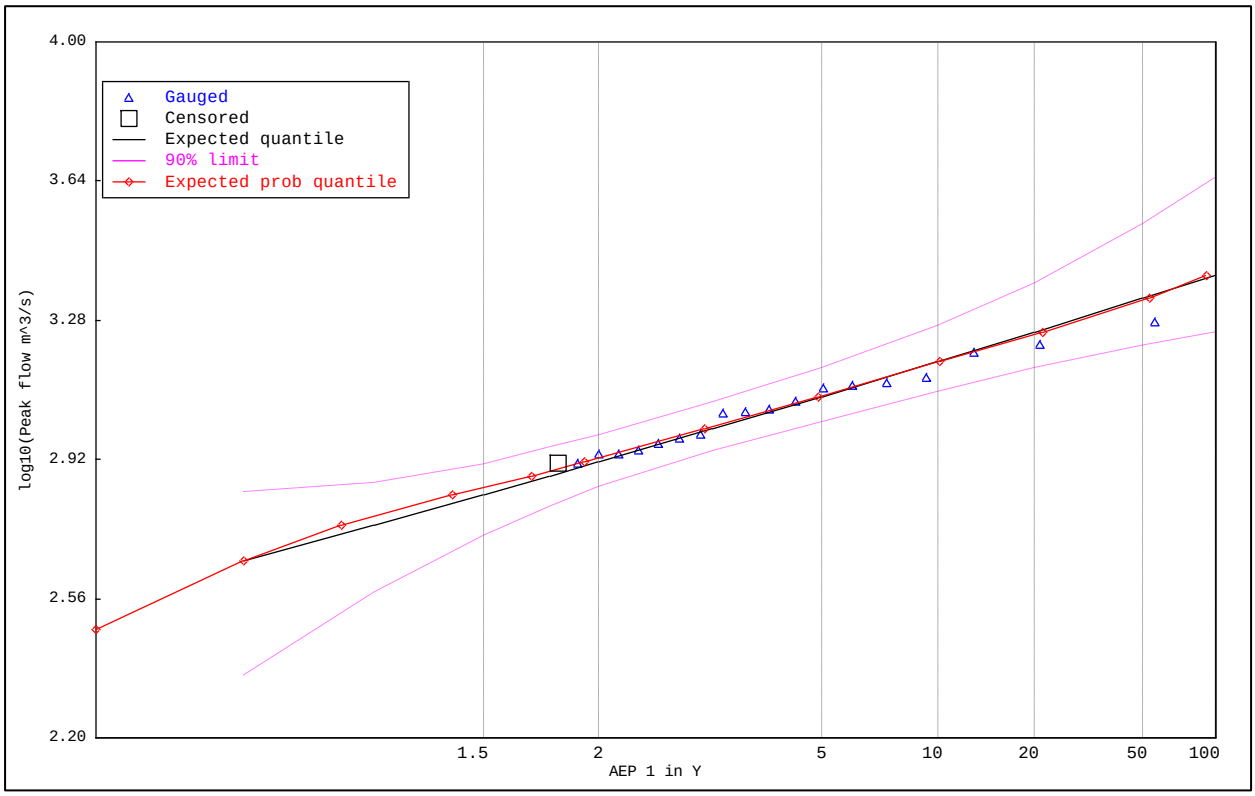


Plate 14 LP3 Probability Plot (Censored)

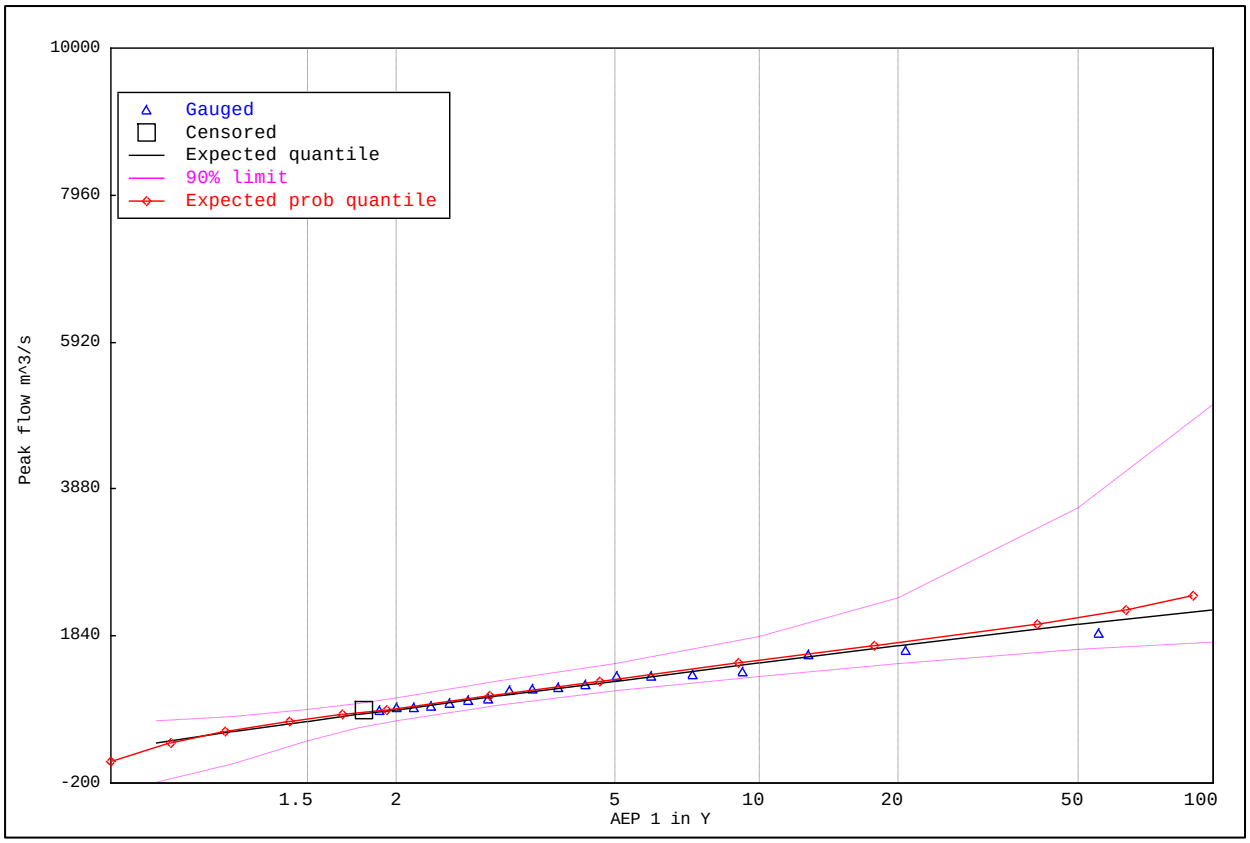


Plate 15 GEV Probability Plot (Censored)

Plates 12 to **15** shows that each of the probability distributions fit the data reasonably well with all plotting positions within the 90% limits. However, the log normal distribution appears to provide the best overall fit and "tightest" 90% confidence limits. The calculated flood frequency for the all probability distributions is shown in **Table 3**.

Table 3 Adopted Flood Frequency Distributions

AEP	Peak Flow (m^3/s)			
	Gumbel	Log Normal	LP3 Distribution	GEV Distribution
20%	1,201	1,196	1,208	1,217
5%	1,678	1,678	1,776	1,705
1%	2,207	2,238	2,491	2,206
0.2%	2,731	2,824	3,302	2,666

The peak discharges listed in **Table 3** shows that with the exception of the LP3 distribution, each of the distributions produce similar peak discharges. Overall, the Log Normal distribution is considered to provide the best overall results.

It is noted that the calculated FFA discharges for the Tumbulgum gauge are lower than the calculated FFA discharges at the Murwillumbah gauge. This is considered to be associated with the significant floodplain storage between Murwillumbah and Tumbulgum that serves to attenuate flows

APPENDIX E

FLOOD DAMAGES ASSESSMENT

E1 FLOOD DAMAGE CALCULATIONS

1.1 Introduction

In an effort to quantify the potential economic impact that flooding has on the South Murwillumbah study area, a flood damage assessment was completed. The following sections summarise the methodology employed to quantify flood damage costs as well as the results of the damage assessment.

1.2 Background

The damage costs associated with inundation can be broken down into a number of categories, as shown in **Plate 1**. However, broadly speaking, damage costs fall under two major categories;

- Tangible damages; and
- Intangible damages.

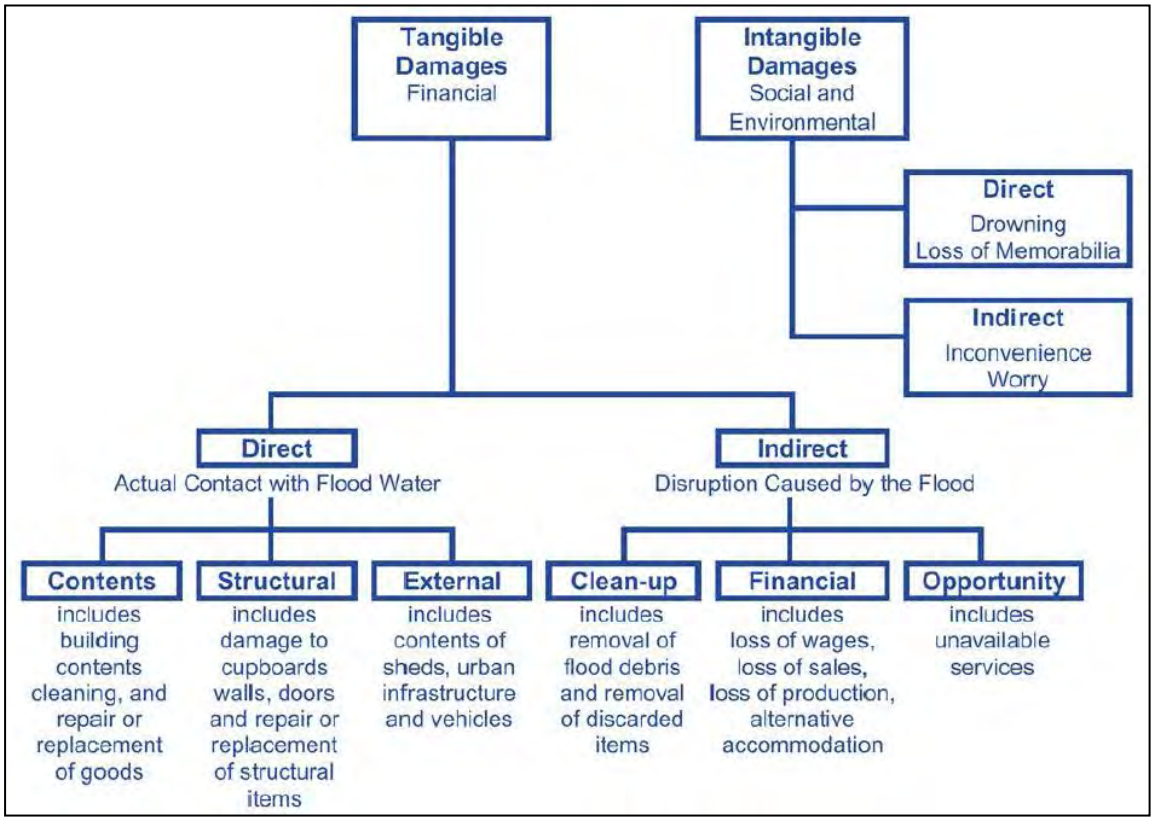


Plate 1 Flood Damage Categories (NSW Government, 2005)

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by water). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with water coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific flood event. Indirect damage costs can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

Due to the difficulty associated with assigning monetary values to intangible damages, only tangible damages were considered as part of this study. Further information on how tangible damages costs were estimated is presented in the following sections.

1.3 Flood Damage Calculations

1.3.1 Property Database

In order to quantify flood damages, it is necessary to have a property database for all residential, commercial and industrial properties in the study area. A property database was previous prepared as part of the 'Tweed Valley Floodplain Risk Management Study' (BMT WBM, 2014) and was also used as part of the current assessment. The property database included the following information:

- Building floor level;
- Property type (i.e., residential, commercial or industrial);
- Building construction type (Brick, Weather Board, etc.);
- Residential building type (i.e., two story, single level high set, single level low set);
- Commercial/Industrial building type (e.g. Office, Hardware, service station)
- Building size;

The building floor levels can then be compared against design flood level information to determine the depth of above floor inundation during each design flood. The over floor flooding depth can, in turn, be used with flood damage curves to estimate the damage costs for the specific property type. Further details on how the flood damage curves were developed is provided below.

1.3.2 Residential Properties

The NSW Office of Environment and Heritage (OEH) has prepared a spreadsheet that provides a standardised approach for deriving damage curves for residential properties (version 3.00, October 2007). The damage curves describe flood damage costs relative to the depth of flooding above floor level.

The spreadsheet requires a range of parameters to be defined to enable a meaningful damage estimate to be derived. The parameters that were adopted for the current study are provided on the following page.

It was noted that the resulting depth-damage curves incorporate a damage allowance for 'negative' depths. This is intended to reflect that property damage can be incurred when the water level is below floor level (e.g., damage to fences, garages, sheds). The damage curves for 'single storey low set' and 'two storey' properties commence at -0.2 metres (m). This was

considered to be too small for the study area due to the undulating terrain across most of the residential sections of the study area. Therefore, this value was increased to -0.5 m.

The default 'single storey high set' damage curves commence at -5 m. In order to verify the suitability of this value, single storey high set building floor levels within the PMF extent were compared against the minimum ground elevation within each lot (i.e., the minimum elevation within each lot at which inundation will first occur and, therefore, where damage is likely to commence). This determined that the median difference between the building floor level and minimum ground level within the corresponding lot was 2.4 m. Accordingly, the 'single-storey high set' damage curves were adjusted so that damage commenced only when the flood level was less than 2.4 m below the floor level.

The building floor area serves as another residential damage curve input. The floor area of all residential buildings within the study area was reviewed and it was determined that the median floor area was 110 m^2.

The resulting residential depth-damage curves are included on the following page. The residential depth-damage curves include allowances for both direct and indirect cost components.

1.3.3 Commercial and Industrial Properties

Depth-damage curves that were used as part of "Murwillumbah CBD Levee & Drainage Study" (Catchment Simulation Solutions, 2018) were extracted and used to define commercial and industrial flood damages for the study area.

As noted in Section 1.3.1, each commercial and industrial property was classified according to the value of the contents (i.e., low or high damage potential). This is intended to reflect the fact that the damage incurred across commercial and industrial properties is likely to be heavily influenced by the value of its contents. **Table 1** provides a summary of common commercial and industrial property types and the associated value of the contents.

The commercial and industrial properties were also broken down based on the size of the building into three categories; small (<186 m^2), Medium (186 – 650 m^2) or large (>650 m^2). This is intended to reflect that the flood damages costs are also related to the size of the property. This size was combined with the contents value to assign the appropriate depth-damage curve for the individual property. The adopted commercial/Industrial depth-damage curves are presented on the following page.

An allowance of 55% of the direct flood damages was included to account for indirect damage costs to commercial and industrial properties, such as clean-up costs and loss of income while clean-up occurs. This was also adopted as part of the *'Tweed Valley Floodplain Risk Management Study'* (*WBM BMT, 2014*).

1.3.4 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, electricity and telephone. For this study, the infrastructure damage was estimated at 15% of total direct damages. This value was also adopted by part of the *'Tweed Valley Floodplain Risk Management Study'* (*WBM BMT, 2014*).

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007

PROJECT	DETAILS	DATE	JOB No.
Smithfield West	**Residential Damages (120m2)**	**18/02/2015**	**xx**

BUILDINGS

Regional Cost Variation Factor	1.03	*From Rawlinsons*
Post late 2001 adjustments	1.75	*Changes in AWE see AWE Stats Worksheet*
Post Flood Inflation Factor	1.00	*1.0 to 1.5*
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*

	Regional City Houses Affected		Factor	Regional Town Houses Affected		Factor
Small scale impact	<	*50*	*1.00*	<	*10*	*1.00*
Medium scale impacts in Regional City		*100*	*1.20*		*30*	*1.30*
Large scale impacts in Regional City	>	*150*	*1.40*	>	*50*	*1.50*

Typical Duration of Immersion	0.5	hours
Building Damage Repair Limitation Factor	0.85	*due to no insurance* *short duration* *long duration*
		Suggested range *0.85* *to* *1.00*
Typical House Size	110	m^2 *240 m^2 is Base*
Building Size Adjustment	0.5	
Total Building Adjustment Factor	**0.70**	

CONTENTS

Average Contents Relevant to Site	$ 29,548	*Base for 240 m^2 house* *$ 60,000*
Post late 2001 adjustments	1.75	*From above*
Contents Damage Repair Limitation Factor	0.75	*due to no insurance* *short duration* *long duration*
Sub-Total Adjustment Factor	1.31	*Suggested range* *0.75* *to* *0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*
Effective Warning Time	0	hour
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*
Total Contents Adjustment Factor AFD <= TTBH	**1.31**	AFD = Above Floor Depth
Total Contents Adjustment Factor AFD > TTBH	**1.31**	

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.75	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ -	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	0	weeks
Additional accommodation costs /Loss of Rent	$ -	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70% Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110% Single Storey Slab on Ground

Base Curves

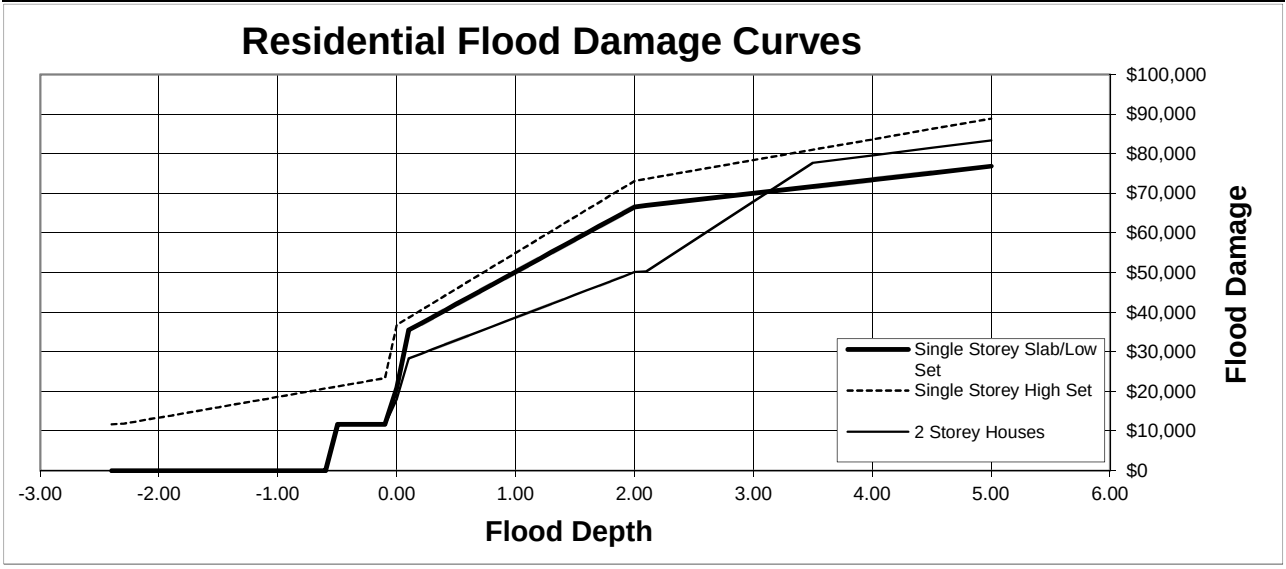
AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871	x	AFD	in metres
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-2.40	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve 0.1 m

	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses
Type	**1**	**2**	**3**
AFD from Modelling	**Damage**	**Damage**	**Damage**
-5.00	$0	$0	$0
-2.40	$11,725	$0	$0
-2.30	$11,857	$0	$0
-2.20	$12,380	$0	$0
-2.10	$12,903	$0	$0
-2.00	$13,427	$0	$0
-1.90	$13,950	$0	$0
-1.80	$14,474	$0	$0
-1.70	$14,997	$0	$0
-1.60	$15,520	$0	$0
-1.50	$16,044	$0	$0
-1.40	$16,567	$0	$0
-1.30	$17,091	$0	$0
-1.20	$17,614	$0	$0
-1.10	$18,137	$0	$0
-1.00	$18,661	$0	$0
-0.90	$19,184	$0	$0
-0.80	$19,708	$0	$0
-0.70	$20,231	$0	$0
-0.60	$20,754	$0	$0
-0.50	$21,278	$11,725	$11,725
-0.40	$21,801	$11,725	$11,725
-0.30	$22,325	$11,725	$11,725
-0.20	$22,848	$11,725	$11,725
-0.10	$23,372	$11,725	$11,725
0.00	$36,822	$20,969	$18,196
0.10	$38,638	$35,531	$28,389
0.20	$40,454	$37,166	$29,533
0.30	$42,271	$38,800	$30,678
0.40	$44,087	$40,435	$31,822
0.50	$45,903	$42,070	$32,966
0.60	$47,719	$43,705	$34,111
0.70	$49,535	$45,339	$35,255
0.80	$51,351	$46,974	$36,399
0.90	$53,167	$48,609	$37,544
1.00	$54,984	$50,244	$38,688
1.10	$56,800	$51,879	$39,832
1.20	$58,616	$53,513	$40,977
1.30	$60,432	$55,148	$42,121
1.40	$62,248	$56,783	$43,265
1.50	$64,064	$58,418	$44,410
1.60	$65,880	$60,052	$45,554
1.70	$67,696	$61,687	$46,698
1.80	$69,513	$63,322	$47,843
1.90	$71,329	$64,957	$48,987
2.00	$73,145	$66,591	$50,131
2.10	$73,668	$66,933	$50,371
3.50	$80,996	$71,722	$77,722
4.00	$83,613	$73,432	$79,603
4.50	$86,230	$75,142	$81,484
5.00	$88,847	$76,853	$83,365



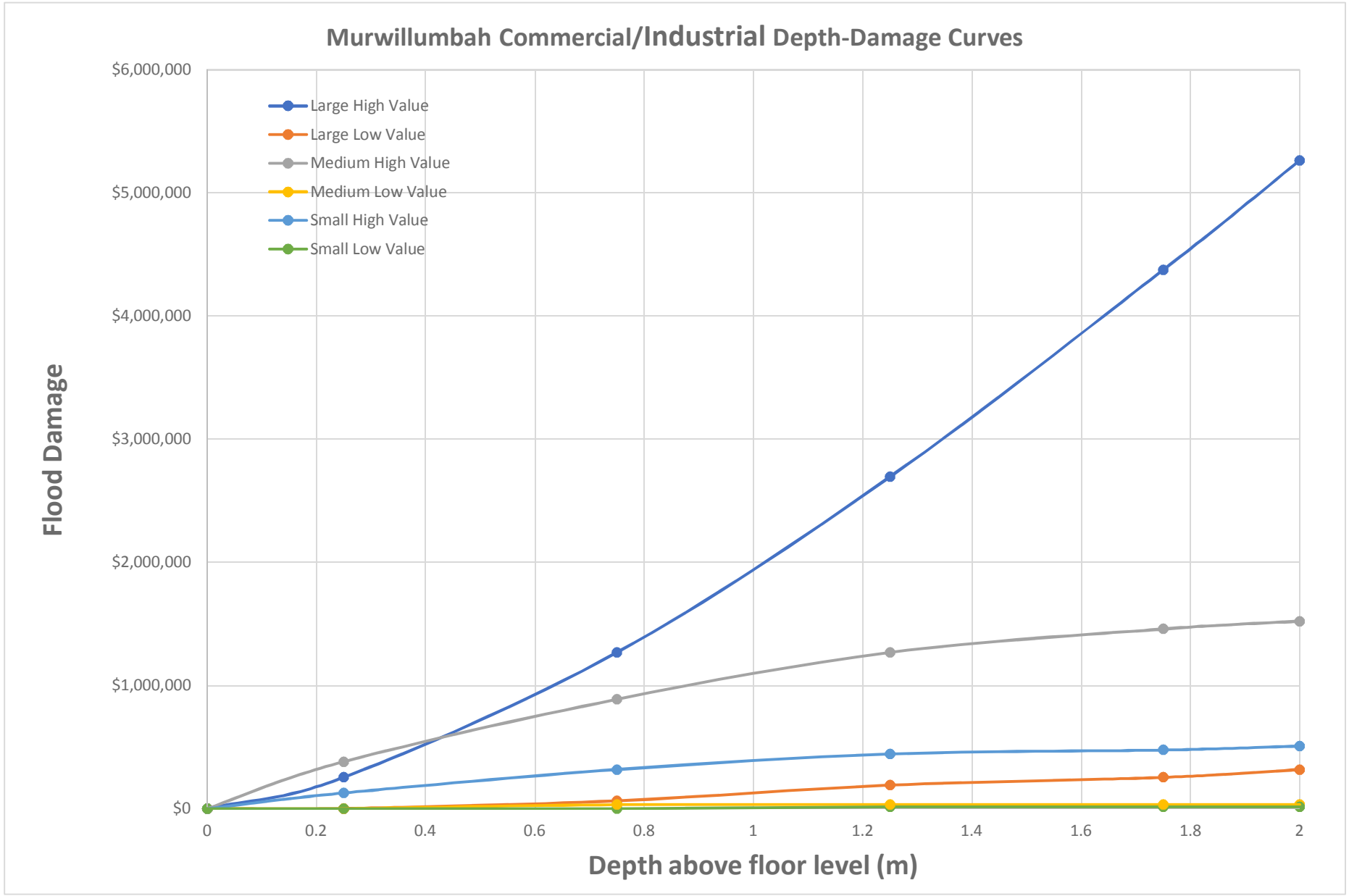

Murwillumbah Commercial/Industrial Depth-Damage Curves
Flood Damage
$6,000,000
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
Large High Value
Large Low Value
Medium High Value
Medium Low Value
Small High Value
Small Low Value
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Depth above floor level (m)

Table 1 Content Value Categories for Commercial and Industrial Property Types

	Low Value Contents	High Value Contents
Commercial	Florists	Chemists
	Garden Centres	Music instruments
	Café/Take away food	Printing
	Restaurants	Electric Goods
	Sports pavilions	Men's & Women's Clothing
	Consulting rooms	Bottle shops
	Doctors' surgeries	Cameras
	offices	Pharmaceuticals
	schools	Electronics
	churches	Advanced Manufacturing
	Post Offices	Transport Depots
	Food, retail outlets	
	Butchers	
	Bakeries	
	Newsagents	
	Pubs	
	Libraries	
	Clubs	
Industrial	Hardware	
	Service Stations	
	Vehicle sales	

1.4 Summary of Inundation Costs

1.4.1 Damage Costs

Flood damages were calculated using the flood level surfaces for each design flood in conjunction with the appropriate depth-damage curves and floor levels for each building. The individual property damage estimates were subsequently summed with calculated infrastructure damage to calculate the total flood damages for each design event.

The total number of buildings expected to be subject to above floor flooding during each design flood across the full Tweed River floodplain between Bray Park and Condong was extracted and is summarised in **Table 2**. The total number of buildings with above floor flooding across the South Murwillumbah study area only was also extracted and is provided in **Table 3**.

Table 3 shows that only a relatively small number of residential properties are predicted to be exposed to above floor flooding during 20% and 5% AEP flood events. However, the numbers of residential properties subject to above floor inundation is predicted to increase significantly during 1% AEP and 0.2% AEP flood events. **Table 3** also shows that a significant

number of commercial properties would be subject to inundation during floods as frequent as the 20% AEP event. Accordingly, flooding does have the potential to cause financial losses and disrupt business during relatively frequent events.

Table 2 Number of Properties with Above Floor Inundation – Bray Park to Condong

Flood Event	Number of buildings with Above Flood Inundation			
	Residential	Commercial	Industrial	Total Number
20% AEP	10	32	6	48
5% AEP	22	51	10	83
1% AEP	44	124	54	222
0.2% AEP	562	262	68	892

Table 3 Number of Properties with Above Floor Inundation – South Murwillumbah Only

Flood Event	Number of buildings with Above Flood Inundation			
	Residential	Commercial	Industrial	Total Number
20% AEP	5	18	3	26
5% AEP	8	22	5	35
1% AEP	51	62	45	158
0.2% AEP	144	75	56	275

It is expected that nearly 160 properties within the study extent would be subject to above floor flooding during a 1% AEP flood. During a 0.2% AEP flood, more than 270 properties are predicted to experience above floor inundation.

The total damage costs for each design flood are summarised in **Table 4** (for the broader floodplain) and **Table 5** (for the South Murwillumbah study area). The results of the damage assessment indicate that if a 1% AEP flood was to occur, over $45 million worth of damage could be expected across the South Murwillumbah (note that this damage estimate does not include any areas outside of the study, including the Murwillumbah CBD). It should also be noted that the damage estimates do not account for agricultural damage costs. Although agricultural impacts are an important consideration, the economic assessment is based on urban damages only, which is consistent with the approach adopted for the *'Tweed Valley Floodplain Risk Management Study'* (*WBM BMT, 2014*).

Table 3 Flood Damage Costs – Bray Park to Condong

Flood Event	Flood Damages ($ millions)				
	Residential	Commercial	Industrial	Infrastructure	Total Damages
20% AEP	4.14	3.51	0.33	0.60	8.58
5% AEP	6.08	4.53	0.90	0.81	12.3
1% AEP	13.3	18.3	17.2	5.33	54.1
0.2% AEP	47.0	61.3	37.7	14.9	161

Table 4 Flood Damage Costs – South Murwillumbah Only

Flood Event	Flood Damages ($ millions)				
	Residential	Commercial	Industrial	Infrastructure	Total Damages
20% AEP	2.66	3.44	0.25	0.55	6.90
5% AEP	3.31	3.88	0.80	0.70	8.69
1% AEP	6.98	16.3	16.8	4.97	45.1
0.2% AEP	12.8	27.1	37.1	9.63	86.6

Table 4 and **Table 5** shows that during the 1% AEP and 0.2% AEP floods, the majority of the flood damage cost is predicted to occur across commercial and, in particular, industrial properties. During more frequent events, residential properties are predicted to contribute a more substantial proportion of the overall damage costs.

Table 4 and **Table 5** also shows a significant increase in flood damage costs between the 5% AEP and 1% AEP floods as well as the 1% AEP and 0.2% AEP floods. Accordingly, once significant overtopping of the levee occurs, flood damage costs can be expected to increase significantly.

1.4.2 Average Annual Damages

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for each property. The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe. The AAD for South Murwillumbah was determined to be $5.1 million. Accordingly, if the "status quo" was maintained, residents and business owners within the catchment as well as infrastructure providers, such as Council, would likely be subject to cumulative flood damage costs of approximately $5.1 million per annum (on average).

1.5 Limitations of Inundation Costs

The damage costs presented in this document are based on the best information that was available at the time this report was prepared. However, the estimates do not take into account future fluctuations in property and asset values. Therefore, the damage estimates should only be considered an approximation.

APPENDIX F

SENSITIVITY ASSESSMENT

F1. Sensitivity Assessment Difference Maps

Levee Failure

20% AEP

The following flood level difference map was prepared by subtracting peak 20% AEP flood levels of the 'base' flood simulation from the 20% AEP simulation with the South Murwillumbah levee failure (Implemented as a 40m breach of the levee before the peak inflow of the event).

Plate F1 20% AEP Flood level difference map with failure of the South Murwillumbah levee

1% AEP

The following flood level difference map was prepared by subtracting peak 1% AEP flood levels of the 'base' flood simulation from the 1% AEP simulation with the South Murwillumbah levee failure.

Plate F2 1% AEP Flood level difference map with failure of the South Murwillumbah levee

Floodgate Failure

20% AEP

The following flood level difference map was prepared by subtracting peak 20% AEP flood levels of the 'base' flood simulation from the 20% AEP simulation with failure of the Blacks Drain and Condong Creek floodgates.

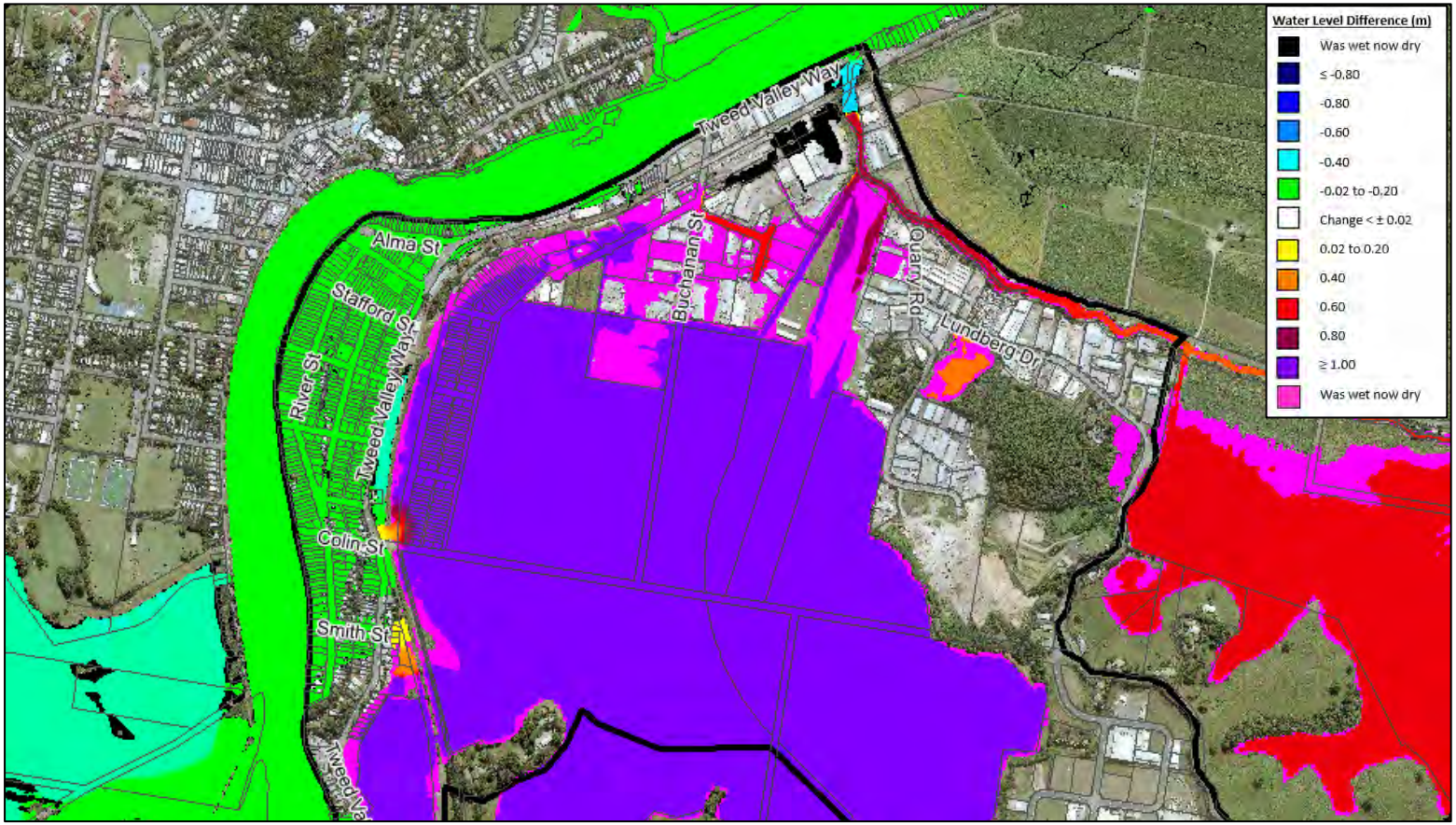


Plate F3 20% AEP Flood level difference map with failure of the floodgates

1% AEP

The following flood level difference map was prepared by subtracting peak 1% AEP flood levels of the 'base' flood simulation from the 1% AEP simulation with failure of the Blacks Drain and Condong Creek floodgates.

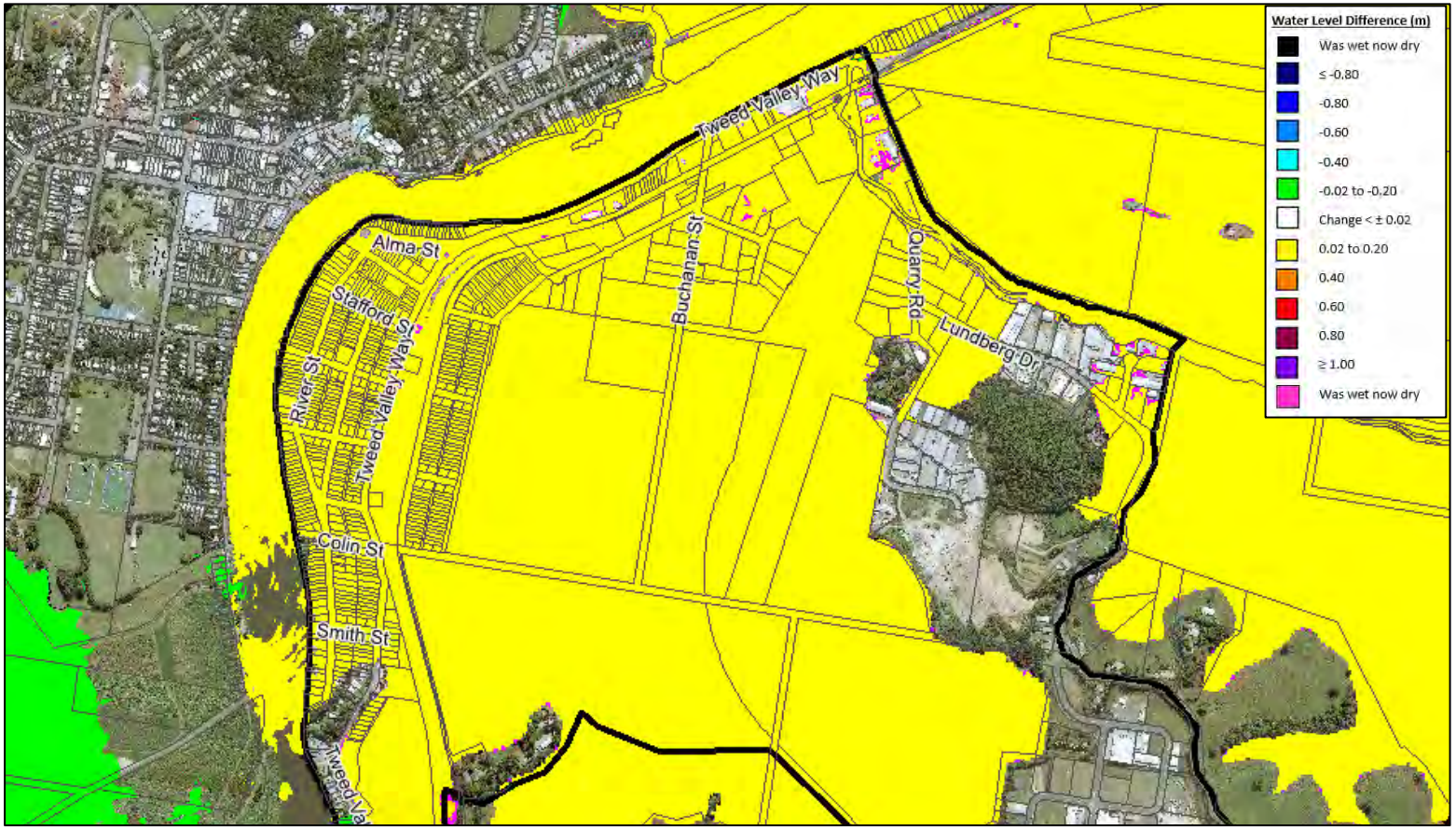


Plate F4 1% AEP Flood level difference map with failure of the floodgates

Blockage of All Hydraulic Structures Except Murwillumbah Bridge

1% AEP

The following flood level difference map was prepared by subtracting peak 1% AEP flood levels of the 'base' flood simulation from the 1% AEP simulation with blockage of all hydraulic structures in the study area except for the Murwillumbah Bridge.

Plate F5 1% AEP Flood level difference map with blockage of all hydraulic structures except Murwillumbah Bridge

Blockage of Murwillumbah Bridge Only

1% AEP

The following flood level difference map was prepared by subtracting peak 1% AEP flood levels of the 'base' flood simulation from the 1% AEP simulation with blockage of the Murwillumbah bridge.

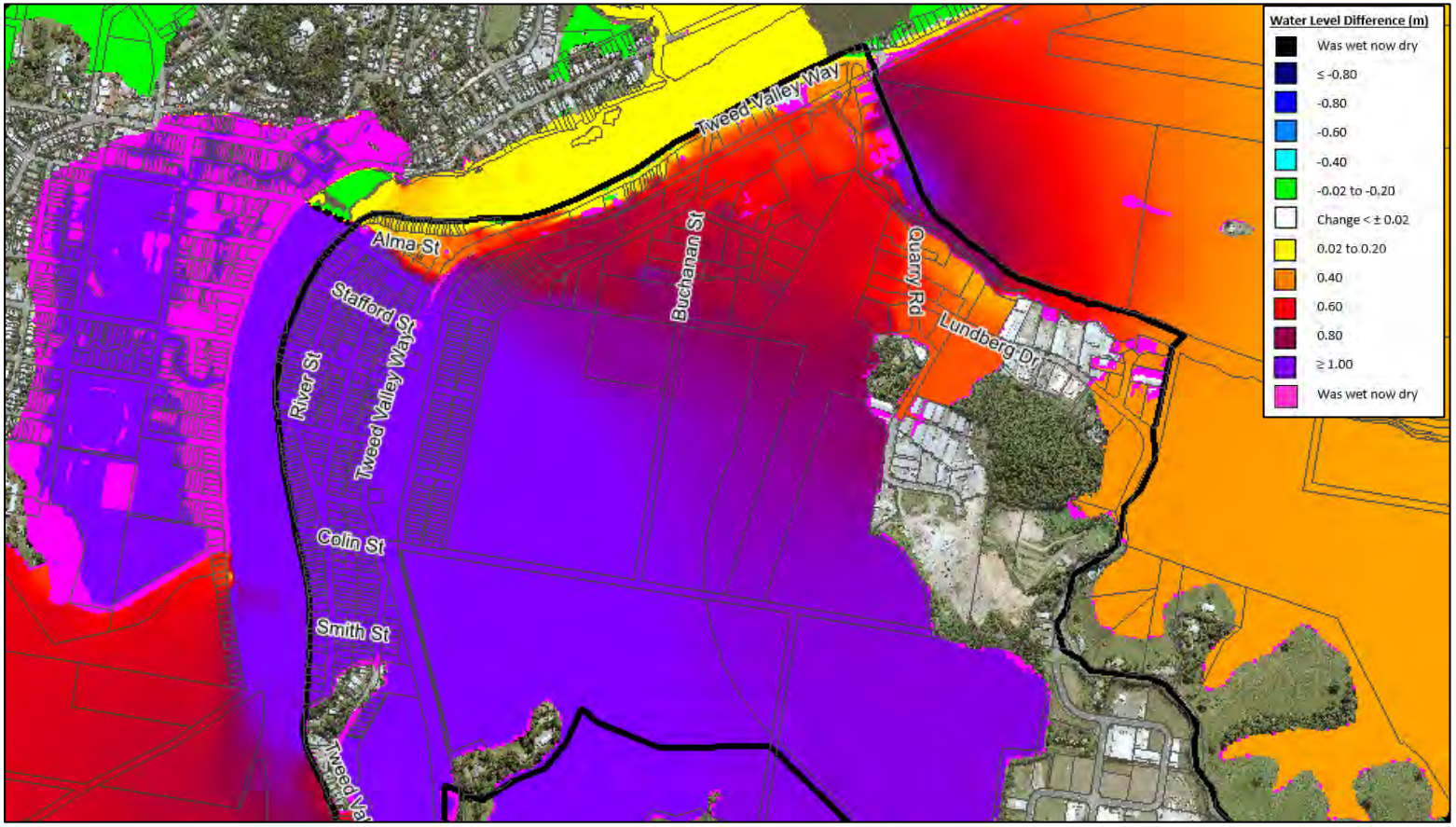


Plate F6 1% AEP Flood level difference map with blockage of Murwillumbah Bridge only

APPENDIX G

AUSTRALIAN RAINFALL & RUNOFF 2016 ASSESSMENT

1 ARR2016 AND ARR1987 HYDROLOGIC AND HYDRAULIC ASSESSMENT

1.1 Overview

Flood Behaviour across the Tweed Shire Council LGA for the past three decades has been defined based upon guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia) (referred to herein as ARR1987). This included the 'Tweed Valley Flood Study' (BMT WBM, 2009).

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, investigations were completed to determine the impact that the revised hydrologic procedures may have on 1% AEP flood estimates in the vicinity of South Murwillumbah.

The outcomes of the assessment are summarised in the following sections as follows:

- Section 1.2: Provides a comparison between the various ARR1987 and ARR2016 hydrologic inputs (e.g., design rainfall);
- Section 1.3: Provides a comparison between the ARR1987 and ARR2016 hydrologic results (e.g., peak discharges); and,
- Section 0: Summarises how the differences in hydrologic results will impact on hydraulic results (e.g., peak flood levels and extents).

1.2 Hydrologic Inputs

1.2.1 Rainfall

Australian Rainfall & Runoff 1987

Design rainfall is one of the primary hydrologic inputs for simulating design floods and is established through statistical analysis of historic rainfall records. Design rainfall for the 1% AEP event were extracted at five locations across the Tweed River catchment to reflect the potential spatial variations in design rainfall across the catchment from the Bureau of Meteorology's ARR1987 intensity-frequency-duration page and are presented in **Table 1**.

The 'Tweed Valley Flood Study' (BMT WBM, 2009), determined that the 36 hour storm duration was the critical duration for the lower Tweed River Valley.

Australian Rainfall & Runoff 2016

Revised design rainfall was established as part of the 2016 revision of Australian Rainfall and Runoff. This revised design rainfall takes advantage of more rainfall gauges and approximately 30 years of additional data, as well as more advanced statistical techniques.

Table 1 1% AEP Design Rainfall Depths for ARR 1987 and ARR 2016

Storm Duration	1% AEP Rainfall Depth (mm)									
	Murwillumbah		Fingal		Jerusalem Mt		Tyalgum		Tomewin	
	ARR 1987	ARR 2016	ARR 1987	ARR 2016	ARR 1987	ARR 2016	ARR 1987	ARR 2016	ARR 1987	ARR 2016
6 hours	254	254	206	258	276	289	208	261	256	304
9 hours	308	308	242	309	343	369	249	330	310	389
12 hours	352	349	273	349	401	434	284	388	359	460
18 hours	420	410	326	406	503	539	344	480	449	572
24 hours (1 day)	472	454	373	446	593	619	393	551	532	659
30 hours (1.25 days)	514	488	415	477	674	683	435	607	610	728
36 hours (1.5 days)	548	514	453	501	748	735	473	653	683	785
48 hours (2 days)	604	554	515	537	878	816	536	724	812	873
72 hours (3 days)	687	606	599	586	1081	923	626	817	1004	990

Design rainfall for the 1% AEP events were extracted at the centroid of the catchment from the Bureau of Meteorology's ARR2016 intensity-frequency-duration page. The ARR2016 rainfall depths are presented in **Table 1**.

The rainfall information presented in **Table 1** shows that the ARR2016 rainfall depths are slightly lower than the equivalent ARR1987 rainfall depths at Murwillumbah. However, across the remainder of the catchment, ARR2016 rainfall depths are typically higher than ARR1987 depths (most notably at Tyalgum where ARR2016 depths are up to 40% higher than ARR1987 depths). On average, the ARR2016 rainfall depths are 13% higher than ARR1987 depths.

1.2.2 Areal Reduction Factors

Australian Rainfall & Runoff 2016

ARR 2016 has also introduced revised areal reduction factors. The areal reduction factors recognise that there is unlikely to be a uniformly high rainfall intensity across all sections of large catchments. Although ARR 1987 did include areal reduction factors, this largely drew from overseas research.

The areal reduction factors parameter at the catchment centroid were downloaded from the ARR2016 data hub (a copy of the information downloaded from the data hub is included at the end of this appendix). The parameters were applied to the areal reduction equations provided in ARR2016 along with the total catchment area draining to Murwillumbah (~800 km^2) to develop the areal reduction factors provided in **Table 2**. These reduction factors were applied to the total rainfall depths listed in **Table 1** before application to the WBNM hydrologic model.

Table 2 ARR 2016 Areal Reduction Factors

Storm Duration	Areal Reduction Factor	
	ARR1987	ARR2016
6 hours	0.86	0.77
9 hours	0.88	0.82
12 hours	0.90	0.84
18 hours	0.91	0.89
24 hours (1 day)	0.92	0.90
30 hours (1.25 days)	0.92	0.91
36 hours (1.5 days)	0.92	0.92
48 hours (2 days)	0.92	0.93
72 hours (3 days)	0.92	0.94

Australian Rainfall & Runoff 1987

The areal reduction factors were also calculated based upon procedures outlined in ARR1987. The factors are provided in **Table 2**. This comparison shows that the ARR1987 reduction factors are typically higher than ARR2016 for storm durations less than 36 hours. For storm durations greater than 36 hours, the ARR2016 reduction factors are slightly higher than ARR1987.

1.2.3 Rainfall Losses

Australian Rainfall & Runoff 1987

During a typical rainfall event, not all of the rain falling on a catchment is converted to runoff. Some of the rainfall may be intercepted and stored by vegetation, some may be stored in small depression areas and some may infiltrate into the underlying soils.

ARR1987 recommends the "Initial-Continuing" loss model to represent rainfall losses. This loss model assumes that a specified amount of rainfall is lost during the initial saturation or wetting of the catchment (referred to as the "Initial Loss"). Further losses are applied at a constant rate to simulate infiltration and interception once the catchment is saturated (referred to as the "Continuing Loss Rate"). The initial and continuing losses are effectively deducted from the total rainfall over the catchment, leaving the residual rainfall to be distributed across the catchment as runoff.

The adopted ARR1987 rainfall losses are provided below. As shown, separate initial and continuing loss rates were applied to pervious and impervious surfaces to reflect the significant variation in rainfall loss potential across these different surfaces. However, it is noted that the ARR1987 rainfall losses are "static" and do not vary with respect to storm duration or storm intensity.

- ARR1987 Rainfall Losses (BMT, 2009):
  - Initial Loss = 0 mm
  - Continuing Loss Rates = 2.5 mm/hour

Australian Rainfall & Runoff 2016

ARR2016 introduced a revised approach for defining rainfall losses for design flood simulations. Although the same initial/continuing loss approach is retained in ARR2016, ARR2016 employs a variable initial rainfall loss (referred to as the "burst" loss) that varies accordingly to the storm severity and duration.

Initial Losses

The ARR2016 initial rainfall losses are calculated by subtracting median pre-burst rainfall depths from the overall "storm" loss for the catchment. This aims to recognise that the most intense "downpour" is frequently preceded by rainfall that would serve to "wet" the catchment, thereby reducing the potential for rainfall during the main "burst" to infiltrate into the underlying soils (i.e., the median pre-burst rainfall depth is intended to reflect the "lead up" rainfall). Accordingly, the ARR2016 approach for calculating the design initial rainfall losses is considered to more closely mimic actual rainfall events.

Unlike ARR1987, which typically applies the same rainfall losses across large geographic areas, ARR2016 provides regionalised estimates of storm rainfall loss and median pre-burst rainfall. This information is available for download from the ARR2016 Data Hub and is intended to reflect the potentially large differences in catchment characteristics (e.g., soils types) and associated rainfall losses. The ARR2016 data hub information for the Tweed River catchment is provided at the end of this Appendix.

The data hub rainfall loss information for the Tweed River catchment indicate a storm loss of 41mm. To convert the "storm" initial loss to a "burst" initial loss, it is necessary to subtract the median pre-burst rainfall depths obtained from the Data Hub (which varies based on storm duration and AEP) from the storm loss. The resulting "burst" initial rainfall losses are summarised in **Table 3**.

Table 3 Burst Rainfall Losses for the 1% AEP flood

Storm Duration	Storm Initial Loss (mm)	Median Pre-Burst Depth (mm)	Burst Initial Loss (mm)
12 hours	41	165	0
18 hours		212	0
24 hours (1 day)		114	0
36 hours (1.5 days)		103	0
48 hours (2 days)		73.2	0
72 hours (3 days)		37.9	3.1

As shown in **Table 3**, burst rainfall losses of between 0 and 3.1mm were calculated (with a burst loss of 0 mm being most common). This does not differ significantly from the 0mm adopted as part of the original flood study for design flood simulations.

Continuing Loss Rates

The data hub rainfall loss information for the Tweed River catchment indicates a continuing loss rate of 2.8mm/hr. However, the ARR2016 Team has advised that calibrated loss rates should be used in preference to data hub loss rates, where available. A 2.5 mm/hr continuing loss rates was utilised as part of the calibration for the 'Tweed Valley Flood Study' (BMT WBM, 2005) and generated reasonable calibration results. Therefore, this loss rate was also retained as part of the ARR2016 assessment.

1.2.4 Temporal Patterns

Australian Rainfall & Runoff 1987

The rainfall depths presented in **Table 1** represent the total rainfall depth falling across the full length of the particular storm duration. Therefore, a temporal pattern must be applied to this rainfall to provide a more realistic description of how the rainfall varies with respect to time through the storm event (i.e., it is unrealistic to assume that the rainfall will be uniformly distributed throughout a storm).

ARR1987 provides temporal patterns for eight different zones across Australia. Two sets of temporal patterns are provided for each zone for each storm duration to describe the temporal distribution of rainfall – one for events more frequent than a 30 year ARI and another one for events less frequent than a 30 year ARI event. These two sets of temporal patterns are further subdivided based upon the storm duration. However, ARR1987 only provides a single temporal pattern to describe the temporal distribution of rainfall for each design storm.

The Tweed River catchment falls near the zone 1 and zone 3 temporal pattern boundaries. Therefore, the 2009 flood study adopted a "hybrid" temporal pattern based upon the zone 1 and zone 3 temporal patterns.

Australian Rainfall & Runoff 2016

One of the most significant differences between ARR2016 and ARR1987 is in the use of storm temporal patterns (i.e., the patterns describing the distribution of rainfall throughout the storm). As discussed, ARR1987 used a single temporal pattern for each AEP/storm duration while ARR2016 uses 10 temporal patterns for each AEP/storm duration. This is intended to provide a better representation of the natural variability of rainfall (i.e., no two storms will be exactly the same). However, this does require simulation of ten times more storms under ARR2016 relative to ARR1987.

The ARR2016 temporal patterns were downloaded from the ARR data hub. In accordance with ARR2016 for catchments with an area greater than 75 km^2, the "areal" temporal patterns rather than "point" temporal patterns were selected to describe the temporal variation in rainfall. The catchment upstream of Murwillumbah comprises an area of about 800 km^2. Therefore, the temporal patterns for the 1000 km^2 catchment area were adopted.

It is noted that areal temporal patterns are not available in ARR2016 for storm durations of less than 12 hours. Therefore, only storm durations of 12 hours or greater were analysed.

Further discussion on how the suite of ARR2016 temporal patterns were analysed is provided in the following section.

1.3 Hydrologic Results

1.3.1 ARR1987 Hydrology

The WBNM model was initially used to simulate rainfall-runoff process for the design 1% AEP storm based upon ARR1987 hydrology.

The results from each simulation were reviewed at each subcatchment in the WBNM model to determine the "critical" storm duration. In accordance with recommendations in ARR1987, the critical storm duration was defined as the storm duration that produced the highest peak design discharge for the Tweed River at Murwillumbah. This determined that the critical storm duration at Murwillumbah was 36 hours, which agrees with the critical duration documented in the 'Tweed Valley Flood Study' (BMT WBM, 2009).

The peak ARR1987 1% AEP discharge for the Tweed River at Murwillumbah was determined to be 5,150 m^3/s.

1.3.2 ARR2016 Hydrology

The WBNM model was also used to simulate rainfall runoff processes for the 1% AEP storm based upon ARR2016.

As outlined in the previous section, a suite of ten temporal patterns were used to represent the temporal variation in rainfall for each design flood frequency and duration. The peak discharges from the full suite of temporal patterns for each design event were reviewed to determine the most representative temporal pattern for each storm duration. The temporal pattern that generated the peak discharge immediately above the mean discharge was selected as the most representative temporal pattern for each subcatchment. This process was completed for all AEPs and storm durations. The peak discharges generated by the representative temporal pattern were then reviewed across all storm durations for a particular AEP and the storm duration that produced the highest peak design discharge for the Tweed River at Murwillumbah was selected as the critical duration and discharge.

The results of the hydrologic analysis indicate that the critical duration for the Tweed River at Murwillumbah was determined to be 12 hours. Accordingly, the critical ARR1987 storm duration is longer than the critical ARR2016 storm duration.

Box plots for the 1%AEP event were also prepared for the Tweed River at Murwillumbah to better display the full range of results produced as part of the ARR2016 hydrologic analysis. The box plots are provided in **Plate 1** and show:

- Median discharge for each storm duration (represented by the blue horizontal line contained within each green box);
- Mean discharge for each storm duration (defined by the "✳");
- The first and third quartiles (defined by the green box), which illustrated the 25th percentile and 75th percentile discharge values;
- The highest and lowest discharge value (represented by the "T" attached to the end of the green box)
- The critical storm duration is highlighted in yellow

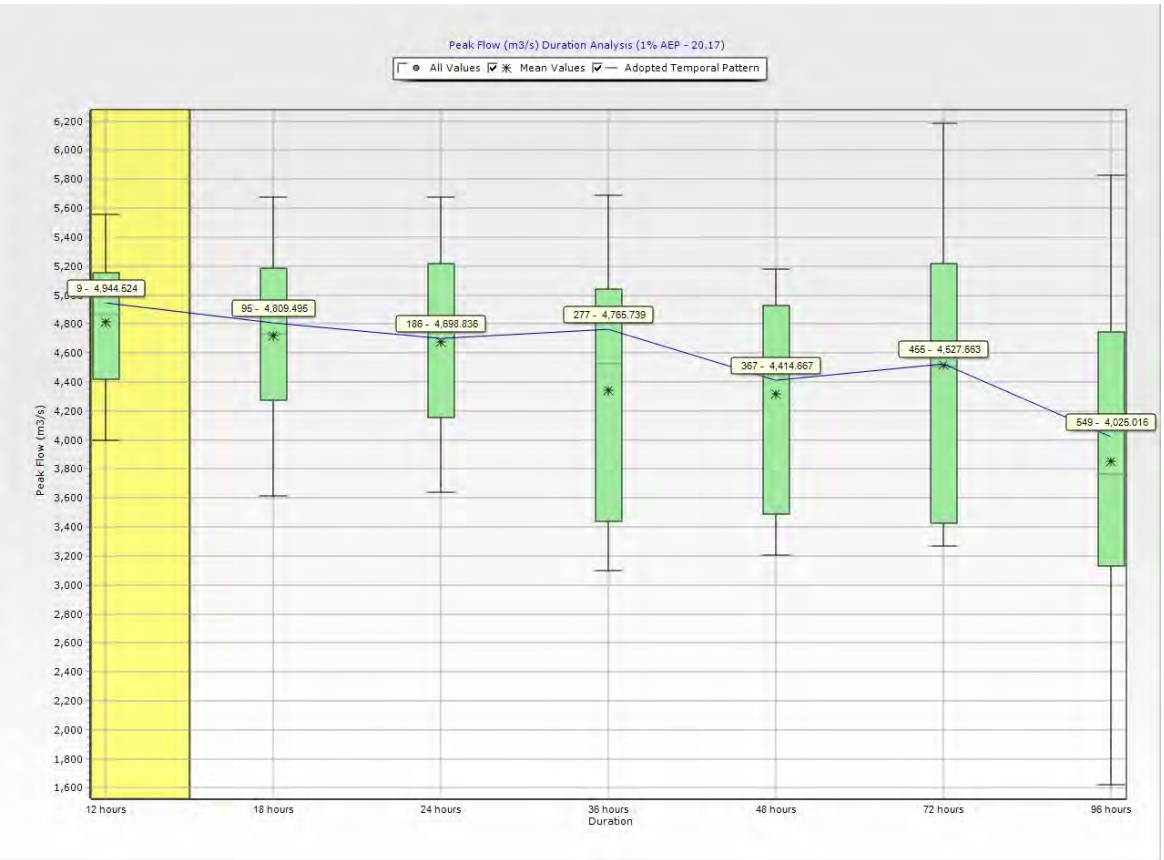


Plate 1 Box Plot for the Tweed River at Murwillumbah

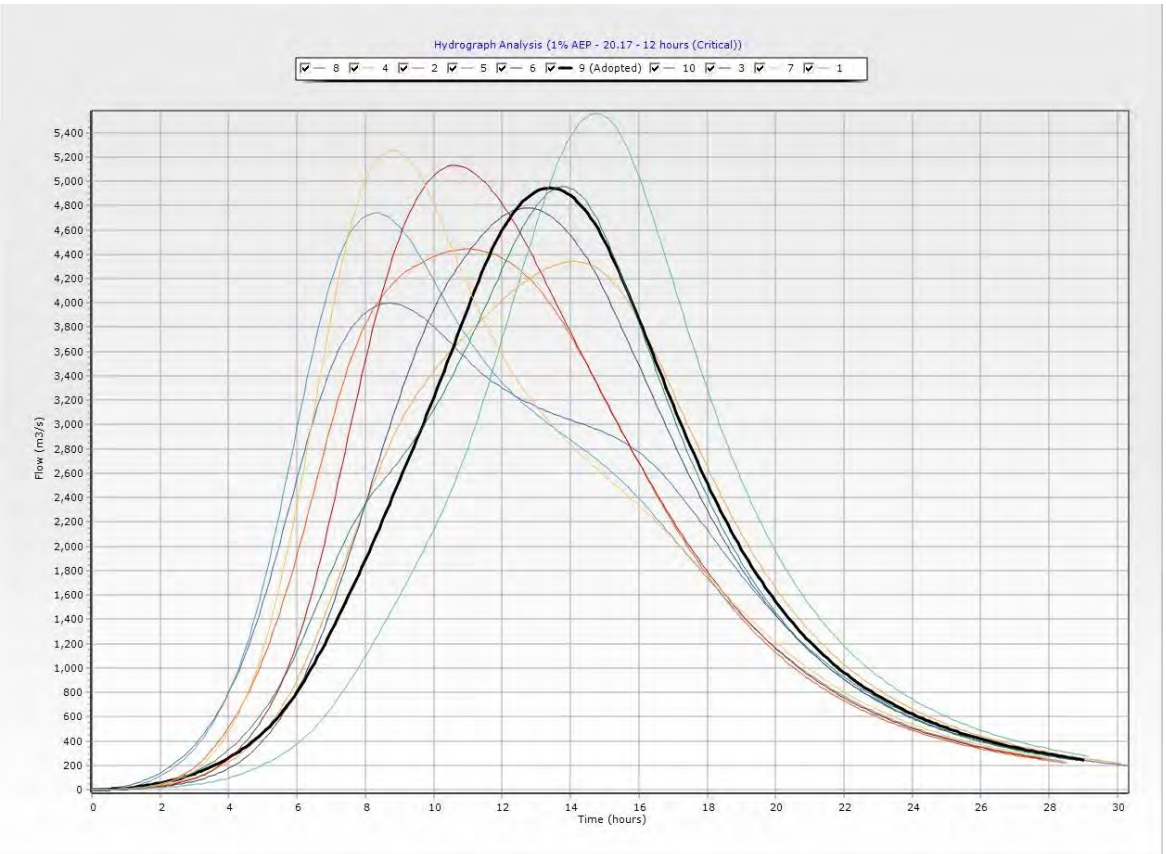


Plate 2 Design flow hydrographs for the Tweed River at Murwillumbah for 12 hour critical duration

Plate 2 shows the full suite of design flow hydrographs for the Tweed River for the 10 different temporal patterns for the critical storm duration of 12 hours.

The box plots and hydrographs show some significant variations in peak flow values, particularly for the longer storm durations. For example, for the Tweed River at Murwillumbah, redistributing the same rainfall depths for the 12-hour storm can produce peak discharge estimates that vary between ~4,000 m^3/s and 5,550 m^3/s.

The peak ARR2016 1% AEP discharge for the Tweed River at Murwillumbah was determined to be 4,994 m^3/s. Accordingly, the ARR2016 1% AEP discharge is slightly lower than the ARR1987 discharge.

1.4 Hydraulic Assessment

1.4.1 Introduction

As discussed in the previous section, ARR2016 is predicted to generate lower peak design discharge estimates relative to ARR1987 for the Tweed River at Murwillumbah. To gain an understanding of how these reductions may impacts on flood hydraulics (i.e., flood levels, depths and velocities), the ARR2016 design hydrographs were applied to the TUFLOW model and were used to re-simulate flood behaviour for the 1% AEP flood. The results of the revised simulations were subsequently compared to the 1% AEP flood results based on ARR1987 hydrology so that an understanding of the flood impacts could be quantified. The outcomes of the hydraulic assessment are presented below.

1.4.2 Hydraulics

Australian Rainfall & Runoff 2016

The TUFLOW model was updated to reflect the ARR2016 hydrology and was used to re-simulate the 1%AEP. As noted above, the ARR1987 critical duration was determined to be 36 hours. Initial simulations showed that despite the comparable peak discharge, the lower volume afforded by the 12-hour storm relative to the 36 hour storm (critical for ARR1987) provided lower peak 1% AEP flood levels across some sections of South Murwillumbah. Therefore, in addition to the 12-hour storm, a 36-hour ARR2016 storm was also simulated. The results from the 12 and 36-hour storms were combined to form a design flood "envelope" reflecting the highest water levels/depth at each location across the study area.

Discussion on Flood Impacts

Difference mapping was prepared to quantify the differences in peak 1% AEP flood levels and extents associated with adopting ARR2016 versus ARR1987 hydrology. The difference map was prepared by subtracting peak water levels generated as part of the ARR2016 model runs from the ARR1987 model runs. This creates a contour map of predicted changes in flood levels and extents. The flood level difference mapping is provided in **Plate 3**. Negative values (i.e., "cooler" colours in difference map) indicate ARR2016 is producing lower flood levels relative to ARR1987 while positive values (i.e., "warmer" colours in difference map) indicate ARR2016 is producing higher flood levels relative to ARR1987.

The difference mapping presented in **Plate 3** shows that the ARR2016 peak 1% AEP flood levels are higher than the ARR1987 1% AEP levels. ARR2016 flood levels are typically between 0.15 and 0.2 metres higher than the ARR1987 flood levels along the Tweed River as well as

across the residential and industrial sections of South Murwillumbah. However, the flood level differences exceed 0.4 metres along some sections of Condong Creek, Quarry Road and the adjoining cane fields to the north.

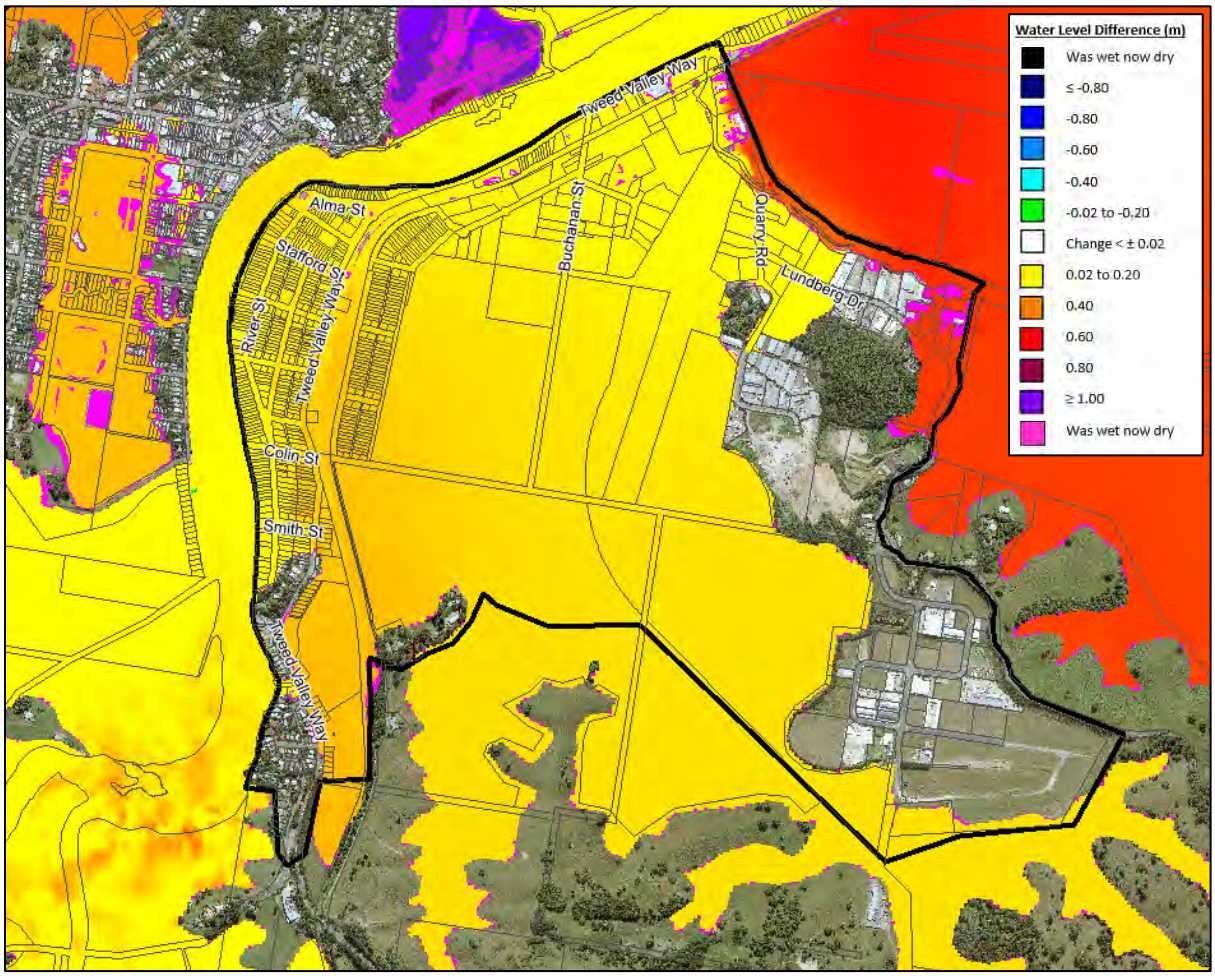


Plate 3 ARR2016 Flood Level Difference Map for 1% AEP flood

1.5 References

- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2016) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia).
- Engineers Australia (1987). Australian Rainfall and Runoff - A Guide to Flood Estimation. Edited by D. Pilgrim.

ARR2016 Data Hub Download

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	153.288
Latitude	-28.388
Selected Regions	
River Region	
ARF Parameters	
Storm Losses	
Temporal Patterns	
Areal Temporal Patterns	
Interim Climate Change Factors	

Region Information

Data Category	Region
River Region	Tweed River
ARF Parameters	East Coast North
Temporal Patterns	East Coast South

Data

River Region

division	South East Coast (NSW)
rivregnum	1
River Region	Tweed River

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2016_v1

ARF Parameters

Long Duration ARF

$$Areal\ reduction\ factor = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	East Coast North
a	0.327
b	0.241
c	0.448
d	0.36
e	0.00096
f	0.48
g	-0.21
h	0.012
i	-0.0013

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are NOT FOR USE in urban areas

id	14686.0
Storm Initial Losses (mm)	41.0
Storm Continuing Losses (mm/h)	2.8

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2016_v1

Temporal Patterns

code	ECsouth
Label	East Coast South

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2016_v2

Areal Temporal Patterns

code	ECsouth
arealabel	East Coast South

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2016_v2

BOM IFD Depths

Click here to obtain the IFD depths for catchment centroid from the BoM website

No data	No data found at this location!

Layer Info

Time Accessed	17 September 2018 08:32AM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.0 (0.051)	5.3 (0.100)	7.5 (0.120)	9.6 (0.132)	10.4 (0.119)	10.9 (0.111)
90 (1.5)	4.3 (0.093)	11.9 (0.186)	16.9 (0.220)	21.7 (0.242)	15.8 (0.145)	11.4 (0.091)
120 (2.0)	6.2 (0.119)	15.6 (0.212)	21.7 (0.244)	27.6 (0.263)	22.9 (0.178)	19.4 (0.131)
180 (3.0)	17.8 (0.282)	30.2 (0.333)	38.5 (0.346)	46.3 (0.349)	68.3 (0.418)	84.8 (0.448)
360 (6.0)	25.7 (0.283)	50.7 (0.376)	67.2 (0.401)	83.1 (0.411)	113.1 (0.451)	135.5 (0.466)
720 (12.0)	25.6 (0.190)	53.2 (0.260)	71.4 (0.279)	88.9 (0.287)	132.7 (0.348)	165.5 (0.377)
1080 (18.0)	18.9 (0.111)	45.4 (0.175)	63.0 (0.194)	79.8 (0.204)	155.2 (0.325)	211.7 (0.388)
1440 (24.0)	11.0 (0.055)	38.5 (0.127)	56.6 (0.149)	74.1 (0.162)	96.8 (0.175)	113.8 (0.182)
2160 (36.0)	12.0 (0.049)	38.9 (0.105)	56.7 (0.123)	73.8 (0.134)	90.7 (0.137)	103.3 (0.139)
2880 (48.0)	2.9 (0.010)	29.5 (0.070)	47.0 (0.091)	63.9 (0.103)	69.2 (0.094)	73.2 (0.089)
4320 (72.0)	0.0 (0.000)	7.8 (0.016)	13.0 (0.022)	18.0 (0.026)	29.4 (0.035)	37.9 (0.041)

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.892 (4.5%)**	0.775 (3.9%)	**0.979 (4.9%)**
2040	**1.121 (5.6%)**	1.002 (5.0%)	**1.351 (6.8%)**
2050	**1.334 (6.7%)**	1.28 (6.4%)	**1.765 (8.8%)**
2060	**1.522 (7.6%)**	1.527 (7.6%)	**2.23 (11.2%)**
2070	**1.659 (8.3%)**	1.745 (8.7%)	**2.741 (13.7%)**
2080	**1.78 (8.9%)**	1.999 (10.0%)	**3.249 (16.2%)**
2090	**1.825 (9.1%)**	2.271 (11.4%)	**3.727 (18.6%)**

Layer Info

Time Accessed	17 September 2018 08:32AM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

APPENDIX H

CLIMATE CHANGE ASSESSMENT

H1. Climate Change Difference Maps

2050 Conditions (10% Increase in Rainfall + 0.4 metre Increase in Sea Level)

20% AEP

The following flood level difference map was prepared by subtracting peak 20% AEP flood levels of the 'base' flood simulation from the 20% AEP simulation with 2050 climate change conditions (rainfall increased by 10% and a sea level rise of 0.4 m).

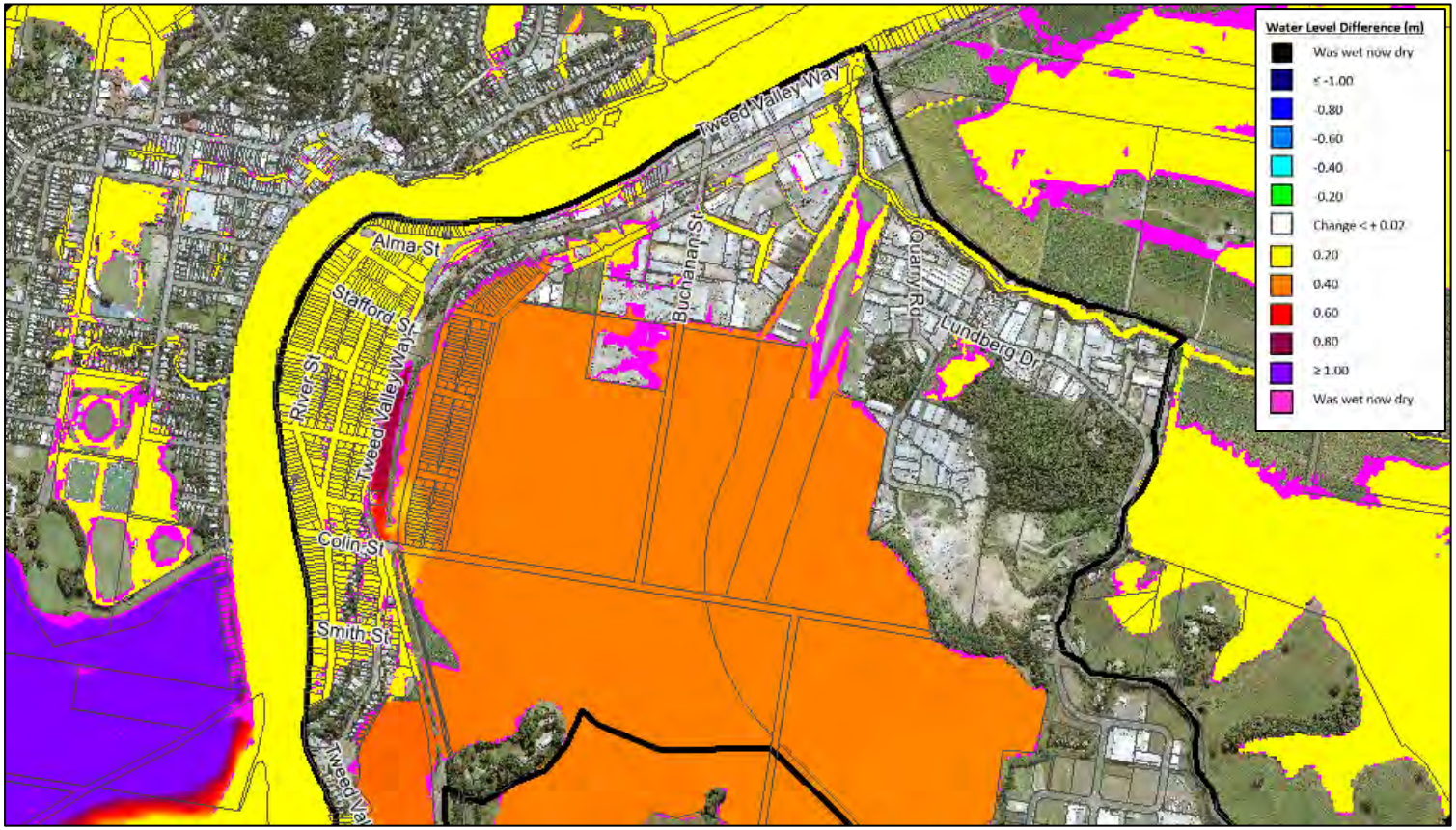


Plate H1 20% AEP Flood level difference map with 2050 Climate Change conditions

5% AEP

The following flood level difference map was prepared by subtracting peak 5% AEP flood levels of the 'base' flood simulation from the 5% AEP simulation with 2050 climate change conditions (rainfall increased by 10% and a sea level rise of 0.4 m).

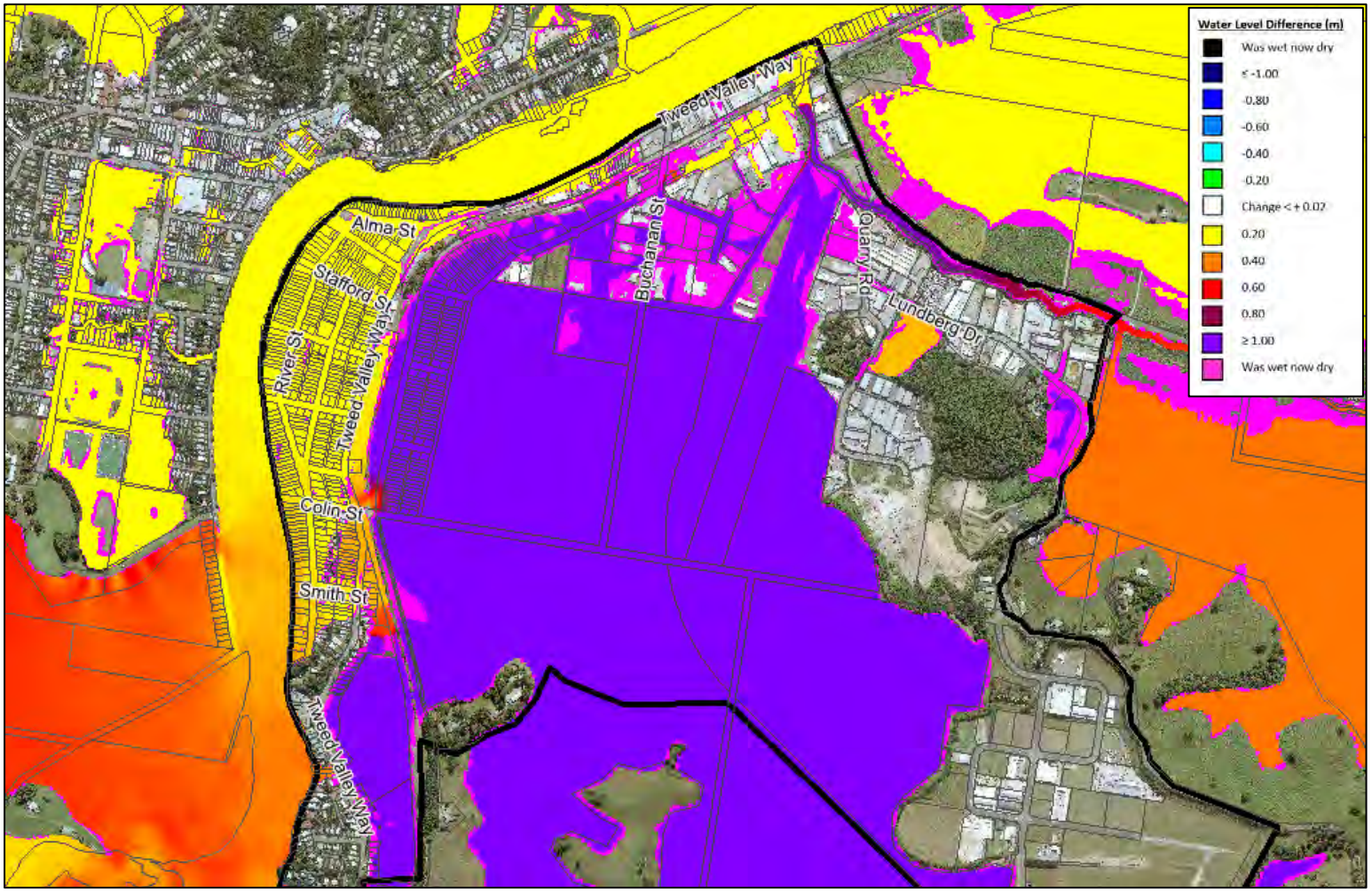


Plate H2 5% AEP Flood level difference map with 2050 Climate Change conditions

1% AEP

The following flood level difference map was prepared by subtracting peak 1% AEP flood levels of the 'base' flood simulation from the 1% AEP simulation with 2050 climate change conditions (rainfall increased by 10% and a sea level rise of 0.4 m).

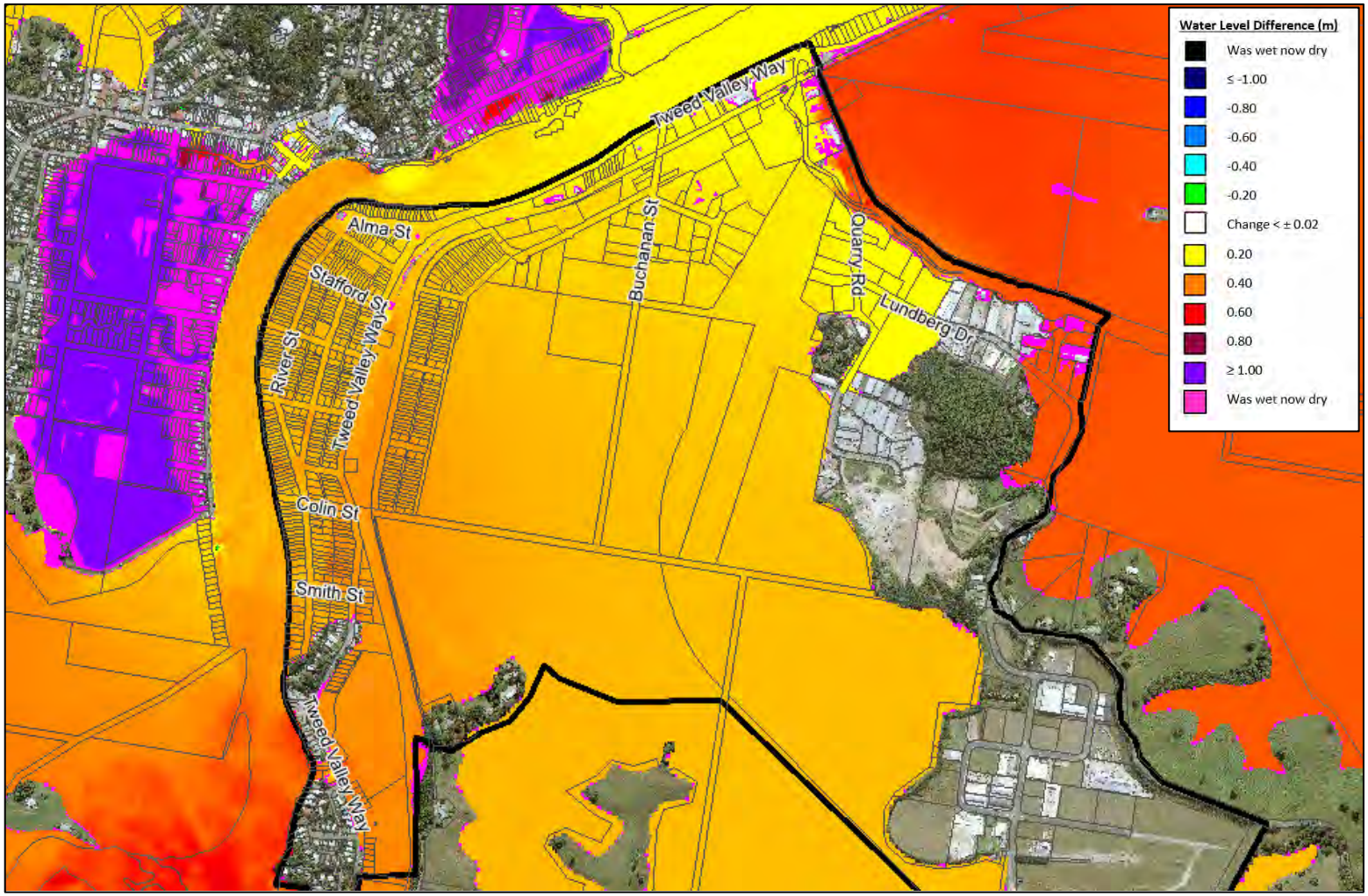


Plate H3 1% AEP Flood level difference map with 2050 Climate Change conditions

2100 Conditions (20% Increase in Rainfall + 0.9 metre Increase in Sea Level)

20% AEP

The following flood level difference map was prepared by subtracting peak 20% AEP flood levels of the 'base' flood simulation from the 20% AEP simulation with 2100 climate change conditions (rainfall increased by 20% and a sea level rise of 0.9 m).

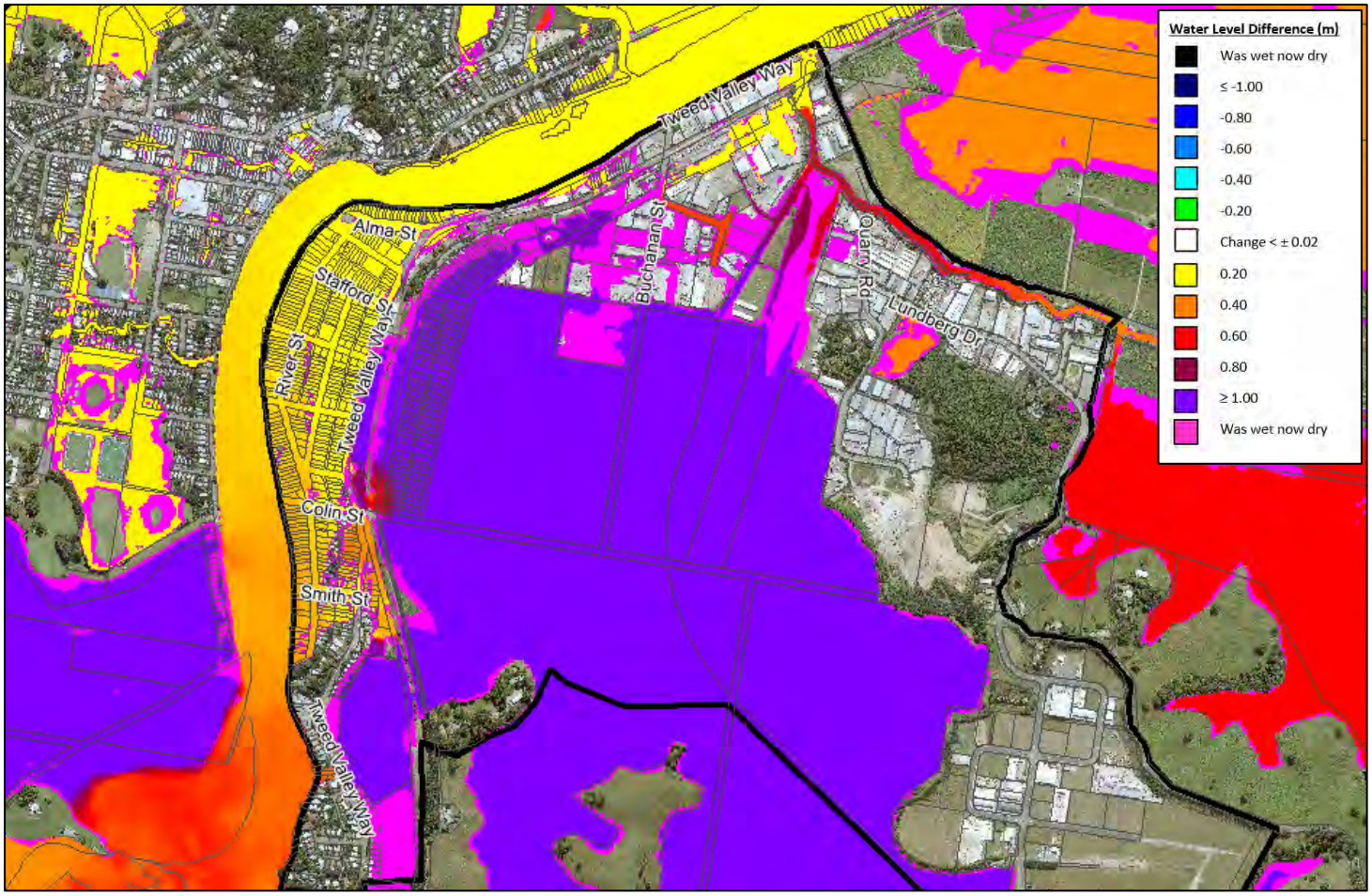


Plate H4 20% AEP Flood level difference map with 2100 Climate Change conditions

5% AEP

The following flood level difference map was prepared by subtracting peak 5% AEP flood levels of the 'base' flood simulation from the 5% AEP simulation with 2100 climate change conditions (rainfall increased by 20% and a sea level rise of 0.9 m).

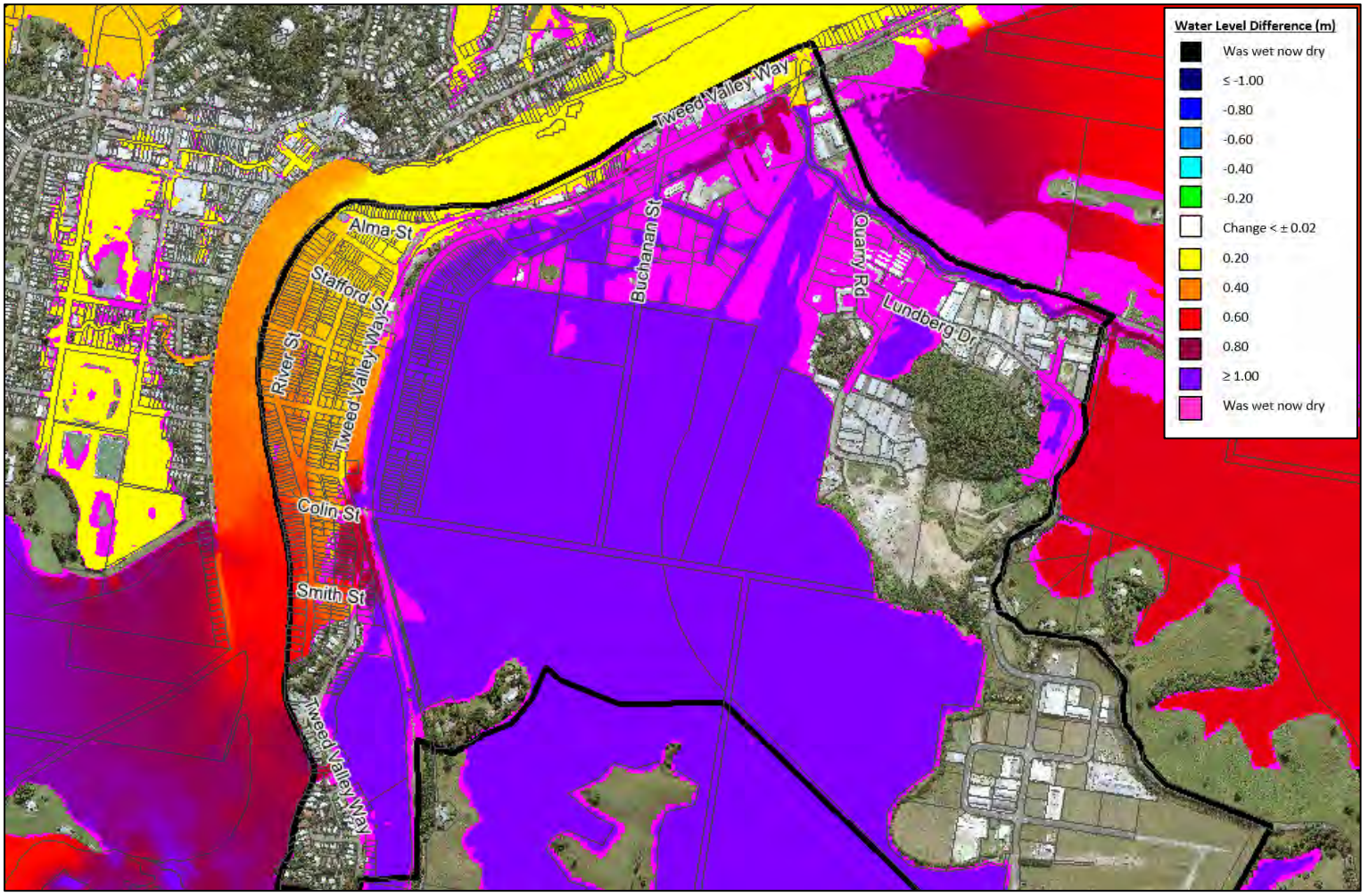


Plate H5 5% AEP Flood level difference map with 2100 Climate Change conditions

1% AEP

The following flood level difference map was prepared by subtracting peak 1% AEP flood levels of the 'base' flood simulation from the 1% AEP simulation with 2100 climate change conditions (rainfall increased by 20% and a sea level rise of 0.9 m).

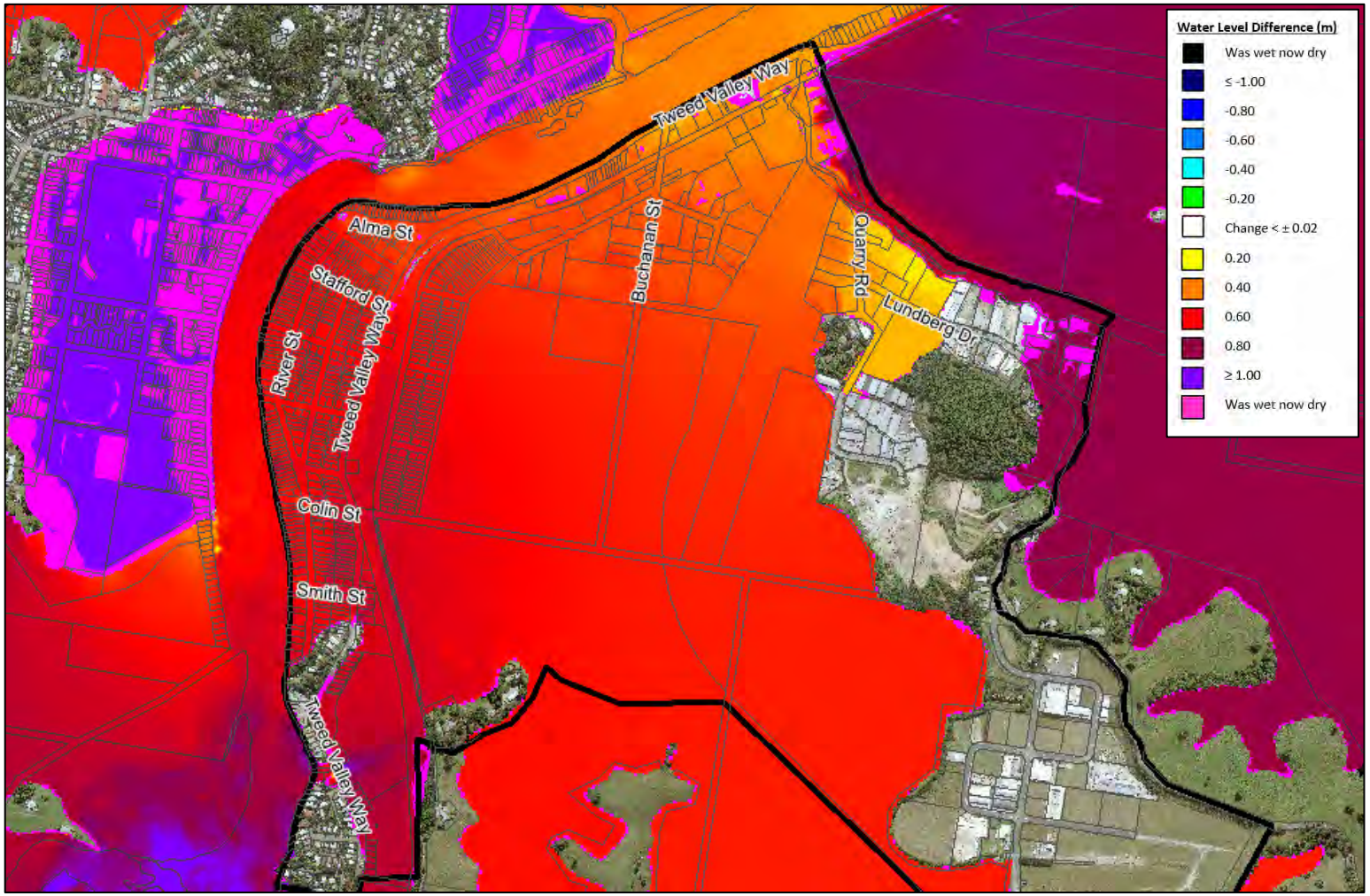
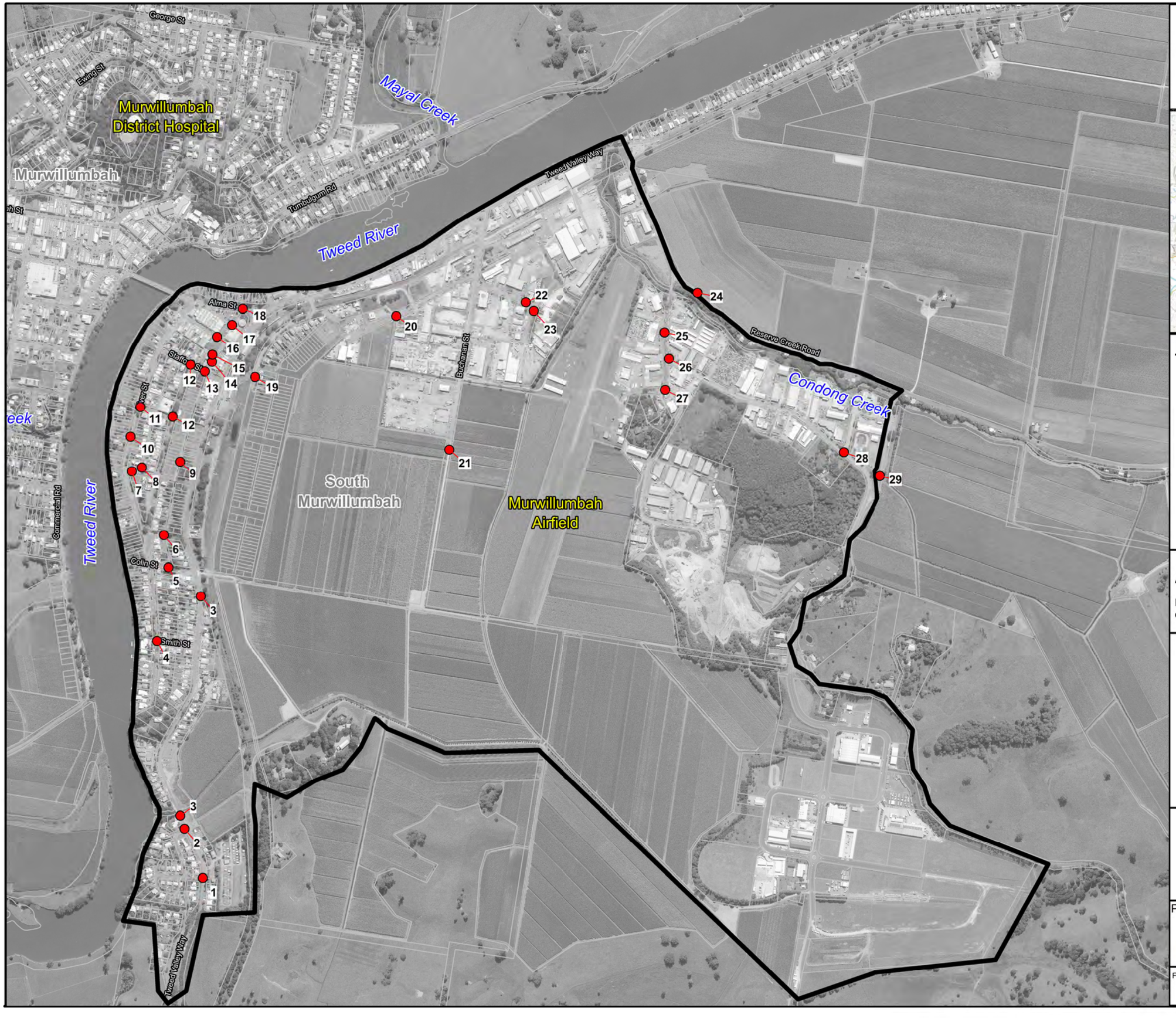


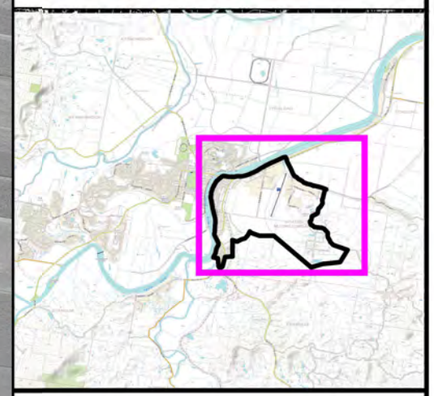
Plate H6 1% AEP Flood level difference map with 2100 Climate Change conditions

APPENDIX I

ROADWAY OVERTOPPING DETAILS



TWEED SHIRE COUNCIL



LEGEND

ID Location of First Overtopping

Notes:

Aerial photograph date: 2016

Refer to following tables for road overtopping details.

N
W E
S

0 0.35 0.70
Km

Figure I1:
Location of Road Overtopping

Prepared By:

Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name: Figure I1 - Location of Road Overtopping.wor

Road Overtopping Details (Sorted Alphabetically)

ID	Road Name	Time First Cut (hours)	Murwillumbah Bridge Gauge Height (mAHD)	Murwillumbah Gauge Height (mAHD)
27	Airfield Avenue	23	6.10	6.22
18	Alma Street	15	5.06	5.12
21	Buchanan Street	17	5.48	5.53
14	Cliffords Lane	15	5.06	5.12
5	Colin Street	15	5.06	5.12
20	Durrington Street	16	5.36	5.41
1	Gloucester Street	21	5.82	5.91
11	Greville Street	15	5.06	5.12
17	Hayes Lane	13	4.30	4.22
28	Hayley Place	23	6.10	6.22
7	Holland Street	15	5.06	5.12
15	Holstons Lane	15	5.06	5.12
23	Kay Street	16	5.36	5.41
26	Lundberg Drive	22	5.92	6.01
22	Mayfield Street	16	5.36	5.41
6	Orme Street	16	5.36	5.41
16	Prospero Street	15	5.06	5.12
25	Quarry Road	23	6.10	6.22
19	Railway Street	17	5.48	5.53
24	Reserve Creek Road	21	5.82	5.91
10	River Street	15	5.06	5.12
2	Rose Lane	21	5.82	5.91
4	Smith Street	15	5.06	5.12
13	Stafford Street	15	5.06	5.12
3	Tweed Valley Way	23	6.10	6.22
9	Unnamed Road Reserve	15	5.06	5.12
8	Wardrop Lane	15	5.06	5.12
12	Wardrop Street	16	5.36	5.41
29	Wardrop Valley Road	22	5.92	6.01

Road Overtopping Details (Sorted by Gauge Height)

ID	Road Name	Time First Cut (hours)	Murwillumbah Bridge Gauge Height (mAHD)	Murwillumbah Gauge Height (mAHD)
17	Hayes Lane	13	4.30	4.22
18	Alma Street	15	5.06	5.12
14	Cliffords Lane	15	5.06	5.12
5	Colin Street	15	5.06	5.12
11	Greville Street	15	5.06	5.12
7	Holland Street	15	5.06	5.12
15	Holstons Lane	15	5.06	5.12
16	Prospero Street	15	5.06	5.12
10	River Street	15	5.06	5.12
4	Smith Street	15	5.06	5.12
13	Stafford Street	15	5.06	5.12
9	Unnamed Road Reserve	15	5.06	5.12
8	Wardrop Lane	15	5.06	5.12
20	Durrington Street	16	5.36	5.41
23	Kay Street	16	5.36	5.41
22	Mayfield Street	16	5.36	5.41
6	Orme Street	16	5.36	5.41
12	Wardrop Street	16	5.36	5.41
21	Buchanan Street	17	5.48	5.53
19	Railway Street	17	5.48	5.53
1	Gloucester Street	21	5.82	5.91
24	Reserve Creek Road	21	5.82	5.91
2	Rose Lane	21	5.82	5.91
26	Lundberg Drive	22	5.92	6.01
29	Wardrop Valley Road	22	5.92	6.01
27	Airfield Avenue	23	6.10	6.22
28	Hayley Place	23	6.10	6.22
25	Quarry Road	23	6.10	6.22
3	Tweed Valley Way	23	6.10	6.22

Road Overtopping Details (Sorted by ID Number)

ID	Road Name	Time First Cut (hours)	Murwillumbah Bridge Gauge Height (mAHD)	Murwillumbah Gauge Height (mAHD)
1	Gloucester Street	21	5.82	5.91
2	Rose Lane	21	5.82	5.91
3	Tweed Valley Way	23	6.10	6.22
4	Smith Street	15	5.06	5.12
5	Colin Street	15	5.06	5.12
6	Orme Street	16	5.36	5.41
7	Holland Street	15	5.06	5.12
8	Wardrop Lane	15	5.06	5.12
9	Unnamed Road Reserve	15	5.06	5.12
10	River Street	15	5.06	5.12
11	Greville Street	15	5.06	5.12
12	Wardrop Street	16	5.36	5.41
13	Stafford Street	15	5.06	5.12
14	Cliffords Lane	15	5.06	5.12
15	Holstons Lane	15	5.06	5.12
16	Prospero Street	15	5.06	5.12
17	Hayes Lane	13	4.30	4.22
18	Alma Street	15	5.06	5.12
19	Railway Street	17	5.48	5.53
20	Durrington Street	16	5.36	5.41
21	Buchanan Street	17	5.48	5.53
22	Mayfield Street	16	5.36	5.41
23	Kay Street	16	5.36	5.41
24	Reserve Creek Road	21	5.82	5.91
25	Quarry Road	23	6.10	6.22
26	Lundberg Drive	22	5.92	6.01
27	Airfield Avenue	23	6.10	6.22
28	Hayley Place	23	6.10	6.22
29	Wardrop Valley Road	22	5.92	6.01

APPENDIX J

COST ESTIMATES

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM1 - Durrington Street Flow Path

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$1,950,000**
A3.1	5 property purchases					
	19 Durrington St	lump sum	1	390,000	390,000	$390,000
	21 Durrington St	lump sum	1	390,000	390,000	$390,000
	22 Durrington St	lump sum	1	390,000	390,000	$390,000
	28 Durrington St	lump sum	1	390,000	390,000	$390,000
	1 Railway St	lump sum	1	390,000	390,000	$390,000
				SUBTOTAL		**$1,970,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$25,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	5,000	5,000	$5,000
B2	**PUBLIC UTILITY ADJUSTMENTS**					**$10,000**
B2.1	Potential adjustments (allowance)	lump sum	1	10,000	10,000	$10,000
B3	**EARTHWORKS**					**$874,251**
B3.1	Production of Durrington Flowpath					
	Cut (Clay, deposit <15km)	m3	29600	16.04	18.53	$548,376
	Bank stabilisation - earth embankment allowing free vegetation growth	m2	1881	11.00	12.71	$23,898
B3.2	Preparation for culvert bank under Tweed Valley Way					
	Cut (Clay, deposit <15km)	m3	16300	16.04	18.53	$301,977
B5	**DRAINAGE**					**$4,438,088**
B5.1	2.7W x 2.1H x 25L culvert	each	29	82,500	95,288	$2,763,338
B5.2	Floodgate (Supply and Commission) - to suit 2.4m x 1.2m rectangular outlet	each	29	50,000	57,750	$1,674,750
B6	**LANDSCAPING AND REMEDIATION**					**$219,205**
B6.1	Sow Grass and water for 6 months	m2	21690	8.75	10.11	$219,205
				SUBTOTAL		**$5,566,543**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$753,654**
	- Includes surveys, site investigations and preparation of plans					
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$753,654
C2	**PROJECT MANAGEMENT**					**$979,751**
C2.1	Construction management/supervision/consultant fees	%	1	10.0		$753,654
C2.2	Project Management	%	1	3		$226,096
				SUBTOTAL		**$1,733,405**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$9,269,948**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$308,556**
D1.1	Replacement of floodgate after 25 years	each	29	9212	10639.86	$308,556
				SUBTOTAL		**$308,556**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$2,780,984**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	30		$2,780,984.27
E2	**PROJECT SCALE**					**$0**

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	E2.1	Large Scale	%	1	0		$0
	E3	**PROJECT SITE CONDITIONS**					**$1,390,492**
	E3.1	Low Congestion Factor	%	1	15		$1,390,492
	E3.2	Average terrain on site	%	0	0		$0
			ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000)			**exc GST**	**$13,750,000**

PRELIMINARY COST ESTIMATE

Description of Works — Revision: 3

FM2 - South Murwillumbah High Flow Bypass Option 1

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$3,120,000**
A3.1	8 Property Purchases (minimum)					
	74 River Street	lump sum	1	390,000	390,000	$390,000
	76 River Street	lump sum	1	390,000	390,000	$390,000
	78 River Street	lump sum	1	390,000	390,000	$390,000
	80 River Street	lump sum	1	390,000	390,000	$390,000
	387 Tweed Valley Way	lump sum	1	390,000	390,000	$390,000
	385 Tweed Valley Way	lump sum	1	390,000	390,000	$390,000
	383 Tweed Valley Way	lump sum	1	390,000	390,000	$390,000
	381 Tweed Valley Way	lump sum	1	390,000	390,000	$390,000
				SUBTOTAL		**$3,140,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$30,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
B2	**DEMOLITIONS**					**$477,654**
B2.1	Housing, including grubbing up foundations, sealing of services and removing debris	m2	1200	62.10	71.73	$86,071
B2.1.1	+ An allowance for concrete foundation slab excavation and removal	m3	176	72.90	84.20	$14,819
B2.2	Allowance for demolition and removal of miscellaneous items (eg. fencing, paving, garbage)	lump sum	1	20,000	20,000	$20,000
B2.3	Demolish existing road surface (hard rock) including dumping of waste material	m3	710	115.00	132.83	$94,306
B2.4	Demolish existing railway embankment concrete slabs and embankment protection (hard rock)	m3	88.80	115.00	132.83	$11,795
B2.5	Steel cutting and removal of the railway (allowance)	lump sum	1	10,000	10,000	$10,000
B2.6	Clearing of trees and medium vegetation	m2	4700	42.61	49.21	$231,308
B2.7	Bulk grubbing of light vegetation from site	m2	22500	0.36	0.42	$9,356
B3	**EARTHWORKS**					**$3,583,920**
B3.1	Excavate (Assuming no rock, deposit into material stockpiles onsite)	m3	19850	15.00	17.33	$343,901
B3.2	Fill from onsite deposit including compaction to 90% (Clay)	m3	7400	13.55	15.65	$115,812
B3.3	Top soil over site (300mm thick)	m2	17400	17.85	20.62	$358,731
B3.4	Cartage of leftover excavated material to landfill (<15km)	m3	12450	7.98	9.22	$114,750
B3.5	Scour Protection - concrete masonry blocks	m2	5100	450.00	519.75	$2,650,725
B4	**DRAINAGE**					**$91,314**
B4.1	Sealing existing pit	each	1	200	200	$200
B4.2	3 holes through the embankment	each	3	22,066	25,486	$76,457
B4.3	Additional drainage through the railway embankment 0.45 diameter pipes	m	54	235.00	271.43	$14,657
B5	**STRUCTURES AND ROADWORKS**					**$2,000,000**
B5.1	Bridge	lump sum	1	2,000,000	2,000,000	$2,000,000
B6	**LANDSCAPING AND REMEDIATION**					**$242,261**
B6.1	Sow Grass and water for 6 months	m2	17400	8.75	10.11	$175,849
B6.2	Fencing	m	500	115.00	132.83	$66,413
				SUBTOTAL		**$6,425,149**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$956,515**
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$956,515
C2	**PROJECT MANAGEMENT**					**$1,243,469**
C2.1	Construction management/supervision/consultant fees	%	1	10.0		$956,515
C2.2	Project Management	%	1	3		$286,954
				SUBTOTAL		**$2,199,984**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$11,765,134**

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$2,941,283**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$2,941,283
	D2	**PROJECT SCALE**					**$0**
	D2.1	Large scale	%	1	0		$0
	D3	**PROJECT SITE CONDITIONS**					**$2,941,283**
	D3.1	Medium Congestion Factor	%	1	25		$2,941,283
	D3.2	Average terrain on site	%	1	0		$0
			ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000)			**exc GST**	**$17,650,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM3 - South Murwillumbah High Flow Bypass Option 2

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$1,535,000**
A3.1	4 Property Purchases (minimum)					
	45 Wardrop Street	lump sum	1	365,000	365,000	$365,000
	52 Wardrop Street	lump sum	1	390,000	390,000	$390,000
	54 Wardrop Street	lump sum	1	390,000	390,000	$390,000
	56 Wardrop Street	lump sum	1	390,000	390,000	$390,000
				SUBTOTAL		**$1,555,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$30,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
B2	**DEMOLITIONS**					**$201,432**
B2.1	Housing, including grubbing up foundations, sealing of services and removing debris	m2	1063	62.10	71.73	$76,244
B2.1.1	+ An allowance for concrete foundation slab excavation and removal	m3	160	72.90	84.20	$13,472
B2.2	Allowance for demolition and removal of miscellaneous items (eg. fencing, paving, garbage)	lump sum	1	20,000	20,000	$20,000
B2.3	Demolish existing road surface (hard rock) including dumping of waste material	m3	195	115.00	132.83	$25,861
B2.4	Steel cutting and removal of the railway (allowance)	lump sum	1	10,000	10,000	$10,000
B2.5	Clearing of trees and medium vegetation	m2	1073	42.61	49.21	$52,807
B2.6	Bulk grubbing of light vegetation from site	m2	7330	0.36	0.42	$3,048
B3	**EARTHWORKS**					**$105,599**
B3.1	Cut (Clay, deposit <15km)	m3	5700	16.04	18.53	$105,599
B4	**STRUCTURES AND ROADWORKS**					**$1,000,000**
B4.1	Bridge	lump sum	1	1,000,000	1,000,000	$1,000,000
B5	**LANDSCAPING AND REMEDIATION**					**$113,926**
B5.1	Sow Grass and water for 6 months	m2	7330	8.75	10.11	$74,079
B5.2	Fencing	m	300	115.00	132.83	$39,848
				SUBTOTAL		**$1,450,958**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$300,596**
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$300,596
C2	**PROJECT MANAGEMENT**					**$390,775**
C2.1	Construction management/supervision/consultant fees	%	1	10.0		$300,596
C2.2	Project Management	%	1	3		$90,179
				SUBTOTAL		**$691,370**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$3,697,328**
D)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
D1	**CONTINGENCIES**					**$924,332**
D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$924,332
D2	**PROJECT SCALE**					**$0**
D2.1	Large scale	%	1	0		$0
D3	**PROJECT SITE CONDITIONS**					**$924,332**
D3.1	Medium Congestion Factor	%	1	25		$924,332
D3.2	Average terrain on site	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$5,550,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM4 - Earthworks across Lot 4 DP 591604 Quarry Road

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$20,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$10,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	5,000	5,000	$5,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	5,000	5,000	$5,000
	B1.3	Traffic Management	lump sum	0	10,000	10,000	$0
	B2	**EARTHWORKS**					**$99,745**
		Cut (Clay, deposit <15km)	m3	5384	16.04	18.53	$99,745
	B3	**LANDSCAPING AND REMEDIATION**					**$87,884**
		Sow Grass and water for 6 months	m2	8696	8.75	10.11	$87,884
					SUBTOTAL		**$197,629**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$21,763**
		- Includes surveys, site investigations and preparation of plans					
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$21,763
	C2	**PROJECT MANAGEMENT**					**$32,644**
	C2.1	Construction management/supervision/consultant fees	%	1	10.0		$21,763
	C2.2	Project Management	%	1	5		$10,881
					SUBTOTAL		**$69,407**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$287,036**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$57,407**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	20		$57,407
	D2	**PROJECT SCALE**					**$71,759**
	D2.1	Small Scale	%	1	25		$71,759
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$420,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM5 - Earthworks across Lot 4 DP 591604 and two adjoining lots on Quarry Road

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$600,000**
A3.1	Landswap 50-56 Quarry Road		1	300000	300000	$300,000
A3.1	Landswap 18-20 Quarry Road		1	300000	300000	$300,000
				SUBTOTAL		**$620,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$20,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	0	10,000	10,000	$0
B2	**EARTHWORKS**					**$1,589,437**
	Cut (Clay, deposit <15km)	m3	85794	16.04	18.53	$1,589,437
				SUBTOTAL		**$1,609,437**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$222,944**
	- Includes surveys, site investigations and preparation of plans					
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$222,944
C2	**PROJECT MANAGEMENT**					**$334,416**
C2.1	Construction management/supervision/consultant fees	%	1	10.0		$222,944
C2.2	Project Management	%	1	5		$111,472
				SUBTOTAL		**$1,172,359**
			TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)			**$3,401,796**
D)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
D1	**CONTINGENCIES**					**$680,359**
D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	20		$680,359
D2	**PROJECT SCALE**					**$0**
D2.1	Large Scale	%	1	0		$0
				ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$4,080,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM6 - Modify Terrain between River Street and Tweed River

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$10,140,000**
A3.1	Aquiring properties	lump sum	26	390000	390000	$10,140,000
				SUBTOTAL		**$10,160,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$30,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
B2	**PUBLIC UTILITY ADJUSTMENTS**					**$0**
B2.1	- Rough estimate based on size of site and expected amenities					
B3	**DEMOLITIONS**					**$969,932**
B3.1	Housing, including grubbing up foundations, sealing of services and removing debris	m2	3800	62.10	71.73	$272,557
B3.1.1	+ An allowance for concrete foundation slab excavation and removal	m3	570	72.90	84.20	$47,994
B3.2	Allowance for demolition and removal of miscellaneous items (eg. Fencing, paving, garbage)	lump sum	1	100,000.00	100,000.00	$100,000
B3.3	Demolish existing road surface (hard rock) including dumping of waste material	m3	981	115.00	132.83	$130,301
B3.4	Clearing of trees and medium vegetation	m2	8000	42.61	49.21	$393,716
B3.5	Bulk grubbing of light vegetation from site	m2	61000	0.36	0.42	$25,364
B4	**EARTHWORKS AND ROADWORKS**					**$2,266,607**
B4.1	Excavate (Assuming no rock, deposit into material stockpiles onsite)	m3	120000	15.00	17.33	$2,079,000
B4.2	Fill from onsite deposit including compaction to 90% (Clay)	m3	2600	13.55	15.65	$40,691
B4.3	Laying of new roadway (including regrade, new base, seal and new kerbs) - 8m wide composite	m	240	530	612	$146,916
B5	**DRAINAGE**					**$26,796**
B5.1	Additional floodgates	per item	3	7,000.00	8,085.00	$24,255
B5.2	Sealing existing pits	per item	11	200.00	231.00	$2,541
B6	**LANDSCAPING AND REMEDIATION**					**$0**
B6.1	Sow grass and water for 6 months	m2	61000	8.75	10.11	$616,481
				SUBTOTAL		**$3,293,335**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$1,345,333**
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$1,345,333
C2	**PROJECT MANAGEMENT**					**$1,748,934**
C2.1	Construction management/supervision/consultant fees	%	1	10.0		$1,345,333
C2.2	Project Management	%	1	3		$403,600
				SUBTOTAL		**$3,094,267**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$16,547,602**
D)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
D1	**CONTINGENCIES**					**$4,136,900**
D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$4,136,900
D2	**PROJECT SCALE**					**$0**
D2.1	Large Scale	%	1	0		$0
D3	**PROJECT SITE CONDITIONS**					**$0**
D3.1	No Congestion Factor (0%)	%	1	0		$0

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					$20,000
		ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000)			**exc GST**	**$20,680,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM7 - South Murwillumbah Levee Rehabilitation

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$20,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$20,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	0	20,000	20,000	$0
	B2	**PUBLIC UTILITY ADJUSTMENTS**					**$0**
	B2.1	No adjustments required (assumed)	lump sum	1	0	0	$0
	B3	**EARTHWORKS - MURWILLUMBAH CBD LEVEE RAISING**					**$330,834**
	B3.1	Cut existing turf into sods and keep watered for re-use	m2	10800	7.85	9.07	$97,921
	B3.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	10800	5.60	6.47	$69,854
	B3.3	Remove crest material and dispose (<15km)	m3	405	16.03	18.51	$7,498
	B3.4	Remove battering to levels appropriate to allow a proper bond between old and new works	m3	5400	5.45	6.29	$33,992
	B3.5	Batter Fill, appropriate locally sourced materials	m3	6100	13.55	15.65	$95,467
	B3.6	Placing appropriate crest cap, including compaction and treatment	m3	405	15.00	17.33	$7,017
	B3.7	Spread, level and batter top soil from onsite spoil heaps	m3	1620	10.20	11.78	$19,085
	B3.8	Spillway scour protection	m2	210	450.00	519.75	$109,148
	B4	**LANDSCAPING AND REMEDIATION**					**$112,266**
	B4.1	Laying turf and watering for 2 weeks	m2	10800	9.00	10.40	$112,266
					SUBTOTAL		**$463,100**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$48,310**
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$48,310
	C2	**PROJECT MANAGEMENT**					**$108,697**
	C2.1	Construction management/supervision/consultant fees	%	1	17.5		$84,542
	C2.2	Project Management	%	1	5		$24,155
					SUBTOTAL		**$172,007**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$655,107**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$200,000**
	D1.1	Levee maintenance (every 5 years)	lump sum	10	20,000	20,000	$200,000
					SUBTOTAL		**$200,000**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$163,777**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$163,777
	E2	**PROJECT SCALE**					**$0**
	E2.1	Large Scale	%	1	0		$0
	E3	**PROJECT SITE CONDITIONS**					**$163,777**
	E3.1	No Congestion Factor	%	1	0		$0.00
	E3.2	Difficult terrain on site	%	1	25		$163,776.79

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					$15,000
		ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000)			**exc GST**	**$1,180,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM8 - Raising South Murwillumbah Levee to 20% AEP Level + Raising the Height of the CBD Levee

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$40,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	2	5,000	5,000	$10,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	2	5,000	5,000	$10,000
	A1.4	Environmental Management Plans	lump sum	3	5,000	5,000	$15,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$1,170,000**
	A3.1	Property Acquisitions		3	390000	390000	$1,170,000
					SUBTOTAL		**$1,220,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$40,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	1	20,000	20,000	$20,000
	B2	**PUBLIC UTILITY ADJUSTMENTS**					**$1,000**
	B2.1	Potential small scale adjustments (allowance)	lump sum	1	1,000	1,000	$1,000
	B3	**EARTHWORKS - SOUTH MURWILLUMBAH LEVEE RAISING**					**$1,152,908**
	B3.1	Cut existing turf into sods and keep watered for re-use	m2	21600	7.85	9.07	$195,842
	B3.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	21600	5.60	6.47	$139,709
	B3.3	Remove crest material and dispose (<15km)	m3	810	16.03	18.51	$14,997
	B3.4	Remove battering to levels appropriate to allow a proper bond between old and new works	m3	10800	5.45	6.29	$67,983
	B3.5	Excavation, treatment and preparation of foundation	m3	1890	44.45	51.34	$97,032
	B3.6	Core Fill, appropriate locally sourced impervious materials	m3	3780	71.00	82.01	$309,979
	B3.7	Batter Fill, appropriate locally sourced materials	m3	17582	13.55	15.65	$275,163
	B3.8	Placing appropriate crest cap, including compaction and treatment	m3	810	15.00	17.33	$14,033
	B3.9	Spread, level and batter top soil from onsite spoil heaps	m3	3240	10.20	11.78	$38,170
	B4	**EARTHWORKS - MURWILLUMBAH CBD LEVEE RAISING**					**$680,126**
	B4.1	Cut existing turf into sods and keep watered for re-use	m2	22800	7.85	9.07	$206,722
	B4.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	22800	5.60	6.47	$147,470
	B4.3	Remove crest material and dispose (<15km)	m3	684	16.03	18.51	$12,664
	B4.4	Remove battering to levels appropriate to allow a proper bond between old and new works	m3	11400	5.45	6.29	$71,760
	B4.5	Batter Fill, appropriate locally sourced materials	m3	12100	13.55	15.65	$189,368
	B4.6	Placing appropriate crest cap, including compaction and treatment	m3	684	15.00	17.33	$11,850
	B4.7	Spread, level and batter top soil from onsite spoil heaps	m3	3420	10.20	11.78	$40,291
	B5	**EARTHWORKS - SOUTH MURWILLUMBAH LEVEE EXTENSION**					**$1,977,298**
	B5.1	Bulk grubbing of light vegetation from site	m2	9100	7.85	9.07	$82,507
	B5.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	1365	7.85	9.07	$12,376
	B5.3	Excavation, treatment and preparation of foundation	m3	13000	44.45	51.34	$667,417
	B5.4	Core Fill, appropriate locally sourced impervious materials	m3	10556	71.00	82.01	$865,645
	B5.5	Batter Fill, appropriate locally sourced materials	m3	21866	13.55	15.65	$342,208
	B5.6	Placing appropriate crest cap, including compaction and treatment	m3	273	15.00	17.33	$4,730
	B5.7	Spread, level and batter top soil from onsite spoil heaps	m3	205	10.20	11.78	$2,415
	B6	**EARTHWORKS AND ROADWORKS - ALMA STREET**					**$424,982**
	B6.1	Demolish existing road surface (hard rock) including dumping of waste material	m3	900	115.00	132.83	$119,543
	B6.2	Raise base fill to required elevations and compact (sand) (source < 10km)	m3	800	59	68.15	$54,516
	B6.3	Raise top soil to new road elevations	m2	500	10.50	12.13	$6,064
	B6.4	Laying of new roadway (including regrade, new base, seal and new kerbs) - 8m wide composite	m	400	530	612.15	$244,860
	B7	**DRAINAGE**					**$1,500**
	B7.1	Elevate existing pits	per item	3	500	500	$1,500
	B8	**LANDSCAPING AND REMEDIATION**					**$558,939**
	B8.1	Laying turf and watering for 2 weeks	m2	53770	9.00	10.40	$558,939
					SUBTOTAL		**$4,836,754**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$605,675**
		- Includes surveys, site investigations and preparation of plans					
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$605,675
	C2	**PROJECT MANAGEMENT**					**$1,362,770**
	C2.1	Construction management/supervision/consultant fees	%	1	17.5		$1,059,932
	C2.2	Project Management	%	1	5		$302,838

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$40,000**
					SUBTOTAL		**$3,178,445**
			TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)				**$9,235,199**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$200,000**
	D1.1	Levee maintenance (every 5 years)	lump sum	10	20,000	20,000	$200,000
					SUBTOTAL		**$200,000**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$2,308,800**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$2,308,800
	E2	**PROJECT SCALE**					**$0**
	E2.1	Large Scale	%	1	0		$0
	E3	**PROJECT SITE CONDITIONS**					**$2,308,800**
	E3.1	No Congestion Factor	%	1	0		$0.00
	E3.2	Difficult terrain on site	%	1	25		$2,308,799.65
			ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**				**$14,050,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM9 - Raising South Murwillumbah Levee to 5% AEP Level

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$40,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	2	5,000	5,000	$10,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	2	5,000	5,000	$10,000
A1.4	Environmental Management Plans	lump sum	3	5,000	5,000	$15,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$1,950,000**
A3.1	Property Acquisitions		5	390000	390000	$1,950,000
				SUBTOTAL		**$2,000,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$40,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	20,000	20,000	$20,000
B2	**PUBLIC UTILITY ADJUSTMENTS**					**$1,000**
B2.1	Potential small scale adjustments (allowance)	lump sum	1	1,000	1,000	$1,000
B3	**EARTHWORKS - SOUTH MURWILLUMBAH LEVEE RAISING**					**$1,513,437**
B3.1	Cut existing turf into sods and keep watered for re-use	m2	27000	7.85	9.07	$244,802
B3.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	27000	5.60	6.47	$174,636
B3.3	Remove crest material and dispose (<15km)	m3	810	16.03	18.51	$14,997
B3.4	Remove battering to levels appropriate to allow a proper bond between old and new works	m3	13500	5.45	6.29	$84,979
B3.5	Excavation, treatment and preparation of foundation	m3	2700	44.45	51.34	$138,617
B3.6	Core Fill, appropriate locally sourced impervious materials	m3	5400	71.00	82.01	$442,827
B3.7	Batter Fill, appropriate locally sourced materials	m3	22417	13.55	15.65	$350,832
B3.8	Placing appropriate crest cap, including compaction and treatment	m3	810	15.00	17.33	$14,033
B3.9	Spread, level and batter top soil from onsite spoil heaps	m3	4050	10.20	11.78	$47,713
B4	**EARTHWORKS - MURWILLUMBAH CBD LEVEE RAISING**					**$749,811**
B4.1	Cut existing turf into sods and keep watered for re-use	m2	25650	7.85	9.07	$232,562
B4.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	25650	5.60	6.47	$165,904
B4.3	Remove crest material and dispose (<15km)	m3	684	16.03	18.51	$12,664
B4.4	Remove battering to levels appropriate to allow a proper bond between old and new works	m3	11400	5.45	6.29	$71,760
B4.5	Batter Fill, appropriate locally sourced materials	m3	13400	13.55	15.65	$209,713
B4.6	Placing appropriate crest cap, including compaction and treatment	m3	684	15.00	17.33	$11,850
B4.7	Spread, level and batter top soil from onsite spoil heaps	m3	3850	10.20	11.78	$45,357
B5	**EARTHWORKS - SOUTH MURWILLUMBAH LEVEE EXTENSION**					**$2,233,206**
B5.1	Bulk grubbing of light vegetation from site	m2	10400	7.85	9.07	$94,294
B5.2	Strip topsoil and store in spoil heaps onsite for re-use	m2	1560	7.85	9.07	$14,144
B5.3	Excavation, treatment and preparation of foundation	m3	15600	44.45	51.34	$800,900
B5.4	Core Fill, appropriate locally sourced impervious materials	m3	11284	71.00	82.01	$925,344
B5.5	Batter Fill, appropriate locally sourced materials	m3	24986	13.55	15.65	$391,037
B5.6	Placing appropriate crest cap, including compaction and treatment	m3	273	15.00	17.33	$4,730
B5.7	Spread, level and batter top soil from onsite spoil heaps	m3	234	10.20	11.78	$2,757
B6	**EARTHWORKS AND ROADWORKS - ALMA STREET**					**$574,901**
B6.1	Demolish existing road surface (hard rock) including dumping of waste material	m3	900	115.00	132.83	$119,543
B6.2	Raise base fill to required elevations and compact (sand) (source < 10km)	m3	3000	59	68.15	$204,435
B6.3	Raise top soil to new road elevations	m2	500	10.50	12.13	$6,064
B6.4	Laying of new roadway (including regrade, new base, seal and new kerbs) - 8m wide composite	m	400	530	612.15	$244,860
B7	**DRAINAGE**					**$1,500**
B7.1	Elevate existing pits	per item	3	500	500	$1,500
B8	**LANDSCAPING AND REMEDIATION**					**$658,211**
B8.1	Laying turf and watering for 2 weeks	m2	63320	9.00	10.40	$658,211
				SUBTOTAL		**$5,772,067**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$777,207**
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$777,207
C2	**PROJECT MANAGEMENT**					**$1,748,715**
C2.1	Construction management/supervision/consultant fees	%	1	17.5		$1,360,112
C2.2	Project Management	%	1	5		$388,603

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$40,000**
					SUBTOTAL		**$4,515,922**
			TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)				**$12,287,988**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$200,000**
	D1.1	Levee maintenance (every 5 years)	lump sum	10	20,000	20,000	$200,000
					SUBTOTAL		**$200,000**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$3,071,997**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$3,071,997
	E2	**PROJECT SCALE**					**$0**
	E2.1	Large Scale	%	1	0		$0
	E3	**PROJECT SITE CONDITIONS**					**$3,071,997**
	E3.1	No Congestion Factor	%	1	0		$0.00
	E3.2	Difficult terrain on site	%	1	25		$3,071,997.08
			ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000)			**exc GST**	**$18,630,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM10 - Alma Street Modification

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$20,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$30,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
	B2	**PUBLIC UTILITY ADJUSTMENTS**					**$1,000**
	B2.1	Potential small scale adjustments (allowance)	lump sum	1	1,000	1,000	$1,000
	B3	**EARTHWORKS AND ROADWORKS**					**$134,698**
	B3.1	Demolish existing road surface (hard rock) including dumping of waste material	m3	360	115.00	132.83	$47,817
	B3.2	Raise base fill to required elevations and compact (sand) (source < 10km)	m3	113	59	68.15	$7,700
	B3.3	Cut existing turf into sods, water and store for re-use	m2	270	7.85	9.07	$2,448
	B3.4	Raise top soil to new road elevations	m2	270	10.50	12.13	$3,274
	B3.5	Laying of new roadway (including regrade, new base, seal and new kerbs) - 8m wide composite	m	120	530	612	$73,458
	B4	**STRUCTURES**					**$0**
	B4.1	No structure adjustments		1	0	0	$0
	B5	**DRAINAGE**					**$1,500**
	B5.1	Adjustments to existing pits	per item	3	500	500	$1,500
	B6	**LANDSCAPING AND REMEDIATION**					**$2,807**
	B6.1	Laying turf and watering for 2 weeks	m2	270	9.00	10.40	$2,807
					SUBTOTAL		**$170,004**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$19,000**
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$19,000
	C2	**PROJECT MANAGEMENT**					**$38,001**
	C2.1	Construction management/supervision/consultant fees	%	1	15.0		$28,501
	C2.2	Project Management	%	1	5		$9,500
					SUBTOTAL		**$57,001**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$247,006**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$61,751**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		
	D2	**PROJECT SCALE**					**$61,751**
	D2.1	Small Scale	%	1	25		$61,751
	D3	**PROJECT SITE CONDITIONS**					**$61,751**
	D3.1	Medium Congestion Factor	%	1	25		$61,751.46
	D3.2	Average terrain on site	%	1	0		$0
					SUBTOTAL		**$185,254**
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$430,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM11 - Modify Railway Embankment

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05
Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$20,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$20,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	0	10,000	10,000	$0
	B3	**EARTHWORKS**					**$343,814**
	B3.1	Excavate (Assuming % rock, includes disposal offsite)	m	90	2,586.00	2,986.83	$268,815
	B3.2	Steel cutting and removal of the railway (allowance)	lump sum	1	30,000.00	30,000.00	$30,000
	B3.3	Embankment stabilisation (concrete in situ wall)	each	2	19,480.00	22,499.40	$44,999
	B6	**LANDSCAPING AND REMEDIATION**					**$24,255**
		Sow Grass and water for 6 months	m2	2400	8.75	10.11	$24,255
					SUBTOTAL		**$388,069**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$40,807**
		- Includes surveys, site investigations and preparation of plans					
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$40,807
	C2	**PROJECT MANAGEMENT**					**$91,815**
		- Percentage of construction costs					
	C2.1	Construction management/supervision/consultant fees	%	1	17.5		$71,412
	C2.2	Project Management	%	1	5		$20,403
					SUBTOTAL		**$132,622**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$540,691**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$135,173**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$135,173
	D2	**PROJECT SCALE**					**$135,173**
	D2.1	Small scale	%	1	25		$135,173
	D3	**PROJECT SITE CONDITIONS**					**$0**
	D3.1	No Congestion Factor	%	1	0		$0
	D3.2	Average terrain on site	%	1	0		$0
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$810,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM12 - Elevate Tweed Valley Way

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with Insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$20,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$30,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
	B2	**PUBLIC UTILITY ADJUSTMENTS**					**$2,000**
	B2.1	Potential small scale adjustments (allowance)	lump sum	1	2,000	2,000	$2,000
	B3	**EARTHWORKS**					**$486,595**
	B3.1	Demolish existing road surface (hard rock) including dumping of waste material	m2	3252	32.73	37.80	$122,936
	B3.2	Raise base fill to required elevations and compact (sand) (source < 10km)	m3	1293	59	68.15	$88,111
	B3.3	Cut existing turf into sods, water and store for re-use	m2	900	7.85	9.07	$8,160
	B3.4	Laying of new roadway (including regrade, new base, seal and new kerbs) - 8m wide composite	m2	3252	60	70	$226,115
	B3.5	Regrading driveways to new elevation	m2	182	157	181.3	$33,003
	B3.6	Laying of pavement	m	80	89.5	103.37	$8,270
	B4	**STRUCTURES**					**$100,000**
	B4.1	Bridge adjustments (Allowance)	lump sum	1	100,000	100,000	$100,000
	B5	**DRAINAGE**					**$3,500**
	B5.1	Adjustments to existing pits	per item	7	500	500	$3,500
	B6	**LANDSCAPING AND REMEDIATION**					**$9,356**
	B6.1	Laying turf and watering for 2 weeks	m2	900	9.00	10.40	$9,356
					SUBTOTAL		**$631,450**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$81,431**
	C1.1	Investigation and Preparation of engineering design plans	%	1	12.5		$81,431
	C2	**PROJECT MANAGEMENT**					**$130,290**
	C2.1	Construction management/supervision/consultant fees	%	1	15.0		$97,718
	C2.2	Project Management	%	1	5		$32,573
					SUBTOTAL		**$211,721**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$863,172**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$258,952**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	30		$258,952
	D2	**PROJECT SCALE**					**$0**
	D2.1	Medium Scale	%	1	0		$0
	D3	**PROJECT SITE CONDITIONS**					**$215,793**
	D3.1	Medium Congestion Factor	%	1	25		$215,792.97
	D3.2	Average terrain on site	%	1	0		$0
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$1,340,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM13 - Dredge Tweed River Channel

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$5,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	0	5,000	5,000	$0
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	0	5,000	5,000	$0
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$5,000**
B)		**CONSTRUCTION COSTS**					
	B1	**DREDGING**					**$4,428,848**
	B1.1	Dredge setup, Dismantling and Removal	lump sum	50	30,000	34,650	$1,732,500
	B1.2	Drege material and deposit on adjoining land	m3	230000	4.20	4.85	$1,115,730
	B1.3	Dewatering (Excavate dredged material stockpile, cart, spread, level for dewatering)	m3	230000	2.95	3.41	$783,668
	B1.4	5km)	m5	230000	3.00	3.47	$796,950
C)		**OPERATION AND MAINTENANCE**					**$1,168,860**
	C1.1	Dredging Operations (assume 20% volume silt-sand redeposited/annually x 50 years) **(NPV @ 7%)**	m3	46000	10.00	11.55	$531,300
	C2.2	Spoil Management (assume 20% volume silt-sand redeposited/annually x 50 years) **(NPV @ 7%)**	m3	46000	12.00	13.86	$637,560
					SUBTOTAL		**$5,597,708**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)			**$5,602,708**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$2,241,083**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	40		$2,241,083.00
	D2	**PROJECT SCALE**					**$0**
	D2.1	Medium scale	%	1	0		$0
	D3	**PROJECT SITE CONDITIONS**					**$0**
	D3.1	No Congestion Factor	%	1	0		$0
	D3.2	Average terrain on site	%	1	0		$0
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$7,840,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM14 - Blacks Drain Modifications

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$798,188**
	A3.1	Aquiring properties	lump sum	2	390000	390000	$780,000
	A3.2	Acquiring sugar cane land	ha	2	9094.17	9094.17	$18,188
					SUBTOTAL		**$818,188**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$20,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	0	5,000	5,000	$0
	B2	**PUBLIC UTILITY ADJUSTMENTS**					**$20,000**
	B2.1	Potential adjustments (allowance)	lump sum	1	20,000	20,000	$20,000
	B3	**EARTHWORKS**					**$1,466,599**
	B3.1	Enlarge inlet Cut (Clay, deposit <15km)	m3	9300	15.31	17.68	$164,452
	B3.2	Channel modifications Cut (Clay, deposit <15km)	m3	15000	15.31	17.68	$265,246
	B3.3	Enlarge Inlet Cut (Rock, deposit <15km)	m3	1900	315.00	545.74	$1,036,901
					SUBTOTAL		**$1,506,599**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$232,479**
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$232,479
	C2	**PROJECT MANAGEMENT**					**$302,222**
	C2.1	Construction management/supervision/consultant fees	%	1	10.0		$232,479
	C2.2	Project Management	%	1	3		$69,744
					SUBTOTAL		**$534,701**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$2,859,489**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE (twice yearly x 50 years @ $7500/year)**					**$111,000**
					SUBTOTAL		**$111,000**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$1,000,821**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	35		$1,000,821.11
	E2	**PROJECT SCALE**					**$0**
	E2.1	Large Scale	%	1	0		$0
	E3	**PROJECT SITE CONDITIONS**					**$0**
	E3.1	No Congestion Factor	%	1	0		$0
	E3.2	Average terrain on site	%	1	0		$0
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$3,970,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM15 - Modify Condong Creek Channel

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
				SUBTOTAL		**$15,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$20,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	0	5,000	5,000	$0
B2	**PUBLIC UTILITY ADJUSTMENTS**					**$1,000**
B2.1	Potential small scale adjustments (allowance)	lump sum	1	1,000	1,000	$1,000
B3	**EARTHWORKS**					**$130,352**
B3.1	Cut (Clay, deposit <15km)	m3	6400	8.05	9.30	$59,506
B3.2	Fill from onsite deposit including compaction to 90% (Clay)	m3	1700	13.55	15.65	$26,605
B3.3	Cartage of leftover excavated material to landfill (<15km)	m3	4800	7.98	9.22	$44,241
				SUBTOTAL		**$151,352**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$16,635**
C1.1	Investigation and Preparation of engineering design plans	%	1	10		$16,635
C2	**PROJECT MANAGEMENT**					**$21,626**
C2.1	Construction management/supervision/consultant fees	%	1	10.0		$16,635
C2.2	Project Management	%	1	3		$4,991
				SUBTOTAL		**$38,261**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$204,613**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE (twice yearly x 50 years @ $7500/year)**					**$85,000**
				SUBTOTAL		**$85,000**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$51,153**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$51,153.28
E2	**PROJECT SCALE**					**$0**
E2.1	Large Scale	%	1	0		$0
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average terrain on site	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$340,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM16 - Condong Creek High Flow Bench

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
	A4	**PREVIOUS WORKS**					**$340,000**
	A4.1	FM8. Modify Condong Creek	lump sum	1	340000	340000	$340,000
					SUBTOTAL		**$360,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$25,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
	B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
	B1.3	Traffic Management	lump sum	1	5,000	5,000	$5,000
	B2	**PUBLIC UTILITY ADJUSTMENTS**					**$5,000**
	B2.1	Potential adjustments (allowance)	lump sum	1	5,000	5,000	$5,000
	B3	**EARTHWORKS**					**$265,558**
	B3.1	Production of High Flow Bench					
		Cut (Clay, deposit <15km)	m3	11500	16.03	18.51	$212,918
		Bank stabilisation - earth embankment allowing free vegetation growth	m2	500	11.00	12.71	$6,353
	B3.2	Preparation for culvert bank under Tweed Valley Way					
		Cut (Clay, deposit <15km)	m3	2500	16.03	18.51	$46,287
	B5	**DRAINAGE**					**$2,301,222**
	B5.1	2.1W x 1.5H x 32L culvert	each	17	67,200	77,616	$1,319,472
	B5.2	Floodgate (Supply and Commission) - to suit 2.1m x 1.5m rectangular outlet	each	17	50,000	57,750	$981,750
	B6	**LANDSCAPING AND REMEDIATION**					**$120,264**
	B6.1	Sow Grass and water for 6 months	m2	11900	8.75	10.11	$120,264
					SUBTOTAL		**$2,717,044**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN** - Includes surveys, site investigations and preparation of plans					**$307,704**
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$307,704
	C2	**PROJECT MANAGEMENT**					**$400,016**
	C2.1	Construction management/supervision/consultant fees	%	1	10.0		$307,704
	C2.2	Project Management	%	1	3		$92,311
					SUBTOTAL		**$707,720**
					TOTAL at 7% NPV (Rounded to nearest $10,000)		**$3,784,764**
					(excluding ongoing maintenance costs, contingency and project adjustments)		
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$180,878**
	D1.1	Replacement of floodgate after 25 years	each	17	9212	10639.86	$180,878
					SUBTOTAL		**$180,878**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$1,135,429**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	30		$1,135,429
	E2	**PROJECT SCALE**					**$0**
	E2.1	Large Scale	%	1	0		$0
	E3	**PROJECT SITE CONDITIONS**					**$567,715**
	E3.1	Low Congestion Factor	%	1	15		$567,715
	E3.2	Average terrain on site	%	0	0		$0
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$5,490,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM17 - High Level Condong Creek Outlet

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05
Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
	A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Environmental Management Plans (Sediment Control, Ecology)	lump sum	2	5,000	5,000	$10,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$20,000**
B)		**CONSTRUCTION COSTS**					
	B1	**PRELIMINARIES**					**$10,000**
	B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff (small scale allowance)	lump sum	1	5,000	5,000	$5,000
	B1.2	Environmental Mitigation	lump sum	1	5,000	5,000	$5,000
	B2	**CROSS DRAINAGE**					**$100,000**
	B2.1	Appropriate temporary waterway adjustment (Allowance)	each	1	100,000	100,000	$100,000
	B3	**STRUCTURES**					**$462,000**
	B3.1	Floodgate & culverts (Supply and Commission) - to suit 2.4m x 1.2m rectangular outlet	each	8	50,000	57,750	$462,000
					SUBTOTAL		**$572,000**
C)		**MANAGEMENT AND DESIGN**					
	C1	**ENGINEERING DESIGN**					**$59,200**
	C1.1	Investigation and Preparation of engineering design plans	%	1	10		$59,200
	C2	**PROJECT MANAGEMENT**					**$88,800**
	C2.1	Construction management/supervision/consultant fees	%	1	10.0		$59,200
	C2.2	Project Management	%	1	5		$29,600
					SUBTOTAL		**$168,000**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$760,000**
D)		**ONGOING MAINTENANCE COSTS**					
	D1	**MAINTENANCE**					**$85,119**
	D1.1	Replacement of floodgate after 25 years	each	8	9212	10639.86	$85,119
					SUBTOTAL		**$85,119**
E)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	E1	**CONTINGENCIES**					**$190,000**
	E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$190,000
	E2	**PROJECT SCALE**					**$190,000**
	E2.1	Small Scale	%	1	25		$190,000
	E3	**PROJECT SITE CONDITIONS**					**$0**
	E3.1	No Congestion Factor	%	1	0		$0
	E3.2	Average terrain on site	%	1	0		$0
					ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**		**$1,230,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM18 - South Murwillumbah High Flow Bypass Option 1 and Industrial Land Swap Option 1B

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**OTHER WORKS**					**$28,880,000**
A1.1	FM2 - South Murwillumbah Bypass Option 1		1	17650000	17650000	$17,650,000
A1.2	PM3 - Land Swap Option A2		1	11230000	11230000	$11,230,000
				SUBTOTAL		**$28,880,000**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$28,880,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM19 - Levee Raising to 5% AEP Level, Condong Creek Modifications and Industrial Land Swap Option 1A

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**OTHER WORKS**					**$25,570,000**
A1.1	FM9 - Raise South Murwillumbah Levee to 5% AEP Level + Raising the Height of CBD Levee		1	18630000	18630000	$18,630,000
A1.2	FM15 - Modify Condong Creek Channel		1	340000	340000	$340,000
A1.3	PM3 - Land Swap Option A1		1	6600000	6600000	$6,600,000
				SUBTOTAL		**$25,570,000**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$25,570,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

FM20 - Raising South Murwillumbah Levee to 20% AEP Level, Raise CBD Levee, Condong Creek Modifications and Lot 4 Quarry Road Earthworks

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**OTHER WORKS**					**$14,810,000**
A1.1	FM8 - Raise South Murwillumbah Levee to 20% AEP Level + Raising the Height of CBD Levee		1	14050000	14050000	$14,050,000
A1.2	FM15 - Modify Condong Creek Channel		1	340000	340000	$340,000
A1.3	FM4 - Lot 4 Quarry Road Earthworks		1	420000	420000	$420,000
				SUBTOTAL		**$14,810,000**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$14,810,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

PM3 - Land Swap Option 1A

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**PROPERTY ACQUISITIONS**					**$6,600,000**
A1.1	Land Swap Option 1A Allowance		1	6600000	6600000	$6,600,000
					SUBTOTAL	**$6,600,000**
				TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)		**$6,600,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

PM3 - Land Swap Option 1B

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**PROPERTY ACQUISITIONS**					**$6,600,000**
A1.1	Land Swap Option 1A Allowance		1	6600000	6600000	$6,600,000
				SUBTOTAL		**$6,600,000**
B)	**CONSTRUCTION COSTS**					
B1	**EARTHWORKS**					**$4,633,277**
B1.1	Excavate (Assuming no rock, deposit into material stockpiles onsite)	m3	267433	15.00	17.33	$4,633,277
				SUBTOTAL		**$4,633,277**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$11,230,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

PM3 - Land Swap Option 2A

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**PROPERTY ACQUISITIONS**					**$13,200,000**
A1.1	Land Swap Option 2A Allowance		1	13200000	13200000	$13,200,000
					SUBTOTAL	**$13,200,000**
					TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)	**$13,200,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 3

PM3 - Land Swap Option 2B

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.05

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**PROPERTY ACQUISITIONS**					**$13,200,000**
A1.1	Land Swap Option 2A Allowance		1	13200000	13200000	$13,200,000
				SUBTOTAL		**$13,200,000**
B)	**CONSTRUCTION COSTS**					
B1	**EARTHWORKS**					**$6,803,857**
B1.1	Excavate (Assuming no rock, deposit into material stockpiles onsite)	m3	392719	15.00	17.33	$6,803,857
				SUBTOTAL		**$6,803,857**
			TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)			**$20,000,000**

APPENDIX K

PUBLIC EXHIBITION SUBMISSIONS

Submission Number	Submission Summary	Response
1	Submission asked what impact the levee raising was predicted to have on downstream towns?	As shown in Plates 23 to 30 in sections 5.3.1 to 5.3.3 of the report, the model results are not showing any increases in water levels for populated areas located downstream of South Murwillumbah.
	Questioned whether raising of the levees removes the amenity value and use of the river?	The extent of any impacts on the amenity afforded by a levee upgrade is largely driven by the height of any levee upgrade. Any further investigation into the levee raising options will need to carefully balance the level of protection afforded by any levee raising with the potential loss of amenity value.
	Submission had no issues with the suggested voluntary purchase properties or the building restrictions in flood zones	No action required
2	Submission questioned why the levee raising was predicted to result in flood level increases across residential areas located south of Smith Street.	Elevating the levee results in more water being contained in the Tweed River channel, resulting in flood level increases in the channel. These increased levels result in more water spilling into some sections of South Murwillumbah even with the extended/elevated levee
	Also requested that any additional investigation into option FM8 consider design options for the levee to ensure no increased flood impacts to these properties on River St south of Smith St.	A key outcome from any future design investigation will be ensuring that no property will be adversely impacted as a result of implementation of a potential flood risk mitigation measure. It is likely that further elevating the levee will help to overcome the flood level increases that are predicted with the current concept.
3	Recommended that modification to the Condong Creek flood gate be considered. Submission included a suggested design.	A concept similar to that suggested as part of this submission was considered as part of this study (refer discussion included in 5.6.3). This determined that modifications to the flood gates would afford small benefits during the rising and falling limb of the flood hydrograph but would provide minimal benefits at the peak of the flood.
4	Submission noted that the use of 600mm rock armour along the river is not a suitable fix. It is understood that this comment relates to levee remediation works that were being completed at the time this study was being prepared.	Comment not associated with any option being investigated as part of the current Floodplain Risk Management Study. Therefore, no action taken.

	Recommended that options need to plan and build for a major event, not just a 5 year event.	This comment is acknowledged and is a key consideration of any floodplain risk management study (i.e., ensuring the flood risk is best managed across the full range of floods that could occur). This is reflected in the study by the breadth of options that were investigated targeting both frequent and rarer floods (e.g., raising of Alma Street versus South Murwillumbah high Flow Bypass). It is often not practical or cost effective to implement structural options that target particularly big floods such as the PMF. This is where emergency response options such as flood warning system become more efficient and cost effective. It is only through this balance of structural and non-structural options that we can best manage the full risk of flooding
5	Submission noted that the use of 600mm rock armour along the river is not suitable for the lee and eddies within the river course. It is understood that this comment relates to levee remediation works that were being completed at the time this study was being prepared.	As discussed in response to submission #4, this comment is not relevant to Floodplain Risk Management Study.
	Submission recommended that on the bends along Tweed River that there be tiered gabion cages that provide better "stitching" of the riverbank and protection during rapid and large volume movements, not just floods.	Although an option such as this is likely to reduce the potential for significant erosion, it is likely to have minimal hydraulic benefits during large floods which is the focus of the current study. Therefore, no specific modifications were completed to the report to address this comment. However, the suggestion was forwarded to Council for consideration outside of the floodplain risk management program.