Attachment 7

Phase 1 Model Extension Result Memo

Stage 1B –
Summary of results from TUFLOW Model Extension

Table of contents

Table index

Figure index

1. Project Diary

Table 1 summarises of the agreed model refinements carried out on the Lower Yarra River Flood Mapping TUFLOW model since the delivery of the 'Draft Deliverables' in February 2020.

Table 1 Progression of Model Refinement

Date	Time	Description\Outcome
23-04-2020	9:00 am	Skype meeting to discuss the Lower Yarra mapping limit
28-04-2020	5:29 pm	Emailed proposal $#####
29-04-2020	8:30 am	Meeting to discuss scope for Lower Yarra
29-04-2020	12:58 pm	Revised proposal $#####
29-04-2020	3:24 pm	MW accepted revised proposal
06-05-2020	10:19 pm	GHD provide Stage 1A results
07-05-2020	10:00 am	Discussion of stage 1A results
07-05-2020	3:30 pm	Meeting to discuss next steps
08-05-2020	10:07 am	Email to MW clarifying scope, fees and discussions with NELP
08-05-2020	2:50 pm	Emails back and forth, MW emailed NELP with formal request
08-05-2020	3:12 pm	MW confirm request for all 6 runs.
12-05-2020	2:57 pm	GHD provide results for the additional 6 runs
13-05-2020	8:30 am	Meeting to discuss results
13-05-2020	3:11 pm	GHD provided email to summarise revised scope
14-05-2020	3:21 pm	MW request information of the 10year tidal boundary time series
14-05-2020	3:45 pm	GHD referred MW to Appendix C of the report
15-05-2020	7:17 am	MW requested GHD to proceed in accordance with revised scope (13/5)
15-05-2020	3:58 pm	MW provide additional info on 1934 event
15-05-2020	4:10 pm	GHD advised that we had responded to NELP and expected that NELP would advise MW of their decision
18-05-2020	6:00 pm	NELP approve use of existing conditions TUFLOW and RORB models for MW
03-06-2020	**6:46 am**	**MW approve Lower Yarra model extension up to top of NELP 'existing' conditions model**

2. Preliminary Results for Discussion

2.1 Modelled Scenarios

Table 2 summarises the modelled scenarios completed since the initial overflow refinement modelling, which added terrain details from the Southbank and Fisherman's Bend TUFLOW models, a new boundary condition at the City Link portal in Southbank area, and a DS tidal boundary based on 10% AEP. We have now added a colum relating to scenarios run with the extended model

Table 2 Modelled Scenarios

Run ID	Hydrology	Yarra River Inflow (m^3/s)	Yarra River Inflow Volume (m^3)	DS TWL	River Roughness (Manning's 'n')	Plot Legend	Modelled with 4400_v24_OR? (refined version of 4400_v24)	Modelled with 4400_v26? (extended version of 4400_v24_OR)
1	Base 1% AEP (Kc=145 w/o ARFs)[1] [Solid blue line on Figure 1]	1475	517,000,000	10% AEP Tide	0.015	100y Kc145 NoARF M0p015 (Current)	Y	N
2	Base 1% (Kc=237 w/o ARFs)[2] [Solid orange line on Figure 1]	1115	517,000,000	10% AEP Tide	0.015	100y Kc237 NoARF M0p015	Y	N
3	Base 1% AEP (Kc=180 w/ ARFs)[3] [Solid green line on Figure 1]	1091	432,000,000	10% AEP Tide	0.015	100y Kc180 ARF M0p015	Y	N
4	CC 18.5% 1% AEP (Kc=145 w/o ARFs)[1] [Dashed blue line on Figure 1]	1792	621,000,000	10% AEP SLR Tide	0.015	100y CC18p5 Kc145 NoARF M0p015 (Current)	Y	N
5	CC 18.5% 1% AEP (Kc=237 w/o ARFs)[2] [Dashed green line on Figure 1]	1352	621,000,000	10% AEP SLR Tide	0.015	100y CC18p5 Kc237 NoARF M0p015	Y	N
6	CC 18.5% 1% AEP (Kc=180 w ARFs)[3] [Dashed green line on Figure 1]	1293	509,000,000	10% AEP SLR Tide	0.015	100y CC18p5 Kc180 ARF M0p015	Y	N
7	Base 1% AEP (Kc=180 w/ ARFs)[3]	-	-	10% AEP Tide	0.020	100y Kc180 ARF M0p020	Y	Y
8	Base 1% AEP (Kc=180 w/ ARFs)[3]	-	-	10% AEP Tide	0.025	100y Kc180 ARF M0p025	Y	Y
9	Base 1% AEP (Kc=180 w/ ARFs)[3]	-	-	10% AEP Tide	0.030	100y Kc180 ARF M0p030	Y	N

Run ID	Hydrology	Yarra River Inflow (m^3/s)	Yarra River Inflow Volume (m^3)	DS TWL	River Roughness (Manning's 'n')	Plot Legend	Modelled with 4400_v24_OR? (refined version of 4400_v24)	Modelled with 4400_v26? (extended version of 4400_v24_OR)
10	CC 18.5% 1% AEP (Kc=180 w ARFs)[3]	-	-	10% AEP SLR Tide	0.020	100y CC18p5 Kc180 ARF M0p020	Y	N
11	CC 18.5% 1% AEP (Kc=180 w ARFs)[3]	-	-	10% AEP SLR Tide	0.025	100y CC18p5 Kc180 ARF M0p025	Y	N
12	CC 18.5% 1% AEP (Kc=180 w ARFs)[3]	-	-	10% AEP SLR Tide	0.030	100y CC18p5 Kc180 ARF M0p030	Y	N
13	CC 18.5% 10% AEP (Kc=145 w/o ARFs)[1]	831	291,000,000	10% AEP SLR Tide	0.015	10y Kc145 NoARF M0p015 (Current)	Y	N
14	CC 18.5% 10% AEP (Kc=180 w ARFs)[3]	616	246,000,000	10% AEP SLR Tide	0.020	10y CC18p5 Kc180 ARF M0p020	Y	N
15	CC 18.5% 10% AEP (Kc=180 w ARFs)[3]	616	246,000,000	10% AEP SLR Tide	0.030	10y CC18p5 Kc180 ARF M0p030	Y	N
16	Base 1% AEP (Kc=145 w/o ARFs)[1] [Solid blue line on Figure 1]	1475	517,000,000	10% AEP Tide	0.020	100y Kc145 NoARF M0p020	N	Y
17	Base 1% AEP (Kc=145 w/o ARFs)[1] [Solid blue line on Figure 1]	1475	517,000,000	10% AEP Tide	0.025	100y Kc145 NoARF M0p025	N	Y

Note:

[1] indicates that the Kc parameter is based on calibration to flood levels using HEC-RAS from "2010 - SP Goh & Associates Study", which didn't use ARFs.

[2] indicates that the Kc parameter is based on calibration to gauge flows from "2010 - SP Goh & Associates Study" , which didn't use ARFs

[3] indicates that the Kc parameter is based on MW work prior to "2010 - SP Goh & Associates Study", but with the application of ARFs

2.2 Yarra River Boundary Conditions

Figure 2-1 and Figure 2-2 summarise the key boundary condition assumptions for the modelling presented in Section 2.1.

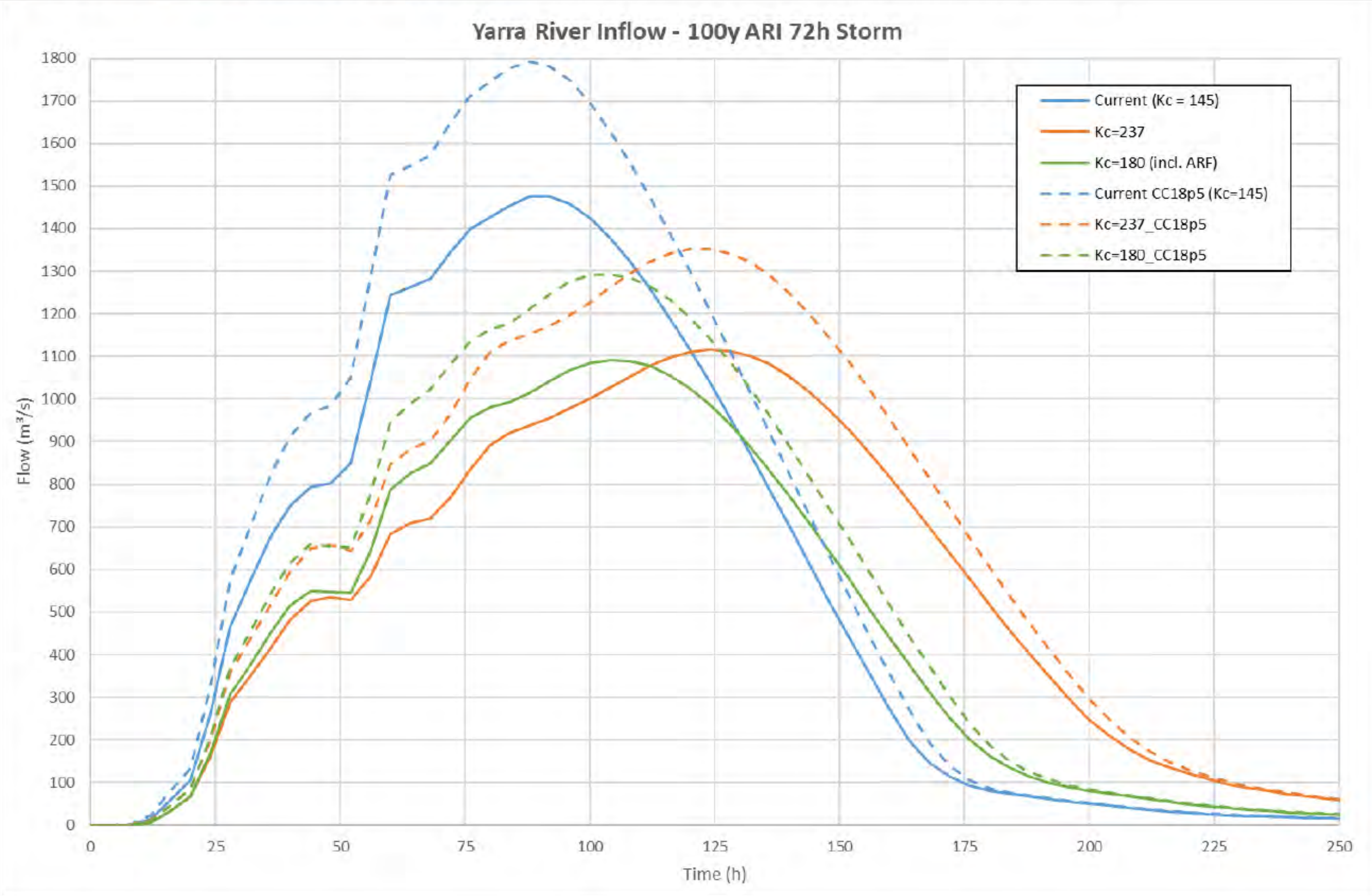


Figure 2-1 Comparison of Yarra Inflows

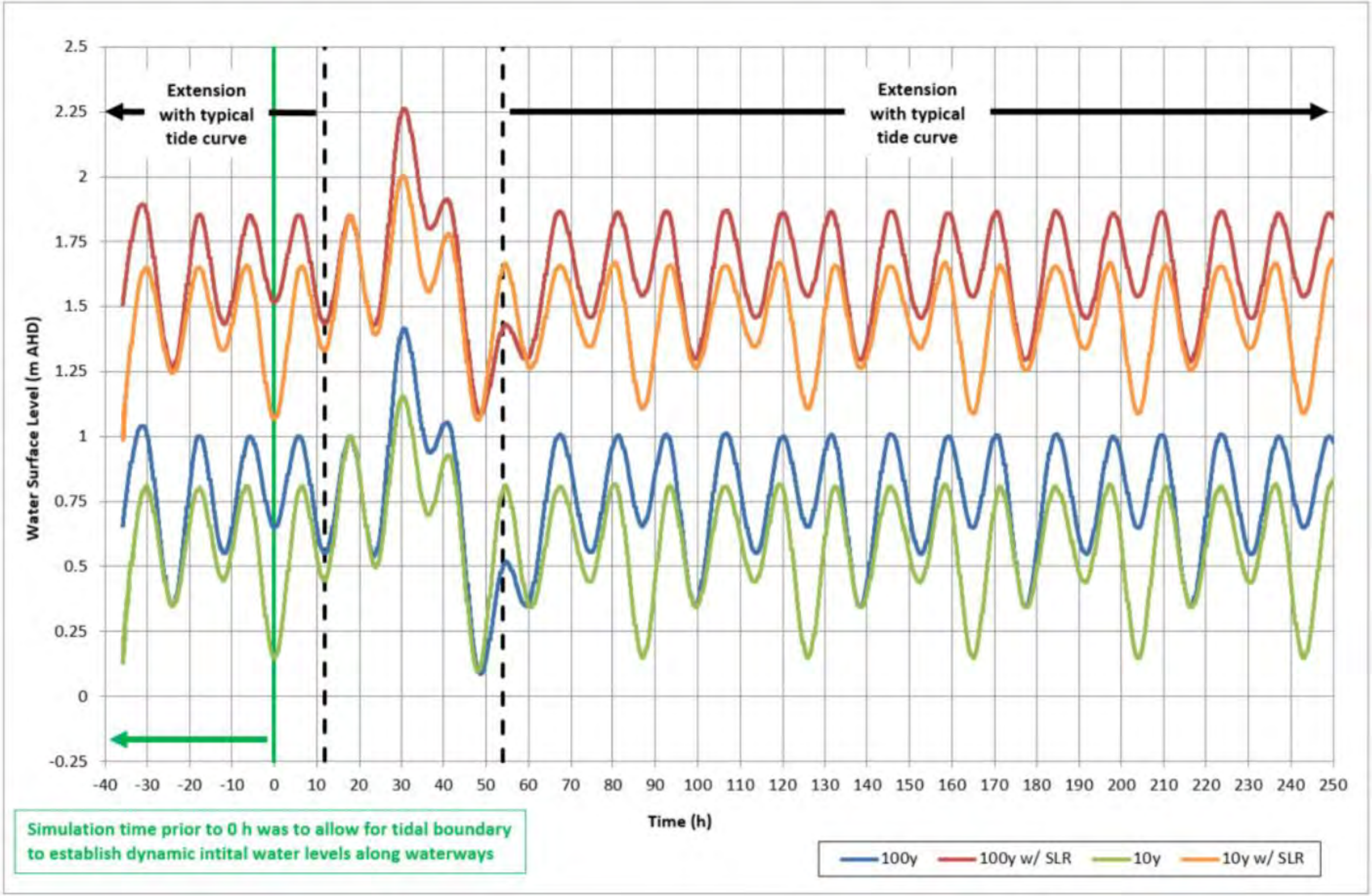


Figure 2-2 Adopted Yarra River DS Tidal Boundary Curves

2.3 Flood Extents (extended model results only)

2.3.1 Run 7

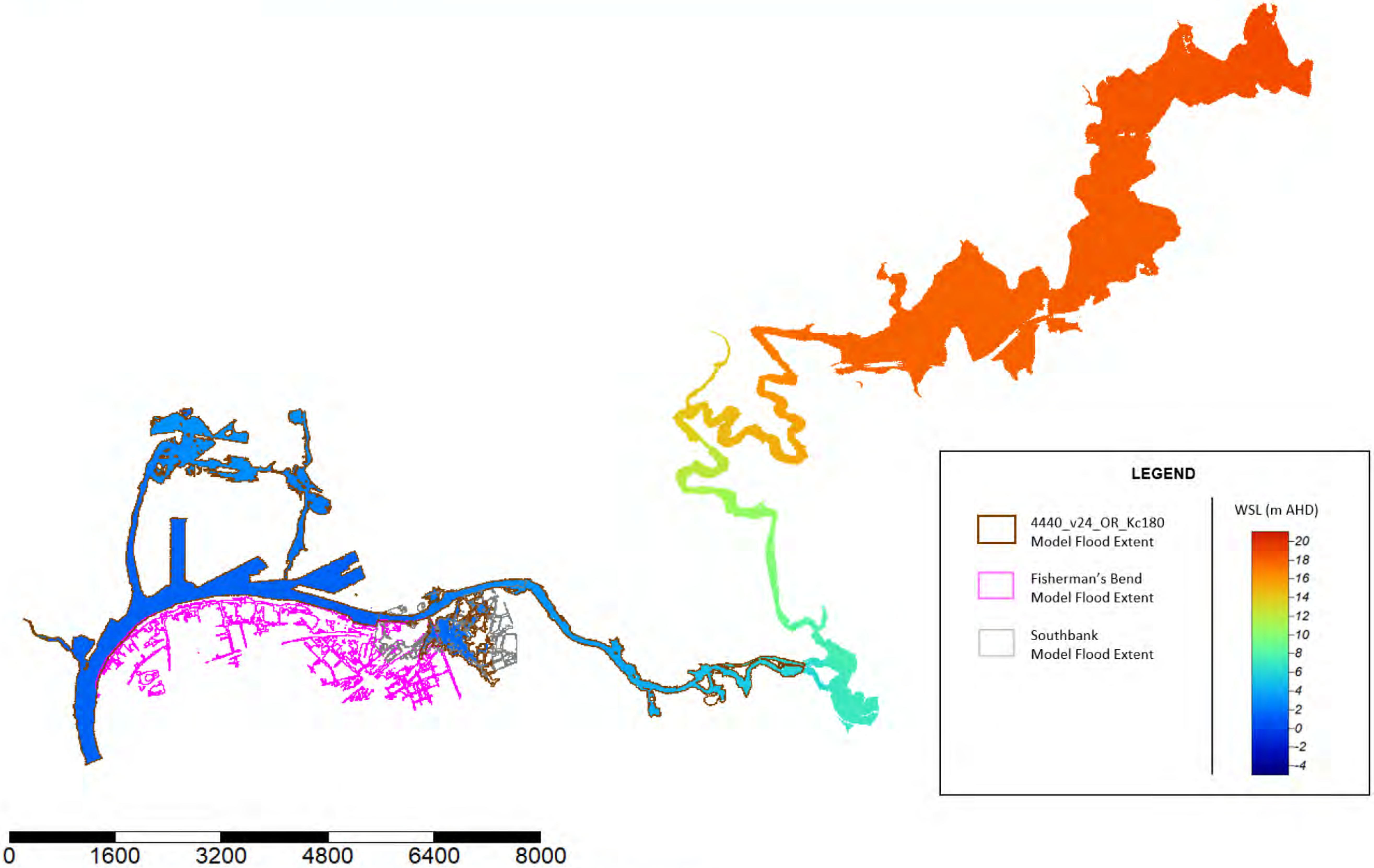


Figure 2-3 Peak 100y WSL Current (Kc=180 w/ ARFs, 10y Tide & River Manning's 'n' of 0.020)

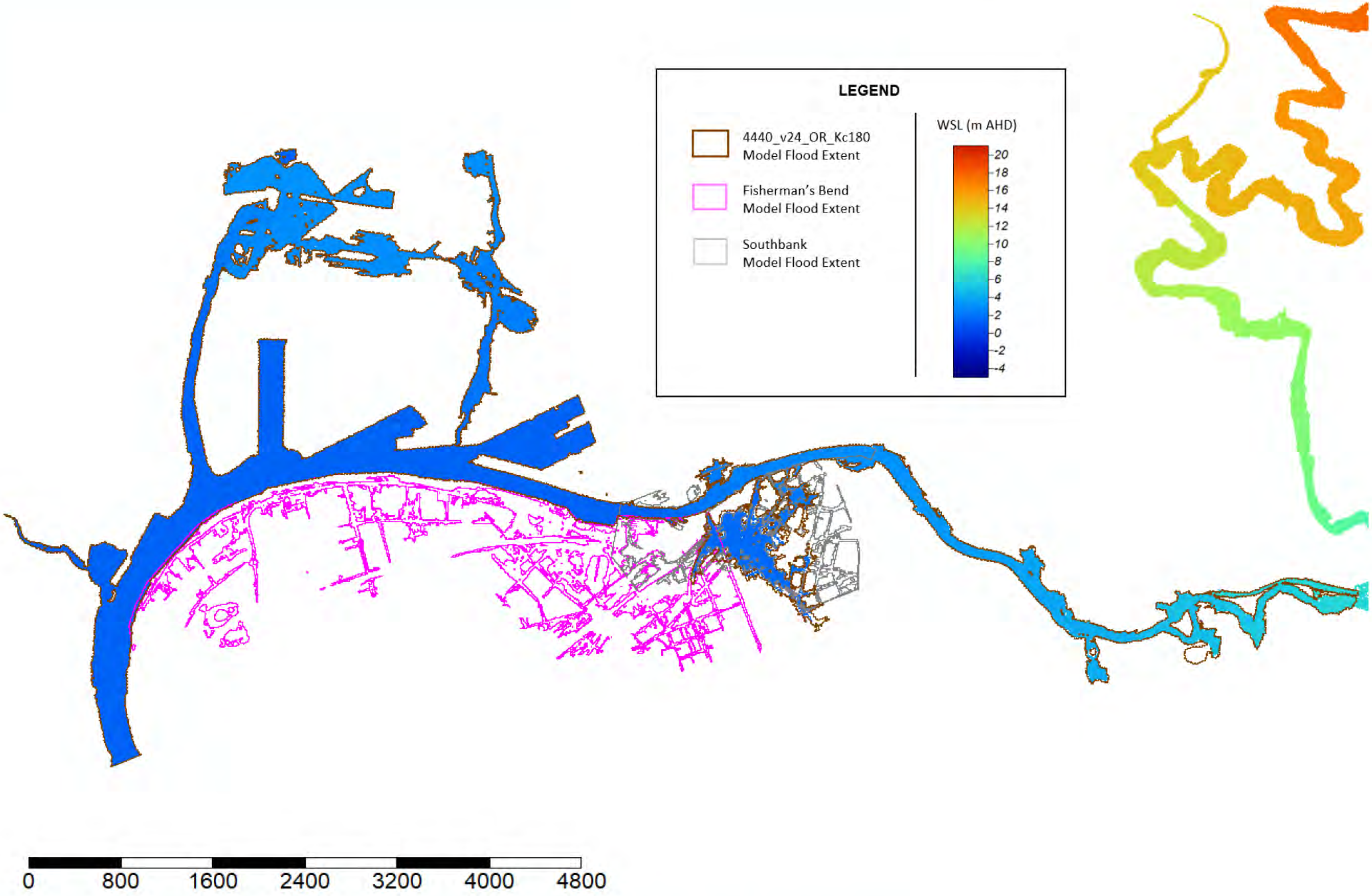


Figure 2-4 Peak 100y WSL Current (Kc=180 w/ ARFs, 10y Tide & River Manning's 'n' of 0.020– Zoomed to refinement area

2.3.2 Run 8

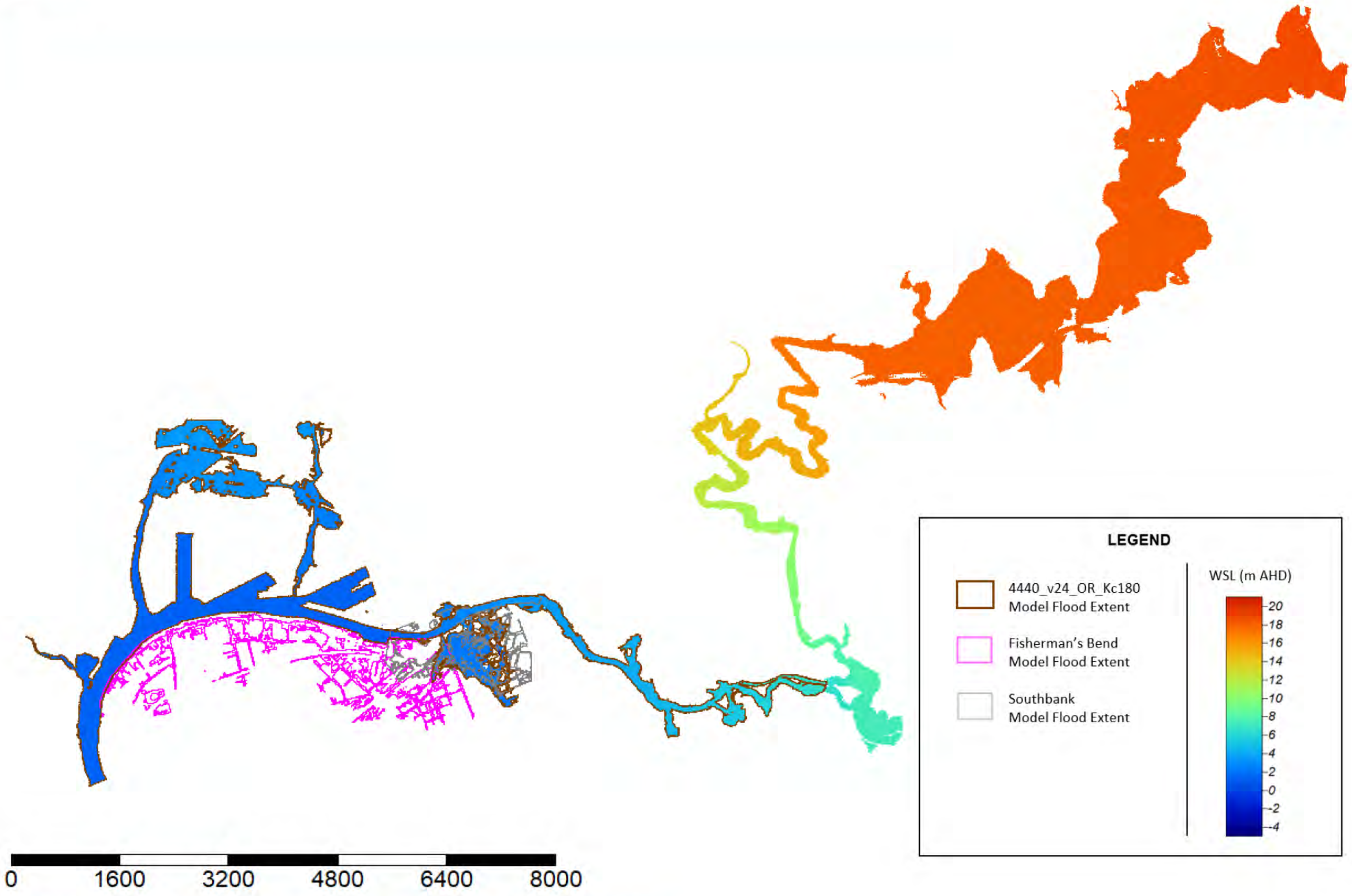


Figure 2-5 Peak 100y WSL Current (Kc=180 w/ ARFs, 10y Tide & River Manning's 'n' of 0.025)

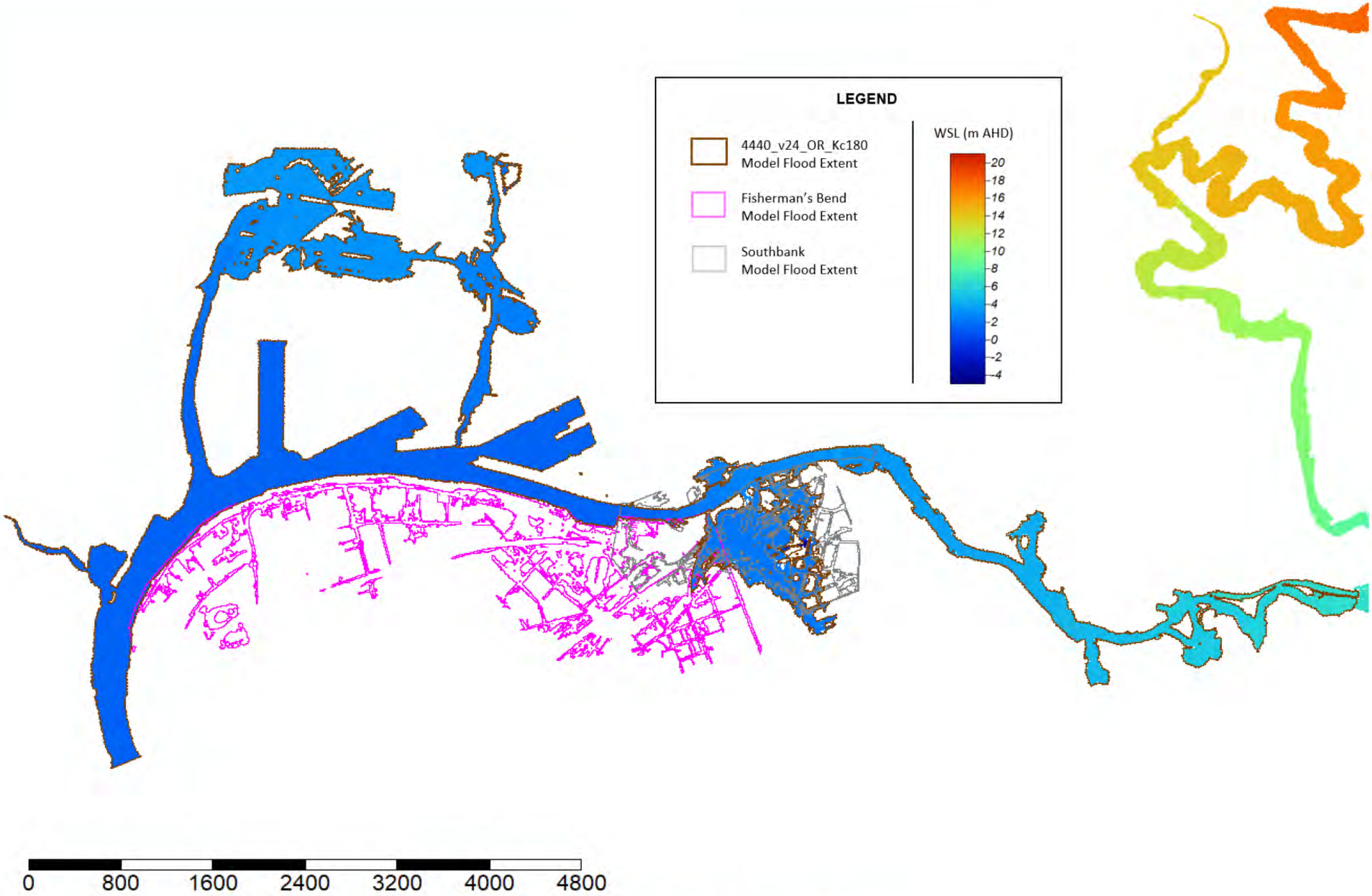


Figure 2-6 Peak 100y WSL Current (Kc=180 w/ ARFs, 10y Tide & River Manning's 'n' of 0.025) – Zoomed to refinement area

2.3.3 Run 16

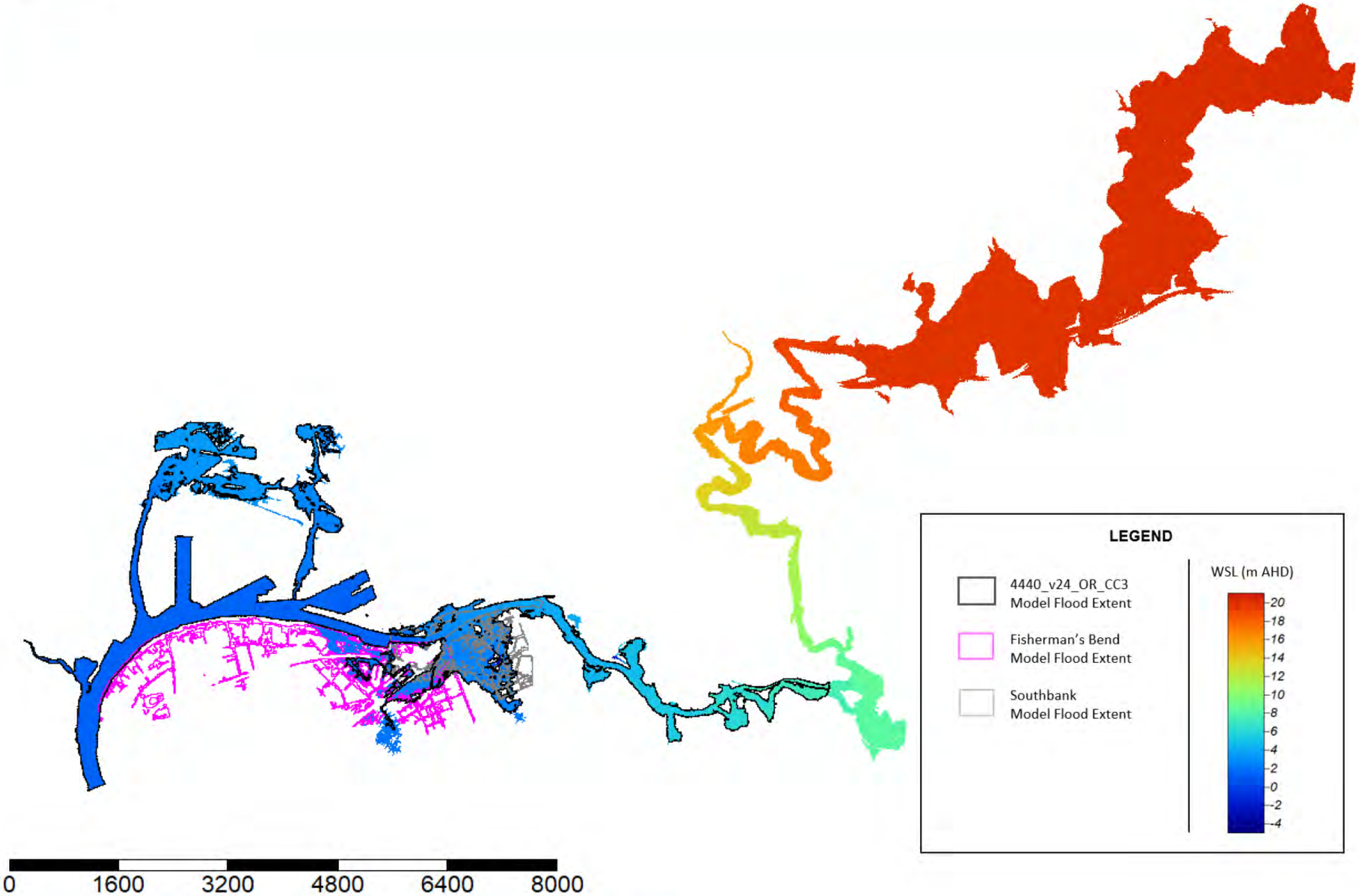


Figure 2-7 Peak 100y WSL Current (Kc=145 w/o ARFs, 10y Tide & River Manning's 'n' of 0.020)

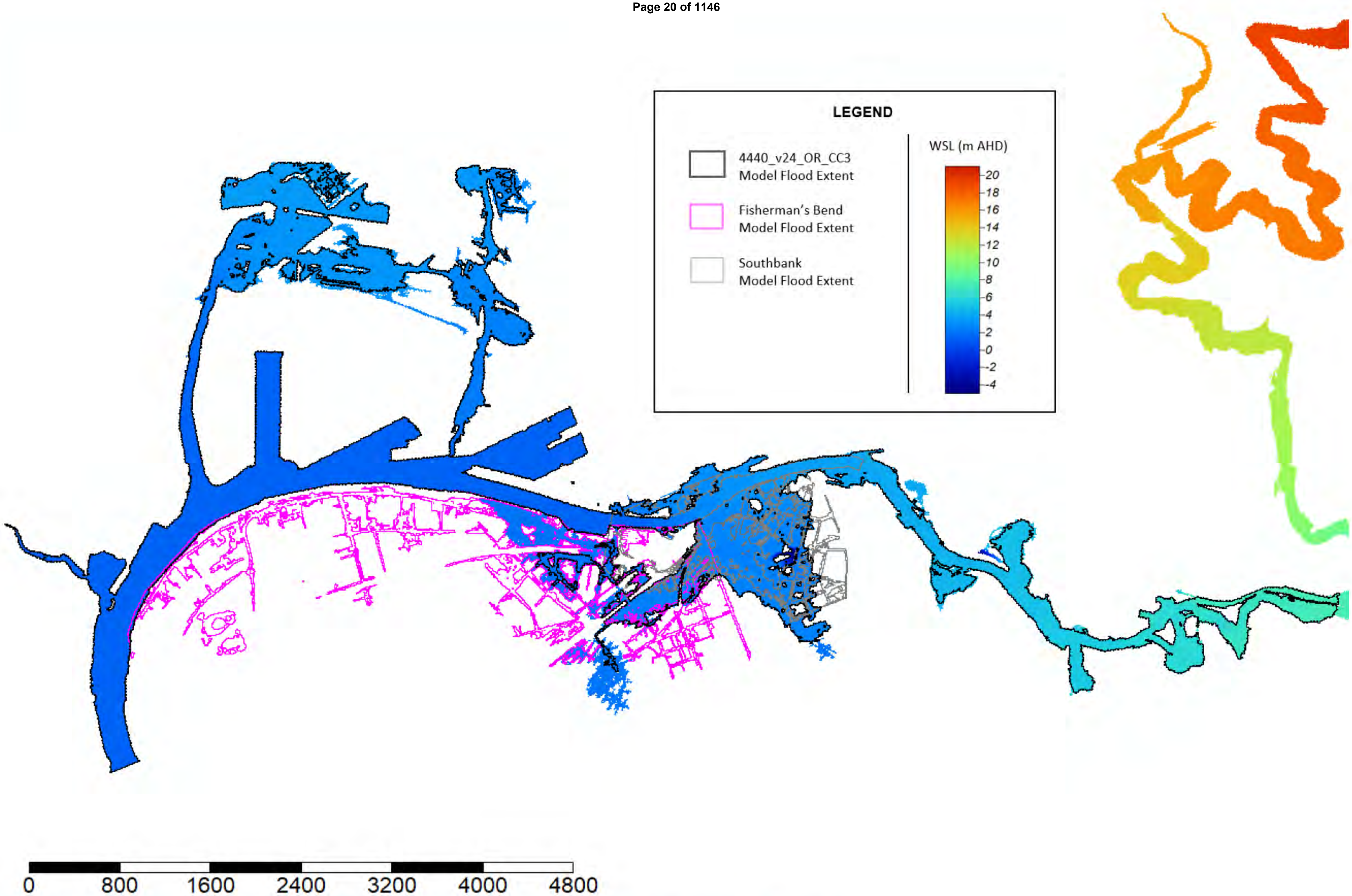


Figure 2-8 Peak 100y WSL Current (Kc=145 w/o ARFs, 10y Tide & River Manning's 'n' of 0.020) – Zoomed to refinement area

2.3.4 Run 17

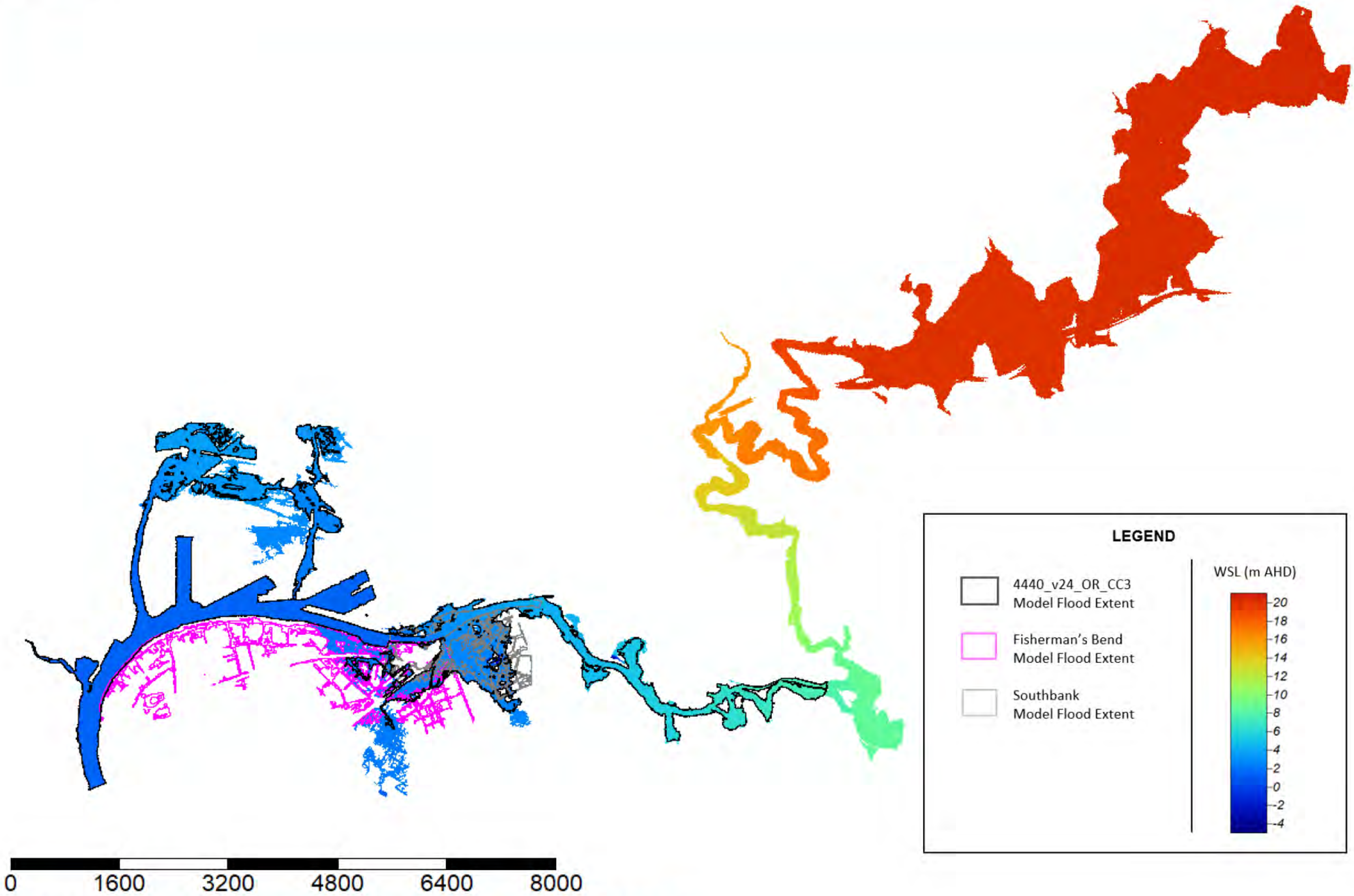


Figure 2-9 Peak 100y WSL Current (Kc=145 w/o ARFs, 10y Tide & River Manning's 'n' of 0.025)

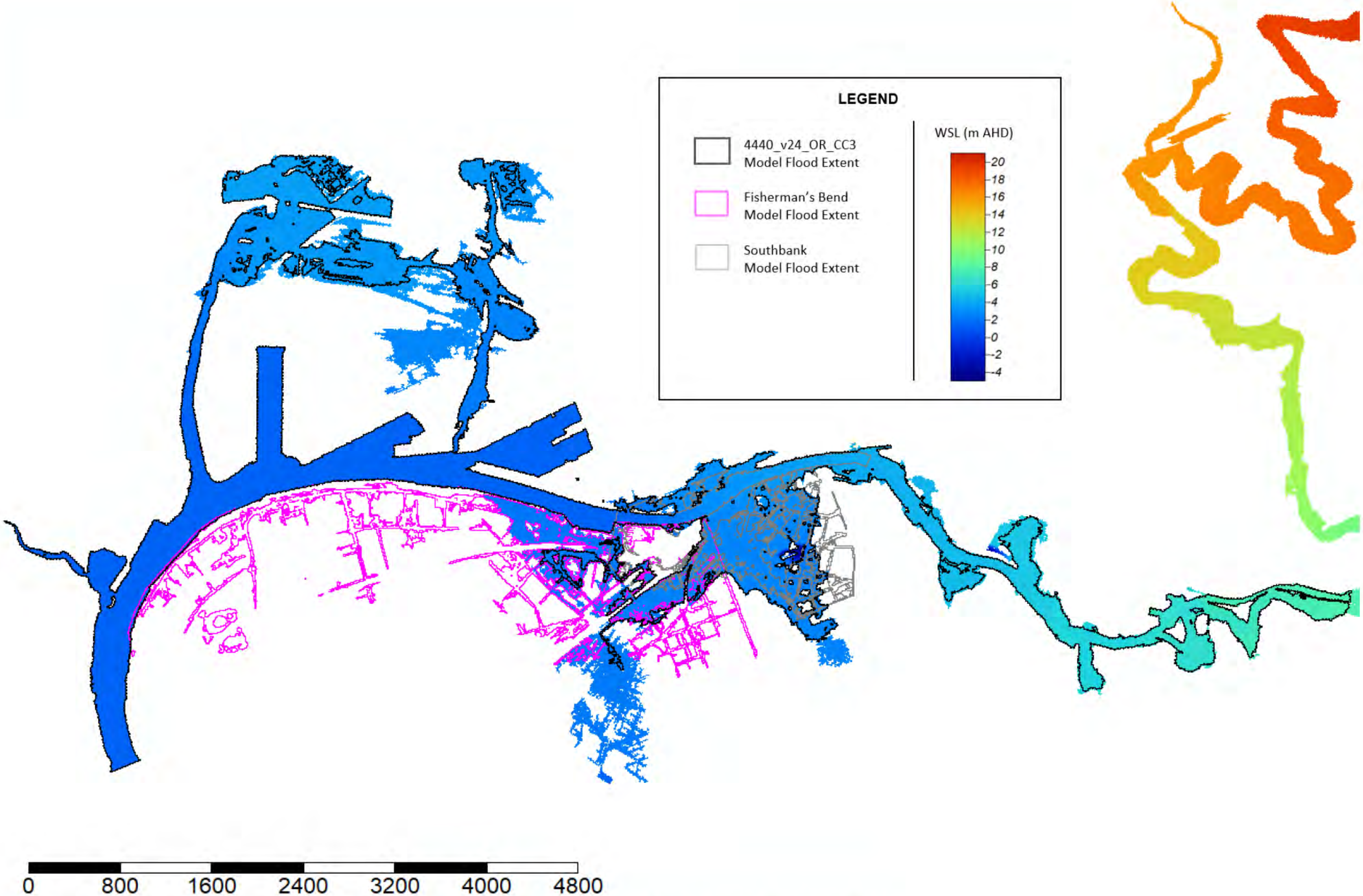


Figure 2-10 Peak 100y WSL Current (Kc=145 w/o ARFs, 10y Tide & River Manning's 'n' of 0.025)– Zoomed to refinement area

2.4 Long Sections

2.4.1 Runs 7 & 8 – Impact of Model Extension and varying Manning's 'n'

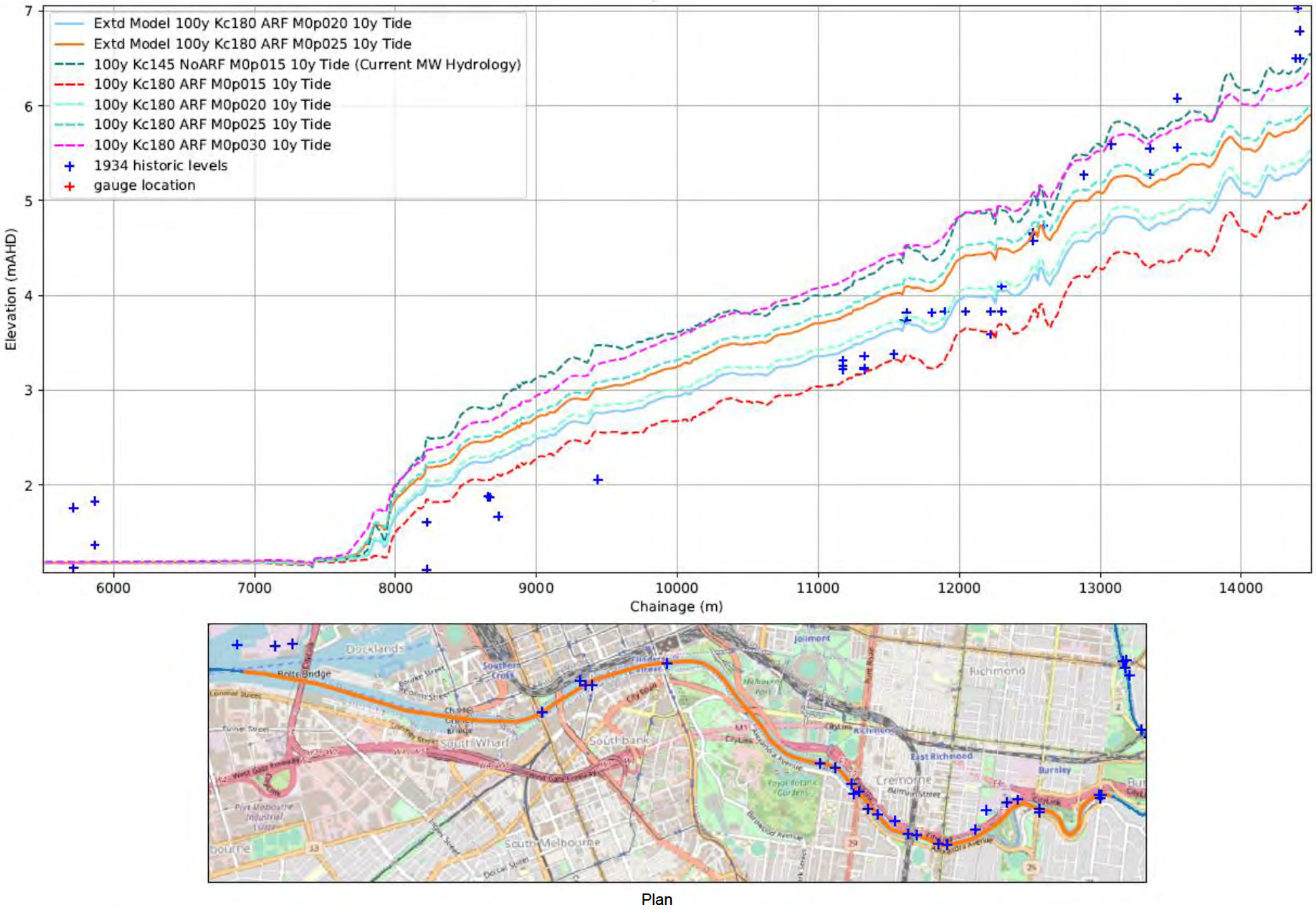


Figure 2-11 1% AEP Long-section along Yarra River comparing WSL along Yarra to historic levels - Impact of Model Extension

2.4.2 Runs 7, 8, 16 & 17 – Impact of Hydrology and varying Manning's 'n'

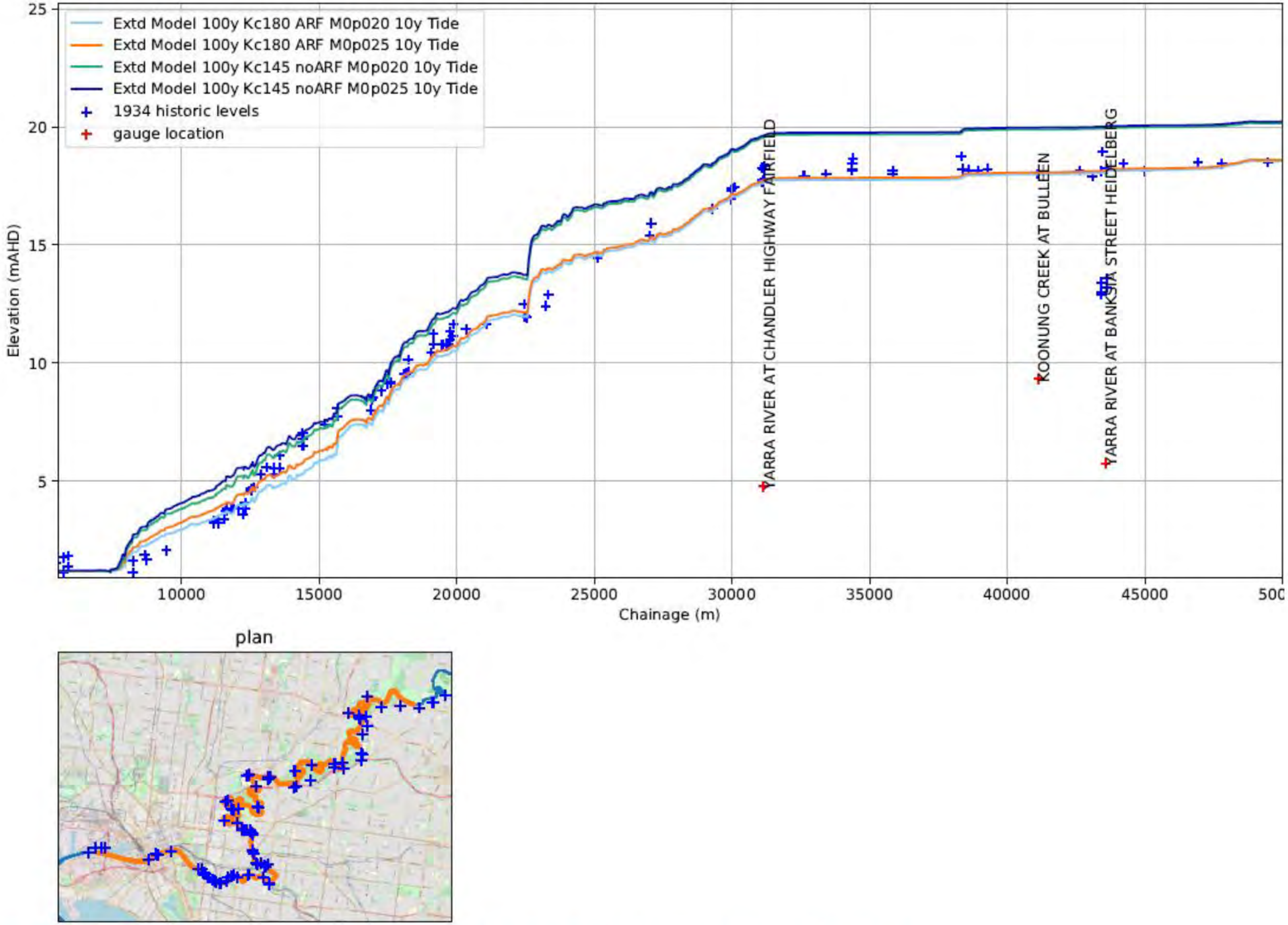


Figure 2-12 1% AEP Long-section along Yarra River comparing WSL along Yarra to historic levels - Impact of River Roughness

2.5 Comparison Point Results – Overflow Refinement Area

Figure 2-13 Location of Comparison Points

Table 3 Comparison Point Locations – Impact of model extension and varying roughness on 1% AEP

ID	Description	Southbank Model 1% AEP CC (18.5%) Flows w/ 10% AEP SLR Tide	Fisherman's Bend Model 1% AEP Flows w/ 10% AEP Tide	4400_v24_OR Model (refined version of Lower Yarra River flood mapping model) 1% AEP Flows w/ 10% AEP Tide				4400_v26 Model (extended version of 4400_v24_OR model) 1% AEP Flows w/ 10% AEP Tide			
				Current - Kc=145 w/o ARFs & n = 0.015	Kc=180 w/ ARFs & n = 0.015	Kc=180 w/ ARFs & n = 0.020	Kc=180 w/ ARFs & n = 0.025	Current - Kc=145 w/o ARFs & n = 0.020	Kc=180 w/ ARFs & n = 0.020	Current - Kc=145 w/o ARFs & n = 0.025	Kc=180 w/ ARFs & n = 0.025
1	Yarra River 1 (US)	2.14	-	3.48	2.55	2.84	3.10	3.62	2.77	3.82	3.03
2	Yarra River 2	2.14	-	2.81	2.06	2.31	2.53	2.92	2.25	3.07	2.47
3	Yarra River 3	2.14	-	1.24	1.20	1.23	1.26	1.31	1.23	1.45	1.27
4	Yarra River 4	-	-	1.19	1.18	1.18	1.19	1.19	1.18	1.21	1.19
5	Yarra River 5 (DS)	-	-	1.19	1.18	1.18	1.18	1.19	1.18	1.20	1.18
6	South Bank Pond	1.28	-	2.31	-	1.65	2.03	2.38	1.44	2.47	1.96
7	Sth Park St	-	-	-	-	-	-	-	-	2.41	-
8	Fwy \ Montague St	-	1.82	-	-	-	-	1.80	-	1.96	-
9	Lorimer St \ Boundary St	-	1.82	-	-	-	-	1.80	-	1.94	-
10	Approx. Boundary St \ Gittus St	-	1.82	1.53	-	-	-	1.80	-	1.96	-
11	Approx. Buckhurst St \ George St	-	1.89	2.13	-	-	-	2.24	-	2.28	-
12	Approx. Heath St \ Raglan St	-	-	-	-	-	-	-	-	2.09	-
13	Edwards Park	-	-	-	-	-	-	-	-	2.02	-
14	Approx. St Vincent St \ Iffla St	-	-	-	-	-	-	-	-	2.02	-

2.6 Comparison with 1934 historic points

Figure 2-14 Location of 1934 Historic Flood Levels

Table 4 1934 Flood Level Comparison Points

ID	1934 Flood Level	4400_v24_OR Model (refined version of Lower Yarra River flood mapping model)				4400_v26 Model (extended version of 4400_v24_OR model)			
		Current - Kc=145 w/o ARFs & n = 0.015	Kc=180 w/ ARFs & n = 0.015	Current - Kc=145 w/o ARFs & n = 0.020	Kc=180 w/ ARFs & n = 0.025	Current - Kc=145 w/o ARFs & n = 0.020	Kc=180 w/ ARFs & n = 0.020	Current - Kc=145 w/o ARFs & n = 0.025	Kc=180 w/ ARFs & n = 0.025
HL1	3.59	4.85	3.61	4.07	4.54	5.19	3.98	5.55	4.43
HL2	3.83	4.89	3.69	4.14	4.60	5.23	4.04	5.59	4.49
HL3	4.58	5.03	3.83	4.31	4.76	5.36	4.21	5.69	4.66
HL4	4.74	5.04	3.84	4.33	4.79	5.39	4.24	5.74	4.68
HL5	1.52	1.19	1.18	1.18	1.18	1.19	1.18	1.19	1.18
HL6	0.64	1.19	1.18	1.18	1.18	1.19	1.18	1.19	1.18
HL7	1.76	-	-	-	-	-	-	-	-
HL8	1.13	-	-	-	-	-	-	-	-
HL9	1.83	-	-	-	-	-	-	-	-
HL10	1.37	-	-	-	-	-	-	-	-
HL11	1.11	2.50	1.85	2.06	2.24	2.60	2.01	2.72	2.19
HL12	1.88	2.84	2.07	2.31	2.53	2.94	2.25	3.08	2.48
HL13	3.26	4.05	3.10	3.49	3.85	4.34	3.42	4.65	3.78
HL14	3.23	4.19	3.18	3.59	3.96	4.50	3.51	4.83	3.88
HL15	3.22	4.19	3.18	3.59	3.96	4.50	3.51	4.83	3.88
HL16	3.38	4.36	3.31	3.72	4.10	4.67	3.64	5.00	4.01
HL17	3.74	4.52	3.38	3.79	4.19	4.84	3.71	5.19	4.10
HL18	6.5	6.34	4.85	5.37	5.84	6.66	5.27	6.97	5.74
HL19	5.28	-	-	-	-	-	-	-	-
HL20	5.56	5.84	4.36	4.89	5.39	6.20	4.79	6.52	5.28
HL21	6.5	6.38	4.88	5.40	5.88	6.72	5.31	7.01	5.79
HL22	1.87	2.80	2.06	2.30	2.52	2.91	2.25	3.06	2.47
HL23	3.83	4.85	3.61	4.07	4.54	5.19	3.98	5.55	4.43
HL24	4.09	4.89	3.69	4.14	4.60	5.23	4.04	5.59	4.49
HL25	4.64	5.03	3.83	4.31	4.76	5.36	4.21	5.69	4.66
HL26	6.08	5.85	4.32	4.89	5.40	6.20	4.78	6.52	5.28
HL27	7.03	6.07	4.60	5.14	5.65	6.45	5.05	6.77	5.57
HL28	1.61	2.50	1.85	2.06	2.24	2.60	2.01	2.72	2.19
HL29	6.79	6.38	4.88	5.40	5.88	6.72	5.31	7.01	5.79
HL30	4.66	5.03	3.83	4.31	4.76	5.36	4.21	5.69	4.66
HL31	5.27	-	-	-	-	-	-	-	-
HL32	3.22	4.05	3.10	3.49	3.85	4.34	3.42	4.65	3.78
HL33	2.06	3.48	2.56	2.84	3.09	3.61	2.76	3.80	3.02
HL34	3.82	4.40	3.28	3.72	4.16	4.78	3.64	5.19	4.07
HL35	3.83	4.46	3.30	3.76	4.24	4.84	3.68	5.25	4.13
HL36	3.74	4.46	3.36	3.78	4.17	4.75	3.70	5.09	4.08
HL37	3.83	4.81	3.74	4.18	4.57	5.12	4.09	5.47	4.49
HL38	1.52	1.19	1.18	1.18	1.18	1.19	1.18	1.19	1.18
HL39	3.31	4.05	3.10	3.49	3.85	4.34	3.42	4.65	3.78
HL40	3.82	4.52	3.38	3.79	4.19	4.84	3.71	5.19	4.10
HL41	3.36	4.19	3.18	3.59	3.96	4.50	3.51	4.83	3.88
HL42	5.55	-	-	-	-	-	-	-	-
HL43	1.67	2.83	2.12	2.36	2.56	2.94	2.30	3.08	2.51
HL44	5.59	5.88	4.50	4.97	5.41	6.17	4.87	6.48	5.29

2.7 Southbank City Link Tunnel Portal results

Table 5 Southbank City Link Tunnel Portal Flows & Volumes

					Southbank Portal		Burnley Exit		Domain Entry	
Scenario	Kc & ARF	Hydrology	Tide	River Roughness (Manning's 'n')	Peak Flow (m^3/s)	Peak Volume (m^3)	Peak Flow (m^3/s)	Peak Volume (m^3)	Peak Flow (m^3/s)	Peak Volume (m^3)
5*	Current (Kc=145 w/o ARFs)	1% AEP Base Case	10% AEP	0.015	-87.4	-9,669,632	0.0	0	0.0	0
3*	Kc=180 w/ ARF	1% AEP Base Case	10% AEP	0.015	0.0	0	0.0	0	0.0	0
7*	Kc=180 w/ ARF	1% AEP Base Case	10% AEP	0.02	-1.0	-84,797	0.0	0	0.0	0
7	Kc=180 w/ ARF	1% AEP Base Case	10% AEP	0.02	0.0	0	0.0	0	0.0	0
15	Kc=145 w/o ARFs	1% AEP Base Case	10% AEP	0.02	-112.4	-15,163,951	-0.5	-21094.4	-0.5	-18849.8
8*	Kc=180 w/ ARF	1% AEP Base Case	10% AEP	0.025	-29.5	-1,967,656	0.0	0	0.0	0
8	Kc=180 w/ ARF	1% AEP Base Case	10% AEP	0.025	-20.5	-1,441,442	0.0	0	0.0	0
16	Kc=145 w/o ARFs	1% AEP Base Case	10% AEP	0.025	-151.8	-23,672,279	-14.5	-1203657.8	-2.3	-196330.8

Note:
* indicates that these runs were from the shorter model (4400_v24_OR)

2.8 Georeferenced Flood Extent

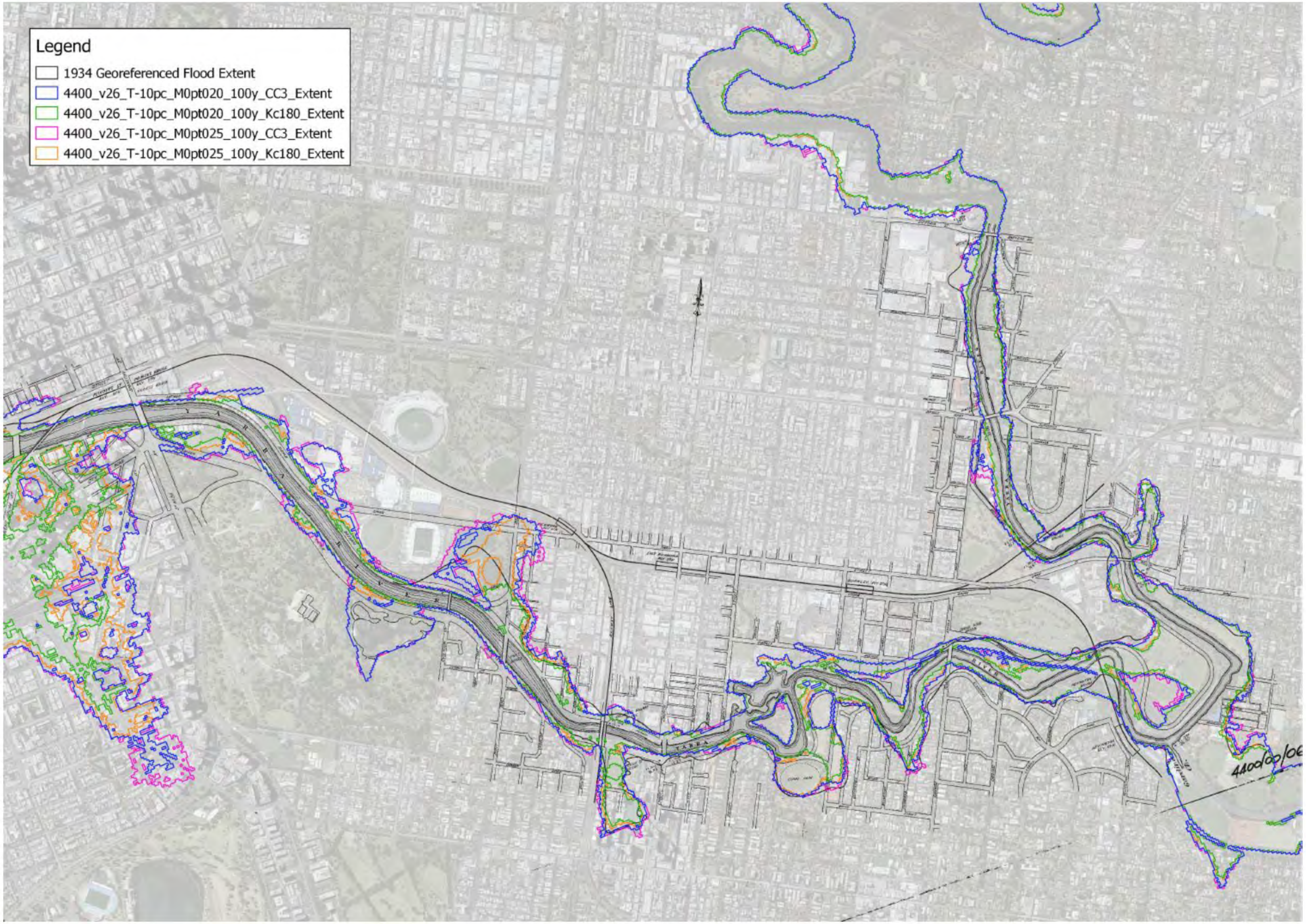
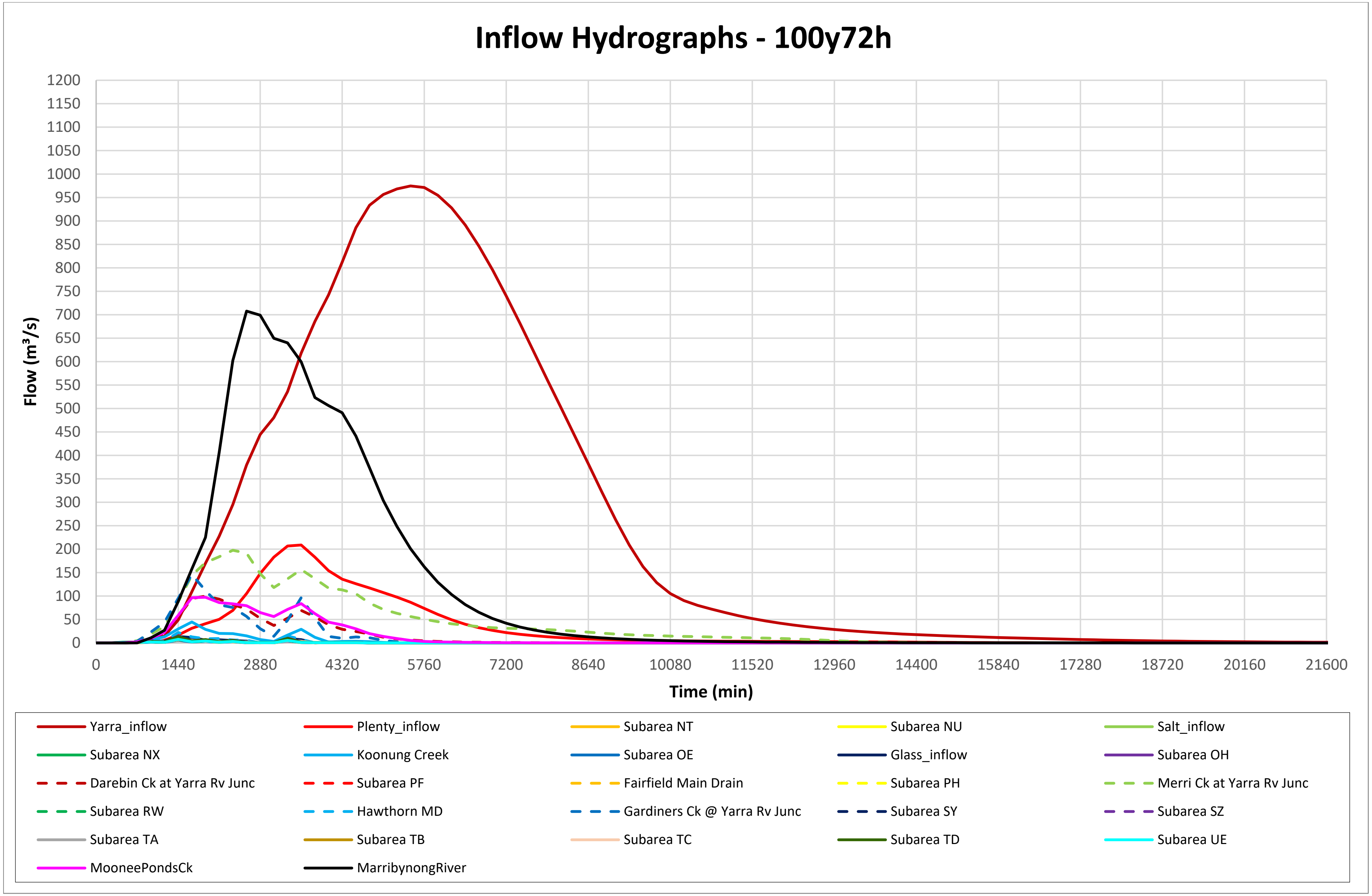
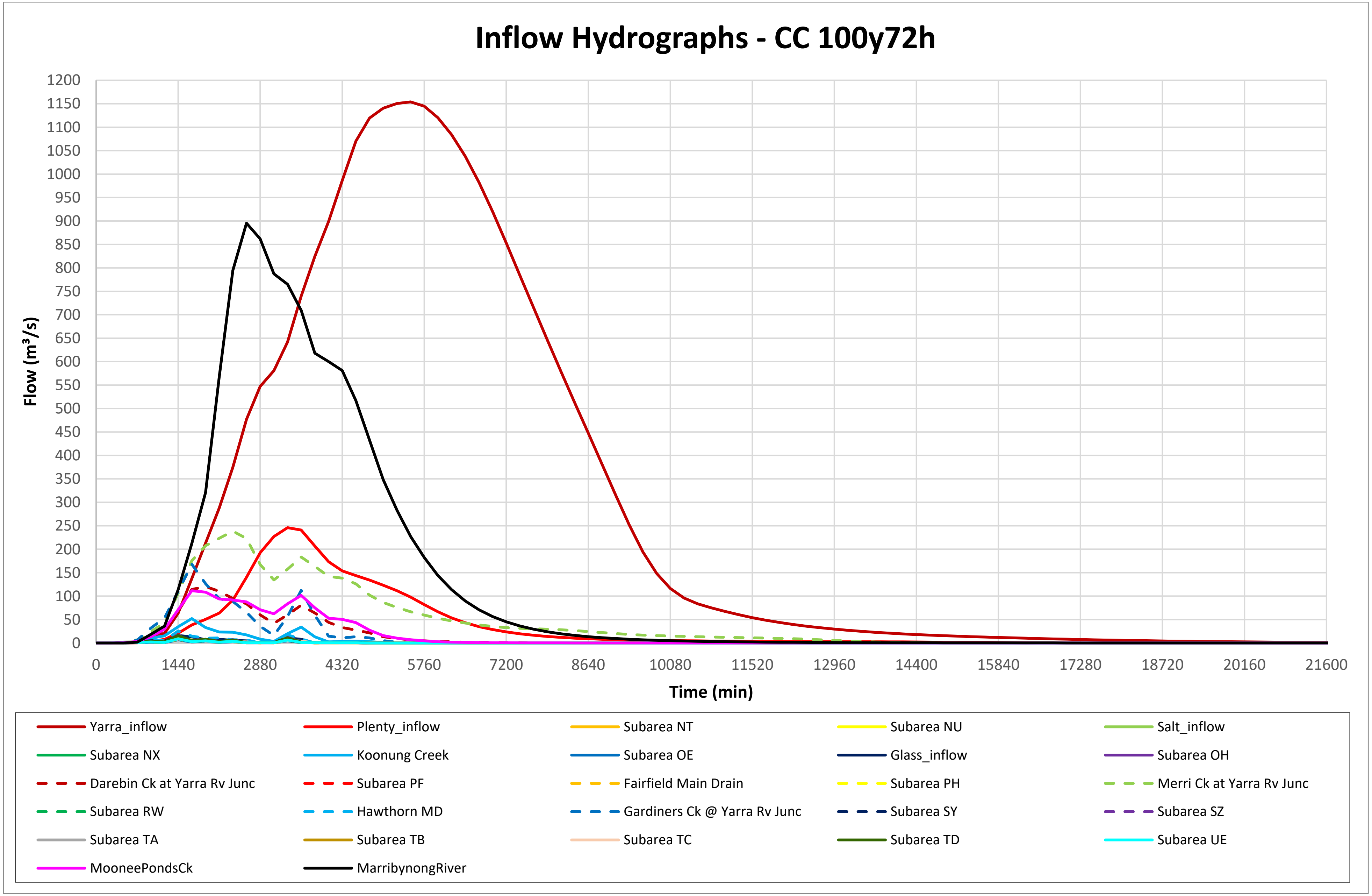


Figure 2-15 Flood Extent Comparison to georeferenced 1934 Flood Extent – St Kilda Road to Victoria Street

Appendix B – Inflow Hydrographs


Inflow Hydrographs - 100y72h
Flow (m³/s)
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
1440
2880
4320
5760
7200
8640
10080
11520
12960
14400
15840
17280
18720
20160
21600
Time (min)
Yarra_inflow
Plenty_inflow
Subarea NT
Subarea NU
Salt_inflow
Subarea NX
Koonung Creek
Subarea OE
Glass_inflow
Subarea OH
Darebin Ck at Yarra Rv Junc
Subarea PF
Fairfield Main Drain
Subarea PH
Merri Ck at Yarra Rv Junc
Subarea RW
Hawthorn MD
Gardiners Ck @ Yarra Rv Junc
Subarea SY
Subarea SZ
Subarea TA
Subarea TB
Subarea TC
Subarea TD
Subarea UE
MooneePondsCk
MarribynongRiver


Inflow Hydrographs - CC 100y72h
Flow (m³/s)
Time (min)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100
1150
1200
0
1440
2880
4320
5760
7200
8640
10080
11520
12960
14400
15840
17280
18720
20160
21600
Yarra_inflow
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Subarea NU
Salt_inflow
Subarea NX
Koonung Creek
Subarea OE
Glass_inflow
Subarea OH
Darebin Ck at Yarra Rv Junc
Subarea PF
Fairfield Main Drain
Subarea PH
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Hawthorn MD
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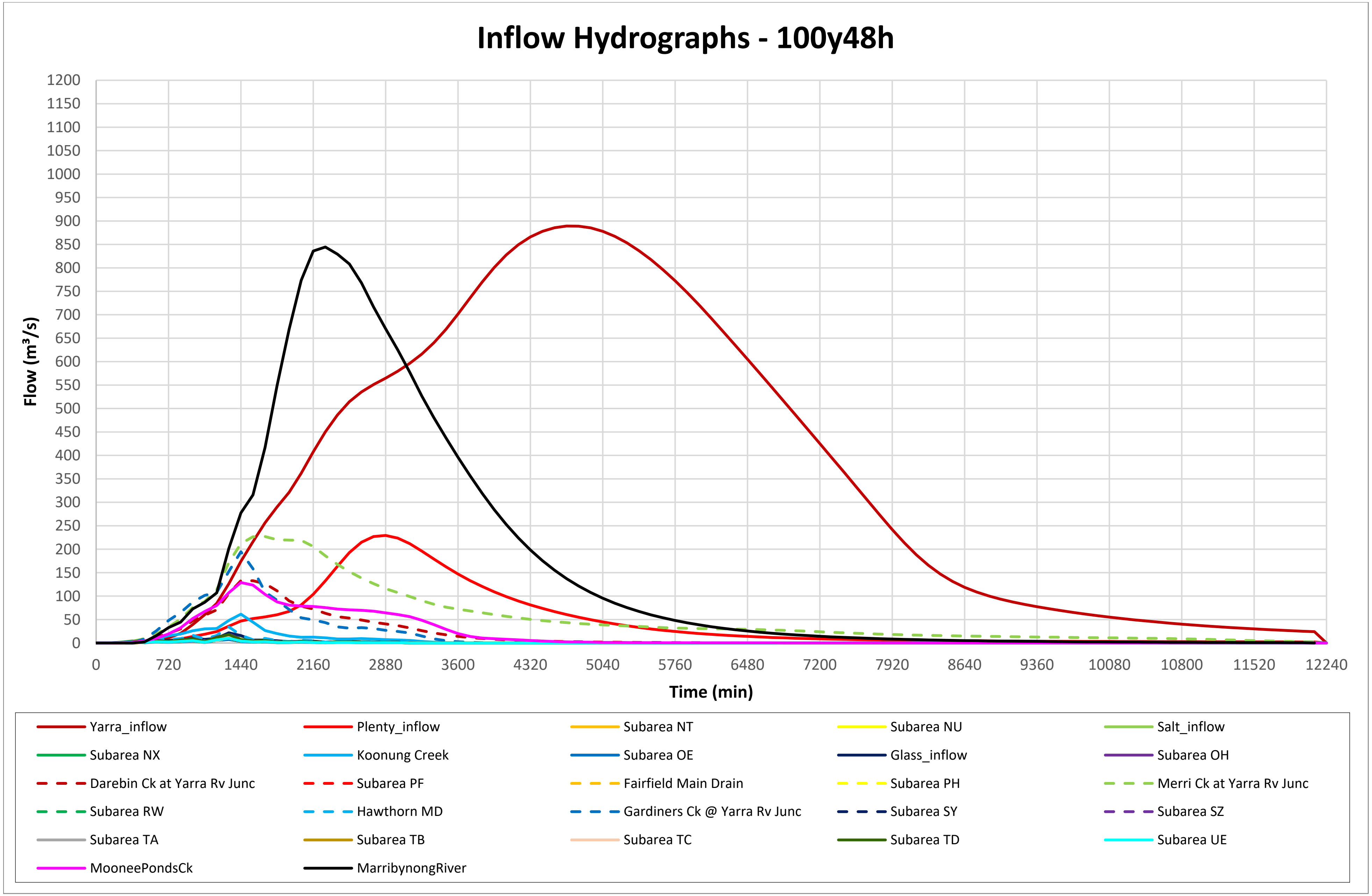

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Flow (m³/s)
Time (min)
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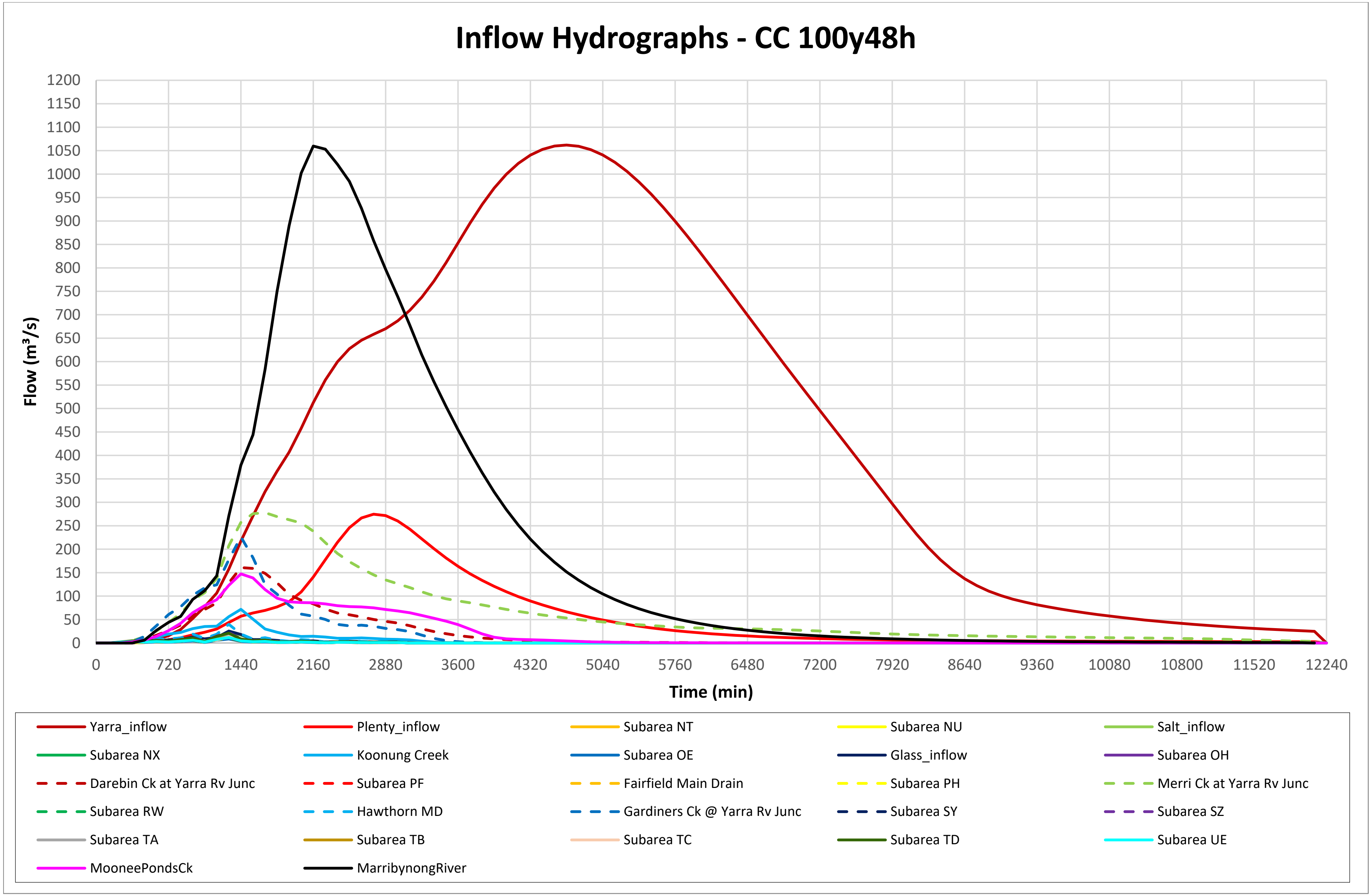
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Time (min)
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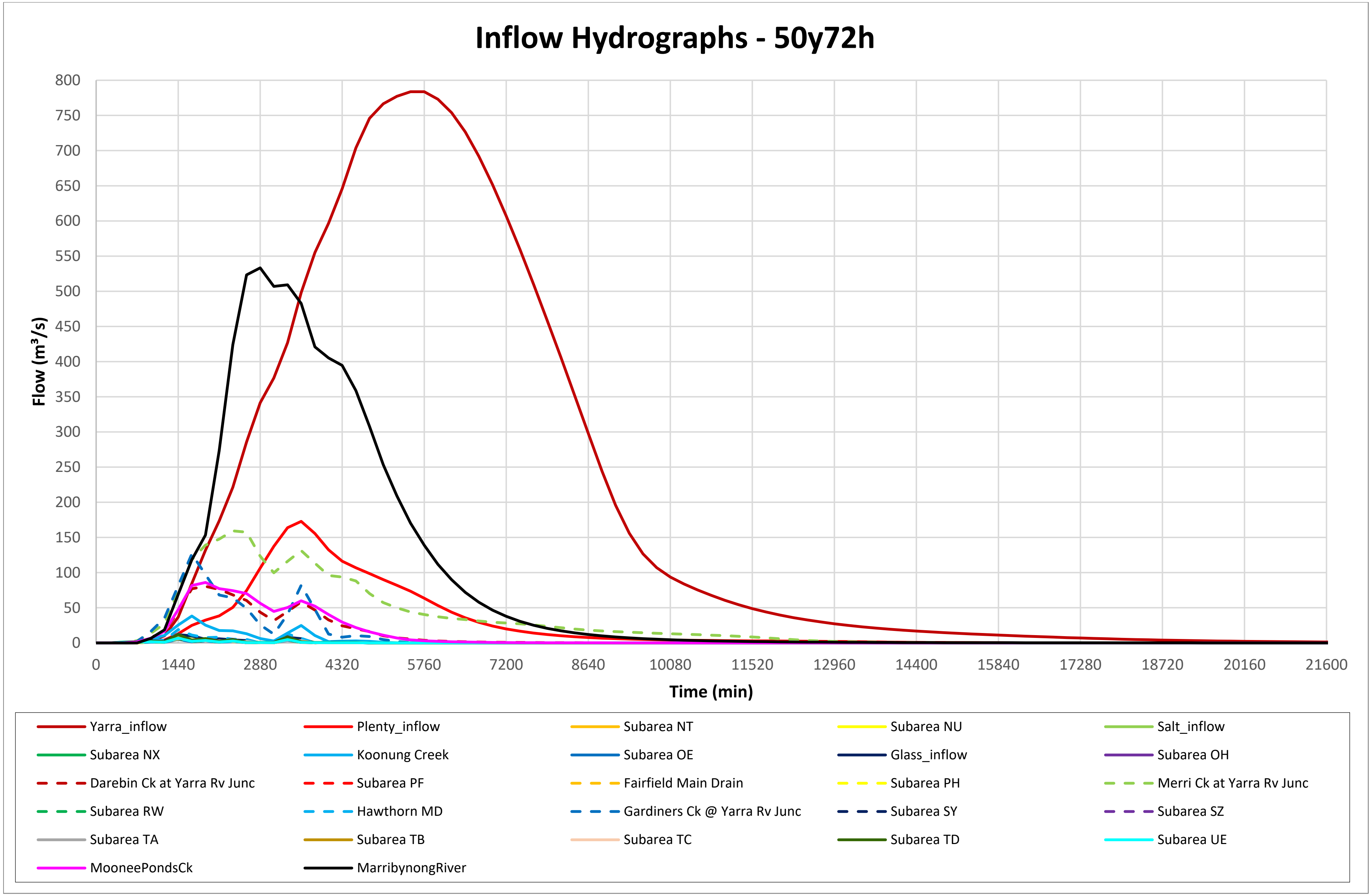
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Flow (m³/s)
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750
700
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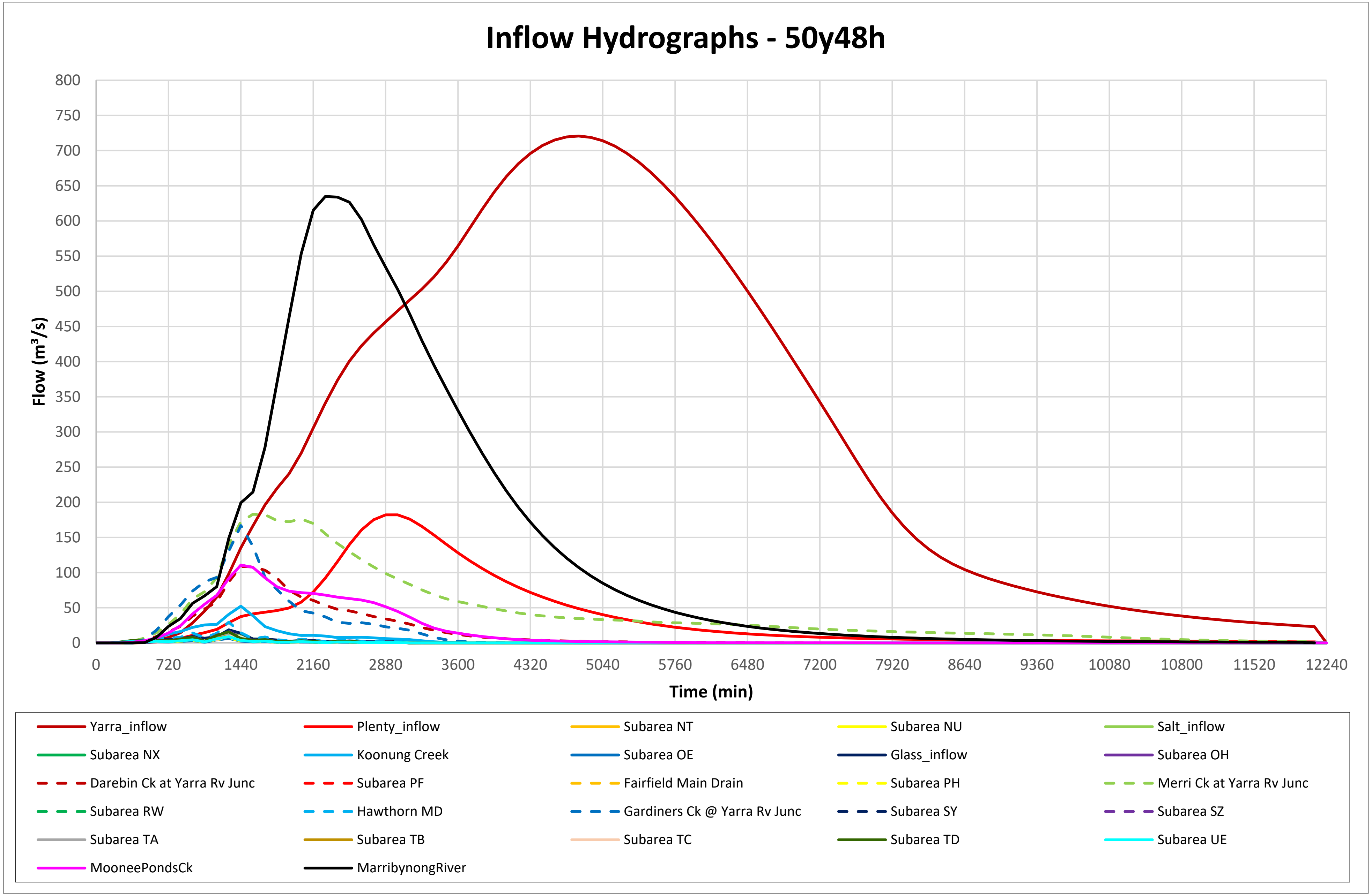
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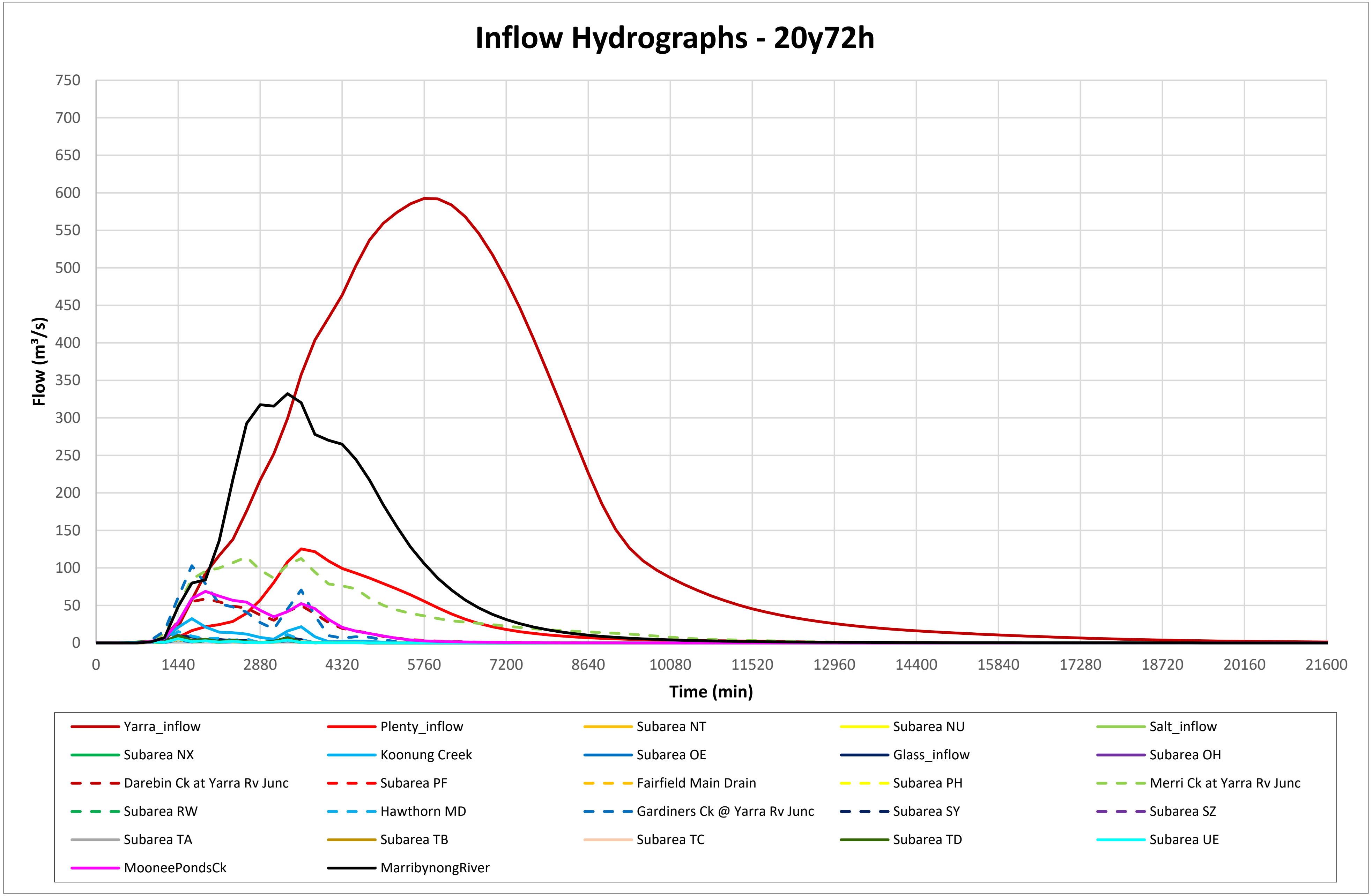
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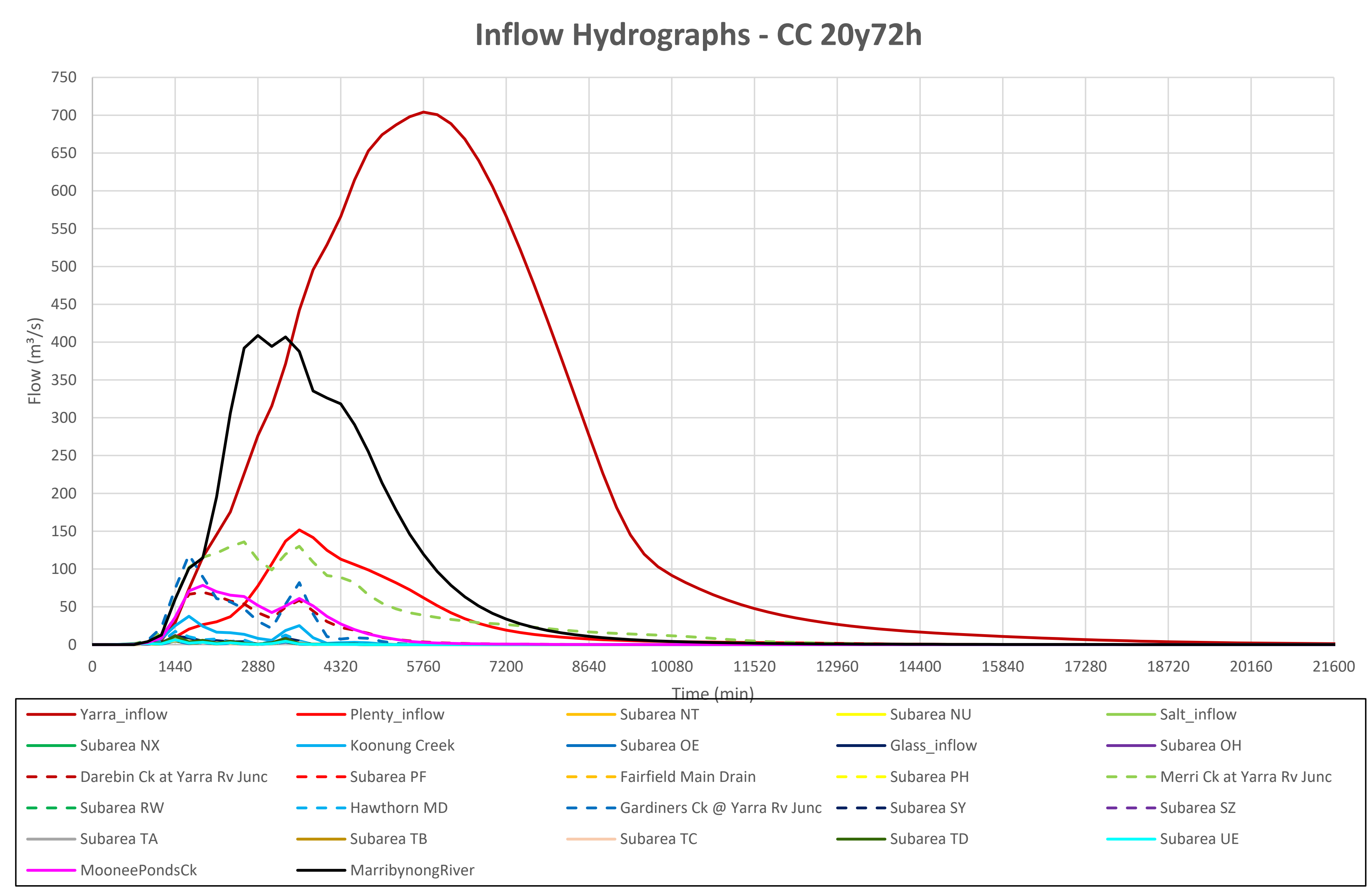
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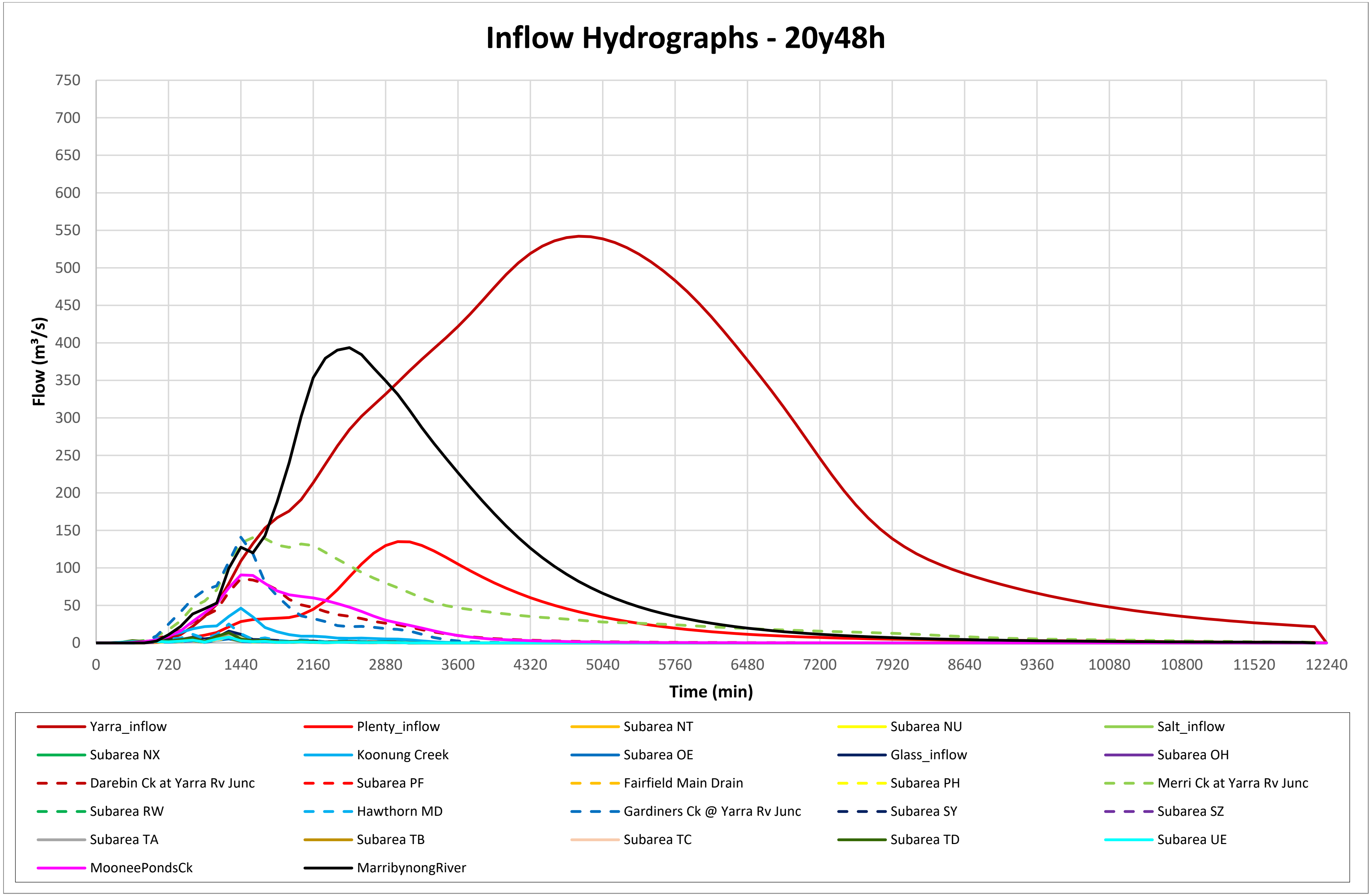

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Flow (m³/s)
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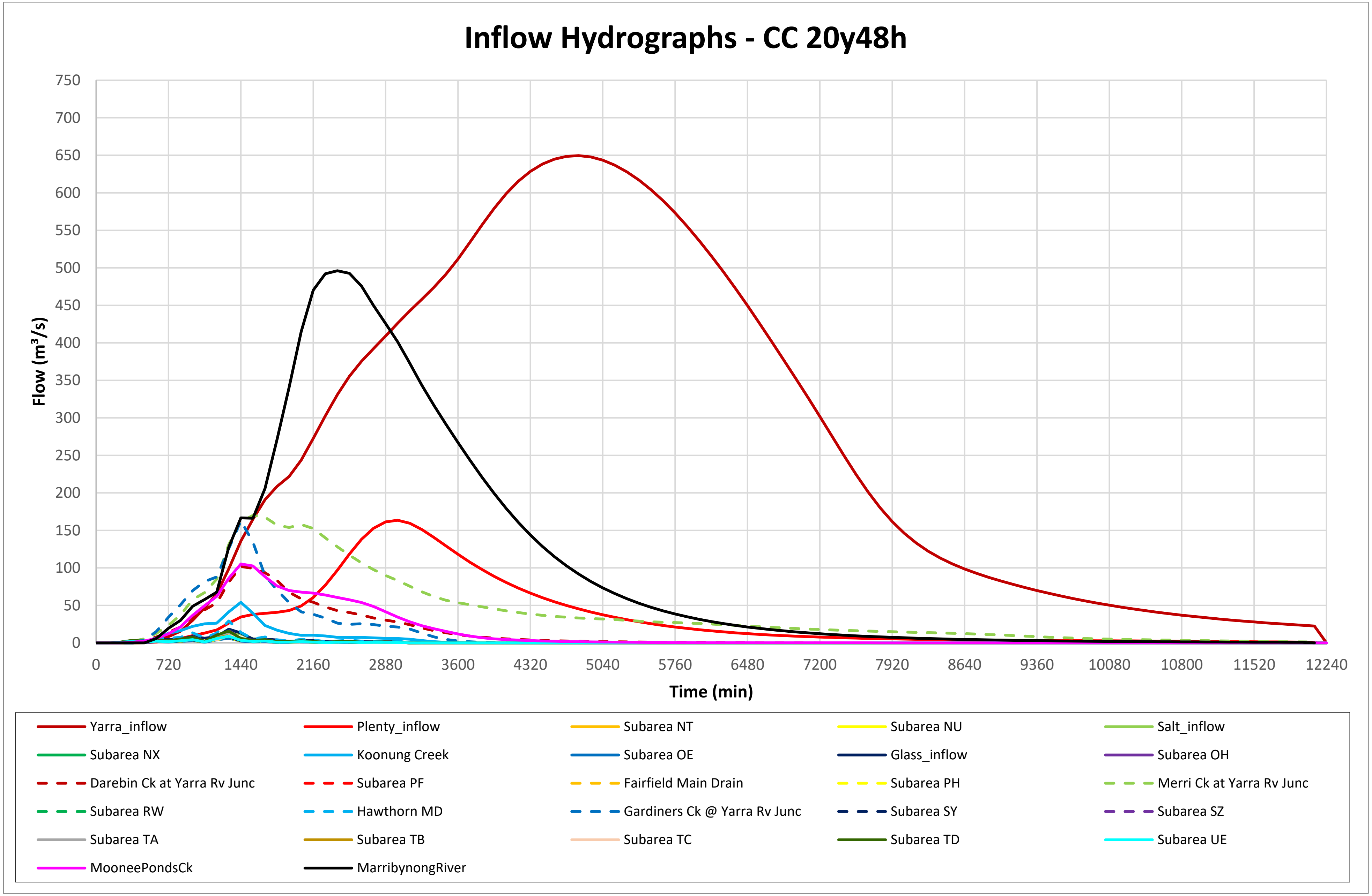
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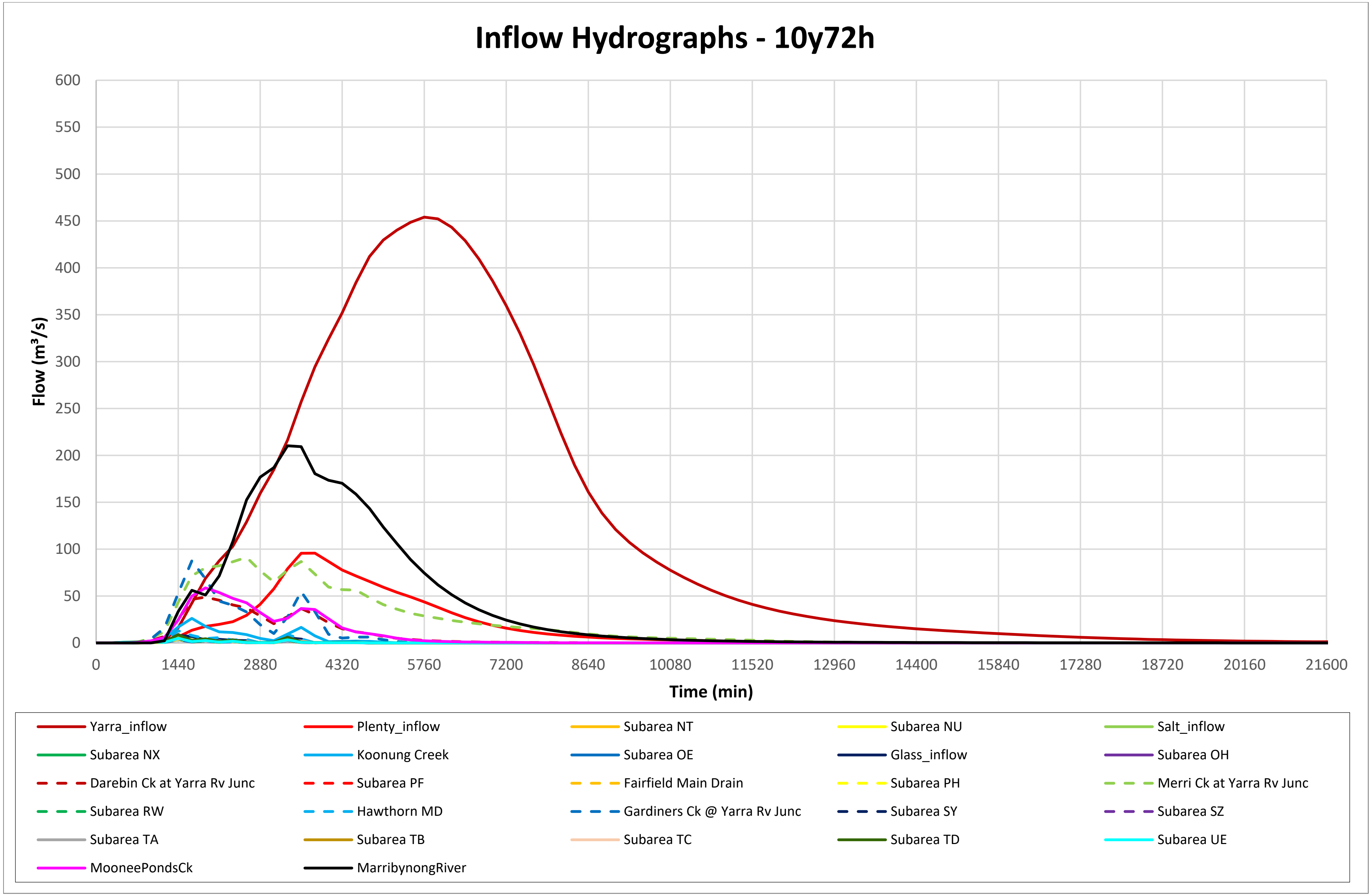
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Time (min)
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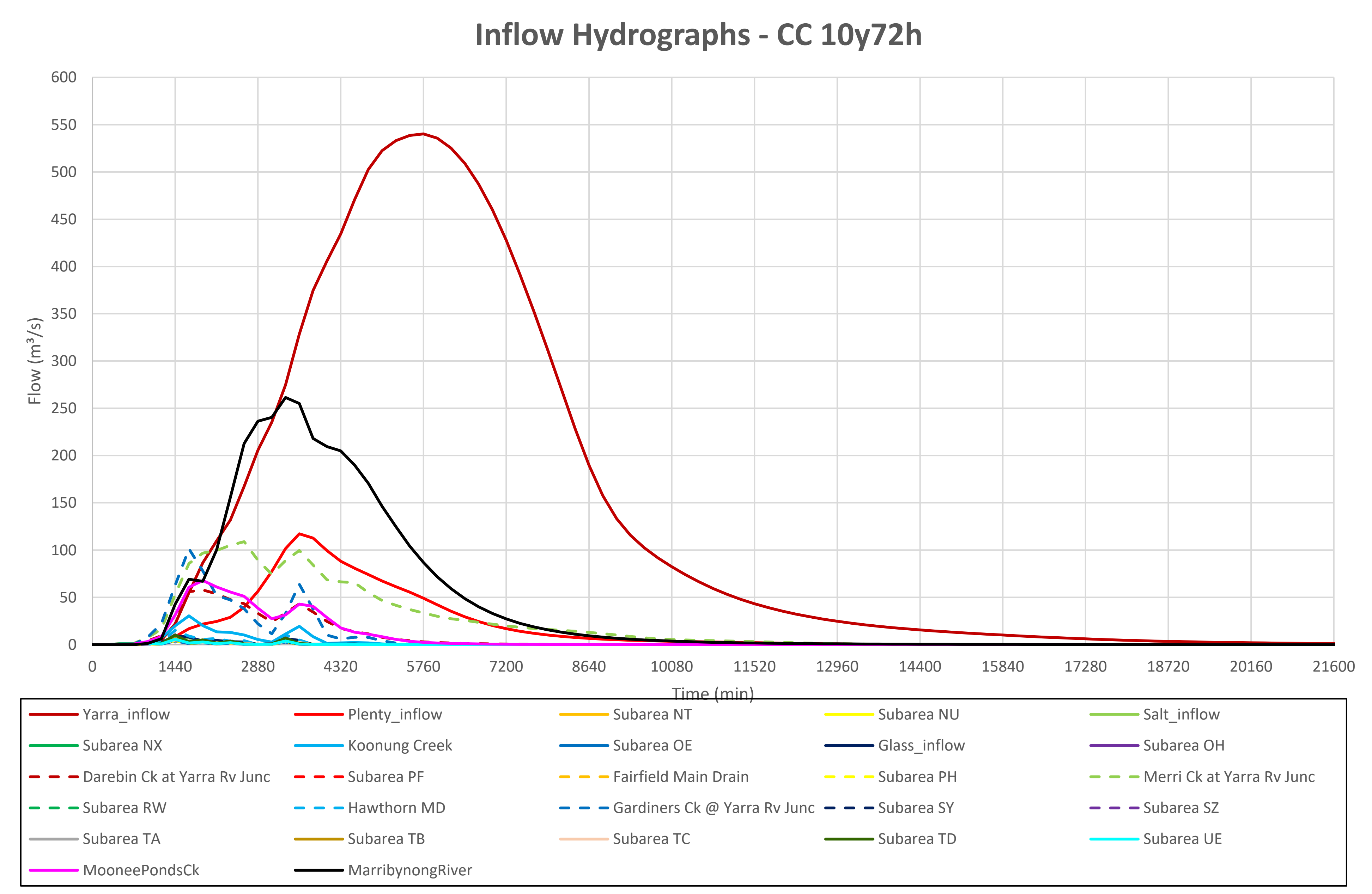
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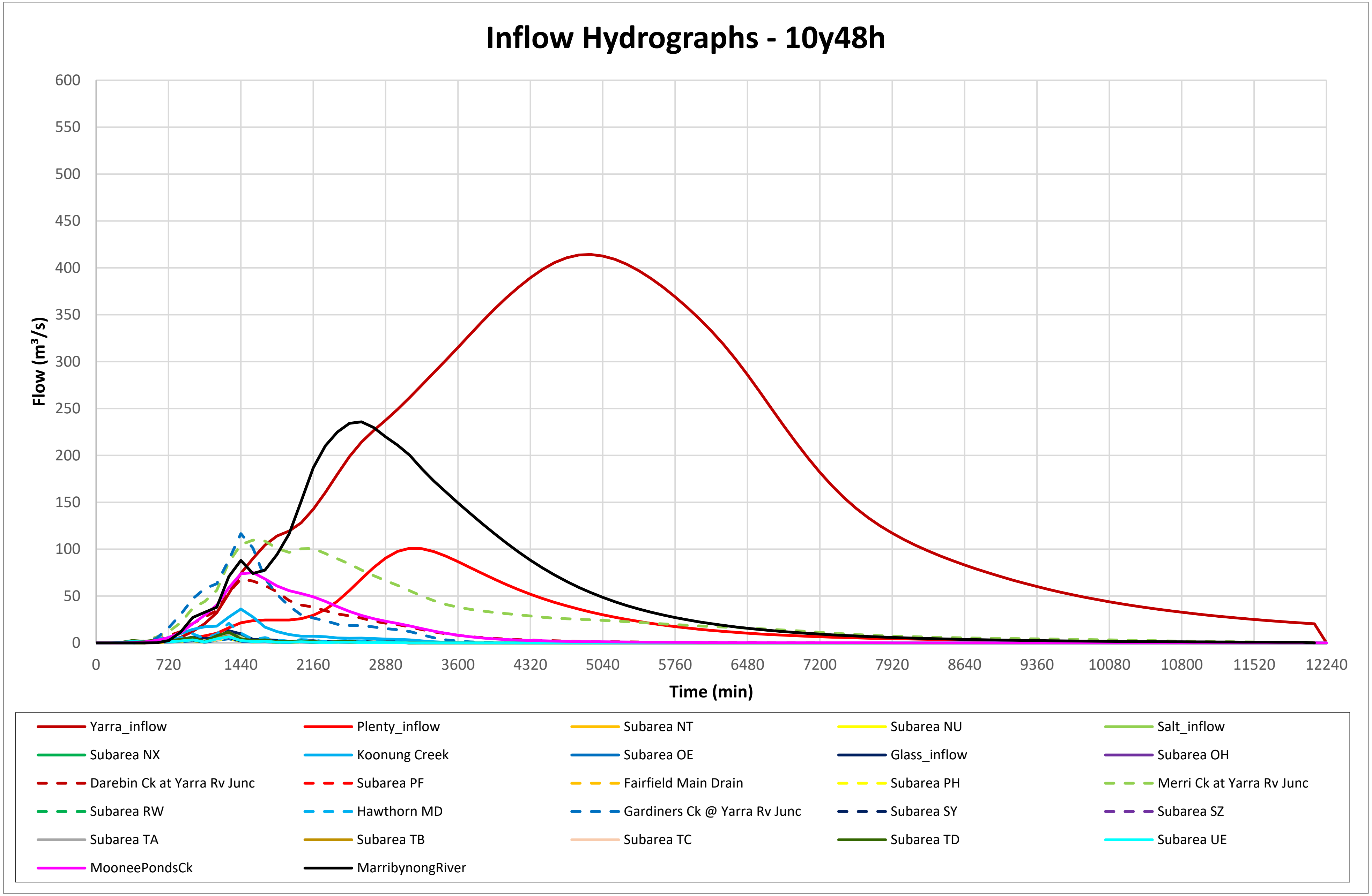

Inflow Hydrographs - 10y48h
Flow (m³/s)
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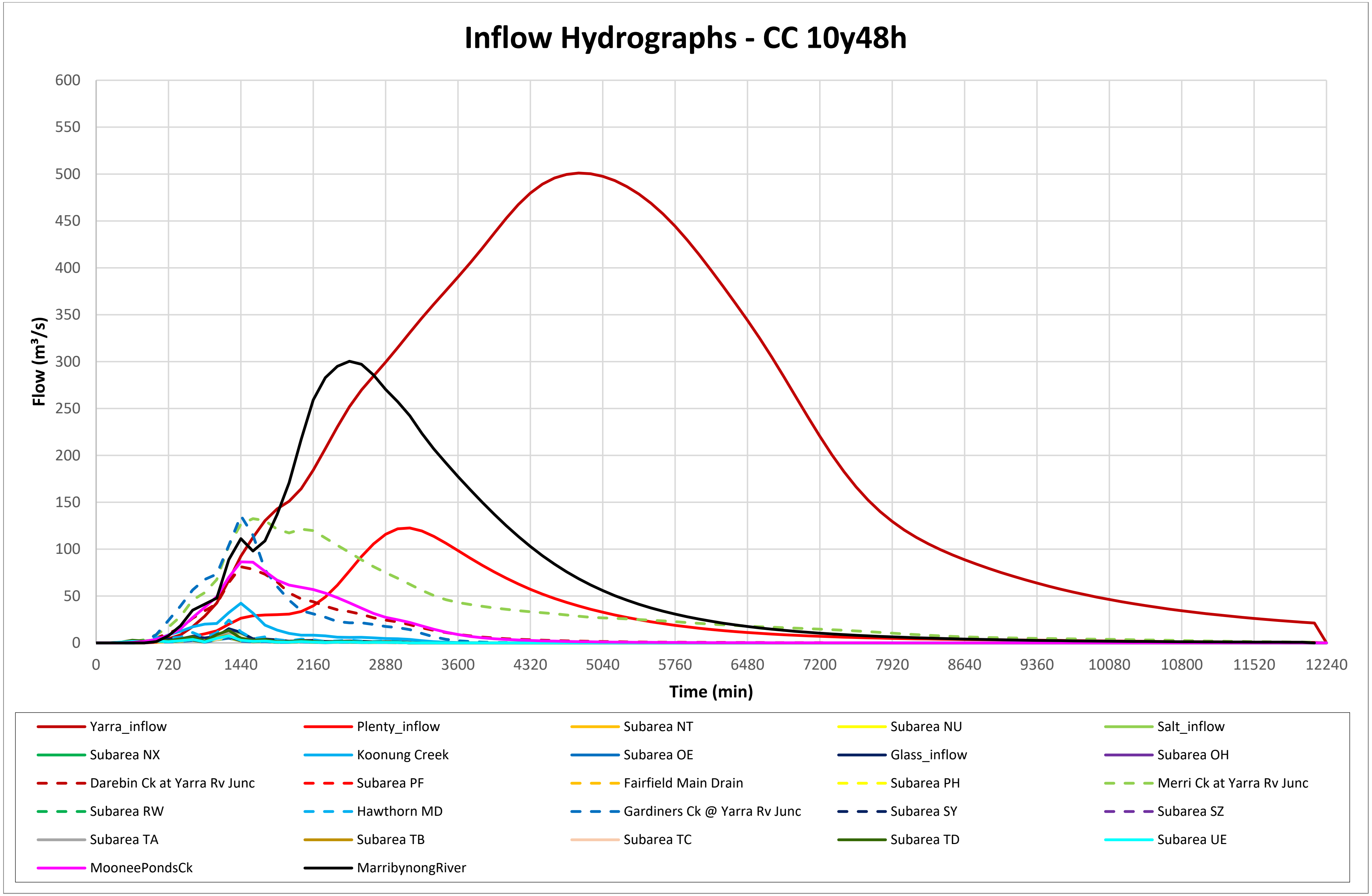
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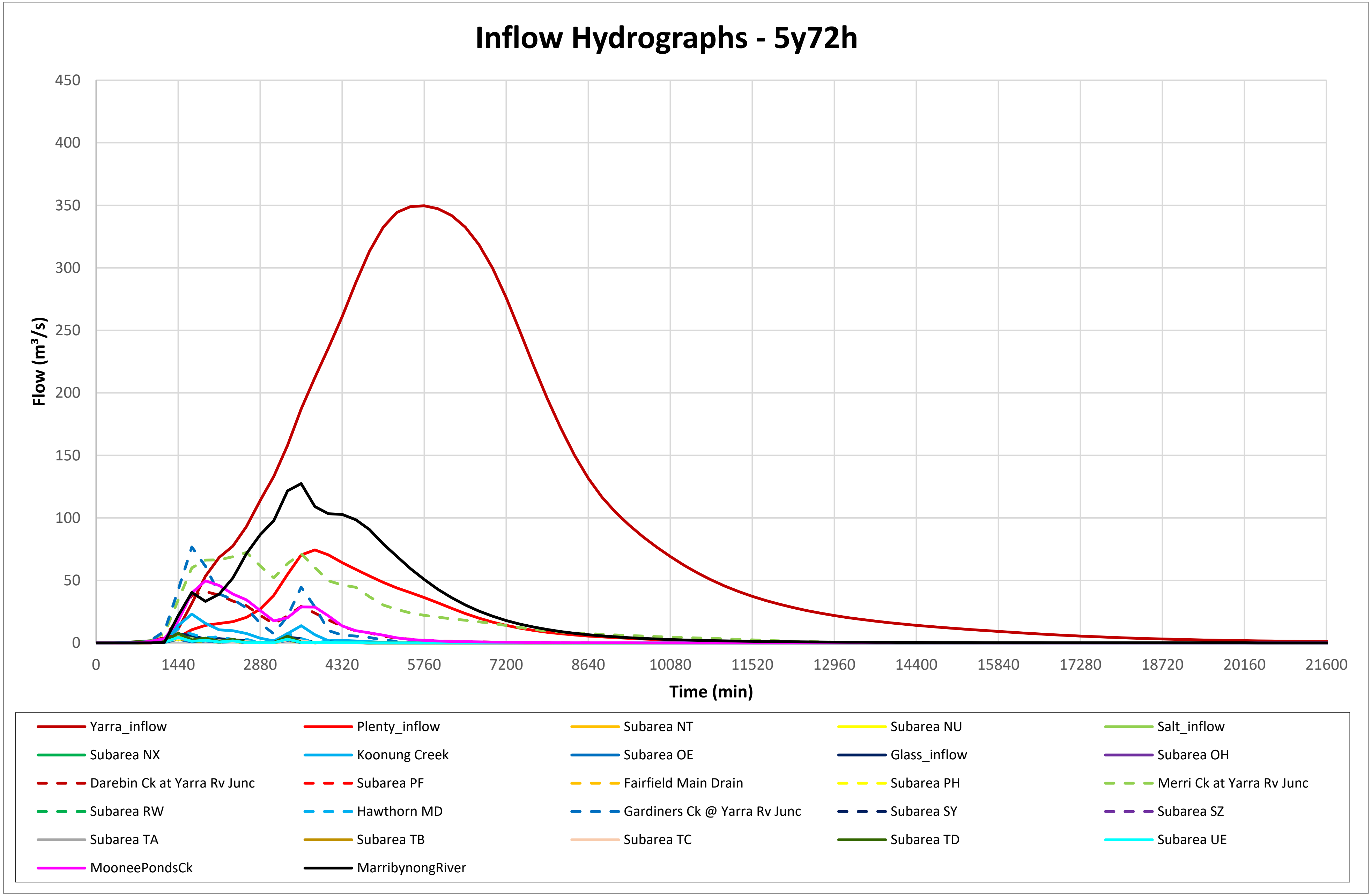

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Flow (m³/s)
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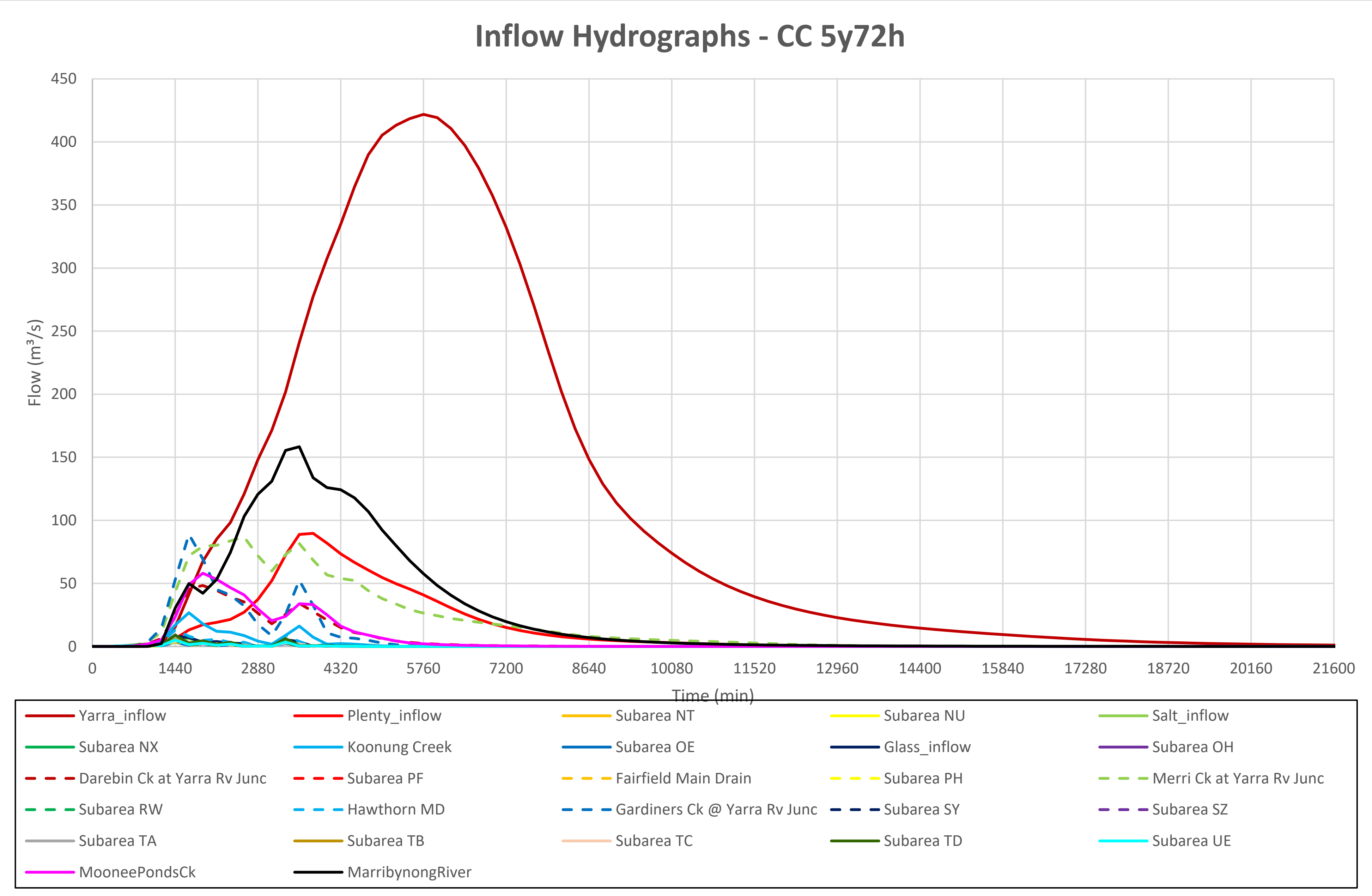
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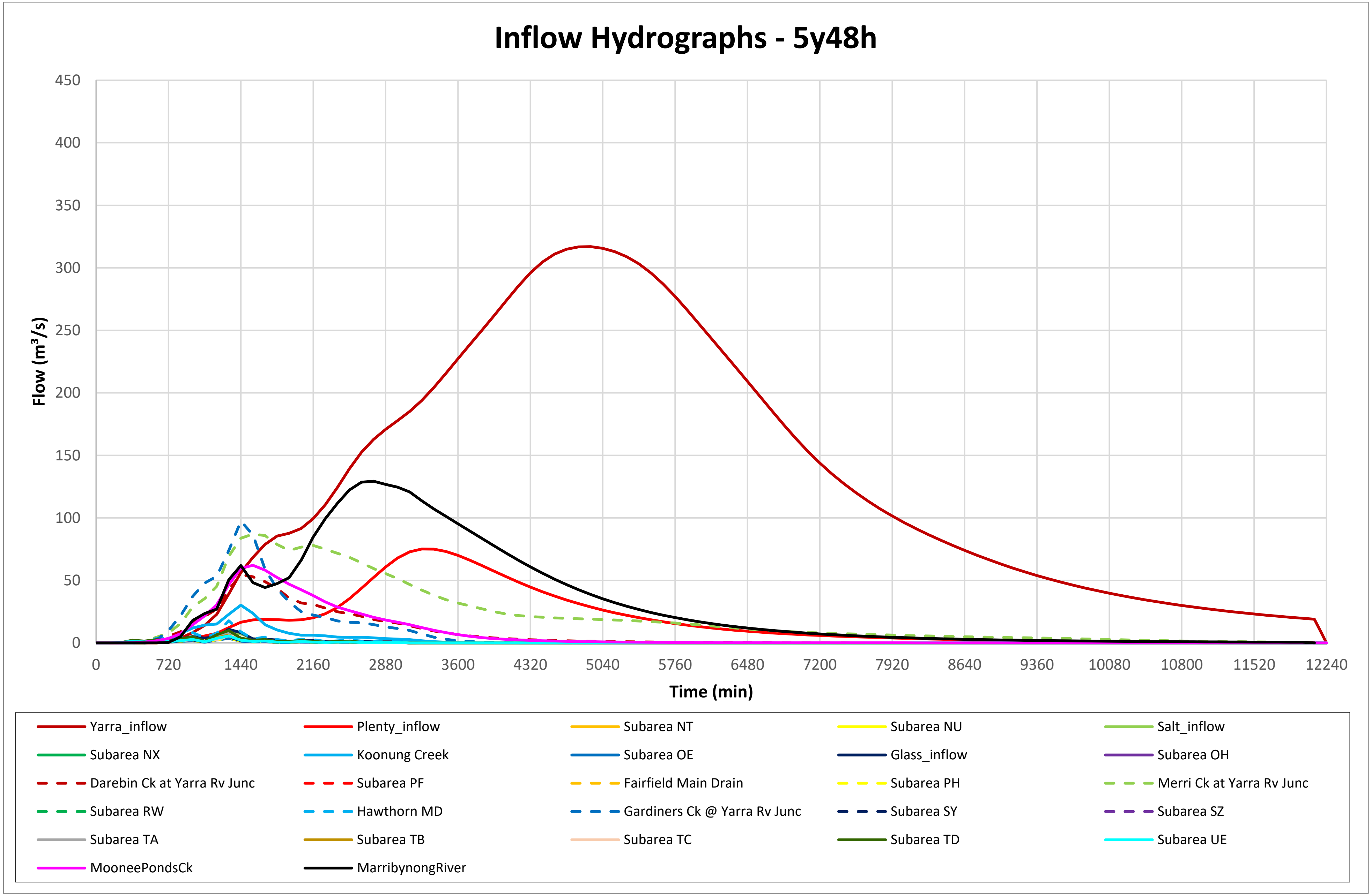
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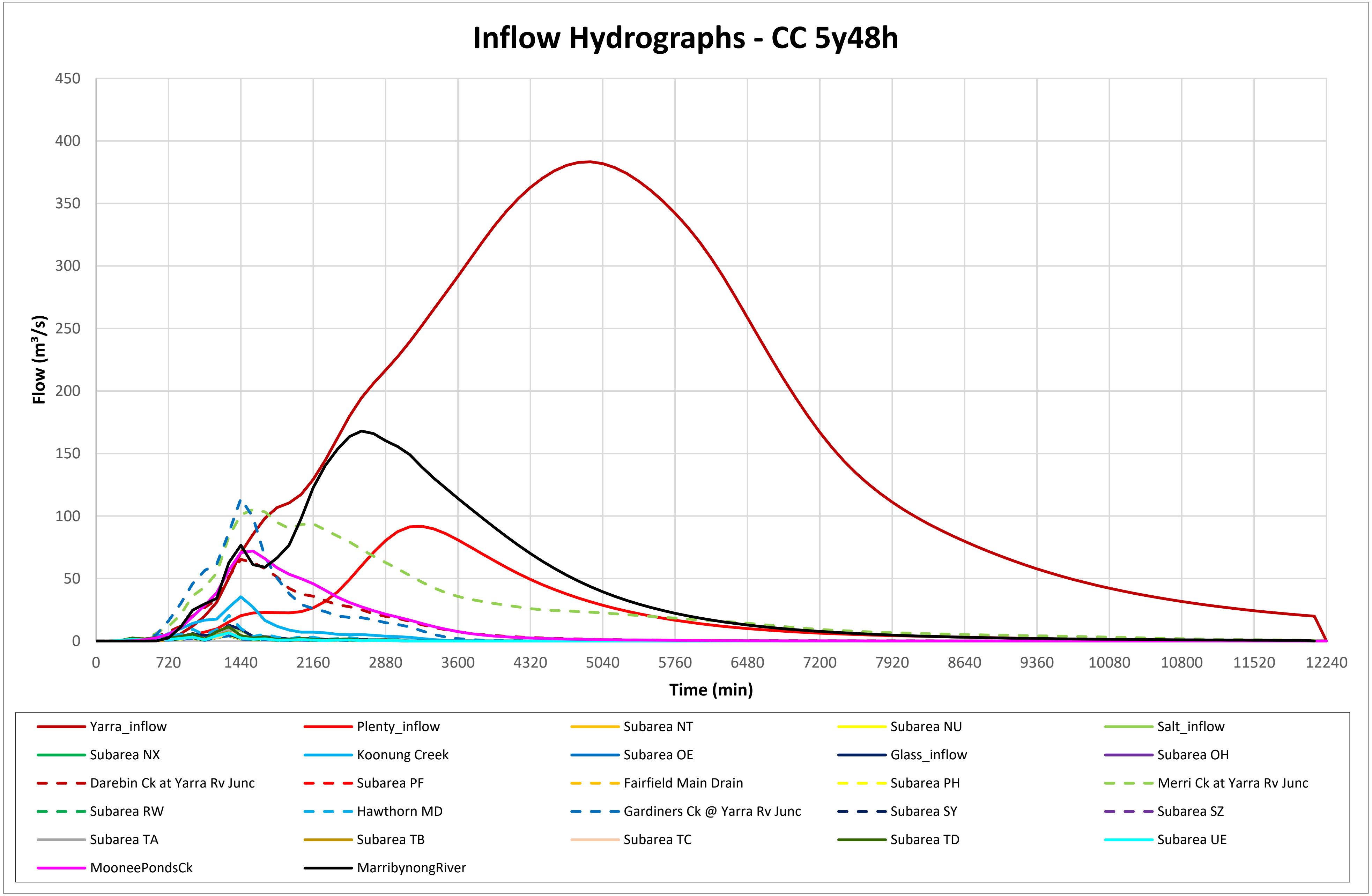
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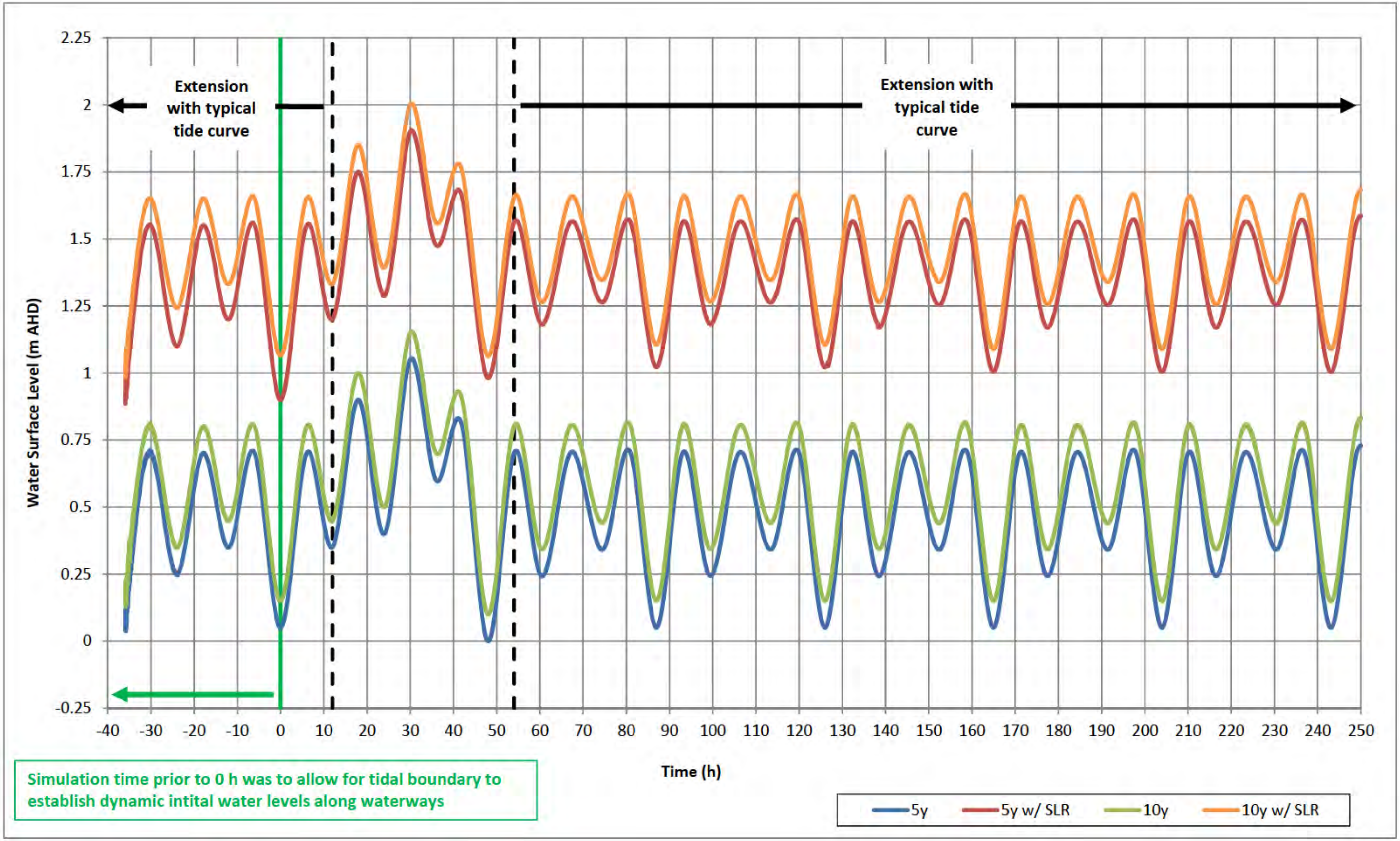
REMAINING FIGURES WILL BE ADDED IN A FUTURE REVISION.

Appendix C – Tidal Curves

Content

10y & 5y Tidal Boundary



Water Surface Level (m AHD)
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
Extension with typical tide curve
Extension with typical tide curve
-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
Time (h)
Simulation time prior to 0 h was to allow for tidal boundary to establish dynamic intital water levels along waterways
5y
5y w/ SLR
10y
10y w/ SLR

Appendix D – Bridge Modelling Approach

1. Introduction

1.1 Background

Following previous investigation by GHD, a refined bridge modelling approach was developed to better represent bridges in TUFLOW that cross waterways. Due to the hydraulic importance of bridge structures in the Lower Yarra River model, this modelling approach has been adopted for this project for such structures within the Study Area. Outside the Study Area, a slightly less detailed approach was adopted to represent the more significant structures given that these were an extension of the model for “verification” and not flood mapping purposes.

1.2 Purpose

This appendix provides:

- An explanation of the need for the refined methodologies for modelling bridge losses,
- The basis of separate deck and pier polygons within the Study Area,
- FLC weighting options and adopted approach in TUFLOW, and
- An overview of the methodology for estimating an adjusted FLC parameter.

2. Refinement of Existing Bridge Modelling Techniques

2.1 Need for refinement of hydraulic analysis

The TUFLOW model is well suited to flood mapping of the Lower Yarra River. It is however limited in its ability to explicitly model bridge losses, relying on parameters and approaches investigated and documented by the Federal Highway Administration and several Universities and road authorities in the publication Hydraulics of Bridge Waterways (Bradley 1978).

Given that bridge losses are a significant aspect of this investigation, their estimation is an important outcome and it was decided that the approach warranted a refined approach. The methodology documented below improves the representation of these characteristics relative to coarser more conventional approaches and is thus better able to represent existing bridge structures.

2.2 The basis of separate deck and pier polygons

The modelling approach taken to represent bridges crossing the waterways was determined in previous projects by testing the relative effectiveness of several different modelling approaches. These approaches included modelling:

- a cross-section averaged bridge with form loss and blockage calculated for the entire bridge span and
- a bridge split up to represent pier and deck polygons individually with application of blockage and form losses varied between different scenarios.

References such as the TUFLOW manual, *Modelling Bridge Piers in 2D using TUFLOW* (TUFLOW 2013) and *Cell Based Modelling of Bridge Piers Using TUFLOW* (Vienot, Sexton and McNulty 2011) were considered and discussed in determining our approach. Both methods can provide a reasonable representation when applied correctly. The split pier and deck polygon approach was adopted within the Mapping limit and upstream of this the slightly simpler cross-sectional average approach was applied.

The more detailed approach was adopted within the Mapping Limit as it provided a good match to Bradley with the added advantage of a more realistic flow and velocity distribution within the bridge leading to more confidence in the representation of effects such as pier shielding and the understanding of scour potential. Although it was found that for pier losses the best representation (relative to Bradley) was achieved using both FLC and blockage factors (consistent with Vienot, Sexton and McNulty 2011 and contrary to TUFLOW 2013) this finding may not be universal or significant since, for most bridges, a low blockage factor is typically applied.

Section 13.1 of Bradley reviews the applicability of the Bradley relationships, several of these numbered points can be related to the current context, sometimes directly and sometimes with a little extrapolation. Some of the more relevant aspects are briefly discussed below:

- Point 1 states that the method of computing backwater is intended to be used for relatively straight reaches. While the Lower Yarra River does meander this characteristic is relatively true.
- Point 10 in Section 13.1 of Bradley essentially states that the method is valid for multiple bridges (hydraulically parallel waterway openings) provided that the flow is properly divided between bridges. While it is a leap to extend this concept to individual cells the logic is somewhat consistent and supported by our testing and that of Vienot, Sexton and McNulty 2011.

2.3 Application of Form Loss Coefficients (FLC) in TUFLOW

As of version 2016-03 AA released on April 4th 2016, TUFLOW provides two methods with which to apply an FLC within layered flow constrictions, the 'Cumulate' method and the 'Portion' method.

- The 'Cumulate' method, which was the only method available in TUFLOW prior to version 2016, effectively sums the FLC of each layer depending on the depth of water within each layer relative to the depth of that layer as shown in Equation 1. This method works well for low flows but fails to reduce the effective FLC when a structure becomes significantly drowned out.
- To address this limitation the 'Portion' method was developed (and is now the default in TUFLOW). It effectively calculates a depth weighted average FLC as shown in Equation 2.

Equation 1 'Cumulate' equation

$$\zeta_{total} = \zeta_1 + \zeta_2 \frac{y_2}{D_2} + \zeta_3 \frac{y_3}{D_3}$$

ζ_n = Layer n FLC

D_n = Depth of layer n

y_n = Layer n water depth (set to zero if dry and cannot exceed depth of layer, D)

ζ_{total} = Applied overall FLC

Equation 2 'Portion' equation

$$\zeta_{total} = \frac{(y_1\zeta_1 + y_2\zeta_2 + y_3\zeta_3)}{y_{total}}$$

$$y_{total} = y_1 + y_2 + y_3 + y_4$$

ζ_n = Layer n FLC

y_n = Layer n water depth (set to zero if dry and cannot exceed depth of layer)

ζ_{total} = Applied overall FLC

Combining either of these methods with the application of standard FLC values (as derived directly from Bradley) yields FLC values as applied by TUFLOW which can be significantly different to those that were intended to be applied. As a result, we looked at how the FLC values could be adjusted to achieve a target FLC at certain levels. A sample set of FLC parameters are defined in Table 2-1, with Figure 2-1 showing how the values are interpreted by TUFLOW. This figure shows the following (when FLCs in Table 2-1 are adopted):

- The 'Cumulate' method (using FLC values of 0.1, 1.5625 and 0 for layers 1, 2 and 3 respectively) perhaps best defines typical Industry Practice (until recently). It applies the desired FLCs up until the top of 'Layer 1'. Above this level the adopted FLC is overstated, but is similar to intended provided the 'Layer 1' FLC is small and that there is not significant overtopping,
- The 'Portion' method (using FLC values of 0.1, 1.5625 and 0) applies the intended FLC for 'Layer 1' only and in the absence of adjustment, applies a much lower than intended FLC for 'Layer 2' and higher.
- The 'Adjusted Cumulate' method (using FLC values of 0.1, 1.4625 and 0) generally results in the intended behaviour provided that there is not significant overtopping (since the applied FLC will never reduce with increasing depth above the top of Layer 2).
- The 'Adjusted Portion' method (using FLC values of 0.1, 7.4125 and 0) applies the desired FLCs up until the top of 'Layer 2', from which point it applies an FLC that diminishes with depth. The reduction of FLC with depth is consistent with a structure becoming more drowned out.

The 'Adjusted Portion' method gives FLCs closest to those intended, and as such this is the method that has been adopted for the Yarra River modelling. It effectively involves the use of the now default 'Portion' option with a higher 'Layer 2' FLC input value to achieve a more correct effective FLC when the deck is fully submerged (and reasonable approximations at other levels).

Table 2-1 Sample FLCs for comparison

FLC Layer	Applied Total FLC		
	Cumulate & Portion	Adjusted Cumulate	Adjusted Portion
1	0.1	0.1	0.1
2	1.5625	1.4625	7.4125
3	0	0	0

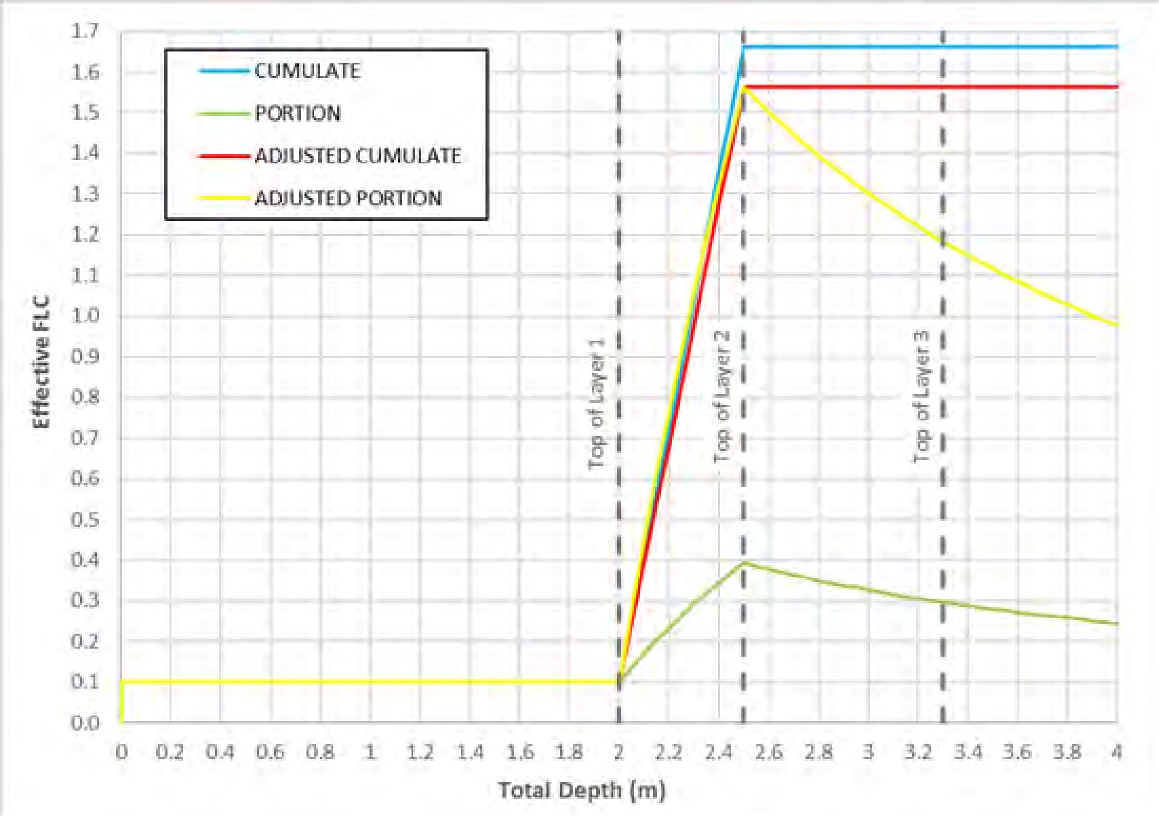


Figure 2-1 Effect of Averaging Method on Effective FLC

2.4 Adjusting FLC Values

This section provides an overview of how the FLC values derived from Bradley were adjusted for use with the default 'Portion' option on the discrete TUFLOW Layered Flow Constriction polygons defining the 'Deck' and 'Pier' sections within the Study Area.

2.4.1 Methodology Overview

To apply the 'Adjusted Portion' method, the following steps were taken.

1. To begin, the '<u>Bradley FLC</u>' values (i.e. the FLC values desired at the top of each layer within the layered flow constriction shapes) were estimated in accordance with Bradley. These targeted FLC values are outlined below.
   - Deck polygon: Layer 1 FLC of 0, Layer 2 FLC of 1.5625, Layer 3 FLC of 0.
   - Pier polygon: Layer 1 FLC values depending on pier type and dimensions, Layer 2 FLC of 1.5625, Layer 3 FLC of 0.

   For pier polygons the 'Bradley FLC' values within 'Layer 1' were scaled up by a factor equal to the number of cells across the span of the bridge (perpendicular to the direction of flow) that the pier is representing to give the 'Target FLC'. This factoring is required due to the pier related FLC being applied on only a small portion of the bridge while the 'Bradley FLC' value represents a cross-sectional average for the entire bridge. For example, given the pier polygon covered only one third of the span which it represented, the FLC on this section would be required to be scaled up three times to account for the FLC not being applied on the adjacent cells that they would otherwise be applied on.

2. The ‘Required FLC’ values that would achieve the ‘Target FLC’ values were next determined. The calculation of these required the average depth beneath each polygon to be determined as an input into the ‘Portion’ equation, with the ‘Required FLC’ of each layer then back-calculated by rearranging the ‘Portion’ equation. The ‘Portion’ equation is reproduced below.

$$\zeta_{total} = \frac{(y_1\zeta_1 + y_2\zeta_2 + y_3\zeta_3)}{y_{total}}$$

$$y_{total} = y_1 + y_2 + y_3 + y_4$$

ζ_n = Layer n FLC

y_n = Layer n water depth (set to zero if dry and cannot exceed depth of layer)

ζ_{total} = Applied overall FLC

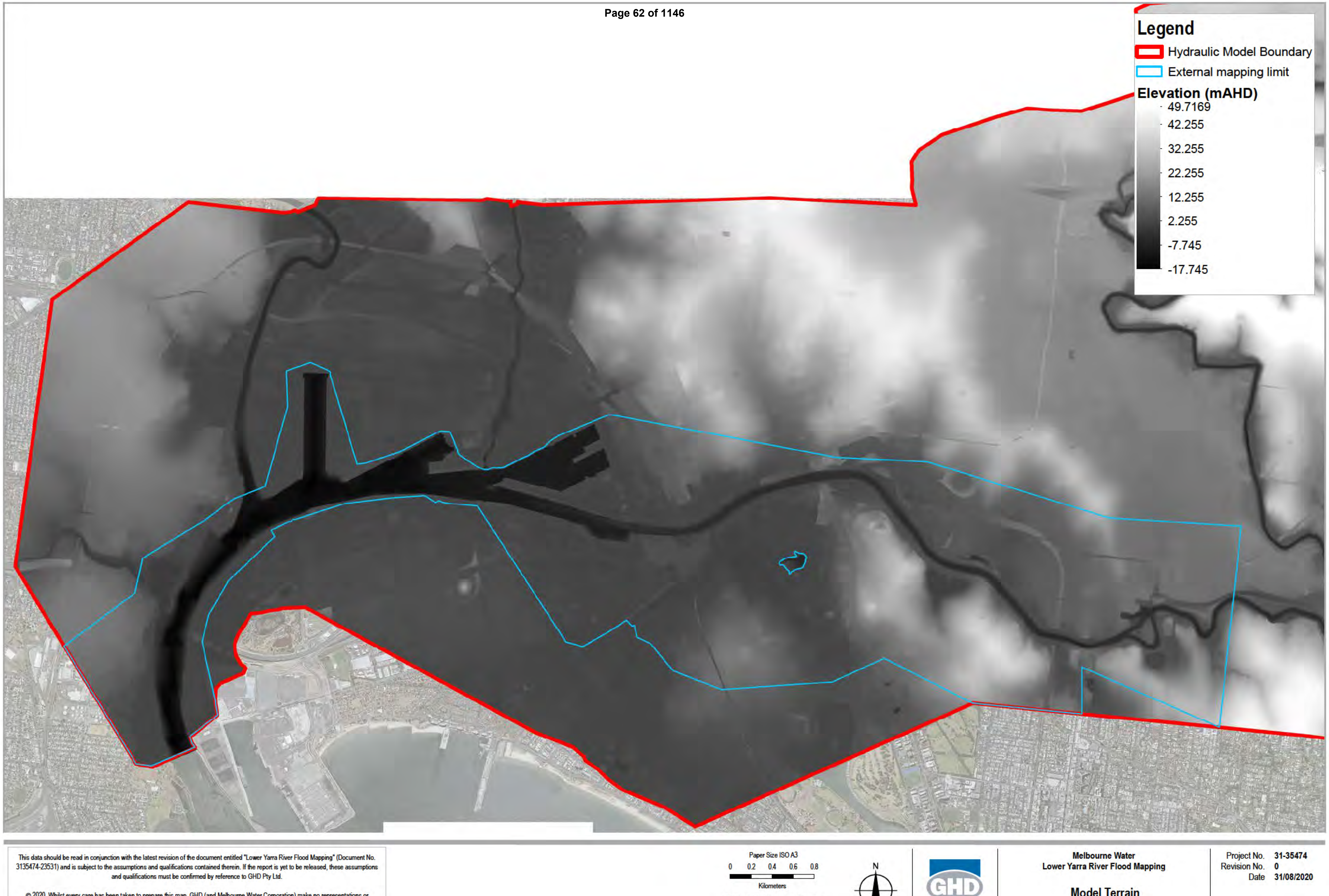
3. The ‘Applied FLC’ values that were input into the layered flow constriction shape attributes were then derived. These were calculated by dividing the ‘Required FLC’ values by the product of the number of cell sides in the direction of flow of the deck/pier polygon and the cell size (i.e. attaining the FLC per metre in the direction of flow along the bridge over as many cells as the number of cell sides crossed by the polygon in the direction of flow).

3. Summary

Due to the hydraulic importance of bridge structures for the Lower Yarra model, a refined bridge modelling approach has been applied to represent the bridges crossing the Lower Yarra River. This approach is considered an improvement on the more traditional bridge modelling approaches and as such has been adopted for all bridges crossing the Lower Yarra River that may be intercepted by flood waters at the deck level (and as such require FLC adjustment).

Appendix E – Flood Maps

Content



This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Model Terrain

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E1

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_TERRAIN.mxd
Print date 31 Aug 2020 - 22 40

Data source . Created by tuflowmeluser

NOTES:

1. Local flooding of other areas, or in excess of the extents shown, may occur. The extent of flooding shown relates to flooding from mapped reaches of Melbourne Water drains or waterways and does not generally include private drainage systems.

2. Flood information shown relates only to floodwaters emanating from riverine flooding associated with the Yarra River, Moonee Ponds Creek and Mariybrnong River, and does not include any allowance for flood events on local catchments that drain into the modellled area or those on downstream receiving waterbodies. In the lower reaches of most drainage systems, greater flood levels, depths and/or velocities than those shown may result from flood events on downstream waterways. Flood levels greater than those shown may occur:
   (a) upstream of the upstream mapping limits of each mapped drain.
   (b) along private or other drains, either within or outside the extents of land liable to flooding shown.

3. The approximate extents of land liable to flooding have been based on survey data available at the time of preparation. The exact extent of flooding for individual properties can only be determined by a licensed surveyor.

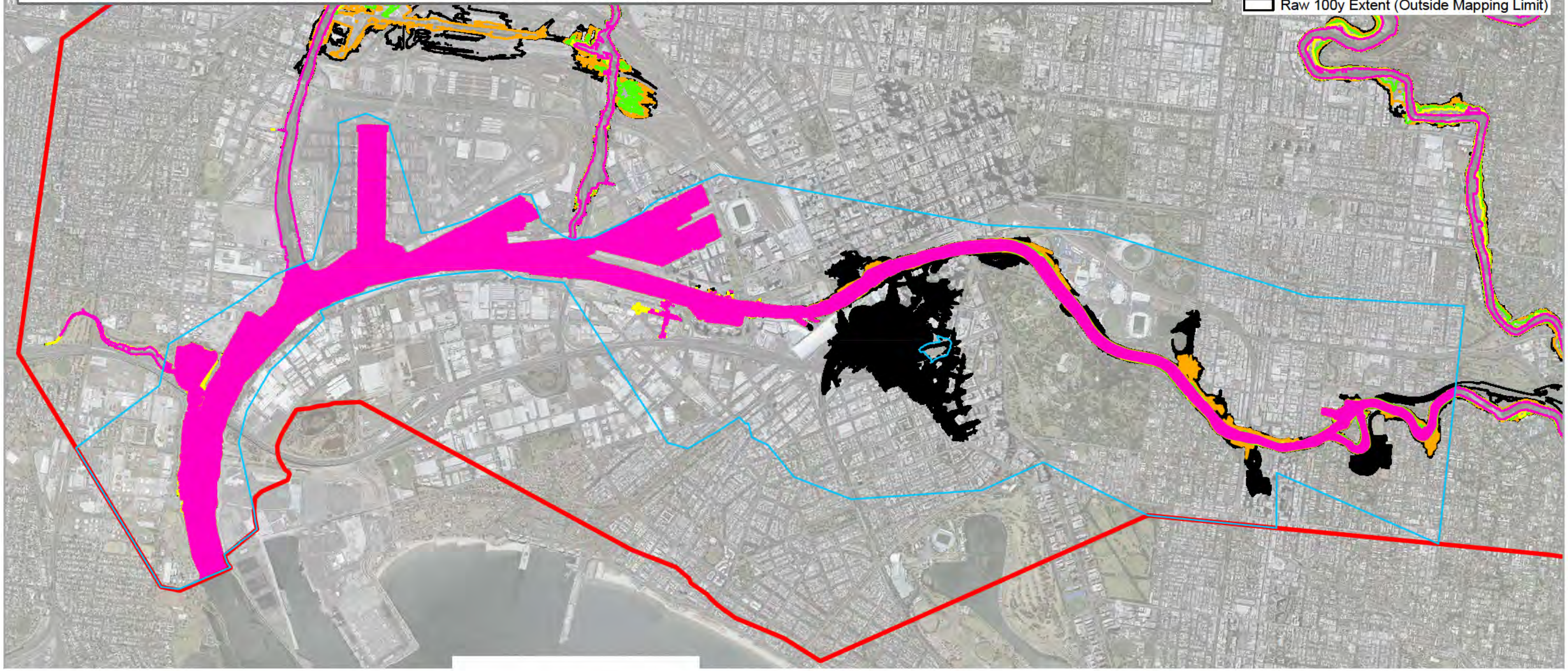
4. Local increases in flood extents, levels, depths and/or velocities shown may result from local factors such as drain blockages, and local obstructions to overland flows such as fences, buildings and cars.

5. The extents should be taken as indicative only. It is likely that the flooding experienced during a real rainfall event may differ to the design events indicated on these maps.

6. Cadastral boundaries and drain locations have been supplied by Melbourne Water and have not been independently verified.

Legend

- Hydraulic Model Boundary
- External mapping limit
- 5y Extent
- 10y Extent
- 20y Extent
- 50y Extent
- 100y Extent
- Raw 5y Extent (Outside Mapping Limit)
- Raw 10y Extent (Outside Mapping Limit)
- Raw 20y Extent (Outside Mapping Limit)
- Raw 50y Extent (Outside Mapping Limit)
- Raw 100y Extent (Outside Mapping Limit)



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Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Flood Extents
Base Case Scenario

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E2

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_EXTENTS.mxd
Print date 31 Aug 2020 - 22:32

Data source . Created by tuflowmeluser

NOTES:

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2. Flood information shown relates only to floodwaters emanating from riverine flooding associated with the Yarra River, Moonee Ponds Creek and Mariybrnong River, and does not include any allowance for flood events on local catchments that drain into the modellled area or those on downstream receiving waterbodies. In the lower reaches of most drainage systems, greater flood levels, depths and/or velocities than those shown may result from flood events on downstream waterways. Flood levels greater than those shown may occur:
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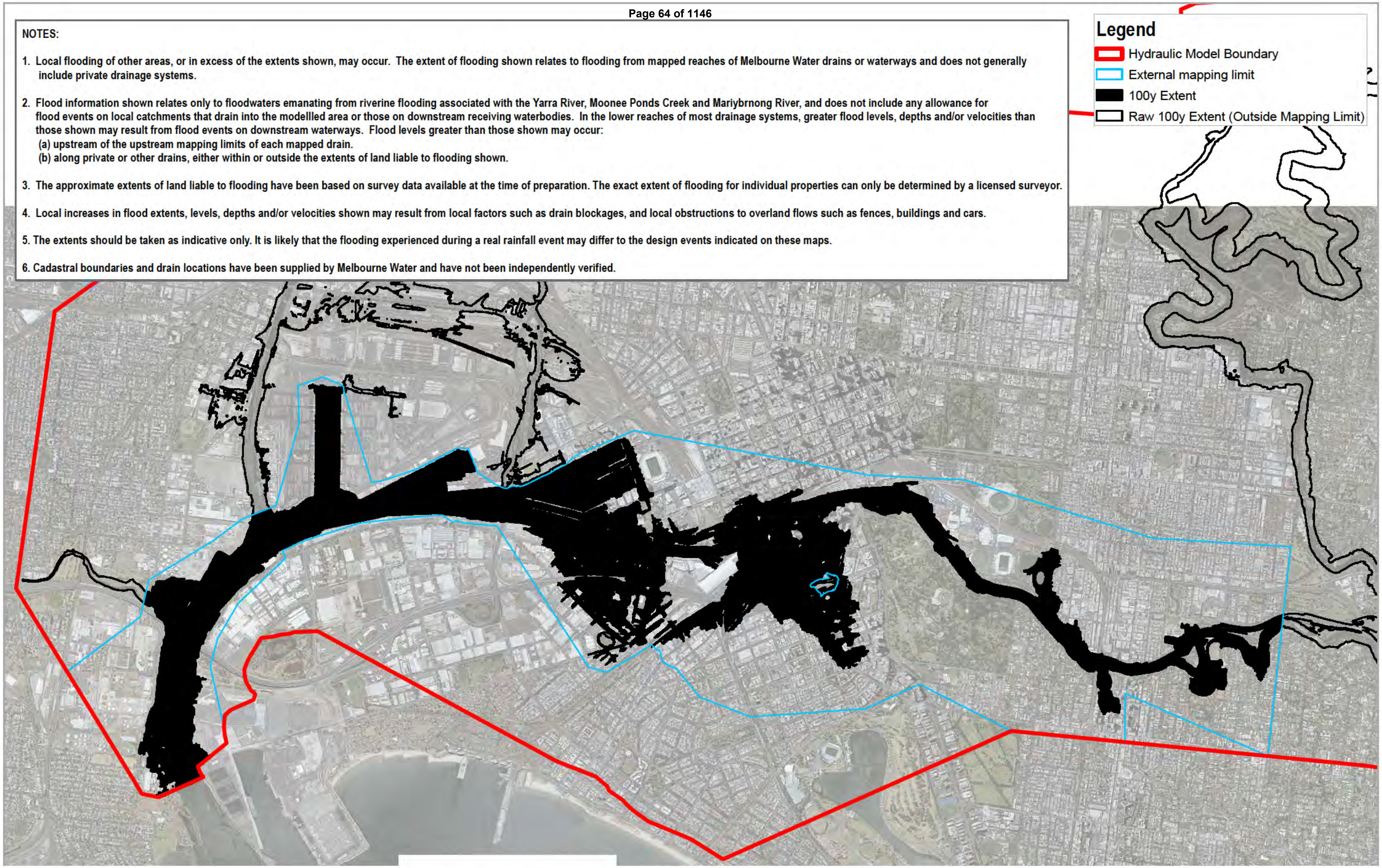

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_EXTENTS.mxd
Print date 31 Aug 2020 - 22 33

Melbourne Water
Lower Yarra River Flood Mapping

Flood Extents
Climate Change 1 Scenario

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E3

Data source . Created by tullowmeliuser

NOTES:

1. Local flooding of other areas, or in excess of the extents shown, may occur. The extent of flooding shown relates to flooding from mapped reaches of Melbourne Water drains or waterways and does not generally include private drainage systems.

2. Flood information shown relates only to floodwaters emanating from riverine flooding associated with the Yarra River, Moonee Ponds Creek and Mariybrnong River, and does not include any allowance for flood events on local catchments that drain into the modellled area or those on downstream receiving waterbodies. In the lower reaches of most drainage systems, greater flood levels, depths and/or velocities than those shown may result from flood events on downstream waterways. Flood levels greater than those shown may occur:
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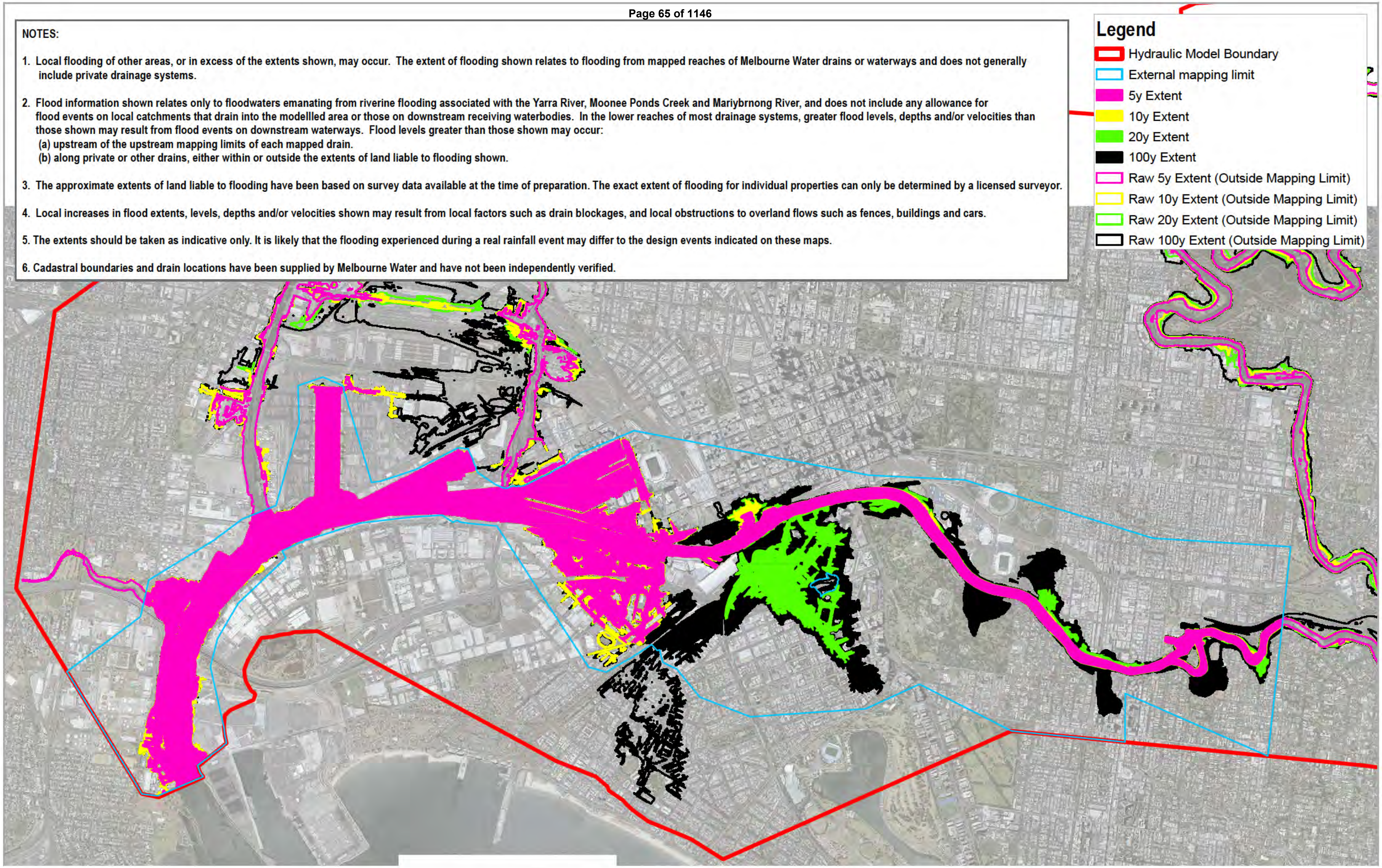
6. Cadastral boundaries and drain locations have been supplied by Melbourne Water and have not been independently verified.



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Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Flood Extents
Climate Change 2 Scenario

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E4

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_EXTENTS.mxd
Print date 31 Aug 2020 - 22 33

Data source . Created by tuflowmeluser

NOTES:

1. Local flooding of other areas, or in excess of the extents shown, may occur. The extent of flooding shown relates to flooding from mapped reaches of Melbourne Water drains or waterways and does not generally include private drainage systems.

2. Flood information shown relates only to floodwaters emanating from riverine flooding associated with the Yarra River, Moonee Ponds Creek and Mariybrnong River, and does not include any allowance for flood events on local catchments that drain into the modellled area or those on downstream receiving waterbodies. In the lower reaches of most drainage systems, greater flood levels, depths and/or velocities than those shown may result from flood events on downstream waterways. Flood levels greater than those shown may occur:
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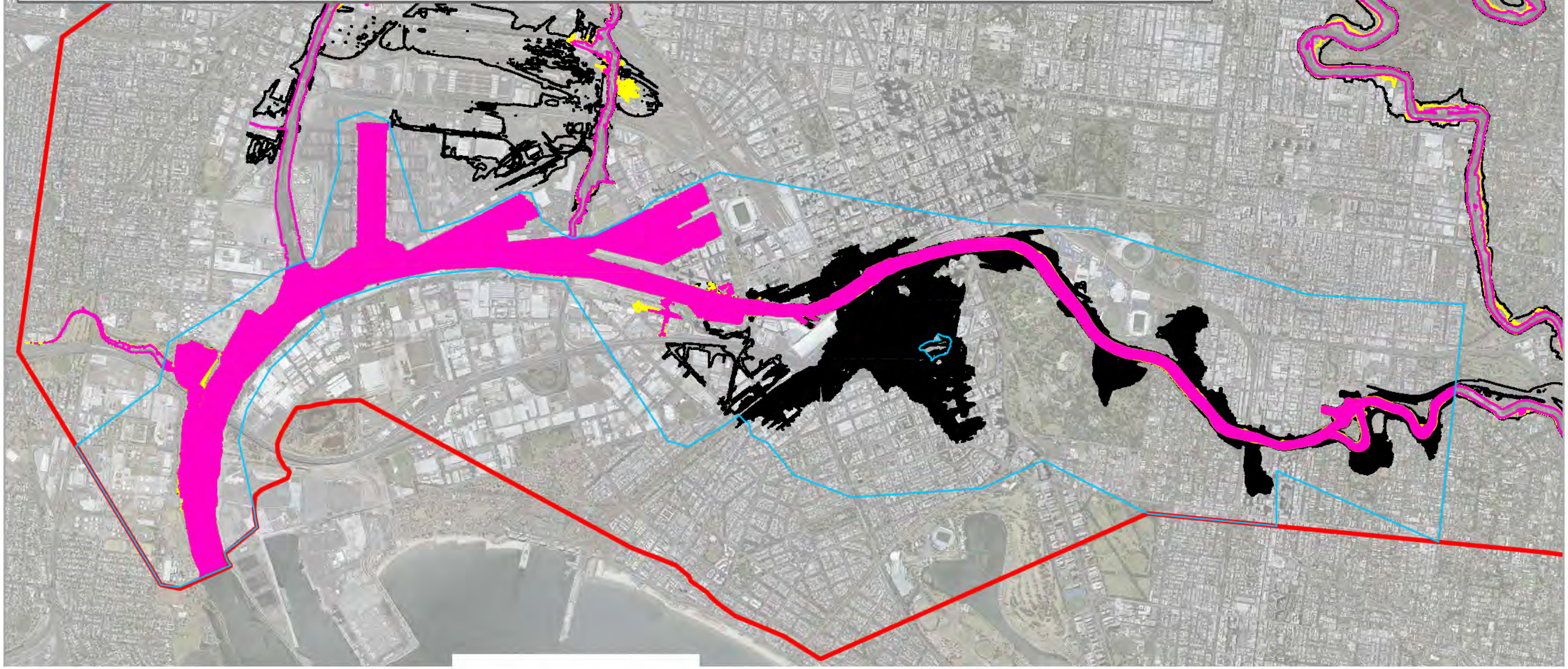
6. Cadastral boundaries and drain locations have been supplied by Melbourne Water and have not been independently verified.

Legend

- Hydraulic Model Boundary
- External mapping limit
- 5y Extent
- 10y Extent
- 100y Extent
- Raw 5y Extent (Outside Mapping Limit)
- Raw 10y Extent (Outside Mapping Limit)
- Raw 100y Extent (Outside Mapping Limit)



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Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Melbourne Water
Lower Yarra River Flood Mapping

Flood Extents
Climate Change 3 Scenario

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E5

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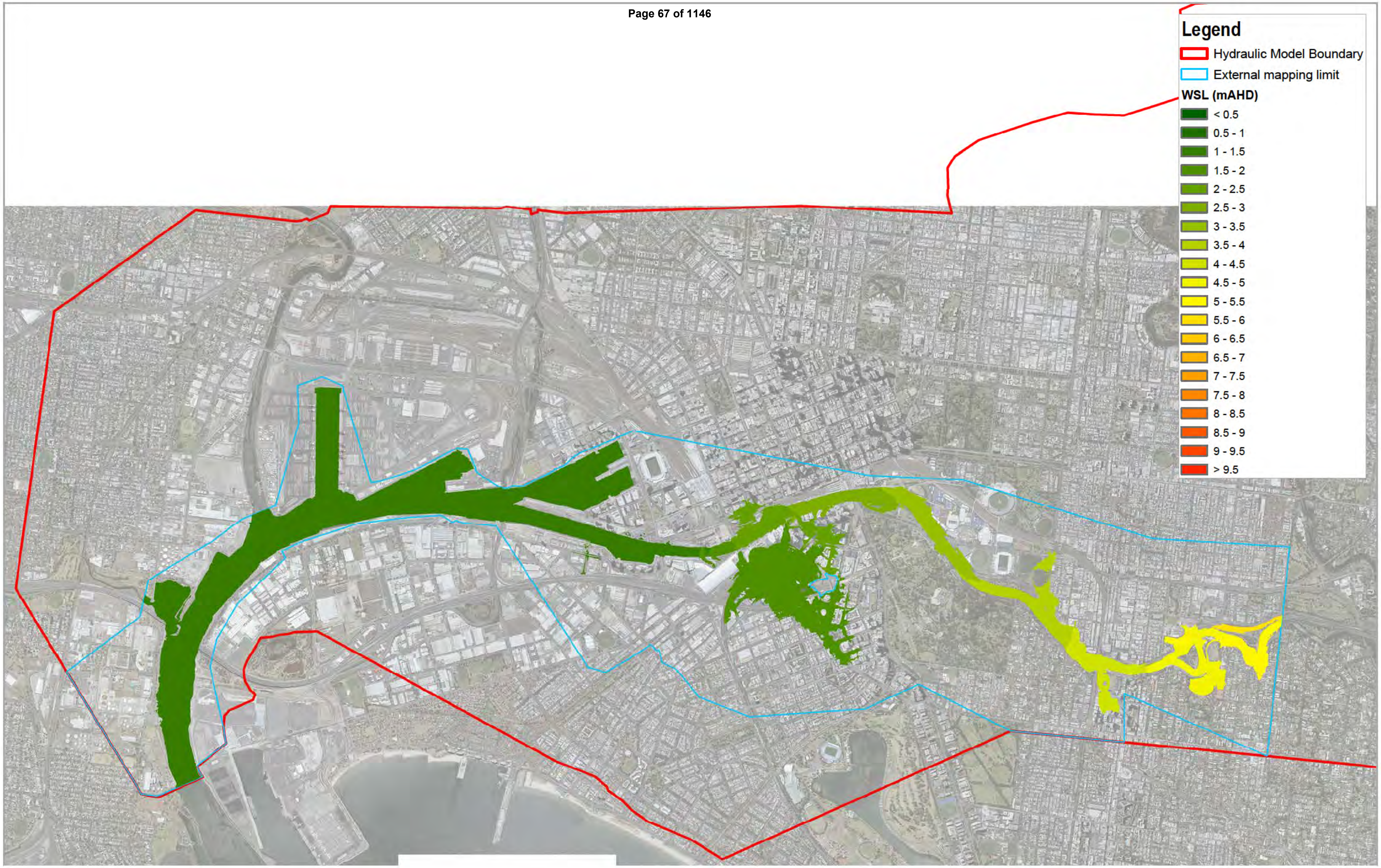

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Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

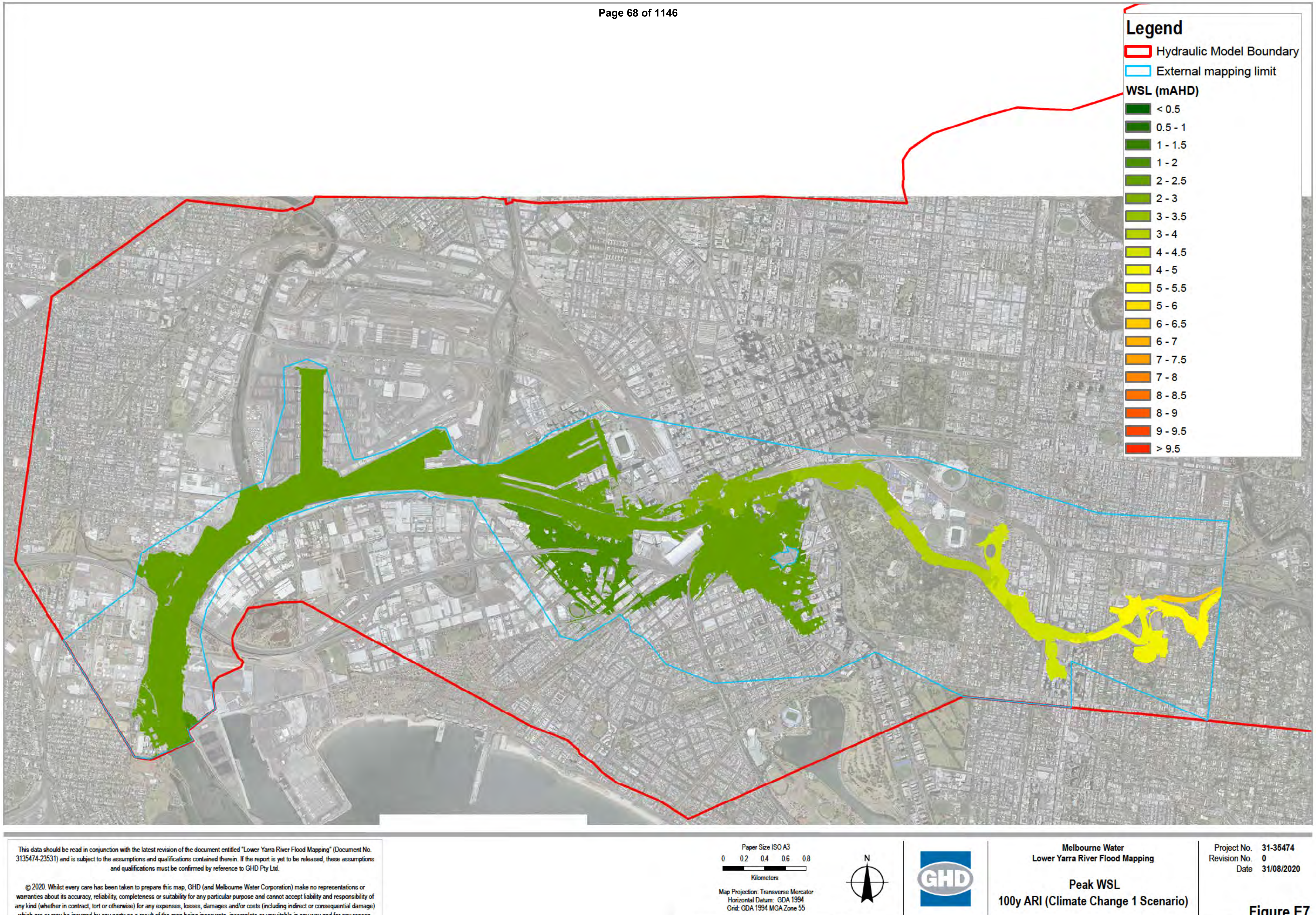
Peak WSL
100y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E6

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09 00

Data source . Created by tuflowmeluser



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Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
100y ARI (Climate Change 1 Scenario)

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E7

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09 01

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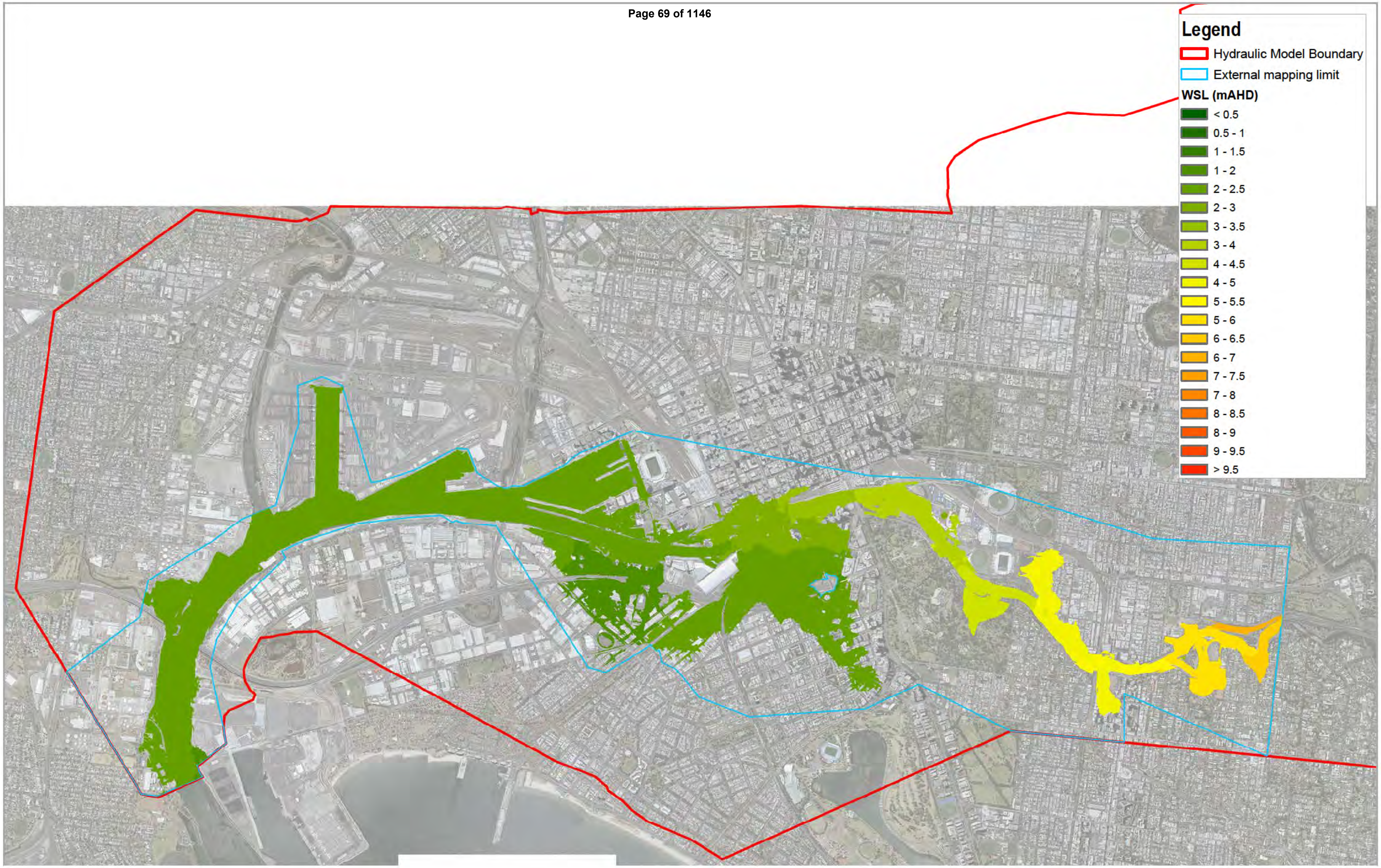


Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

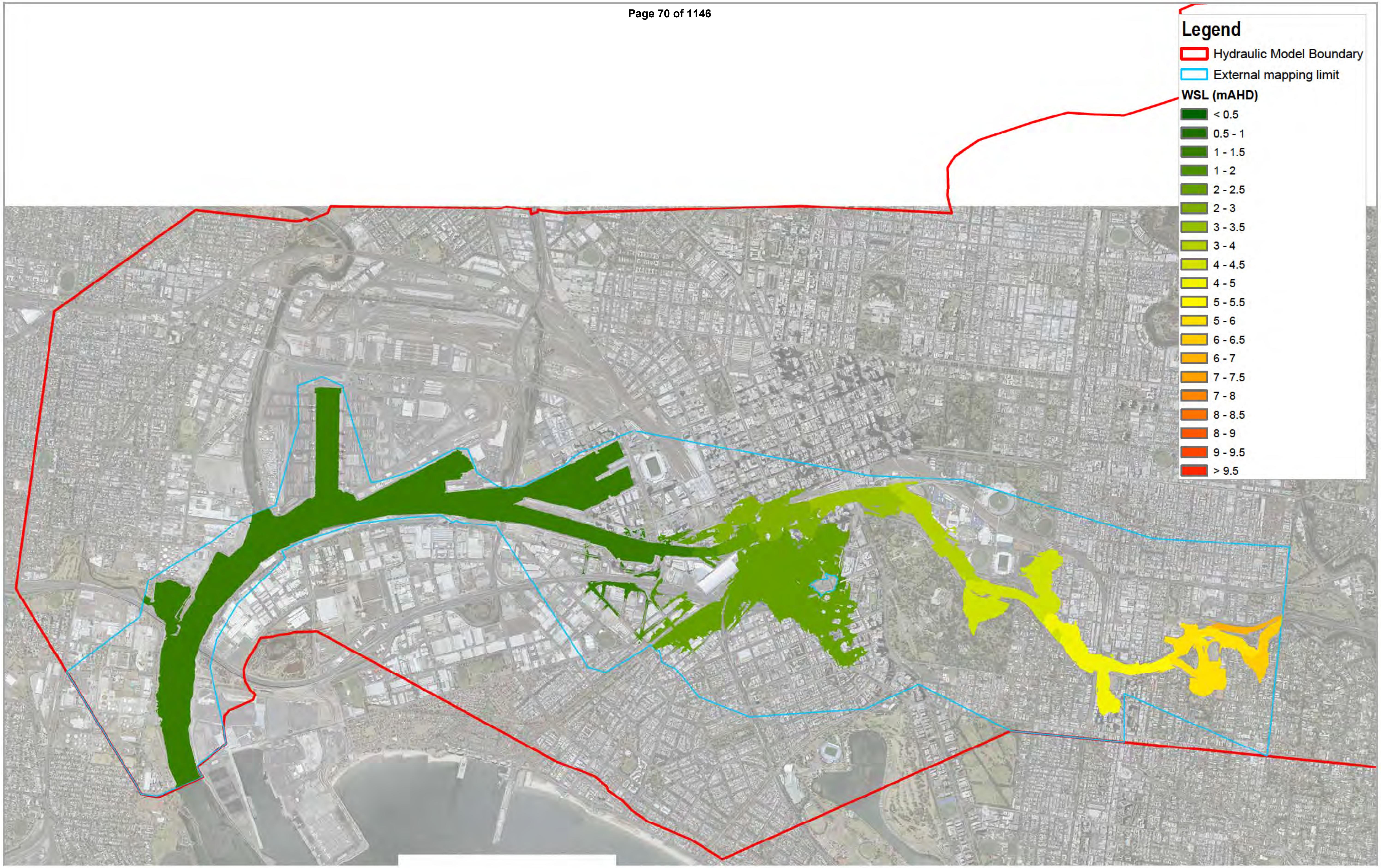
Peak WSL
100y ARI (Climate Change 2 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E8

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09:01

Data source . Created by tuflowmeluser



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Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
100y ARI (Climate Change 3 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E9

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09 01

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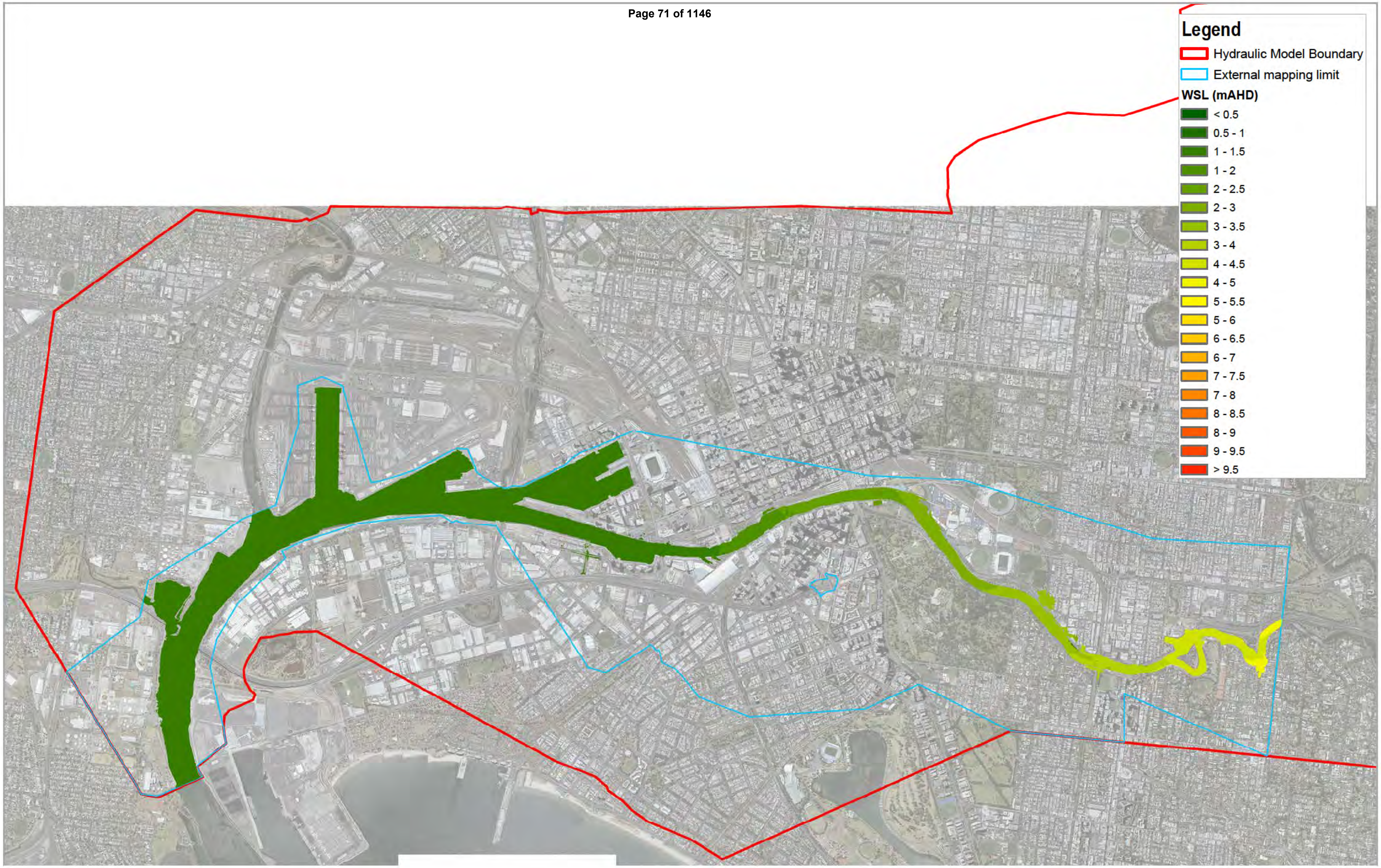

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Melbourne Water
Lower Yarra River Flood Mapping

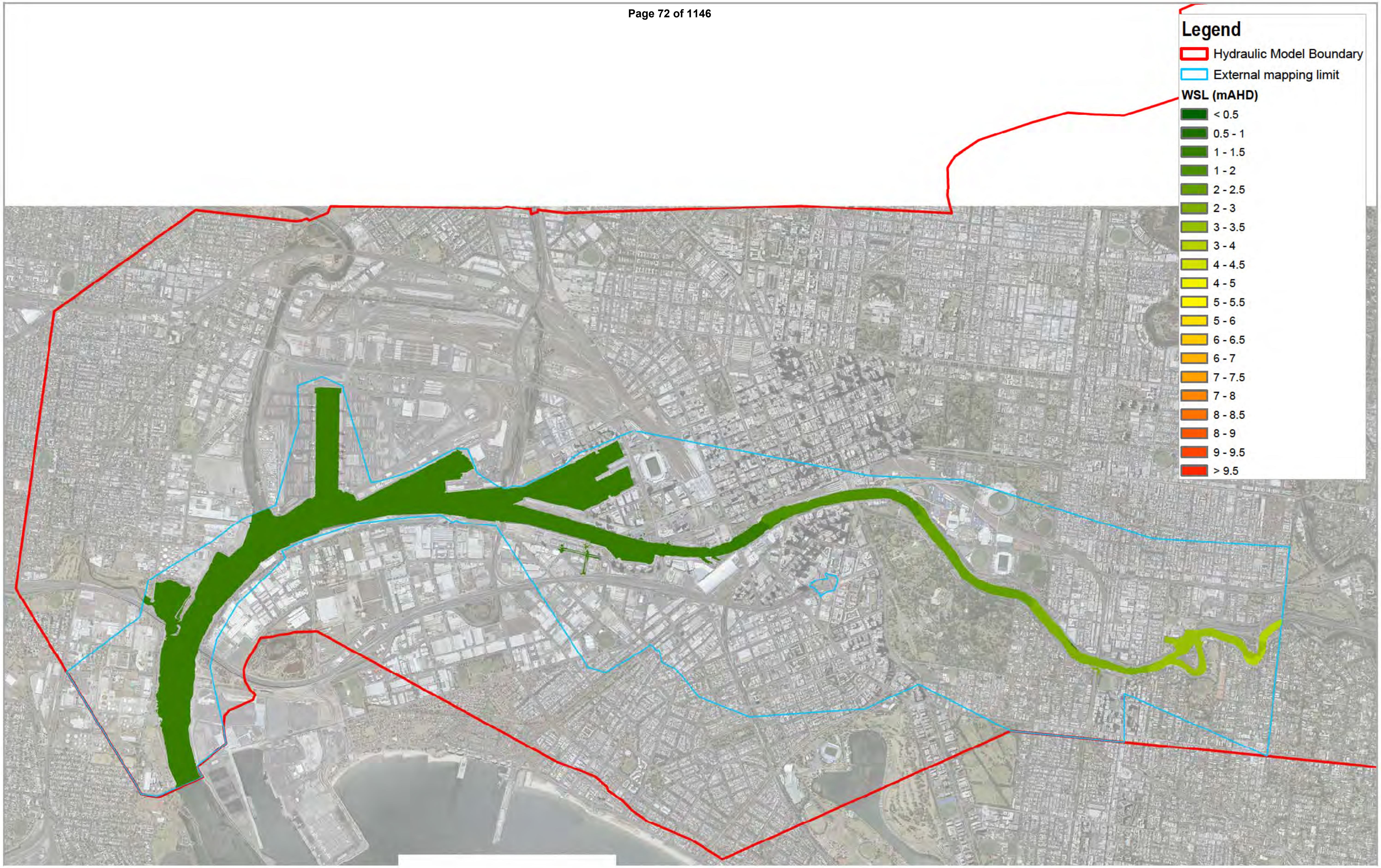
Peak WSL
50y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E10

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09 01

Data source . Created by tuflowmeluser



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
20y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E11

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09:02

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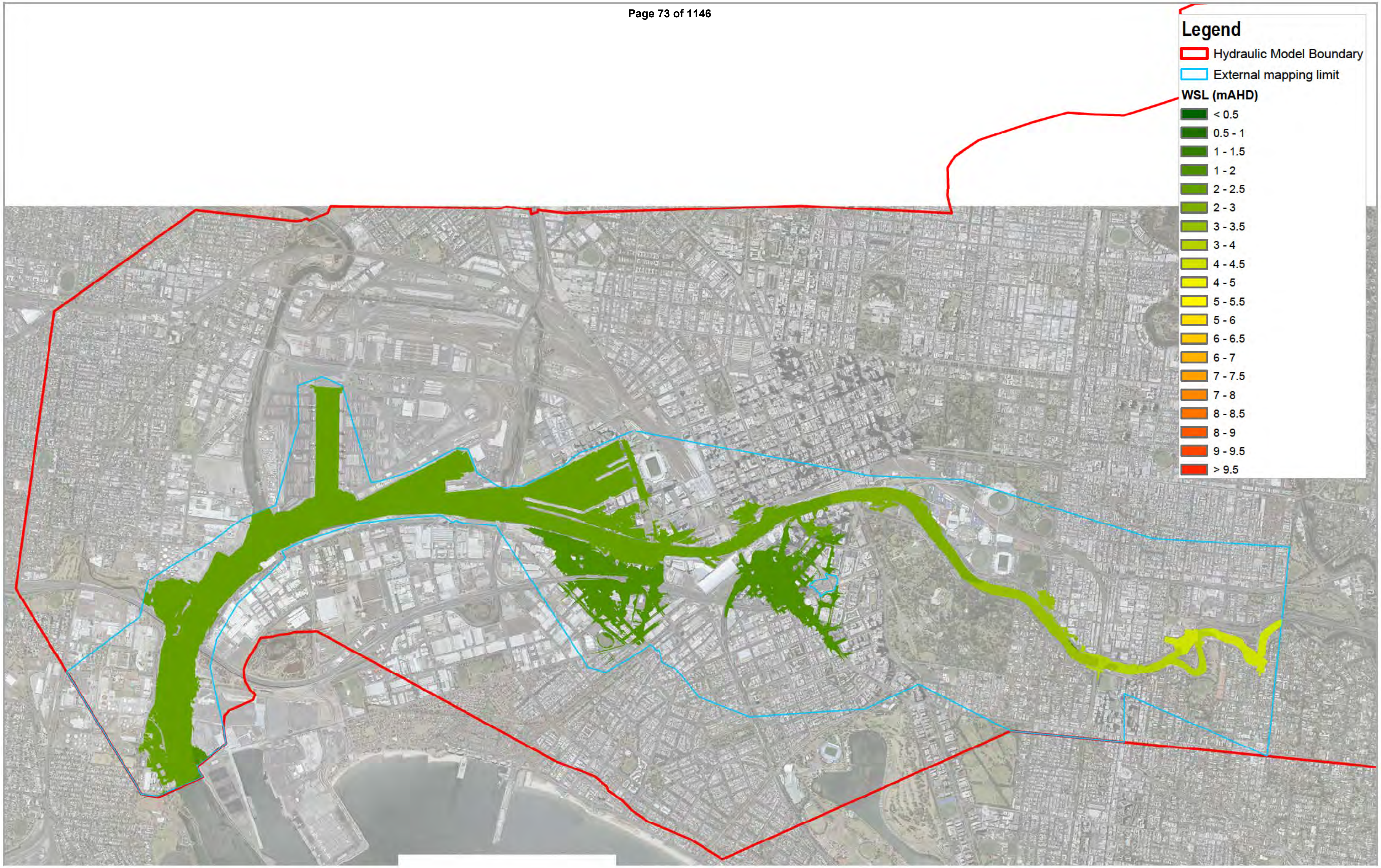

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Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

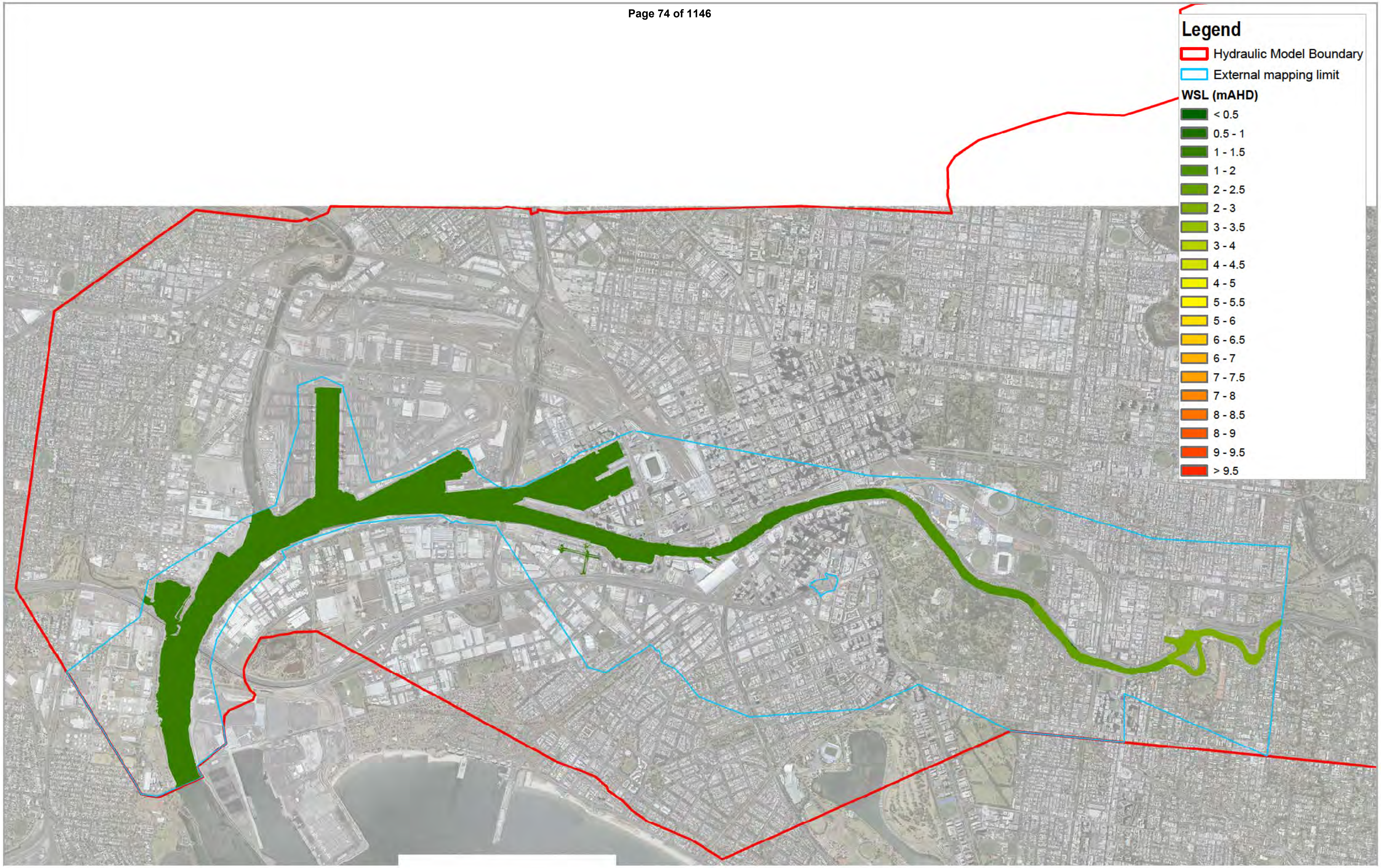
Peak WSL
20y ARI (Climate Change 2 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E12

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09 02

Data source . Created by tuflowmeluser



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
10y ARI (Base Case Scenario)

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E13

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09:02

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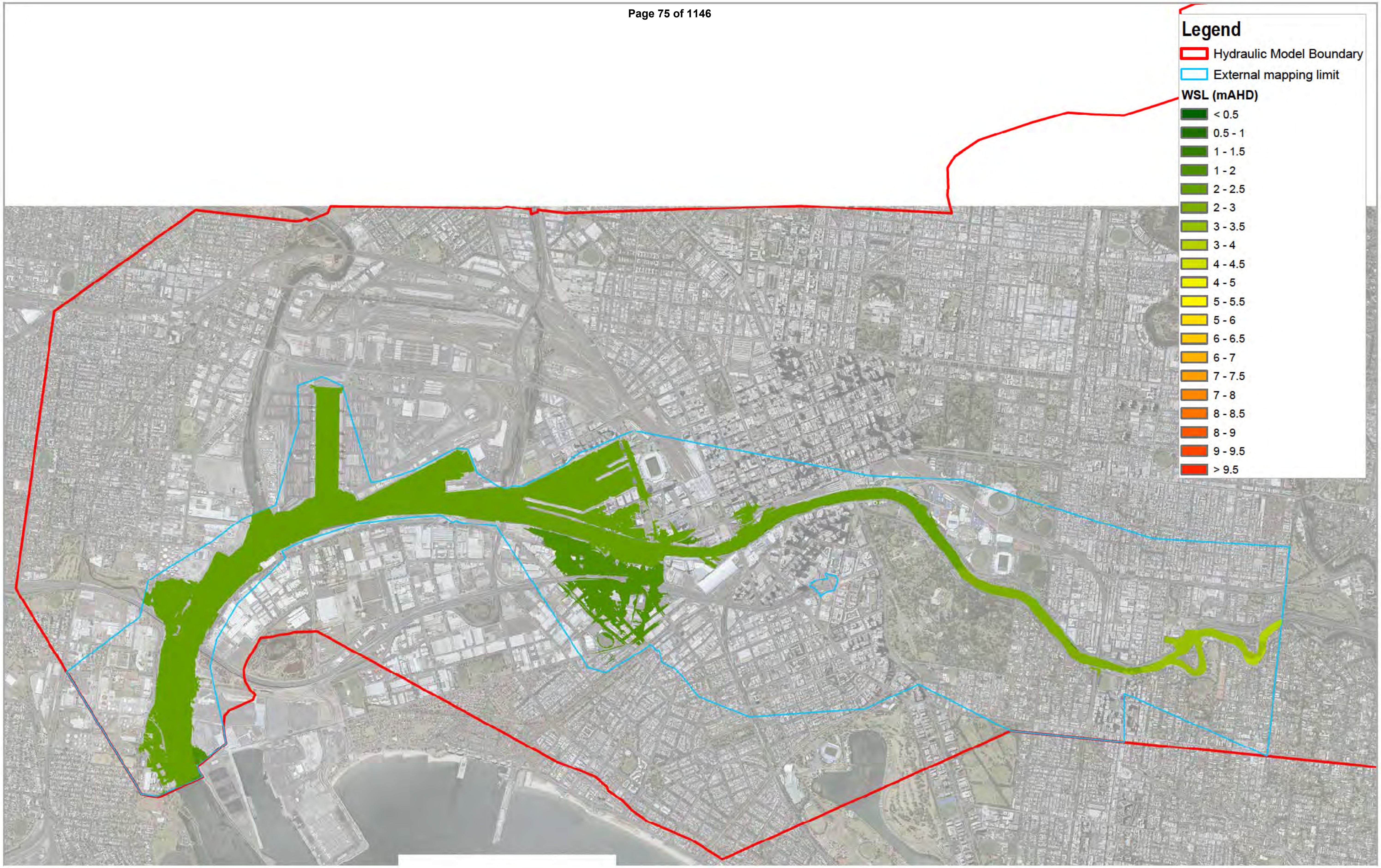

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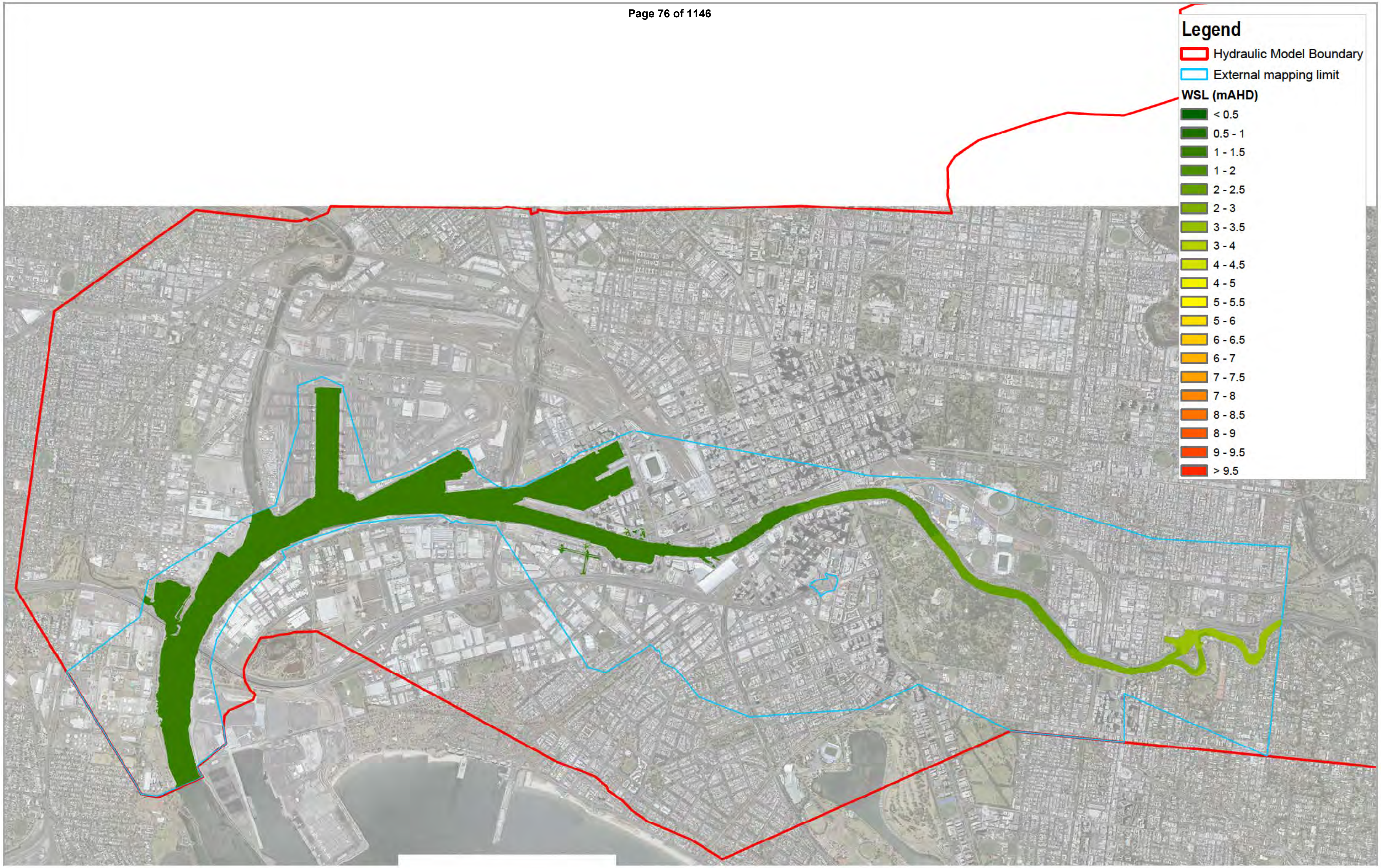
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
10y ARI (Climate Change 2 Scenario)

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E14



This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
10y ARI (Climate Change 3 Scenario)

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E15

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Print date 01 Sep 2020 - 09 03

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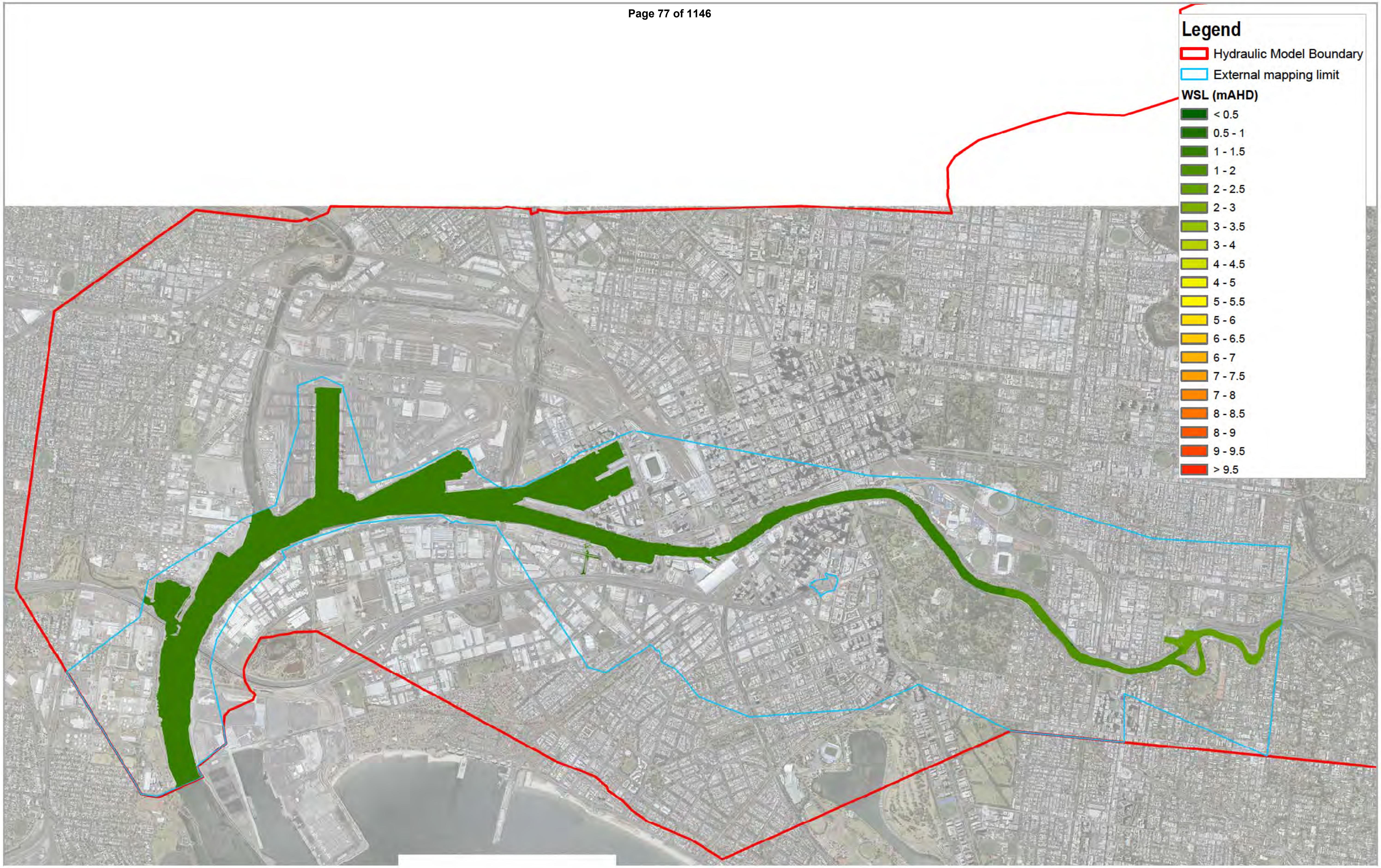

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
5y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E16

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09 03
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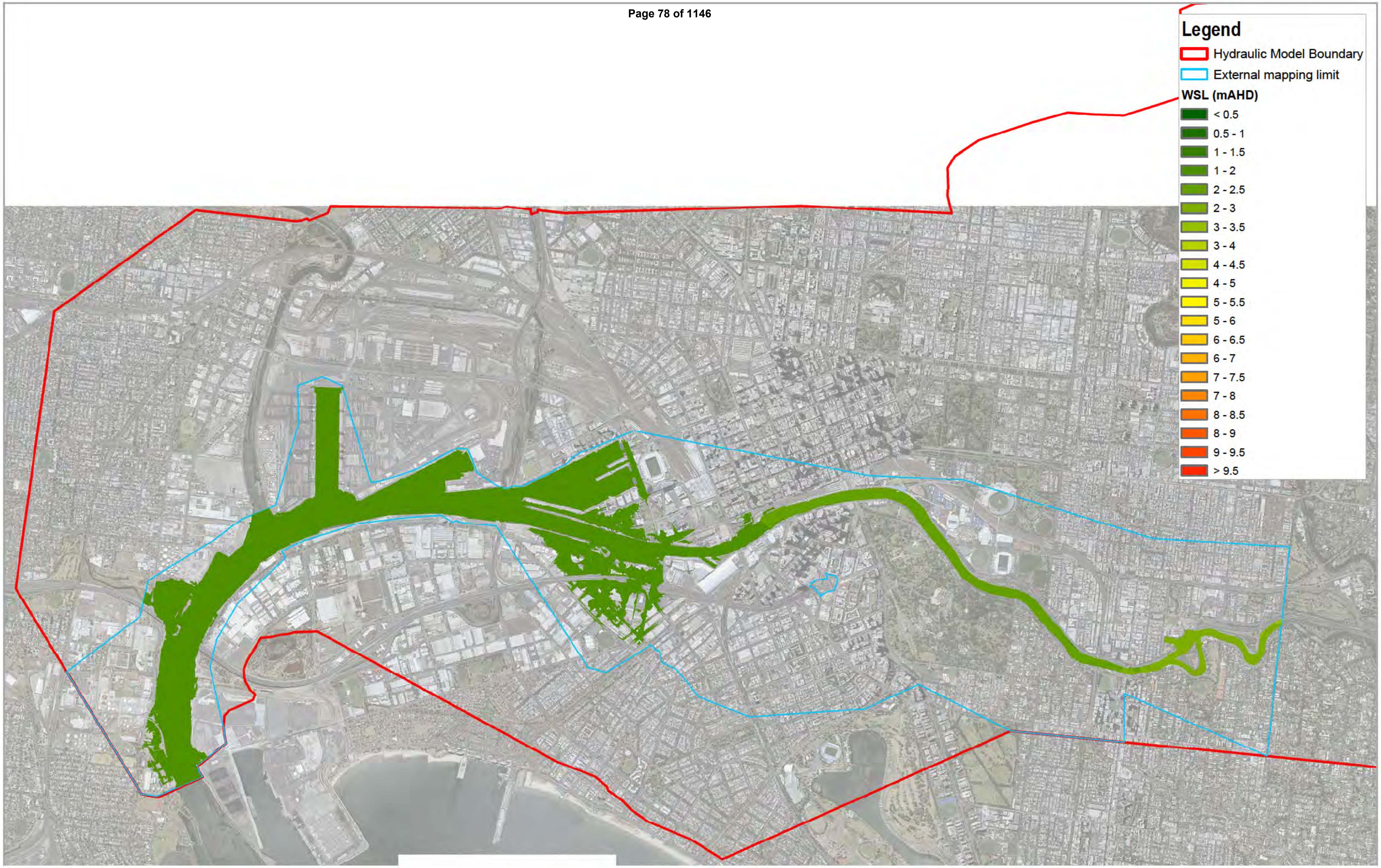

Paper Size ISO A3
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Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
5y ARI (Climate Change 2 Scenario)

Project No. 31-35474
Revision No. 0
Date 31/08/2020

Figure E17

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_WSL.mxd
Print date 01 Sep 2020 - 09:03

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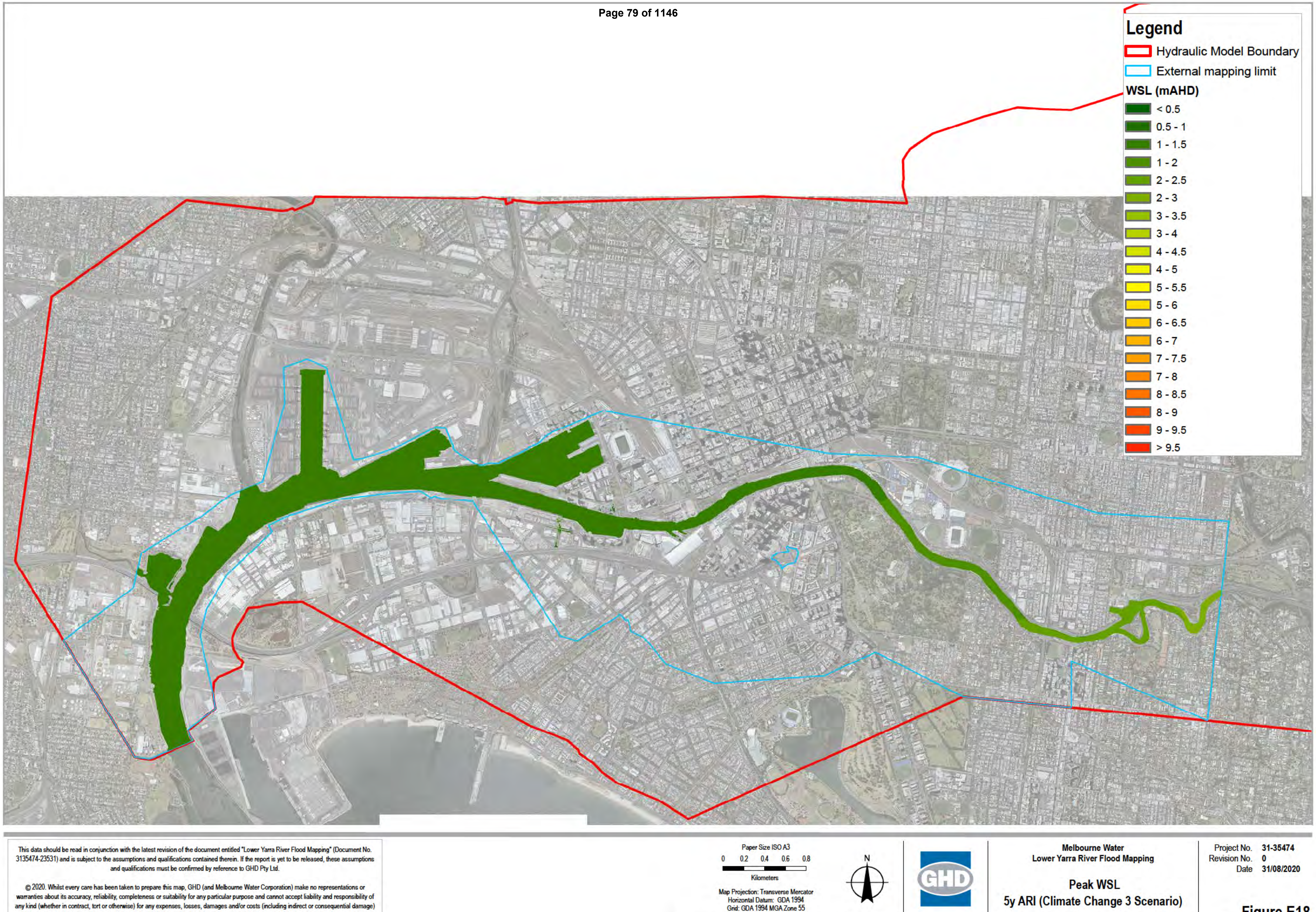

Melbourne Water
Lower Yarra River Flood Mapping

Peak WSL
5y ARI (Climate Change 3 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E18

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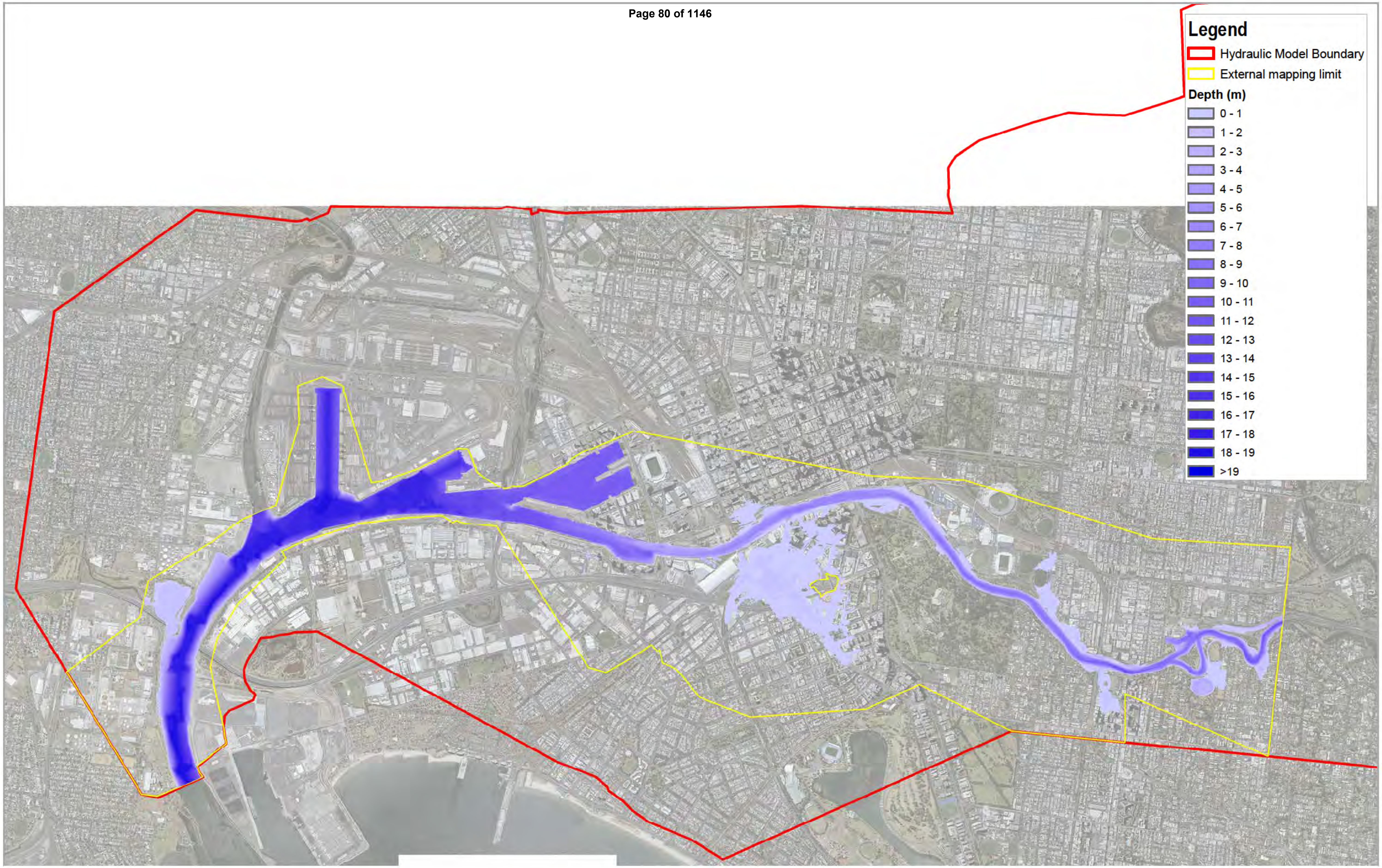

Paper Size ISO A3

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
100y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E19

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_DEP.mxd
Print date 01 Sep 2020 - 08 54

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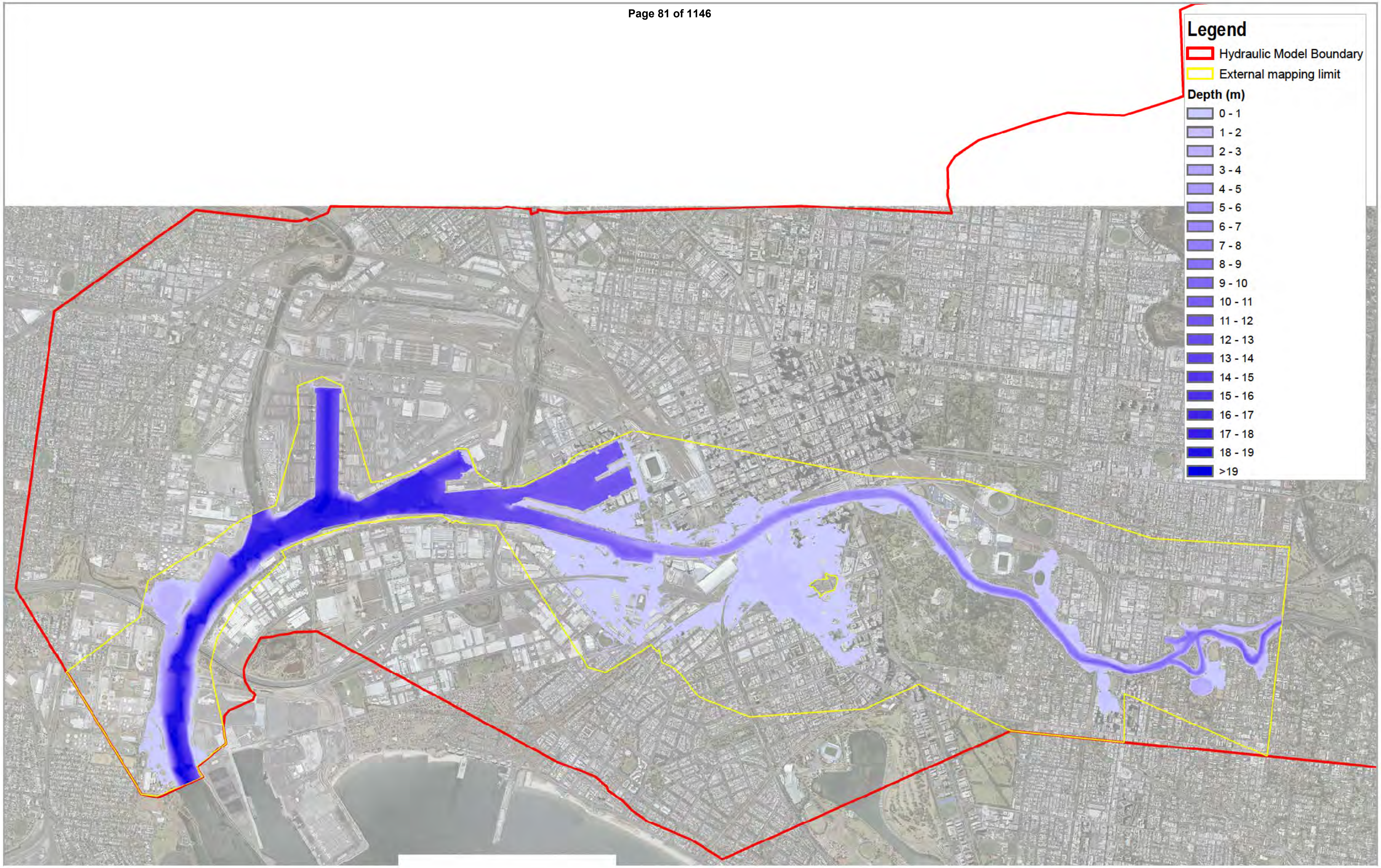

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
100y ARI (Climate Change 1 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E20

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_DEP.mxd
Print date 01 Sep 2020 - 08 55

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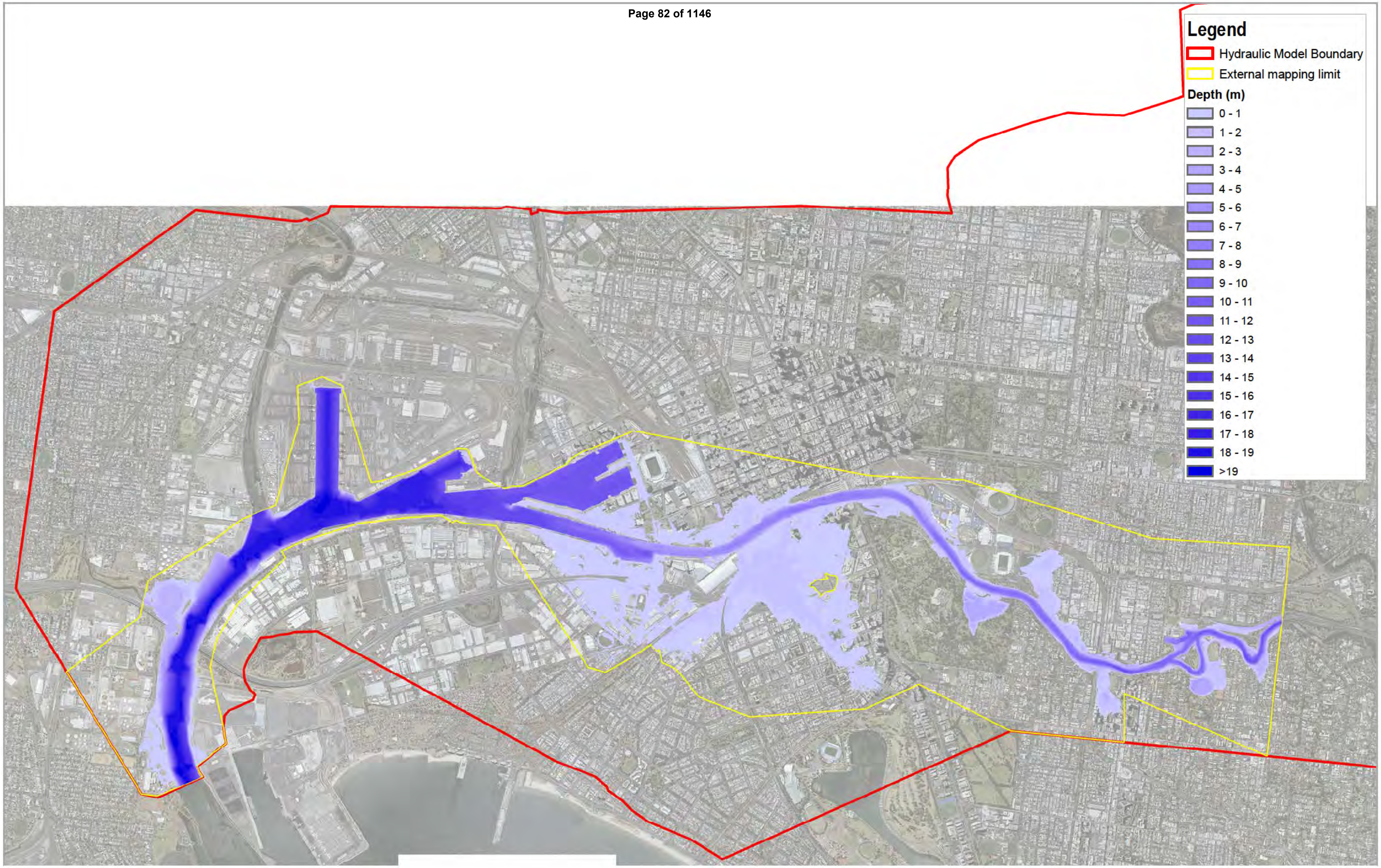

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Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
100y ARI (Climate Change 2 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E21

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_DEP.mxd
Print date 01 Sep 2020 - 08 55

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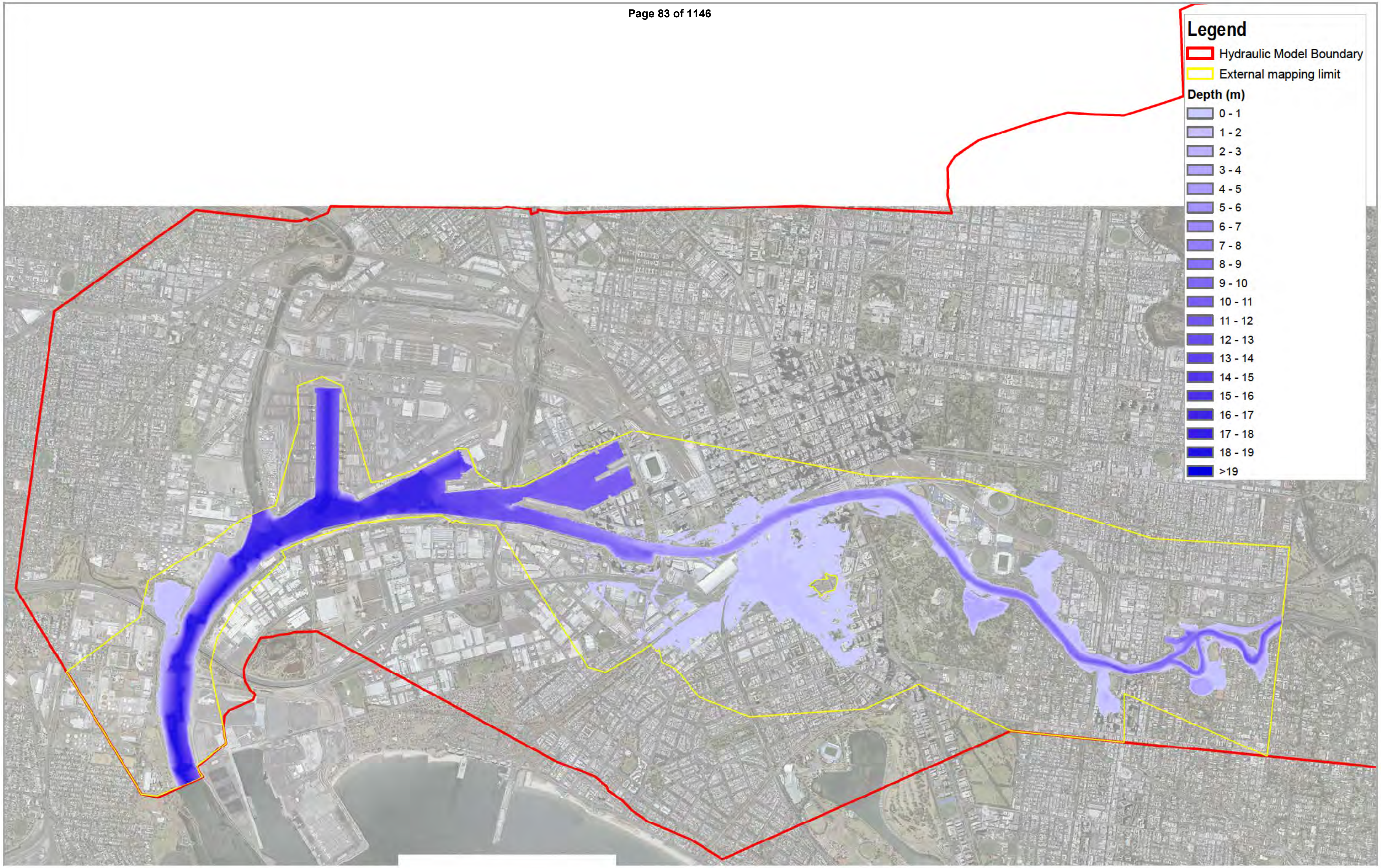

This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
100y ARI (Climate Change 3 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E22

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_DEP.mxd
Print date 01 Sep 2020 - 08 55

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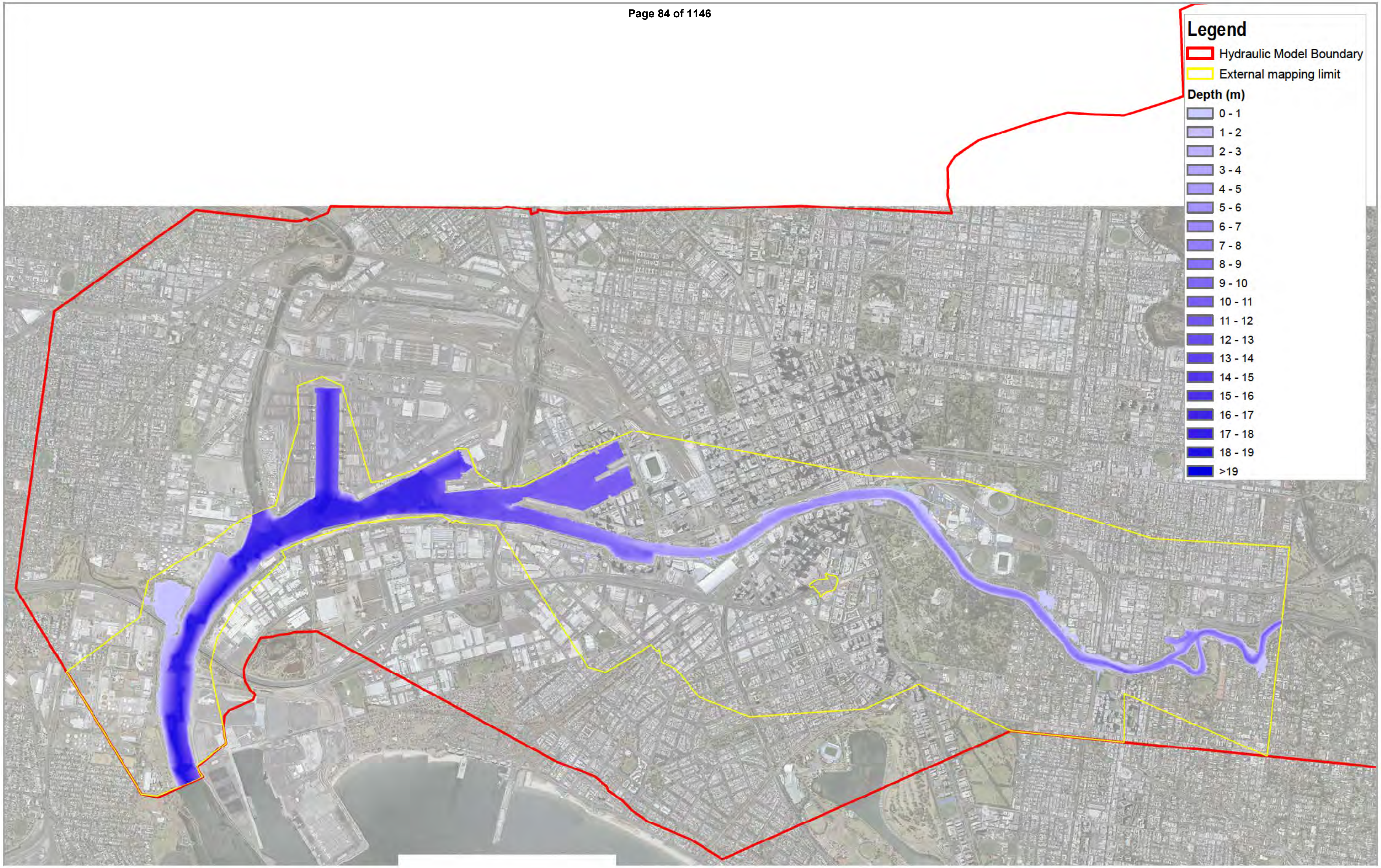

This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
50y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E23

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Print date 01 Sep 2020 - 08 55

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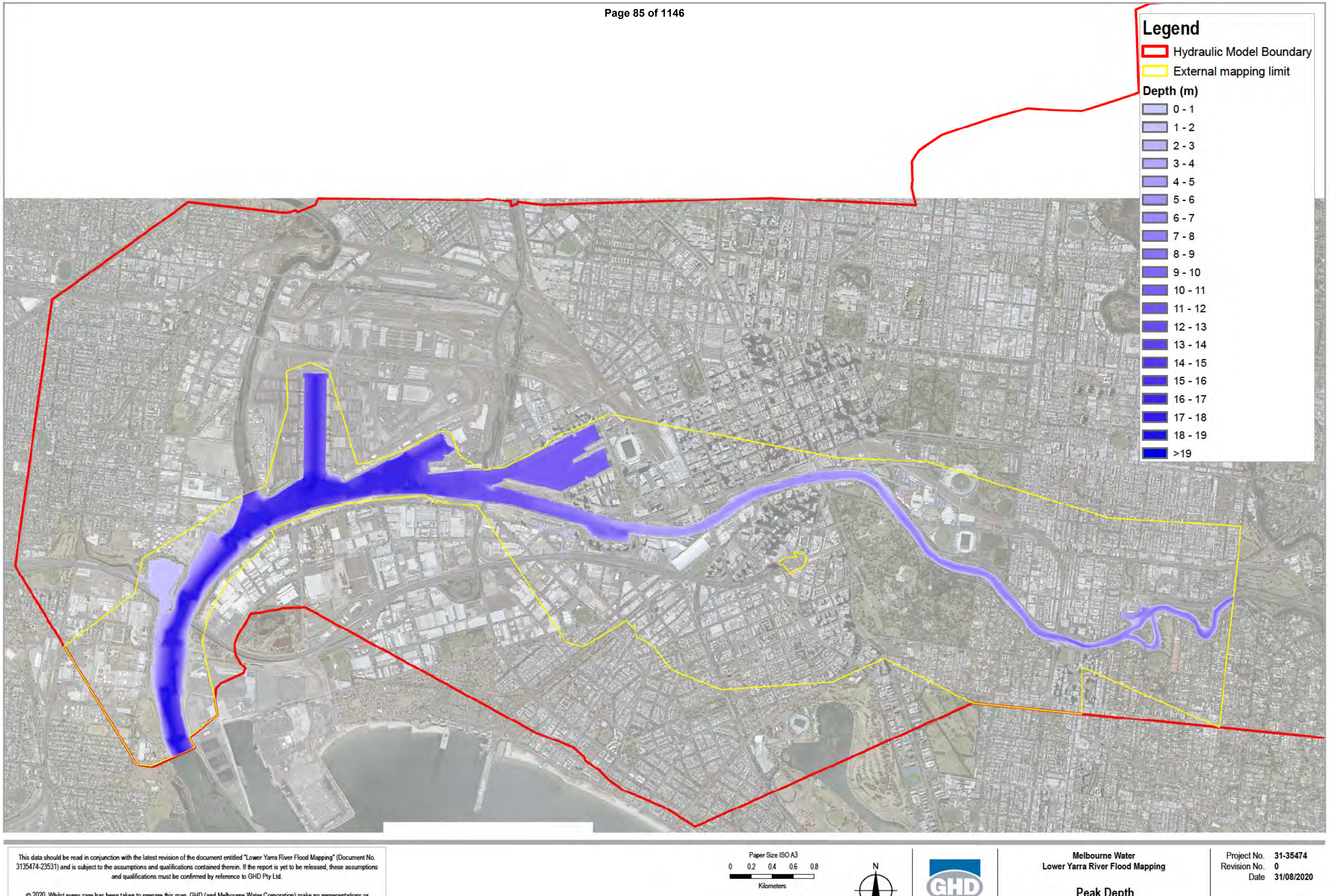

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
20y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E24

G:\31\35474\GIS\Maps\Working\3135474_LowerYarraRiver_Final Flood Maps_v8_REV0_DEP.mxd
Print date 01 Sep 2020 - 08:56

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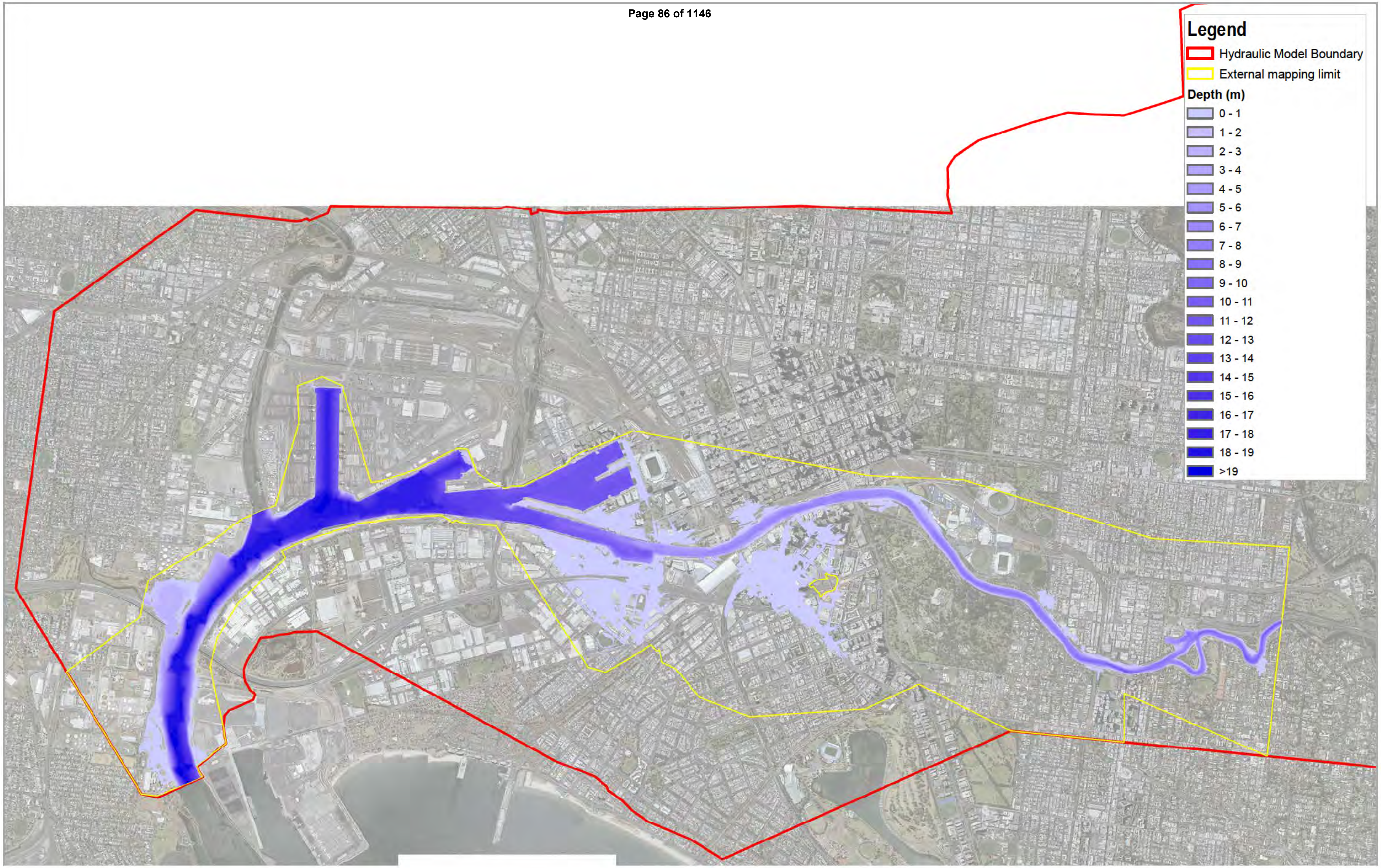

This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
20y ARI (Climate Change 2 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E25

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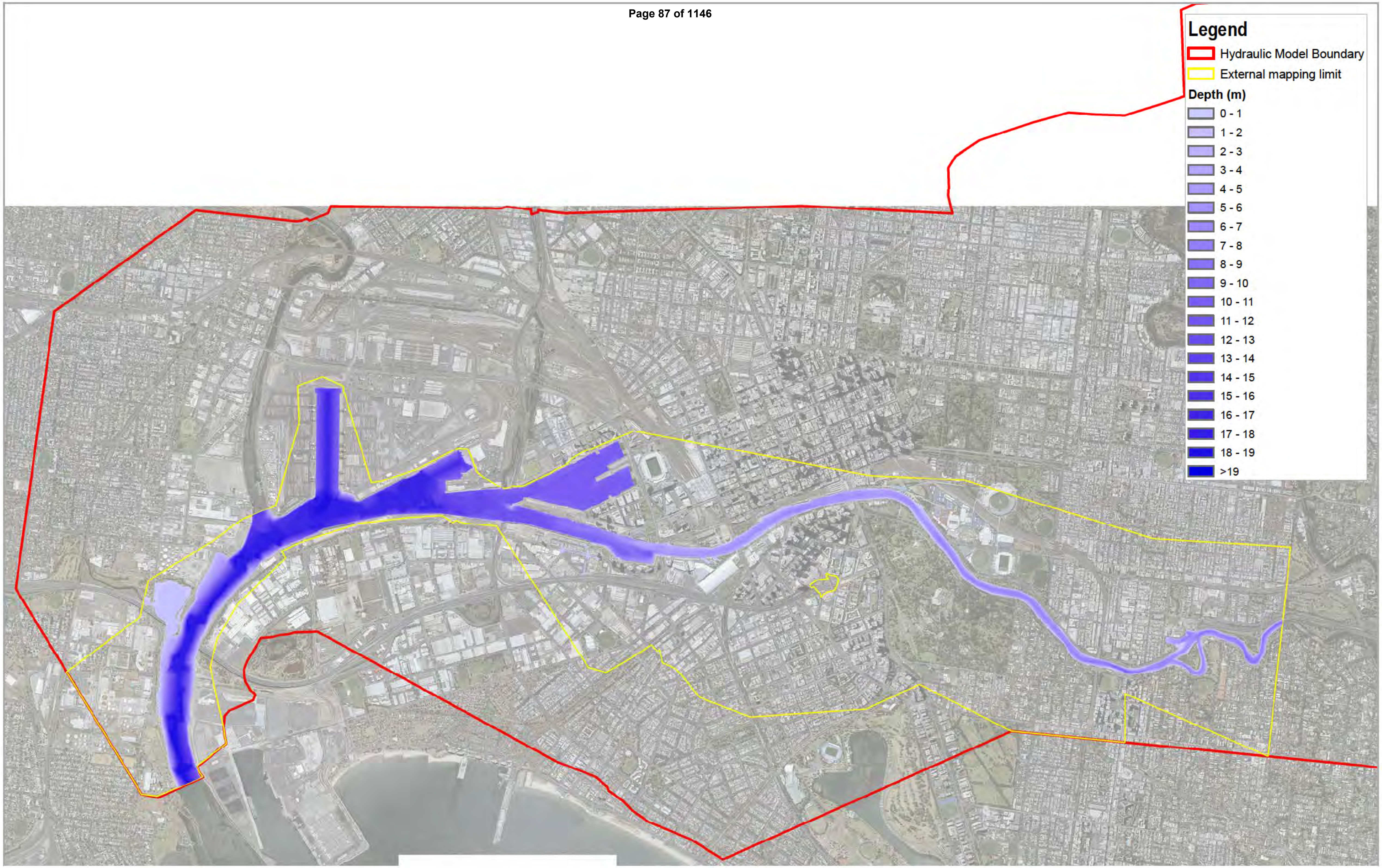

This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
10y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E26

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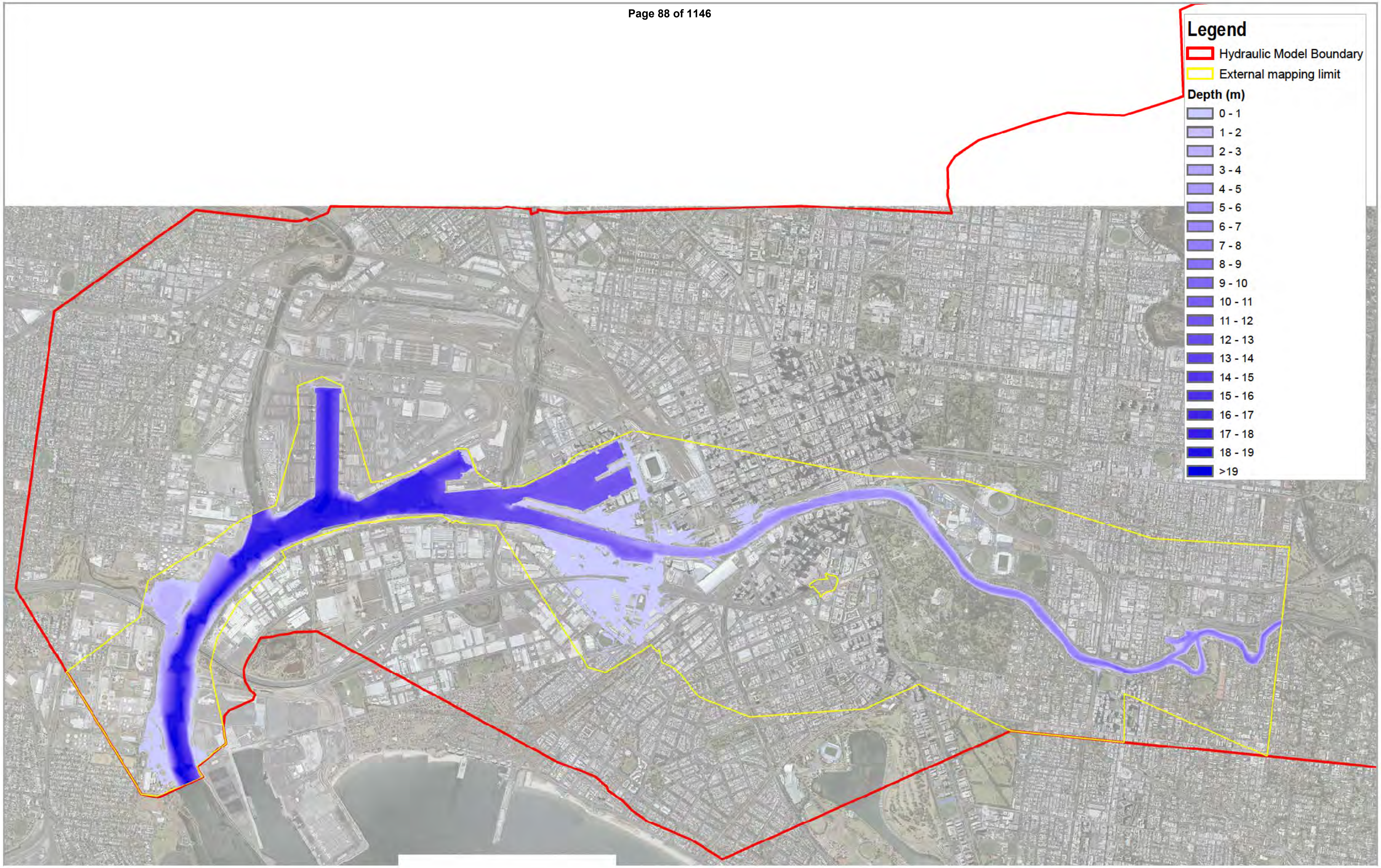

This data should be read in conjunction with the latest revision of the document entitled "Lower Yarra River Flood Mapping" (Document No. 3135474-23531) and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to GHD Pty Ltd.

Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
10y ARI (Climate Change 2 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E27

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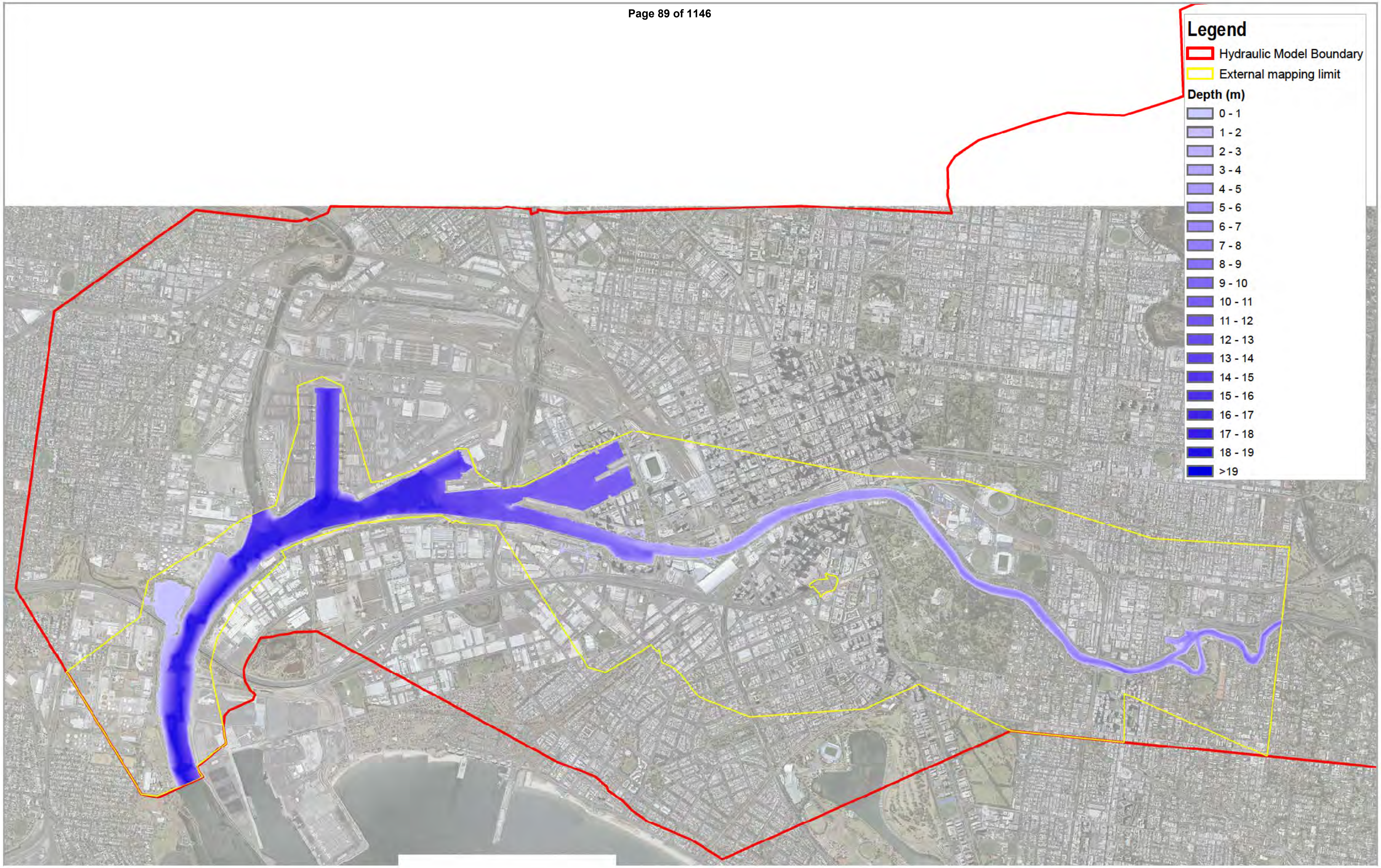

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
10y ARI (Climate Change 3 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E28

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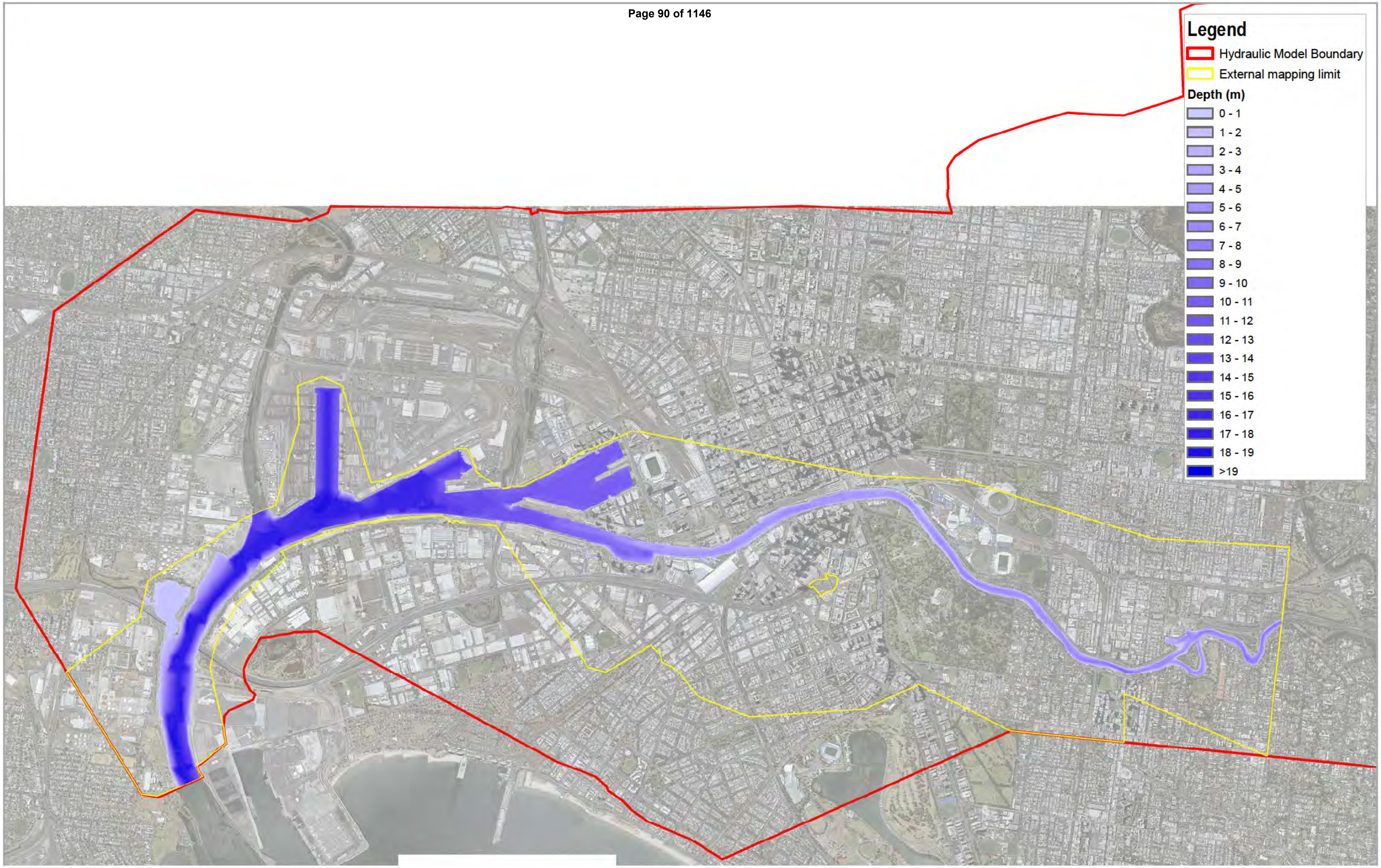

Paper Size ISO A3
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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
5y ARI (Base Case Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E29

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Print date 01 Sep 2020 - 08 57

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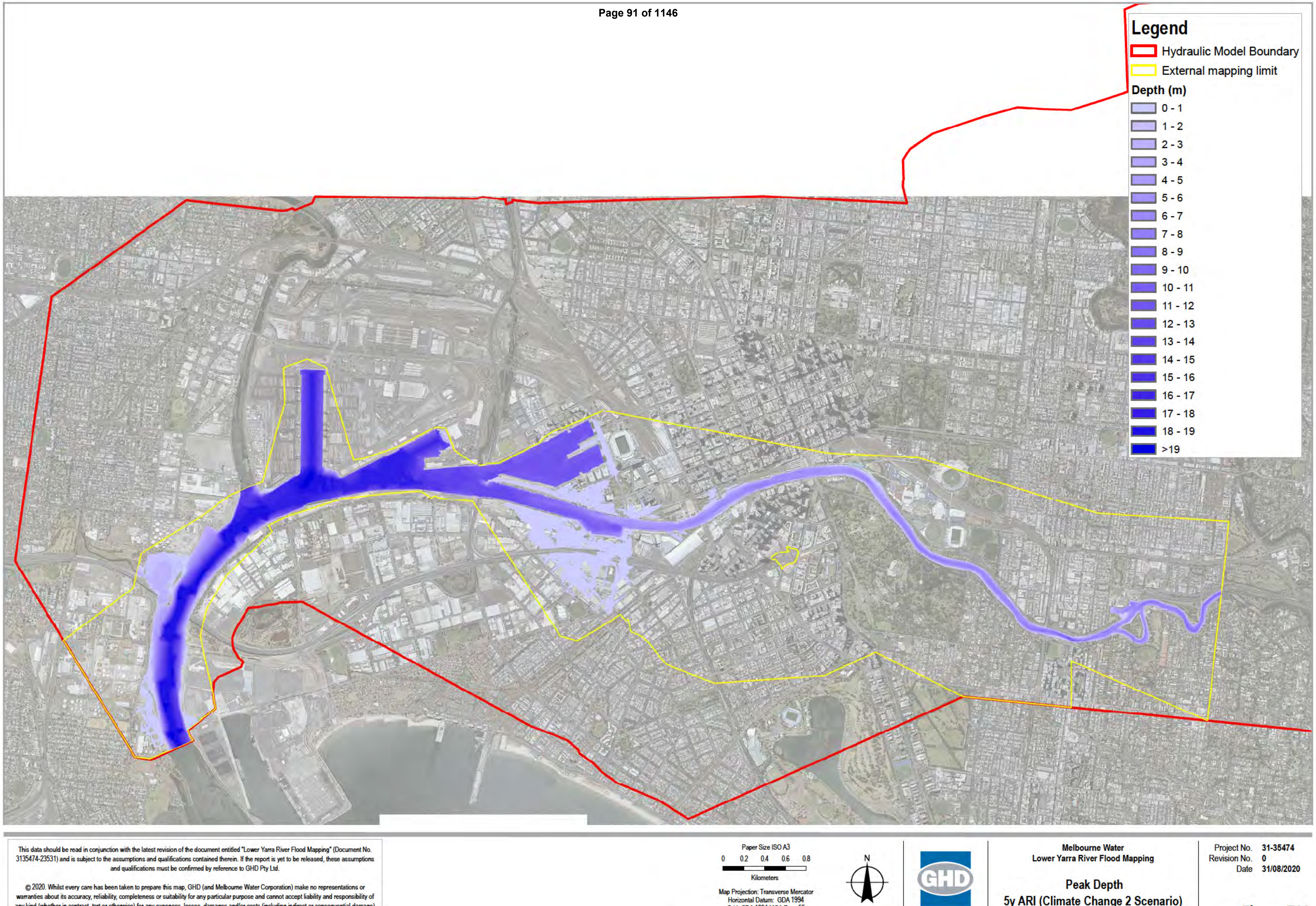

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
5y ARI (Climate Change 2 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E30

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Print date 01 Sep 2020 - 08 57

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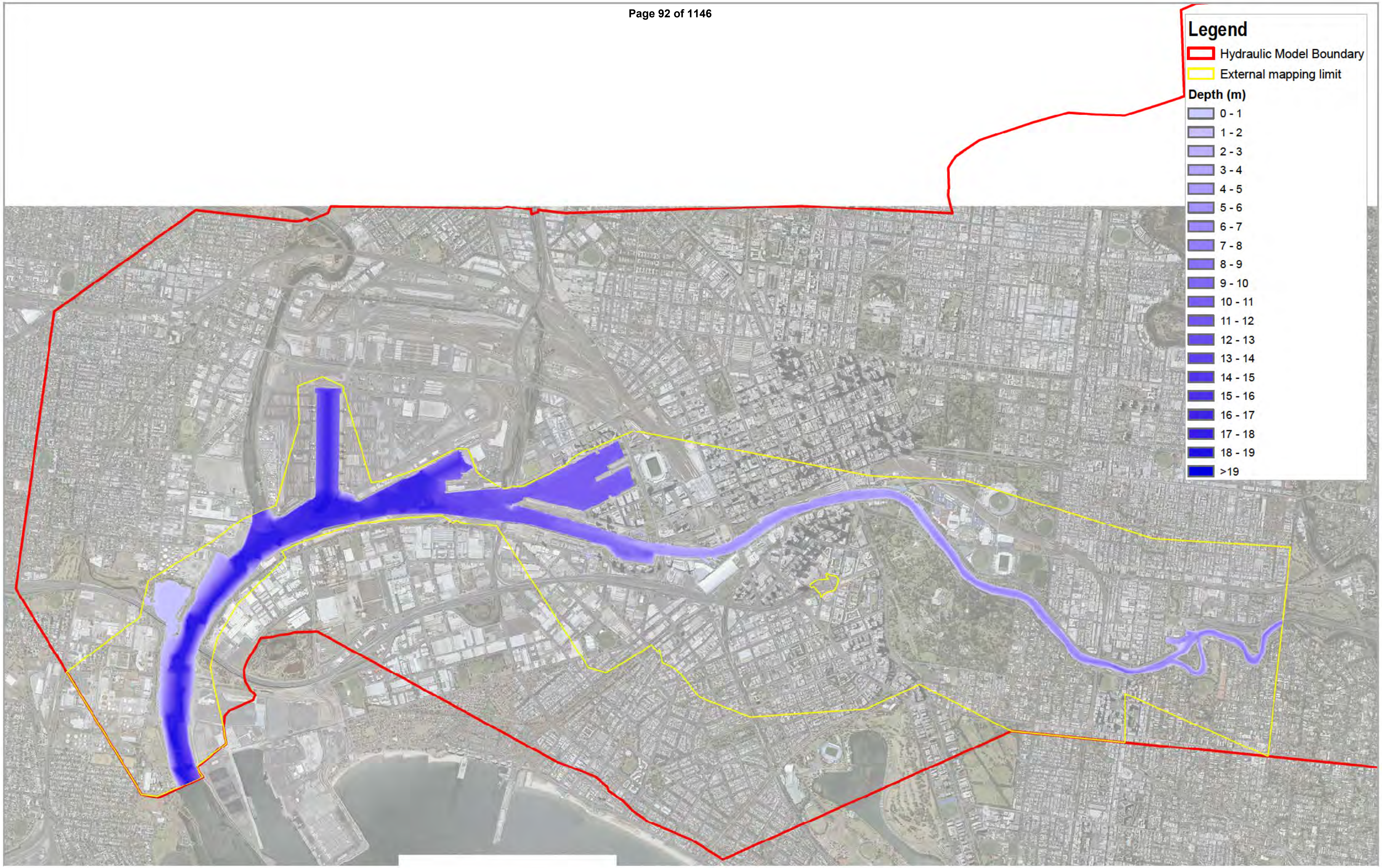

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Paper Size ISO A3
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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Melbourne Water
Lower Yarra River Flood Mapping

Peak Depth
5y ARI (Climate Change 3 Scenario)

Project No. **31-35474**
Revision No. **0**
Date **31/08/2020**

Figure E31

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Print date 01 Sep 2020 - 08 57

Data source . Created by tuflowmeluser

GHD

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3135474-33979-22/https://projects.ghd.com/oc/Victoria/loweryarrariverflood/Delivery/Documents/3135474-REP-1-Lower Yarra River Flood Mapping Report.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	P.Woodman	G.Hay	[signature]	G.Hay	[signature]	01/09/2020

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Our Ref: MJ: L.M00227.01.03.Report.docx

17 June 2020

City of Melbourne
GPO Box 1603
Melbourne VIC 3001
kate.berg@melbourne.vic.gov.au

Attention: Kate Berg

Dear Kate

RE: Hobsons Road Catchment Flood Mapping Update

Background

The City of Melbourne (Council) engaged Venant Solutions to review and update Council's Hobsons Road catchment 1% AEP (annual exceedance probability) flood mapping for the purposes of a planning scheme amendment (PSA) to introduce a special building overlay (SBO). The current flood mapping was prepared for Council by Engeny Water Management (Engeny) for the *JJ Holland Park Stormwater Harvesting Investigation* (Engeny, 2016) and the *Hobsons Road Flood Management Plan* investigation (Engeny, 2017).

The Hobsons Road catchment is shown in Figure 1. The 178 ha catchment slopes to the west with stormwater runoff discharging to the Maribyrnong River via the Dynon Road drain and a number of pipe outlets and overland flow paths. Other than the JJ Holland Park the catchment is fully urbanised with residential and commercial development, including the rail yards which occupy a large area within the catchment.

This letter presents the findings from the model review and the updated mapping, which is also provided electronically to Council in a GIS format.

Scope and Methodology

The scope of works was as follows:

- Review the Engeny RORB and TUFLOW models to ensure their suitability for the preparation of mapping for the PSA;
- Modify RORB and TUFLOW models as required;
- Increase design rainfall in RORB to account for potential changes associated with climate change and run the 1% AEP event;
- Adopt Maribyrnong River 10% AEP flood levels for the TUFLOW downstream water level boundaries;
- Run the TUFLOW model for the 1% AEP event
- Prepare unfiltered flood mapping;
- Prepare letter report.

The lower parts of the Hobsons Road catchment can be affected by flooding from both local catchment runoff and flooding from breakout and/or backwater flooding from the Maribyrnong River. The Hobsons Road catchment is significantly smaller than the Maribyrnong River catchment and hence the peak flooding from Hobsons Road catchment is caused by storm durations that are significantly shorter than those that cause flooding in the Maribyrnong River. Therefore the likelihood of peak local catchment runoff coinciding with peak runoff in the Maribyrnong River is remote. However, it is more likely that there will be some flooding in the Maribyrnong River when there is local catchment flooding in the Hobsons Road catchment. Therefore it was agreed in consultation with Council and Melbourne Water to assume a 10% AEP flood in the Maribyrnong River coinciding with the 1% AEP flood in the Hobsons Road catchment.

The 10% AEP Maribyrnong River flood levels were sourced from Melbourne Water's HEC-RAS model. The HEC-RAS model has a downstream water level boundary at the confluence with the Yarra River. Melbourne Water has recently completed an update to their Yarra River modelling and supplied the 10% AEP mapping, which incorporated climate change conditions. Venant Solution updated the downstream boundary of the HEC-RAS model and ran the 10% AEP event.

As noted above the lower parts of the Hobsons Road catchment can be affected by flooding from breakout and/or backwater flooding from the Maribyrnong River. Mapping of the 1% AEP flood extent resulting from Maribyrnong River flooding was beyond the scope of this project.

The rainfall intensities adopted in the Engeny RORB model were based on the Bureau of Meteorology's 1987 data, the latest available at the time the mapping was prepared. Council required that the modelling be updated to account for potential increases in rainfall intensity associated with climate change. Council and Melbourne Water agreed on an 18.5% increase for the year 2100 in accordance with representative concentration pathway (RCP) 8.5.

It is beyond the scope of this report to document the RORB and TUFLOW model development as this was done by Engeny and included in Engeny (2016) and Engeny (2017). There was limited documentation of the development of the RORB model in these reports, but Engeny advised the following by email on 7 March 2019:

- The RORB model is based on ARR 1987 methodologies, including the loss approaches consistent with the Melbourne Water technical specification at the time, i.e., an initial loss of 10 mm and runoff coefficient of 0.6 for the 1% AEP event;
- Rainfall excess hydrographs from RORB were applied to TUFLOW as 2d_SAs and 1d_BCs:
    - This means that no routing was undertaken in RORB and hence validation of k_c and reach type was not required as they had no influence on the hydraulic modelling.
    - The 2d_SA is applied to the JJ Holland Park and the 1d_BC approach is applied across the remainder of the model;
    - The 1d_BC approach applies runoff directly into the pipes with flow in excess of the pipe capacity surcharging into the 2D domain thereby flowing as overland flow. An alternative approach now available in TUFLOW is to apply the flows to the 2D domain into the grid/s to which the pipe is connected. There are advantages and disadvantages to both approaches and either is considered suitable for the purposes of this modelling and would give very similar outcomes.
    - This approach to applying the inflows boundaries is considered to be a suitable for the purposes of this modelling.

Model Review

The model review found that the RORB and TUFLOW models were suitable for the purposes of the PSA with only the following modifications to the TUFLOW model required:

1. Adjustment to loss modelling approach in the underground pipe network;
2. Adjustment to downstream boundary condition on the pipe in ;
3. Corrections to Manning's 'n' in rail yard;
4. Minor modifications to the spatial distribution of the inflows to the TUFLOW model;

Further details on changes 1 to 3 are provided below.

The supplied model applied the Engelund approach for manhole losses as well as inlet and outlet losses at the manholes of 0.5 and 1.0 respectively. This approach is in effect duplicating losses in the pipe network. The model was run using the Engelund approach which resulted in negligible changes to the 1% AEP flood levels and extents. This is not surprising given the majority of 1% AEP runoff is conveyed in overland flowpaths rather than in the pipe network.

As shown in Figure 3 an outflow (downstream) boundary was placed on the pipe network at the intersection of Mercantile Parade and Flockhart St. At this location the pipe discharges into 2D domain but in an area outside the mapping extent for this model. The area between the mapping extent and the 2D model extent is generally in the next catchment to the north, but there is crossflow from the Hobson Road catchment via the pipe network (see Figure 3) and overland flow. The supplied model applied a fixed level of 1.4 m AHD to this boundary which is approximately the pipe obvert. This is a typical approach when a pipe outlets into a receiving waterbody and is not submerged. However, at this location the controlling level on the pipe flow at the peak of the flood will be the flood level in the street, assuming the pipe is surcharging. A sensitivity test was undertaken using a fixed level of 2.2 m AHD. This change was found to only increase flood levels locally by about 15 mm and was adopted for the final run in the model.

In the rail yard the supplied model applied a Manning's 'n' for building to some of the parking and storage areas, i.e. 'n' was too high. There was also the 'n' value applied to different areas of rail was not consistent. These changes resulted in changes in flood level in the range ± 100 mm, but no areas outside of the rail yard were affected.

Modelling and Mapping Outcomes

The RORB model rainfall input data was increased by 18.5% to account for potential changes in rainfall intensities associated with climate change and the 1% AEP was run for durations from 10 minutes to 18 hours.

The TUFLOW model was updated with the corrections noted above, the 10% AEP downstream water level boundary which incorporated climate change conditions, and the revised inflows from RORB. A fixed water level boundary was adopted because the HEC-RAS model was steady-state, but the variation in peak water level along the river shown in the HEC-RAS model was reflected in the TUFLOW model boundaries. The TUFLOW model was run for each of the durations from 10 minutes to 18 hours and the results enveloped to obtain the peak water level. Over most of the area for which SBO mapping will be applied, the critical durations were less than two hours as would be expected. At some localised locations where runoff volume rather than peak flow rate controls the peak flood level, the critical duration was up to 9 hours.

The 1% AEP unfiltered flood depth and extent mapping is shown in Figure 4. Digital copies of the models and flood mapping data will be provided to Council.

Please do not hesitate to contact the undersigned should you have any questions.

Yours faithfully,

Dr Mark Jempson

Director

Title: Maribyrnong Water Management Strategy
Hobsons Road Catchment

Figure:	Rev:	Scale	Disclaimer		
1	A	N 0 250 500m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: RG	Date: Jan 2020

VENANT SOLUTIONS
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Filepath: S:\Projects\M00227.MJ.MaribyrnongIWMStrategy\GIS\Drawings\L.M00227.001\Fig1_Catchment.WOR

Title: Maribyrnong Water Management Strategy
TUFLOW Schematisation

VENANT SOLUTIONS

Figure:	Rev:	Scale		By: RG
2	A	N 0 250 500m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Dec 2019

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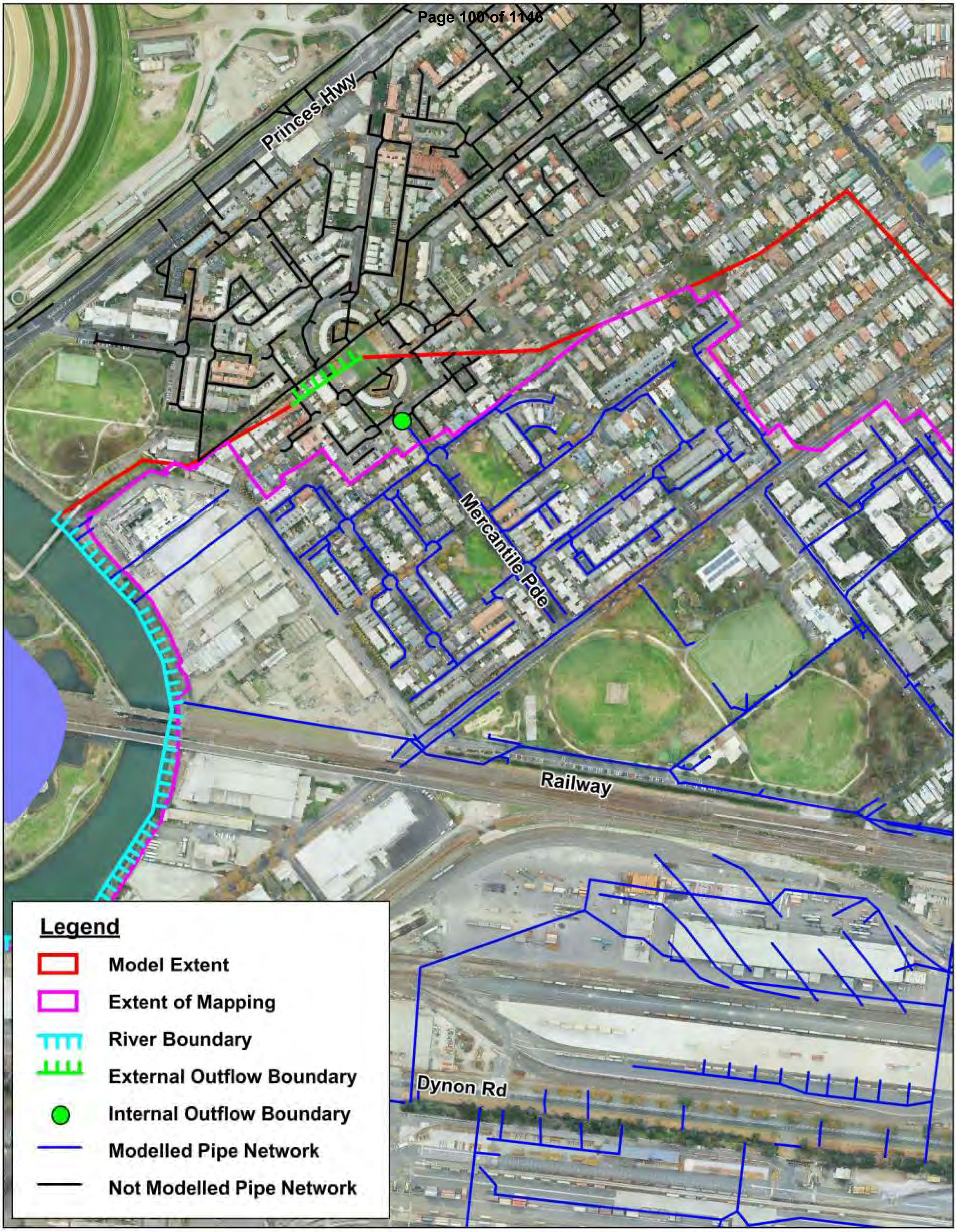

Title: Maribyrnong Water Management Strategy
Pipe Schematisation on Mercantile Pde

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Figure:	Rev:	Scale	Disclaimer	By: RG
3	A	N 0 125 250m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Apr 2020

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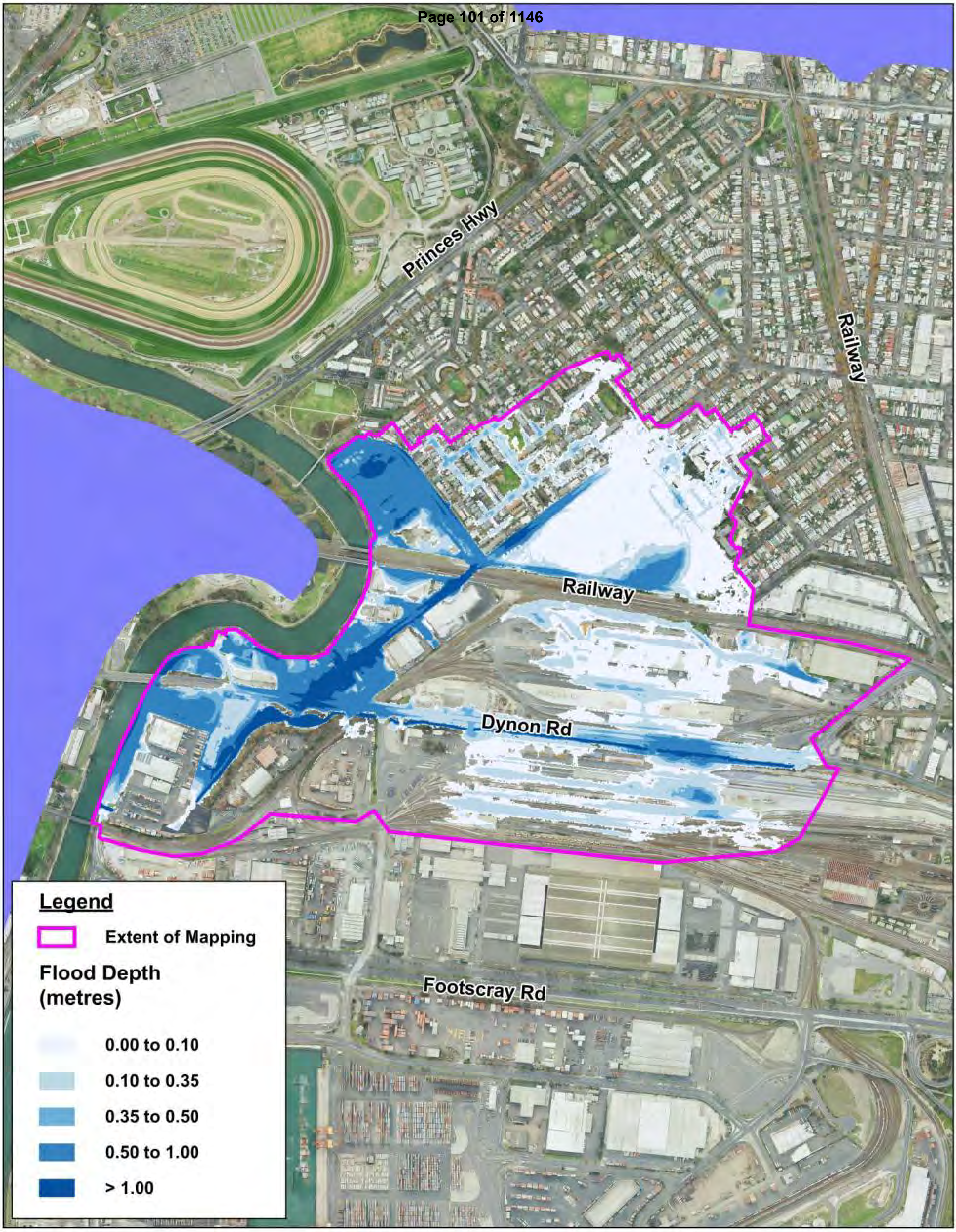

Title: Maribyrnong Water Management Strategy
Flood Depth - 1% AEP with 10% Maribyrnong River Flood Level

Figure:	Rev:			
4	A	N; 0 250 500m; Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: RG Date: Apr 2020

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Our Ref: MJ: L.M00227.02.01.ReviewResponse.docx

22 April 2020

City of Melbourne
GPO Box 1603
Melbourne VIC 3001
kate.berg@melbourne.vic.gov.au

Attention: Kate Berg

Dear Kate

RE: Hobsons Road Catchment Flood Mapping – Response to Rain Consulting Model Review

Rain Consulting provided feedback from their review of the Hobson Road modelling and report in a letter dated 28/2/202. The letter raised a number of matters requiring a response from Venant Solutions. The feedback and response are documented in the table below.

Issue	Response
A wetting and drying depth of 0.002 has been used with areas of very shallow depth within the model. Do Venant Solutions believe that the use of this, over a lower depth (0.0002), would impact the flood extents for the PSA?	A depth of 0.002 m is the standard wetting and drying depth. A value of 0.0002 m is recommended when adopting a rain-on-grid approach, particularly in steep terrain, to assist in stability and mass error issues. A rain-on-grid approach was not adopted for this modelling. Putting aside stability and mass error issues, adopting a value of 0.0002 m does not improve mapping accuracy as even 0.002 m is well within the accuracy of the modelling and mapping. The value was left at 0.002 m.
Manning's values in the south of the model do not correlate well with the land-use, particularly around the rail yards. Within the rail yards, there are large sections of type 10 - open waterway. The section to the north (looks like a truck container loading area) is modelled with a very high roughness for rail lines. Upon review of the Manning's values used across the model, do Venant Solutions believe that the use of different Manning's values would impact the flood extents for the PSA?	The Manning's 'n' were reviewed and updates made in the rail yard as documented in the letter report.
The Engleund method of losses has been applied with entry and exit losses across all of the network set to 1 and 0.5. Would pit losses in line with Melbourne Water recommendations be likely to change the extent of flooding within the model?	The pipe losses in the model were reviewed and adjusted as documented in the letter report.

Minor negative depths are seen in the log files. Are these likely to be impacting the results at all?	The log files report 1 negative depth in the 2D domain. This will not be impacting on the results.
Please remove the reference to 800 mm sea level rise from the Lower Yarra – it's ended up being a bit more complex.	Letter report adjusted.
Are results from the checking of the Engeny model documented? Please provide	Findings are documented in the letter report.
Are you able to broadly comment on the RORB and inflow approach adopted by Engeny?	Additional commentary added to the letter report.
Please provide a comment in the report around why modelling was not completed past the 9-hour duration.	Additional commentary added to the letter report.

Please do not hesitate to contact the undersigned should you have any questions.

Yours faithfully,

Dr Mark Jempson

Director

City of Melbourne

Fishermans Bend Flood Mapping

November 2020

Table of contents

Table index

Figure index

Appendices

1. Introduction and background

1.1 Introduction

The City of Melbourne engaged GHD to update flood modelling for the areas within the Fishermans Bend urban renewal area that fall within the City of Melbourne municipal boundary for the purpose of flood mapping.

Fishermans Bend is an area located on a peninsula between the lower reaches of the Yarra River and Port Philip Bay and is currently built out with a mix of primarily commercial and industrial premises. The area has been rezoned as ‘Capital City Zone’, and is expected to transform over the next 40 years to become an extension of the CBD towards the Bay.

The area is relatively low lying with ground levels generally varying from 1.0 m AHD to 4.0 m AHD. Significant parts of Fishermans Bend are therefore potentially subject to inundation in tidal events, particularly towards the east within the Montague Precinct. The effects of climate change through sea level rise further exacerbate this.

The extent of Fishermans Bend that is covered in this flood mapping project is illustrated by the plan in Figure 1.

1.2 Purpose of this report

The purpose of this report is to document the methodology, underlying assumptions, and results of the updated modelling and flood mapping of the existing Melbourne Water and local council drainage system within the Fishermans Bend area in Melbourne.

The outputs of the project are raw flood extents that are intended for the City of Melbourne’s use in preparing flood plain maps. These maps will assist with planning approvals, determining flood risk within the catchment, and as a base case for comparing future mitigation options.

1.3 Background

In April 2019, a Water Sensitive Drainage and Flood Strategy for Fishermans Bend was completed by GHD. That strategy undertook flood modelling for Fishermans Bend using RORB and TUFLOW. These models form the basis of the flood modelling for this flood mapping project.

1.4 Scope

The City of Melbourne engaged GHD to undertake this current flood mapping study of Fishermans Bend to bring the mapping up to date and consistent with other recent flood mapping projects. In particular, the flood mapping was required for the areas of Fishermans Bend covered by the City of Melbourne (Lorimer and Employment precincts). The other areas of Fishermans Bend covered by the City of Port Phillip were not required to be flood mapped.

This study builds on the knowledge of the catchment and experience gained through undertaking previous projects within the catchment. The scope for this project was as follows:

- Adopt existing RORB and TUFLOW models that were prepared for the Fishermans Bend Water Sensitive Drainage & Flood Strategy, but with adjustments to the TUFLOW model.
- Adjustments to the TUFLOW model included:
  - Reduce grid size from 8m to 3m.
  - Reduce the extent of the model to primarily cover the parts of Fishermans Bend within the City of Melbourne, which is the focus of this project.
- Run the existing RORB model to obtain flow hydrographs for the scenarios outlined in Table 1
- Adopt and setup a TUFLOW (unsteady-state 1D/2D hydraulic) model with adjustments highlighted above.
- Run the TUFLOW model to obtain flows and flood levels under existing drainage conditions for the scenarios outlined in Table 1
- Process the TUFLOW results and produce GIS layers (in MapInfo format) similar to those produced for previous flood mapping projects for Council. GIS layers include raw flood extent results for each of the two scenarios listed in Table 1

Deliverables which are common to a flood mapping project but are outside of the scope of this project were:

- Setup a revised RORB (hydrologic) model based on current LiDAR information to refine the distribution of flow hydrographs.
- Process the TUFLOW results and produce flood mapping GIS layers for the two scenarios listed in Table 1

General project requirements were in accordance with Melbourne Water's Guidelines and Technical Specifications for Flood Mapping Projects (*MWC Nov, 2018*) – referred to herein as "the Guidelines".

Table 1 Scenarios Modelled and Mapped

Scenario Reference1	Impervious Fractions	Rainfall Intensities	Tailwater Levels2	Yarra Flood Levels	5 yr	10 yr	20 yr	50 yr	100 yr
A - Climate Change 1	Existing	18.5% increase in rainfall intensity	Increased by 0.8 m	10% AEP					✓
B - Climate Change 2	Existing	18.5% increase in rainfall intensity	Increased by 0.8 m	1% AEP					✓

1 The scenario references are taken from Melbourne Water's Guidelines and Technical Specifications for Flood Mapping Projects (MWC 2012)

2 For each of the above scenarios, it will be necessary to define whether the tidal condition from Port Phillip Bay is Highest Astronomical Tide of 1% AEP with 0.8m seal level rise to allow for climate change.

The tidal conditions listed will be cyclical as was adopted for the Fishermans Bend Water Sensitive Drainage & Flood Strategy.

Both are Base Case scenarios where modelling is based on existing conditions impervious fractions, existing drainage infrastructure and "standard" Australian Rainfall and Runoff (AR&R) rainfall intensities (*IEAust 1997*). Both the downstream tail water level and rainfall intensities are increased by 0.8 m and 18.5% respectively to simulate Climate Change.

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND
Model Boundary
Mapping Limits
Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Catchment Locality

Job Number	12511721
Revision	A
Date	19/09/2019

Figure 1

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

1.5 Limitations

This Report has been prepared by GHD for the City of Melbourne and may only be used and relied on by the City of Melbourne for the purpose agreed between GHD and the City of Melbourne as set out in Section 1.2 of this Report.

GHD otherwise disclaims responsibility to any person other than the City of Melbourne arising in connection with this Report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in the Report and are subject to the scope limitations set out in the Report.

The opinions, conclusions and any recommendations in this Report are based on conditions encountered and information reviewed at the date of preparation of the Report. GHD has no responsibility or obligation to update this Report to account for events or changes occurring subsequent to the date that the Report was prepared. Once issued, this Report and associated modelling files are no longer subject to GHD's control and may include changes made by others. It is anticipated that Melbourne Water will update (Appendix D) of this Report.

The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD described in this Report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this Report on the basis of information provided by Melbourne Water, the City of Melbourne and the City of Port Phillip, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The precision (number of significant figures) of results and parameters documented in this Report should not be taken as an indication of their accuracy (level of uncertainty).

1.6 Available information

The following information was utilised in undertaking this flood mapping study:

- General information obtained from Melbourne Water and the City of Melbourne throughout the course of the project:
  - Cadastral boundaries (e.g. properties boundaries, easements, roads in MapInfo format)
  - Drainage layers (e.g. Melbourne Water underground, channel and natural drains, retarding basins, manholes, the City of Melbourne Council drains in MapInfo format)
  - Elevation information (e.g. 1 m contours, spot heights, natural surface contours in MapInfo format)
  - Planning information (e.g. planning scheme zones, LSIO, SBO, Urban Growth Boundaries in MapInfo format)
  - Aerial laser survey data (LiDAR – thinned ground points)
  - Design Drawings for many (not all) Melbourne Water drains within the catchment
  - Aerial ortho-photos (Dec, 2013)
  - Available field survey within the catchment
  - Melbourne Water default impervious fractions for Existing Conditions
  - Tailwater levels for Port Phillip Bay and the Yarra River

- General information obtained from the City of Port Phillip throughout the course of the project (directly or via Melbourne Water):
  - Drainage layers (pipes and pits) in MapInfo format
  - Design drawings of key drainage assets for inclusion in the modelling
  - Details and/or drawings of a number of significant developments within the Study Area
- Relevant information from the references listed in Chapter 7.

1.7 Assumptions

The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD when undertaking services and preparing this Report ("Assumptions"), including (but not limited to):

- All data provided by Melbourne Water Corporation, the City of Melbourne and the City of Port Phillip is correct, unless explicitly noted.
- Selected design inputs such as rainfall losses, definition of the climate change rainfall scenario, downstream boundary conditions and the outer catchment boundary are in accordance with Melbourne Water Corporation requirements.
- The normal limitations of an investigation of an ungauged catchment, including (but not limited to) the inability to calibrate or verify either or both of the hydrologic and hydraulic models to a known situation or event.
- The qualifications outlined throughout the report, including Section 4.2

GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with any of the assumptions being incorrect.

2. Catchment and drainage description

2.1 Site Context

Fishermans Bend is currently predominantly privately owned light industrial and warehousing. Four precincts totalling 250 hectares were rezoned to Capital City Zone (Montague, Wirraway, Lorimer and Sandridge) enabling high density development. The 230 hectare Employment Precinct has industrial zoning and is one of Melbourne's seven National Economic and Innovation Clusters (NEIC). Fishermans Bend presents some relatively unusual challenges for planning drainage and flood management works, particularly when compared to a green field development or redevelopment of a single land parcel.

2.2 Existing Flood Risk

Some areas in Fishermans Bend are already subject to flooding today, and this may be a constraint for development in those areas without the provision of significant flood mitigation infrastructure in the short term.

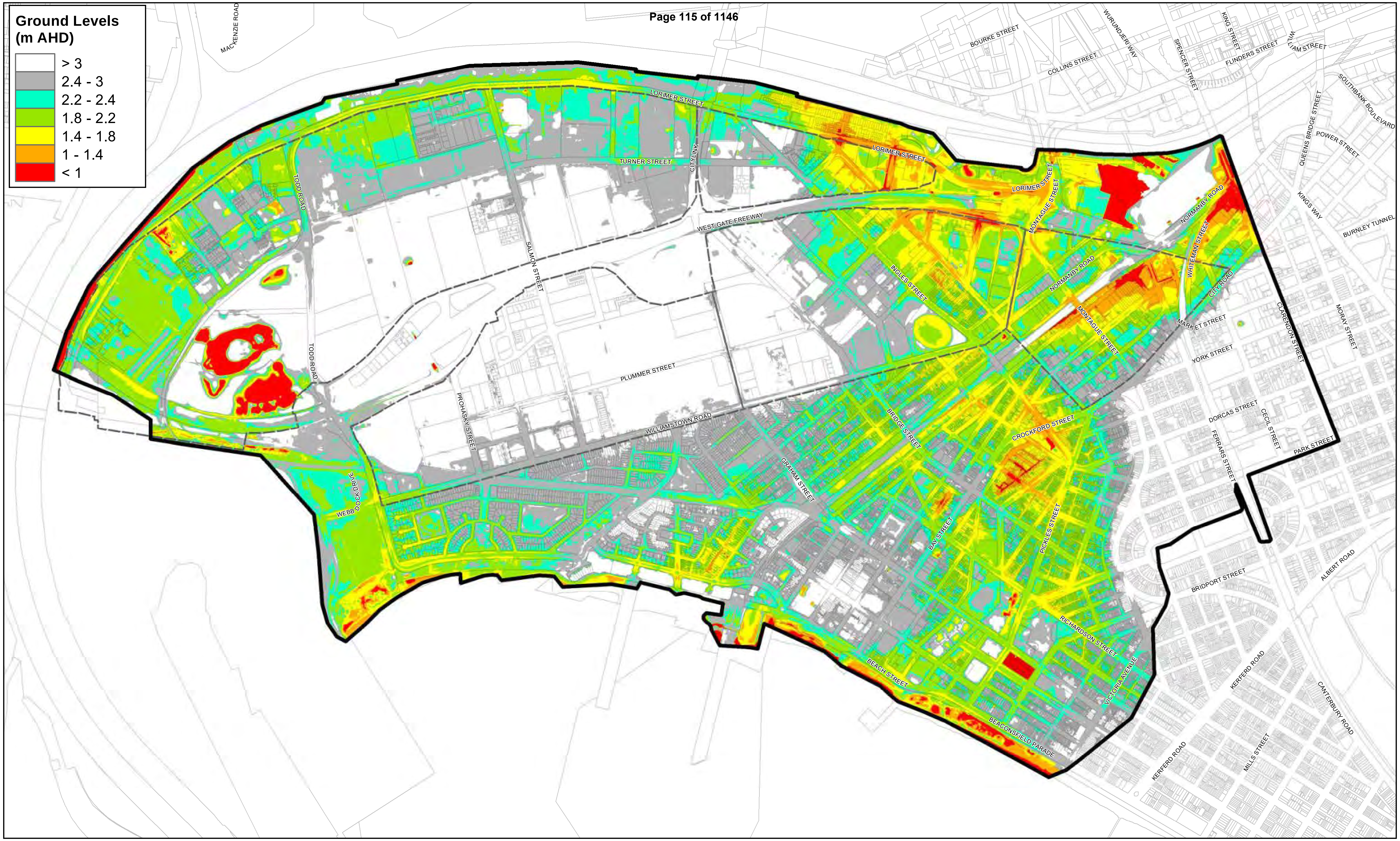
2.3 Imperviousness

Fishermans Bend is currently highly developed and impervious, with close to the maximum possible stormwater runoff being generated from rainfall today. The modelled imperviousness of the area is shown below in Figure 3.

2.4 Elevation

Fishermans Bend is low lying, with ground levels as low as 0.6 m AHD, as shown in Figure 2. This means that some areas are currently exposed to coastal flooding, which will increase over time due to sea level rise.

Approximately 25 ha (or 5%) of Fishermans Bend is below the current 1% AEP flood level (1.6 m AHD), and 166 ha (or 35%) of Fishermans Bend is below the predicted 2100 1% AEP flood level (2.4 m AHD). Noting both these numbers exclude the Westgate Lakes area.



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary

Precinct Boundaries

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Ground levels

Job Number	12511721
Revision	A
Date	19/09/2019

Figure 2

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_TUFLOW_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: sng

2.5 Climate Change

Rainfall Intensity

Climate change is predicted to increase the intensity of rainfall events (against a background of hotter and drier climate with fewer overall rainfall days). This will result in increased stormwater flooding over time. All future condition modelling has allowed for an increase in rainfall intensity (as per the City of Melbourne). The rainfall intensity was increase by 18.5% to model climate change conditions. It should be noted that the scaling factors provided in Australian Rainfall and Runoff 2019 results in a rainfall intensity increase by 18.4%.

Sea Level Rise

Global sea level rise (SLR) will increase the risk of coastal flooding at Fishermans Bend and result in higher tail-water levels for the underground drainage network. Current planning requirements and practice are to plan for a sea level rise of 0.8m by 2100. This is however only one scenario, and it is important to acknowledge that (i) 0.8m may be reached some time before or after 2100, and (ii) 0.8m is not an end point that sea levels will continue to rise beyond this. As discussed in Appendix G (Levee Discussion Memorandum), the latest science indicates 0.8m SLR could be reached as early as 2070 and that by 2100 SLR could be as high 1.8m. Refer to City of Melbourne's Planning for Sea Level Rise document regarding further discussion of sea level rise (Planning for Sea level Rise Guidelines, Melbourne Water 2017).

For the purpose of setting a tail-water level for future conditions flood modelling, a time varying tail-water level peaking at 2.25m AHD (from Water Technology for Melbourne Water, 2017) was used, which combines a 1% AEP extreme water level event in Port Phillip Bay of 1.45m AHD with 0.8m sea level rise.

Note that for the purpose of setting flood levels for development, Melbourne Water has adopted a 2100 1% AEP flood level of 2.4m AHD for Port Phillip Bay (Planning for Sea level Rise Guidelines, Melbourne Water 2017). Noting that this level makes some allowance for wave action, and for 0.8m of sea level rise.

2.6 Three Sources of Flooding

Flooding may arise from three separate sources: Coastal (or tidal) flooding from Port Phillip Bay and extending into the Lower Yarra River, Riverine (or fluvial) flooding from flows in the Yarra River, and Stormwater (or pluvial or surface) flooding from local rainfall events overwhelming the underground drainage network.

Upstream of Wurundjeri Way the Yarra River levels are flow-dominated during flood events and may be higher than peak Port Phillip Bay levels. Upon completion of the Yarra River Flood Mapping project, it was both concluded and advised that for the Fishermans Bend Precinct, Yarra River levels could be set to tidal levels from Port Phillip Bay.

Coastal and riverine flooding can increase the effect of stormwater flooding. This is because the ability of the stormwater drainage network to free drain under gravity is constrained if there is a high water level at the outlet of the network (e.g. in Port Phillip Bay or the Yarra River).

Catchment Context

Fishermans Bend's precinct boundaries do not align with stormwater catchment boundaries, meaning there are interdependencies between development conditions and management of stormwater outside of Fishermans Bend. In particular:

- Flooding in the Montague Precinct (and Wurundjeri Way PS catchment) is hydraulically connected to the adjacent Hannah St Main Drain catchment in South Melbourne. Flooding in that catchment impacts Fishermans Bend.

3. Modelling approach

3.1 Overview

Hydrologic modelling of the Fishermans Bend catchment was undertaken using RORB. An "undiverted" RORB model was initially created for "calibrating" to 100 year ARI Rational Method flow estimates. The "final" RORB model has been set up for the purposes of providing hydrographs for input into an unsteady hydraulic model only. With mainstream hydrograph routing being undertaken in the hydraulic model, the RORB model should not be directly used to provide total flow estimates along key flow paths. Hydrographs are printed for individual subareas along the drainage network, or for groups of subareas above hydraulically modelled drains. The final RORB model has been run for all standard storm durations (10 minutes to 72 hours) for the events and scenarios listed in Table 1.

For consistency with previous investigations, design storms were based on pre ARR 2019 design methodologies. On 13 May 2019, ARR 2019 was officially released and is no longer considered a draft document. The implications of any changes to ARR2019 with respect to this project have not been considered at this stage as all of the analysis was completed prior to its release despite its release predating the date of this report by about a few month. Original RORB modelling, which was conducted pre 2016, was undertaken with ARR1987 design methodologies. The current model was not updated for this flood mapping project in order to stay consistent with the mapping for the rest of the municipality, as well as acknowledging that there was no time or budget allocated to updating the model to ARR2019.

Hydraulic modelling of the Fishermans Bend catchments was undertaken using TUFLOW. TUFLOW is a hydrodynamic model used for simulating one-dimensional (1D) and two-dimensional (2D) flows. The TUFLOW model was created using drainage details and boundary conditions provided by Melbourne Water, LiDAR (and survey) based terrain data, drainage details provided by the City of Melbourne, and inflow hydrographs from RORB. The TUFLOW model was run to determine flood levels for the events listed in Table 1.The results of the TUFLOW runs were post-processed to create GIS layers.

3.2 Digital Terrain Model

A Digital Terrain Model (DTM) was created for the catchment, based on LiDAR information provided by Melbourne Water. This DTM was used to assist in the development of the hydrologic and hydraulic models for this investigation. Survey information was used in preference of the LiDAR information where there was overlap due to the age of the LiDAR and higher claimed accuracy of the field survey. A field survey completed in May 2017 called the Port Philip Sea Wall Survey undertaken for Melbourne Water was used to manipulate data in the DTM for levels along the Yarra River and Port Phillip Sea Wall. Checking the accuracy of the supplied terrain data is beyond the scope of this project and was not undertaken by GHD.

Creation of the DTM was undertaken using 12D and formed the basis of RORB catchment and subarea delineation, and of the two dimensional grid for use in the TUFLOW model. The DTM was also used in the post-processing of TUFLOW results to generate flood extents and depths.

The 2d model is based on a 3 m grid, with elevations assigned from the 2008 LiDAR data set. Changing the underlying terrain was necessary as the URS models did not provide the full extent required, and were on different orientations from model to model.

3.3 Hydrology

3.3.1 Introduction

RORB (*Laurenson et al 2010*) is a non-linear rainfall runoff and streamflow routing model for calculation of flow hydrographs in drainage and stream networks.

The model requires catchments to be subdivided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Design losses are then deducted, and the excess routed through the reach network.

Each reach is assumed to have storage characteristics as follows:

$$S = 3600 \times k \times Q^m$$

where S is storage (m^3);
Q is outflow discharge (m^3/s); and
k and m are dimensionless parameters.

The coefficient k is the product of two factors:

$$k = k_c \times k_r$$

where k_c is an empirical coefficient applicable to the entire catchment, and
k_r is the relative delay time applicable to each reach.

The relative delay time for each reach, k_{ri}, is determined as follows:

$$k_{ri} = F_i \times \left(\frac{L_i}{d_{av}}\right)$$

where L_i is the reach length (km),
d_{av} is the average distance along the reach network from each subareas' centroid to the catchment outlet (km), and
F_i is an empirical factor, and a function of reach type as follows (where S_c is the reach slope as a percentage):

- for natural reaches $F_i = 1.0$
- for excavated but unlined reaches $F_i = \frac{1}{(3 \times {S_c}^{0.25})}$
- for lined or piped reaches $F_i = \frac{1}{(9 \times {S_c}^{0.5})}$
- for drowned reaches $F_i = 0.0$

The model is also able to simulate:

- Lakes, retarding basins and similar storages.
- Concentrated and distributed inflows and outflows.

3.3.2 History of RORB modelling in the catchment

GHD did not create the RORB model. Much of the modelling approach (e.g. use of rain on grid) was continued from the TUFLOW model URS prepared for the City of Port Phillip in 2011, which GHD was asked to adopt and make only necessary adjustments to. Key changes were generally made only where key shortcomings were found, this included:

- Modelling additional durations to the two durations (45 minute and 1.5 hour) modelled by URS.
- Further dividing land use categories into 10% impervious fraction ranges to represent differing losses.
- Changing a single rainfall polygon to multiple rainfall polygons based on impervious fractions with appropriate factors to replicate the RORB runoff co-efficients prescribed by Melbourne Water.

3.3.3 RORB model layout

In this investigation, all inflows were routed overland from the centroid of their subcatchment to the drainage network. For the purpose of determining routing, each reach was assigned a type and for this study we generally applied the following rules:

- Overland flow along roads was generally assumed to be “lined or piped” (reach type 3).
- Overland flow through properties, or grassed surfaces, was generally classed as “Excavated, but unlined” (reach type 2).
- Overland flow through golf courses or densely vegetated areas was generally classed as “Natural” (reach type 1).
- Overland flow through lakes or waterbodies was generally classed as “Drowned” (reach type 4).

A GIS representation of the RORB model can be found in Appendix A

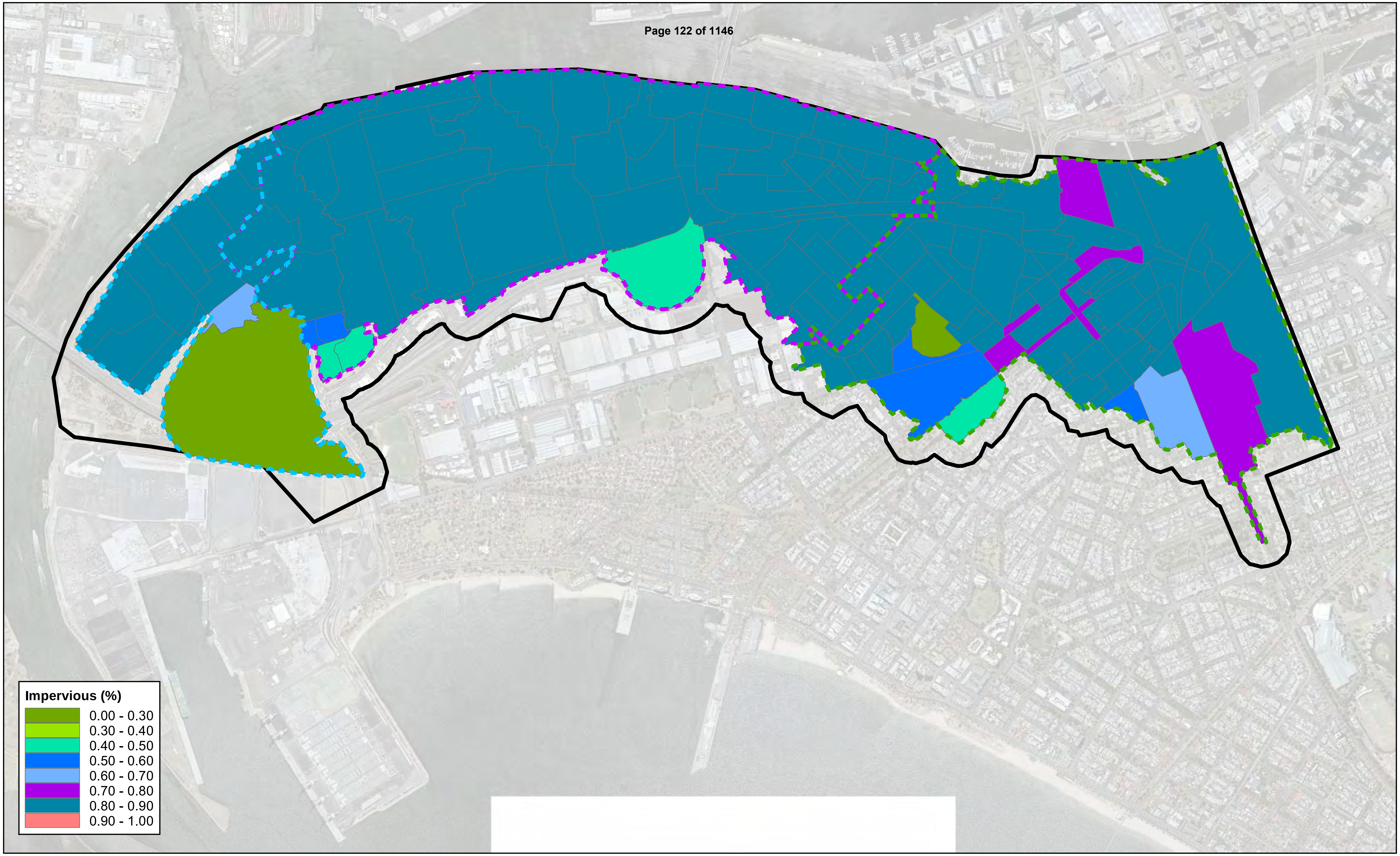
3.3.4 Impervious fractions

Impervious fractions for each subarea were determined based on default impervious fraction values assigned to each Planning Scheme Zone type. This approach was adopted to bring this study in line with the Guidelines (*MWC 2018*) and replaces the previous approach that utilised default impervious fractions from the Planning Model. In some locations the default impervious fraction values were adjusted based on visual inspection of aerial photography and/or known development details. The default impervious fractions adopted for each zone type are listed in below.

Table 2 Adopted Default Impervious Fractions

Planning Scheme Zone Type	Impervious Fraction
Residential Zone (R1Z)	0.6
Residential Zone (R2Z)	0.75
Business Zones (B1Z, B2Z, B4Z, B5Z)	0.9
Business Zone (B5Z)	0.8
Comercial Zone (C1Z, C2Z)	0.9
Industrial Zone (IN1Z)	0.9
Mixed Use Zone (MUZ)	0.7
Public Use Zone – Service and Utility (PUZ1)	0.05
Public Use Zone – Education (PUZ2)	0.7
Public Use Zone – Health and Community (PUZ3)	0.8
Public Use Zone – Transport (PUZ4)	0.75
Public Use Zone – Cemetery/Crematorium (PUZ5)	0.7
Public Use Zone – Local Government (PUZ6)	0.7
Public Park and Recreational Zone (PPRZ)	0.1
Road Zone – Category 1 (Major roads and freeways) (RDZ1)	0.8
Road Zone – Category 2 (Secondary and local roads) (RDZ2)	0.7
Capital City Zone (CCZ1, CCZ3, CCZ4)	0.9
Docklands Zone (DZ1, DZ7)	0.9
Special Use Zone (SUZ3)	0.5

The adopted impervious fractions were used to determine weighted impervious fractions for each subarea, as shown in Figure 3. A table showing the area and impervious fraction of each subarea and a breakdown of the zones in each subarea is shown in Appendix A



Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Model Boundary
- RORB NE Catchment Boundary
- RORB Wst Catchment Boundary
- RORB NW Catchment Boundary

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
Revision	A
Date	30/09/2019

Impervious Fraction Distribution by Subarea

Figure 3

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

3.3.5 Design rainfall intensities

Design rainfall intensities were determined based on the methods prescribed in Book 2 of the 1997 Edition of Australian Rainfall and Runoff (*IEAust 1997*). The IFD parameters adopted for the Fisherman's Bend catchments were obtained from the Bureau of Meteorology's webpage for creating IFD data (*BOM 2013*) and are presented in Table 3 and Table 4 below. The full IFD table is presented in Appendix A in A.4 IFD Table.

Table 3 IFD Parameters for Fishermans Bend Catchments*- Normal Intensities

Parameter	Rainfall Intensities
${}^{2}i_{1}$ (1 hr duration, 2 yr ARI)	18.77 mm/hr
${}^{2}i_{12}$ (12 hr duration, 2 yr ARI)	3.62 mm/hr
${}^{2}i_{72}$ (72 hr duration, 2 yr ARI)	1.08 mm/hr
${}^{50}i_{1}$ (1 hr duration, 50 yr ARI)	39.07 mm/hr
${}^{50}i_{12}$ (12 hr duration, 50 yr ARI)	7.08 mm/hr
${}^{50}i_{72}$ (72 hr duration, 50 yr ARI)	2.20 mm/hr
G (skewness)	0.36
F2 (2 yr ARI geographical factor)	4.29
F50 (50 yr ARI geographical factor)	14.94

*(Location: 144.925°E, 37.825°S)

Table 4 IFD Parameters for Fishermans Bend Catchments*- 18.5% Higher Intensities

Parameter	Rainfall Intensities
${}^{2}i_{1}$ (1 hr duration, 2 yr ARI)	22.24 mm/hr
${}^{2}i_{12}$ (12 hr duration, 2 yr ARI)	4.29 mm/hr
${}^{2}i_{72}$ (72 hr duration, 2 yr ARI)	1.28 mm/hr
${}^{50}i_{1}$ (1 hr duration, 50 yr ARI)	46.30 mm/hr
${}^{50}i_{12}$ (12 hr duration, 50 yr ARI)	8.39 mm/hr
${}^{50}i_{72}$ (72 hr duration, 50 yr ARI)	2.61 mm/hr
G (skewness)	0.36
F2 (2 yr ARI geographical factor)	4.36
F50 (50 yr ARI geographical factor)	15.99

*(Location: 144.925°E, 37.825°S)

3.3.6 RORB loss parameters

RORB's initial loss/runoff coefficient model was used for the 100 year to 5 year ARI design runs. Adopted parameters for *pervious* areas were as follows:

- Initial loss = 10 mm
- 100 year ARI Runoff coefficient = 0.6

The model automatically sets the loss parameters for *impervious* areas as follows:

- Initial loss = 0 mm
- Runoff coefficient = 0.9

A value of 0.8 was adopted for the model exponent, m, throughout.

The design storms used in the modelling were based on point storms, fully filtered temporal patterns and the IFD parameters described in Section 1.1.

3.3.7 Determination of k_c value

In RORB, the kc value is used as a method of calibrating the storage and attenuation that's modelled within the RORB model. The exercise of defining a kc values depends on the knowledge of the catchment and some known data to calibrate to or validate the model against. Unfortunately no historical streamflow or flood level information was available within the Study Area, so the value of kc had to be determined using empirically derived formulas.

A kc value, based on the RORB equation (kc $=2.2 \times A^{0.5}$), was adopted for the Fishermans Bend model. This can be seen in Table 5. Due to the unique nature of the Fishermans Bend Catchments, it is important to keep in mind the following points when considering a kc value:

- Could not compare kc flows to rational method flows due to the imbedded storage that is within the Fishermans Bend model.
- Fishermans Bend has a relatively flat topography. In this situation, the kc value plays a smaller role in characterising flows. Due to the flat topography, inflows were routed in the TUFLOW model rather than RORB model.
- The importance of the kc parameter diminishes as the amount of routing done within the RORB model is insignificant compared to the routing in the hydraulic model.

As most of the routing will be in the hydraulic model, the final results are relatively insensitive to k_c, which arguably becomes less important than the adopted loss model parameters (which will affect the volume of runoff).

Table 5 Kc values calculated for Fishermans Bend Catchments.

Fishermans Bend Catchment	Catchment Area (km^2)	Kc
North East Catchment	1.927	3.05
North West Catchment	2.554	4.04
West Catchment	0.813	1.91

3.4 Hydraulic modelling

3.4.1 Introduction

The model extends from the top of the Fishermans Bend catchments which drain north to the Yarra River, and broadly from the end of Lorimer Street in the west to Clarendon Street in the East. A plan showing the layout of the TUFLOW model for the Fishermans Bend catchments, as described below, is included in Appendix B.

Hydraulic modelling was undertaken using TUFLOW version 2018-AE-iDP-w64. TUFLOW (*WBM 2018)* is a hydrodynamic model used for simulating one-dimensional (1D) and two-dimensional (2D) flows.

The model is based on the solution to the free-surface flow equations. The TUFLOW model consists of a 2D domain (TUFLOW) representing the catchment terrain, a 1D network (ESTRY) representing the pipe systems and a set of boundary conditions comprising the calculated RORB hydrograph inflows and the downstream water levels.

TUFLOW modelling was undertaken to determine the peak water levels throughout Fishermans Bend; Lorimer and Employment precincts for the events listed in Table 1 Scenarios Modelled and Mapped. The model was initially run for 16 different 100 year ARI storm durations ranging from 10 minutes to 30 hours in order to determine the critical peak flood levels (i.e. 16 runs in total for each scenario). The longest storm duration run was later revised to 30 hours after a review of an initial set of results showed that running longer storms was unnecessary for the current design storms and model configuration (i.e. longer duration events did not result in peak flood levels).

3.4.2 History of TUFLOW modelling in the catchment

GHD did not create the TUFLOW model. Much of the modelling approach (e.g. use of rain on grid) was continued from the TUFLOW model URS prepared for the City of Port Phillip in 2011, which GHD was asked to adopt and make only necessary adjustments to. Key changes were generally made only where substantial errors were found.

Key changes made included:

- Mannng's "n" values were adopted from the previous model, checked and adjusted where necessary.
- Changing inverts on pipes which had negative slopes or were above the inverts of incoming pipes, except where these are at bifurcation locations where they are likely to form a high level relief system, or where Melbourne Water GIS layer inverts indicated that slopes were negative, or there was a step up.
- Changing pipes from circular to rectangular where Melbourne Water GIS layers indicated these were not circular.
- Changing inverts on pipes which had no cover (were effectively sticking out of the ground).
- Increasing the tail water levels to those provided by Melbourne Water.
- Adding additional City of Port Phillip pipes and pits from Council's GIS layers that were located within or close to the precincts and not present in the URS model.
- Adding City of Melbourne pits and pipes in areas the model was extended and connecting the City of Port Phillip network to these as appropriate.
- Added Melbourne Water pits and pipes were development had caused realignments to Melbourne Water drainage infrastructure.
- The fixed water level that was used for the downstream boundary conditions in the previous TUFLOW modelling was replaced with a tidal cycle boundary condition.
- The terrain data within the TUFLOW model was updated with data from the Port Phillip Sea Wall Survey (Port Melbourne to Williamstown) (May 2017) undertaken for Melbourne Water.
- The pipe drainage under the West Gate Fwy and through the site of the Melbourne Convention Centre had not been represented correctly within the hydraulic model used previously for the drainage plan options. This had likely occurred as a result of the recent redevelopment of the site and the changes that were understood to have been made then to the drainage. The pipe drainage has been updated for the modelling undertaken for this baseline drainage plan.

Where elaboration is required these changes are further described in the following sections.

3.4.3 2D domain

The 2D domain represents the ground surface and hence the overland flow paths within the model. A DTM was created to represent the catchment topography, as described above in Section 1.1. Using this terrain model, grids comprising 3 metre square cells were formed, covering an area of 5400 m by 3680 m. Each cell is made up of nine points, with the elevation for each point based on the DTM. Given there was no obviously dominant street direction, the grid was rotated to minimise the size of the 2D domain. The 2D domain was used to model all overland flow paths.

2d Domain Corrections

Some major flow control features critical in determining overland flow distribution and/or levels of ponding were included in the 2D domain by modifying the elevations of cell points (through the use of additional z-shapes and/or z-lines). “Z shapes” have been used to alter the terrain in the model where anomalies were observed in key areas (such as holes where large buildings were under construction and significant excavation was seen in the data set within or upstream of the precincts), or in areas where bridges had caused obstructions to flow in the DEM.

The 2D domain was compared to current day images (both aerial and street view) to highlight areas of development and the appropriate use of terrain manipulation was used to produce flood extents that better replicate expected flooding. In areas where there is a noticeable change to terrain since LiDAR data was gathered, i.e. the development of buildings, “z shapes” and/or “z lines” were used to adjust terrain to more appropriate levels. Along with “Z shapes”, “Z lines” have been used to alter the terrain in the model in areas where flow paths should not exist because a structure is now preventing water from flowing in that direction. “Z lines” create a hypothetical wall by modifying the elevations of cell points, redirecting flow paths. “Z lines” were used to incorporate the Port Philip Sea Wall Survey manipulating data in the DTM for levels along the Yarra River and Port Phillip Sea Wall. This enabled a better representation of ground levels along the Yarra River to be represented in the model.

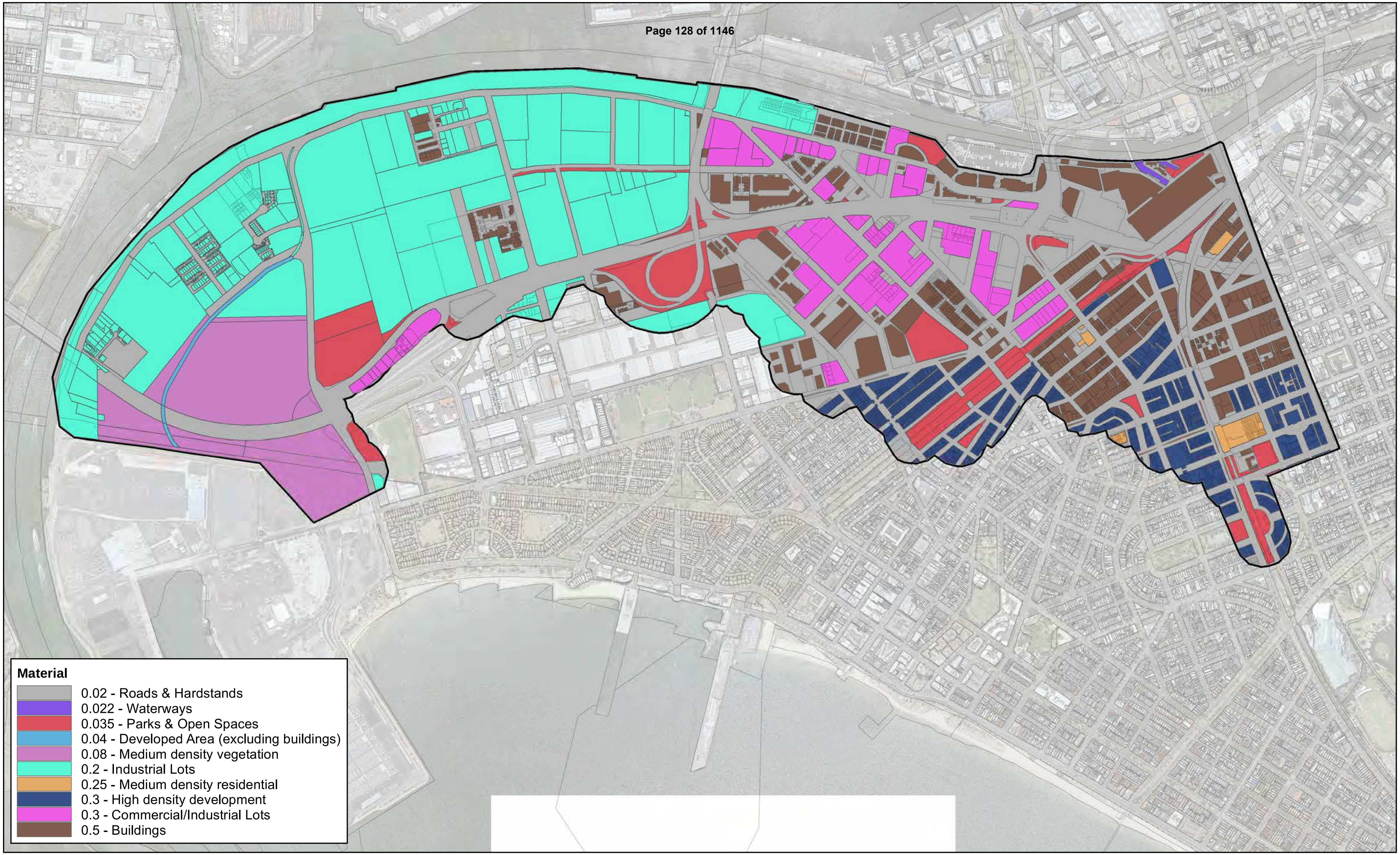
Bed Resistance

The bed resistance was allocated to each cell as a Manning’s n value based on land use type and aerial photography. Adopted Manning’s n values are displayed in Table 6 below. Figure 4

shows the distribution of Manning’s n values throughout the 2D domain.

Table 6 Bed Resistance Values for 2D Domain

Material Number	Land Use	Manning's n
1	Roads and Hardstands	0.02
2	Parks and Open Space (well maintained grass/lawn)	0.035
3	Medium density residential, buildings not separated	0.25
4	High density development, buildings not separated	0.3
5	Buildings	0.5
6	Waterways	0.022
7	Commercial/industrial lots, buildings not separated	0.3
8	Developed areas excluding buildings	0.04
9	Medium density vegetation	0.08
10	Industrial lots, buildings not separated	0.2



Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary

Parcels

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Manning's 'n' Distribution

Job Number	12511721
Revision	A
Date	13/09/2019

Figure 4

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

3.4.4 1D network

The one-dimensional network comprises all Melbourne Water and City of Melbourne, as well as a number of City of Port Phillip, underground pipes. The existing underground drainage network was mostly sourced from the original modelling and supplemented with information from MW provided GIS data.

Pipe networks

The pipe networks include underground pipes and connections to the surface (pits). Pipes were mostly modelled as circular (“C”) or rectangular (“R”) channels.

Modelled inlet pits have typically been generously sized to enable the pipes to be more easily filled in recognition of the fact that other directly connected drainage systems are not explicitly modelled. Inlet losses were generally based on typical design values. These values were sometimes reduced using engineering judgement where they were considered too conservative (large).

Manning’s n pipe roughness values of 0.015 were adopted for all concrete pipes for consistency with the URS base model.

Details of the Melbourne Water pipes (i.e. dimensions, invert levels and location) were generally adopted from Melbourne Water’s GIS layers and/or design drawings of the drains. Details of Council pipes were based on GIS layers of Council drainage received from City of Melbourne and the City of Port Phillip.

Although many of the underground assets are reasonably well documented, a number of assumptions have been made in building and or updating the model, these typically include assumptions regarding invert levels and sometime even connectivity. These assumptions and others, which may remain from the original URS source model, are not considered sufficiently representative for the current modelling purposes however they may not be appropriate for other objectives. It is recommended that any future modelling considers the potential significance of these assumptions and refers to the original drawings, GIS databases and survey to confirm key characteristics.

Pits

‘Pits’ are defined in TUFLOW as being locations where flow can interchange between pipes and the surface (excluding pipe inlets/outlets at headwalls). While Council provided a GIS layer of all pits identifying different pit types (e.g. junction pits, side entry pits, grated pits, etc.), it was agreed with Council to model all Council pits as model ‘pits’. The exception to this was where there was no physical evidence on site of a pit of any kind existing. In those instances, the GIS pit was modelled as a ‘Node’ and did not provide connectivity to the surface. This general pit modelling assumption recognises that pit lids could blow off during a flood event regardless of the pit type and that other inlets may exist which are not explicitly included in the model.

For modelling purposes, pits have generally been modelled as 3 m wide weirs, unless real pits were actually larger than this. This approach partially allows for additional inlet capacity to the drainage system not otherwise explicitly included in the model (such as private property connections, etc.). The resultant flood characteristics are therefore mostly influenced by the capacity of the modelled pipes and less by inlet capacity.

Losses

Form loss coefficients were determined throughout the pipe network based on standard pit loss tables (*MWC 2018*). Pit loss values were generally assigned to the downstream pipe as a form loss, rather than in the pits themselves. A typical entrance loss of 0.5 and exit loss of 1.0 was applied to culverts and to the ends of pipes. While the loss coefficients are generally conservative, no allowance has been made for blockage due to debris.

In order to apply this method of form loss application, the command “Manholes at All Culvert Junctions == OFF” was added to the model ECF files. By adding this command, TUFLOW’s default approach of applying Engelund loss values is deactivtated.

3.4.5 Boundary conditions

Boundary conditions in the TUFLOW model include inflow hydrographs and downstream tailwater conditions.

Inflows

Inflow hydrographs for the events listed in Table 1 were generated using the RORB models and adopted as the flow boundary conditions (“QT” – flow versus time). Hydrographs were input to the TUFLOW model by applying the hydrograph in one of the following ways:

- As a point on a single node on the 1D network (via a 1d_bc layer).
- As a polygon distributing a hydrograph evenly between a number of nodes on the 1D network (via a 1d_bc layer); or

The vast majority of these boundaries are however applied directly to the 1D network to encourage the pipes to flow full before surface flow occurs.

Inflow hydrographs were created from four RORB catchment models; North-Eastern, North-Western, Western and Southern catchments. The NE, NW and Wst catchment inflows are included in the RORB model used for this flood mapping project. Southern catchment inflows were applied from Fishermans bend existing southern catchment model (external from this current flood mapping project). Southern Catchment inflows were required and applied at the Salmon Street and Rocklea Drive intersection, where a two way drain is located. The pipe network along Salmon street heads both north underneath the West Gate Freeway and south down Salmon Street, outside of the hydraulic model boundary. Creating a boundary condition for this particular drain is described below. The RORB catchment boundaries can be seen in Appendix A.

Downstream boundaries

Following consultation with Melbourne Water, cyclical Port Phillip Bay tidal levels were adopted as tail water levels for the Melbourne Water and council pipes discharging to the Yarra River. These levels were applied in the TUFLOW model as head versus time boundary conditions (“HT” boundary with head remaining constant) at the ends of the pipe networks (via a 1d_bc layer).

A 1D boundary condition was applied to a pipe exiting the model to the south along Salmon Street. A level of 2.541 m AHD was nominated which represents the obvert of the pipe outlet closest to the hydraulic model boundary. This level was applied in the TUFLOW model as a “HT” boundary conditions (via a 1d_bc layer).

2D boundary conditions were also included at multiple locations along the edge of the model. A 2D boundary condition along the Yarra River was applied as a “HT” boundary (via a 2d_bc layer) representing the Yarra River Levels and Sea Levels.

To allow overland flow that reaches the southern boundary to exit the model, multiple “HQ” boundaries (via a 2d_bc layer) are at locations identified from previous flood modelling results.

Tidal cycle boundary

Based on discussions with Melbourne Water, it was decided that tide cycle data from Port Phillip Bay should be used for the downstream boundary condition of the Fishermans Bend model instead of flood levels from the recently completed Yarra River flood modelling project. The decision was made in light of the fact that the critical storm event for the Yarra River is much longer than what is critical for Fishermans Bend and therefore the two events would likely not coincide. A comparison of the Yarra River Flood Model results with Port Phillip Tide Cycle Levels results found that there was less than 50mm difference in water levels.

Tide cycle data was supplied by Melbourne Water from a tidal model of Port Phillip and consisted of 500, 100, 20 and 5 year ARI time series results for both current conditions and 2100 climate change conditions. Tide data from Cowderoy Road in St Kilda was used for the Fishermans Bend flood modelling. Based on this data, the peak tide level for the 100-year ARI event, including the effects of climate change, was 2.25 mAHD, The 10-yr and 100-yr ARI tidal cycles from the tidal model for existing conditions and 2100 are shown in Figure 5 below. The 10 year ARI data was interpolated from the 20 and 5 year ARI time series results.

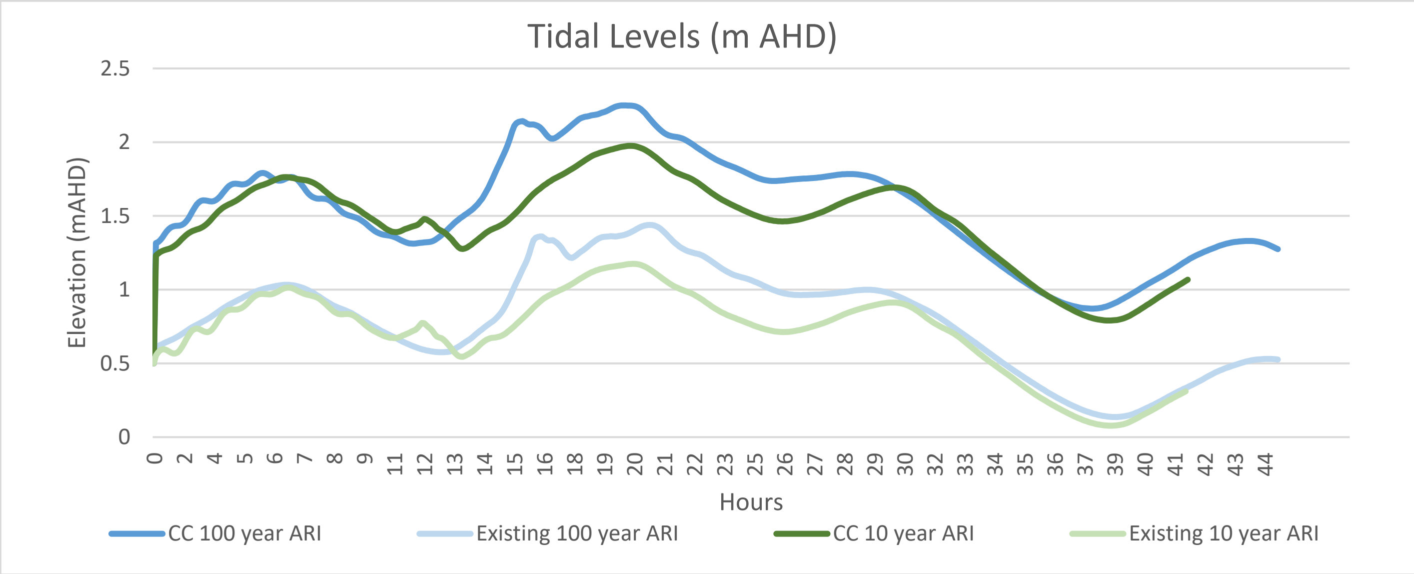


Figure 5 Adopted tidal cycle data

Table 7 Adopted Tailwater Levels

Scenario	Event	Yarra Flood Levels	1D Boundary Condition Tailwater Levels (m AHD)		2D Boundary Condition Tailwater Levels (m AHD)		
			Yarra River	Salmon Street*	Yarra River	Southern Boundary^	Salmon St
A - Climate Change 1	100 year ARI	10% AEP	#	2.541	#	1 in 500 slope	1 in 100 slope
B - Climate Change 2	100 year ARI	1% AEP	#	2.541	#	1 in 500 slope	1 in 100 slope

Note:

refer to Tidal Cycle data shown in Table 7.

* indicates that this level represents the obvert of the pipe outlet closest to the hydraulic model boundary.

^ includes all 2D boundary conditions along the southern boundary of the model except for Salmon Street (15 in total).

Initial water level

The tailwater levels listed above were also applied as initial water levels to the entire respective models (in both the 1D network and 2D domain) to improve stability at the start of a simulation. These global 1D and 2D initial water level boundary conditions were overridden at the following permanent water bodies:

- West Gate Park: Fresh and Salt Water Lakes – an initial water level of 0.5 m was set for the two lakes.

Clarendon Street boundary/ Hanna Street Main Drain catchment approach

A "glass wall" boundary was modelled at the Clarendon Street boundary in areas below 2.22 m AHD. The limitation of this approach is that it does not account for the additional flood storage or pipe capacity which may be available in the large depressed area on the eastern side of the road, or conversely any flows which may be crossing the road from east to west from the Hanna St drain catchment if this is experiencing greater surcharging. Overcoming this limitation would involve extensive model extension. The Hanna St Drain has a catchment area of 421 ha according to the 'DR_MW_Catchment tab', the Crown Casino Pumping Station is also located at the end of the Hanna St main drain.

Only between half and two thirds of the Hanna St Main Drain catchment is shown in the DR_MW_Catchment tab which was included in the URS Catchment 4 model, stopping at the CoPP boundary. The pipe continues to the Yarra in the 1d only without further inflows and the Crown Casino Pump Station is not included.

An additional pump station at Clarendon Street was sized to limit flooding originating from the system on the western side of the road for all scenarios except Scenario 0 (Conventional servicing with rainwater tanks as per SFP and no precinct based drainage) so that ponding on Whiteman Street does not drive flow into the 525 mm Council drain southwest into the Montague precinct (somewhere between approximately 0.8m and 0.95 m AHD). There is potential to provide additional capacity for the Hanna St catchment if desired, subject to detailed investigation in the future.

3.4.6 Model run parameters

Following several test runs trialling various parameters, the following parameters were found to achieve the most stable model runs across a wide range of storm durations, and have been adopted for all runs (unless otherwise specified):

- Cell size – 3m
- 2D domain size – 5400 m x 3680 m.
- A time step of 1 seconds for the 2D domain and 0.25 seconds for the 1D network.
- Maximum Velocity Cutoff Depth == 0.05 (default is 0.1) – this allows maximum velocities to be recorded once depth is above 0.05m.
- Cell Wet/Dry Depth == 0.0002 (default is 0.002)
- Initial water levels in the 1D and 2D domains as described above in Section 1.1.
- "Manholes at All Culvert Junctions == OFF" command has been used to override the automatic calculation of losses and apply the parameters determined in accordance with Melbourne Water's standard pit loss tables (see discussion in Section 1.1).
- Minimum NA == 2 (used to increase nodal storage slightly at 'nodes' in the 1D network where pits are not digitised).

- "Weir Flow == METHOD B" (default approach for weirs prior to 2013 versions of TUFLOW – necessary to improve the stability of the "W" pits and reduce total cumulative mass error).
- Model run times long enough for peak flood levels to occur throughout the drainage system for each storm duration.
- For each duration the starting time of the rainfall event was set such that the peak tide cycle level coincided with the end of the rainfall event. For the purpose of this flood mapping project, this approach was deemed acceptable by Melbourne Water. Although the joint probability of the peak of a 1% AEO tidal event coinciding with the end of a 1% AEP rainfall event is probably less than 1%, this approach provides a more conservative result.

3.4.7 Final TUFLOW Model Input Layers

A list of description of the layers read into the TUFLOW model are presented in Appendix B – Table B16.

4. Mapping output

4.1 Raw flood extent results

The raw results of the TUFLOW modelling were post-processed to produce raw flood extent layers as outlined in Melbourne Water's Guidelines and Technical Specifications for Flood Mapping Projects (*MWC Nov, 2018*). The model results produced for the selected storms, envelopes of maximum values were produced for each AEP and for each of the key output parameters (i.e. flood level, depth, velocity, velocity-depth) using the "DAT to DAT" utility. Further details of the mapping output is described in the following sections.

4.2 Qualifications relating to flood mapping output

The hydraulic model and its results extend beyond the region being mapped for to achieve a number of objectives, including:

- To improve the distribution of model inflows.
- To reduce the significance of downstream boundary conditions.
- To facilitate flow diversions.

Therefore, the flood mapping outputs described in the following sections, and provided to the City of Melbourne as 3 m grid points in accordance with the Guidelines and Technical Specifications for Flood Mapping Projects (*MWC Nov, 2018*) are for the entire model and extend beyond the "Mapping Limit" line. This line designated the extent of meaningful results. Outside of the "Mapping Limit" the results shown may be misleading due to a number of reasons, including:

- Boundary conditions
- Incomplete representation of drainage assets
- Detail to which the 2d surface is presented

The accuracy of the final results is in part a function of the resolution of the TUFLOW model (which uses a 3 m cell size).

4.3 GIS output

The MapInfo layers listed below were provided to City of Melbourne as a primary output of this flood mapping project. This report describes the methodology and steps taken to arrive at these layers. The layers listed in Table 8, Table 9 and Table 10 conform to Melbourne Water's supplied metadata standards and naming conventions, as outlined in the Guidelines and Technical Specifications for Flood Mapping Projects (*MWC, 2018)*. The projection of all layers is Map Grid of Australia Zone 55 (GDA94).

4.3.1 Flood Extents

Table 8 Deliverables – GIS Layers

Layer name	Description
Mapping_Limits.TAB	Extent of meaningful results.

Table 9 Deliverables - Flood Extent Results

Name	Units	Comment
FB_Base_10yTide_100y_Water_Level.flt	m AHD	Maximum water level for 10y ARI Tide and 100y ARI Rainfall
FB_Base_100yTide_100y_Water_Level.flt	m AHD	Maximum water level for 100y ARI Tide and 100y ARI Rainfall
FB_Base_10yTide_100y_Water_Depth.flt	m	Maximum depth for 10y ARI Tide and 100y ARI Rainfall
FB_Base_100yTide_100y_Water_Depth.flt	m	Maximum depth for 100y ARI Tide and 100y ARI Rainfall
FB_Base_10yTide_100y_Velocity.flt	m/s	Maximum velocity for 10y ARI Tide and 100y ARI Rainfall
FB_Base_100yTide_100y_Velocity.flt	m/s	Maximum velocity for 100y ARI Tide and 100y ARI Rainfall
FB_Base_10yTide_100y_Velocity_x_Depth.flt	m^2/s	Maximum velocity-depth product for 10y ARI Tide and 100y ARI Rainfall
FB_Base_100yTide_100y_Velocity_x_Depth.flt	m^2/s	Maximum velocity-depth product for 100y ARI Tide and 100y ARI Rainfall

Table 10 Deliverables - RORB Model Layers

Layer name	Description
RORB MapInfo Layers	
FB_NE_catch_region.TAB	North East Catchment Boundary
FB_NE_subarea_region. TAB	North East Sub area boundaries
FB_NE_node_point. TAB	North East Nodes
FB_NE_reach_polyline. TAB	North East reaches
FB_NW_catch_region. TAB	North West and West Catchment Boundary
FB_NW_subarea_region. TAB	North West and West Sub area boundaries
FB_NW_node_point. TAB	North West and West Nodes
FB_NW_reach_polyline. TAB	North West and West reaches
Imp_Fracs_region. TAB	Sub Area Impervious Factions

5. Recommendations

It is recommended that:

- The City of Melbourne adopts the outcomes of this investigation to assist in the classification of the catchment in terms of severity of flooding.
- The City of Melbourne adopts the outcomes of this investigation for future planning purposes and assessment of potential future mitigation options.
- Any future mitigation option assessment makes allowance for the impact of future development within the catchment.
- The planning assumptions used in this modelling are reviewed periodically and updated as required.

Improvements to the modelling for future flood mapping projects:

- Update LiDAR to current data
- Update the RORB model with ARR2019 design methodologies.
- Complete a Monte Carlo simulation on the joint starting times of the tide cycle and the rainfall event to correctly identify probability events.
- Update 1D network with current asset data;.

6. References

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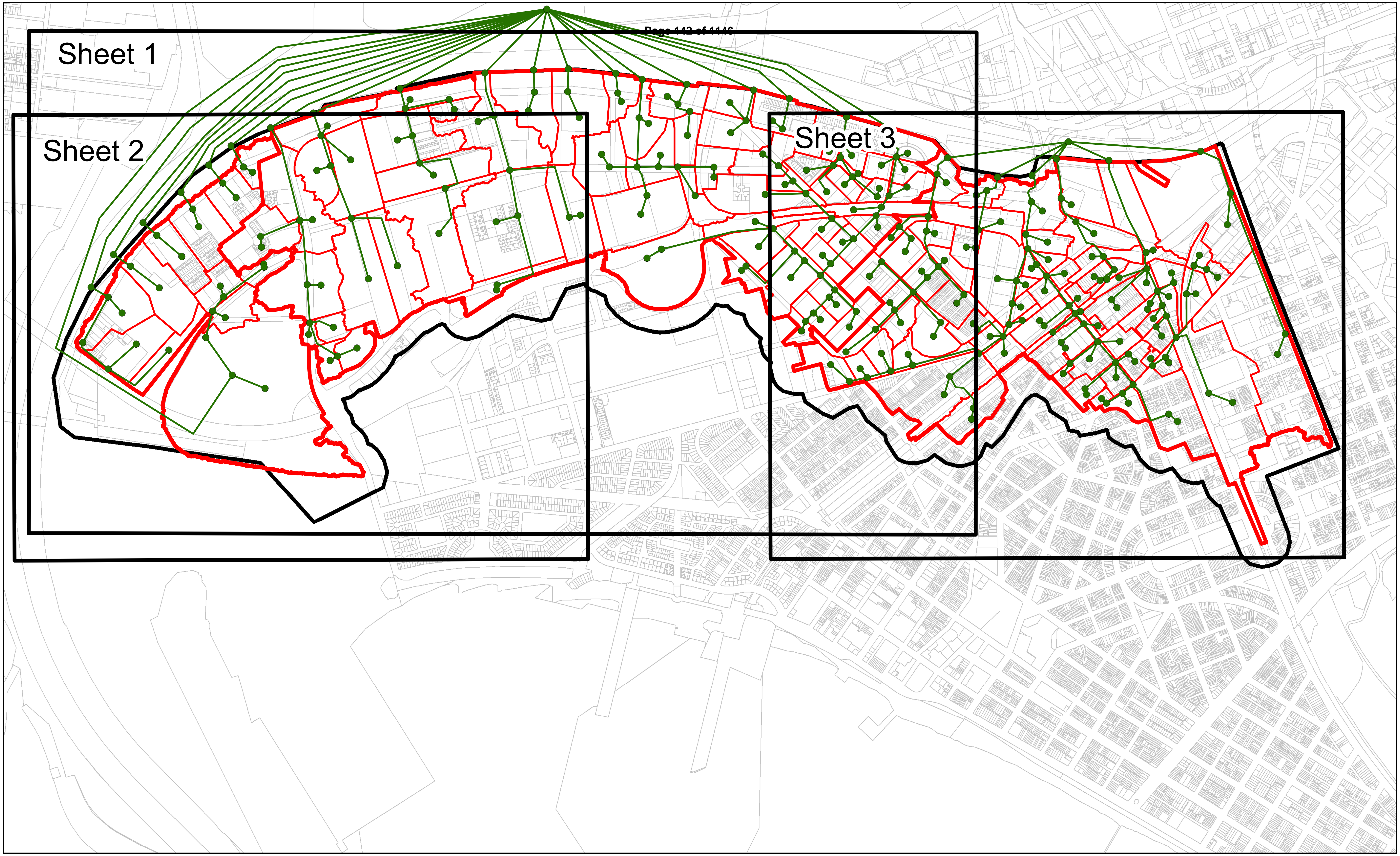
Appendices

Appendix A – Hydrological Modelling

Contents

A.1 RORB Network Layout



Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary	Subcatchment Boundaries
Parcels	RORB Model Nodes
Catchment Boundary	RORB Model Reaches

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number 12511721
Revision A
Date 23/09/2019

RORB Network Layout
Key Map

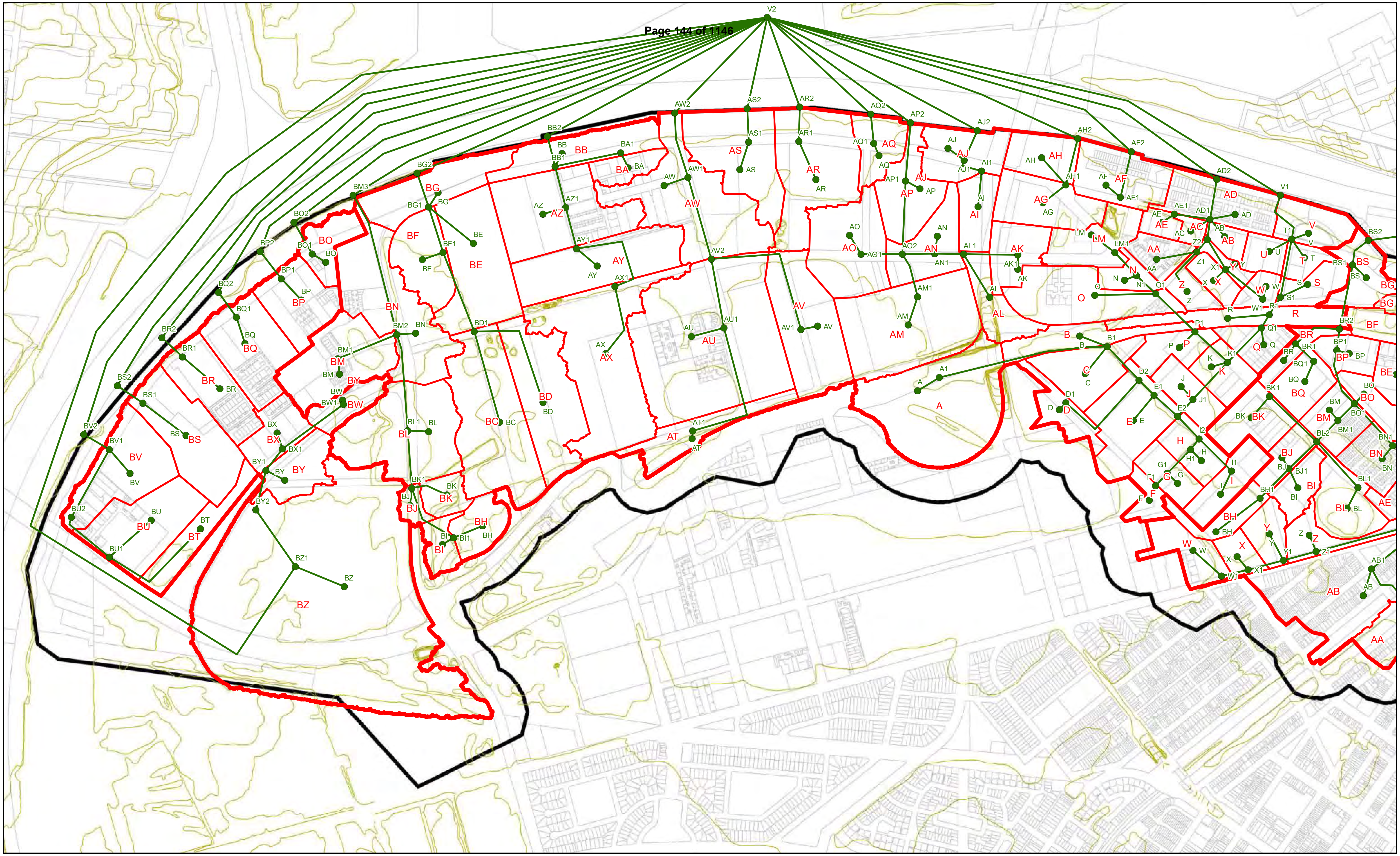
Figure A.1

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

A.2 RORB Catchment Files



Paper Size A3

0 45 90 180 270 360

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Model Boundary
- Parcels
- Ground Contours (1m Interval)
- Catchment Boundary
- Subcatchment Boundaries
- RORB Model Nodes
- RORB Model Reaches

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
Revision	A
Date	23/09/2019

RORB Network Layout

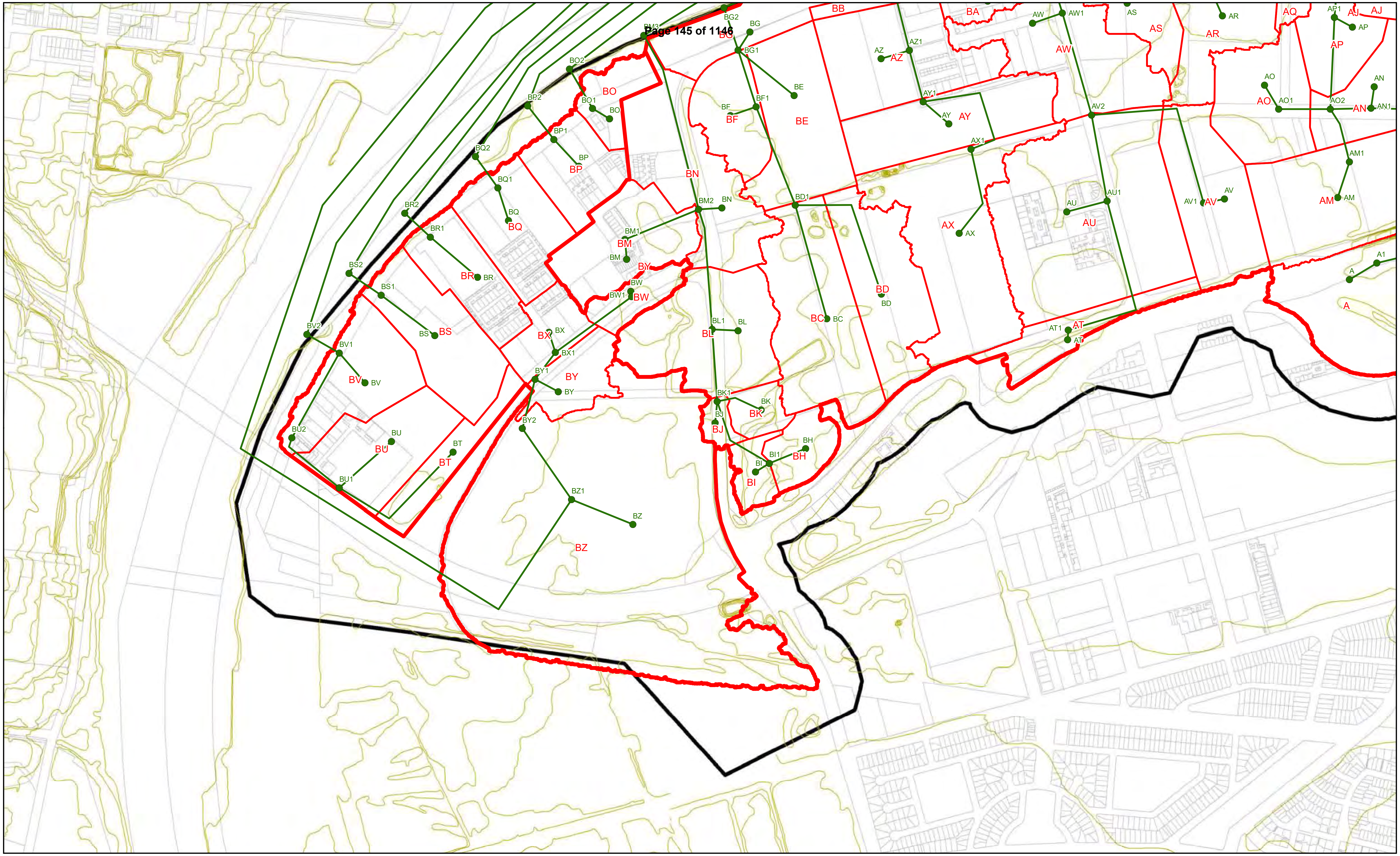
Sheet 1 of 3 - NW Catchments

Figure A.2

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan



Paper Size A3

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Model Boundary
Parcels
Ground Contours (1m Interval)
Catchment Boundary
Subcatchment Boundaries
RORB Model Nodes
RORB Model Reaches

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
Revision	A
Date	23/09/2019

RORB Network Layout

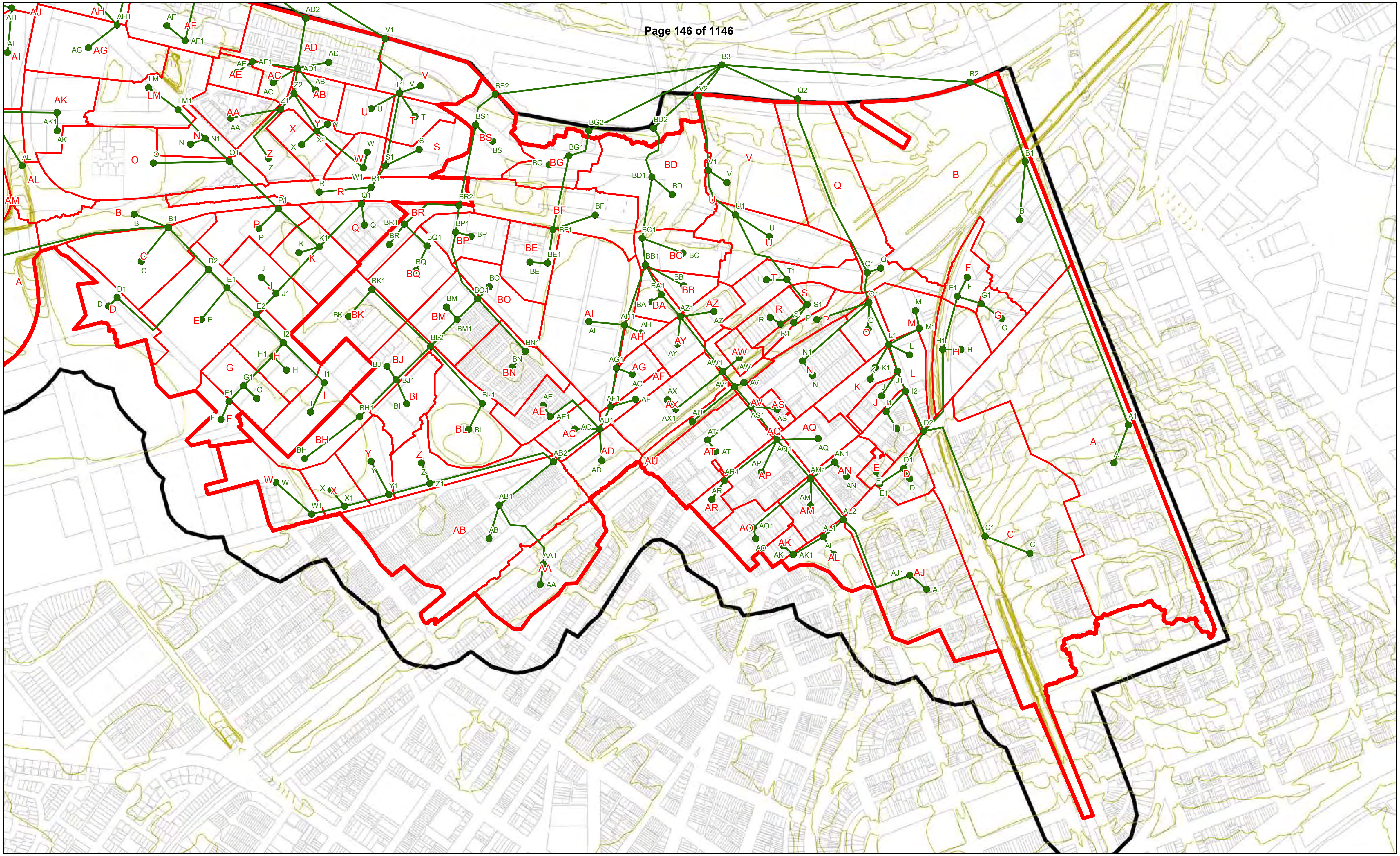
Sheet 2 of 3 - West Catchments

Figure A.3

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com



Paper Size A3

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Model Boundary
- Parcels
- Ground Contours (1m Interval)
- Catchment Boundary
- Subcatchment Boundaries
- RORB Model Nodes
- RORB Model Reaches

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
Revision	A
Date	23/09/2019

RORB Network Layout
Sheet 3 of 3 - NE Catchments

Figure A.4

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

A.3 Subarea-Weighted Impervious Fraction

Table A-11 North Eastern Catchments – Adopted Subarea Impervious Fraction

SubArea	Area (ha)	Impervious Fraction	SubArea	Area (ha)	Impervious Fraction	SubArea	Area (ha)	Impervious Fraction
A	18.8	0.85	AE	1.5	0.862	BI	1.7	0.88
B	16.8	0.863	AF	0.6	0.709	BJ	1.6	0.9
C	16.4	0.776	AG	0.8	0.9	BK	3	0.9
D	1.1	0.825	AH	0.6	0.9	BL	3.3	0.262
E	0.4	0.899	AI	6.5	0.9	BM	2.4	0.9
F	1.2	0.843	AJ	7.9	0.669	BN	2.7	0.9
G	1	0.872	AK	0.5	0.9	BO	1.7	0.9
H	2.2	0.864	AL	1.6	0.51	BP	1.8	0.9
I	1.2	0.9	AM	1.3	0.87	BQ	2.2	0.9
J	0.7	0.9	AN	1.4	0.873	BR	1.2	0.897
K	1.3	0.9	AO	1.5	0.9	BS	2.6	0.849
L	1.2	0.9	AP	2	0.88			
M	1.7	0.876	AQ	1.5	0.879			
N	3	0.9	AR	0.6	0.9			
O	1	0.9	AS	0.3	0.9			
P	1	0.9	AT	3.5	0.888			
Q	5.8	0.803	AU	0.6	0.783			
R	0.9	0.9	AV	1.1	0.733			
S	0.8	0.9	AW	0.6	0.9			
T	2	0.769	AX	2.6	0.873			
U	3.6	0.831	AY	1.1	0.823			
V	5.1	0.793	AZ	1	0.861			
W	2.6	0.885	BA	0.8	0.853			
X	1.2	0.873	BB	0.8	0.852			
Y	1.7	0.889	BC	1.8	0.837			
Z	2.1	0.577	BD	4.9	0.833			
AA	3.9	0.497	BE	1.9	0.9			
AB	10.2	0.566	BF	3.8	0.831			
AC	1.1	0.83	BG	1.9	0.865			
AD	1.6	0.709	BH	1.9	0.9			

Table A-12 North Western Catchments – Adopted Subarea Impervious Fraction

SubArea	Area (ha)	Impervious Fraction	SubArea	Area (ha)	Impervious Fraction	SubArea	Area (ha)	Impervious Fraction
A	10.6	0.457	AF	4	0.887	BJ	0.8	0.53
B	2.8	0.805	AG	3.9	0.887	BK	1.4	0.511
C	3.5	0.9	AH	2.5	0.898	BL	8	0.882
D	2	0.9	AI	2.2	0.871	BM	5.6	0.9
E	5.1	0.9	AJ	3.4	0.876	BN	7.9	0.868
F	1.1	0.9	AK	2.6	0.897			
G	1.8	0.9	AL	2.5	0.842			
H	2.2	0.9	AM	9.2	0.858			
I	2.5	0.9	AN	3.5	0.899			
J	2.1	0.9	AO	5.7	0.9			
K	2.1	0.9	AP	3.8	0.896			
LM	3.3	0.9	AQ	2.4	0.881			
N	1.2	0.9	AR	7.5	0.889			
O	5.7	0.898	AS	6.2	0.886			
P	1.9	0.9	AT	3.1	0.828			
Q	1.9	0.894	AU	16.9	0.9			
R	3.2	0.8	AV	6.7	0.898			
S	1.8	0.883	AW	8.9	0.898			
T	1.1	0.884	AX	11	0.9			
U	1.3	0.887	AY	6.4	0.9			
V	2.5	0.893	AZ	7.6	0.9			
W	1	0.884	BA	1.4	0.9			
X	1.2	0.898	BB	4	0.857			
Y	0.7	0.9	BC	9.3	0.821			
Z	1.3	0.894	BD	6.7	0.884			
AA	1.6	0.9	BE	7.1	0.9			
AB	0.9	0.882	BF	3.7	0.9			
AC	0.6	0.877	BG	4.3	0.873			
AD	4.1	0.89	BH	2.1	0.5			
AE	0.8	0.887	BI	1.4	0.5			

Table A-13 Western Catchments – Adopted Subarea Impervious Fraction

SubArea	Area (ha)	Impervious Fraction
BO	2.2	0.9
BP	3.8	0.9
BQ	5.1	0.9
BR	4.1	0.9
BS	6	0.9
BT	2.7	0.9
BU	5.5	0.9
BV	5.6	0.9
BW	1.8	0.868
BX	2.5	0.9
BY	2.7	0.637
BZ	39.2	0.272

A.4 IFD Table

Table A-14 Rainfall IFD Table

Location: Fishermans Bend (144.925 E, 37.825 S)

	18.77	
12 HR DUR 2 ARI	3.62	mm/hr
72 HR DUR 2 ARI	1.08	mm/hr
1 HR DUR 50 ARI	39.07	mm/hr
12 HR DUR 50 ARI	7.08	mm/hr
72 HR DUR 50 ARI	2.20	mm/hr
G (skewness)	0.36	mm/hr
F2 Geo factor 2 ARI	4.29	
F50 Geo factor 50 ARI	14.94	

Duration		Design Rainfalls for Average Recurrence Intervals								
(min)	(hr)	1 (mm/hr)	2 (mm/hr)	5 (mm/hr)	10 (mm/hr)	20 (mm/hr)	50 (mm/hr)	100 (mm/hr)	200 (mm/hr)	500 (mm/hr)
5	0.083	46.7	62.5	86.7	103.4	125.5	157.7	184.6	214.2	257.7
6	0.100	43.7	58.5	80.9	96.4	116.9	146.7	171.6	199.0	239.2
7	0.117	41.2	55.0	76.0	90.5	109.7	137.5	160.8	186.3	223.8
8	0.133	39.0	52.1	71.9	85.5	103.6	129.7	151.6	175.5	210.7
9	0.150	37.2	49.6	68.3	81.2	98.3	123.0	143.6	166.3	199.5
10	0.167	35.5	47.4	65.2	77.4	93.6	117.1	136.7	158.2	189.6
11	0.183	34.1	45.4	62.4	74.0	89.5	111.9	130.5	151.0	180.9
12	0.200	32.7	43.6	59.9	71.0	85.9	107.3	125.1	144.6	173.1
13	0.217	31.6	42.0	57.7	68.3	82.5	103.1	120.1	138.8	166.2
14	0.233	30.5	40.6	55.6	65.9	79.5	99.3	115.6	133.6	159.8
15	0.250	29.5	39.3	53.7	63.6	76.8	95.8	111.5	128.8	154.1
16	0.267	28.6	38.1	52.0	61.6	74.3	92.6	107.8	124.4	148.8
17	0.283	27.8	36.9	50.4	59.7	72.0	89.7	104.3	120.4	143.9
18	0.300	27.0	35.9	49.0	57.9	69.8	86.9	101.1	116.7	139.4
19	0.317	26.3	34.9	47.6	56.3	67.8	84.4	98.2	113.3	135.2
20	0.333	25.6	34.0	46.3	54.8	66.0	82.1	95.4	110.0	131.4
25	0.417	22.8	30.2	41.1	48.4	58.2	72.3	84.0	96.8	115.3
30	0.500	20.6	27.4	37.1	43.7	52.4	65.0	75.4	86.8	103.3
35	0.583	18.9	25.1	33.9	39.9	47.9	59.3	68.7	79.0	93.9
40	0.667	17.6	23.3	31.4	36.8	44.2	54.6	63.2	72.6	86.3
45	0.750	16.4	21.7	29.2	34.3	41.1	50.8	58.7	67.4	80.0
50	0.833	15.4	20.4	27.4	32.2	38.5	47.5	54.9	63.0	74.7
55	0.917	14.6	19.3	25.9	30.3	36.2	44.7	51.6	59.2	70.2
60	1.000	13.9	18.3	24.5	28.7	34.3	42.3	48.8	55.9	66.2
75	1.250	12.0	15.9	21.2	24.8	29.6	36.4	42.0	48.1	56.9
90	1.500	10.7	14.1	18.8	22.0	26.2	32.2	37.1	42.5	50.2
120	2.000	8.9	11.7	15.5	18.1	21.5	26.4	30.4	34.8	41.0
180	3.000	6.8	8.9	11.8	13.7	16.3	19.9	22.9	26.2	30.8
240	4.000	5.6	7.4	9.7	11.3	13.4	16.3	18.7	21.4	25.1
300	5.000	4.8	6.3	8.3	9.7	11.5	14.0	16.0	18.3	21.4
360	6.000	4.3	5.6	7.4	8.5	10.1	12.3	14.1	16.1	18.8
420	7.000	3.9	5.1	6.6	7.7	9.1	11.1	12.7	14.4	16.9
480	8.000	3.5	4.6	6.1	7.0	8.3	10.1	11.5	13.1	15.4
540	9.000	3.3	4.3	5.6	6.5	7.6	9.3	10.6	12.1	14.1
600	10.000	3.1	4.0	5.2	6.0	7.1	8.6	9.9	11.2	13.1
660	11.000	2.9	3.7	4.9	5.6	6.7	8.1	9.2	10.5	12.3
720	12.000	2.7	3.5	4.6	5.3	6.3	7.6	8.7	9.9	11.6
780	13.000	2.6	3.4	4.4	5.1	6.0	7.3	8.3	9.4	11.0
840	14.000	2.5	3.2	4.2	4.8	5.7	6.9	7.9	9.0	10.5
900	15.000	2.3	3.1	4.0	4.6	5.5	6.6	7.6	8.6	10.1
960	16.000	2.3	2.9	3.9	4.5	5.3	6.4	7.3	8.3	9.7
1020	17.000	2.2	2.8	3.7	4.3	5.1	6.2	7.0	8.0	9.4
1080	18.000	2.1	2.7	3.6	4.1	4.9	5.9	6.8	7.7	9.1
1140	19.000	2.0	2.6	3.5	4.0	4.7	5.7	6.6	7.5	8.8
1200	20.000	2.0	2.6	3.4	3.9	4.6	5.6	6.4	7.2	8.5
1440	24.000	1.7	2.3	3.0	3.5	4.1	5.0	5.7	6.5	7.6
1800	30.000	1.5	2.0	2.6	3.0	3.5	4.3	5.0	5.6	6.6
2160	36.000	1.3	1.7	2.3	2.7	3.1	3.8	4.4	5.0	5.9
2880	48.000	1.1	1.4	1.9	2.2	2.6	3.2	3.6	4.2	4.9
3600	60.000	0.9	1.2	1.6	1.9	2.2	2.7	3.1	3.6	4.2
4320	72.000	0.8	1.1	1.4	1.6	1.9	2.4	2.7	3.1	3.7

Table A-15 Rainfall IFD Table - 18.5% Higher Intensities

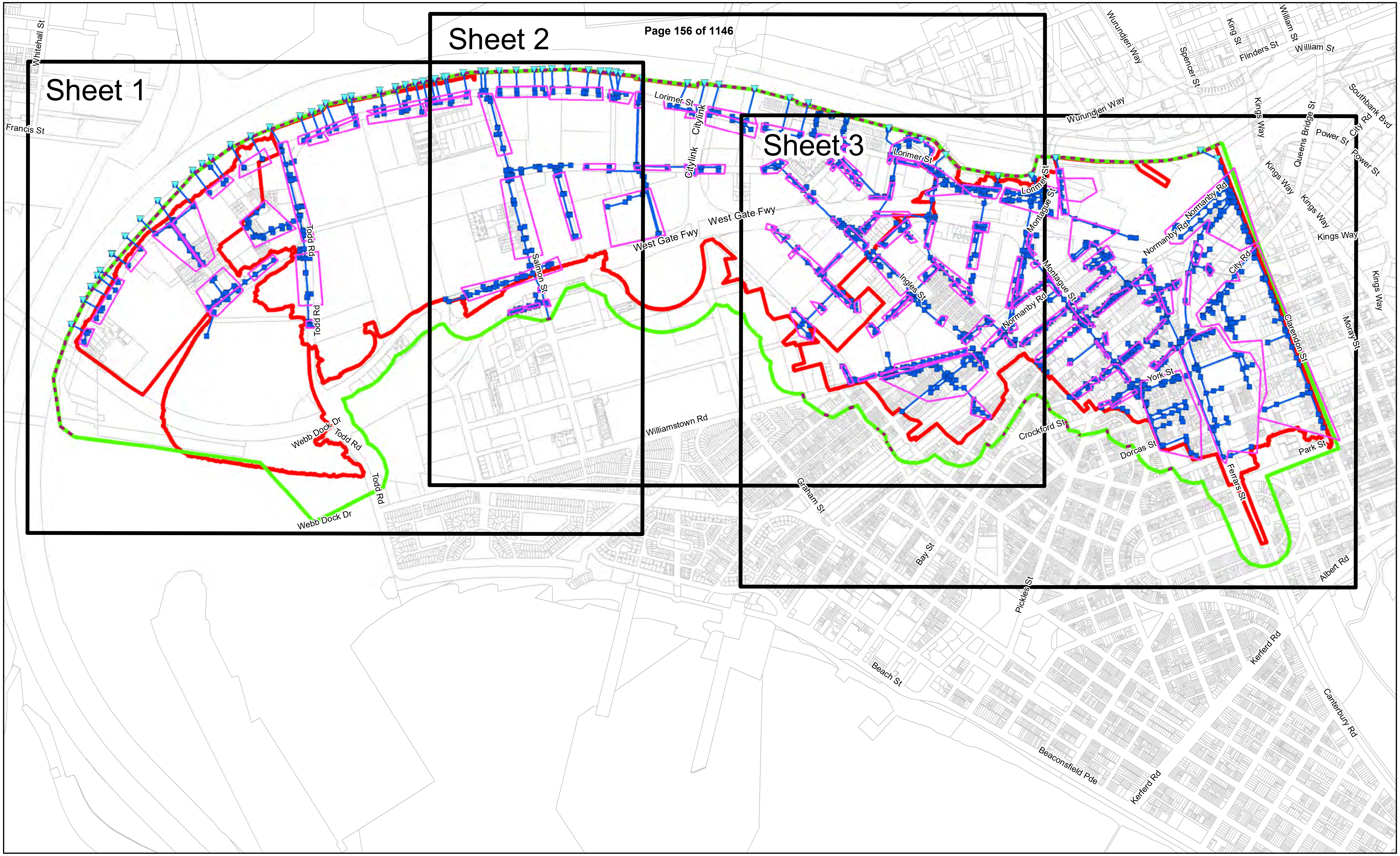
Location: Fishermans Bend (144.925 E, 37.825 S)

	22.24	
12 HR DUR 2 ARI	4.29	mm/hr
72 HR DUR 2 ARI	1.28	mm/hr
1 HR DUR 50 ARI	46.30	mm/hr
12 HR DUR 50 ARI	8.39	mm/hr
72 HR DUR 50 ARI	2.61	mm/hr
G (skewness)	0.36	mm/hr
F2 Geo factor 2 ARI	4.36	
F50 Geo factor 50 ARI	15.99	

Duration		18.5% Higher Design Rainfalls for Average Recurrence Intervals								
(min)	(hr)	1 (mm/hr)	2 (mm/hr)	5 (mm/hr)	10 (mm/hr)	20 (mm/hr)	50 (mm/hr)	100 (mm/hr)	200 (mm/hr)	500 (mm/hr)
5	0.083	55.4	74.1	102.7	122.5	148.7	186.9	218.7	253.8	305.4
6	0.100	51.8	69.3	95.8	114.2	138.5	173.9	203.4	235.8	283.5
7	0.117	48.8	65.2	90.1	107.2	130.0	163.0	190.5	220.8	265.2
8	0.133	46.3	61.8	85.2	101.3	122.7	153.8	179.6	208.0	249.7
9	0.150	44.0	58.8	81.0	96.2	116.5	145.8	170.2	197.0	236.4
10	0.167	42.1	56.1	77.2	91.7	111.0	138.8	162.0	187.4	224.7
11	0.183	40.4	53.8	73.9	87.7	106.1	132.6	154.7	178.9	214.4
12	0.200	38.8	51.7	71.0	84.2	101.7	127.1	148.2	171.3	205.2
13	0.217	37.4	49.8	68.3	81.0	97.8	122.1	142.3	164.5	196.9
14	0.233	36.1	48.1	65.9	78.1	94.3	117.6	137.0	158.3	189.4
15	0.250	35.0	46.5	63.7	75.4	91.0	113.5	132.2	152.6	182.6
16	0.267	33.9	45.1	61.7	73.0	88.0	109.7	127.7	147.5	176.3
17	0.283	32.9	43.8	59.8	70.7	85.3	106.2	123.6	142.7	170.5
18	0.300	32.0	42.5	58.0	68.6	82.7	103.0	119.9	138.3	165.2
19	0.317	31.1	41.4	56.4	66.7	80.4	100.0	116.3	134.2	160.3
20	0.333	30.3	40.3	54.9	64.9	78.2	97.2	113.1	130.4	155.7
25	0.417	27.0	35.8	48.7	57.4	69.0	85.7	99.6	114.7	136.7
30	0.500	24.5	32.4	43.9	51.7	62.1	77.1	89.4	102.8	122.4
35	0.583	22.5	29.7	40.2	47.3	56.7	70.2	81.4	93.6	111.3
40	0.667	20.8	27.6	37.2	43.7	52.3	64.7	74.9	86.1	102.3
45	0.750	19.5	25.7	34.7	40.7	48.7	60.1	69.6	79.9	94.8
50	0.833	18.3	24.2	32.5	38.1	45.6	56.3	65.1	74.6	88.5
55	0.917	17.3	22.9	30.7	35.9	42.9	53.0	61.2	70.2	83.2
60	1.000	16.4	21.7	29.1	34.0	40.6	50.1	57.8	66.3	78.5
75	1.250	14.3	18.8	25.1	29.4	35.1	43.1	49.8	57.0	67.4
90	1.500	12.7	16.7	22.3	26.0	31.0	38.1	44.0	50.3	59.5
120	2.000	10.5	13.8	18.4	21.4	25.5	31.3	36.1	41.2	48.6
180	3.000	8.0	10.6	14.0	16.3	19.3	23.6	27.2	31.0	36.5
240	4.000	6.6	8.7	11.5	13.3	15.8	19.3	22.2	25.3	29.8
300	5.000	5.7	7.5	9.9	11.5	13.6	16.6	19.0	21.6	25.4
360	6.000	5.1	6.6	8.7	10.1	12.0	14.6	16.7	19.0	22.3
420	7.000	4.6	6.0	7.9	9.1	10.8	13.1	15.0	17.1	20.0
480	8.000	4.2	5.5	7.2	8.3	9.8	11.9	13.7	15.5	18.2
540	9.000	3.9	5.1	6.6	7.7	9.1	11.0	12.6	14.3	16.8
600	10.000	3.6	4.7	6.2	7.1	8.4	10.2	11.7	13.3	15.6
660	11.000	3.4	4.4	5.8	6.7	7.9	9.6	11.0	12.4	14.6
720	12.000	3.2	4.2	5.5	6.3	7.4	9.0	10.3	11.7	13.7
780	13.000	3.0	4.0	5.2	6.0	7.1	8.6	9.8	11.1	13.0
840	14.000	2.9	3.8	5.0	5.7	6.8	8.2	9.4	10.7	12.5
900	15.000	2.8	3.6	4.8	5.5	6.5	7.9	9.0	10.2	12.0
960	16.000	2.7	3.5	4.6	5.3	6.2	7.6	8.7	9.8	11.5
1020	17.000	2.6	3.4	4.4	5.1	6.0	7.3	8.3	9.5	11.1
1080	18.000	2.5	3.2	4.2	4.9	5.8	7.0	8.1	9.2	10.7
1140	19.000	2.4	3.1	4.1	4.7	5.6	6.8	7.8	8.9	10.4
1200	20.000	2.3	3.0	4.0	4.6	5.4	6.6	7.6	8.6	10.1
1440	24.000	2.1	2.7	3.5	4.1	4.8	5.9	6.8	7.7	9.0
1800	30.000	1.8	2.3	3.1	3.5	4.2	5.1	5.9	6.7	7.8
2160	36.000	1.6	2.1	2.7	3.1	3.7	4.6	5.2	6.0	7.0
2880	48.000	1.3	1.7	2.2	2.6	3.1	3.8	4.3	4.9	5.8
3600	60.000	1.1	1.4	1.9	2.2	2.6	3.2	3.7	4.2	5.0
4320	72.000	0.9	1.2	1.7	1.9	2.3	2.8	3.2	3.7	4.4

Appendix B – Hydraulic Modelling

Contents



Paper Size A3

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Catchment Boundary
- 2D Domain (Code Boundary)
- Parcels
- Modelled Pipes
- Modelled Pits
- Inflow Hydrograph Locations
- 1D Downstream Boundary Conditions
- 2D Downstream Boundary Conditions

GHD

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
Revision	A
Date	01/10/2019

TUFLOW Model Layout

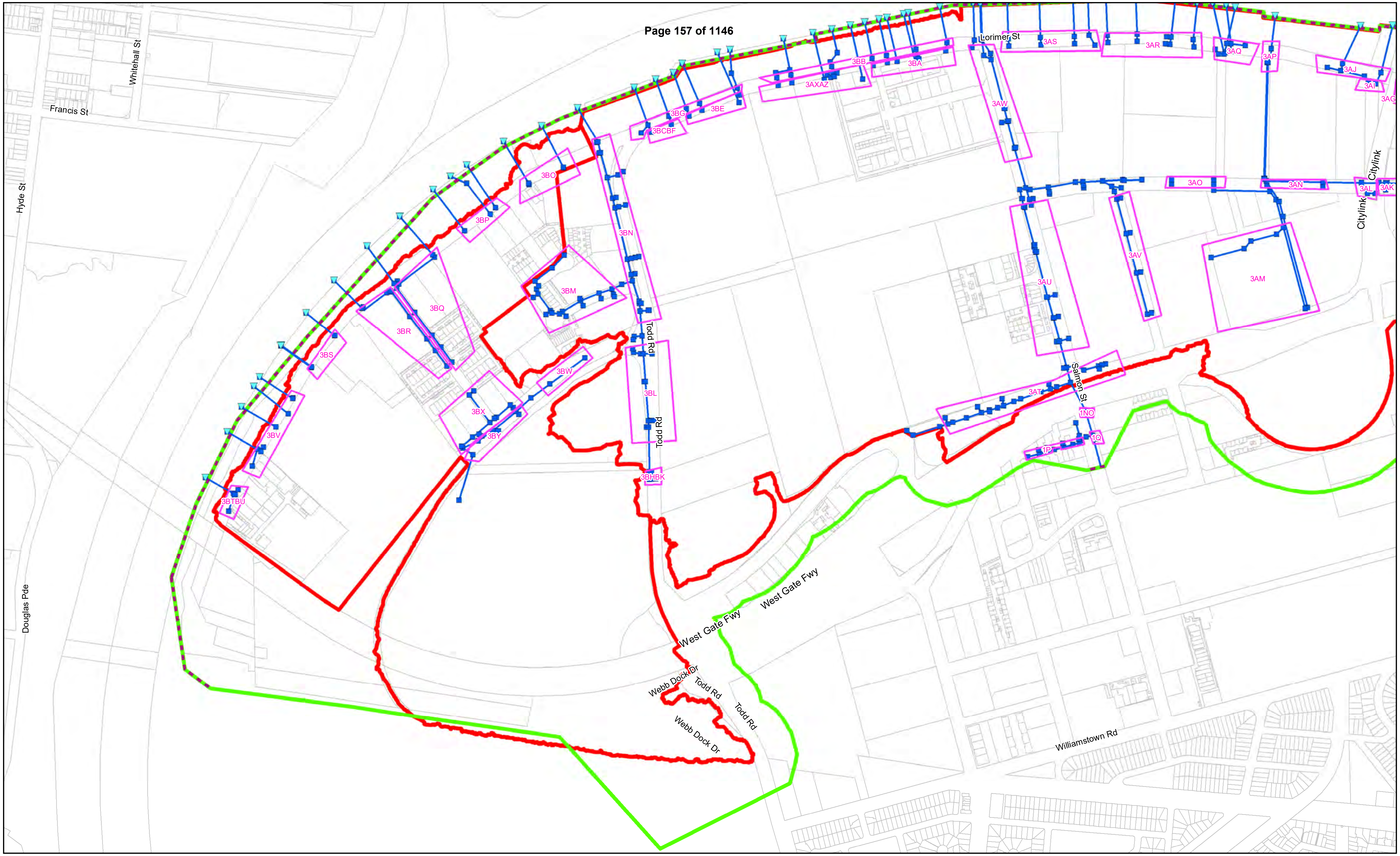
Key Map

Figure B.1

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan



Paper Size A3

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Catchment Boundary
- 2D Domain (Code Boundary)
- Parcels
- Modelled Pipes
- Modelled Pits
- Inflow Hydrograph Locations
- 1D Downstream Boundary Conditions
- 2D Downstream Boundary Conditions

MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
Revision	A
Date	01/10/2019

TUFLOW Model Layout

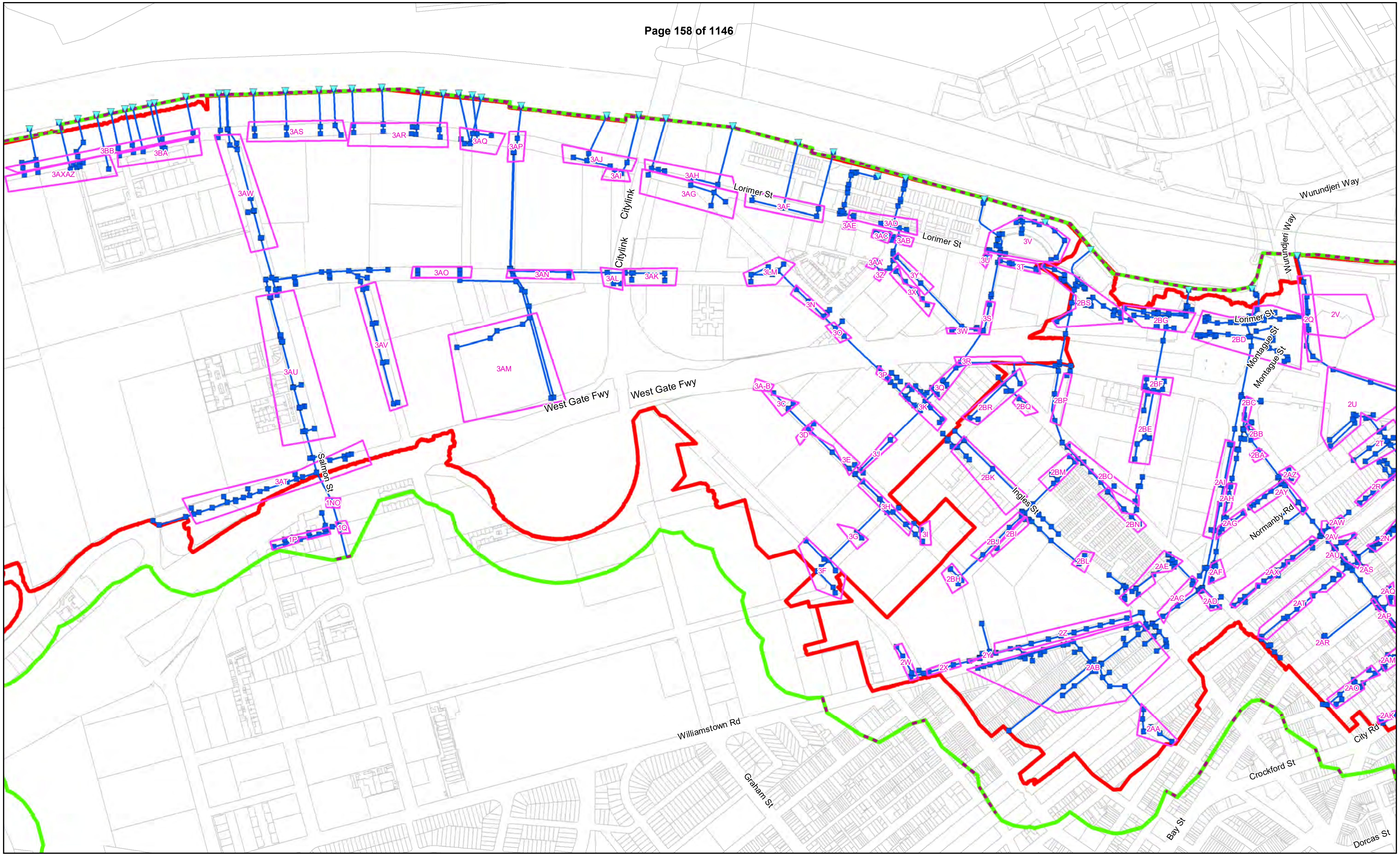
Sheet 1 of 3

Figure B.2

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan



Paper Size A3

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Catchment Boundary
- 2D Domain (Code Boundary)
- Parcels
- Modelled Pipes
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- Inflow Hydrograph Locations
- 1D Downstream Boundary Conditions
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MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
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TUFLOW Model Layout

Sheet 2 of 3

Figure B.3

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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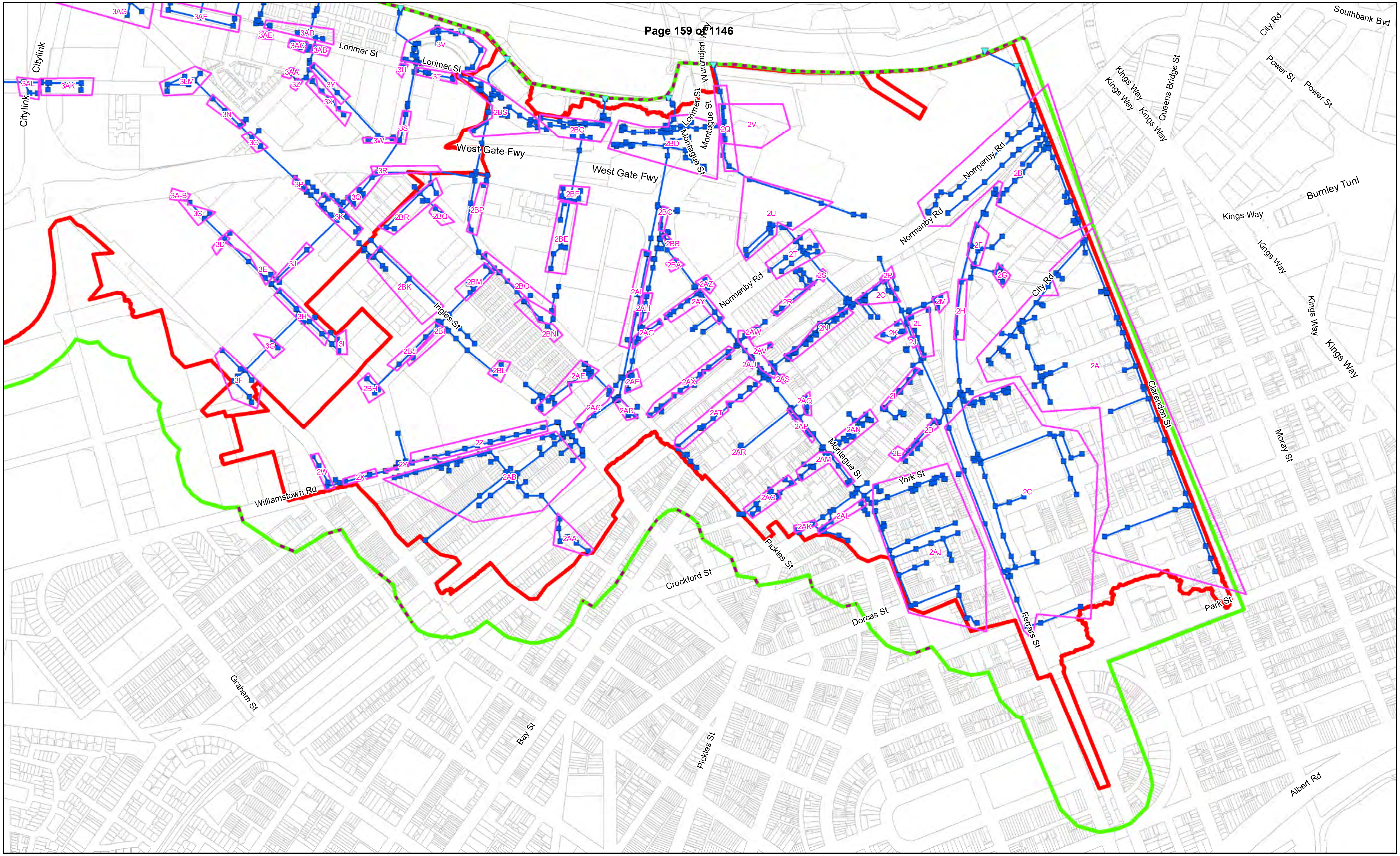

Paper Size A3

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Catchment Boundary
- 2D Domain (Code Boundary)
- Parcels
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- Inflow Hydrograph Locations
- 1D Downstream Boundary Conditions
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MELBOURNE WATER
FISHERMANS BEND WATER SENSITIVE DRAINAGE & FLOOD STRATEGY

Job Number	12511721
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TUFLOW Model Layout

Sheet 3 of 3

Figure B.4

G:\31\36555\GIS\Maps\Working\3136555_Fishermans_Bend_Flood_Mapping_A3L.mxd

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Data source: VicMap, 2017; Melbourne Water, LiDAR, Precinct Boundaries, 2018. Created by: bkryan

Table B-16 MapInfo Deliverables –TUFLOW Model Layers

Layer name	Description
TCF FILE	
2d_po_FB.TAB	Printout lines
2d_po_FB_Cut_Down.TAB	Printout lines
2d_iwl_FB_Lake.TAB	Initial water level polygons for Salt Water Lake and Fresh Water Lake.
ECF FILE	
1d_nwk_FB_ExClarendonFuturePumpNodes.TAB	Clarendon future pump nodes
1d_nwk_FB_ExPipes.TAB	City of Melbourne, City of Port Phillip and Melbourne Water Pipes
1d_nwk_FB_ExPits.TAB	City of Melbourne, City of Port Phillip and Melbourne Water Pits
1d_nwk_FB_FutureClarendonPumpNode.TAB	Clarendon future pump nodes
1d_bc_FB_inflows.TAB	Inflow polygons for hydrographs
1d_bc_FB_TWL.TAB	Downstream boundary conditions on the Yarra River pipe outlets
1d_bc_FB_TWL_ToBeRemoved.TAB	Downstream boundary conditions on the Yarra River pipe outlets
TGC FILE	
2d_loc_FB.TAB	Location line defining origin and angle of 2D domain
2d_code_FB_Cut_Down_r1.TAB	Code boundary
LiDAR 1m DEM.flt	Underlying terrain data
2d_zsh_FB_CecilSt.TAB	Smoothing DTM
2d_zsh_FB_DEM_Corrections.TAB	Underlying terrain raised
2d_zsh_FB_LightRail.TAB	Removing bridge decks from the LiDAR DTM
2d_zsh_FB_MCEC.TAB	Smoothing DTM
2d_zsh_FB_Plummer.TAB	Removing bridge decks from the LiDAR DTM
2d_zsh_FB_Plummer2.TAB	Removing bridge decks from the LiDAR DTM
2d_zsh_FB_ToddRd.TAB	Removing bridge decks from the LiDAR DTM
2d_zsh_FB_YarraSpotLevels.TAB	Survey levels along the Yarra River – draped over the DTM
2d_mat_FB_Existing.TAB	Underlying materials polygons
2d_mat_FB_ExistingNarrowLaneways.TAB	Underlying materials polygon for laneways
TBC FILE	
2d_bc_FB_Cross_Catchment.TAB	Downstream boundary conditions for ‘cross-catchment’ overland flow paths
2d_bc_FB_r1.TAB	Boundary conditions

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12511721-87947/https://projectsportal.ghd.com/sites/pp17_02/fishermansbendfloodm/ProjectDocs/12511721-RPT-Fishermans Bend Flood Mapping.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A						20.12.19
0	B. Ryan	R. Kanakaratne	*R. Kanakaratne*	P. Joyce		06.11.20

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Job no. and Project Name: V3000_111 City of Melbourne Planning Scheme Overlays
Doc Path File: \\online.com\files\ManagementMelbourne\Projects\V3000_Melbourne Water\V3000_111 CoM Planning Scheme Overlays\07 Deliv\Docs\Report\Revs\V3000_111-REP-001-1-OverlayDelineationReport.docx

Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	27/10/2020	Client Issue	Paul Clemson	Glenn Ottrey	Paul Clemson	Glenn Ottrey
1	4/11/2020	Client Issue	Paul Clemson	Glenn Ottrey	Paul Clemson	Glenn Ottrey
Signatures						

Contents

Appendices

List of Tables

List of Figures

1 INTRODUCTION

1.1 REPORT OBJECTIVE

Melbourne Water and City of Melbourne engaged Engeny Water Management (Engeny) to develop flood related planning scheme overlays for flood prone areas of the municipality. The development of the planning scheme overlays follows on from six flood studies undertaken within the municipality.

Planning authorities (such as Melbourne Water and City of Melbourne) can use flood information to articulate local planning objectives and strategies for flooding in their Local Planning Policy Framework (LPPF) and apply the most appropriate flood provision to control land use and development in flood affected areas as defined by the relevant planning scheme overlay.

This report documents the processes undertaken by Engeny to develop the flood related planning scheme overlays.

1.2 RELEVANT STUDIES

The delineation of the planning scheme overlays is based on flood modelling results from the following studies:

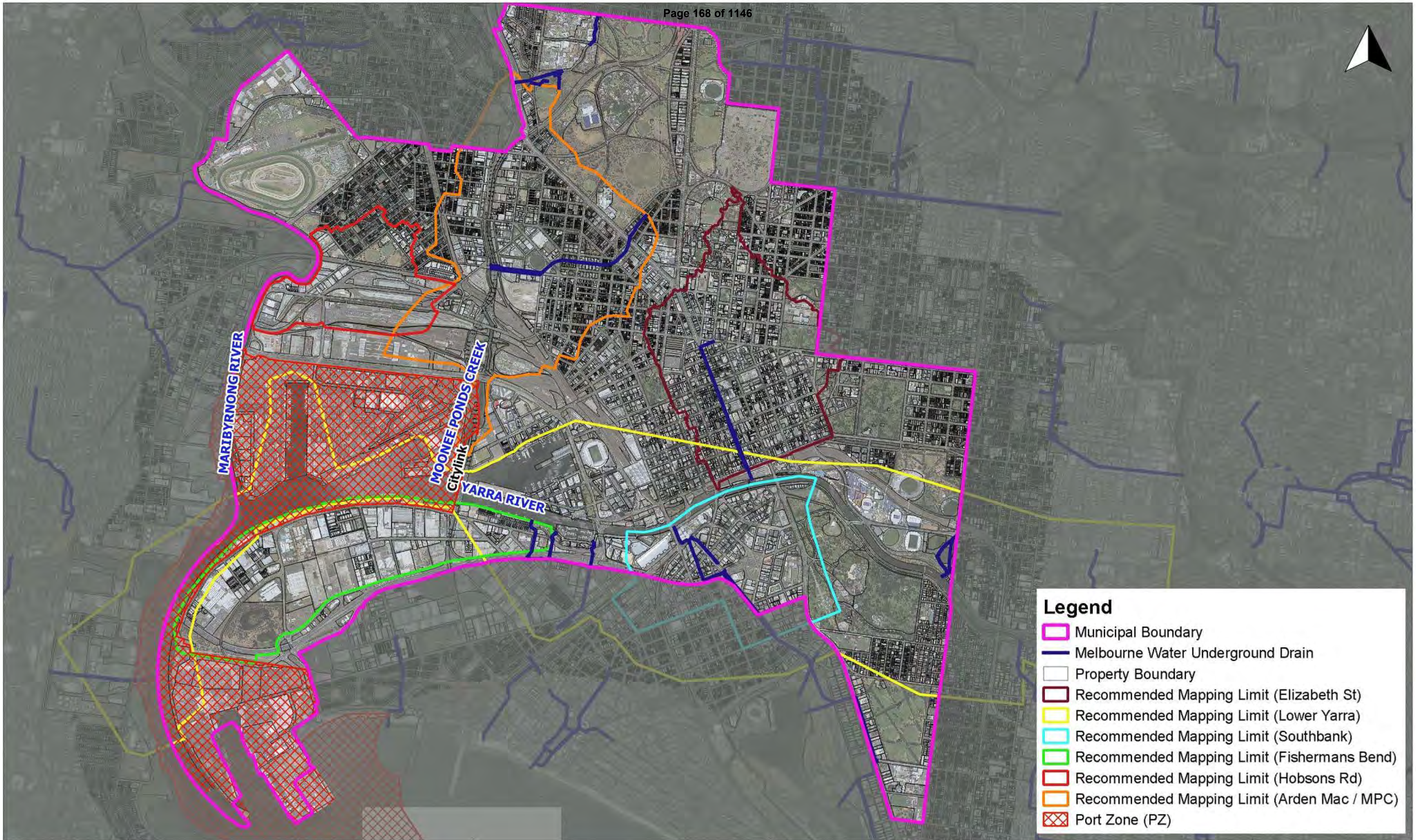
- Arden Macaulay Precinct and Moonee Ponds Creek
- Elizabeth Street Drain
- Fishermans Bend
- Hobsons Road
- Lower Yarra
- Southbank

For each of the flood studies, the delineation of the planning scheme overlays is based on the 1 % annual exceedance probability (AEP) storm event for a year 2100 climate change scenario. The year 2100 climate change scenario includes an 18.5 % increase in rainfall intensity compared to current climate conditions and allowance for sea level rise of 0.8 metres.

Figure 1.1 displays the locations of the relevant flood studies used for the basis of the planning scheme overlays within the City of Melbourne. Some of the flood studies extend beyond the Melbourne municipality boundary, but planning scheme overlays are only proposed within the City of Melbourne. Planning scheme overlays are not proposed within the Port of Melbourne as this area is within a different planning scheme.

This report documents the methodology adopted to develop the planning scheme overlays and does not provide details of the flood modelling studies. The following documentation can be referred to for details of the flood modelling studies:

- Technical Report: Australian Rainfall Runoff Sensitivity Analysis (Engeny Water Management, 22/07/2020)
- Southbank Flood Modelling Update and Climate Change Scenarios (Water Modelling Solutions, 21/04/2020)
- Southbank Stormwater Infrastructure Assessment: Final Report (BMT WBM, August 2015)
- Elizabeth Street Melbourne - Flood Modelling Report (Water Technology, August 2017)
- Addendum to Elizabeth Street, Melbourne Flood Modelling Report (Water Technology, August 2017) (Water Technology, 20/12/2019)
- Elizabeth Street Main Drain Catchment Flood Modelling (Water Technology, 13/02/2020)
- Elizabeth Street Main Drain Catchment Flood Modelling (Water Technology, 9/04/2020)
- Fishermans Bend Flood Mapping (GHD, December 2019)
- Arden Macaulay Precinct & Moonee Ponds Creek Flood Modelling (Engeny Water Management, August 2020)
- Hobsons Road Catchment Flood Mapping Update (Venant Solutions, 17/06/2020)
- Hobsons Road Catchment Flood Mapping – Response to Rain Consulting Model Review (Venant Solutions, 22/04/2020)
- Lower Yarra River Flood Mapping (GHD, 24/09/2020)



Legend

- Municipal Boundary
- Melbourne Water Underground Drain
- Property Boundary
- Recommended Mapping Limit (Elizabeth St)
- Recommended Mapping Limit (Lower Yarra)
- Recommended Mapping Limit (Southbank)
- Recommended Mapping Limit (Fishermans Bend)
- Recommended Mapping Limit (Hobsons Rd)
- Recommended Mapping Limit (Arden Mac / MPC)
- Port Zone (PZ)

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ENGENY WATER MANAGEMENT

Melbourne Water

CITY OF MELBOURNE

300 0 300 600 900 1200 m

Scale in metres (1:35000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Melbourne Planning Scheme Overlays

Figure 1.1
Locality Plan

Job Number: V3000_111
Revision: 0
Drawn: ML
Checked: PC
Date: 27/10/2020

2 APPLICABLE FLOOD PLANNING ZONES AND OVERLAYS

Planning authorities (such as Melbourne Water and City of Melbourne) have a range of tools to choose from to identify flood affected land in the planning scheme. There are four types of flood provisions available, which are:

- Urban Floodway Zone (UFZ);
- Floodway Overlay (FO);
- Land Subject to Inundation Overlay (LSIO); and
- Special Building Overlay (SBO).

The various flood provisions have been derived based on the type of flooding and the potential level of risk to life and property. The level of planning control in each provision is commensurate with the potential flood risk. For example, the UFZ is a restrictive provision that prohibits most uses and development. It is designed to be applied to urban environments where there is a high potential flood risk and only low intensity uses and development (such as recreation) are suitable. In contrast, the LSIO is used for both urban and rural environments to identify land with a lower potential flood risk. The LSIO requires a permit for buildings and works and does not prohibit either use or development.

The UFZ, FO and LSIO all relate to mainstream flooding from a river or stream, while the SBO relates to stormwater flooding along overland flow paths in catchments with underground drainage systems.

Within the City of Melbourne, management of drainage assets is summarised by the following:

- Melbourne Water manages rivers and creeks, and flooding related to these assets.
- Melbourne Water manages the trunk drainage system, which is typically larger underground drainage assets with a contributing catchment area exceeding approximately 60 hectares, and the flooding related to these assets.
- City of Melbourne manages the local drainage system, which is typically smaller underground drainage assets that discharge stormwater into Melbourne Water's drainage system, and the flooding related to these assets.

To ensure that appropriate planning controls are implemented for the different types of flooding within the municipality, and so that flooding is separated into areas of management by Melbourne Water and by City of Melbourne, it is proposed to implement the following planning scheme overlays:

- Land Subject to Inundation Overlay Schedule 3 (LSIO3): this overlay defines flooding relating to rivers and creeks, managed by Melbourne Water.
- Special Building Overlay Schedule 2 (SBO2): this overlay defines overland flow paths associated with Melbourne Water's underground drainage system, managed by Melbourne Water.
- Special Building Overlay Schedule 3 (SBO3): this overlay defines overland flow paths associated with City of Melbourne's underground drainage system, managed by City of Melbourne.

3 DEVELOPMENT OF THE OVERLAYS

3.1 METHODOLOGY OVERVIEW

The delineation of the flood extents to define the planning scheme overlays is based on the methodology defined in Flood Mapping Projects Guidelines and Technical Specifications Version 9 (Melbourne Water, 2018). The same methodology has been adopted for the delineation of the LSIO3, SBO2 and SBO3.

The overlays are based on the predicted flooding as a result of the 1 % AEP storm event for a year 2100 climate change scenario. For a rainfall event of this magnitude, all areas of the municipality will have some degree of runoff on the surface. The intention of the overlays is to define areas of flooding in which it is appropriate to implement the controls associated with the LSIO and SBO.

The delineation of the planning scheme overlays used the raw flooding modelling results from the various flood studies, which consist of large datasets of gridded data with results such as flood depth for each grid cells. A series of processes is applied to the gridded data in order to define the extent of the overlay.

The overlay delineation process is summarised by the following:

- Flood extent filtering criteria were applied to the flood modelling results. The filtering criteria:
  - Include areas where the predicted flood depth is equal to or greater than 0.05 metres
  - Exclude isolated areas of flooding with an area less than 100 square metres
  - Include surrounded dry areas if the area is less than or equal to 100 square metres
- After the application of the filtering criteria, a smoothing process was applied to the edges of the flood extent to convert the gridded shape to a smoothed flood extent.
- The flood extent was removed from properties if the following criteria were satisfied:
  - Less than 2 % of the total area of the property was impacted by the flood extent, AND
  - Less than 25 % of the road frontage of the property was impacted by the flood extent.
- In areas that the flood extent was discontinuous, but joined by wet cells in the raw modelling outputs (which may have been filtered from the flood extent due to low depths of flow), the discontinuous sections of the flood extent were joined.
- Manual adjustments were made to remove the overlays from bridges or elevated roads, where the flood modelling identified that water was flowing underneath the bridge or elevated road, but the bridge deck of surface of the elevated road was not predicted to be inundated by the main flow path.
- The overlays were manually separated between LSIO3, SBO2 and SBO3.

The following sections of this report provide specific examples of the delineation of the overlays.

3.2 FLOOD EXTENT SMOOTHING

The flood modelling results used as the basis of the planning scheme overlays consist of large datasets of gridded data with results such as flood depth for each grid cell. The initial process of applying the filtering criteria identified in Section 3.1 results in a gridded flood extent, which represents the gridded cells that have satisfied the filtering criteria.

A smoothing process is then applied to the edges of the gridded flood extent to create a less blocky flood extent.

Figure 3.1 provides an example of the smoothing process.

Figure 3.1: Example of the flood extent smoothing process

3.3 PROPERTY AREA AND ROAD FRONTAGE CRITERIA

Where the smoothed flood extent only covered a small portion of a property, the planning scheme overlay was removed from the property if the following criteria are satisfied:

- Less than 2 % of the total area of the property was impacted by the flood extent, AND
- Less than 25 % of the road frontage of the property was impacted by the flood extent.

Figure 3.2 provides an example of two properties where areas of the initial flood extent were removed from the final planning scheme overlay as the above conditions were satisfied. The predicted flood risk for these properties is relatively low and implementing the planning scheme overlay for these properties would have provided limited benefits.

Figure 3.3 provides an example where small portions (less than 2 % of the property area) of several properties are predicted to be flooded, but the planning scheme overlay has been retained as more than 25 % of the property's road frontage is impacted by the flood extent. In these instances, if the property was to redevelop with a below ground car park or garage, there would be a potential risk of floodwater flowing into the underground area. Retaining the planning scheme overlay allows for this risk to be managed.

Figure 3.2: Example where flooded areas removed from the planning scheme overlay

Figure 3.3: Example where small flooded areas within properties retained in the planning scheme overlay

3.4 FORMING CONNECTED FLOW PATHS

In areas that the flood extent produced by the initial application of the filtering criteria to the raw modelling outputs was discontinuous, but joined by wet cells in the raw modelling outputs (which may have been filtered from the flood extent due to low depths of flow in steeper sections of the flow path), the discontinuous sections of the flood extent were joined.

No additional properties have been impacted by the planning scheme overlays due to the process of joining the discontinuous sections of the flood extent.

Figure 3.4 provides an example of where discontinuous sections of the flood extent have been connected in the final planning scheme overlay.

Figure 3.4: Example of joining discontinuous sections of the flood extent

3.5 BRIDGES AND ELEVATED ROADS

In some areas, particularly along creeks and rivers, manual adjustments were made to remove the overlays from bridges or elevated roads, where the flood modelling identified that water was flowing underneath the bridge or elevated road, but the bridge deck of surface of the elevated road was not predicted to be inundated by the main flow path.

Flood modelling, such as the flood studies used as the basis for the delineation of the planning scheme overlays, typically use Light Detection and Ranging (LiDAR) data as the main source of topographical data to define surface levels in the model. Typically, structures such as bridges and elevated roads have been removed from the LiDAR data by interpolating surface levels on either side of the structure. This allows the LiDAR to approximate the surface levels beneath the bridge or raised road.

In order to identify whether bridges or road structures are predicted to be overtopped, first return LiDAR was used to define the surface level of the bridge or elevated road. The first return LiDAR is the raw LiDAR prior to interpolation being applied to remove features such as bridges, elevated roads and vegetation. The surface level of the bridge or elevated road was compared to the water surface level predicted by the flood modelling and if the water surface level was below the surface level of the bridge or elevated road, the bridge or elevated road was removed from the planning scheme overlay.

Figure 3.5 provides an example of where a bridge was removed from the planning scheme overlay, while Figure 3.6 provides an example of where an elevated train line was removed from the planning scheme overlay. Figure 3.7 provides an example of where a bridge was retained in the planning scheme overlay as the deck of the bridge is predicted to be overtopped.

Figure 3.5: Example of bridge removed from the planning scheme overlay

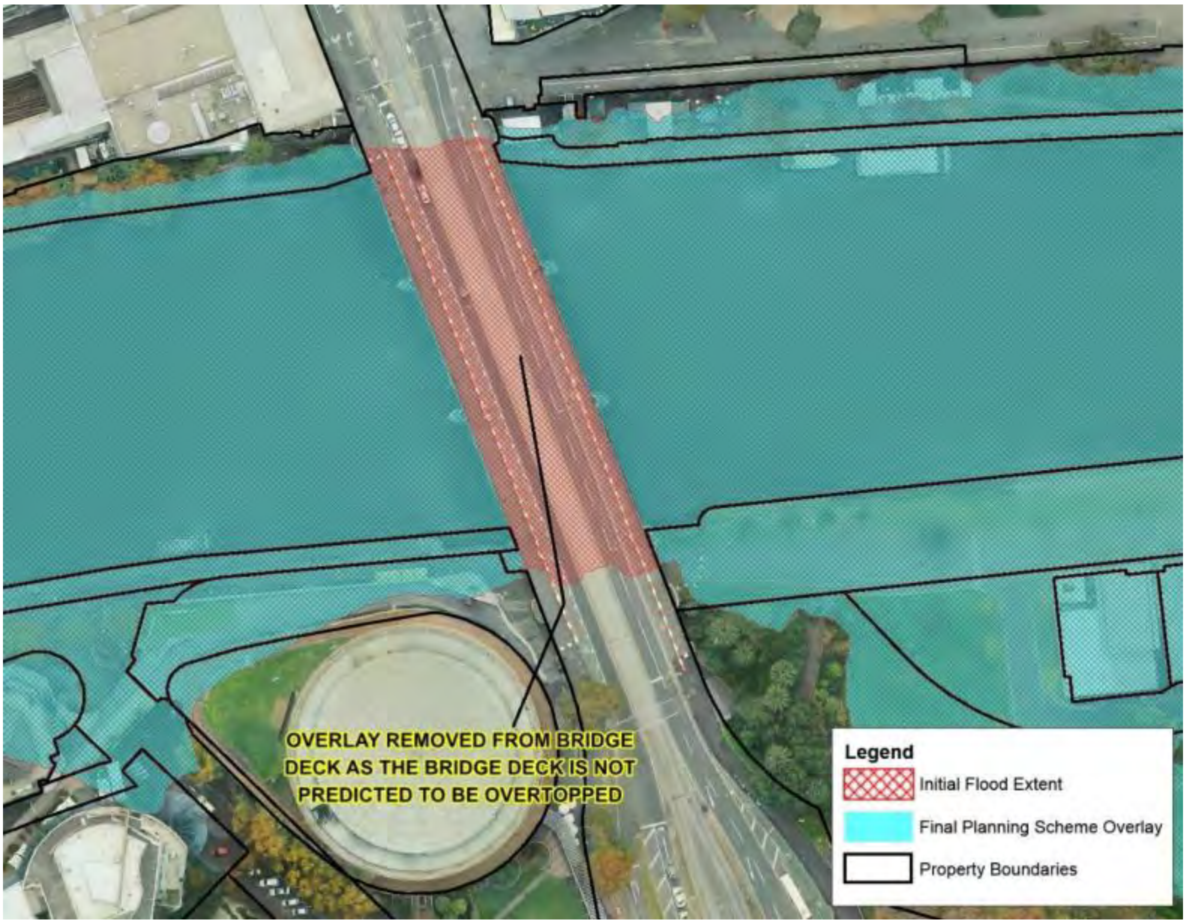


Figure 3.6: Example of elevated train line removed from the planning scheme overlay

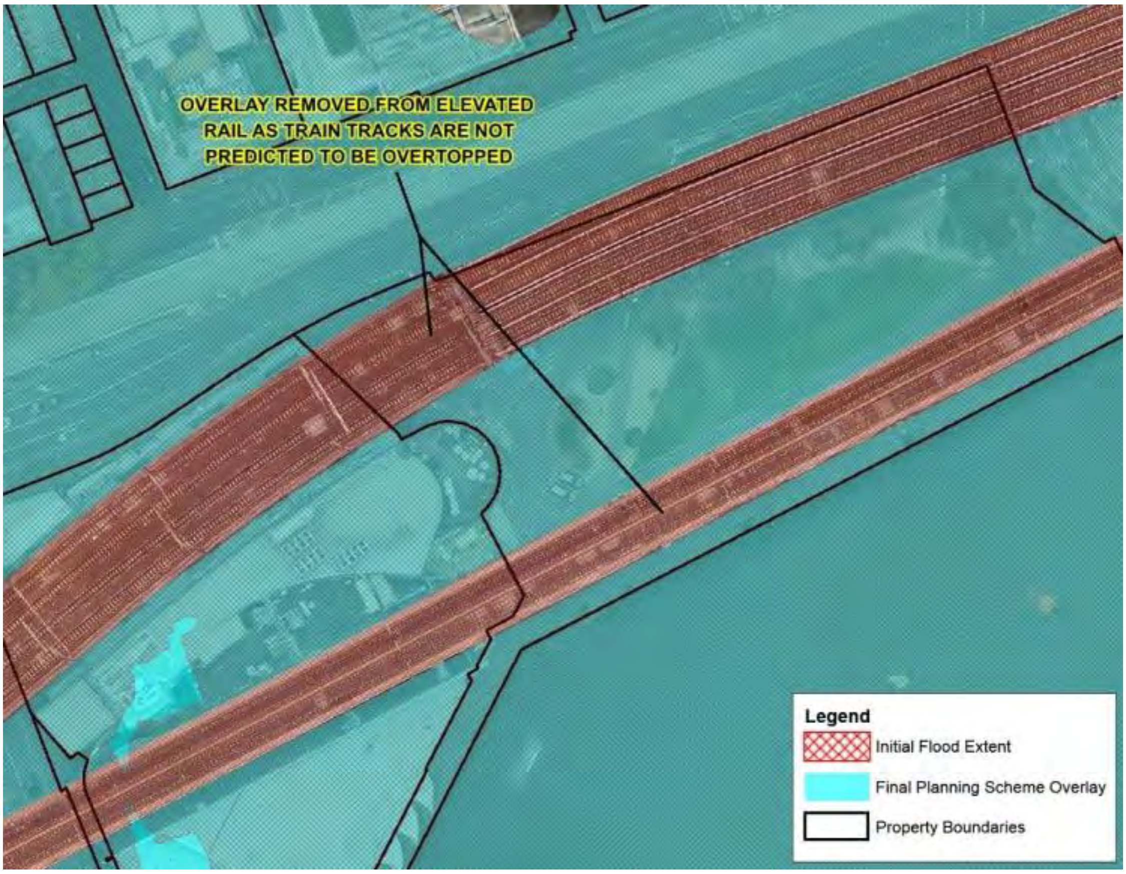


Figure 3.7: Example of bridge retained in the overlay, as well as elevated road removed from the overlay

3.6 SEPARATING MELBOURNE WATER AND CITY OF MELBOURNE OVERLAYS

The flood extents were separated into the various planning scheme overlays so that:

- The LSIO3 defines flooding associated with Melbourne Water's creeks and rivers
- The SBO2 defines overland flow paths associated with Melbourne Water's underground drainage system
- The SBO3 defines overland flow paths associated with City of Melbourne's underground drainage system

Typically, the approach taken avoids having more than one planning scheme overlay overlapping a property, where appropriate. In some instances, such as large properties or properties in which there is a large difference (~0.5 metres) in the flood level associated with Melbourne Water's and City of Melbourne's drainage system, more than one planning scheme overlay has intentionally been applied to a property.

3.7 MAP

Appendix A provides a series of plans displaying the final extents of the LSIO3, SBO2 and SBO3.

3.8 PROPERTIES IMPACTED

Table 3.1 provides a summary of the number of properties that are impacted by the planning scheme overlays. The assessment of the number of properties impacted by the overlays is based on the property boundaries as defined by the Department of Environment, Land, Water and Planning's VMPROP_PARCEL_VIEW layer, in ESRI Shape format, downloaded from the Spatial Datamart Victoria website on 5 October 2010. It should be noted that this layer includes some property boundaries that relate to road reserves.

As shown in the table, there is a total of 3448 property boundaries that are impacted by the planning scheme overlays. Of these properties, 47 properties are impacted by more than one planning scheme overlay and 42 properties would be referred to both City of Melbourne and Melbourne Water as they are impacted by both a City of Melbourne overlay (SBO3) and at least one of Melbourne Water's overlay (LSIO3 and / or SBO2).

Table 3.1: Number of properties impacted by each planning scheme overlay

Planning Scheme Overlay	Number of Properties
Properties impacted by LSIO3 (referral to Melbourne Water)	1731
Properties impacted by SBO2 (referral to Melbourne Water)	295
Properties impacted by SBO3 (referral to City of Melbourne)	1470
Total properties impacted	3448
Properties with more than one overlay	47
Properties that would be referred to Melbourne Water and City of Melbourne (i.e. impacted by SBO3 and either LSIO3 or SBO2)	42

4 SUMMARY

This report documents the processes undertaken by Engeny to develop flood related planning scheme overlays with the City of Melbourne. The delineation of the planning scheme overlays is based on flood modelling results from the following studies:

- Arden Macaulay Precinct and Moonee Ponds Creek
- Elizabeth Street Drain
- Fishermans Bend
- Hobsons Road
- Lower Yarra
- Southbank

For each of the flood studies, the delineation of the planning scheme overlays is based on the 1 % AEP storm event for a year 2100 climate change scenario. The year 2100 climate change scenario includes an 18.5 % increase in rainfall intensity compared to current climate conditions and allowance for sea level rise of 0.8 metres.

It is proposed to implement the following planning scheme overlays:

- Land Subject to Inundation Overlay Schedule 3 (LSIO3): this overlay defines flooding relating to rivers and creeks, managed by Melbourne Water.
- Special Building Overlay Schedule 2 (SBO2): this overlay defines overland flow paths associated with Melbourne Water's underground drainage system, managed by Melbourne Water.
- Special Building Overlay Schedule 3 (SBO3): this overlay defines overland flow paths associated with City of Melbourne's underground drainage system, managed by City of Melbourne.

The delineation of the flood extents to define the planning scheme overlays is based on the methodology in Flood Mapping Projects Guidelines and Technical Specifications Version 9 (Melbourne Water, 2018). The same methodology has been adopted for the delineation of the LSIO3, SBO2 and SBO3.

There is a total 3448 properties that are impacted by the planning scheme overlays. Of these properties, 47 properties are impacted by more than one flood related planning scheme overlay and 42 properties would be referred to both City of Melbourne and Melbourne Water as they are impacted by both a City of Melbourne overlay (SBO3) and at least one of Melbourne Water's overlays (LSIO3 and / or SBO2).

5 QUALIFICATIONS

a) In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

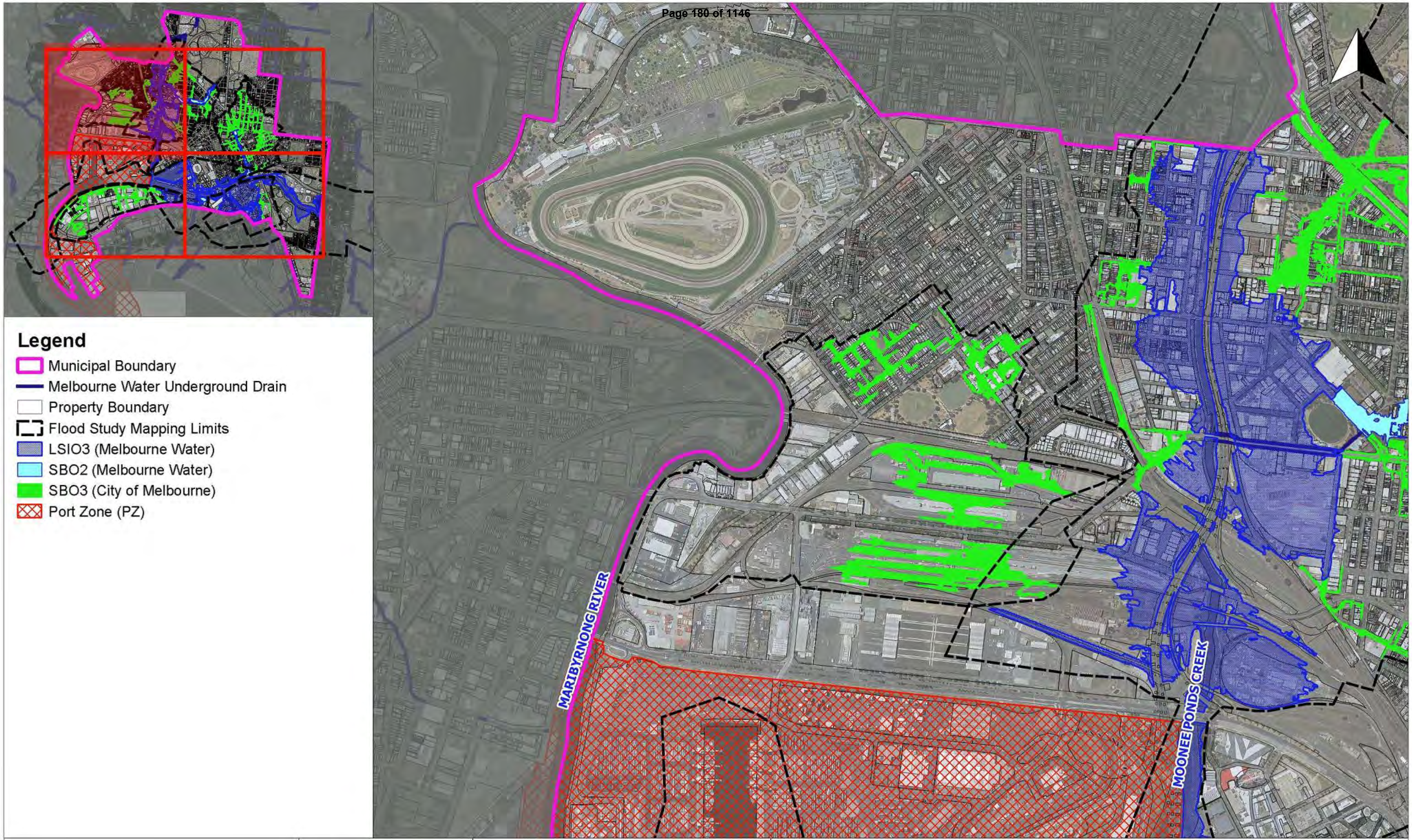
d) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g) This Report does not provide legal advice.

Appendix A:
Planning Scheme Overlay Map



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ENGENY WATER MANAGEMENT

Melbourne Water

CITY OF MELBOURNE

100 0 100 200 300 400 m

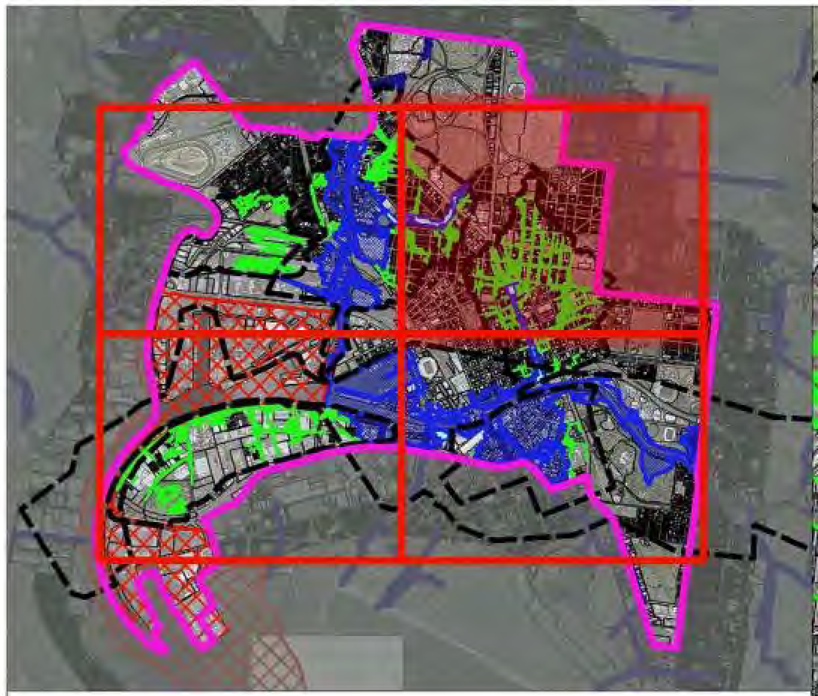
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Melbourne Planning Scheme Overlays

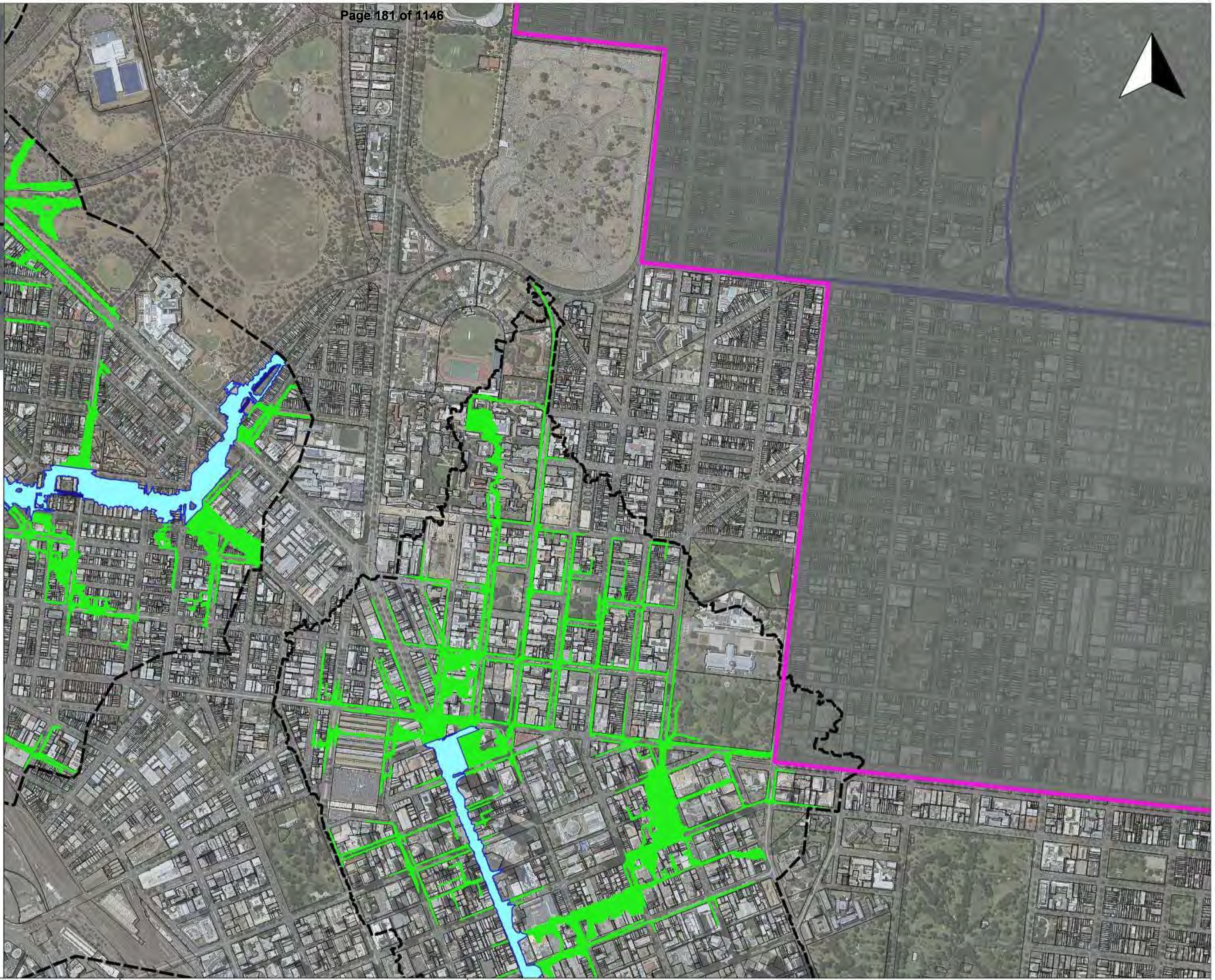
Appendix A
Planning Scheme Overlays
Map Location 1 of 4

Job Number: V3000_111
Revision: 0
Drawn: ML
Checked: PC
Date: 27/10/2020



Legend

- Municipal Boundary
- Melbourne Water Underground Drain
- Property Boundary
- Flood Study Mapping Limits
- LSIO3 (Melbourne Water)
- SBO2 (Melbourne Water)
- SBO3 (City of Melbourne)
- Port Zone (PZ)



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ENGENY WATER MANAGEMENT

Melbourne Water

CITY OF MELBOURNE

100 0 100 200 300 400 m

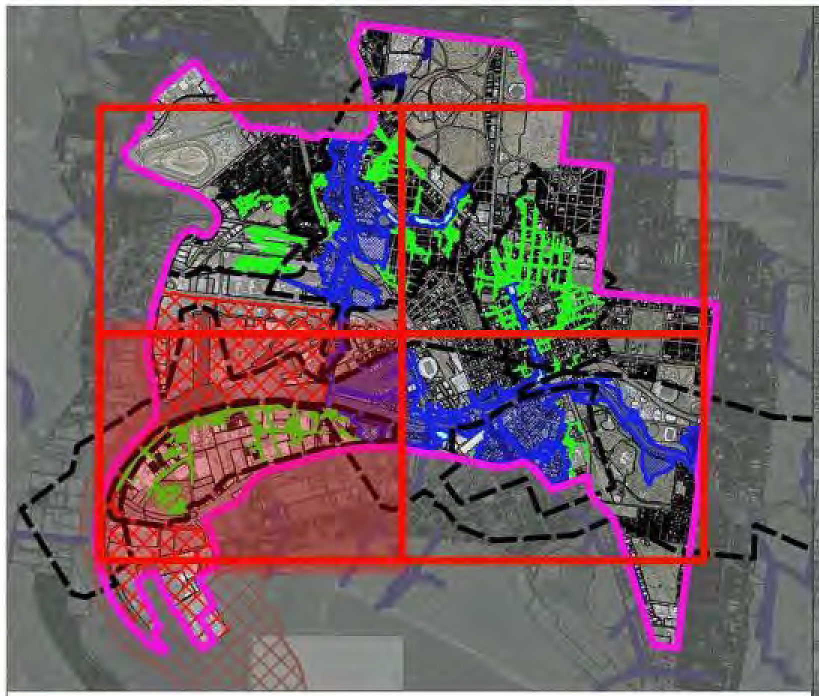
Scale in metres (1:14000 @ A3)

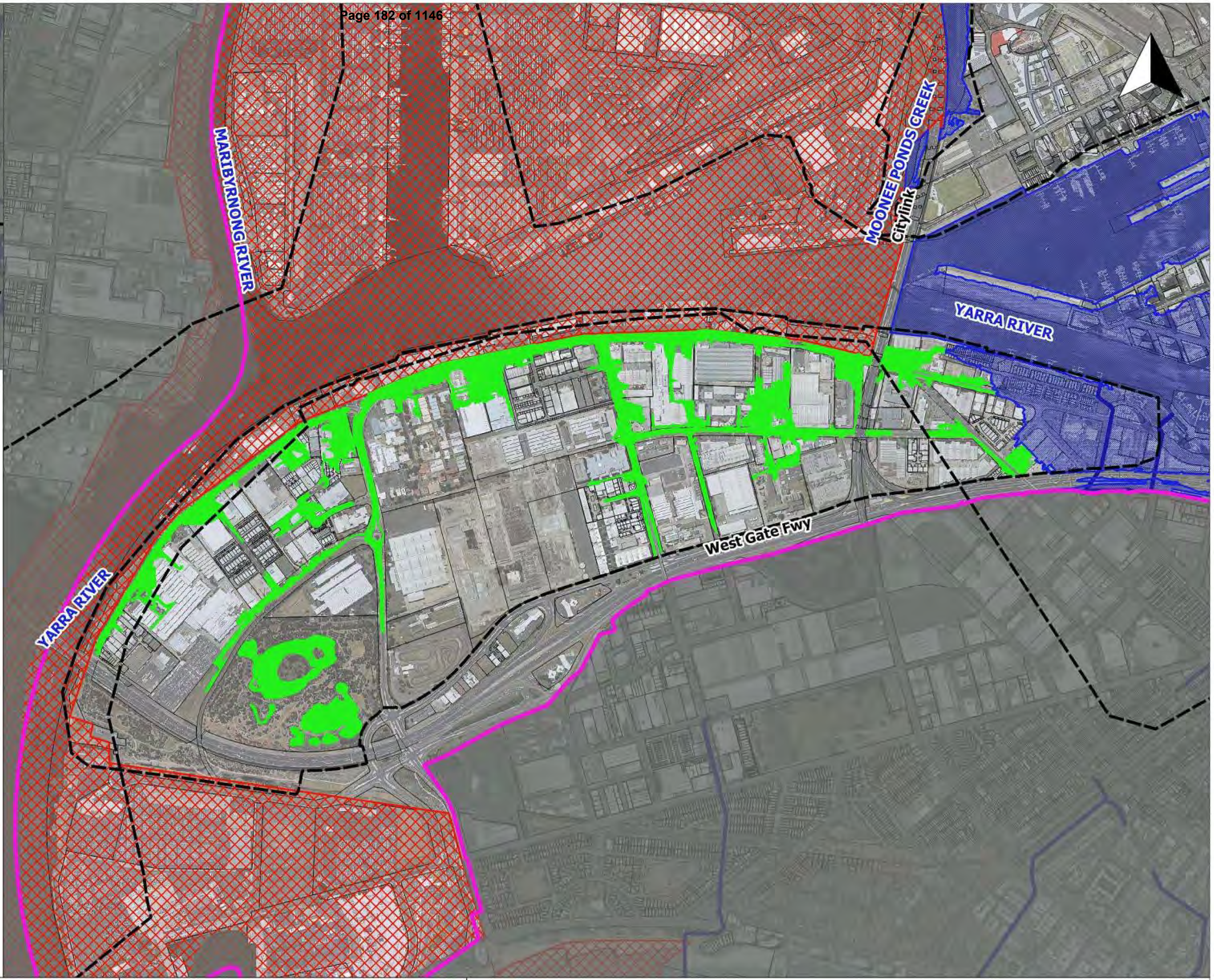
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Melbourne Planning Scheme Overlays

Appendix A
Planning Scheme Overlays
Map Location 2 of 4

Job Number: V3000_111
Revision: 0
Drawn: ML
Checked: PC
Date: 27/10/2020





Legend

- Municipal Boundary
- Melbourne Water Underground Drain
- Property Boundary
- Flood Study Mapping Limits
- LSIO3 (Melbourne Water)
- SBO2 (Melbourne Water)
- SBO3 (City of Melbourne)
- Port Zone (PZ)

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Melbourne VIC 3000
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VIC 8006
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E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

Melbourne Water

CITY OF MELBOURNE

100 0 100 200 300 400 m

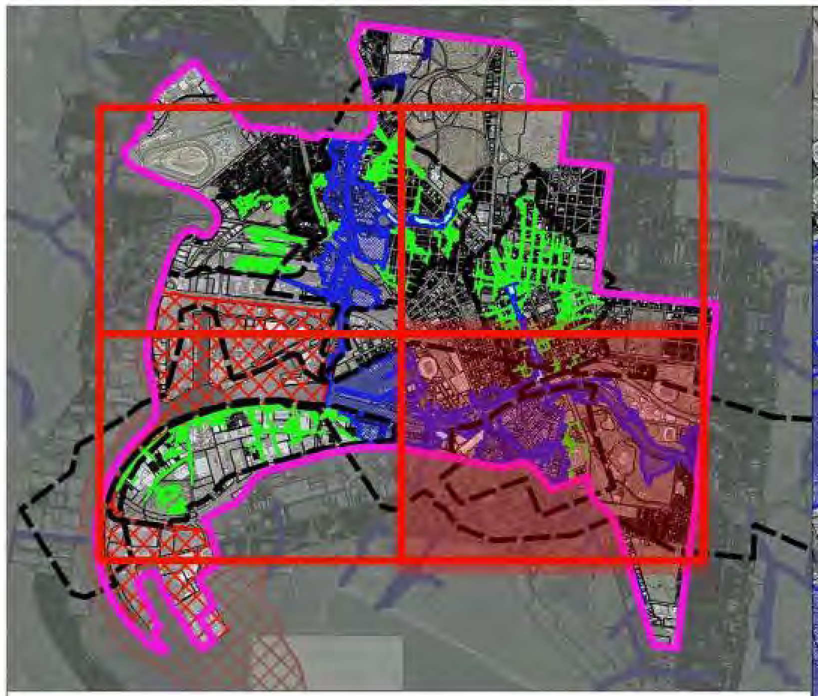
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Melbourne Planning Scheme Overlays

Appendix A
Planning Scheme Overlays
Map Location 3 of 4

Job Number: V3000_111
Revision: 0
Drawn: ML
Checked: PC
Date: 27/10/2020



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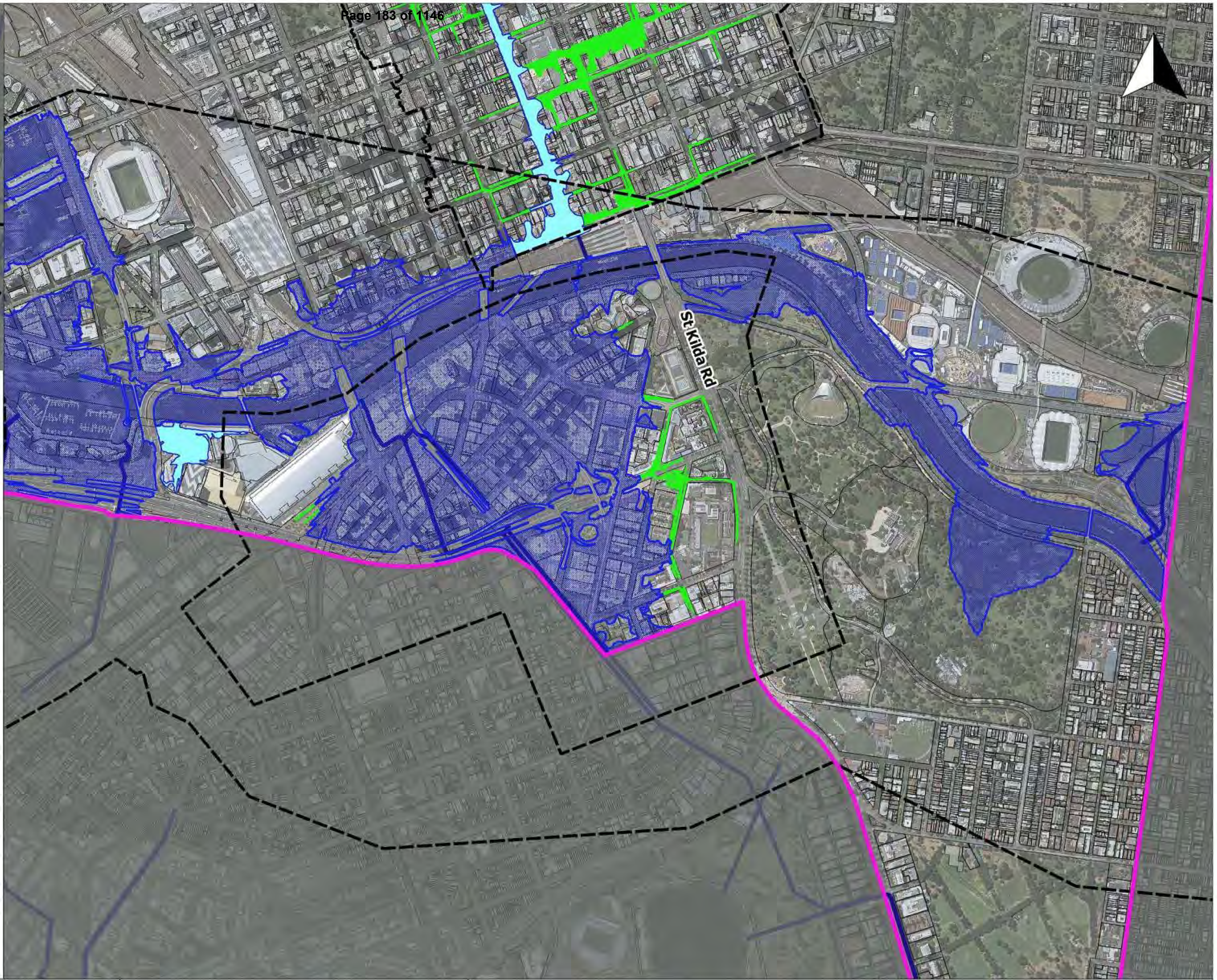

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City of Melbourne Planning Scheme Overlays

Appendix A
Planning Scheme Overlays
Map Location 4 of 4

Job Number: V3000_111
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Planning for Sea Level Rise

Guidelines

February 2017

Port Phillip and Westernport Region

VICTORIA State Government

Melbourne Water

Contents

1 Introduction

Due to increases in ocean warming and loss of mass from glaciers and ice sheets, global mean sea levels will continue to rise during the 21st century (IPCC Fifth Assessment Report 2013). This will increase the risk of coastal hazards, necessitating appropriate planning and building controls for areas at risk of current or future tidal inundation.

Purpose of these guidelines

These *Planning for Sea Level Rise* guidelines set out the specific requirements that apply to development proposals in areas that will be affected by tidal inundation (including storm surge and wave action) as a result of predicted sea level rise. The aim of these guidelines is to ensure that proposed development is compatible with any flood risk.

These guidelines were developed to:

- help property owners, developers, designers and builders to understand the specific requirements that apply in areas at risk of tidal inundation
- detail the relevant considerations to be taken into account by Melbourne Water when assessing development proposals
- provide for consistency and transparency in decision-making.

Consistent with state planning policy to 'plan for possible sea level rise of 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes …', these guidelines apply to areas that will be affected by tidal inundation within the Port Phillip and Westernport region.

The guidelines detail how the planning benchmarks for sea level rise established for Victoria should be applied to different development types. They establish the predicted future flood levels for Port Phillip Bay and Western Port – the flood levels that Melbourne Water applies for planning purposes. In addition, they specify appropriate freeboard and minimum floor level requirements to ensure flood protection for different development types.

This 2017 revision of the guidelines updates the adopted flood levels for Western Port to reflect the findings of the *Western Port Local Coastal Hazard Assessment* (DEPI et. al. 2015) and Melbourne Water's more recent flood modelling, as well as providing additional detail on general development assessment criteria. These guidelines are intended to form part of a broader response to planning for sea level rise. They will be reviewed and updated as more detailed risk and hazard assessment information becomes available, and in response to any relevant climate change adaptation planning advances.

This document should be used in conjunction with the principles and core requirements contained in Melbourne Water's *Guidelines for Development in Flood-prone Areas* (2007) and any relevant statewide guidelines.

[1] The WPLCHA was commissioned by the Victorian Government's then *Future Coasts* program and delivered by DEPI in partnership with Melbourne Water, South East Councils Climate Change Alliance, Bass Coast Shire Council, Cardinia Shire Council, the City of Casey and the Mornington Peninsula Shire Council.

Get in touch with Melbourne Water — early in the development process

Reviews of tidal data and updates to local coastal hazard assessments may lead to revised flood levels from time to time. Therefore, we recommend that permit applicants obtain up-to-date flood levels relevant to the property prior to commencing detailed planning and design.

We also advise applicants to engage with us early in the design process so that you can get a timely appreciation of any applicable site-specific requirements.

Development Enquiries

Melbourne Water
PO Box 4342,
Melbourne, VIC, 3001

Telephone 131 722
Email land.development@melbournewater.com.au

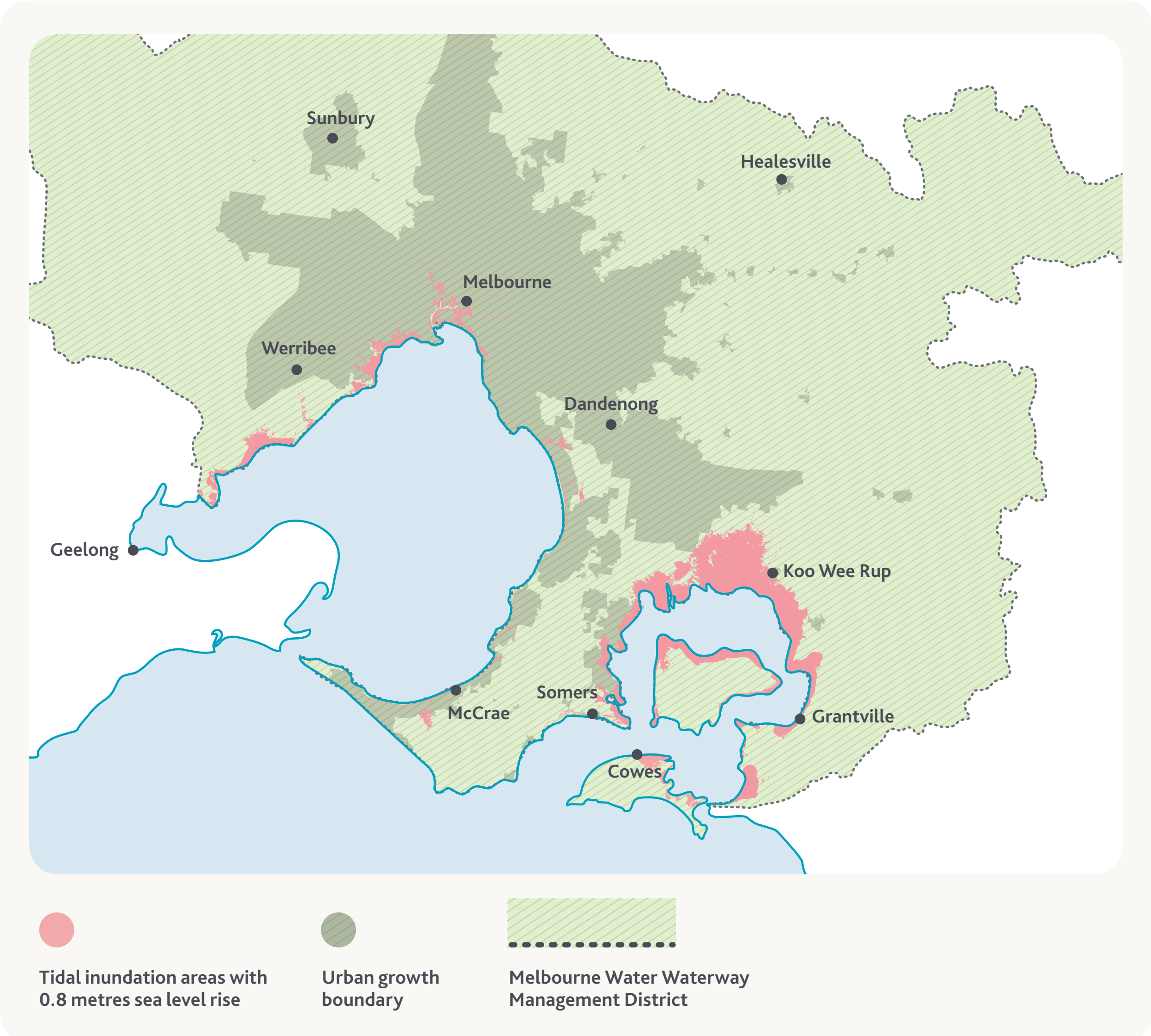
Flood Level Data

To order flood level information, contact one of the following providers:

SAI Global
saiglobal.com
Telephone 1300 730 000

Landata
land.vic.gov.au
Telephone (03) 8636 2456

2100 tidal inundation areas in the Port Phillip and Westernport region



Melbourne Water's role in planning for sea level rise

Melbourne Water has floodplain management functions which are established under the *Water Act 1989*, with related functions under the *Planning and Environment Act 1987* and the *Building Regulations 2006*.

As the floodplain management authority, Melbourne Water is a determining referral authority under Section 55 of the *Planning and Environment Act 1987* and Clause 66.03 of the *Victoria Planning Provisions* (VPP) for planning permit applications to develop or subdivide land affected by a flood overlay control in a municipal planning scheme. In this capacity, we assess proposals and ensure developments are compatible with any flood risk through the application of appropriate development requirements.

In the absence of a flood overlay control, Clause 65 of the VPPs states that 'Before deciding on an application or approval of a plan, the responsible authority must consider, as appropriate … The degree of flood, erosion or fire hazard associated with the location of the land and the use, development or management of the land so as to minimise any such hazard'. These guidelines support responsible authorities in considering flood hazard from predicted sea level rise in accordance with the requirements of Clause 65.

Where flooding information has not been included in the planning schemes and where arrangements have been entered into with councils, we can also provide advice on development proposals under the provisions of Section 52 of the *Planning and Environment Act 1987.*

In certain circumstances, and where we have determined that land is liable to flooding by including advice about predicted sea level rise on a Property Information Statement issued under Section 158 of the *Water Act 1989*, Melbourne Water also has a role in recommending minimum floor levels for building permits issued under regulation 802 of the *Building Regulations 2006*.

The *Victorian Floodplain Management Strategy* (DELWP 2016) clarifies that Melbourne Water is accountable for maintaining guidelines that detail the way in which the state planning policies regarding sea level rise should be applied in the context of the Port Phillip and Westernport region. (These state planning policies are detailed later.)

Our floodplain management role in planning for sea level rise currently does not extend to the consideration of coastal processes contributing to coastal physical vulnerability such as erosion and saline incursion. While councils may also request a coastal vulnerability risk assessment, it is not our role to provide comments and approval on these assessments.

2 Guiding our decisions: sea level rise policy and planning benchmarks

The sea level rise policy and planning benchmarks established for Victoria are set out in state policies and strategies. These provide the strategic basis for Melbourne Water's approach to development assessment.

What guides our development assessment

The *Victorian Coastal Strategy 2014*

The *Victorian Coastal Strategy* (VCS) (Victorian Coastal Council 2014), made under the *Coastal Management Act 1995,* establishes the sea level rise planning benchmarks and policy for decision-making for Victoria, as summarised here:

- *Plan for possible sea level rise of not less than 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology, when assessing risks and coastal impacts associated with climate change.*
- *In planning for possible sea level rise, an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 may be used for new development in close proximity to existing development (urban infill).*
- *For new greenfield development outside of town boundaries, plan for not less than 0.8 metre sea level rise by 2100.*

The VCS states, 'It is important to note that these benchmarks are for a horizon up to 2100. Sea level rise is likely to continue beyond this horizon'.

The State Planning Policy Framework

When assessing development applications, Melbourne Water must consider the relevant objectives and strategies of the State Planning Policy Framework (SPPF). The SPPF has also assisted in providing the strategic justification for applying the planning benchmarks to different development types, as detailed later in these guidelines.

The sea level rise planning benchmarks for Victoria established in the VCS (above) are given effect as planning strategies in Clause 13.01-1 *Coastal Inundation and Erosion* of the SPPF.

These, and other key strategies of the SPPF relevant to development assessment in planning for sea level rise, are:

Clause 13.01-1 *Coastal Inundation and Erosion*

- *In planning for possible sea level rise, an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 may be used for new development in close proximity to existing development (urban infill).*
- *Plan for possible sea level rise of 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change.*
- *Consider the risks associated with climate change in planning and management decision-making processes.*
- *For new greenfield development outside of town boundaries, plan for not less than 0.8 metre sea level rise by 2100.*
- *Ensure that land subject to coastal hazards are identified and appropriately managed to ensure that future development is not at risk.*
- *Ensure that development or protective works seeking to respond to coastal hazard risks avoids detrimental impacts on coastal processes.*
- *Avoid development in identified coastal hazard areas susceptible to inundation (both river and coastal), erosion, landslip/landslide, acid sulfate soils, bushfire and geotechnical risk.*

Clause 13.02-1 *Floodplain Management*

- *Identify land affected by flooding, including floodway areas, as verified by the relevant floodplain management authority, in planning scheme maps. Land affected by flooding is land inundated by the 1 in 100 year flood event or as determined by the floodplain management authority.*
- *Avoid intensifying the impacts of flooding through inappropriately located uses and developments.*
- *Locate emergency and community facilities (including hospitals, ambulance stations, police stations, fire stations, residential aged care facilities, communication facilities, transport facilities, community shelters and schools) outside the 1 in 100 year floodplain and, where possible, at levels above the height of the probable maximum flood.*
- *Locate developments and uses which involve the storage or disposal of environmentally hazardous industrial and agricultural chemicals or wastes and other dangerous goods (including intensive animal industries and sewage treatment plants) must not be located on floodplains unless site design and management is such that potential contact between such substances and floodwaters is prevented, without affecting the flood carrying and flood storage functions of the floodplain.*

Planning Practice Note 53

Planning Practice Note 53: Managing coastal hazards and the coastal impacts of climate change (DELWP 2015) provides guidance on planning for coastal development in coastal areas. It summarises sea level rise policy and planning benchmarks as set out in the VCS and given effect in the SPPF to guide statutory planning decision-making. It also details the process for referring a planning permit application or development proposal to a floodplain manager.

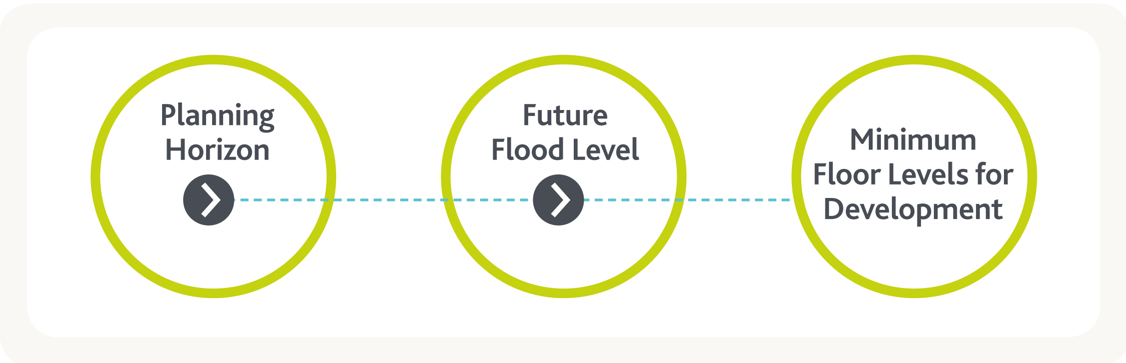
3 Applying the planning benchmarks to development assessment

This section details how the planning benchmarks for sea level rise established for Victoria should be applied to different development types in the Port Phillip and Westernport region.

How we apply the planning benchmarks to different development types

Before assessing an application, we identify the appropriate planning horizon; that is, how far into the future we are planning, and the corresponding future flood level based on current sea level rise projections.

We recommend floor levels be raised above the relevant predicted future flood level.



How we determine the planning horizon

The 1% Annual Exceedance Probability (AEP) flood (that is, a flood with a 1% chance of occurring in any given year) is the current design flood event for the land use planning and building systems in Victoria.

In planning for sea level rise, Melbourne Water adopts either the predicted 2040 1% AEP flood level or the predicted 2100 1% AEP flood level, depending on the planning horizon considered to be suitable for the development.

Consistent with the planning benchmarks, 0.2 metres sea level rise is assumed for developments planned to 2040, whereas 0.8 metres sea level rise is assumed for developments requiring a long-term planning approach, to 2100.

Important flood risk factors

We consider the following important flood risk factors when establishing whether we apply the predicted 2040 1% AEP flood level or the predicted 2100 1% AEP flood level to development assessment:

- the potential for the development to significantly increase flood risk by increasing the potential for property damage or the number of occupants at risk of flooding
- the likely asset life of the development or the ease with which a development could be rebuilt to higher flood protection standards in future
- whether the development is isolated or in a remote rural area
- the proximity and intensity of surrounding development already built to a lower flood protection standard
- the opportunity to apply a long-term planning approach for entire new development areas or redevelopment areas (e.g. greenfield or urban renewal areas)
- the likelihood and practicality of mitigation or adaptation activities being undertaken at some stage in future to protect the area in question
- the sensitivity of a particular use and development to inundation (e.g. hospital or childcare centre).

Predicted future flood levels by development type

The State Planning Policy Framework (SPPF) identifies the need to plan to 2100 and enables planning to 2040 for urban infill. Here, we provide further detail on how to apply the relevant clauses of the SPPF to different development types in the Port Phillip and Westernport region.

Urban infill development

- Single dwellings, dwelling extensions and small multi-unit developments

The majority of applications that Melbourne Water currently assesses in areas affected by future for sea level rise are dispersed urban infill development comprising new or replacement dwellings, minor dwelling extensions and smaller urban subdivisions in established urban areas.

These types of developments may be assessed against the predicted 2040 1% AEP flood level given the proximity of surrounding urban development already built to a lower flood protection standard, and the shorter asset life typical of single dwellings. This approach is consistent with state policy directions.

- Multistorey residential buildings

Multistorey buildings, such as apartment buildings, will be complex to rebuild at the end of the design life of the building. This difficulty in upgrading to future flood protection standards will pose an increased flood risk over time; therefore, a long-term planning approach to 2100 is preferred for these types of buildings.

- Commercial and mixed-use buildings

Standalone urban infill development comprising a retail premises or office will be assessed against the predicted 2040 1% AEP flood level. In the case of multistorey commercial or mixed-use buildings the predicted 2100 1% AEP flood level will be applied.

Greenfield development

Planning policy identifies the need to apply a long-term planning approach to 2100 for new greenfield development. Therefore, greenfield development will be assessed against the predicted 2100 1% AEP flood level. Greenfield development includes the construction of buildings and subdivisions in greenfield areas.

Urban renewal areas

Similar to greenfield development, urban renewal areas provide an opportunity to apply a long-term planning approach to an entire development or redevelopment area. Also, these areas will see an increased number of occupants at risk of flooding in future. Therefore, urban renewal development will be assessed against the predicted 2100 1% AEP flood level.

Emergency, community or hazardous facilities

The SPPF provides for the application of more stringent flood controls to emergency, community and hazardous facilities, including hospitals, ambulance stations, police stations, fire stations, residential aged care facilities, communication facilities, transport facilities, community shelters, schools and buildings associated with hazardous uses, including intensive animal industries and sewage treatment plants or where hazardous chemicals may be stored. For this reason such development will be assessed against the predicted 2100 1% AEP flood level.

Isolated or rural development

For isolated or rural development there is little likelihood of mitigation or adaptation activities being undertaken in future, and therefore these types of development will be assessed against the predicted 2100 1% AEP flood level.

Summary: predicted future flood levels for development assessment

The table below summarises the relevant predicted future flood level to be applied to each development type for development assessment.

Predicted future flood levels for development assessment	
Development type	**Predicted future flood level**
Urban infill development (single dwelling/retail/office in established urban areas)	2040 1% AEP flood level
Greenfield development Urban renewal area development Emergency, community or hazardous facilities Isolated or rural development All other development	2100 1% AEP flood level

4 Flood levels for Port Phillip Bay and Western Port

This section details the current 1% AEP flood levels adopted by Melbourne Water for Port Phillip Bay and Western Port, as well as the predicted 2040 1% AEP flood level and predicted 2100 1% AEP flood level, on the basis of 0.2 metres and 0.8 metres sea level rise, respectively.

Current adopted flood levels

Port Phillip Bay

Melbourne Water has adopted 1.6 metres AHD as the current 1% AEP flood level for Port Phillip Bay. This level has been determined from a frequency analysis of observed tide levels from a tidal gauging station located at St Kilda Marina. This flood level makes some allowance for wave action.

(For further information on the derivation of the current 1% AEP flood level for Port Phillip Bay, refer to Appendix A.)

Western Port

Following the release of the *Western Port Local Coastal Hazard Assessment* (WPLCHA) (DEPI et.al.) in June 2015, and some additional wind analysis work with inundation modelling, Melbourne Water has updated the Western Port flood levels. As a result, we have adopted graduated 1% AEP flood levels across Western Port, ranging from 2.1 metres AHD at the southern end of the bay to 3.3 metres AHD at the north east shore of Western Port.

Flood levels for Western Port vary from north to south because of its unique hydrodynamic setting. Recent analysis of a range of wind directions has been undertaken to determine peak flood levels around the bay with consideration of storm surge. Together, these comprise the current adopted 1% AEP flood levels for Western Port.

(For further information on the WPLCHA and the additional wind analysis work, refer to Appendix B.)

Predicted flood levels in 2040 and 2100

Port Phillip Bay

For Port Phillip Bay, the predicted 2040 1% AEP flood level is 1.8 metres AHD. This assumes 0.2 metres sea level rise above the current adopted 1% AEP flood level of 1.6 metres AHD.

The predicted 2100 1% AEP flood level is 2.4 metres AHD, assuming 0.8 metres sea level rise.

Western Port

For Western Port, the predicted 2040 1% AEP flood levels range from 2.3 metres AHD to 3.5 metres AHD. This assumes 0.2 metres sea level rise above the current adopted 1% AEP flood levels which range from 2.1 metres AHD to 3.3 metres AHD.

The predicted 2100 1% AEP flood levels range from 2.9 metres AHD to 4 metres AHD. This is based on modelling 0.8 metres sea level rise at the ocean side of the bay; however, because of the bathymetry and wind variations across the bay, this has not resulted in all future flood levels consistently 0.8 metres above current flood levels.

(The predicted 2040 and 2100 1% AEP flood levels, as they vary around Western Port, are shown later in these guidelines.)

Summary: applicable flood levels

This table summarises Melbourne Water's adopted current, and predicted future flood levels for Port Phillip Bay and Western Port.

Applicable flood levels to Australian height datum (AHD)

Region	Current adopted 1% AEP flood level	Predicted 2040 1% AEP flood level	Predicted 2100 1% AEP flood level
Port Phillip Bay	1.6 metres	1.8 metres	2.4 metres
Western Port			
North east	3.3 metres*	3.5 metres*	4.0 metres*#
South	2.1 metres*	2.3 metres*	2.9 metres*#

* Flood levels for Western Port vary around the bay. Please contact Melbourne Water for site-specific flood levels.
# Predicted 2100 1% AEP flood levels for Western Port have been determined from flood modelling and are not a simple addition of 0.8 metres to current 1% AEP flood levels.

Predicted future flood extents

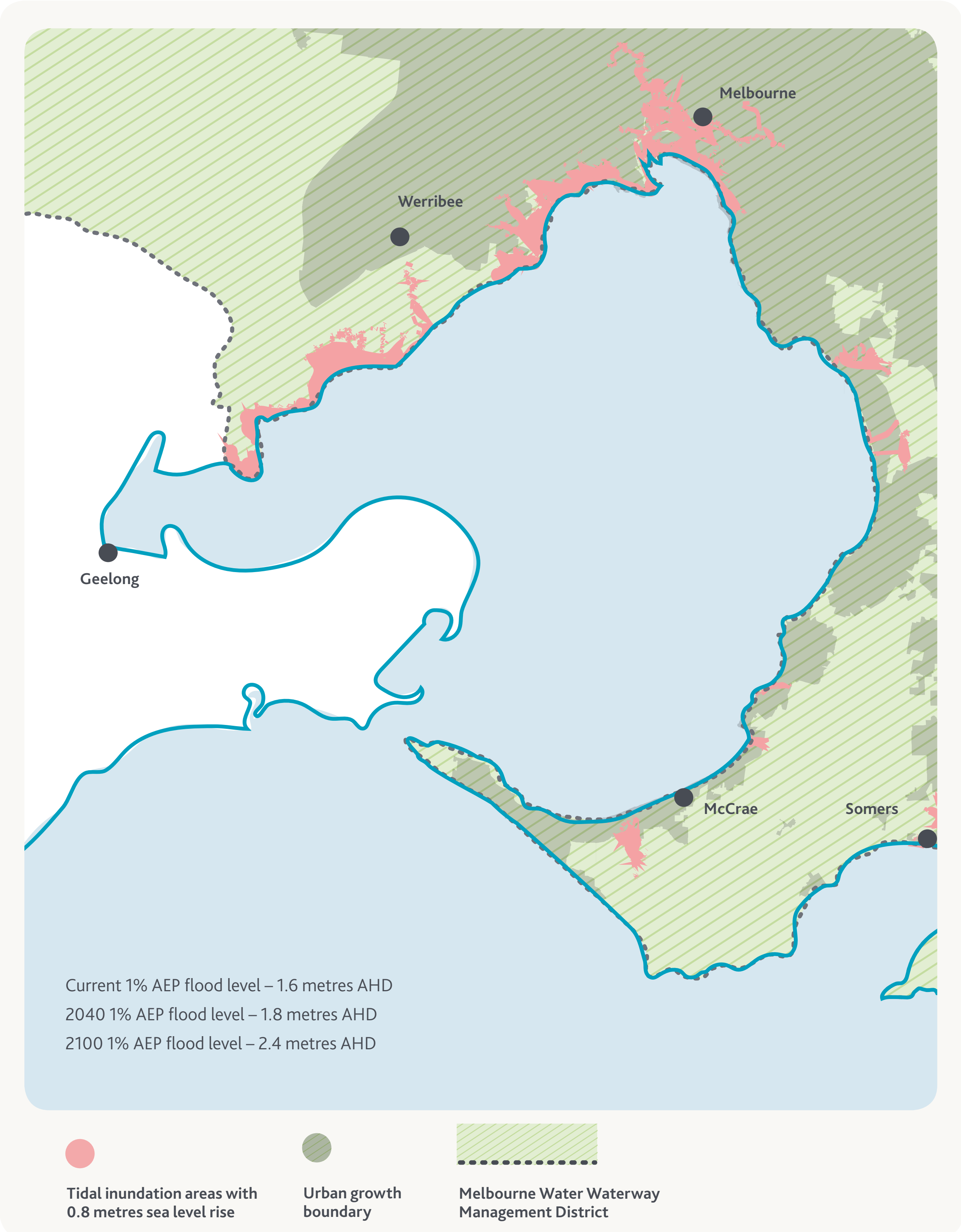
For strategic planning purposes, Melbourne Water has prepared flood extent mapping showing land predicted to be inundated by the 2100 1% AEP flood for Port Phillip Bay and Western Port.

In addition, Melbourne Water has updated Property Information Statements issued under Section 158 of the *Water Act 1989* to identify land liable to flooding from predicted sea level rise.

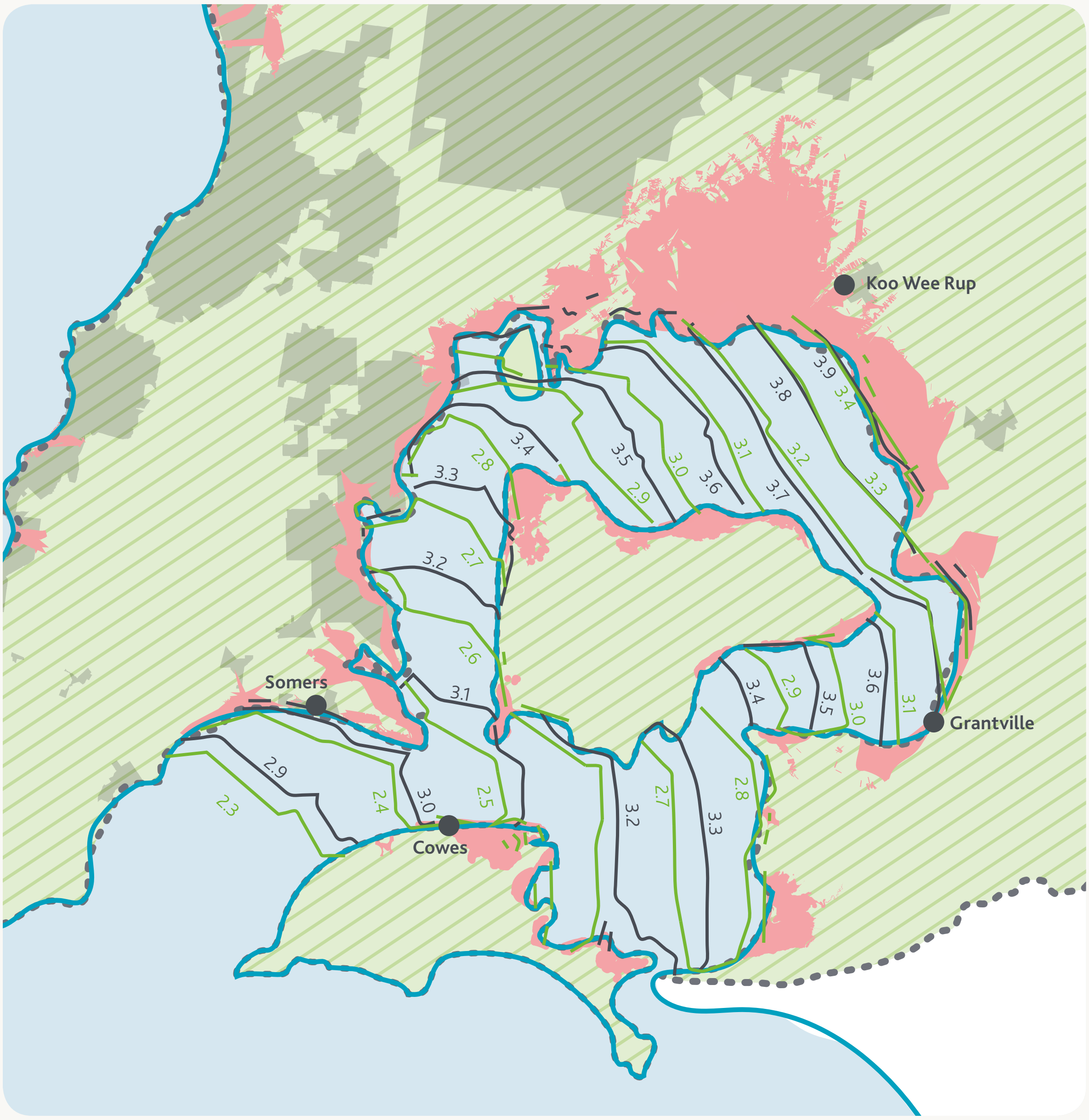
Development applications within these areas should be assessed in accordance with these guidelines to ensure the development requirements are met. (See the next section for development requirements.)

**Disclaimer: The maps contained in this document are indicative only and are not intended for assessment purposes.*

Tidal inundation areas and flood levels for Port Phillip Bay



Tidal inundation areas and flood levels for Western Port



Tidal inundation areas with 0.8 metres sea level rise (indicative)

Urban growth boundary

Melbourne Water Waterway Management District

2100 flood level contours (m)

2040 flood level contours (m)

5 Requirements for development

This section includes the requirements that apply to development proposed in areas affected by tidal inundation to ensure people, property and infrastructure are protected from floods. This includes appropriate freeboard and minimum floor level requirements for development.

Areas affected by tidal inundation as well as riverine flooding or overland flows may be subject to additional requirements, in accordance with Melbourne Water's *Guidelines for Development in Flood-prone Areas* (2007).

General requirements

There are a number of requirements that apply to development proposed in areas affected by flooding to ensure that development is compatible with the level of flood risk.

In the context of tidal inundation, the development requirements of most relevance aim to protect people from flood hazards and to protect property or infrastructure from flood damage.

When we assess development proposals, the depth of flooding at a property is an important factor we take into consideration to ensure that site and access safety can be achieved. We also take into consideration the frequency and extent of tidal inundation affecting a site, as well as the distance to high ground.

Due to the tidal nature of extreme sea levels, the duration of a 1% AEP flood event is typically short, and is not as critical a consideration for development as it can be with riverine flooding. Similarly, tidal inundation floodwaters are unlikely to be fast-flowing, and so velocity is also not a critical consideration.

Provided flood depths and risks are not too great, development can proceed with raised floor levels to protect people, buildings and their contents.

Refer to Melbourne Water's *Guidelines for Development in Flood-prone Areas* (2007) for more information on general development requirements.

Freeboard

Freeboard is the difference between the floor level of a building and the 1% AEP flood level. Freeboard requirements are designed to ensure that valuable buildings and their contents, and the people in those buildings, are safely above the 1% AEP flood level. Lifting the minimum floor height reduces the risk of damage to development from inundation.

Under the Victorian Building Regulations 2006, floor level heights for buildings should be set a minimum 300 millimetres above the applicable flood level, or as otherwise determined by the floodplain management authority.

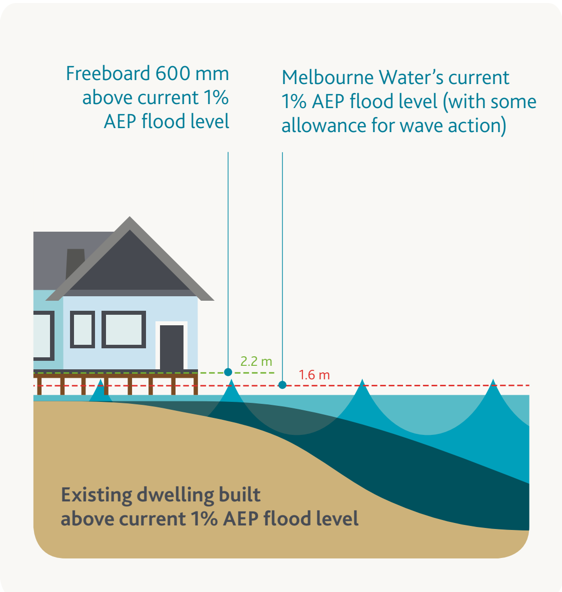
Higher minimum freeboards are required by Melbourne Water to manage increased risk associated with tidal inundation due to wave action and other storm surge activity, and are consistent with our practice in relation to open waterways.

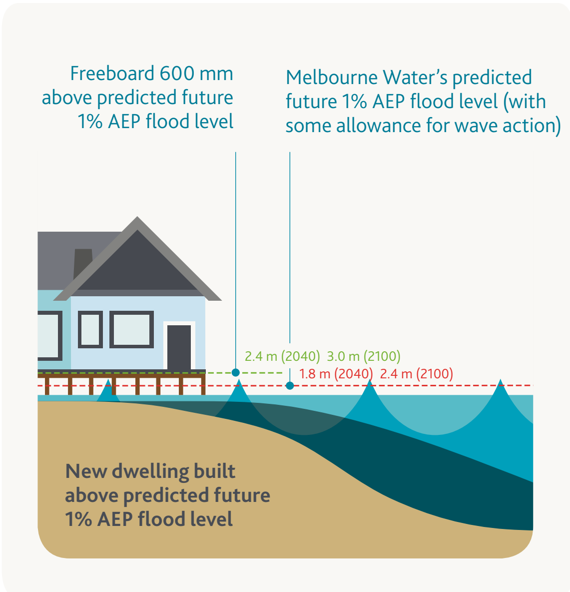
Freeboard requirements for tidal inundation

In areas prone to tidal inundation, building floor levels should be at least 600 millimetres above the relevant predicted future 1% AEP flood level, and floor levels of outbuildings should be at least 300 millimetres above the relevant predicted future 1% AEP flood level.

The freeboard requirement for outbuildings is lower than that required for buildings, on the basis that the impacts from flooding to the contents and uses of outbuildings are usually not as severe.

Freeboard for current and future tidal inundation





Additional freeboard considerations

Subdivisions

For greenfield subdivisions , it is necessary to fill the site to a minimum of 600 millimetres above the applicable flood level.

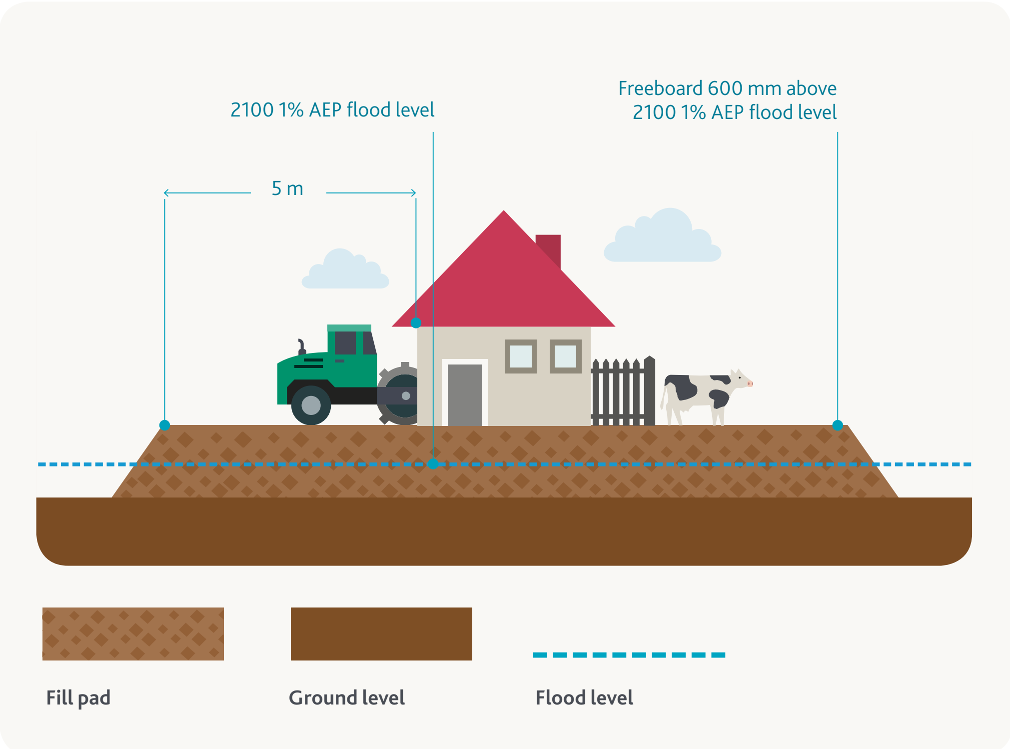
We will assess smaller subdivisions in established urban areas on a case-by-case basis and may support them if compatible with future flood risk.

Isolated or rural development

Fill pads are recommended for isolated or rural development comprising dwellings. Fill pads will provide an area around the dwelling that may act as a place of refuge for livestock and storage for machinery.

A fill pad is required to extend at least 5 metres beyond the building and a minimum of 600 millimetres above the applicable flood level.

Fill pads are not required for non-habitable outbuildings; however, minimum floor level requirements are still applicable.



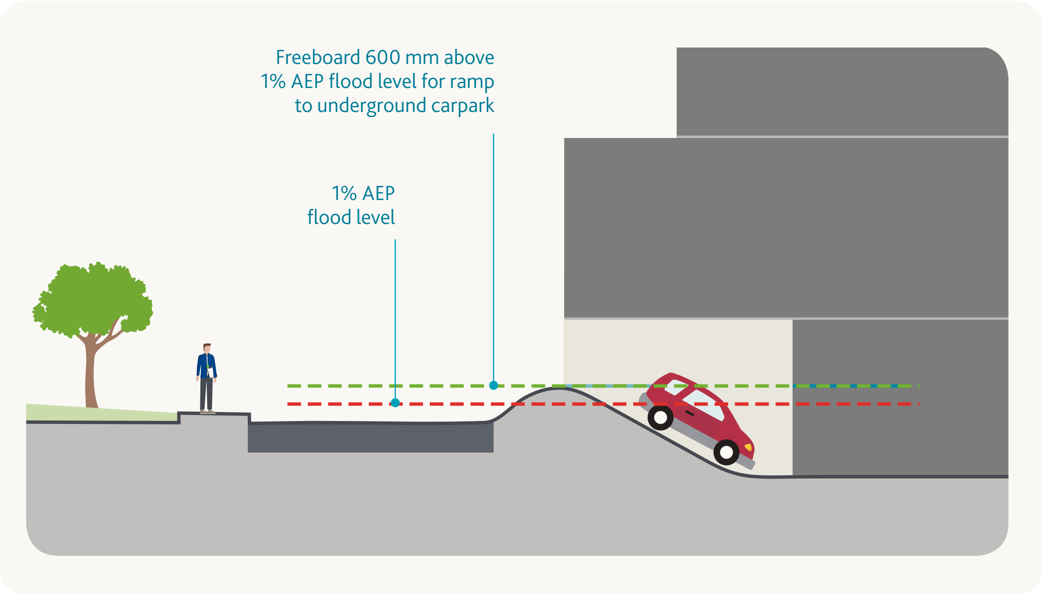
Basements / underground car parks

Entries to basements (non-habitable floors below ground level e.g. underground car parks) with finished floor levels below the relevant predicted future 1% AEP flood level should incorporate a continuous apex of any entry or exit ramp that is at least 600 millimetres above the predicted future 1% AEP flood level.

Melbourne Water does not support the reliance on mechanical mechanisms or other engineered solutions (e.g. flood gates, retaining walls, levees) to achieve appropriate levels of protection because of failure risk.

However, where entry levels cannot be raised above the relevant predicted future flood level due to local constraints, we may allow self-closing flood gates to provide the freeboard protection.

Multistorey development with basement carparking



Floor level concessions

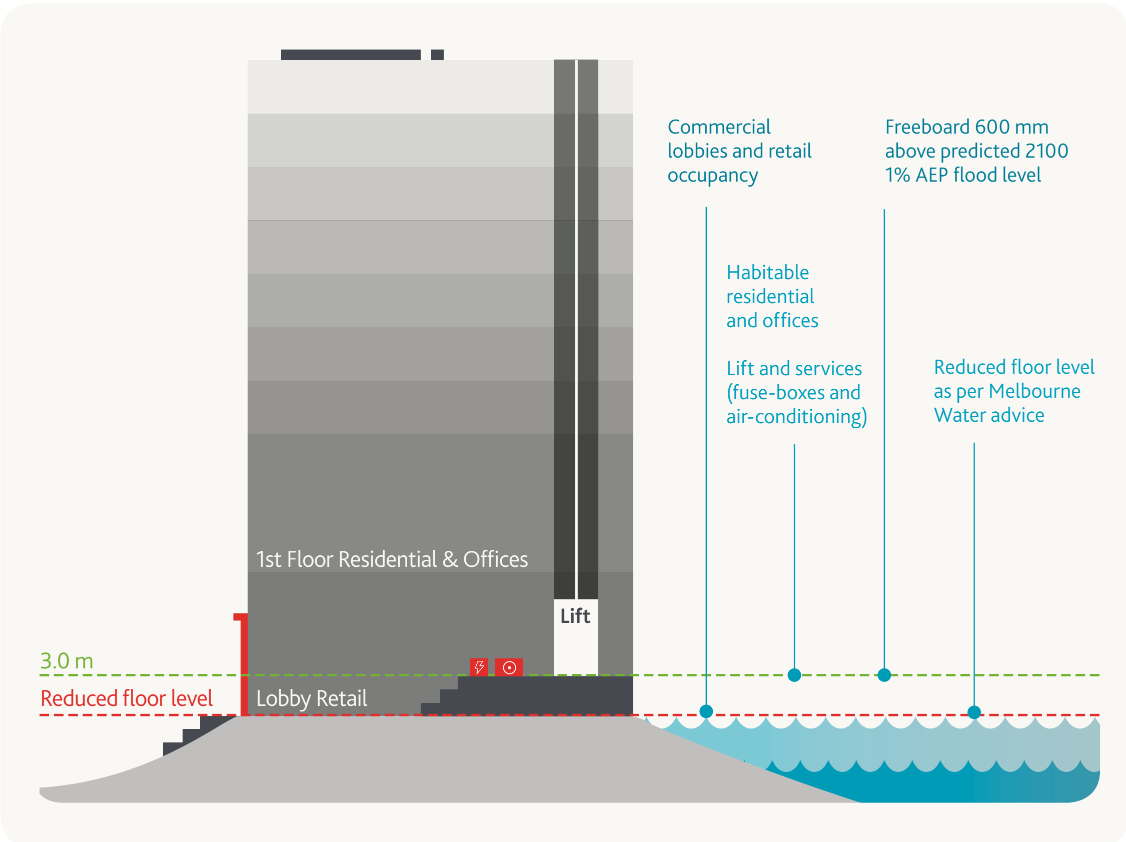
Where we consider that the existing surface levels and design constraints at a proposed development site create access problems, some floor level concessions may apply.

In these cases, a minimum freeboard of 600 millimetres above the predicted 2100 1% AEP flood level will still be required for habitable residential or office floors, and for lifts and services (such as fuse-boxes and air-conditioning). However, minimum floor levels for commercial lobbies and retail occupancies may be marginally reduced at our discretion.

The onus is on the applicant to demonstrate that meeting the minimum floor level requirements will result in an impractical outcome. In addition, you should discuss these proposals with us before lodging any formal application.

The figure below shows an example of how floor level concessions may apply to a multistorey residential or office building in a low-lying area of Port Phillip Bay where access problems exist at a site

Multistorey development with floor level concessions



6 Examples of development proposals

The following examples demonstrate how to calculate the minimum floor level requirements for different development types and locations using these guidelines.

Example 1: Residential urban infill

A proposal includes demolishing an existing dwelling and constructing a replacement dwelling with a garage in an established urban area in Elwood, within the Port Phillip catchment.

These guidelines state:

- The predicted future flood level applicable to urban infill development is the 2040 1% AEP flood level.
- The predicted future flood level for the Port Phillip Bay catchment in 2040 is 1.8 metres AHD.
- The minimum freeboard is 600 millimetres for buildings and 300 millimetres for outbuildings.

Minimum floor level requirements:

- The dwelling floor level should be at least 600 millimetres above 1.8 metres AHD, which is 2.4 metres AHD.
- The garage floor level should be at least 300 millimetres above 1.8 metres AHD, which is 2.1 metres AHD.

Example 2: Urban renewal area development – multistorey office building

A new 8 storey office building is proposed on a vacant site in the Docklands, within the Port Phillip Bay catchment. The site has been identified as being liable to flooding from predicted sea level rise.

These guidelines state:

- The predicted future flood level applicable to urban renewal areas is the 2100 1% AEP flood level.
- The predicted future flood level for the Port Phillip Bay catchment in 2100 is 2.4 metres AHD.
- The minimum freeboard for buildings is 600 millimetres.

Minimum floor level requirements:

- Melbourne Water considers the existing surface levels and design constraints at the site create access problems for the building. Some floor level concessions therefore apply, where the freeboard requirements may be reduced.
- The floor level for the offices, lift and services would need to be at least 600 millimetres above 2.4 metres AHD, which would be 3.0 metres AHD.
- The floor level for the building lobby and any ground level café or other retail may be marginally reduced to address access constraints as advised by Melbourne Water.

Example 3: Greenfield subdivision

A greenfield subdivision is proposed on Phillip Island, within the Western Port catchment. The site has been identified as being liable to flooding from predicted sea level rise.

These guidelines state:

- The predicted future flood level applicable to greenfield subdivision is the 2100 1% AEP flood level.

Given the flood levels within the Western Port catchment are graded, the applicant has confirmed with Melbourne Water that the applicable flood level for the subject site on Phillip Island in 2100 is 2.9 metres AHD.

Finished surface level requirement:

- The site should be filled to a minimum 600 millimetres above 2.9 metres AHD, which is 3.5 metres AHD.

Glossary and abbreviations

Glossary

1% AEP flood also known as the 1 in 100 year Average Recurrence Interval (ARI) flood, has a 1% chance of occurring in any given year.

Freeboard is the difference between the floor level of a building and the 1% AEP flood level.

Greenfield areas include areas not previously developed for urban purposes, outside the established urban area, and may include land inside the Urban Growth Boundary.

Greenfield development comprises development, including subdivision, that occurs in greenfield areas.

Outbuilding is a non-habitable building being a private garage, carport, shed, or the appurtenances to a building used for domestic purposes.

Tidal inundation refers to the flooding of land by sea waters associated with the rise and fall of the tides.

Urban renewal areas includes areas designated as urban renewal areas or precincts in Plan Melbourne or as identified by the Minister for Planning or as shown in municipal planning schemes.

Victoria Planning Provisions are a set of state standard planning provisions or template from which all planning schemes in Victoria are formed.

Abbreviations

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DELWP	Department of Environment, Land, Water and Planning
DEPI	Department of Environment and Primary Industries (former)
IPCC	Intergovernmental Panel on Climate Change
SPPF	State Planning Policy Framework
VCS	Victorian Coastal Strategy (2014)
VFMS	Victorian Floodplain Management Strategy (2016)
VPP	Victorian Standard State Planning Provisions
WPLCHA	Western Port Local Coastal Hazard Assessment (2015)

Appendices

Appendix A: Origins of Port Phillip Bay flood levels

The Melbourne and Metropolitan Board of Works (MMBW)[2] adopted 1.6 metres AHD as the 1% AEP flood level for Port Phillip Bay over 20 years ago. This level was adopted on the basis of the highest tide level ever recorded in the bay, which occurred during the major flood event on the Yarra River catchment in December 1934.

Originally this peak level was thought to be 1.52 metres AHD, and this was rounded up to 1.6 metres AHD as a starting water level for flood modelling on various waterways.

The MMBW Hydrology and Flood Warning Unit undertook a further study in 1987. A frequency analysis of flood high tide levels that occurred during the 1934 flood found that the maximum level at Williamstown in the 1934 flood event was more likely to have been 1.33 metres AHD.

In 2005, Melbourne Water's Hydrology and Flood Warning Team undertook an initial frequency analysis of tide levels for a tidal gauging station located at St Kilda Marina. The results of this analysis found the 1% AEP design tide level to be 1.30 metres AHD for St Kilda Marina.

In 2009, Melbourne Water completed further investigations comprising a frequency analysis of the annual maximum series of observed tide levels for St Kilda Marina. Using 31 years in available data (1977-2008), this study found that a reasonable flood level for a 1% AEP event to be 1.4 metres AHD. We added a minor allowance for wave action to this level to arrive at 1.6 metres AHD. This confirms the appropriateness of adopting 1.6 metres AHD as the 1% AEP flood level for Port Phillip Bay.

Melbourne Water tidal flood levels (vs) CSIRO tidal flood levels

You will note that 1% AEP flood levels adopted by Melbourne Water are different to those contained in the CSIRO report *The Effect of Climate Change on Extreme Sea Levels in Port Phillip Bay* (2009). This is because our process considers all available records on flood events and flood levels, while the CSIRO does not factor in tide levels regarded as outliers (i.e. severe storm events/levels considered to be statistical anomalies). For example, in calculating the existing 1% AEP sea level at St Kilda, the CSIRO calculated a level of 1.15 metres AHD, whereas we calculated a level of 1.4 metres AHD (both for still water with no wave action).

In addition, CSIRO flood levels are based on 'still water' levels, which are an average of the peaks and troughs of any wave action. However, in our view it is the peaks of the waves that should be considered when setting floors levels. Property damage is increased significantly when floors become wet – even if only for a short period of time.

Melbourne Water's flood levels make some allowance for wave action. However, when we assess a development proposal, we give consideration to the adequacy of these levels based on the location of the development

[2] The Melbourne and Metropolitan Board of Works (MMBW) is Melbourne Water's predecessor. The MMBW merged with a number of smaller urban water authorities to form Melbourne Water in 1992.

Appendix B: Updated Western Port flood levels

Western Port Local Coastal Hazard Assessment

The *Western Port Local Coastal Hazard Assessment* (WPLCHA), commissioned by the State Government's then *Future Coasts* program and delivered by DEPI in partnership with Melbourne Water and others[3] , provides information on the extent of coastal hazards and their physical impacts for the coastal environment of Western Port, with a focus on inundation and erosion. A hydrodynamic model was used as part of this project to assess inundation hazards.

Key outputs of the study include inundation extents and water surface elevation contours for each of the modelled sea level rise scenarios (+0.2m, +0.5m and +0.8m to 2040, 2070 and 2100 respectively).

Following on from the work undertaken as part of the WPLCHA, Melbourne Water carried out additional inundation modelling and mapping of Western Port.

Due to the large expanse of shallow intertidal areas in the north and north east of the bay, and the amplification of tides in Western Port, there is potential for significant wave set up due to local winds, and a range of wind directions needed to be assessed to determine the peak flood levels around the bay.

The outcome of this additional modelling is that 1% AEP storm tide inundation extents have been prepared for current mean sea level and 0.8 metres sea level rise for each wind direction tested. The combined extents reveal that the greatest inundation occurs in the north east of Western Port, resulting from south west and southerly winds. These pushed the water inland towards Pakenham South and Cardinia. At this northern end the extent is similar for the current mean sea level and +0.8m sea level rise scenarios.

[3] The WPLCHA was commissioned by the State Government's then *Future Coasts* program and delivered by DEPI in partnership with Melbourne Water, South East Councils Climate Change Alliance, Bass Coast Shire Council, Cardinia Shire Council, the City of Casey and the Mornington Peninsula Shire Council.

Western Port wind analysis and inundation modelling

In November 2015, Melbourne Water undertook inundation modelling and mapping of Western Port following on from the work undertaken as part of the *Western Port Local Coastal Hazard Assessment*.

The modelling was done using the coupled Mike 21 Flexible Mesh Hydrodynamic and Spectral Wave Model. This model allows the grid size defining surface levels to be adjusted so that accurate results can be obtained while keeping model data to a reasonable level. Grid sizes range from 100 metres in offshore areas down to a 1 metre grid along the shore and in inland areas.

To develop an understanding of storm surges in Western Port, the water level gauge data from Stony Point was analysed. A continuous data set was available from 1993 to 2011 and all storm surge events greater than 0.4 metres were extracted and used to develop a synthetic storm surge. The 1% AEP synthetic storm surge has a duration of five days, so occurs over several tide cycles, and has a peak storm surge height of 0.82 metres (McInnes 2009).

The typical wind and wave conditions were then reviewed by assessing the maximum wind speeds during the period storm surges greater than 0.4 metres. Maximum wind speeds of 18 metres per second or greater tend to accompany storm surges of 0.6 metres or more, with the most number of wind events over 15 metres per second coming from the west to north west. Wind direction and speed can vary through these storm surge events.

We adopted a 1% AEP design wind speed of 25.1 metres per second for the modelling based on Australian Standard, *AS1170.2-1989* 'SAA Loading Code, Part 2: Wind Loads'. This is consistent with the wind speeds assessed above, but using a constant velocity and direction is likely to produce slightly conservative results as compared to varying wind speed and direction.

Due to the large expanse of shallow intertidal areas in the north and north east of the bay, and the amplification of tides in Western Port, there is potential for significant wave set up due to local winds, and a range of wind directions need to be assessed to determine the peak flood levels around the bay.

The Mike 21 Flexible Grid model was used to assess flood levels in Western Port for constant 25.1 metres per second wind speeds and using the synthetic storm surge added to the astronomical tidal time series for wind directions of 135°, 180°, 240°, 270° and 315°. Both existing mean sea level and 2100 with +0.8 m sea level rise were assessed.

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Guidelines for Development in Flood Affected Areas

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Acknowledgements

These guidelines have been prepared in consultation with floodplain managers from the nine regional Catchment Management Authorities, Melbourne Water and representatives from 22 local councils. The department gratefully acknowledges the advice received.

Please contact the floodplain manager of your local Catchment Management Authority or Melbourne Water for more information on how these guidelines are applied.

Corangamite CMA, www.ccma.vic.gov.au
East Gippsland CMA, www.egcma.com.au
Glenelg Hopkins CMA, www.ghcma.vic.gov.au
Goulbourn Broken CMA, www.gbcma.vic.gov.au
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Cover photo: *Urban development in Lynbrook*

Photo credit: Viktor Brenners, DELWP

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Contents

Part One - Introduction

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1. Introduction

These guidelines provide an assessment framework and method to assist decisions on development in flood affected areas. In principle, development should not intensify the harmful impacts of flooding.

The purpose of the guidelines is to provide a clear, consistent and transparent process for managing land use and development in flood affected areas in Victoria. They are intended to be used with the land use planning and development system. Usually the information in the guidelines is sufficient to guide decision making. However, the guidelines cannot cover all the circumstances and aspects of flood behaviour.

Development includes the construction, alteration or demolition of a building or works and the subdivision or consolidation of land.

Floodplain managers have discretion to vary from the guidelines, considering local circumstances, the nature of the development proposal and the flood risk.

As can be seen in subsequent chapters, assessment of flood risk requires technical skills and knowledge of flood behaviour. Floodplain managers have these attributes, and are required to work with council staff, who are involved in the administration of planning permit applications and in undertaking planning scheme amendments. The two systems must work together.

Structure of these guidelines

For convenience, these guidelines comprise three parts.

Part One introduces the guidelines, plus basic information on flood risk management and climate change.

Part Two contains information on the regulatory framework used in decision-making. It examines key legislation and the roles and responsibilities of the key agencies that are affected by the legislation. The administrative processes for preparing, assessing and reviewing planning permits are also explained.

Part Three provides the methodology used by floodplain management authorities when assessing development proposals referred to them. This is achieved by considering four objectives:

- safety
- flood damage
- off-site impacts
- waterway and floodplain protection.

This results in development outcomes that respond appropriately to the flood risk. Sometimes this means no development is appropriate.

Part Three has been written specifically for floodplain managers. If the information in this part is too technical, you should seek advice from a floodplain manager.

Why the guidelines are necessary

Victoria has many floodplains and overland flow paths, each with distinctive characteristics. This makes managing development in flood affected areas challenging. The risks posed by flooding are not equal from one floodplain to another, and the level of risk varies even within a discreet floodplain area. Understanding flood behaviour is crucial to any assessment of flood risk.

Historically, development has often occurred in floodplains and coastal areas. Some reasons for this are the availability of water for drinking, ease of transportation, amenity and recreation. The benefits of regular flooding to agriculture also means that towns were established on river flats to act as service centres for surrounding rural areas.

Victoria's variable climate means the flood risk is not always obvious to someone who wants to develop.

Current population projections for Victoria indicate continuing growth in urban areas. This creates pressure to extend development into areas affected by flooding and previously set aside as 'too difficult' to develop. Managing this development is important if we are to avoid increasing costs associated with flooding of built up areas.

These factors support a need to provide transparent guidance on how proposals to use and develop flood affected land are assessed.

There are also some state government drivers that support the guidelines.

The Victorian Floodplain Management Strategy

The *Victorian Floodplain Management Strategy* sets the direction for floodplain management in Victoria. Part 2, "avoiding or minimising future risks," endorses the use of planning controls to manage the potential growth in risk. The guidelines respond to Objective 3 in the strategy: "not making things worse."

Planning and Environment Act

The guidelines respond to several planning objectives set out in the *Planning and Environment Act 1987*:

- to provide for the fair, orderly, economic and sustainable use and development of land;
- to secure a pleasant, efficient and safe working, living and recreational environment for all Victorians and visitors to Victoria
- to facilitate development in accordance with the objectives in the Planning and Environment Act.

Who should use the guidelines

Floodplain Managers

The guidelines are primarily a tool for those providing flood advice to assess development proposals. Floodplain managers are employed by Melbourne Water and the Catchment Management Authorities. There are some situations in which council officers have a role (see Chapter 4).

Flood advice is mostly provided for individual development proposals requiring a planning permit. Flood advice can also be provided for strategic land use planning, such as when rezoning is proposed. This is explained in greater detail in Chapter 5.

Council Staff

Councils are involved in administrative processes in amending planning schemes, authorising a specific use or development of land though planning permits, or through regulating building permits. Where referral arrangements enable the floodplain management authorities to provide flood advice, there is usually no requirement to understand the technical nature of flood behaviour.

Where there are no referral arrangements to the floodplain managers, council staff are sometimes required to make their own assessments of development proposals.

Private Building Surveyors

Most councils have municipal building surveyors on staff or contract, and they are responsible for the building control functions of councils. This includes the issuing of building permits.

Building surveyors are authorised to assess building plans with a view to ensuring they comply with the *Building Act 1993*, the *Building Regulations 2018* and the *National Construction Code*.

Developers

Developers do not usually have technical training to appraise flood risk. However, developers may find the guidelines of benefit to understand how and why decisions are made.

Applicants are encouraged to contact the floodplain management authority for feasibility advice. Many councils also encourage applicants to seek advice from planning and development staff before lodging an application.

Pre-application advice can allow floodplain managers and council staff to provide general feedback and identify key planning considerations. Decision making should be based on the best available information for assessing flood risk. Early identification of the issues and available information can help reduce requests for changes and further information following lodgement.

How to use these guidelines

As the target audience varies from floodplain managers to councils to developers, a brief overview has been provided at the start of each chapter, in plain English.

Users can read the detail in each chapter if greater understanding is required.

Key principles for development

The following principles are relevant to these guidelines:

The flood risk to people (including emergency services personnel) should be kept to acceptable safety thresholds, as per the latest updated Australian Rainfall and Runoff Guidelines.

People become vulnerable if they walk, ride or drive through floodwater. Research into the stability of vehicles and people allows us to consider the combination of flood depths and flow velocities that leads to hazardous conditions. This applies to emergency services personnel as much as the building occupants.

Any development in a flood affected area, including associated infrastructure, should be planned to avoid or minimise the flood damage potential.

Consideration of what a building is made of, and what can be done to protect a building's contents from flooding, will reduce the flood damage potential.

Given the future impacts of climate change, and higher densities of residential development, development that relies on new or extended flood mitigation infrastructure to provide flood protection should not occur if alternatives are available. Flood mitigation infrastructure is not fail-safe and is dependent on ongoing management and maintenance.

There should be no detrimental impacts to nearby properties, particularly properties downstream.

Developers must give due consideration of the impact of the development on others. Locating buildings and works in areas that are important for flow conveyance or flood storage can increase flood levels and flow velocities locally.

Development should preserve, and if possible enhance, the social and environmental values and benefits of floodplains and waterways.

Waterways and floodplains often have significant environmental attributes. These can be threatened if development occurs too close to these natural assets, or if water from a development site is not controlled.

New dwelling on a fill pad

Credit: Ian Gauntlett, DELWP

2. Flood risk management

Floods are part of the Australian landscape. Because of Australia's highly variable climate, the hazardous nature of flooding is not always obvious. Flood studies are a necessary first step to understanding flood behaviour.

Flooding occurs when water covers land that is normally dry. In Victoria, the three main types are riverine, overland flow and coastal flooding. Flooding from dam failure is not considered in the guidelines.

- Riverine flooding occurs when water escapes or is released from the normal confines of a lake, river, creek or other natural watercourse, whether altered or modified. It also includes water that has escaped or been released from any reservoir, canal or dam. For catchments with high altitude areas, snow melt can influence riverine flooding, and this needs to be considered in the flood modelling.
- Overland flow (sometimes called stormwater flooding) occurs when runoff from heavy rainfall moves over the landscape, following the grade of the land. Flooding can occur by several mechanisms: local runoff exceeding the capacity of urban stormwater drainage systems; floodwater flowing overland though poorly defined drainage paths; and water backing up through drainage systems.
- Coastal flooding occurs in low-lying coastal areas, including estuaries. It can be caused by storm surge events, very high tides or both. Properties that may currently be above tidal or storm surge levels may be at risk under future climate change scenarios. These predict rising sea levels and increasing storm surge intensity.

Flood behaviour

Flood behaviour varies with the type of flooding, the location and intensity of development, the shape and size of the catchment and the slope of the ground. As explained in Australian Disaster Resilience Handbook 7 the safety of people and the susceptibility of structures are linked to flood behaviour.

Flood studies

Flooding remains one of the most predictable natural hazards encountered in land use and development planning. It is relatively straight forward to predict and measure aspects of flood behaviour though flood studies with a high level of confidence. Flood studies look at flood behaviour for a range of floods, from small to very large.

Flood studies need to be updated periodically, as they are dependent on the best available data, which is influenced by many factors, including:

- changes in land use
- changes in topography (such as the removal of an irrigation channel that is no longer required, road raising or land fill)
- a longer record of flood data
- climate change.

Updated technology and improved guidance on mapping standards also improve the quality of the flood studies.

Information from flood studies is incorporated in planning schemes. See Chapter 5.

Authorities are encouraged to share information from flood studies with other authorities so that decision making is informed by the best available data.

Flood risk

Flood risk is determined by the frequency of flooding and the potential economic, social and environmental consequences to the community. They are interlinked: the less frequent the event, the larger the potential consequences.

Usually, it is not practical to eliminate the flood risk. A challenge for the floodplain management authorities is to determine what flood risk is acceptable to the community.

Future growth in the flood risk can be limited by encouraging development intensification away from areas of high hazard. Where development does occur on flood affected land, the risk must be reduced at the property scale. Examples include elevating the floors of buildings and flood proofing.

Risk reduction solutions are not always appropriate. They need to be considered in terms of the impacts on people, property and the environment.

The nature and understanding of flood risk are not set in stone. Changes in topography, climate change, a longer record of flood data and other factors can signal changes to the flood hazard. Changes in demographics also affect the human interaction and exposure to the flood hazard. Development proposals are therefore assessed against the best available information, not by comparing what might have been previously allowed for other developments in an area.

Flood probability

The best way to express probability when talking to the community about flood risk is using percentage Annual Exceedance Probability (AEP). This refers to the probability each year of a certain size event being exceeded and reinforces that there is an ongoing flood risk every year. If a site experiences a flood at a point in time, it could experience another similarly sized event, or a larger one, the next month, the next year, over the next decade or two hundred years later. Floods occur randomly and in different magnitudes.

Flood variability

Piped drainage systems are usually designed for the more frequent floods. Larger floods causing significant community impacts may occur at the same location several times in a lifetime, or sometimes, not within a lifetime.

Flood behaviour is never uniform. A severe storm may result in severe flooding at one location and little or no flooding at another location.

Cumulative impacts

Cumulative impacts must be considered in development proposals, even if one application on its own does not have measurable impacts on flood behaviour. The cumulative impact of many development proposals can result in changes to the flood extent and depth, and the flow velocity.

Some flood studies may account for the broad effects of changing development patterns. If not, it may be necessary to impose tight controls on development to offset the cumulative impacts.

The design flood

The probable maximum flood (PMF) is the largest flood that could possibly occur in a particular location. It is an extremely rare flood, which when it does occur, can result in significant community disruption and loss of life. It is not usually feasible, or socially or economically justifiable to adopt the PMF as the standard for all floodplain management activities.

In Victoria, the 1% AEP flood is the design flood that most affects most decisions on development. Suffering the economic impact of rarer events is considered tolerable for most sectors of the community. Floods larger than the 1% AEP flood can and do occur.

The 1% AEP flood is also known as a 100-year Average Recurrence Interval (ARI) event. This does not mean that, if an area has experienced a “one-in-one hundred flood” it won’t have another flood for the next 100 years.

Floods vary greatly in size and frequency. Governments generally provide additional support or implement additional measures for a range of floods, including the more hazardous ones. Examples include flood warning systems and emergency management plans. Key community infrastructure such as power supplies, communication centres, emergency response headquarters and evacuation centres may also require additional protection. They need to be fit for purpose in emergency response and recovery.

Flood safety considerations

Depth and velocity

The most important determinants of flood hazard are the flood velocity and flood depth. Fast-flowing, shallow water, or slow-moving, deep water can unbalance people and sweep them away. Buildings can be undermined or damaged by floodwater and debris. The contents of buildings can also be severely damaged or destroyed.

Research by the Bushfire and Natural Hazards CRC reveals that about half of all documented fatalities are from people driving though floodwater. Flood awareness does not significantly affect their choice; neither does the availability of flood warnings. More detailed information on the research is provided in Appendix 1.

Detailed information on the safety of people in floods is provided in Book 6, Chapter 7 *of Australian Rainfall and Runoff*. It applies to vehicle stability criteria, the safety of children and adults in floodwater and the stability of buildings. The information is based on controlled conditions and / or assumptions made on the data and subjects analysed. Some important qualifiers include:

- The test data excludes infants, very young children, physically and / or mentally disabled people and frail older persons. Such people are more vulnerable than children and adults.

- The ability to withstand flood flows is influenced by the mental disposition, perception, specific training and experience of the person affected.
- The information in *Australian Rainfall and Runoff* excludes the inherent dangers of drivers losing control of vehicles under speed (aquaplaning) and people swimming through floodwater.

Wading through floodwater may result in injuries because you can't see what is beneath the water. Potential obstacles can include an uneven ground surface, potholes, fences, major storm water drains, displaced manhole covers, flood debris, pollutants or dangerous fauna.

Walking short distances through safe flood depths and velocities may be possible, but there will still be a risk of injuries. Walking long distances though floodwaters requires sustained physical exertion and increases the potential exposure to obstacles below the surface of the water.

Driving though floodwater can result in a loss of control of the vehicle. Once a vehicle loses traction it can float, be pushed or topple into deeper water. Electric systems that lock doors and wind down windows can also fail, making extraction from the vehicle difficult.

Isolation

How long floodwaters remain present can also be important if it leads to people being isolated. Isolation can result in people entering unsafe floodwaters to access services, employment or family members. Any situation that increases people's need to cross floodwaters increases the likelihood of an injury or fatality.

The impacts of isolation include:

- People are cut off from transport, drinking water, medical treatment, sewerage and electricity.
- People can run out of food and drinking water.
- It diverts limited resources of emergency services away from other activities.
- Anxiety (as rescue may not be possible).

For this reason, consideration needs to be given to ensuring there are safe, external connecting routes that do not lead to isolation. They should safely connect to emergency relief services, not just to the nearest high ground.

Isolation is not an issue for short duration flooding, such as occurs when urban drainage systems are overloaded. How quickly floodwaters rise and fall does become important however, as it restricts the time available for safe evacuation, and flow velocities can often still be quite high. Judgement is still required about the exposure of people to flood debris, the length of an evacuation route through floodwater and the likelihood of being swept into deeper floodwater.

Frequency of flooding

The frequency of flooding also contributes to the flood risk. Any floodwater on a site will affect the occupants to some degree. The more often people evacuate, the greater the cumulative exposure to wading or driving through floodwater.

Vulnerability

Some individuals or groups of individuals are dependent on more able people for mobility and basic needs. They include the elderly, infirmed, mentally or physically incapacitated, incarcerated and very young children. *Australian Rainfall and Runoff* considers them to be unlikely to be safe in any flow regimes.

There are also services that the community expects in times of flood. Buildings that are linked to these services include ambulance stations, police stations, fire stations, communication facilities, transport facilities, community shelters and emergency service facilities.

Such facilities should be located outside the 1% AEP flood extent. If this is not feasible, the development proposal should determine how the site safety and building operation issues can be addressed.

Buildings housing vulnerable people and community services often have a high flood damage potential. If it is not feasible to locate these facilities outside flood affected areas, a higher freeboard may be applied by the floodplain management authority to offset the impacts.

3. Climate change

Rising temperatures in the Earth's atmosphere are strongly linked to human activity. This leads to increased sea levels and incidences of the extreme rainfall that drives flooding.

As far as practicable planning of settlements should discourage development intensification for areas predicted to have a high flood risk in coming decades, unless strategies are in place to mitigate the impacts.

There is now widespread acceptance that human activities are contributing to observed climate change. This has the potential to alter the prevalence and severity of rainfall extremes, storm surge and floods. Recognition and management of the risks associated with climate change will help reduce future impacts.

Impacts on flood behaviour

Riverine and overland flooding

Climate change is expected to result in significant changes in storm behaviour. The information currently available suggests that the extreme rainfall events that drive major flooding are likely to increase over the next few decades. However more detailed research is required to identify how the global and regional trends affect flooding.

Australian Rainfall and Runoff (Book 1 Chapter 6) provides interim guidance and a methodology that can be considered in flood studies. The first step is to establish the life of the infrastructure. The next step is to apply an increase in the design rainfall intensity, based on a consideration of climate change.

If flood studies have not assessed the impacts of climate change, allowance should be considered through applying additional freeboard to development proposals.

Coastal flooding

Climate change is also expected to result in sea level rise. Most of this is associated with thermal expansion of the Earth's oceans and melting ice caps. Sea levels will continue to rise for many decades, even if strong action is taken worldwide to curb emissions. Sea level rise will increase the extent and duration of tide and storm induced coastal inundation.

Coastal flooding is also influenced by high tides, and storm surge, which is the rise in seawater level during a storm. Coastal hazard assessments look at these effects, and the potential impacts of coastal erosion.

Combined flooding

Estuaries are sensitive to a combination of coastal flooding and riverine or overland flooding. This adds to the complexity of flood investigations, as a joint probability analysis is required. *Australian Rainfall and Runoff* (Book 6 Chapter 5) provides guidance for those experts able to understand and apply the suggested methods.

Current policy setting

There are two important documents that contain policies relating to climate change: the *Victorian Floodplain Management Strategy 2016* and the *Victorian Coastal Strategy 2014*, which will be superseded by a *Marine and Coastal Environment Strategy* around 2020.

Victorian Floodplain Management Strategy

The *Victorian Floodplain Management Strategy* acknowledges the impacts of climate change on weather. This includes changes in average stream flows, increased stream flow variability, more intense storms and increased sea levels.

Uncertainty about future rainfall requires preparation for a range of climate conditions. Policies in the *Victorian Floodplain Management Strategy* provide requirements for flood studies to:

- consider a location's sensitivity to climate change
- meet the needs of a range of users (including land use planning)
- be of sufficient quality for inclusion in planning schemes

- consider, as relevant, the state policies embedded in planning schemes.

The Department of Environment, Land, Water and Planning will support local councils and their communities to strengthen their capacity to adapt to the effects of coastal flooding. Where councils amend their planning schemes to show land subject to inundation by coastal flooding, the Catchment Management Authorities and Melbourne Water will act as referral authorities for applications to use and develop land.

Victorian Coastal Strategy

The *Victorian Coastal Strategy 2014* establishes the long-term framework for the planning and management of the coast. It sets out the state's policies on coastal hazards and benchmarks for planning for sea level rise. The coastal environment includes land directly influenced by the sea or directly influencing the coastline, and the rivers and drainage systems that affect the coastal zone, including estuaries.

The Victorian Coastal Strategy was established under the *Coastal Management Act*, which has been replaced by the *Marine and Coastal Act 2018*. The new Act will introduce significant changes to coastal policy though a multi- year transition plan, including:

- developing improved climate change impact projections for the Victorian coast
- preparing a state-wide policy for the marine and coastal environment
- preparing a state-wide strategy for the marine and coastal environment (to replace the Victorian Coastal Strategy)
- extending the role of Catchment Management Authorities to include providing advice on coastal erosion and greater coverage of coastal and marine issues in the next round of Regional Catchment Strategies in 2019-20
- reviewing planning benchmarks for sea level rise
- considering how climate change and adaptation policy can be strengthened through the planning and building systems
- supporting strategic planning for coastal settlements and areas that reflects the best available coastal and erosion climate science
- establishing state-wide objectives, standards, databases, and guidance to build capability and understanding of coastal erosion and flooding in Victoria
- ensuring a greater role for Traditional Owners in formal management and planning for marine and coastal areas.

Coastal processes cross land tenure, land management, jurisdictional and policy boundaries. The Victorian Coastal Strategy takes a holistic view of coastal management. This will continue with the changes.

Some of the desired outcomes are:

- updating sea level rise planning policy benchmarks in the Policy Planning Framework in planning schemes
- aligning the growth of coastal settlements with the strategic directions for settlements identified in Regional Growth Plans
- maintaining non-urban breaks between coastal settlements to preserve the character of the coastline
- ensuring that new development and redevelopment on the coast protects environmentally and culturally significant places, accommodates biodiversity, connectivity and adaptation, does not interfere with natural coastal processes, and avoids areas subject to coastal hazards.

Application of climate change policies

The additional impacts of climate change are gradual. However, once communities are established, it is difficult for them to retreat because of a flood threat.

If urban growth is planned, consider the most suitable location. This should be informed by flood studies and coastal hazard assessments. The flood controls in planning schemes may need to be updated if there are significant changes to the predicted flood behaviour.

Melbourne Water and the Catchment Management Authorities have prepared separate guidelines for assessing development in areas subject to coastal flooding. They are listed in the bibliography. Development proposals will be assessed against those guidelines where appropriate.

Part Two - regulation

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4. Legislation

Legislation provides the authorising environment and establishes the arrangements for regulating land use and development. To be effective, floodplain management authorities and municipal councils need to work in partnership.

Relevant legislation

Planning and Environment Act

Victoria's statutory land use planning system operates through planning schemes, which are subordinate instruments under *the Planning and Environment Act 1987*. Section 62(e) of the Act enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous'. As a result, planning schemes contain land use and development controls to enable flood risk to be managed.

Building Act

The *Building Act 1993* governs building activity in Victoria. It sets out the legislative framework for the regulation of building construction, building standards and the maintenance of specific building safety features. The *Building Regulations 2018* are subordinate instruments under the Building Act. The *Building Code of Australia* is adopted by and forms part of these regulations. This in turn is incorporated into the *National Construction Code*.

Water Act

Part 10 of the *Water Act 1989* enables floodplain management authorities to have waterway management, regional drainage and floodplain management functions. Specific activities are guided by the *Victorian Waterway Management Strategy*, the *Victorian Floodplain Management Strategy* and the *Victorian Rural Drainage Strategy*.

A key floodplain management function is to advise about flooding and controls on development to local councils, the Secretary to the Department of Environment, Water, Land and Planning and the community.

Climate Change Act

Part 4 of the *Climate Change Act 2017* requires the Victorian Government to endeavour to ensure that any decision, policy, program or process developed or implemented by the Government to appropriately consider climate change, if relevant by having regard to the policy objectives and guiding principles, listed in that part of the Act.

The most relevant policy objectives are to:

- build the resilience of the state's infrastructure, built environment and communities through effective adaptation and disaster preparedness action
- manage the state's natural resources, ecosystems and biodiversity to promote their resilience
- support vulnerable communities and promote social justice and intergenerational equity.

The most relevant key guiding principles relate to informed decision making, integrated decision making, risk management and equity. Decisions relating to climate change should be based on:

- a comprehensive analysis of the best practicably available information about the potential impacts
- an integrated consideration of all relevant issues
- assessing, managing and allocating the risks in a manner that is easily understood, aims to achieve best practice and avoids, wherever practicable, serious or irreversible damage
- creating opportunities to increase capacities for current and future generations to adapt to climate change
- considering the long-term, medium-term and short-term consequences.

Other Acts

Developers may need to comply with other legislation, where there are potential impacts on environmental, cultural and landscape values. They include:

- the *Commonwealth Environment Protection and Biodiversity Act 1999*, which provides for the protection of matters of national environmental significance, including nationally significant threatened species and wetlands protected under the Convention of Wetlands of International Importance (the Ramsar Convention)
- the *Flora and Fauna Guarantee Act 1988*, which provides protection for species and ecosystems that are of state-wide importance
- *the Aboriginal Heritage Act 2006* and *Aboriginal Heritage Regulations 2018*, which set the framework for identifying and protecting Aboriginal Cultural heritage.

Roles and responsibilities

The administration and enforcement of a planning scheme is the duty of a responsible authority. Usually this will be a local council, but it can be the Minister administering the Planning and Environment Act 1987 or any other Minister or public authority specified in Clause 61.01 of the scheme.

Councils play a significant role in managing extensive networks of stormwater drains, which can often be the cause of flooding.

Melbourne Water and the nine regional Catchment Management Authorities are floodplain management authorities. They provide flood information and development advice to municipal councils, who administer the planning schemes and building regulations. They also apply advice to others, for example requests for flood information.

For flood impacts to be managed holistically, collaboration between councils and floodplain management authorities is essential. Arrangements vary, depending on the working relationship between the floodplain management authority and the relevant council, and whether the flood hazard has been identified in the planning scheme.

Sometimes councils will consider flood impacts without seeking advice from floodplain management authorities. The localised nature of the flooding may be better understood by council, or there may be a written agreement exempting a need for referral.

Compliance with the guidelines will not give immunity from prosecution. Those involved in decision-making will still need to take reasonable care that granting a permit does not lead to negligence claims.

Flood protection levee – Rochester Water Treatment Plant

Credit: North Central Catchment Management Authority

5. Regulating development

Most forms of development will require a planning permit, a building permit or both. This chapter describes the requirements. The process of applying the flood controls is described in Chapter 6.

The difference between planning and building

The planning permit and building permit systems operate under different forms of legislation. Planning permits are legal documents giving permission for a land use or development. Building permits relate specifically to the carrying out of building construction.

Most forms of development in flood affected land require a planning permit. They include subdivisions, buildings and works.

If building construction is proposed in a flood affected area or in a waterway, Building Regulations 153 or 154 also apply, unless dealt with through the planning permit system. The report and consent of the relevant council must be obtained. Before giving consent, the council must consult with Melbourne Water or the Catchment Management Authority.

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Figure 1 shows the differences between the two systems.

Planning schemes

The planning scheme determines the circumstances in which a planning permit is required. Just because a person can apply for a permit does not imply that a permit should or will be granted.

The planning scheme lists the matters that councils must consider. They include:

- the state and local planning policies
- the purpose of the zone, overlay and any other provision
- the degree of flood hazard associated with the location of the land and the use, development or management of the land to minimise the hazard.

Before flood provisions can be introduced to a planning scheme, information on the type and extent of flooding is required to accurately map land affected by flooding and apply the most appropriate flood provision.

Unlike most controls for the use and development of land, the flood zone and the flood overlays do not represent the full extent of flooding. Floodplain management planning is about planning for an acceptable level of risk.

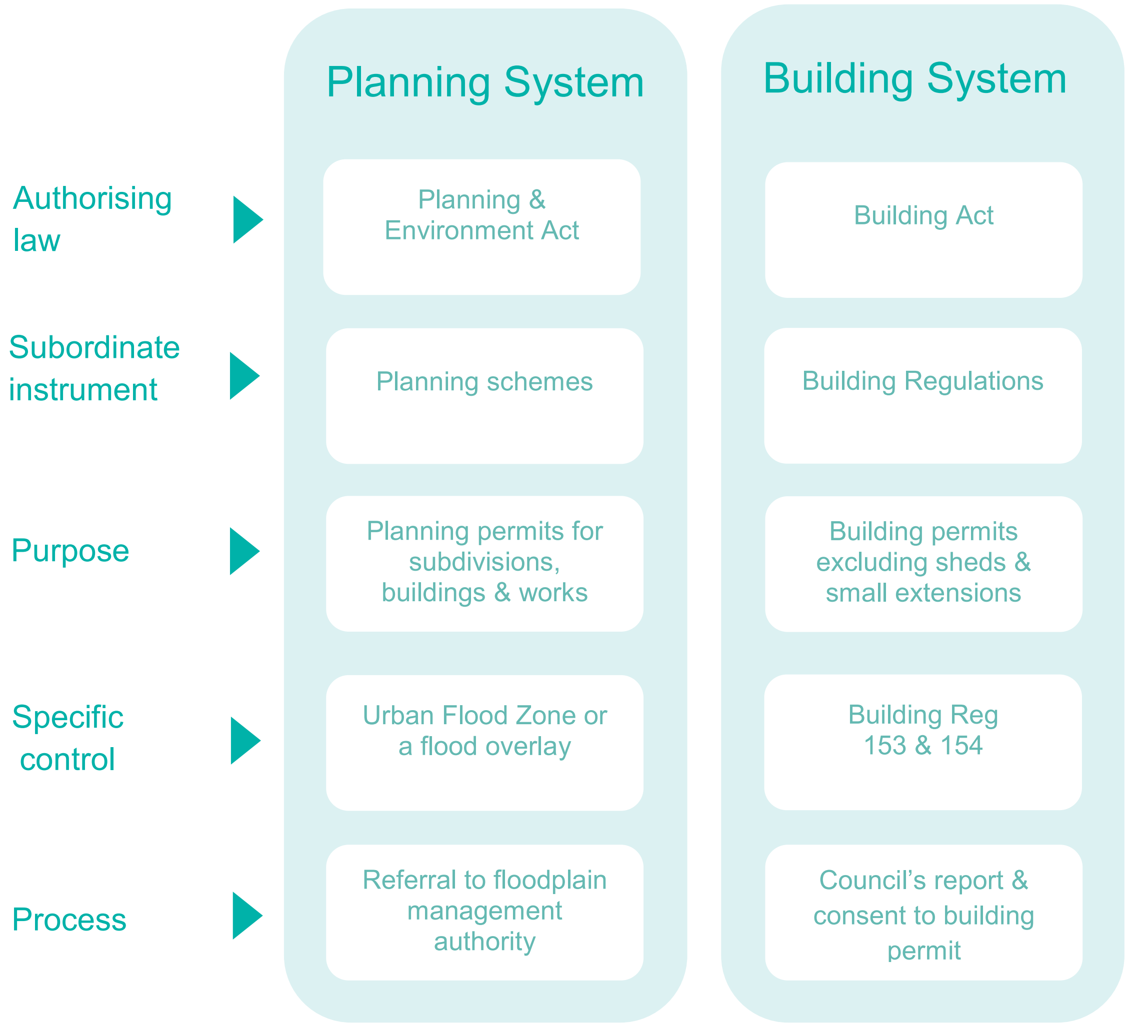

Figure 1: The planning and building frameworks

State, regional and local planning policies

Planning policies are transitioning into a new integrated framework that provides for three tiers of planning policy: state-wide, regional and local. Mandatory policies of state significance and regional policies of state significance have been migrated into the new framework. They are based on geographical and thematic policy groupings. Over time, policies of local significance in the Local Planning Policy Framework will be introduced into the new framework. Both the old and the new systems allow for local flood issues to be addressed.

Planning policies specifically relevant to these guidelines include:

- Water bodies and wetlands (Clause 12.03).
- Climate change impacts (Clause 13.01).
- Floodplains (Clause 13.03).
- Water (Clause 14.02).

These policies support the following:

- Identify land affected by flooding.
- Avoid intensifying the impacts of flooding though inappropriately located uses and developments.
- Plan for sea level rise and associated coastal effects.
- Ensure development does not compromise bank stability, increase erosion or impact on a water body or wetland's natural capacity to manage flood flow.
- Ensure development is sensitively designed and sited to maintain and enhance environmental assets, significant views and landscapes along river corridors and waterways and adjacent to lakes and wetlands.
- Retain natural drainage corridors with vegetated buffer zones at least 30 metres wide along each side of a waterway to: maintain natural drainage function, habitat and landscape values; to minimise erosion; and to reduce polluted surface runoff from adjacent land uses.

Zones

Each planning scheme zones land for particular uses, for example, residential, industrial, business, rural or farming. Each zone has its own purpose and set of requirements.

An Urban Floodway Zone is sometimes used in urban areas of high flood hazard, to support the natural function to convey and store floodwater. It is the strongest flood control.

An Urban Floodway Zone provides limited opportunity for most forms of development. Low development intensity uses that are compatible with the flood storage and conveyance function are generally permitted. They include agriculture, bee keeping, grazing of animals, and some forms of temporary trading, leisure and recreation (Clause 62.01 provides more specific details).

The Urban Floodway Zone is not often used, because of its restrictive nature. More commonly, a flood overlay is used in conjunction with an appropriate zone (such as residential, farming or rural). This allows the primary use of the land to be recognised at the same time as acknowledging its flooding characteristics.

Flood Overlays

Flood overlays identify where a planning permit may be required for subdivision, the construction of a building, or other changes to the land. Where data is available, flood related overlays typically reflect the 1% AEP flood hazard. Not all areas at risk of flooding are covered by overlays.

The three main types of flood overlays are described below. They do not define the absolute extent of flooding, which is defined by the probable maximum flood. Flooding outside the flood overlays will still occur at some stage. The purpose of the overlays is to define what is considered an acceptable threshold for managing flood risk.

Floodway Overlay

Floodways are those parts of the floodplain that are important for the discharge or storage of water during major floods. They are usually aligned with naturally defined waterways, channels and depressions and often carry relatively deep and high velocity flows.

Floodways can be defined in various ways, depending on what data is available. Some common methods include considering various combinations of depth and flow velocity, identifying those parts of the floodplain that are important for conveying or storing floodwater, or mapping a flood extent corresponding to a major flood, say a 10% AEP event.

Filling or even partial blockage of floodways can redistribute flood flows, causing increased flood levels and flow velocities and increased flood risk for nearby properties.

A blockage of a floodway can also have adverse environmental impacts, such as isolating wetlands, destroying natural habitats, eroding stream channels and increasing siltation.

A Floodway Overlay provides transparency over what forms of development are likely to be inappropriate because of the high flood risk. It is the strongest form of flood overlay.

Flood overlays specify certain types of development that do not require a planning permit.

Land Subject to Inundation Overlay

The Land Subject to Inundation Overlay applies to riverine and coastal flooding and represents the area of land flooded by the 1% AEP flood. If the high hazard Floodway Overlay component has also been identified, it is excluded from the Land Subject to Inundation Overlay.

Special Building Overlay

The Special Building Overlay applies to stormwater flooding. It is used to recognise that many urban drainage systems were designed for much lower storm capacity than the 1% AEP flood. Usually no provision was made for overland flows, so land is often flooded when the capacity of the underground drainage system is exceeded. The Special Building Overlay enables development to be managed in these areas.

The Special Building Overlay includes standard exemptions for common urban developments such as minor extensions to dwellings, replacement fencing, carports, pergolas and in-ground swimming pools.

Schedules

In addition to standard exemptions for some types of development, the overlays can also contain schedules. A schedule exempts certain types of buildings and works from the need for a permit. This reduces the number of planning permit applications the council and the flood plain management authority need to process.

Schedules are used in low risk situations. For example, rural shires often have large farming communities, which are affected by slow and relatively shallow flooding. It may therefore be appropriate to include a hay shed in a schedule.

Such exemptions should only apply to low risk situations.

Local Floodplain Development Plans

A local floodplain development plan enables the council and local floodplain management authority to include specific local requirements in the planning scheme. It is a way to insert detail into the planning scheme where overlay schedules are inappropriate. Consideration can also be given to special circumstances, for example introducing requirements for specific types of development. It simplifies and streamlines the work required to prepare and assess planning permit applications.

Each plan provides a set of requirements and guidelines for development in an area. It should address local circumstances and record local flooding information.

If a local floodplain development plan has been developed for a specific area and has been incorporated into the planning scheme, an application must be consistent with the plan.

Local floodplain development plans are prepared by municipal councils in consultation with the floodplain management authorities. Once a council has adopted the plan, it is incorporated into the planning scheme via a planning scheme amendment.

Decision guidelines in planning schemes

Issuing a planning permit can be challenging: the relevant Council must determine that the proposal will produce acceptable outcomes. For the flood zone and flood overlays, the matters to be examined are identified as decision guidelines. The things to consider are:

- The Municipal Planning Strategy and the Planning Policy Framework.
- Any Local Floodplain Development Plan.
- Any comments from the relevant floodplain management authority.
- The existing use and development of the land.
- Whether the proposed use or development could be located on flood-free land or land with a lesser flood hazard.
- The susceptibility of the development to flooding and flood damage.
- The potential flood risk to life, health and safety associated with the development.
- The effect of the development on redirecting or obstructing floodwater, stormwater or drainage water.

- The effect of the development on reducing flood storage and increasing flood levels and flow velocities.
- The effect of the development on river health values including wetlands, natural habitat, stream stability, erosion, environmental flows, water quality and sites of scientific significance.

The Decision Guidelines do not provide guidance on how to decide whether proposed development is compatible with the flood risk, or what things are more important than others. This gap is addressed in Part Three.

The development guidelines are not intended to override the consideration of any overlays, their schedules, Local Floodplain Development Plans or local circumstances.

Further guidance

More information available through Planning Practice Note (Planning Practice Note 12, *Applying the flood provisions in planning schemes*).

Strategic planning

Inappropriate development in flood affected areas can lead to fundamental changes in the nature and impact of flooding. It can also increase the potential for loss of life and flood damages to the community and the environment. This is contrary to the objectives of planning in Victoria, listed in the *Planning and Environment Act 1987*.

The Development Assessment Framework in Part Three of the guidelines is primarily aimed at property-specific development. It can also be used by municipal councils for strategic planning. In principle:

- Land should not be rezoned for a higher density land use without adequate consideration of the flood risk, including the cumulative impacts, and loss of safe access during floods.
- Land that is affected by flooding should be identified by a flood overlay, unless it is zoned for flood purposes. This makes the flood risk clear to all and provides the necessary trigger for development proposals to be referred to a floodplain management authority. It also enables future purchasers of land to be informed of the flood risk through vendor disclosure statements.

Any rezoning to a higher density land use should consider 'the island effect,' where access to flood-free ground is lost during floods. Residents can be physically cut off from their home or workplace, which increases the risk of people entering floodwater.

Sustained isolation can affect the ability of residents or communities to function normally. They can also lose access to food and essential services such as water, sanitation and electricity. This increases the burden on emergency service providers to supply residents with basic needs and potentially risk the lives of their staff.

Councils should consult with their local floodplain management authority when undertaking strategic planning. This enables the specialist advice on flood behaviour to be considered along with the other matters that planners need to consider.

Redevelopment of existing sites can be challenging if the current use of the land permits intensifying urban development. Redevelopment often increases the area of impermeable surfaces, resulting in deteriorating water quality and increased flows in existing drainage systems. Clause 53.18 and Clause 56.07 in planning schemes provide guidance for how this can be addressed. Detailed modelling will usually be required to assess how development intensification affects flood behaviour.

Cumulative impacts

It is often difficult to estimate small changes in flood behaviour for individual development proposals. Over time these small changes accumulate, which can result in more frequent flooding if stormwater systems are overloaded. It can also increase the depth, velocity and extent of flooding.

Flood mapping that considers changes in flood behaviour for cumulative impacts can be useful for strategic planning. One way is to require flood modellers to adjust the ratio of impervious surfaces to pervious surfaces in their computer models. Another way is to require sensitivity testing of the impacts of increased development on flood behaviour, including the impact on stormwater drainage. Significant changes in flood behaviour may require structural works, such as retarding basins.

Levee protection

Well maintained levees can provide community protection to the 1% AEP standard (plus freeboard). The flood provisions on the "dry side of a levee" should only be removed if the drainage systems are able to fully control localised flooding.

Levees cannot be guaranteed to provide flood protection in all circumstances. Therefore, the emergency management plan for the affected community must provide for the potential for sudden and complete failure of that infrastructure.

Regulating buildings

The reduction of flood damage to buildings and their contents is also controlled through the *Building Regulations 2018.* The regulations adopt the *Building Code of Australia* with a few modifications.

Regulation 153 requires the consent of the council for a building permit if a site is subject to inundation. The council must specify a minimum floor level for the proposed building in consultation with the relevant floodplain management authority and assess the flood risk associated with the site. The council must not consent to a permit if it believes that there is a likely danger to the life, health and safety of the occupants of the building due to flooding of the site.

The council must specify a minimum floor level with a freeboard margin of at least 300 mm above the 1% AEP flood level, unless the floodplain management authority consents to a lower level. The regulations do not apply to a Class 10 building (non-habitable garage, carport or shed), an unenclosed floor area of a building or an extension to an existing building which is less than 20 square metres.

Regulation 154 requires the consent of the council for a building permit for a building on designated land or designated works. Designated land and designated works are defined in the Water Act.

Before giving its consent, the council must consult with Melbourne Water or the Catchment Management Authority.

Section 194 of the Water Act creates an offense for works which interfere or affect the quality, quantity or flow of water in designated land or works within an Authority's waterway management district.

Building standards

The *National Construction Code* requires that a building or structure does not collapse when subject to the action of liquids, ground water and rainwater ponding. A standard and handbook have been developed to provide more specific requirements for building construction in flood hazard areas. Deemed-to-satisfy provisions require buildings to be subject to flood velocities less than 1.5 metres per second. Above this threshold, the building must be designed by an expert to withstand flood impacts.

Floodplain managers do not have the expertise to assess the structural integrity of buildings. These guidelines do not address building design or building safety.

6. Applying the flood controls

This chapter provides a general overview of the process of preparing, assessing and reviewing planning permits, for the benefit of those unfamiliar with the planning system.

A planning permit allows a certain use or development to proceed on a parcel of land. It is required for most forms of development on flood affected land.

Development includes the construction, alteration or demolition of a building or works and the subdivision or consolidation of land.

A council will impose conditions when granting a permit and endorsed plans will also usually form part of the permit. The proposal must satisfy all the conditions on a planning permit.

For the benefit of those not familiar with the planning system, a simplified procedure of the process is illustrated in Figure 2. More detail is available in Chapter 3 *of Using Victoria's Planning System*. This includes guidance on:

- amending applications
- fast-tracking eligible proposals through VicSmart
- the role of VCAT in reviewing planning decisions or processes
- the time taken to assess applications
- special categories such as subdividing land, restrictive covenants, and earth and resources industries.

Applying for a planning permit does not guarantee that a permit should or will be granted. The council must decide whether the proposal will produce an acceptable planning outcome. Decisions are guided by planning policies in the planning scheme and the decision guidelines in Clause 65 of the planning scheme, the zone and the flood controls.

Feasibility advice

Consulting the relevant council before formally applying for a planning permit can be useful as:

- a planning permit may not be required
- the planning scheme may prohibit the proposed use
- it allows the applicant to focus on those aspects of the proposal which require a permit.

Discussing the initial plans with neighbours can ascertain concerns and modify the proposal before it is fully developed. This is not mandatory, but these discussions may avoid an objection at the application stage.

Seeking feasibility advice from floodplain managers can help an applicant refine or modify the proposal, to avoid potential rejection, or onerous conditions. The floodplain manager will be able to advise what information is required to help assess the proposal. This reduces the likelihood of being asked to supply additional information after a planning permit application is lodged.

As explained below, there are ways for flood advice to be considered without a need for a referral. This can reduce the time for the council to decide on the application.

Establishing good working relationships between councils and floodplain management authorities will enable the efficient use of knowledge and skills. Agreements can be established on what information is required by the floodplain manager and if there are local considerations that could influence decision making.

A request for flood advice can also come from the community, rather than from a municipal council, as:

- people interested in purchasing properties often want to understand the flood risk
- developers are interested in the likelihood of gaining approval for a development proposal.

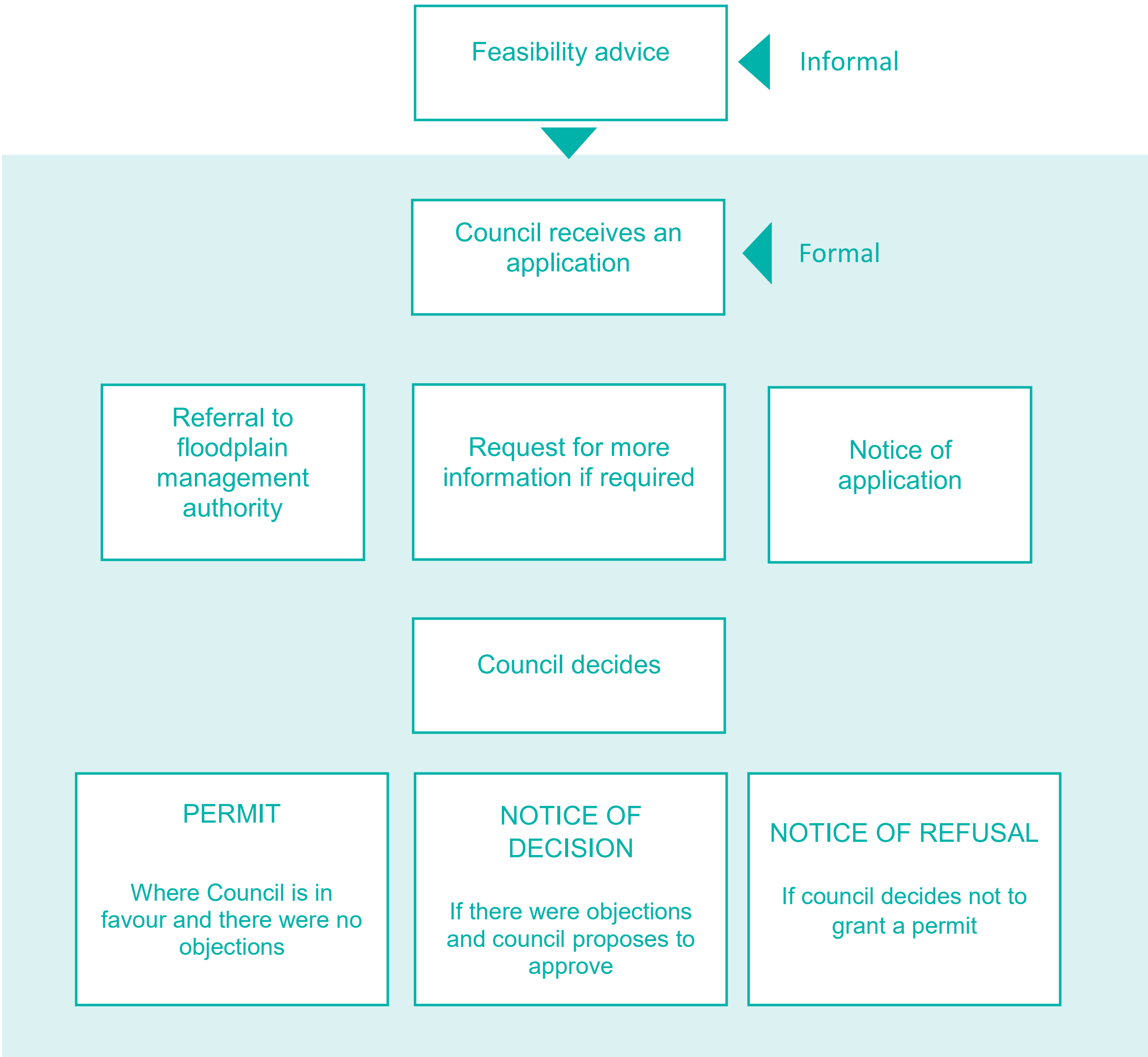

Figure 2: Applying for and assessing a planning permit

Receiving an application

An application must be made to the relevant council in accordance with the *Planning and Environment Regulations 2015* (the Regulations). The application must be accompanied by the prescribed fee and information required by the planning scheme. Before lodgement, it is helpful to check with the council planning officer that:

- the application is accompanied by any information required by the planning scheme
- an accurate description of the land has been given
- the proposal has been described satisfactorily
- it includes a copy of any registered restrictive covenant affecting the land
- the application addresses the state and local planning policies (see Chapter 5)
- the application addresses the relevant planning scheme provisions
- the application fee has been paid
- the applicant is the owner of the land or has notified the owner of the land about the application.

To avoid delay, proposals in flood affected areas should be supported by information about the property, what is proposed and how it could impact on flood behaviour. The following information, in the form of plans, cross sections, descriptions and any other data, should be provided, where relevant:

- the existing and proposed use of the site
- the number of people expected on-site during normal operations
- the existing natural surface levels and proposed finished surface levels (to Australian Height Datum)
- the existing and proposed buildings, including floor levels
- the existing and proposed earthworks, including crest levels
- the existing and proposed roads, including centre lines, kerbs, footpaths and crest levels
- the existing and proposed drainage systems, including waterways, pipelines, drains, culverts and bridges
- details of any other physical features that may affect flows, such as levees, fences and retaining walls.

Referral to a floodplain management authority

Floodplain management authorities are listed as referral authorities in Clause 66.03 of planning schemes. Section 55 of *the Planning and Environment Act, 1987* provides for planning permit applications to be referred to them.

The need for formal referral to the floodplain management authority can be avoided if:

- the authority specifies in writing that it does not object to the granting of a permit within three months before the council receiving an application
- in the council's opinion, the proposal satisfies requirements or conditions previously agreed in writing between council and the floodplain management authority
- there is an exemption in the schedule to an overlay.

Floodplain managers will assess the proposal against the guidelines, and any local considerations or guidance, and advise whether it:

- does not object to the granting of a permit
- does not object to the granting of a permit providing that certain conditions are included on the permit, or that certain matters are done to its satisfaction
- objects to the granting of a permit on specified grounds.

The floodplain management authority may also provide any other advice which it believes is relevant to the application and may assist the council in reaching its decision.

The Planning and Environment Act categorises referral authorities as either determining or recommending. If the floodplain management authority is a determining referral authority the council must refuse a permit, if this is the decision of the referral authority, or include its conditions of permit. A referral authority cannot direct a council to issue a permit.

In contrast, the council must consider a recommending referral authority's advice but is not obliged to refuse the application or to include any recommended conditions.

Request for more information

A council can require the applicant to provide more information about a proposal, either for itself or for a referral authority. A failure to provide this information can result in a planning permit application lapsing. An application that has lapsed cannot be recommenced.

Notice of application

The requirements for giving notice of an application are set out in section 52(1) of the Planning and Environment Act. This allows those potentially affected by the proposal to have the opportunity to make submissions or objections.

Floodplain management authorities may receive section 52 notices if the planning scheme does not list them as a referral authority. For example, the land may be flood affected but not identified in a flood zone of flood overlay.

Councils are responsible for giving notice of the application, or for requiring the applicant to give notice. It may involve a personal notice to owners and occupiers of nearby land, a notice in newspapers and signs placed on the site.

Council decides

After considering the proposal in relation to the requirements of the planning scheme, advice from the referral authorities and objections and submissions from those notified, the council makes its decision:

- If the council decides not to grant a permit it issues a Notice of Refusal.
- If the council decides to grant a permit and there were non-trivial objections, or if a condition proposed by a recommending referral authority is not included on the permit, it issues a Notice of Decision. If there are no requests for VCAT to review the decision within the prescribed time council issues a planning permit.
- If the council decides to grant a permit and there were no objections, it issues a planning permit.

What happens next

If an application for a permit is refused, the applicant can apply to VCAT for a review of the Notice of Refusal.

If a Notice of Decision to grant a permit is issued, objectors and recommending referral authorities can apply to VCAT for a review. A recommending referral authority can also appeal a Decision not to include a condition on a permit it requested.

These and other appeal provisions are described in Chapter 5 of *Using Victoria's Planning System*. They include a request to review a condition in the permit, and an application to cancel or amend a permit.

Depending on the outcome of the review, a planning permit may be refused, altered, or accepted.

Further guidance

More information is available through Planning Practice Note 11 (*Applying for a planning permit under the flood provisions)*.

Part Three - assessing development proposals

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7. Overview

Floodplain managers assess development proposals against four key objectives. Criteria have been developed to assess the impacts.

The development guidelines consider four objectives for demonstrating compliance.

***Objective 1 – Safety*:**

Protect human life and health and provide safety from flood hazard.

> Applies to all development proposals.

> Proposals that are unable to meet the safety objective will be rejected.

***Objective 2 – Flood damage*:**

Minimise flood damage to property and associated infrastructure.

> Applies to building proposals

> The objective is usually satisfied by setting floor level requirements as a condition of permit.

Objective 3 – Offsite impacts:

Maintain free passage and temporary storage of floodwaters.

> Applies to buildings and works in flow conveyance and flood storage areas, including those associated with a subdivision.

> The objective is usually satisfied by siting the works appropriately.

> Requirements are reinforced through conditions of permit. Sometimes design modifications are necessary.

Objective 4 – Waterway and floodplain protection:

Protect and enhance the environmental features of waterways and floodplains.

> Applies to subdivisions, buildings and works near waterways and those parts of the floodplain that are regularly flooded.

> The objective is usually satisfied by incorporating setbacks, works to prevent harm and appropriate vegetation into site plans.

> Requirements are reinforced through conditions of permit.

Compliance

The objectives respond to the decision guidelines and other matters in the planning scheme's flood provisions, described in Chapter 5.

All development proposals are to be assessed against the relevant objectives. Assessment is on merits, having regard for the flood risk.

Guiding principles and assessment criteria

Guiding principles for each objective describe what to look for when assessing a planning permit application. For example, when considering life, health and safety (Objective 1), a floodplain manager wants to know if the development is in the most appropriate location, whether the site and access is safe and if there are any hazardous materials.

Each guiding principle has one or more criteria, which are used to establish relevant requirements. Where the development proposal satisfies the relevant criteria, it is deemed to comply with the guiding principle.

Compliance against the guiding principle can be achieved in three ways:

- By setting a condition of permit that is consistent with the relevant criteria, for example, by setting a minimum floor level for a building.
- By requiring a design modification, for example by re-siting a building to a safer location on the site.
- By accepting what is proposed without change. For example, a development proposal might include plans that demonstrate compliance with site safety requirements.

Development having a low net impact

Some proposals can be so minor that there is no appreciable impact on flood risk (e.g. a small back-yard shed). Other proposals may not significantly add to the existing flood risk (e.g. a minor house extension). Usually the assessment criteria will take this into account.

Alternative solutions

A permit applicant may propose an alternative solution. If so, the proposal must demonstrate to the floodplain management authority's satisfaction that the relevant guiding principles and objectives can be achieved.

Solutions should be feasible and not pose a burden on future occupants or impact other properties. For example, a requirement for future occupants to keep open a flow path so that a building can be located over it is not acceptable. Likewise, it would not be appropriate for a flow path to be modified if it affects other properties.

Assessing proposals

Each objective, and the related guiding principles and assessment criteria, are discussed in detail in Chapters 8 to 11. Background information is also given, to assist decision making.

If floodway land has been identified in a planning scheme map, many forms of land use and development will be inappropriate or a prohibited use. This can simplify the assessment process.

Flood affected areas may be used productively when development proposals respond appropriately to the degree of risk. Land uses that promote significant development intensification can change the balance however.

Appendix 2 sets out, in general terms, how the different types of land use align with the four objectives and the associated assessment criteria. For consistency the land use terms in Planning schemes have been used.

The assessment criteria in Appendix 2 will not always be applicable. For example, the waterway protection objective will only be relevant if the proposed development impacts a waterway.

Construction adjacent to a creek in Bendigo

Credit: Ian Gauntlett, DELWP

8. Flood safety

When considering the risk to life, health and safety, a key determinant is when flood depths and flow velocities become unsafe. If a site or access is unsafe a planning permit will be rejected. If hazardous materials are present, they must be managed.

The most common cause of flood-related deaths is people drowning in their own properties, or when travelling to or from their properties. Less common causes of death are heart attacks and electrocutions.

Buildings and their foundations can be made safer through good design. It is not so easy to prevent cars, bikes or people attempting to move through floodwater to escape its effects.

The flood risk to life, health and safety of any person who will use or access a development includes:

- the effects of isolation and loss of essential services if access is cut off
- the danger to occupants of the development, other floodplain residents and emergency personnel.

Flood safety can be compromised if hazardous chemicals leach into the water. The Planning Policy Framework in planning schemes requires strategies to avoid contamination.

All development proposals must address Objective One.

Objective One: Protect human life and health, and provide safety from flood hazard

Guiding principle	Assessment criteria
Site and access safety must not be compromised	1.1. **Depth and flow**. Development should not be allowed on properties where the depth and flow of floodwaters would be hazardous to people or vehicles entering and leaving the properties. See Tables 1, 2 and 3.
Development must be located on sites of lowest overall hazard.	1.2. **Siting.** Development and access should be located on land with the lowest overall hazard.
Greenfield development sites must be designed to be safe from flood impacts.	1.3. **Greenfield development**. Greenfield development sites should either be flood free or contain building envelopes filled to the Nominal Flood Protection Level (NFPL - the 1% AEP flood level plus freeboard).
Hazardous materials must not contaminate floodwater.	1.4. **Hazardous materials**. Developments and uses which involve the storage or disposal of hazardous materials must not be located on floodplains unless the materials are totally isolated from floodwaters.
Vulnerable people must not be exposed to floods and facilities providing vital community or emergency services must be operational during floods.	1.5. **Vulnerability.** Buildings housing vulnerable people, community services facilities and emergency services should be sited outside the 1% AEP flood extent and, where possible, at levels above the height of the probable maximum flood.

Depth and flow

People attempting to enter or leave a property during a flood should not be endangered by deep or fast-flowing water. This includes emergency response personnel, property occupants and visitors.

The areas of most interest are:

- around building envelopes
- at entrance and exit points to buildings
- along driveways and internal connecting routes to outbuildings and car parking
- along external connecting routes leading to safety.

Buildings and their foundations must also be safe from collapse or erosion.

The depth and velocity of floodwaters are key determinants of flood safety. Table 1 shows the thresholds applying for the three categories.

Note that Table 1 does not apply to vulnerable community members such as infants and the elderly.

Table 1: Thresholds for safety of children, small cars and light buildings

Source: Adapted from Australian Rainfall and Runoff

Category	Maximum depth (D), velocity (V) and product (VD)		
	D max metres	Vmax Metres/second	VD max Metres^2/second
Children	0.5	3.0	0.4
Small cars	0.3	3.0	0.3
Light buildings	2.0	2.0	1.0

For still water situations, small cars can become buoyant at flood depths of 0.3 metres. Children (but not infants) are able to safely wade in depths of 0.5 metres. Lightly constructed buildings, such as dwellings, can safely withstand depths of flooding of 2 metres.

When flow velocities are high, lower depths apply. A maximum flow velocity of 2 metres per second has been adopted for site and access safety for all development proposals. This is considered the upper limit for lightly constructed buildings in *Australian Rainfall and Runoff*.

Note that the "deemed to satisfy" provisions of the building standard, *Construction of buildings in flood hazard areas,* applies a lower limit of 1.5 metres per second for the buildings subject to this standard. For higher velocities the building regulators require the buildings to be designed to withstand the forces from flood impacts.

All proposed development should satisfy the safety requirements specified in Tables 2 and 3. They are based on three categories:

- Building stability for residential development and other lightly constructed buildings.
- The safety of small children evacuating on foot.
- The stability of small cars being driven though floodwater.

The information in the tables considers research into flood behaviour on vehicles, people and buildings from *Australian Rainfall and Runoff*.

Table 2: Safety criteria for subdivision of land

Type	Maximum depth (D), velocity (V) and product (VD)			Applicable to
	D max metres	V max metres/second	VD max metres2/sec	
Greenfield residential	0.3	2.0	0.3	Entrance to lots and accessway
Other residential	0.3	2.0	0.3	Lots (including entrance) and accessway
Commercial or industrial	0.5	2.0	0.4	Lots (including entrance) and accessway
Agricultural, if it involves a proposal to construct a new dwelling	0.5	2.0	0.4	Entrance to lots

Table 3: Safety criteria for development other than subdivisions

If a building or works are not specified in the table, use a category that is similar, considering the scale, purpose and risk to future occupants.

Type	*Maximum depth (D), velocity (V) and product (VD)*		
	D max metres	V max metres/second	VD max metres2/second
Accommodation			
New single dwelling on vacant block	0.5	2.0	0.4
Replacement dwelling - less than 20 square metres increase in footprint	n/a	n/a	n/a
Replacement dwelling - more than 20 square metres increase in footprint	0.5	2.0	0.4
Dwelling extensions less than 20 square metres	n/a	n/a	n/a
Dwelling extensions greater than 20 square metres	0.5	2.0	0.4
Additional dwelling Dependent person's unit Group accommodation Residential building Residential village Retirement village Basement	0.3	2.0	0.3
Camping and caravan park:			
• Permanent sites	0.3	2.0	0.3
• Temporary sites where caravans can be quickly evacuated	n/a	n/a	n/a
• Other sites	0.5	2.0	0.4

Type	*Maximum depth (D), velocity (V) and product (VD)*		
	D max metres	V max metres/second	VD max metres2/second
Non-accommodation buildings, other than for an agricultural use or associated with car parking, outbuildings, sheds or carparking. Includes child care and education, industry, office, place of assembly, retail & warehouse			
Industrial building, office, place of assembly, retail building, or warehouse	0.5	2.0	0.4
Child care or education building (other than schools)	0.3	2.0	0.3
Replacement buildings or expansions – less than 130% of the original footprint	n/a	n/a	n/a
Replacement buildings or expansions – more than 130% of the original footprint	0.5	2.0	0.4
Agricultural buildings			
Buildings associated with grazing, crop raising and animal husbandry, including animal keeping, animal training and animal production. Excludes sheds and outbuildings	0.5	2.0	0.4
Sheds and outbuildings less than 40 square metres	n/a	n/a	n/a
Sheds and outbuildings greater than 40 square metres	0.5	2.0	0.4
Sheds and outbuildings (other than agricultural buildings) and car parking			
Shed used for domestic purposes	n/a	n/a	n/a
Carports, garages and non-domestic sheds associated with urban and low-density residential development	0.5	2.0	0.4
Replacement carports, garages, sheds and outbuildings	n/a	n/a	n/a
Non-domestic carpark enclosed by walls or similar barrier	0.5	2.0	0.4
Open air carpark without walls	0.5	2.0	0.4

Siting

It makes good sense to locate a building or building site on the highest available ground. However, access must also be considered. Low-level access can increase the evacuation risk to future occupants of the property. Locating development on land with the lowest overall flood hazard reduces exposure to the hazard.

Greenfield development

Greenfield development sites can increase the number of people exposed to a flood hazard. For safety reasons, the subdivided sites should be flood free. Depending on the scale of the development and the impact of fill on flood behaviour, this may not always be possible. The floodplain management authority may therefore agree to restrict fill to building envelopes in some instances. The accessway should be within the site safety criteria specified in Table 2.

Hazardous materials

Developments and uses can involve the storage or disposal of environmentally hazardous chemicals and wastes. The sources of such material include agricultural, industrial and sewage treatment uses.

Exposure to these materials can lead to serious contamination. The potential contact between such substances and floodwaters should be considered as part of the design of the building. Materials that could become pollutants should be stored above the NFPL. Some councils and floodplain management authorities may require storage above larger floods, such as the 0.5 per cent AEP flood.

Vulnerability

Some services need to function continuously and should be located outside the 1% AEP flood extent, and preferably above the Probable Maximum Flood. They include hospitals, ambulance stations, police stations, fire stations, transport or communications facilities, community shelters and schools. This is referenced in the Planning Policy Framework in planning schemes.

Buildings housing vulnerable people, including dependent persons' units and residential villages, should also be located outside the 1% AEP flood extent. Vulnerable people are defined in the glossary.

Where redevelopment is proposed, effort should be made to explore relocation to flood free areas. The applicant should provide evidence of why this has been ruled out, in documentation provided to the floodplain management authority. The applicant should also demonstrate how the flood risk can be reduced, and what contingency arrangements are in place if the site becomes isolated.

Car driving through floodwaters at Bendigo

Credit: North Central Catchment Management Authority

9. Flood damage

Buildings and their contents are susceptible to flood damages. This can result in trauma and economic loss. Raising floor levels, protecting basements and using flood resistant building materials are some options to reduce flood damage.

Buildings that require a planning permit must address Objective Two.

Flood damages

Tangible damages can be quantified, often in dollars. They include direct physical damage to buildings and fittings, and indirect damage arising from the disruption of normal social and economic activities.

Intangible damages are also important, but they cannot be expressed in monetary terms and are often difficult to quantify. They include loss of life, health impacts, loss of ecological values and social trauma. Intangible damages can be reduced if the economic costs of flooding are reduced.

The smaller, more frequent 'nuisance' floods don't usually cause as much damage individually as the larger floods, although the cumulative damage over time can still be significant.

When development occurs in flood affected areas, the flood damage potential must be considered.

Floor levels

Raising floors higher than the flood levels is the easiest way to reduce flood damage. When floors are overtopped valuable contents such as carpets, furniture, electrical appliances and furnishings are damaged.

When determining a minimum floor level, freeboard is added to the flood level estimate to provide certainty that the floors won't be inundated. The level obtained by adding freeboard to the flood level is called the Nominal Flood Protection Level (NFPL).

The cost or inconvenience of raising the floors of minor buildings or building alterations may need to be weighed against the flood damage prevented.

Freeboard

Freeboard is added to the 1% AEP flood level to provide reasonable certainty of a desired level of service. Floodplain management authorities will apply a range of freeboards, based on their assessment of flood behaviour and uncertainties in flood level estimates.

For a building not requiring a planning permit, the building regulations prescribe a minimum of 300 mm freeboard. The regulations do not apply to a Class 10 building (non-habitable garage, carport or shed), an unenclosed floor area of a building or an extension to an existing building which is less than 20 square metres.

If a planning permit is required, the floodplain management authorities apply a range of freeboard, typically 300 mm to 600 mm, depending on their assessment of flood behaviour. The higher freeboards can be a result of poor reliability of flood information, a steep and narrow catchment (the flood profile is steep), wave action or an allowance for long-term climatic effects.

Freeboard may be reduced for buildings with a low flood damage potential.

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Objective Two: Minimise flood damage to property and associated infrastructure

Guiding Principle	Assessment criteria
Buildings must not interfere with existing or proposed water, sewer or drainage services. (Applies to Melbourne Water or council).	2.1. **Water services**. Buildings and building envelopes should be located sufficiently away from a water, sewer or drainage asset to enable that asset to be serviced.
Buildings must be designed to avoid significant financial impacts of flood damage.	2.2. **Floor levels**. The floor levels of buildings should be set in accordance with Tables 4 to 6.
The basements of any new buildings must not flood.	2.3. **Basements**. Basements should be designed to be protected from flooding.
Those parts of buildings affected by flooding must be able to withstand the effects of inundation.	2.4. **Materials**. Any building or portion of a building below the 1% AEP flood level should be constructed from flood-resistant materials.
Services to a building must be capable of functioning during and after a flood.	2.5. **Building services**. Essential services to a building should be flood proofed or raised above the NFPL.

Water services

Melbourne Water and councils manage an extensive network of pipes and other infrastructure. Most, but not all, are on land owned or managed by Melbourne Water and the councils. Adequate distances between a building and the water service are required to protect the assets and to avoid encroachment. Formal approval is required from Melbourne Water to build, develop and renovate property on or near Melbourne Water assets.

Floor levels

Minimum floor levels for buildings are specified in Tables 4 to 6. This enables tangible flood damages to buildings and their contents to be avoided or reduced. Freeboard requirements are relaxed for minor development:

- where the flood damage potential is likely to be low
- where the cost and inconvenience of raising floors for building extensions is disproportionate to the benefits.

As it is not possible to foresee all circumstances, floodplain management authorities have discretion to relax floor level requirements, if appropriate, after considering:

- the building's purpose and flood damage potential
- how the flood damage potential can be kept as low as reasonably practical, e.g. by requiring storage areas above this level or locating a building to the highest feasible part of the site
- the ability of a future occupant to recover from a flood.

Basements

This criterion applies to buildings with basements, and associated lifts, vents and drainage systems. To avoid floodwaters entering the basement, all entry points should be protected. Entry to basements should incorporate a continuous apex (or crest) that is at the NFPL or higher.

Table 4: Floor level requirements

If a building is not specified in the table, use a category that is similar, considering the scale, purpose and risk to future occupants

Type	Minimum floor level
New or replacement dwelling	NFPL
Dwelling extensions	As specified in Tables 5 and 6
Dependent person's unit Host farm Group accommodation Residential building Residential village Retirement village Basement	NFPL
Permanent caravans or cabins	NFPL
Industrial building, office, place of assembly, retail building, or warehouse	NFPL
Child care or education building	NFPL
Leisure and recreation building	NFPL
Replacement buildings or expansions	NFPL
Buildings associated with grazing, crop raising and animal husbandry, including animal keeping, animal training and animal production. Excludes sheds and outbuildings	NFPL
Shed less than 20 square metres	None
Shed between 20 and 40 square metres	1% AEP flood level
Shed larger than 40 square metres	NFPL
Garage	1% AEP flood level
Carpark without walls	None

Table 5: Floor level requirements for dwelling extensions with existing floor levels below the 1% AEP flood level

Size of extension	If the difference between the 1% AEP flood level and the existing floor level is:	
	300 mm or more	Between 0 and 300 mm
	Set the floor level of the extension at:	
Up to 20 m^2	Existing floor level	Existing floor level
20 to 40 m^2	NFPL	Existing floor level
Greater than 40 m^2	NFPL	NFPL

Table 6: Floor level requirements for dwelling extensions with existing floor levels above the 1% AEP floor level

Size of extension	If the existing floor level is ……	
	Between the 1% AEP and the NFPL	Above the NFPL
	Set the minimal floor level of the extension at	
Up to 20 m^2	Existing floor level	Existing floor level
20 to 40 m^2	Existing floor level	Existing floor level
40 to 80 m^2	Existing floor level	Existing floor level
Greater than 80 m^2	NFPL	Existing floor level

Materials

Any building or portion of a building below the 1% AEP flood level should be constructed from flood-resistant materials. Floodplain management authorities may specify a condition of permit to this effect.

Some materials are not resilient to flooding. Waterlogging can reduce the strength of timber or cause warping. Plasterboard, insulation and heating ducts may require replacing after a flood and building cavities can fill with silt.

Floodplain management authorities may require those parts of a building to be constructed of flood resistant material to minimise flood damage. They are not building regulators and cannot advise on the choice of building materials.

Building services

Essential services are associated with the supply of electricity, gas, power, telecommunications, water supply, drainage and sewage. Apart from safety and contamination issues, they can be costly to repair or replace. Constructing new buildings or redeveloping old buildings provides an opportunity for essential services to function during floods. They are required to be flood proofed or raised above the NFPL.

Flood damages at Bridgewater, Jan 2011.

Credit: Rob Scholes, Bridgewater resident

10. Flood impacts

Development in flood affected areas can affect flow conveyance and flood storage. This causes flood levels and flow velocities to increase and may divert floodwater onto other land. Careful consideration to the location and alignment of buildings and the placement of fill can reduce the impacts.

Floodplains temporarily store floodwaters and allow for the passage of flood peaks downstream. The conveyance and storage functions of floodplains and flow paths interact to control the timing, duration and level of flooding at a site.

Works within the floodplain can alter flood behaviour by:

- Diverting flows to areas of land not previously subject to flooding.
- Constricting the passage of flows passing through the site along the river channel or flow path. This causes flood levels and flow velocities to rise at and upstream of the site.
- Reducing the volume of temporary storage within the floodplain. This results in a more rapid passage of floodwaters and an increase in peak flow in downstream reaches. Increasing the flow increases flood levels and flow velocities.

Reducing the effectiveness of flood conveyance or flood storage areas increases the risk of property damage to third parties. Important considerations are:

- The effect of increased flood depths and flow velocities. Freeboard for adjacent areas could be reduced. Erosion could be more prevalent. The area flooded could increase.
- The effect of flow diversions. There may be a change in flow direction.
- The cumulative impacts of lost flood storage.

The floodplain management authority will need to consider how sensitive the flow conveyance or flood storage areas are in relation to development. This will vary with location.

Earthworks, buildings or any other type of development that has the potential to affect flood storage or flow conveyance, must address Objective Three.

Objective Three: Maintain free passage and temporary storage of floodwaters

Guiding principle	Assessment criteria
The natural function of floodplains and overland flow paths to convey and store floodwater must not be compromised.	3.1. **Flow diversion**. Development (including earthworks) should not divert floodwaters to the detriment of any adjoining property.
	3.2. **Velocity impact**. Development (including earthworks) should not increase the flood velocity on any adjoining property
	3.3. **Flood level impact**. Development (including earthworks) should not increase flood levels on any adjoining properties.
	3.4. **Flood storage**. Earthworks and buildings should not result in a detrimental loss of flood storage.

Flow diversion

Floodwater will try to find a way around a blockage caused by inappropriately positioned earthworks or a building. This can also change the distribution of floodwater, which affects adjoining properties.

Floodplain managers will therefore look at the potential consequences of flow diversions when assessing development proposals. For example, drainage patterns may be altered because of the filling of land or obstructions.

Velocity impact

Obstructing flow paths will cause flow velocities near the obstruction to increase during a flood. This can result in scouring as floodwaters try and find a way around the obstruction, increasing the amount of sediment and debris downstream. It can also affect site safety.

Buildings or works that significantly obstruct flows should be realigned or moved away from the flow path. Replacement buildings should be designed so that their footprints are no larger than the original building.

Flood level impact

Obstructing flow paths will also increase flood levels locally, increasing the area flooded and increasing the amount of flood damage, particularly if above floor flooding occurs. Increases in flood levels can be avoided by reducing the amount of obstruction in flow paths.

Flood storage

Large buildings (relative to the size of the floodplain or overland flow path) reduce flood storage, as does landfill. Reducing flood storage can change flood behaviour. Floodplain managers will seek to minimise the amount of fill, reduce a building's footprint or require construction on elevated footings in preference to slabs on the ground.

Flow conveyance

Flow conveyance can be adversely affected by changes to the cross-sectional flow area, grade or alignment of the flow path. This increases flood levels and flow velocities. Not interfering with existing flow paths will minimise a development's impact on flow conveyance (see Figure 3).

Increases in flow velocity and the flood level are influenced by the size of the obstruction relative to the size of the flow path. Mesh fencing and bridges can also have adverse effects. The cumulative effects are important: the more obstructions, the greater the impact.

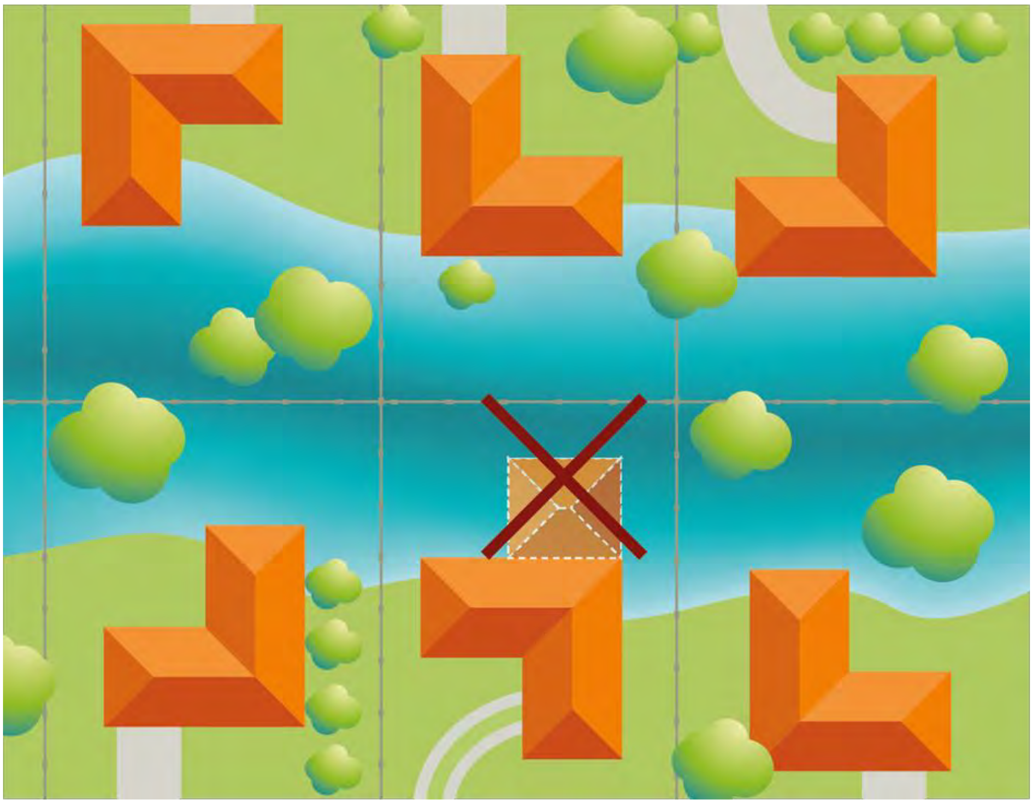

Figure 3: Impacts on flood flows

Flood storage

Flood storage is the volume available to temporarily store water during a flood. It is a natural function of the floodplain and can also be significant in areas subject to overland flooding.

The temporary storage of floodwaters commences before the peak of the flood event. It reduces the peak flow rate at and downstream of the storage area, delays its arrival and reduces the size of the flood.

Reducing flood storage can change flood behaviour at the site and other properties (see Figure 4). This affects flood levels, flow velocities, how long flood waters are around for and how quickly floodwaters rise and fall. As with flow conveyance, the cumulative impacts of proposals that reduce flood storage are important.

Flood storage is reduced by filling of land to raise a property above the flood level. It can also be reduced by the construction of the building itself.

The effect of development depends on the scale of the development relative to the size of the flood storage area. Multiple developments will have a cumulative impact.

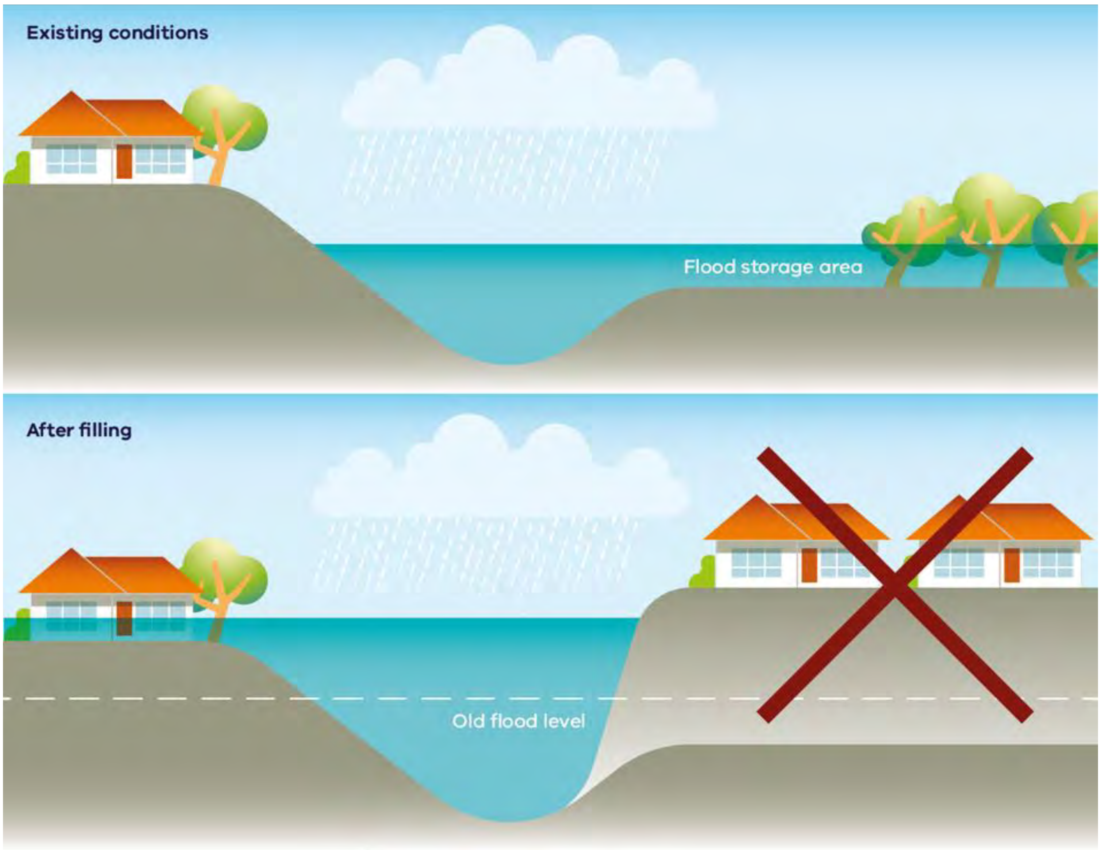

Figure 4: Impacts on flood storage

11. Waterway and floodplain protection

Waterways often have natural environmental values. Floodplain managers will examine development proposals for their potential impact, to preserve or enhance these values.

Waterways are rivers and streams, those parts of estuaries and floodplains that are associated with them (including floodplain wetlands) and non-riverine wetlands. A more comprehensive definition is given in the Water Act.

Protecting the form and function of waterways, particularly riparian corridors and those parts of the floodplain that are regularly flooded, also protects their benefits. Not least of these is the natural benefit of storing and slowing the progression of floods through catchments and low-lying areas.

Other benefits include:

- providing water to communities
- offering recreational, landscape and amenity values
- improving water quality and filtering nutrients
- preserving stream habitat and wildlife corridors
- providing cultural connectivity to Traditional Owners and Aboriginal Victorians
- replenishing ground water
- reducing erosion of stream banks.

By maintaining or improving waterway and floodplain condition, the values provided can be preserved for both current and future generations.

Works on waterways licences may be required to provide for the protection and enhancement of the environmental qualities of waterways and their instream uses.

Access to an authority's assets

Separate approval may be required from Melbourne Water, Catchment Management Authorities and councils for any connections to, crossing of or work near floodplain management assets, waterways, water supply and drainage assets. This may include bridges, pathways, sewers, jetties and moorings.

Development that has the potential to adversely affect the environmental benefits provided by waterways and floodplains must address Objective Four.

Objective Four: Protect and enhance the environmental features of waterways and floodplains

Guiding principle	Assessment criteria
Development impacting on waterways and floodplains must consider their environmental qualities.	4.1. **Waterway and floodplain condition**. Development should maintain or improve waterway and floodplain conditions.
	4.2. **Access to riparian corridors.** Development should allow access to maintain riparian corridors.
	4.3. **Water quality**. Development should maintain or improve water quality.
	4.4. **Natural function**. Development should maintain (by avoidance or offset) the natural function of floodplains and waterways in storing and conveying floodwater.
	4.5. **Amenity**. Development should retain or improve significant vistas or landscapes within the riparian corridor.

While described separately, the five assessment criteria are interlinked. Design plans that show modifications to waterways to compensate for increased runoff, vegetation, the location of paths, etc. will provide a means of ensuring that the assessment criteria are addressed holistically.

The impacts of development can include erosion, altered flood behaviour, loss of habitat, a reduction in water quality and a reduction in species diversity. Site disturbance can create conditions that lead to native vegetation being displaced with weeds and woody debris, such as willows, which choke the waterways.

Waterway and floodplain condition

Waterway condition is an umbrella term for the overall state of key features and processes that underpin functioning ecosystems. They include:

- the number and diversity of species associated with riparian and aquatic flora and fauna, and their habitat and connectivity
- water quality
- the physical form of the waterway, including waterway and bank stability
- waterway environs and continuity of a vegetated corridor
- ecosystem processes such as nutrient recycling and carbon storage.

All forms of development have the potential to negatively impact the condition of waterways or floodplains. For example:

- Stormwater drainage systems can alter the frequency of water flows and cause unnatural flow behaviour and may contain contaminants and pollutants that affects water quality.
- Earthworks can result in loss of wetlands that provide both essential habitat for fauna and flora but also significant natural flood mitigation services by reducing runoff and peak flows.
- Earthworks and building construction can result in vegetation removal, cause increased erosion and pollute waterways.
- Development too close to a waterway can reduce the riparian zone, impede access and reduce amenity values.

If a proposal is located in a Floodway Overlay or Land Subject to Inundation Overlay, the floodplain manager will look at how a development proposal impacts on waterway and floodplain condition. If located in a waterway with natural drainage corridors, the development should support the retention of vegetation corridors, in accordance with the Planning Policy Framework (see Chapter 5).

Access to riparian corridors

Land that adjoins rivers, creeks, estuaries, lakes and wetlands is known as riparian land (often called 'frontage'). Riparian land can vary in width from a narrow strip to a wide corridor and is often the only remaining area of remnant vegetation in the landscape. Riparian corridors provide habitat for rare or threatened species, connecting larger patches of remnant vegetation and a corridor for the movement of animals and native plants.

Riparian land is valued for recreational activities and tourism. It also provides sites of significance to Aboriginal people.

Paths and waterway access can be incorporated alongside waterways for maintenance and recreational access. The two functions can often be combined. Sometimes councils may have requirements for recreational trails or shared paths.

Water quality

Water quality can be affected if development occurs. Several requirements are specified in planning schemes for stormwater management and integrated water management (e.g. Clause 56.07 of planning schemes). Floodplain managers may specify conditions of permit that are consistent with these requirements. For example:

- Establishing waterway corridors and paying close attention to drainage discharge points allow for surface runoff to be filtered.
- Designing waterway features to reduce stagnation will discourage algal blooms and mosquito infestation.

Natural function

Urban development results in significant changes to the amount of stormwater runoff into waterways. It is good practice to:

- design and construct drainage features that mimic natural conditions
- maintain flow behaviour to pre-development conditions
- avoid erosion and excessive sedimentation.

Amenity

Past practices of converting minor drainage lines into straight line concrete channels are no longer an appropriate design solution. Constructed waterways, that slow water down, meander, preserve or enhance remnant vegetation and allow public access are preferred.

12. Design responses

In this chapter, general guidance is provided for certain types of development. This is intended to supplement the guidance in Chapters 8 to 11.

Basements

If basements are proposed, the flood risk, site constraints and ease of entry needs to be considered. Access points need to comply with the site safety requirements specified in Table 3 and the ramp must be designed so that vehicles can safely enter and leave the basement. It is good practice for:

- entry and exit points to incorporate a continuous apex set to the NFPL or higher.
- the drainage system to be designed so that external flooding (both above ground and within any piped system) is unable to penetrate the basement area
- vents, staircases, lift wells and any other openings to be designed so that they not act as floodwater inlets to the basement.
- signage to be provided indicating potential to flood in extreme events.

The use of demountable barriers, pumps or other mechanical mechanisms to provide flood protection is not supported because of the risk of malfunction or operational issues.

Buildings

Building materials located below the NFPL can be susceptible to deterioration, corrosion or decay if inundated. This can compromise the safety and function of the building. Factors to consider are the time in contact with floodwater and the time to dry out.

If there are doubts on the structural integrity of those parts of a building below the NFPL, professional advice should be sought.

Buildings with flood affected areas below the ground floor should be free draining and resistant to scour, silt build up and erosion. This reduces clean-up costs.

Enclosures and storage rooms below the NFPL should not be supported as they can often get converted into habitable rooms.

Access to building services (water, sewerage, drainage, etc.) should be preserved by reserves, easements or development setbacks.

Safe access to buildings can often be provided by reshaping land to reduce the depth of flooding near its entrances. To avoid the possibility of cars floating into deeper floodwaters, it may be feasible to include barriers such as trees between the low and high hazard parts of a site.

For building proposals in sensitive flow conveyance or significant flood storage areas, some of the things that could be considered to lessen impacts include:

- using elevated footings in preference to slabs on the ground
- locating or realigning a building to allow for an unobstructed flow path parallel to the direction of the flow
- restricting the size of a building's footprint.

Camping and caravan parks

New permanent caravan or cabin sites have a similar function to house sites in new residential estates, with similar safety issues. If flood-free sites are unavailable, flood emergency plans that provide for safe evacuation are essential.

Carparks

Carparks which are enclosed on all sides by a wall or similar barrier can pose safety risks. Design plans need to demonstrate that car movement can be safely managed, and that people cannot be trapped in a carpark or lift well.

Cut and fill

As noted in Handbook 7, some development proposals will seek to balance fill with compensatory excavation. Flood storage created through excavation will be lost if the excavated area fills with floodwater before the flood peak arrives.

Floodplain managers will need to be satisfied that:

- Flood levels or flow velocities do not increase. A range of floods must be considered.
- The area excavated, and the area filled do not significantly change the cross-sectional area perpendicular to the flow.
- The excavated area is not filled before the arrival of the flood peak.

If the amount of fill is substantial, the developer may be required to provide expert advice. Geotechnical experts must demonstrate that the relevant slopes are stable and safe, and that filled areas are compacted correctly.

Modelling may be required for large developments. A floodplain manager may require more cut than fill to compensate for uncertainties in flood behaviour.

Fences

Designing a fence in a flow path to be more resistant or resilient to flood debris and high velocities may reduce future flood damage See *Guidelines for riparian fencing in flood-prone areas*. Open style fencing is encouraged.

Flood protection structures

Permanent or temporary flood walls, flood barriers, levees or other flood protection structures are sometimes proposed for new development. Their purpose is to reduce the costs of new building and infrastructure construction or to make development sites more viable. They are not fail safe and should only be considered for protecting existing development. They should not be used to justify new buildings or roads in unsafe locations or to offset floor level requirements for new buildings.

Greenfield development

Greenfield development involves urban expansion for residential, industrial or commercial purposes (the glossary provides a detailed definition). Proposals need to:

- Consider the hazard over the internal roads and the public roads leading to safety.
- Avoid isolation during floods.
- Avoid situations in which vehicles can be swept into areas of deeper flooding.
- Consider the effect of floods larger than the 1% AEP event. Flow paths that are safe during lesser events may lead to catastrophic flooding for these rarer events.
- Avoid active flow paths and areas downstream from retarding basin overflow paths.

Safe access for infill development

Proponents for infill development or redevelopment usually have no control over the access from the site to safe ground. This can be challenging for communities with a high flood risk. Requiring a shop floor to be built 1.5 metres above the footpath creates access issues for those unable to use stairs, for example.

Proposals that increase the population at risk should follow the requirements for safe access. For example, subdivision in a residential area should not be supported if the depth and velocities exceed the thresholds in Table 2, because it increases the population affected. Likewise, Table 3 provides restrictions to buildings in unsafe areas: replacement structures and small expansions are acceptable, but not other development.

Wherever possible, the criteria relating to floor level heights should be followed, particularly for dwellings. As can be seen from the example of a shop, there may be instances in which floodplain managers use their discretion to reduce minimal floor level requirements, after considering:

- the scale of the proposal and its purpose
- site constraints
- the amount of flood warning time
- the distance to safe ground.

Where discretion is exercised, a flood emergency plan may be required. The plan sets out appropriate actions to minimise flood damage, risk to occupants, and demands on emergency services.

Subdivisions

To reduce flood conveyance or flood storage impacts, a subdivider may be required to restrict the size of fill pads and specify building envelopes.

Residential subdivision applications are also required to comply with Clause 56 in planning schemes. This includes requirements to manage stormwater.

Sediment and other wastes may need to be filtered before its discharge into waterways, through wetlands, retention basins or other works. Stormwater runoff may also need to be retarded.

Vulnerable people

Vulnerable people depend on others for mobility and basic needs. Wherever possible, buildings for vulnerable people should be located well outside the area affected by the 1% AEP flood.

If this is not possible, the practicality and convenience of community access to significant facilities, such as hospitals, needs to be balanced against the flood risk. Highest priority must be given to the safety of future occupants.

Decision makers need to consider each application on merits, having regard for:

- the scale of the proposal
- its purpose

- the availability of alternate safe sites
- the inconvenience of relocation if an expansion is required
- the community value of the service provided
- the consequences to the community should a proposal be rejected
- the impacts on emergency services
- the effect of isolation.

If it is considered appropriate to support a proposal, increasing freeboard and having an effective emergency management plan in place can help offset safety concerns.

Waterways

It is good practice to improve waterway condition and landscape. Development may affect waterways because of stormwater connections or because it adjoins a waterway. Land use and development proposals should minimise nutrient contributions to waterways and water bodies and the potential for the development of algal blooms.

Existing flow paths and natural floodplain features should be retained in most instances. Development should be sympathetic to the local waterway corridor landscape and seek to improve amenity values. Indigenous riparian vegetation should be used for any revegetation of riparian corridors.

Waterway setbacks

Waterway setbacks, in the form of reserves and easements, provide access to protect and improve waterway condition. They also retain the natural drainage function of waterways, especially ephemeral waterways that have a significant role in flood storage.

In determining an adequate setback, consideration should be given to:

- the condition of the waterway
- its environmental and social values
- the potential for trees or limbs to fall in backyards or on buildings
- the potential for river banks to collapse: this can affect properties outside the 1% AEP flood extent
- Clause 14.02 in the Planning Policy Framework in planning schemes
- whether access is desirable for recreational purposes or to maintain riparian vegetation.

The design of constructed waterways should, wherever practical, mimic the natural stream forms in the immediate region. Two Melbourne Water guidelines are listed in the bibliography.

Evergreen Waters estate, Bendigo

Credit: North Central Catchment Management Authority

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Glossary

1% AEP flood: a large flood having a 1% chance of occurring in any given year.

Accessway: a path, route, etc. that provides access to a specific destination or property. This includes legally protected routes through private land and public roads.

Accommodation: Land used to accommodate persons. It includes land associated with the following uses (Victoria Planning Provisions): camping and caravan park, corrective institution, dependent person's unit, dwelling, group accommodation, host farm, residential building, residential village and retirement village.

Adjoining property: All public and private land that is not part of the development site.

Annual Exceedance Probability (AEP): The likelihood of occurrence of a flood of a given size or larger happening in any one year. AEP is usually expressed as a percentage, e.g. 1% AEP.

Assessment criterion: An approach, action, practice or method that permit applicants to demonstrate compliance with the guiding principle.

Average Recurrence Interval (ARI): A statistical estimate of the average number of years between the occurrences of a flood of a given size or larger. The ARI of a flood event gives no indication of when a flood of that size will occur next.

Building envelope: The area on a site where new buildings or extensions to existing buildings are proposed.

Catchment: The area of land draining to a site. It always relates to a specific location and includes the catchment of the main stream and tributary streams.

Coastal flooding: Flooding of low-lying areas by ocean waters caused by higher than normal sea level, due to tidal or storm-driven coastal events, including storm surges in lower coastal waterways.

Community services facilities: Buildings providing services that a community expects to be either resilient to or fully operational during an extreme flood. They include hospitals, residential aged care facilities, community shelters and schools.

Consequence: The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse, e.g. death or injury to people, damage to property and disruption of the community, or beneficial, e.g. activation of seasonal wetlands or depositing of nutrients on agricultural floodplains.

Design flood: The flood selected for design and planning purposes that is used to define the flood zone. In Victoria, for most types of development, this is the 1% AEP flood (or 100 year ARI flood).

Development: The construction or exterior alteration or exterior decoration of a building; the demolition or removal of a building or works; the construction or carrying out of works; the subdivision or consolidation of land, including buildings or airspace; the placing or relocation of a building or works on land; and the construction or putting up for display of signs or hoardings (*Planning and Environment Act, 1987)*.

Domestic: Of the home, household.

Emergency services facilities: buildings expected to remain fully functional during floods up to the Probable Maximum Flood. They include ambulance stations, fire stations and police stations.

Essential Services: For these guidelines, means the supply of electricity, gas, power, telecommunications, water supply, drainage or sewerage services

Flood: For these guidelines, the covering of normally dry land by water. The insurance industry considers flooding to be water that has escaped or been released from the normal confines of: (a) a lake, river, creek or other natural watercourse, whether or not altered or modified; or (b) any reservoir, canal, or dam.

Flood affected land: Land inundated by the 1% AEP flood from time to time.

Floodplain: Low-lying land adjoining a waterway (e.g. an open river creek or drainage path) that is covered by water when the river overflows during floods. The extent of the floodplain is defined as the area of land inundated during a Probable Maximum Flood.

Floodplain management authority: In Victoria, a Catchment Management Authority or Melbourne Water.

Floodplain manager: Usually a member of a floodplain management authority, but sometimes a member of a local council. A floodplain manager has the skills, knowledge and expertise to assess flood behaviour and flood risk.

Flood proofing: A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural damage and, sometimes, to reduce contents damage.

Flood-resistant materials: Materials used in building construction that are capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage.

Flood risk: The potential risk of flooding to people, their social setting and their built and natural environment. The degree of risk varies with the circumstances across a range of flood events, not just the 1% AEP flood.

Flood storage: An area of the floodplain or drainage area important for the temporary storage of floodwater that is later discharged as the flood recedes.

Flow: The rate of flow of water measured in volume per unit time; for example, cubic metres per second (m^3/s). Flow is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example metres per second (m/s).

Freeboard: The height above the design flood level. It is a factor of safety typically used in relation to the setting of floor levels, apex of underground carpark entrances and so on. Freeboard compensates for a range of factors, including wave action and localised flow effects. It can also compensate for uncertainties in the accuracy of the 1% AEP flood level estimate.

Greenfield development: For these guidelines, greenfield development refers to intensification of development of a completely different nature to that associated with the former land use. It can be for a residential, industrial or commercial purpose.

Greenfield development requires major extensions of existing urban services, such as roads, water supply, sewerage and electricity, and can include or lead to detached or semi-detached dwellings in new residential 'estates'. Building sites and access routes need to be kept safe from flooding so that the flood risk to future occupants does not intensify. Associated land may require rezoning, or it might be land set aside for urban development without necessarily understanding the flood risk.

Guiding principles: Rules to help a decision maker understand how the relevant objective they are linked to can be applied.

Hazard: An object, situation or event that presents danger to life, health or safety. A flood is considered a hazard because it has the potential to cause damage to people and the community.

Infill development: For these guidelines, infill development refers to the development of vacant blocks of land within an existing township boundary that are generally surrounded by other developed properties. To avoid confusion, infill development and redevelopment are treated in the same manner in these guidelines.

Inundation: The covering of land by water.

Nominal Flood Protection Level (NFPL): The 1% AEP flood level plus the applicable freeboard.

Objective: The desired outcome to be achieved.

Outbuilding: a building subordinate to but separate from a main building.

Overland flooding: Inundation by local runoff caused by heavier than usual rainfall. It can be the result of local runoff exceeding the capacity of an urban stormwater drainage system or water backing up urban stormwater drainage systems. In rural settings it can also be flow overland on the way to waterways.

Probable Maximum Flood: The largest flood that could conceivably occur at a location. It is usually estimated from the greatest depth of precipitation meteorologically possible for that location, coupled with the worst flood-producing catchment conditions.

Redevelopment: For these guidelines, redevelopment means any rebuilding or improvements to an existing development on a site that has pre-existing uses (as defined by the relevant zone in the planning scheme). It can include subdivisions.

Redevelopment generally does not require either rezoning or major extensions to urban services, such as roads, water mains, sewer lines or electricity cables.

While redevelopment is often associated with urban communities, it can also include farming-related activities to boost tourism and business, as permitted in the relevant farming and rural activity zone.

Riparian zone: Land that adjoins a river, creek, estuary, lake or wetland.

Riverine flooding: The covering of normally dry land by water that has escaped or been released from: the normal confines of a lake, river, creek or other natural watercourse (whether or not altered or modified); or a reservoir, canal or dam.

Runoff: The amount of rainfall that is not intercepted, captured or absorbed into the ground during a storm and that subsequently runs along the ground surface. It is also known as rainfall excess.

Planning Policy Framework: The principles, policies and strategies in the Victoria Planning Provisions, for how land is to be used and developed in Victoria. It includes mandatory state-wide components. For example, the State planning policy for floodplain management is to protect life, property and community infrastructure, and to protect areas of environmental significance and river health. The policy requires land affected by a 1% AEP flood to be identified in Planning Scheme maps and for planning decisions to avoid intensifying the impacts of flooding through inappropriately located uses and developments.

Stormwater flooding: overland flooding associated with urban drainage systems.

Storm surge: A rise above the normal sea level along a shore resulting from strong onshore winds and or reduced atmospheric pressure. Storm surges can be formed by intense low-pressure systems.

Subdivision: the division of land into two or more parts which can be disposed of separately (*Subdivision Act 1988*). For these guidelines, subdivision also includes proposals to set aside building envelopes or fill pads.

Waterway: Rivers and streams, their associated estuaries and floodplains (including floodplain wetlands) and non-riverine wetlands.

Victoria Planning Provisions: A comprehensive set of standard planning provisions, including compulsory State policies and strategies, and zones and overlays used locally. They provide a standard format and consistent policies and controls for all Victorian planning schemes.

Vulnerable people: For these guidelines, individuals or groups of individuals who are dependent on more able people for mobility and basic needs. They include the elderly, infirmed, mentally or physically incapacitated, incarcerated and very young children.

Works: Includes any change to the natural or existing condition or topography of land including the removal, destruction or lopping of trees and the removal of vegetation or topsoil.

Acronyms

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
NFPL	Nominal Flood Protection Level
PMF	Probable Maximum Flood
VCAT	Victorian Civil and Administrative Tribunal

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Appendix 1: Information on flood fatalities

The Bushfire & Natural Hazards Cooperative Research Centre examined the socio-demographic and environmental circumstances surrounding flood fatalities in Australia, between 1900 and 2015. Of the 1859 documented flood fatalities:

- 787 were attempting to cross a bridge, culvert, ford or similar structure
- 77 were attempting to cross floodwaters over normally dry land away from watercourses
- 215 were engaged in an activity near the water (e.g. on the river bank or on a bridge)
- 49 were engaged in an activity in or near a stormwater drain
- 116 were engaged in an activity in the water, such as rescue or swimming
- 93 were engaged in an activity on the water, such as boating
- 226 were engaged in an activity not near a watercourse: this includes 136 in or on a house that was destroyed or severely flooded, and 54 outside a house
- 6 died from other causes
- 290 died from unknown causes.

The CRC research also looked at other factors.

Cause of death

- 54.9% of people were recorded as dying from drowning
- 33.1% of people were likely to have died from drowning or from circumstances that led to drowning (such as exposure and heart attack)
- 3.1% died from other causes such as being hit by flood debris or submerged objects, landslide, vehicle accidents, falling tree limbs, shock, collapse or electrocution
- 8.9% died from unknown causes or were missing and presumed dead.

Flood awareness:

- 12.8% were aware of the flood but did not expect to encounter it (e.g. walking their dog on the riverbank)
- 43.6% were aware, but the depth, speed and / or debris took them by surprise
- 13.2% were unaware and taken by surprise
- 15.5% were children less than 11 years old (limited understanding, or a parent made the choice)
- the awareness of the remaining 14.9% was unknown.

Flood type

- 71.3% of fatalities occurred near the coast. Most were associated with short duration riverine flooding with little or no flood warning.
- 15.9% of deaths occurred along inland rivers (extensive, slow moving flooding)
- 7.6% occurred in an urban setting (stormwater flooding).

Flood severity

- 33.8% of fatalities occurred in a minor/moderate flood
- 13.1% occurred in a major flood
- 22.7% associated with a severe or record flood
- for the remainder, the link to flood severity was unknown.

Death rates have steadily declined over the years. Looking at a more recent time, from 2000 to 2015, there were 178 deaths: 16 of these in Victoria.

- 53.4% (95 people) died while attempting to cross a watercourse
- 11.2% (20 people) died in an activity not near a normal watercourse
- 48.3% (86 people) were in a vehicle at time of death
- 25.3% (45 people) were on foot.

Appendix 2: Specific development requirements

Development type	Assessment criteria for the following objectives			
	Flood safety	Flood damage	Flood function	Waterway protection
Subdivisions				
Subdivisions that provide for earthworks	1.1 - 1.3	2.1	3.1 - 3.4	4.1 - 4.4
All other subdivisions	1.1 - 1.3	2.1	3.1 - 3.4	4.1 - 4.4
Accommodation building other than minor buildings and works				
Dwelling or dependent persons unit	1.1 - 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Dwelling extension	1.1 - 1.2	2.1 – 2.5	3.1 - 3.4	4.1 - 4.4
Extensions to an accommodation building other than a dwelling	1.1 – 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Retirement village	1.1, 1.2 & 1.5	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Residential building: E.g. backpacker's lodge, boarding house, hostel, nurses' home, residential aged care facility, residential aged care facility, residential college, residential hotel	1.1, 1.2 & 1.5	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Camping and caravan park: permanent buildings, permanent caravans and permanent cabins	1.1 - 1.2	2.1, 2.2, 2.4 & 2.5	3.1 - 3.4	4.1 -4.4
Camping and caravan park - temporary accommodation sites where sites can be quickly evacuated	Nil	Nil	Nil	4.1 - 4.4
Agriculture				
Buildings associated with grazing, crop raising and animal husbandry, including animal keeping, animal training and animal production	1.1, 1.2 & 1.4	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Child care and education				
Child care centre	1.1, 1.2 & 1.5	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Education centre (other than schools)	1.1, 1.2 & 1.5	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Industry				
Research and development centre	1.1, 1.2 & 1.4	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Rural industry	1.1, 1.2 & 1.4	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Service industry	1.1, 1.2 & 1.4	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Office				
E.g. bank, electoral office, medical centre, real estate agency, travel agency	1.1 - 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Place of assembly				
Exhibition centre, function centre, nightclub, cinema, library	1.1 - 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Place of worship, restricted place of assembly	1.1 - 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4

Development type	Assessment criteria for the following objectives			
	Flood safety	Flood damage	Flood function	Waterway protection
Retail				
Food and drink premises	1.1 - 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Gambling premises	1.1 - 1.2	2.1.- 2.5	3.1 - 3.4	4.1 - 4.4
Market	1.1 - 1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Motor vehicle, boat or caravan sales	1.1-1.2 & 1.4	2.1 – 2.5	3.1 - 3.4	4.1 - 4.4
Shop	1.1-1.2 & 1.4	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Hardware, trade, agricultural supplies	1.1, 1.2 & 1.4	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Warehouse				
Commercial display area	1.1-1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Mail centre	1.1-1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Store	1.1-1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Car parking, outbuildings and works				
Non-domestic carpark enclosed by walls	1.1-1.2	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4
Open air carpark not attached to a dwelling or residential building	1.1-1.2	Nil	Nil	4.1 - 4.4
Outbuilding (including a shed) less than 20 square metres	1.2	2.1, 2.2 & 2.4	3.1 - 3.4	4.1 - 4.4
Outbuilding greater than 20 square metres	1.1, 1.2 & 1.4	2.1, 2.2, 2.4 & 2.5	3.1 - 3.4	4.1 - 4.4
Carport	1.1, 1.2	2.1, 2.4	3.1-3.4	4.1-4.4
Small flood-protection levee around immediate curtilage of existing rural dwelling or other rural building	Nil	2.1	3.1 - 3.4	4.1 - 4.4
Earthworks not associated with a development type listed above	Nil	2.1	3.1 - 3.4	4.1 - 4.4
Fencing	Nil	Nil	3.1 - 3.3	4.1 - 4.4
Emergency and community service facilities				
Emergency and community services facilities, including hospitals, ambulance stations, fire stations, police stations, residential aged care facilities, community shelters and schools	1.1, 1.2, 1.4 & 1.5	2.1 - 2.5	3.1 - 3.4	4.1 - 4.4

Notes

1. If a proposed building or works are not specified in the table, use a category that is similar, considering the scale, purpose and risk to future occupants.
2. The assessment criteria listed won't apply for all circumstances. Assess against the net increase in risk, considering the population exposed to flooding, the vulnerability of occupants and the relevance of the guiding principles.