Colac Otway Shire

Engineering Drainage and Apportionment Analysis

Apollo Bay

REP/221842/Rev1

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1 Executive Summary

This study has been undertaken by Arup Pry Ltd (Arup) as Contract 1110-Engineering Drainage Design and Apportionment Analysis – Apollo Bay (Contract). The performance of the drainage system has been addressed. Some specific drainage problem areas identified by the Client in the inception meeting have also been analysed.

The catchment plan was prepared using the software package CatchmentSIM. The drainage modelling was carried out with the help of the standard software package 12d.

In consultation with the Client, Arup has considered possible options to improve the drainage system to handle 1:10 year flow for residential and 1:20 year flow for commercial areas, respectively. The options are:

Option 1: Existing alignment;
Option 2: Twin outlets;
Option 3: McLachlan St Diversion (Diversion);
Option 4: Twin outlets plus Diversions; and
Option 5: Retardation through a temporary storage.

The study has resulted in following main conclusions:

- The drainage system in its current state cannot handle design flows;
- The specific drainage problems exist because of the inadequate capacity of the drainage system;
- The retardation option (Option 5) is not effective;
- A combination of twin outlets and McLachlan St Diversion (Option 4) is the most effective option for solving the drainage problems;
- The capacity of the drainage system will have to be increased further (to the recommendations for Option 4) to address impacts of the climate change;
- The drainage outlet can be raised by 0.8 m if the system is designed to cater for climate change.

2 Introduction

Colac Otway Shire (Client) commissioned Arup through its letter dated 23 May 2011 to undertake work on the Contract. The inception meeting with the Client took place in Apollo Bay on 2 June 2011.

Some problem drainage areas of Apollo Bay (Section 4) were discussed in the inception meeting. The accessible parts of the drainage problem areas were visually inspected by Arup staff after the inception meeting. The available survey information along with the relevant project background information and reports were collected from the Client.

The agreed scope of work of the project consists of the following tasks:

Task 1: Development of Catchment Plan including sub-catchments and translation of information to electronic format.

Task 2: Determination of Main Drainage Sizes to cater for future development and mapping onto electronic system – Existing Areas

Task 3: Determination of Main Drainage Sizes to cater for future development and mapping onto electronic system – Developing Areas

Task 3: Development of Main Drainage Costing and Apportionment model (contribution rate/ha/catchment)

Task 4: Community Consultation and Presentation at Council

Task 5: Finalisation of Drainage Plans and Presentation to Council

The catchment delineation involved in the study was carried out using the software package CatchmentSIM. The drainage modelling was undertaken using the standard software package 12d.

This study has a focus at identifying the drainage problems and suitable treatment options. In all, 5 treatment options have been identified and compared for their relative effectiveness (Section 5).

The Client was consulted as the investigation of this study progressed. It was agreed that Option 4 (Section 5.4) is the best option to treat the drainage issues in question. The investigation of the climate change impacts was also based on the selected option (Option 4). The analysis undertaken by Arup includes modelling of the drainage problem areas with the proposed solution built in the output for each treatment option.

3 Catchment Plan and Overland Flow (Task1)

Arup used the survey data supplied by the Client and the software program called CatchmentSIM to accomplish this task. CatchmentSIM is a GIS based terrain analysis program designed to help hydrologic investigations and an overview of overland flow regime. The software created the sub-catchment network appropriate to the project requirements.

The survey data supplied by the Client covered an area much larger than the project area. The catchment delineation has been extended beyond the limits of the study area for the Client's record.

Two catchment plans were created. A total catchment of 3126 ha (31.26 km^2) was delineated into 61 sub-catchments with areas ranging from 15.33 ha to 84.3 ha. The plan includes areas surrounding Apollo Bay and is shown on Drawing A1-221842 (Appendix A). The second catchment plan (Drawing A2-221842, Appendix A) covers only the project area.

The catchment plans provide comprehensive information for hydrologic assessment. The information includes sub-catchment areas, downstream sub-catchments, length of the main flow path and slope of the main flow path.

The catchment plans have also been presented in AutoCAD format to satisfy the requirement of Task 1. The GIS data, as required, can be extracted from the supplied electronic file. The electronic version in AutoCAD is being supplied to the Client together with this report.

4 Drainage Problem Areas

The drainage problem areas were identified by the Client at the inception meeting on 2 June 2011. Drainage plans covering the drainage problem areas are presented in Drawings A3-221842 and A4-221842 in Appendix A. The problem areas identified through pit numbers with a reported history of surging (overflow) have been summarised the Table 1.

Table 1: Drainage Problem Areas

Problem Area	Location	Possible Surging Pits	Reference Drawing
Pa1	Intersection of Thomson St and Great Ocean Rd	Pit 25	A3-221842
Pa2	Between Murray St and Thomson St	Pits 32,33	A3-221842
Pa3	Between Cawood St and Murray St	Pits 92,93	A3-221842
Pa4	Intersection of McLachlan St and Thomson St	Pits 49-52	A3-221842

The hydraulic performance of the drainage system was modelled using the standard software package 12d with the data supplied by the Client. The supplied data included pit invert levels only for Pa1. For other problem areas Pa2 to Pa4, the pit invert levels were approximated assuming the drainage pipe slopes to be same as the road surface slope subject to a minimum slope of 1:250 and pipe cover of 600 mm.

The other modelling assumptions included:

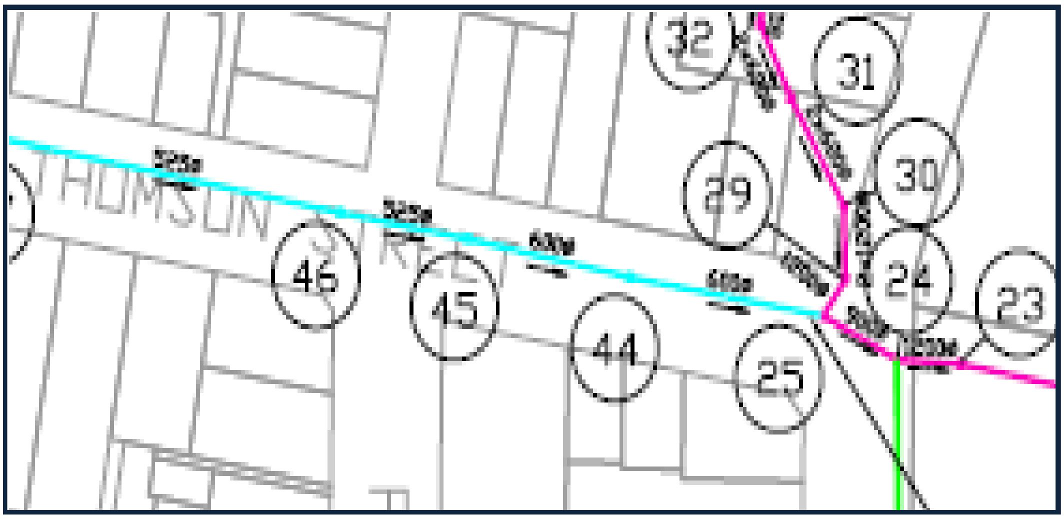
- The downstream water level is the obvert of the main outlet (1.9 m AHD). This is consistent with the information supplied by Client that ‘the sea level rises to about half way up the pipe at the outlet about every two months”. The adopted downstream water level is between the mean sea level (about 1.6 m AHD) and maximum sea level (about 2.8 m AHD) recorded at Lorne, the closest measuring point.

- The longitudinal grade of the drainage pipes was generally assumed to be the same as that of the ground surface with a minimum grade of 1 in 250;
- The problem areas were checked for peak flows for the 1 in 5 year Average Recurrence Interval (ARI) events. For rest of the drainage areas, the design discharges for residential and commercial areas were assumed to be the peak flows for the 1 in 10 and 1 in 20 year ARI events, respectively
- Fraction impervious for the urban areas: 0.55;
- Minimum time of concentration: 6 minutes; and
- Manning’s pipe roughness parameter: 0.013.

4.1 Drainage Problem Area Pa1

The intersection of Thomson St with Great Ocean Road where Pit 25 is located (Drawing A3-221842) gets frequently flooded from the overland flow combined with the pit overflow. The location plan is presented in Fig 1.

Figure 1: Location Plan for Problem Area Pa1



Hydraulic modelling of area Pa1 has shown the following:

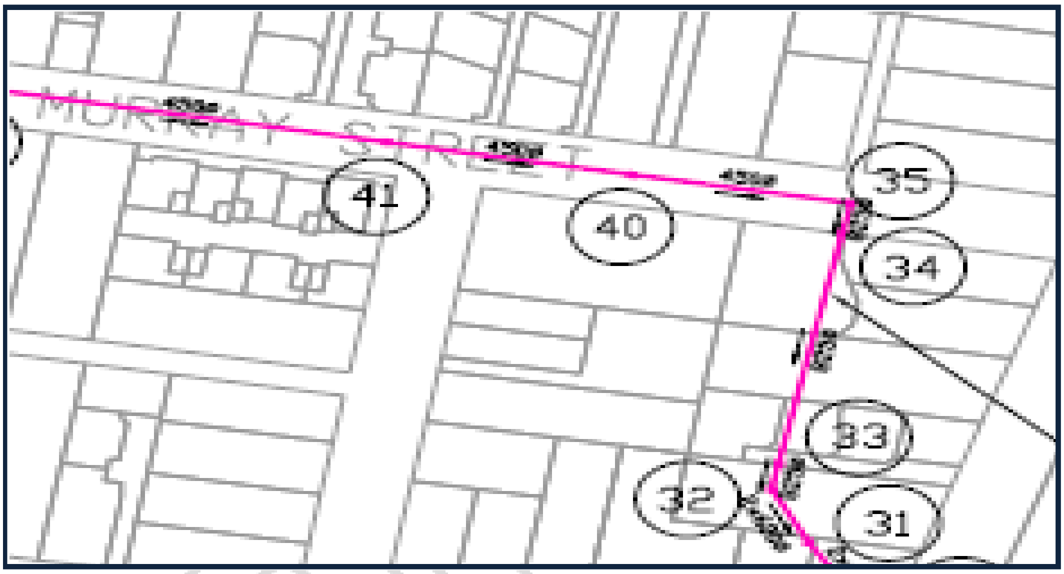
- Pit 32 (Drainage Line 1) and Pits 44, 45 and 46 (Drainage Line 2) surge increasing overland flow to Pit 25; and
- The capacity of the system just above Pit 25 along Drainage Lines 1 &2 is not adequate to handle the 1 in 5 year ARI event.

The Client informed Arup during the inception meeting that the flooding pattern in area Pa1 shows a quick accumulation of surface water around Pit 25 which gets drained by the pit in a short span of time. The above noted observations from the hydraulic investigation explain that the overland flow to Pit 25 is increased by surge from upstream pits.

4.2 Drainage Problem Area Pa2

The problem area Pa2 is located on Drainage Line 1 at the segment connecting the drainage along Murray Street and Thompson Street. Pit 33 (Fig. 2) is reported to surge.

Figure 2: Location Plan of Problem Area Pa2



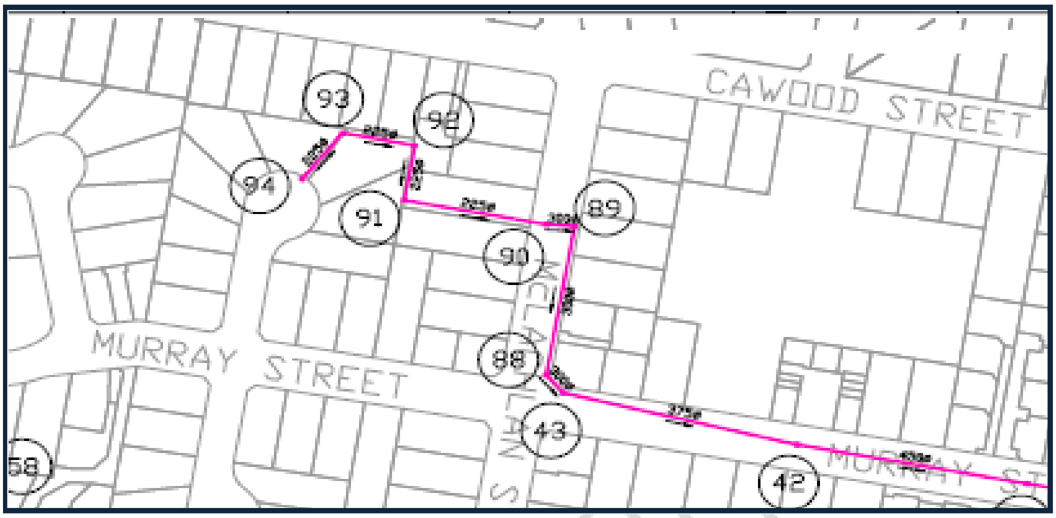
A pipe size of 825 mm from Pit 35 to Pit 32 is connected to 2 pipes 600 mm each from Pit 32 to Pit 31. The modelling has shown inadequate pipe sizes to be the reason behind the drainage problem.

4.3 Drainage Problem Area Pa3

The problem area Pa3 is located on Drainage Line 1 between Cawood Street and Murray Street to the west of McLachlan Street (Fig. 3). The drainage problem is characterised by reported flooding around Pits 92 and 93.

The pipe size from Pit 94 to Pit 90 is 225 mm. The modelling has shown that the pipe size of 225 mm is inadequate and is responsible for the drainage problem.

Figure 3: Location Plan for Problem Area Pa3

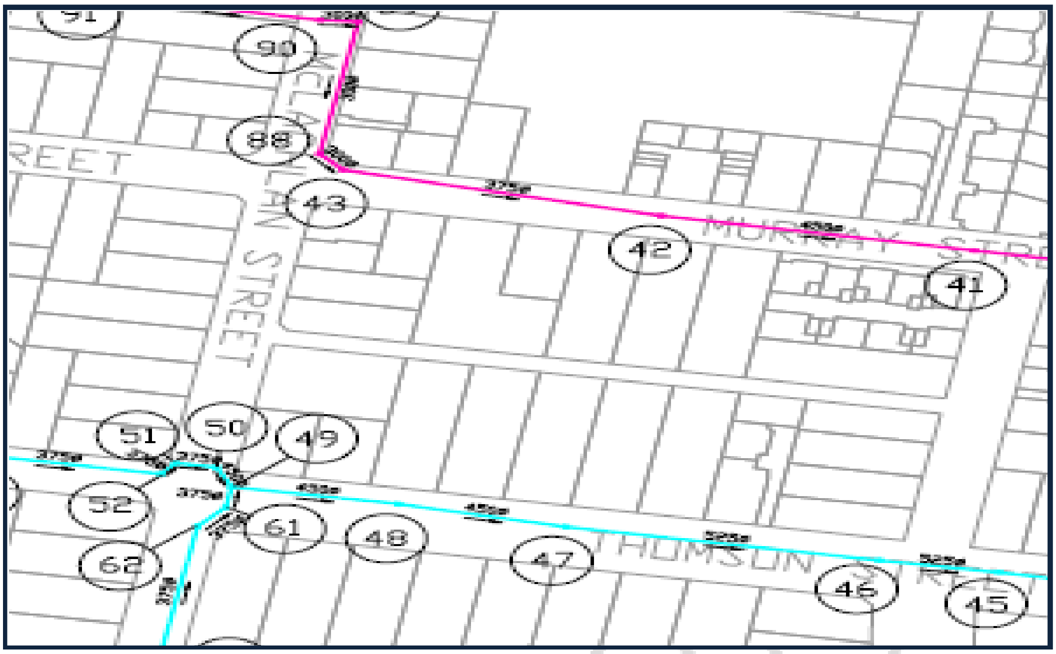


Investigations have shown the pipe has failed between Pits 90 and 93, the Council is currently repairing the problem separate from this work.

4.4 Drainage Problem Area Pa4

The problem area Pa4 is located on Drainage Line 2 at intersection of McLachlan Street and Thompson Street (Fig. 4). Flooding around Pits 50 to 52 is the reported problem.

Figure 4: Location Plan of Problem Area Pa4



The pipe size from Pits 52 to 50 is 375 mm and from Pit 50 to Pit 49 is 450 mm. The model output shows these sizes to be smaller than required to convey the incoming flows.

5 Main Drainage Sizes for Existing Areas (Task 2)

The scope of work requires determination of the main drainage sizes. Sections 5.1 to 5.7 deal with Drainage Lines 1 to 5 where the drainage pipes have been assessed to be undersized. The remaining of drainage lines (Lines 6 and 7) have been discussed in Section 5.8.

The main drainage segments should consist of Drainage Line 5 (Drawing A4-221842) and the lower part of Drainage Line 1 (Drawing A3-221842) from Pit 24 to Outlet. For a comprehensive assessment, the modelling output reflecting the entire drainage system has been presented below.

A number of options have been considered to improve the drainage system to handle 1:10 year flow for residential and 1:20 year flow for commercial areas. The options have been described in detail in Sections 5.1 to 5.5. The options are:

Option 1: Existing alignment;
Option 2: Twin outlets;
Option 3: McLachlan St Diversion (Diversion);
Option 4: Twin outlets plus Diversions; and
Option 5: Retardation through a temporary storage.

5.1 Option 1: Main Drainage Sizes for Existing Areas with Existing Outlet

Modelling carried out for drainage problem areas (Section 4) has shown the existing pipes to be undersized. Extension of the model to the rest of the drainage system confirms the existing pipes to be undersized.

Tables 2 to 6 present the pipes sizes to cater for the design discharges in existing conditions without any changes to the alignment of the drainage infrastructure.

Table 2: Option 1 - Drainage Line 1 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
94	93	26.64	225	300
93	92	29.66	225	300
92	91	24.54	225	300
91	90	58.51	225	675
90	89	11.34	300	675
89	88	66.60	300	675
88	43	10.50	300	675
43	42	97.25	375	675
42	41	94.38	450	750
41	40	57.44	450	750
40	35	51.28	450	825
35	34	9.45	825	825
34	33	75.29	825	975
33	32	8.37	825	1050
32	31	18.96	2x600	1050
31	30	28.49	2x600	1050
30	29	16.47	2x1200	1050
29	25	10.71	1200	1050
25	24	22.93	900	2700x1200
24	23	17.71	1200	2700x1200
23	Outlet	108.21	1200	1200

Table 3: Option 1 - Drainage Line 2 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
60	59	52.47	300	375
59	58	166.51	375	450
58	57	80.86	375	675
57	56	21.07	375	675
56	55	53.11	375	750
55	54	48.00	375	750
54	53	9.44	375	750
53	52	63.82	375	750
52	51	6.87	375	750
51	50	12.31	375	750
50	49	10.60	450	750
49	48	50.23	450	1050
48	47	50.98	450	1050
47	46	94.52	525	1050
46	45	35.86	525	1050
45	44	45.91	600	1050
44	25	54.24	600	1050
65	64	37.74	375	825
64	63	90.66	375	825
63	62	66.43	375	825
62	61	12.64	375	825
61	49	10.21	375	825

Table 4: Option 1- Drainage Line 3 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
87	86	83.90	300	450
86	85	86.50	300	450
85	84	8.40	300	525
84	83	11.47	300	600
83	82	13.65	300	600
82	81	60.10	300	600
81	80	103.22	300	600
80	79	109.58	375	750
79	78	6.22	450	975
78	77	20.00	450	975
77	76	60.18	675	975
76	75	14.49	600	975
75	74	35.24	900	975
74	73	53.64	900	975
73	72	6.30	900	1200
72	71	20.05	900	1200

Table 5: Option 1 - Drainage Line 4 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
14	13	109.31	300	1050
13	12	138.26	300	1050
12	11	72.19	450	1200
11	10	27.52	525	1200
10	9	25.02	600	1200
9	8	97.66	600	1350
8	7	10.23	600	1800x900
7	5	23.21	600	1800x900

Table 6: Option 1 - Drainage Line 5 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
6	5	228.86	600	2x2700x900
5	4	16.38	900	2x2700x900
4	3	106.71	1200	2x2700x900
3	2	106.07	1200	2x2700x900
2	1	43.15	1200	2x2700x900
1	24	187.53	1200	2x2700x900

5.2 Option 2: Main Drainage Sizes for Existing Areas with Twin Outlets

This option involves an additional outlet pipe running next to the existing outlet on its southern side to receive flow from drainage lines 3, 4 and 5. The existing outlet will continue to receive flow from drainage lines 1 and 2. The outcome of the hydraulic model for this option is presented in Tables 7 to 11.

Table 7: Option 2 - Drainage Line 1 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
94	93	26.64	225	300
93	92	29.66	225	300
92	91	24.54	225	300
91	90	58.51	225	675
90	89	11.34	300	675
89	88	66.60	300	675
88	43	10.50	300	675
43	42	97.25	375	675
42	41	94.38	450	750
41	40	57.44	450	750
40	35	51.28	450	825
35	34	9.45	825	900
34	33	75.29	825	900
33	32	8.37	825	975
32	31	18.96	2x600	975
31	30	28.49	2x600	975
30	29	16.47	2x1200	975
29	25	10.71	1200	975
25	24	22.93	900	2400x1200
24	23	17.71	1200	2400x1200
23	Outlet	108.21	1200	1200

Table 8: Option 2 - Drainage Line 2 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
60	59	52.47	300	375
59	58	166.51	375	450
58	57	80.86	375	675
57	56	21.07	375	675
56	55	53.11	375	750
55	54	48.00	375	750
54	53	9.44	375	750
53	52	63.82	375	750
52	51	6.87	375	750
51	50	12.31	375	750
50	49	10.60	450	750
49	48	50.23	450	1050
48	47	50.98	450	1050
47	46	94.52	525	1050
46	45	35.86	525	1050
45	44	45.91	600	1050
44	25	54.24	600	1050
65	64	37.74	375	825
64	63	90.66	375	825
63	62	66.43	375	825
62	61	12.64	375	825
61	49	10.21	375	825

Table 9: Option 2 - Drainage Line 3 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
87	86	83.90	300	450
86	85	86.50	300	450
85	84	8.40	300	525
84	83	11.47	300	600
83	82	13.65	300	600
82	81	60.10	300	600
81	80	103.22	300	600
80	79	109.58	375	750
79	78	6.22	450	975
78	77	20.00	450	975
77	76	60.18	675	975
76	75	14.49	600	975
75	74	35.24	900	975
74	73	53.64	900	975
73	72	6.30	900	1200
72	71	20.05	900	1200

Table 10: Option 2 - Drainage Line 4 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
14	13	109.31	300	1050
13	12	138.26	300	1050
12	11	72.19	450	1200
11	10	27.52	525	1200
10	9	25.02	600	1200
9	8	97.66	600	1350
8	7	10.23	600	1800x900
7	5	23.21	600	1800x900

Table 11: Option 2 - Drainage Line 5 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
6	5	228.86	600	2x1500x900
5	4	16.38	900	2x1800x900
4	3	106.71	1200	2x1800x900
3	2	106.07	1200	2x1800x900
2	1	43.15	1200	2x1800x900
1	24	187.53	1200	2x1800x900

Option 2 has a significant impact on the lower segment of Drainage Line 1 (Pits 34 to 23) and the entire Drainage Line 5. It has no impact on Drainage Lines 2, 3 and 4.

5.3 Option 3: Main Drainage Sizes for Existing Areas with McLachlan Street Diversion and Existing Outlet

This option involves a drainage line along McLachlan St which will intercept flow from the drainage system to the west of McLachlan St. The drainage line will consist of 600 mm pipe running northward from Pengilley Ave discharging into Milford Creek. The same size pipe (600 mm) will run southward from Pengilley Ave discharging into the Braham River. Tables 12 to16 present pipe sizes for Option 3.

Table 12: Option 3 - Drainage Line 1 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
94	93	26.64	225	300
93	92	29.66	225	300
92	91	24.54	225	300
91	90	58.51	225	675
90	89	11.34	300	675
89	88	66.60	300	450
88	43	10.50	300	525
43	42	97.25	375	600
42	41	94.38	450	675
41	40	57.44	450	675
40	35	51.28	450	675
35	34	9.45	825	825
34	33	75.29	825	975
33	32	8.37	825	1050
32	31	18.96	2x600	1050
31	30	28.49	2x600	1050
30	29	16.47	2x1200	1050
29	25	10.71	1200	1050
25	24	22.93	900	1500x1200
24	23	17.71	1200	1800x1200
23	Outlet	108.21	1200	1200

Table 13: Option 3 - Drainage Line 2 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	From Pit	Size (mm)
60	59	52.47	300	375
59	58	166.51	375	450
58	57	80.86	375	675
57	56	21.07	375	675
56	55	53.11	375	750
55	54	48.00	375	750
54	53	9.44	375	750
53	52	63.82	375	750
52	51	6.87	375	750
51	50	12.31	375	750
50	49	10.60	450	750
49	48	50.23	450	375
48	47	50.98	450	375
47	46	94.52	525	375
46	45	35.86	525	375
45	44	45.91	600	750
44	25	54.24	600	750
65	64	37.74	375	825
64	63	90.66	375	825
63	62	66.43	375	825
62	61	12.64	375	825
61	49	10.21	375	825

Table 14: Option 3 - Drainage Line 3 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	From Pit	Size (mm)
87	86	83.90	300	450
86	85	86.50	300	450
85	84	8.40	300	525
84	83	11.47	300	600
83	82	13.65	300	600
82	81	60.10	300	375
81	80	103.22	300	375
80	79	109.58	375	375
79	78	6.22	450	525
78	77	20.00	450	825
77	76	60.18	675	825
76	75	14.49	600	825
75	74	35.24	900	825
74	73	53.64	900	825
73	72	6.30	900	1200
72	71	20.05	900	1200

Table 15: Option 3 - Drainage Line 4 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)
14	13	109.31	300	375
13	12	138.26	300	450
12	11	72.19	450	1200
11	10	27.52	525	1200
10	9	25.02	600	1200
9	8	97.66	600	1200
8	7	10.23	600	1800x900
7	5	23.21	600	1800x900

Table 16: Option 3 - Drainage Line 5 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes
From Pit	To Pit	Length (m)	From Pit	Size (mm)
6	5	228.86	600	2x1500x900
5	4	16.38	900	2x1800x900
4	3	106.71	1200	2x1800x900
3	2	106.07	1200	2x1800x900
2	1	43.15	1200	2x1800x900
1	24	187.53	1200	2x2100x900

Option 3 has a minor impact on Drainage Lines 1 and 4. It has some impact on Drainage Lines 2 and 3 and a significant impact on Drainage Line 5.

5.4 Option 4: Main Drainage Sizes for Existing Areas with McLachlan Street Diversion and Twin Outlets

This option is a combination of Option 2 and Option 3. Tables 17 to 21 present the pipe sizes for Option 4. The tables also include the cost estimate of the proposed design as Option 4 is the recommended option (see Section 9).

Table 17: Option 4 - Drainage Line 1 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
94	93	26.64	225	300	176	4689.33
93	92	29.66	225	300	176	5220.42
92	91	24.54	225	300	176	4318.74
91	90	58.51	225	675	275	16089.07
90	89	11.34	300	675	275	3117.65
89	88	66.60	300	450	205	13653.47
88	43	10.50	300	525	225	2363.24
43	42	97.25	375	600	248	24117.01
42	41	94.38	450	675	275	25953.70
41	40	57.44	450	675	275	15795.15
40	35	51.28	450	675	275	14102.03
35	34	9.45	825	825	339	3202.53
34	33	75.29	825	975	416	31320.06
33	32	8.37	825	1050	459	3843.34
32	31	18.96	2x600	1050	459	8701.58
31	30	28.49	2x600	1050	459	13077.60
30	29	16.47	2x1200	1050	459	7561.98
29	25	10.71	1200	1050	459	4915.25
25	24	22.93	900	1200x900	839	19239.11
24	23	17.71	1200	1200x900	839	14856.51
23	Outlet	108.21	1200	1200	556	60161.98
					Total	296299.75

Table 18: Option 4 - Drainage Line 2 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
60	59	52.47	300	375	189	9917.26
59	58	166.51	375	450	205	34133.81
58	57	80.86	375	675	275	22235.54
57	56	21.07	375	675	275	5793.92
56	55	53.11	375	750	305	16197.64
55	54	48.00	375	750	305	14640.24
54	53	9.44	375	750	305	2878.04
53	52	63.82	375	750	305	19464.92
52	51	6.87	375	750	305	2096.27
51	50	12.31	375	750	305	3754.73
50	49	10.60	450	750	305	3233.31
49	48	50.23	450	375	189	9493.49
48	47	50.98	450	375	189	9635.48
47	46	94.52	525	375	189	17865.21
46	45	35.86	525	375	189	6777.86
45	44	45.91	600	750	305	14003.65
44	25	54.24	600	750	305	16543.93
65	64	37.74	375	825	339	12793.52
64	63	90.66	375	825	339	30732.82
63	62	66.43	375	825	339	22519.94
62	61	12.64	375	825	339	4284.96
61	49	10.21	375	825	339	3459.83
					Total	282456.37

Table 19: Option 4 - Drainage Line 3 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
87	86	83.90	300	450	205	17199.34
86	85	86.50	300	450	205	17732.44
85	84	8.40	300	525	225	1889.48
84	83	11.47	300	600	248	2843.74
83	82	13.65	300	600	248	3384.63
82	81	60.10	300	375	189	11358.65
81	80	103.22	300	375	189	19509.39
80	79	109.58	375	375	189	20710.13
79	78	6.22	450	525	225	1400.00
78	77	20.00	450	825	339	6781.08
77	76	60.18	675	825	339	20402.31
76	75	14.49	600	825	339	4912.58
75	74	35.24	900	825	339	11944.90
74	73	53.64	900	825	339	18182.54
73	72	6.30	900	1050	459	2892.30
72	71	20.05	900	1200	556	11149.25
					Total	172292.76

Table 20: Option 4 - Drainage Line 4 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
14	13	109.31	300	375	189	17199.34
13	12	138.26	300	450	205	17732.44
12	11	72.19	450	1200	556	1889.48
11	10	27.52	525	1200	556	2843.74
10	9	25.02	600	1200	556	3384.63
9	8	97.66	600	1200	556	11358.65
8	7	10.23	600	1800x900	1148	19509.39
7	5	23.21	600	1800x900	1148	20710.13
					Total	211040.13

Table 21: Option 4 - Drainage Line 5 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
6	5	228.86	600	2400x900	1493	17199.34
5	4	16.38	900	2x1500x900	1932	17732.44
4	3	106.71	1200	2x1500x900	1932	1889.48
3	2	106.07	1200	2x1500x900	1932	2843.74
2	1	43.15	1200	2x1500x900	1932	3384.63
1	24	187.53	1200	2x1500x900	1932	11358.65
					Total	1230091.51

Option 4 impacts all drainage lines to varying degrees. The impacts are most significant for Drainage Lines 1 and 5. In general, this option yields the minimum required pipe sizes.

5.4.1 Cost Estimate of Option 4 and Clarifications

The total estimated cost (of Option 4) including all the upgrade works on the pits is $2,470,000. It should be noted that the above estimates are presented as an order of magnitude only (±20%), based on experience from similar, past projects.

Ancillary works include road re-profiling, the introduction of "speed humps" and re-profiling earth bunds where required.

The following cost items are not included in the cost estimate:

1. Preliminaries, including survey fees, design fees, procurement fees, approval processes
2. Site establishment
3. Rock excavation
4. Off-site disposal of excavated material
5. Landscaping
6. Clashes with existing services
7. Staging of the works
8. Traffic management
9. Contingencies
10. Profits and overheads
11. Premiums for extended delivery distances
12. Any land costs and legal fees
13. Future cost escalation
14. GST

It should also be noted that some of the above exclusions, such as rock excavation, off-site disposal and extended delivery distances could have a substantial affect on actual construction (trade) costs.

5.5 Option 5: Retardation Option

Option 6 involves a temporary storage basin placed at the location shown in Fig 5. The objective is to reduce peak flow to the outlet by diverting some flow from Drainage Line 5 to the temporary storage.

To implement this option, a surcharge pit will be needed in the vicinity of Pit 1 (Drawing A3-221842). The excess discharge will flow through gravity from the surcharge pit into the temporary storage reducing load on the outlet below Pit 23 (Drawing A3-221842).

An examination of the site topography in relation to the top levels of the relevant pits revealed serious limitations of this option. The option was considered to ineffective in view of the following:

1. A surcharge pit at a top level lower than that of Pit 1with a deep temporary storage will surcharge at flows less than the peak of a 10-year event making outflows to the temporary storage unnecessarily frequent;
2. A surcharge pit with the same top level as that of Pit 1 (RL 3.127m AHD) barely meets the requirements of gravity flow into the temporary storage;
3. Allowing surcharge from the top level of Pit 1 cannot reduce pipe sizes in all drainage lines up to Pit 1; and
4. The concept of pumping the stored runoff back into the underground system introduces maintenance constraints that cannot be justified by the minor impact of the storage on infrastructure below the proposed surcharge pit.

Figure 5: Location of the proposed storage facility

5.6 Key Observations

The options discussed above contribute to drainage improvement to varying degrees. This information provided in Section 5.7 will help identify their relative merits. The following observations relate to the strategy adopted for possible solutions to the drainage problems:

1. The existing underground drainage system (Drainage Lines 1 to 5) is grossly inadequate. The system is incapable of carrying the 1 in 5 year ARI peak flow without causing local flooding;

2. The proposed upgrade to 1 in 10 year ARI event for residential and 1 in 20 year ARI event for commercial areas requires sizeable changes in the existing pipe sizes for Drainage Lines 1 to 5;

3. The above observations suggest care in selection of design water level at the outlet for Drainage Lines 1 to 5. The selected downstream water level of 1.9 m AHD is consistent with the available information (Section 4) and has been decided in consultation with the Client. The system with the proposed pipe sizes will perform its design function with the downstream

water level up to 1.9 m AHD. A design storm occurring simultaneously with the rise of downstream water level above 1.9 m AHD will impact performance of the system for some time. A downstream water level above 1.9 m AHD is not appropriate as it results in increase of the upgrade costs.

4. This observation relates to the drainage alignment at intersection of Thompson Street with Great Ocean Road. The modelled and the existing alignments are shown in Figs 6A and 6B respectively. The modelled alignment is part of GIS data supplied by the Client. For a clear reference, Junction Pit 3 of Fig. 6B is Pit no. 25 of Fig. 6A. The existing alignment (Fig. 6B) connects Junction 3 to Junction 2 with a 900 mm pipe and then connects Junction 2 with Pit no. 24 (Fig. 6A).Presence of Junction 2 (Fig. 6B) is unnecessary as well as problematic. It creates avoidable head loss which adversely affects the conveyance of the system. The modelled alignment (Fig. 6A) presents more efficient alignment at the intersection.

Figure 6A: Modelled Drainage Alignment at Intersection of Thompson Street and Great Ocean Road

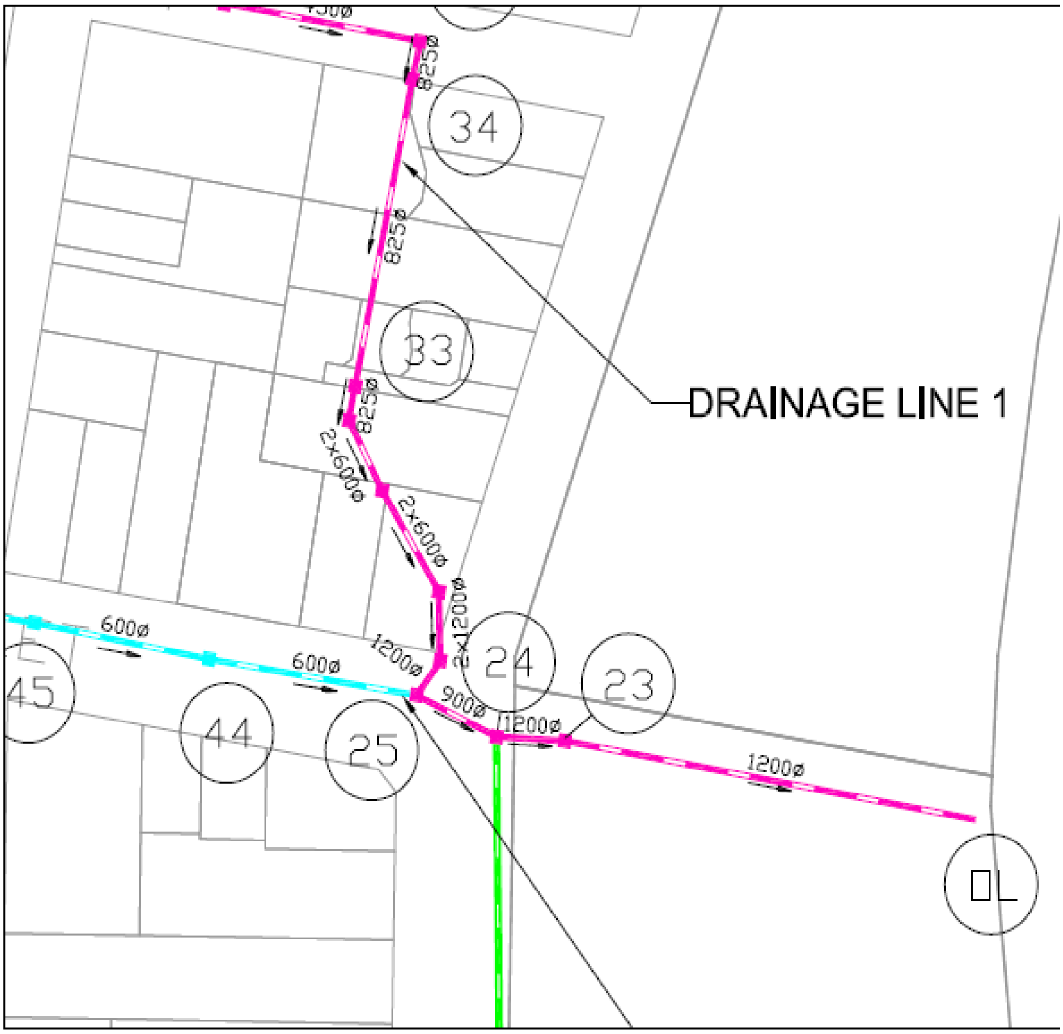
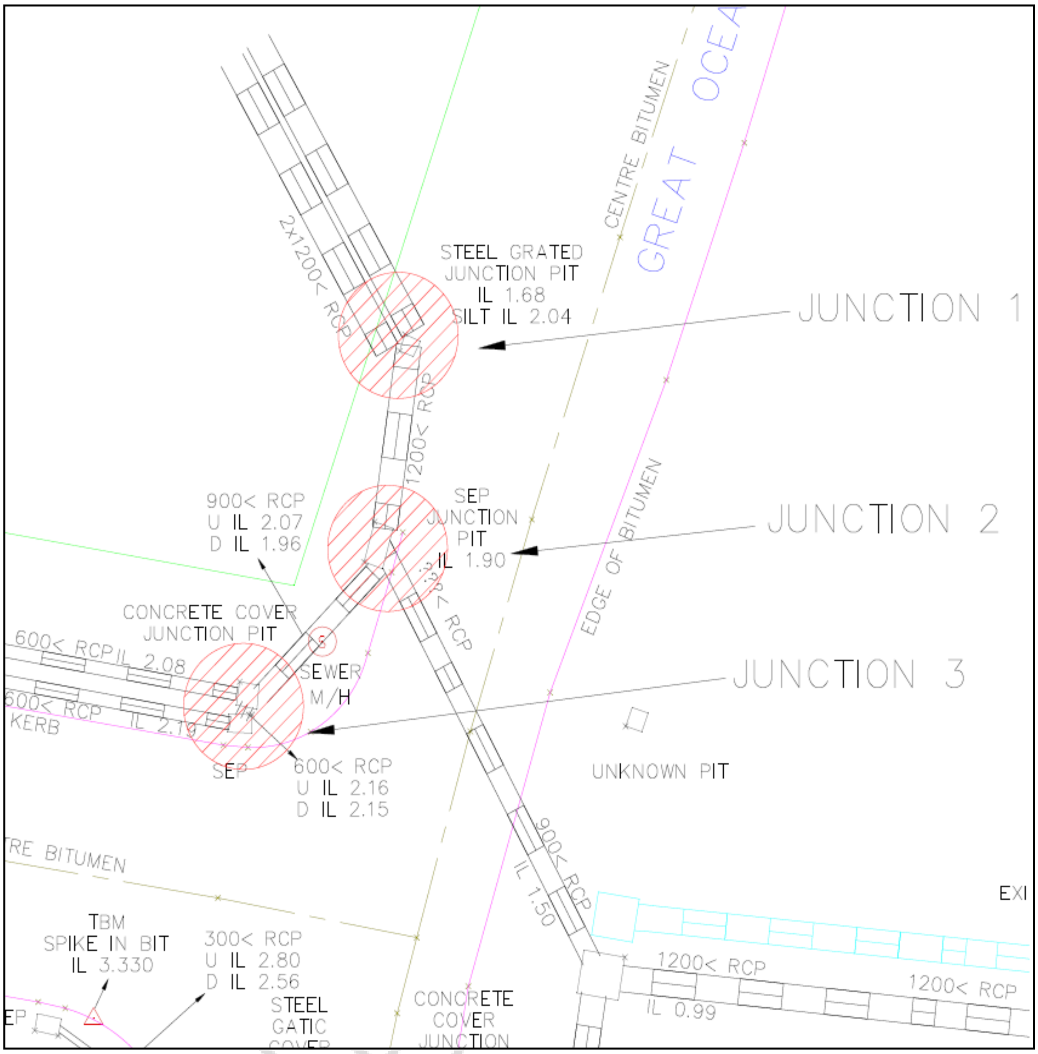


Figure 6B: Existing Drainage Alignment at Intersection of Thompson Street and Great Ocean Road [Source: Colac Otway Shire]



5.7 Comparative Assessment of the Options

For a quick comparison, the options have been referred to by their names and numbers as described in Section 5. The following tables present a comparison of the different options, with a brief summary below each table.

Table 22: Drainage Line 1

Existing Pipe Sizes			Proposed Pipe Sizes			
From Pit	To Pit	Size (mm)	Option 1 Existing Alignment	Option 2 Twin O/L	Option 3 Diversion	Option 4 Twin O/L+ Diversion
94	93	225	300	300	300	300
93	92	225	300	300	300	300
92	91	225	300	300	300	300
91	90	225	675	675	675	675
90	89	300	675	675	675	675
89	88	300	675	675	450	450
88	43	300	675	675	525	525
43	42	375	675	675	600	600
42	41	450	750	750	675	675
41	40	450	750	750	675	675
40	35	450	825	825	675	675
35	34	825	825	825	825	825
34	33	825	975	900	975	900
33	32	825	1050	975	1050	975
32	31	2x600	1050	975	1050	975
31	30	2x600	1050	975	1050	975
30	29	2x1200	1050	975	1050	975
29	25	1200	1050	975	1050	975
25	24	900	2700x1200	2400x1200	1500x1200	1200x900
24	23	1200	2700x1200	2400x1200	1800x1200	1200x900
23	Outlet	1200	1200	1200	1200	1200

Summary of impacts on Drainage Line 1:

- Twin outlets reduce pipe sizes from Pit 34 to Pit 23;
- Diversion has a minor impact limited to Pits 25-23;
- The impact of Twin outlets plus diversion is practically the same as of the Twin outlet only.

Table 23: Drainage Line 2

Existing Pipe Sizes			Proposed Pipe Sizes			
From Pit	To Pit	Size (mm)	Option 1 Existing Alignment	Option 2 Twin O/L	Option 3 Diversion	Option 4 Twin O/L+ Diversion
60	59	300	375	375	375	375
59	58	375	450	450	450	450
58	57	375	675	675	675	675
57	56	375	675	675	675	675
56	55	375	750	750	750	750
55	54	375	750	750	750	750
54	53	375	750	750	750	750
53	52	375	750	750	750	750
52	51	375	750	750	750	750
51	50	375	750	750	750	750
50	49	450	750	750	750	750
49	48	450	1050	1050	375	375
48	47	450	1050	1050	375	375
47	46	525	1050	1050	375	375
46	45	525	1050	1050	375	375
45	44	600	1050	1050	750	750
44	25	600	1050	1050	750	750
65	64	375	825	825	825	825
64	63	375	825	825	825	825
63	62	375	825	825	825	825
62	61	375	825	825	825	825
61	49	375	825	825	825	825

Summary of impacts on Drainage Line 2:

- Twin outlets have no impact;
- Diversion reduces pipe sizes from Pit 49 to Pit 44;
- The impact of Twin outlets plus diversion is the same as that of Diversion only.

Table 24: Drainage Line 3

Existing Pipe Sizes			Proposed Pipe Sizes			
From Pit	To Pit	Size (mm)	Option 1 Existing Alignment	Option 2 Twin O/L	Option 3 Diversion	Option 4 Twin O/L+ Diversion
87	86	300	450	450	450	450
86	85	300	450	450	450	450
85	84	300	525	525	525	525
84	83	300	600	600	600	600
83	82	300	600	600	600	600
82	81	300	600	600	375	375
81	80	300	600	600	375	375
80	79	375	750	750	375	375
79	78	450	975	975	525	525
78	77	450	975	975	825	825
77	76	675	975	975	825	825
76	75	600	975	975	825	825
75	74	900	975	975	825	825
74	73	900	975	975	825	825
73	72	900	1200	1200	1200	1050
72	71	900	1200	1200	1200	1200

Summary of impacts on Drainage Line 3:

- Twin outlets have no impact;
- Diversion reduces pipe sizes from Pit 82 to Pit 73;
- The impact of Twin outlets plus diversion is the same as that of Diversion only.

Table 25: Drainage Line 4

Existing Pipe Sizes			Proposed Pipe Sizes			
From Pit	To Pit	Size (mm)	Option 1 Existing Alignment	Option 2 Twin O/L	Option 3 Diversion	Option 4 Twin O/L+ Diversion
14	13	300	1050	1050	375	375
13	12	300	1050	1050	450	450
12	11	450	1200	1200	1200	1200
11	10	525	1200	1200	1200	1200
10	9	600	1200	1200	1200	1200
9	8	600	1350	1350	1200	1200
8	7	600	1800x900	1800x900	1800x900	1800x900
7	5	600	1800x900	1800x900	1800x900	1800x900

Summary of impacts on Drainage Line 4:

- Twin outlets have no impact;
- Diversion slightly reduces pipe sizes from Pit 14 to Pit 12 and Pit 9 to Pit 8;
- The impact of Twin outlets plus diversion is the same as that of Diversion only.

Table 26: Drainage Line 5

Existing Pipe Sizes			Proposed Pipe Sizes			
From Pit	To Pit	Size (mm)	Option 1 Existing Alignment	Option 2 Twin O/L	Option 3 Diversion	Option 4 Twin O/L+ Diversion
6	5	600	2x2700x900	2x1500x900	2x1500x900	2400x900
5	4	900	2x2700x900	2x1800x900	2x1800x900	2x1500x900
4	3	1200	2x2700x900	2x1800x900	2x1800x900	2x1500x900
3	2	1200	2x2700x900	2x1800x900	2x1800x900	2x1500x900
2	1	1200	2x2700x900	2x1800x900	2x1800x900	2x1500x900
1	24	1200	2x2700x900	2x1800x900	2x2100x900	2x1500x900

Summary of impacts on Drainage Line 5:

- Twin outlets reduce the pipe sizes significantly;
- Diversion also reduces the pipe sizes significantly;
- Twin outlets plus diversion have a major impact.

5.8 Drainage Lines 6, 7 and 8

Drainage Lines 6 and 7 (Drawings A7 and A8-221842) were modelled using same approach adopted for Drainage Lines 1 to 5. The lines are situated in the residential area, therefore the system was checked for the peak flow of the 1 in 10 year ARI event.

The northern area of Apollo Bay has two separate drainage systems. The system was modelled as Drainage Line 6A and 6B. The pipe sizes range from 300 mm to 1200 mm diameter. Drainage Lines 6a drains the majority of the runoff from this area through an outlet to the ocean.

Drainage Line 6b drains a small area north of Cawood Street. This drainage system has its own outlet discharging into the nearby creek.

Drainage Line 7 is located in the southern part of the Apollo Bay Township. The pipe sizes of this system range from 300 mm to 450 mm diameter.

The underground pipe system of Drainage Liens 6 and 7 was found to be adequate for the design event.

Drainage Line 8 (Drawing A9-221842) was checked for the flow of 1 in 20 year ARI event due to its location in industrial area. The pipe sizes for Drainage Line 8A range from 225 mm to 975 mm. All pipes were found to be adequate except for 225 mm pipe from Pit no. 235 to Pit no. 236. The diameter of this pipe should be 300 mm. For Drainage Line 8B, the existing pipe sizes (ranging from 225 mm to 525 mm) were found to be adequate.

6 Main Drainage Sizes for Future Developments (Task 3)

The future development areas (Drawing A5-221842) have been adopted from Apollo Bay Structure Plan Volume 1, 2007. The areas subdivided for effective drainage outfalls have been shown on Drawing A6-221842.

In view of the existing drainage problems of Apollo Bay and the requirement of rather large sizes of the main drainage to handle the existing areas, it is recommended that the future areas do not burden the existing drainage infrastructure. To achieve this objective, we propose that:

1. The onsite retardation of stormwater runoff should be made a precondition for new developments; and
2. The main drainage pipes outfall into the adjoining creeks.

The site topography governs the location of drainage outfalls of future areas as shown on Drawing A6-221842. The main drainage sizes and the concept level retardation volumes have been determined with a proposed impervious fraction of

0.55. The summary of the required drainage sizes and approximate retardation volumes have been presented in Table 27.

Table 27: Summary of Required Drainage Sizes and Retardation Volumes

Area	Catchment Size (ha)	Q_{10} (m^3/s)	Approximate Retardation Volume (m3)	Main Drainage Pipe Size (mm)	Main Drainage Pipe Length (m)
2	26.2	2.52	6500	375 to 1200	500
3A	31.5	3.02	7800	375 to 1350	460
3B-1	13.1	1.05	2000	375 to 900	648
3B-2	7.2	0.7	970	375 to 750	445
3B-3	35.5	2.5	6010	375 to 1200	786

6.1 Development Contribution Rates for Future Developments

The development contribution rates for future developments have been worked out on the basis of estimate of main drainage line sizes and length added to the estimated cost of the wetlands needed to treat the stormwater to achieve best practice targets laid out in the Land Development Manual (LDM) maintained and regularly updated by the Melbourne Water Corporation. The results are presented in Table 27a which is based on the following assumptions:

1. An estimate of the length of main drainage lines;
2. Sizes of the main drainage lines varying from 375 mm to 1200 mm;
3. 3% of the total catchment area allocated to the proposed wetlands to achieve the best practice water quality treatment targets;
4. A unit cost of $65/m^2 for the construction of wetlands as specified by the Model for Urban Stormwater Improvement Conceptualisation (MUSIC), assuming large-scale wetlands.

Table 27a: Development Contribution Rates

Area	Catchment Size (ha)	Approximate Retardation Volume (m3)	Main Drainage Pipe Size (mm)	Main Drainage Pipe Length (m)	Pipe Cost Estimate ($)	Wetland Cost Estimate ($)	Rate / ha ($)
2	26.2	6500	375 to 1200	500	157,300	510,900	25,504
3A	31.5	7800	375 to 1350	460	179,768	614,250	25,207
3B-1	13.1	2000	375 to 900	648	173,988	255,450	32,782
3B-2	7.2	970	375 to 750	445	106,652	140,400	34,313
3B-3	35.5	6010	375 to 1200	786	247,276	692,250	26,466

7 Overland Flow

The catchment plans show the overland flow paths (OLFP 1 to 8) determined by CatchmentSIM in line with the available topography of the study area. Flow for the 1 in 100 year ARI event for each flow path is presented in Table 28.

Table 28: 100-year Peak Flow for Identified Overland Flow Paths

Overland Flow Path	Q_{100} (m^3/s)
OLFP 1	0.364
OLFP 2	0.951
OLFP 2A	0.614
OLFP 3	0.439
OLFP 4	0.681
OLFP 5	1.020
OLFP 6	2.510
OLFP 7	2.164
OLFP 8	13.590

The overland flow is conveyed over roads through the developed area except for large flow along OLFP8 which represents contribution of the study catchment to the Braham River. The information has been provided for documentation in this study dealing with the underground infrastructure.

8 Impact of Climate Change

The impact of the climate change has been quantified with further work on the design for Option 4. The design has been upgraded in view of two factors namely, the expected sea level rise (SLR) and expected increase in the intensity of the rainfall.

In consultation with the Client, the expected SLR of 0.8 m has been adopted as recommended by “The Victorian Coastal Strategy (2008) - State Government's policy for coastal, estuarine and marine environments in Victoria” for the year 2100. The downstream water level adopted for drainage design options (see Section 5.6) has been increased by 0.8 m to model impact of the SLR.

The impact of the climate change on increase in rainfall intensity has been quantified by various studies. In their poster for OZwater09, Dr Mohammad N Cheema and Ray Borg have observed that using results of 13 Climate models, CSIRO project an increase of 1 to 13% (average 4 %) in the annual rainfall for the greater Melbourne region by 2050. In absence of a policy guideline such as the one for SLR, we have adopted an expected increase of 15% in the rainfall intensity which is consistent for the current industry practice for the long-term effects of the climate change.

The hydraulic model was re-run for the expected SLR and increase in the rainfall intensity. The results are presented Tables 29 to 33.

Table 29: Climate Change - Drainage Line 1 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
94	93	26.64	225	300	176	4689.33
93	92	29.66	225	300	176	5220.42
92	91	24.54	225	300	176	4318.74
91	90	58.51	225	675	275	16089.07
90	89	11.34	300	675	275	3117.65
89	88	66.60	300	450	205	13653.47
88	43	10.50	300	525	225	2363.24
43	42	97.25	375	675	275	26742.65
42	41	94.38	450	675	275	25953.70
41	40	57.44	450	675	275	15795.15
40	35	51.28	450	675	275	14102.03
35	34	9.45	825	1050	459	4336.17
34	33	75.29	825	1050	459	34557.47
33	32	8.37	825	1050	459	3843.34
32	31	18.96	2x600	1050	459	8701.58
31	30	28.49	2x600	1050	459	13077.60
30	29	16.47	2x1200	1050	459	7561.98
29	25	10.71	1200	1500	791	8470.50
25	24	22.93	900	2100x900	1297	29741.51
24	23	17.71	1200	1800x900	1148	20328.10
23	Outlet	108.21	1200	1200	556	60161.98
					Total	322825.68

Table 30: Climate Change - Drainage Line 2 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
60	59	52.47	300	375	189	9917.26
59	58	166.51	375	450	205	34133.81
58	57	80.86	375	675	275	22235.54
57	56	21.07	375	675	275	5793.92
56	55	53.11	375	750	305	16197.64
55	54	48.00	375	750	305	14640.24
54	53	9.44	375	750	305	2878.04
53	52	63.82	375	750	305	19464.92
52	51	6.87	375	750	305	2096.27
51	50	12.31	375	750	305	3754.73
50	49	10.60	450	750	305	3233.31
49	48	50.23	450	375	189	9493.49
48	47	50.98	450	375	189	9635.48
47	46	94.52	525	375	189	17865.21
46	45	35.86	525	375	189	6777.86
45	44	45.91	600	750	305	14003.65
44	25	54.24	600	750	305	16543.93
65	64	37.74	375	825	339	12793.52
64	63	90.66	375	825	339	30732.82
63	62	66.43	375	825	339	22519.94
62	61	12.64	375	825	339	4284.96
61	49	10.21	375	825	339	3459.83
					Total	282456.37

Table 31: Climate Change - Drainage Line 3 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
87	86	83.90	300	450	205	17199.34
86	85	86.50	300	450	205	17732.44
85	84	8.40	300	525	225	1889.48
84	83	11.47	300	600	248	2843.74
83	82	13.65	300	600	248	3384.63
82	81	60.10	300	375	189	11358.65
81	80	103.22	300	375	189	19509.39
80	79	109.58	375	600	248	27175.20
79	78	6.22	450	600	248	1543.11
78	77	20.00	450	825	339	6781.08
77	76	60.18	675	900	375	22568.93
76	75	14.49	600	900	375	5434.28
75	74	35.24	900	900	375	13213.39
74	73	53.64	900	900	375	20113.43
73	72	6.30	900	1050	459	2892.30
72	71	20.05	900	1200	556	11149.25
					Total	184788.62

Table 32: Climate Change - Drainage Line 4 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
14	13	109.31	300	375	189	20660.25
13	12	138.26	300	450	205	28343.53
12	11	72.19	450	1200	556	40136.42
11	10	27.52	525	1200	556	15300.23
10	9	25.02	600	1200	556	13912.68
9	8	97.66	600	1200	556	54297.79
8	7	10.23	600	1800x900	1148	11745.42
7	5	23.21	600	1800x900	1148	26643.82
					Total	211040.13

Table 33: Climate Change - Drainage Line 5 Main Drainage Sizes

Existing Pipe Sizes				Proposed Pipe Sizes	Cost Estimate	
From Pit	To Pit	Length (m)	Size (mm)	Size (mm)	Rate/m ($)	Estimated Cost ($)
6	5	228.86	600	2x2400x900	2986	683365.51
5	4	16.38	900	3x1500x900	2898	47462.86
4	3	106.71	1200	3x1500x900	2898	309232.54
3	2	106.07	1200	3x1500x900	2898	307402.16
2	1	43.15	1200	3x1500x900	2898	125044.35
1	24	187.53	1200	3x1500x900	2898	543471.21
					Total	2015978.64

8.1 Cost Estimate of Climate Change Impact and Clarification

The total estimated cost by including all the upgrade works on the pits is \$3,300,000. It should be noted that the above estimates are presented as an order of magnitude only (±20%), based on experience from similar, past projects. The clarifications described in Section 5.4.1 also apply this cost estimate.

9 Hydraulic Grade Lines

Hydraulic grade lines (HGLs) have been created from 12d model. The HGLs cover design of Option 4 (Appendix B drawings) and design of Option 4 including the impact of climate change (Appendix C drawings).

10 Conclusions

This study has examined the drainage system of Apollo Bay and four drainage problem areas. Detailed modelling has revealed that the drainage system cannot handle the design flow.

We have identified 5 treatment options in consultation with the Client. The drainage system has been modelled for 1 in 10 and 1 in 20 year events for residential and commercial areas respectively. Once an option is selected by the Client, it will be remodelled to include impacts of climate change. Broadly, the consideration for climate change will require sizes larger by 10 to 15% than those estimated by the modelling undertaken so far.

The options considered by this study are:

Option 1: Existing alignment;
Option 2: Twin outlets;
Option 3: McLachlan St Diversion (Diversion);

Option 4: Twin outlets plus Diversions; and
Option 5: Retardation through a temporary storage.

Our findings can be summarised as:

1. The existing system is inadequate even for a 1 in 5 year event;
2. The retardation option (Option 5) has severe constraints posed by the site topography and maintenance requirements. The preliminary analysis has shown that the retardation option is not effective for treating the drainage problems.
3. Option 2 reduces the required pipe sizes for the lower segment of Drainage Line 1 and Drainage Line 5. It is not effective for Drainage Lines 2, 3 and 4.
4. Option 3 has significant impact on Drainage Line 5, some impact on Drainage Lines 2 and 3 minor impact on Drainage Lines 1 and 4.
5. Option 4 is the only option that impacts all drainage lines. Its impacts are most significant on Drainage Lines 1 and 5.
6. We have recommend, in consultation with the Client, Option 4 to be adopted for effective treatment of the drainage problems experienced in Apollo Bay. The implementation of the recommendation is subject to the establishment of no adverse impacts on the creeks which will receive the stormwater flow diverted from west of McLachlan St. This assessment is not included in the scope of the current study.
7. The recommended drainage alignment at the intersection of Thompson Street involves elimination of an unnecessary and problematic junction pit described in Section 5.6 of this report.
8. Analysis of climate change impacts permits the downstream water level to be raised by 0.8 m. Based on this, the proposed twin outlets can be raised by 0.8 m if the design is to reflect the climate change.
9. The future development areas should not be drained through the existing drainage system.
10. Future developments must have onsite retardation facilities and the stormwater outflow must be discharged into the surrounding creeks.
11. The detailed survey information was not available for most of the study area due to which assumptions were made (see Section 4) on the pipe grades. The design output of this investigation in terms of drainage pipes sizes and grades needs to be improved with the help of detailed survey information for a design suitable for construction.