



Dunedin 3 Waters Strategy



Mosgiel Integrated Catchment Management Plan: 2011–2060



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Mosgiel Integrated Catchment Management Plan 2011-2060

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Dunedin 3 Waters Strategy



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Table of Contents

Executive Summary	9
Part 1: Introduction	24
1 Introduction	25
1.1 Background	25
1.2 Context	26
1.3 Scope	26
1.4 Overview	27
2 Planning and Statutory Background	30
2.1 Planning Framework	30
2.2 The Local Government Act (2002)	31
2.3 Resource Management Act (1991)	32
2.4 Building Act (2004)	36
2.5 Civil Defence Emergency Management Act (2002)	37
2.6 Non Statutory Documents	37
2.7 Resource Consents	41
2.8 Strategic Catchment Management Objectives	41
3 Consultation	46
3.1 3 Waters Strategy Consultation- Stakeholder Workshops and Community Survey	46
3.2 Mosgiel Community Board Consultation	48
3.3 Annual Plan Submissions	48
Part 2 Baseline	50
4 Catchment Description	51
4.1 Catchment Location	51
4.2 Topography and Geology	51
4.3 Land Use	55



4.4	Catchment Imperviousness.....	61
4.5	Surface Water.....	64
4.6	Groundwater	69
4.7	Water Supply Network	71
4.8	Stormwater Network.....	74
4.9	Wastewater Network.....	81
4.10	Asset Condition and Criticality	86
4.11	Catchment Complaints.....	90
5	Receiving Environment.....	94
5.1	Introduction	94
5.2	Location and Description	95
5.3	Silver Stream	97
5.4	Owhiro Stream	103
5.5	Receiving Environment Summary	109
6	Network Discharges	111
6.1	Stormwater Quality.....	111
6.2	Wastewater Emergency Overflows.....	116
7	Model Results	118
7.1	Introduction	118
7.2	Model Results	121
7.3	Sensitivity Analysis.....	126
	Part 3: Analysis.....	130
8	Assessment of Environmental Effects	131
8.1	Network Benefits.....	131
8.2	Quantity Effects	132
8.3	Quality Effects.....	160



9	Catchment Problems & Issues Summary	166
9.1	Quantity Issues	166
9.2	Quality Issues	168
Part 4: Targets		172
10	Issues Prioritisation	173
11	Catchment Specific Targets and Approaches for Network Management.....	180
11.1	Quantity Targets and Approaches	181
11.2	Quality Targets and Approaches.....	194
Part 5: Solutions.....		200
12	Catchment Management Options.....	201
12.1	Introduction	201
12.2	Potential Options.....	202
13	Options Evaluation	224
13.1	Options Evaluation Criteria & Methodology.....	224
13.2	Options Comparison	225
14	Option Selection	254
14.1	Approaches for Active Management.....	254
14.2	Approaches for Passive Management	256
Part 6: Way Forward.....		258
15	Recommendations	260
16	Implementation, Monitoring and Continuous Improvement of the ICMP	264
16.1	Implementation	264
16.2	Monitoring and Continuous Improvement	264
17	References.....	265



Appendix A: Imperviousness Study

Appendix B: Rainfall Analysis

Appendix C: Customer Complaints 2005 - 2010

Appendix D: Mosgiel Stream Assessment Report

Appendix E: Predicted Network Flooding

Appendix F: Integrated Decision Making Framework

Appendix G: Options Information, QBL Framework and Analysis



Table of Figures

Figure 1-1 Scope of Work.....	28
Figure 1-2: ICMP Development Process	29
Figure 2-1: Legislative and Planning Document Hierarchies.....	30
Figure 4-1: Mosgiel Catchment Location	52
Figure 4-2: Mosgiel Catchment Contour Map	53
Figure 4-3: Mosgiel Catchment Geology Map	54
Figure 4-4: Resource Consents Granted by DCC and Designations within the Mosgiel Catchment	58
Figure 4-5: Archaeological and Heritage Sites within the Mosgiel Catchment.....	59
Figure 4-6: Contaminated Land Sites within the Mosgiel Catchment.....	60
Figure 4-7: DCC District Plan Land Use Zones for the Mosgiel Catchment	62
Figure 4-8: Current Imperviousness of the Mosgiel Catchment	63
Figure 4-9: Mosgiel Fluvial Flood Risk.....	68
Figure 4-10: Mosgiel Ground Water Levels 1994 (ORC, 2010).....	70
Figure 4-11: Contingency Plan for Contaminants in Groundwater Supply	71
Figure 4-12: 3 Waters Networks in the Mosgiel Catchment	73
Figure 4-13: Stormwater Pipe Diameter Frequency Distribution	75
Figure 4-14: Stormwater Drainage Network	76
Figure 4-15 : Stormwater Pipe Network Age.....	78
Figure 4-16: Wastewater Pipe Diameter Frequency Distribution.....	82
Figure 4-17: Wastewater Drainage Network	83
Figure 4-18: Wastewater Pipe Network Age	85
Figure 4-19: Stormwater Network Criticality	88
Figure 4-20: Wastewater Network Criticality	89
Figure 4-21: Mosgiel Stormwater Customer Complaints.....	91
Figure 4-22: Mosgiel Wastewater Customer Complaints	93
Figure 5-1: Freshwater Receiving Environment and Stream Assessment Sites	96
Figure 5-2: Puddle Alley Assessment Site	99
Figure 5-3: Gordon Road Assessment Site	99
Figure 5-4: Riccarton Road Assessment Site.....	100
Figure 5-5: Fish Distribution Records in the Silver Stream Catchment.	102
Figure 5-6: Soper Road Assessment Site.....	105
Figure 5-7: Burns Street Assessment Site.....	105
Figure 5-8: Quarry Creek Assessment Site	106
Figure 5-9: Riccarton Road Assessment Site.....	106
Figure 5-10: Fish Distribution Records in the Owhiro Stream Catchment.....	108
Figure 7-1: Rainfall Routing for Mosgiel's Stormwater and Wastewater System Model.....	118
Figure 7-2: Mosgiel Study Catchment and Combined Model Extent	120
Figure 8-1: Current (30 min) 1 in 10 yr ARI (Stormwater Model Results).....	134
Figure 8-2: Current (24 hr) 1 in 10 yr ARI (Wastewater Model Results).....	136
Figure 8-3: Wastewater Flow Monitoring Sub-Catchments with High Groundwater Infiltration...	137
Figure 8-4: Current (30 min) 1 in 5 yr ARI (Stormwater Model Results).....	141



Figure 8-5: Current (30 min) 1 in 10 yr ARI (Stormwater Model Results)	142
Figure 8-6: Current (12 hr) 1 in 10 yr ARI (Stormwater Model Results)	143
Figure 8-7: Current (30 min) 1 in 10 yr ARI (Stormwater Model Results)	144
Figure 8-8: Stormwater Flooding Current (30 min) 1 in 10 yr ARI (Model Results)	146
Figure 8-9: Current (24hr) 1 in 10 yr ARI (Stormwater Model Results)	147
Figure 8-10: Flood Hazard Future (30 min) 1 in 100 yr ARI (Model Results)	151
Figure 8-11: Flood Risk Cherry Drive PS Failure (May 2010 event) (Model Results)	155
Figure 8-12: Flood Risk Reid Avenue PS Failure (May 2010 event) (Model Results)	156
Figure 8-13: Flood Risk Carlyle Road PS Failure (May 2010 event) (Model Results)	157
Figure 9-1: Mosgiel Catchment Issues	170
Figure 10-1: Risk/Consequence Matrix for Issues Prioritisation	173
Figure 11-1: Target Development Process	180
Figure 13-1: Option Mo1: Catchment Wide Network Upgrade (Stormwater)	226
Figure 13-2: Option Mo2: New Stormwater Relief Main and Terminal PS	227
Figure 13-3: Option Mo6 Reduce Overland Flows to Kinmont Crescent	233
Figure 13-4: Option Mo10: Upsize Local Pipework Gow Street (Stormwater)	237
Figure 13-5: Option Mo13: Upsize Main Reid Avenue (Stormwater)	240
Figure 13-6: Option Mo14: Upsize Pipework Woodland Avenue (Stormwater)	244
Figure 13-7: Option WMo1: Reduce Baseflow: Renew Pipeline Murray Street (Wastewater)	248
Figure 13-8: Option WMo5: Upsize Pipes on Tyne Street (Wastewater)	249



Table of Tables

Table ES 1: Mosgiel Catchment Issues, Approaches and Targets Summary	12
Table ES 2: Further Study Recommendations	21
Table ES 3: Planning and Education Recommendations	22
Table ES 4: Operation & Maintenance Recommendations	22
Table ES 5: Capital Works Recommendations	23
Table 2-1: 3 Waters Strategic Management Objectives	40
Table 2-2: Strategic Catchment Management Objectives	42
Table 2-3: Stormwater Activity Management Plan Measures and Targets	44
Table 2-4: Wastewater Activity Management Plan Measures and Targets	45
Table 4-1: Current Land Use in the Mosgiel Catchment	55
Table 4-2: Stormwater Pipe Network Age and Length Composition	77
Table 4-3: Stormwater Operational Issues	79
Table 4-4: Wastewater Pipe Network Age and Length Composition	84
Table 4-5: Wastewater Operational Issues	86
Table 4-6: Asset Criticality Score Criteria	87
Table 4-7: Key Stormwater Flood Complaints	90
Table 4-8: Key Wastewater Customer Complaints	92
Table 5-1: Summary of Silver Stream Water Quality 2005-2010 Riccarton Road SOE Site (ORC)	98
Table 5-2: Silver Stream Assessment Site Characteristics	100
Table 5-3: Kai Tahu Values for the Silver Stream ORC Regional Plan: Water for Otago	103
Table 5-4: Summary of Owhiro Stream Water Quality 2005-2010, Burns Street SOE Site (ORC) ..	104
Table 5-5: Owhiro Stream Assessment Site Characteristics	107
Table 5-6: Kai Tahu Values for the Owhiro Stream ORC Regional Plan: Water for Otago	109
Table 5-7: Summary of Habitat and Ecosystem Quality in the Mosgiel Catchment	110
Table 6-1: Sources of Stormwater Contaminants	111
Table 6-2: Mosgiel Stormwater Quality Monitoring Results	114
Table 6-3: Dunedin City Time Proportional Stormwater Monitoring Results	115
Table 6-4: Comparison of Mosgiel Stormwater Quality with Other Stormwater Quality Data	115
Table 7-1: Wastewater Current DWF Performance	121
Table 7-2: Model Results – Wastewater Dry Weather Flow (DWF)	122
Table 7-3a: Model Results – Current Landuse	123
Table 7-4: Model Results – Future Landuse / Climate Change	125
Table 7-5: Model Results – Wastewater I&I Results (1 in 10 yr ARI)	126
Table 7-6: Model Results – Quarry Creek Sensitivity Analysis	127
Table 8-1: Summary of Significant Stormwater Flooding	139
Table 8-2: Summary of Wastewater Flooding	148
Table 8-3: Flood Hazard Rating	150
Table 10-1: Issues Prioritisation	174
Table 11-1: Mosgiel Catchment Management Targets – Quantity	187
Table 11-2: Mosgiel Catchment Management Targets: Quality	197



Table 12-1: Stormwater Design Criteria	220
Table 13-1: Option Mo1: Model Results	226
Table 13-2: Option Mo2: Model Results	228
Table 13-3: Option Mo3: Model Results	229
Table 13-4: Stormwater Flooding: Catchment Wide – Shortlist Comparison	230
Table 13-5: Stormwater Flooding: Gordon Road – Shortlist Comparison.....	232
Table 13-6: Stormwater Flooding: Kinmont Crescent - Shortlist Comparison.....	235
Table 13-7: Option Mo13: Model Results	241
Table 13-8: Stormwater Flooding: Reid Avenue Swale – Shortlist Comparison	242
Table 13-9: Stormwater Flooding: Woodland Avenue – Shortlist Comparison	246
Table 13-10: Wastewater Flooding/Overflows – Options Shortlist	252
Table 13-11: Wastewater Flooding/Overflows – Shortlist Comparison	252
Table 14-1: Active Management Issues and Approaches – Mosgiel Catchment	254
Table 14-2: Passive Management Issues and Approaches – Mosgiel Catchment	256
Table 15-1: Further Study Recommendations	261
Table 15-2: Planning and Education Recommendations.....	262
Table 15-3: Operation & Maintenance Recommendations.....	262
Table 15-4: Capital Works Recommendations	263



Executive Summary

The Mosgiel Integrated Catchment Management Plan (ICMP) is one of a number of ICMPs to be developed as part of Dunedin City Council's (DCC) 3 Waters Strategy.

The Mosgiel ICMP is a combined stormwater and wastewater ICMP and is the eleventh to be developed for Dunedin. The ICMP's production is not driven by discharge consent requirements but instead by a need to understand future network development requirements in relation to expected growth; and identify opportunities to resolve existing and potential future flooding problems. Additional focus has been placed on aspects of planning (land use changes, growth projections and options for planning controls), emergency wastewater discharges and flood risk.

The Mosgiel ICMP has been developed to identify these system deficiencies and test potential solutions in line with the DCC 3 Waters Strategic Objectives relating to stormwater and wastewater management.

Strategic objectives for stormwater and wastewater management provide the overarching objectives that guide the development of this ICMP. These objectives stem from the 3 Waters Strategic Direction Statement and are at the core of the relevant statutory and non-statutory documents addressing stormwater and wastewater management. These objectives have been developed with the aim of achieving benefits across the four 'wellbeings' (environmental, social, economic and cultural), and have been set within the context of a 50 year timeframe, and cover the following:

- Development;
- Levels of service;
- Environmental outcomes;
- Tangata whenua values;
- Natural hazards; and
- Affordability.

Mosgiel township covers an area of approximately 600 ha and lies on the north-eastern extremity of the Lower Taieri Plains. The wastewater and stormwater catchments for the Mosgiel township cover the urbanised area of Mosgiel, which is almost entirely located on flat land, with a small area on hillside to the east of the town centre. The ICMP study catchment extends some distance from the urban area, in an effort to quantify flows at the receiving environment discharge points.

The township of Mosgiel is bounded by two watercourses, the Silver Stream to the north and the Owhiro Stream to the south. Both are tributaries of the Taieri River. The smaller Quarry Creek, a tributary of the Owhiro Stream, flows through the southern part of the study catchment. There are also a number of open channels within the catchment to convey stormwater and additional 'drains' crossing the Taieri Plains, mostly serving as drainage for farm land.

All stormwater from the urban area of Mosgiel is reticulated towards either the Silver Stream to the north of the catchment, the Owhiro Stream to the south, or an unnamed field drain west of Lanark Street. Wastewater overflow from the Mosgiel wastewater treatment plant (WWTP) also discharges to the Silver Stream.



Stormwater quality monitoring is not carried out within the Mosgiel catchment on a regular basis. For the purposes of this study time-proportional monitoring was carried out during September 2010. The ORC has completed some historic stormwater quality monitoring in Mosgiel using grab-samples in 2004 and 2005. Whilst there is only a small data set of stormwater quality for this catchment, in general the majority of contaminants measured within the stormwater from the catchment are generally within the range typically observed for urban stormwater.

A linked 1 and 2-dimensional hydrological and hydraulic model of the Mosgiel wastewater and stormwater networks was developed to replicate the performance of each system, assess any interactions between them, and to predict flood extents during a range of land use, storm event and climate change scenarios.

Flow monitoring of the stormwater and wastewater networks was undertaken for this catchment and the model calibrated to replicate the observed flow, depth and velocity data as well as was possible, confidence in the model is considered to be moderate to high.

An assessment of environmental effects, based on the interpretation of the outcomes of the stormwater and wastewater network hydraulic modelling; stream assessments; information gathered during catchment walkovers; DCC flood complaints records; and information gathered during workshops with DCC Water and Waste Services Business Unit staff, identified a number of stormwater and wastewater related issues in the catchment.

Catchment issues were prioritised, then management targets and catchment specific approaches were developed for Mosgiel based on each issue, and the strategic objectives for stormwater and wastewater management. Table ES-1 below summarises the key issues, effects, targets and catchment specific approaches for the Mosgiel catchment.

The prioritisation score assigned to each issue indicates whether 'Active' or 'Passive Management' is required. 'Active Management' indicates that DCC will seek to implement changes to stormwater/wastewater management in the catchment, whereas 'Passive Management' would tend more towards monitoring and review of existing management practices to ensure that the targets set can be met.

Of all of the issues identified in the catchment, the following were identified as requiring Active Management:

- Fluvial Flood Risk;
- Stormwater Flooding;
 - Catchment-wide (nuisance flooding)
 - Gordon Road/Lanark Street
 - Kinmont Crescent
 - Gow Street/McGlashan Street
 - Woodland Avenue
 - Reid Avenue Swale



- Wastewater Flooding
 - Unconfirmed manhole overflows
 - Private property gully trap/boundary trap overflows
 - Tyne Street/Silverstream Drive manhole overflow
 - Woodland Avenue wastewater PS manhole overflow
 - Mosgiel WWTP emergency overflow to the Silver Stream
- Potential Wastewater Contamination
- WWTP Emergency Overflow Quality

The remaining issues were categorised as requiring Passive Management. This is predominantly due to the location and /or level or nature of the resulting adverse effects.

For many of the Active Management issues identified in this catchment a number of management options were available when taking into account the catchment specific approach and targets set. The multiple options were evaluated against Quadruple Bottom Line (QBL) evaluation criteria, with the most favourable management option being selected.

For those issues prioritised for 'passive management', in general all management approaches were selected.

Tables ES- 2 to ES-5 outline the recommendations, split into further studies, planning and education, operation and maintenance, and capital works task, with a priority placed according to the risk matrix scoring. The further studies recommended will assist in improving certainty around catchment management targets, or provide further information in order to develop options. Note that where a recommendation is to be resourced internally at DCC, a cost of \$0 has been assigned.

The implementation of these recommendations will be determined by the 3 Waters Strategic Plan, which will assess all of the ICMPs developed by DCC, and develop a prioritised programme of works across the city.


Table ES 1: Mosgiel Catchment Issues, Approaches and Targets Summary

Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Fluvial Flood Risk	Quarry Creek recorded to flood at least annually. Modelling predicts significant flood effects during a 1 in 10 yr Average Recurrence Interval (ARI). Silver Stream predicted to flood, with a risk to urban Mosgiel, during current events of between a 1 in 10 yr and 1 in 50 yr ARI. Owhiro Stream predicted to flood, with a risk to urban part of the catchment, during current events of 1 in 50 yr ARI and greater. Current level of fluvial flood protection in Mosgiel to a rural standard only.	Ensure there will be no increase in the numbers of properties at risk of flooding.	Manage Actively Ensure adequate planning controls so new development is not at risk of fluvial flooding during events up to and including 1 in 100 yr ARI. Avoid development of vulnerable sties/critical infrastructure in flood risk areas. Educate property owners to ensure private sections of watercourses are properly managed/maintained.	Develop adequate planning controls to reduce the risk of fluvial flooding to new development. No new development is at risk of interior flooding during events up to a 1 in 100 yr ARI.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Wastewater Flooding - Unconfirmed manhole overflows; - Private property gully trap/boundary trap overflows; - Tyne Street/Silverstream Drive manhole overflow; and - Woodland Avenue PS manhole overflow	Flooding from the wastewater network is predicted to occur during events as small as a 1 in 2 yr ARI event, due to insufficient system capacity resulting from combined influence of elevated DWF, wet weather I&I and WWTP operation. 1 % of manholes in the catchment predicted to occur during a current 1 in 10 yr ARI rainfall event, rising to 2.4 % with future growth and climate change applied. Historic customer complaints indicate private property boundary/gully trap overflows occurs within the catchment although the cause is uncertain. Stormwater inundation of the wastewater system may also result in overflows.	Reduce the number of wastewater overflows arising as a result of capacity. Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives. Invest adequately in renewals to maintain the performance of wastewater infrastructure. Ensure there will be no increase in the numbers of properties at risk of wastewater flooding, despite increasing pressure on the network. Service calls are responded to promptly. Wastewater is managed without risk to public health. > 65 % residents' satisfaction with the sewerage system.	Manage Actively Improve existing level of service in the network. Ensure reduction in the number of wastewater overflows predicted during a 1 in 10 yr ARI rainfall event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment. Enhance understanding of effects of wastewater flooding, particularly on private property. Undertake works where required to reduce flood effects.	No wastewater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. > 63 % of wastewater pipes to convey a 1 in 10 yr ARI rainfall event by 2060. Ensure customer complaints recording highlights causes of any private property flooding issues and/or undertake site visits to confirm. > 65 % resident's satisfaction with the sewerage system (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Stormwater Flooding - Catchment-wide; - Gordon Road/Lanark Street; - Kinmont Crescent; - Gow Street/McGlashan Street etc. - Woodland Avenue; - Reid Avenue Swale; and - Gladstone Road.	During events as small as a 1 in 2 yr ARI, widespread nuisance flooding is predicted affecting approximately 0.07 % of the catchment, rising to 0.3 % during a 1 in 10 yr ARI. Effects are considered unacceptable to the local community board. Deep flooding is also predicted in a number of isolated locations during high frequency events with a potential risk to building interiors. Catchment wide, modelling predicts approximately 10 parcels affected by deep flooding during 1 in 10 yr ARI rainfall event; rising to 22 during a current 1 in 50 yr ARI event. Potential of stormwater flooding to inundate wastewater network and result in wastewater overflows.	Ensure new development provides a 1 in 10 year level of service for stormwater, and avoids habitable floor flooding during a 1 in 50 yr ARI rainfall event. Invest adequately in renewals to maintain the performance of stormwater infrastructure. Ensure there will be no increase in the numbers of properties at risk of flooding. > 60 % residents' satisfaction with the stormwater collection service.	Manage Actively Ensure no increase in the number of stormwater manholes predicted to overflow in a 1 in 10 yr ARI rainfall event. Design new pipes with capacity to convey a 1 in 10 year ARI rainfall event. Reduce the number of properties predicted to flood during a current 1 in 10 yr ARI rainfall event. Ensure new development does not increase potential habitable floor flooding due to the stormwater system in events up to a 1 in 50 yr ARI rainfall event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment. Enhance understanding of effects of deep flooding, particularly on private property. Undertake works where required to reduce flood effects.	> 29 % of stormwater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. < 0.07 % of catchment surface area predicted to flood during a 1 in 2 yr ARI rainfall event by 2060. < 10 properties at risk of deep flooding (> 300 mm) during a 1 in 10 yr ARI rainfall event by 2060. Undertake habitable floor survey and/or damage assessment of potentially flooded properties. No stormwater inundation of the wastewater network by 2060. > 60 % resident's satisfaction with the stormwater collection service (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Potential Wastewater Contamination of Stormwater	Potential wastewater contamination of stormwater in 2 locations. Unknown whether potential contamination persists (Titri Place). Extent of contamination unknown (Woodland Avenue).	Improve the quality of stormwater discharges to minimise the impact on the environment. Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of stormwater discharges. Ensure stormwater discharge quality does not deteriorate.	Manage Actively Investigate potential catchment wastewater contamination. Incorporate a feedback process to the ICMP if / when monitoring indicates potential wastewater contamination.	Improve data relating to levels microbial contamination and potential sources within the catchment by 2013.
WWTP Emergency Overflow Quality	WWTP emergency overflow is predicted to operate in rainfall events of 1 in 5 yr ARI or greater. Prior to 2010 it was known to operate at approximately once per year. Discharge is not considered to be having a significant adverse effect on the watercourse. Key stakeholder issue.	Reduce the number of wastewater overflows arising as a result of capacity. Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of discharges.	Manage Actively Monitor operation of overflow to enable better understanding of triggers and frequency of operation.	No wastewater overflows due to capacity during a 1 in 10 yr ARI rainfall event. Ensure adequate recording of frequency of overflow operation by 2013.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Stormwater Network Maintenance	Flooding extents and durations in catchment potentially exacerbated by variations in the frequency and standards of cleaning and maintenance of stormwater structures (inlets and catchpits). City-wide inconsistencies in frequency and standards of cleaning and maintenance of stormwater structures can lead to discrepancies in level of service.	Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives.	Manage Passively Identify areas in catchment where more regular stormwater structure cleaning and maintenance could reduce flooding risk. Ensure consistency city-wide of stormwater structure cleaning and maintenance. Ensure cleaning and maintenance schedules and contracts are sufficiently robust.	Develop consistent cleaning and maintenance criteria for all stormwater assets (in conjunction with city-wide criteria) by 2013. Develop list of key stormwater assets in Mosgiel catchment requiring additional cleaning and maintenance by 2013. Document cleaning and maintenance responsibilities for catchment stormwater assets by 2013.
Wastewater Network Maintenance	High risk of blockages in pipe network due to flat catchment and low flow velocities. Blockage/partial blockages significantly reduce network capacity and increase the risk of overflow. Cleaning and maintenance of network currently carried out on ad hoc basis when problems arise.	Reduce the number of wastewater overflows arising as a result of capacity. Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives.	Manage Passively Identify areas in the network prone to blockage. Identify cleaning/maintenance requirements and frequency for pipes at higher risk of blockage. Ensure cleaning and maintenance schedules and contracts are sufficiently robust.	Ensure complaints and operational issues are reported with incident and asset details. Develop list of key areas of the wastewater network prone to blockage by 2013. Develop a cleaning and maintenance schedule for wastewater assets which require regular attention by 2013.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Low Level of Service – Stormwater Network	29 % of stormwater network unable to accept rainfall during a 1 in 10 yr ARI, primarily due to insufficient network capacity. This low level of service is currently occurring with no capacity for climate change effects. Effects include widespread nuisance flooding, deep flooding in isolated locations with risk of flooding of habitable floors and inundation of wastewater system causing overflows. Effects unacceptable to local community in some locations.	Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives. Ensure new development provides a 1 in 10 year level of service for stormwater, and avoids habitable floor flooding during a 1 in 50 yr ARI rainfall event. Invest adequately in renewals to maintain the performance of stormwater infrastructure. Ensure there will be no increase in the numbers of properties at risk of flooding. > 60 % residents' satisfaction with the stormwater collection service.	Manage Passively Improve existing level of service in network. Ensure no increase in the number of stormwater manholes predicted to overflow in a 1 in 10 yr ARI rainfall event. Design new pipes with capacity to convey a 1 in 10 year storm event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment.	<0.07 % of catchment surface area predicted to flood during a future 1 in 2 yr ARI rainfall event. < 29 % stormwater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. Undertake survey of property owners to determine any occurrence of flooding on properties during high frequency events. > 60 % resident's satisfaction with the stormwater collection service (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Low Level of Service – Wastewater Network	1 % of wastewater manholes predicted to overflow during a 1 in 10 yr ARI. WWTP emergency overflow predicted to operate during a 1 in 5 yr ARI rainfall event. Effects driven by network capacity problems resulting from combined influence of elevated DWF, wet weather I&I and WWTP operation. This low level of service is currently occurring with no capacity for future growth or climate change effects. Effects include widespread network surcharging, overflows from manholes and private property boundary/gully traps, emergency overflow operation.	Ensure that the reticulated network has sufficient capacity to meet community needs. Reduce the number of wastewater overflows arising as a result of capacity. Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives. Invest adequately in renewals to maintain the performance of wastewater infrastructure. Ensure there will be no increase in the numbers of properties at risk of wastewater flooding, despite increasing pressure on the network. > 65 % residents' satisfaction with the sewerage system.	Manage Passively Improve existing level of service in the network. Ensure reduction in the number of wastewater overflows predicted during a 1 in 10 yr ARI rainfall event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment.	No wastewater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. No occurrence of WWTP emergency overflow during events if 1 in 10 yr ARI or less by 2060. > 63 % of wastewater pipes to convey a 1 in 10 yr ARI rainfall event by 2060. > 65 % resident's satisfaction with the sewerage system (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Flood Hazard (1 in 100 yr ARI)	Areas of moderate to significant flood hazard are predicted during current event affecting local roads and commercial and residential areas. Extent of 'moderate to significant' flood hazard predicted to increase in the future (2060) event exacerbated by predicted climate change effects.	Ensure there will be no increase in the numbers of properties at risk of flooding from the stormwater network.	Manage Passively Ensure new development does not increase the number of properties predicted to flood due to the stormwater system in a 1 in 100 yr ARI rainfall event. Protect key and vulnerable infrastructure (e.g. pump stations, works depots, schools, hospitals, electricity supply etc.) from flood hazard. Avoid development of vulnerable sites / critical infrastructure in flood prone areas. Develop a better understanding of the likely effects and magnitude of climate change.	Provide modelled flood predictions to DCC Climate Change Adaptation Group to ensure information is taken into account during the development of a city-wide climate change adaptation plan.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Ongoing Stormwater Discharge	Uncertainty regarding stormwater quality throughout catchment. Based on available data, consequence currently believed to be minor. Key stakeholder issue.	Improve the quality of stormwater discharges to minimise the impact on the environment. Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of stormwater discharges. Ensure stormwater discharge quality does not deteriorate.	Manage Passively Consider the cost / benefit of stormwater quality treatment as part of flood mitigation works where practicable. Require source control of stormwater contaminants in new development of high-contaminant generating land uses. Enforce the Trade Waste Bylaw, and educate occupiers of high-risk sites with respect to stormwater discharge quality.	Identify locations of high risk land uses within the catchment and implement an education programme targeting stormwater discharges. No deterioration of stormwater quality due to land use change or development in the catchment.


Table ES 2: Further Study Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
210	Improve understanding of flood levels and hydraulic capacity of the Quarry Creek (investigations by ORC in collaboration with DCC).	\$100-150k	12 months
200	Design framework to investigate stormwater quality, in particular the extent of microbial contamination.	\$8-\$15k	2-4 months
200	Implement framework for investigating stormwater quality with focus on extent of microbial contamination within catchment.	\$20-\$30k	8-10 months
200	Improve quality of wastewater network data through (level survey, GIS confirmation, CCTV).	\$0	Ongoing
160	Improve quality of stormwater network data through (level survey, GIS confirmation, CCTV).	\$0	Ongoing
160	Community consultation followed by feasibility study for catchment-wide stormwater network upgrade (pipes or swales).	\$100 - \$200k	12 months
120	Identify and undertake floor level survey and damage assessment of properties potentially affected by deep (habitable floor) flooding up to a 1 in 50 yr ARI event prior to detailed development of options for Gow Street.	\$20-40k	3-6 months
120	Identify and undertake floor level survey and damage assessment of properties potentially affected by deep (habitable floor) flooding up to a 1 in 50 yr ARI event prior to detailed development of options for Kinmont Crescent.	\$20-40k	3-6 months
80	Investigate current surface water drainage on Gordon Road and Lanark street and update management approach as required.	\$5-\$10k	2-4 months
40	Develop Response Plan for event of stormwater PS failure.	\$10-\$20k	3-6 months
40	Utilise stormwater and wastewater complaints, ROS and Community Board feedback information to continuously gauge customer satisfaction with the stormwater and wastewater services.	\$0	Ongoing
40	Review/amend capital works options for Gow Street/McGlashan Street stormwater flooding issues following outcomes of catchment investigations (Quarry Creek/Habitable floor flooding).	\$0	6 months
40	Ongoing assessment of wastewater system performance, develop/amend capital works options to address future growth as required.	\$0	ongoing
40	Review/amend capital works options Gladstone Road North stormwater flooding issues following outcomes of catchment investigations (Habitable floor flooding).	\$0	6 months


Table ES 3: Planning and Education Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
210	Collaborate with ORC to ensure appropriate level of fluvial flood protection is provided in Mosgiel.	\$0	6-12 months
210	Review/amend business processes (landuse planning, subdivision and development) to ensure new development/growth areas are not at risk from fluvial flooding.	\$0	12 months
210	Review the education/advice provided to property owners responsible for watercourses to ensure adequate information and assistance is provided.	\$0	3-6 months
50	Identify locations of high risk land uses within the catchment and implement an education programme targeting stormwater discharges.	\$10-20	3-6 months
40	Include the Mosgiel catchment in the development of a city-wide Climate Change Adaptation Plan.	\$0	6-12 months

Table ES 4: Operation & Maintenance Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
50	Review/amend wastewater complaints logging/incident reporting procedures to enable recording of incidents against assets.	\$0	3 months
50	Compile an inventory of wastewater assets prone to blockage or other problems. Update regularly using complaints/incident reporting.	\$0	ongoing
50	Develop a cleaning and maintenance schedule for the wastewater network documenting locations, nature of cleaning/maintenance and frequency.	tba	Ongoing
50	Compile an inventory of stormwater structures including asset condition, ownership and identify sensitive locations for more frequent cleaning and maintenance.	\$20k	3-6 months
50	Develop consistent cleaning and maintenance criteria for all stormwater assets (in conjunction with city-wide criteria).	\$20k	2 months


Table ES 5: Capital Works Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
200	Option WMoA (wastewater) - detailed development, programming, implementation (staged approach).	\$800K - \$1.5M	12-24 months
200	Option Mo4: Upsize Stormwater Pipe Woodland Avenue- Identify and undertake floor level survey and damage assessment of properties potentially affected by deep flooding up to a 1 in 50 yr ARI, detailed option development, implementation.	\$400-\$600k	tba
160	Include additional or improved catchpits in stormwater capital works.	tba	ongoing
80	Improve outlet screen – Reid Avenue Swale.	\$50-\$100k	tba
80	Increase outlet capacity – Reid Avenue swale.	\$100-\$200k	tba
40	Review gravity outfalls to the Silver Stream and improve outfall seals.	\$50-\$100k	tba
40	Implement works resulting from the development of the Response Plan for stormwater PS failure.	\$1M-\$2M	tba



1 Introduction

1.1 Background

Dunedin City Council (DCC) is currently in the process of implementing an integrated approach to asset management and a business improvement project in order to meet capital and operational delivery targets. The process has two main components. The first; review of the existing business structure was completed in 2009. This established a better alignment between people, processes and outcomes. The second; to undertake a significant strategy development project incorporating the three water networks; water supply, wastewater and stormwater. This 3 Waters Strategy project includes the development of hydraulic models examining the entire water cycle within Dunedin's urban catchments, and providing critical information on the performance of the networks. The 3 Waters Strategy will then be used to inform decisions on future capital expenditure programmes to address the following:

- Current known issues in the networks;
- Urban growth;
- Climate change; and
- Environmental sustainability (particularly in relation to new stormwater consents).

As part of this future strategy the 3 Waters Strategy project has been developed with the aim of providing an integrated decision making process for DCC. The objectives of the 3 Waters Strategy are:

- Determine required levels of service for each of the three waters networks;
- Determine capital and operational costs associated with improvements to the three waters networks, including priorities and phasing for investment;
- Develop a greater understanding of the operations of the three waters networks through targeted asset and flow data collection;
- Develop decision support tools including network models;
- Develop Integrated Stormwater Catchment Management Plans; and
- Provide sufficient data to support the development of Council's Annual Plan and Long Term Plan (LTP).

To achieve the objectives of the Strategy the project comprises a three phase process:

Phase 1: Development of capital and operational investment needs at a macro level, determine the needs for more detailed investigations to be carried out in Phase 2, and determine high priority capital and operational works for major infrastructure items to be carried out in Phase 3.

Phase 2: Detailed investigations to determine capital and operational needs at a catchment or zonal level.



Phase 3: Implementation of capital and operational works to realise the required level of service improvements.

1.2 Context

The development of the Mosgiel Integrated Catchment Management Plan (ICMP) 2011-2060, is part of the 3 Waters Strategy being undertaken. It is the eleventh long term plan produced as part of Phase 2 of the 3 Waters Strategy project. The other ten ICMP's produced as part of the Strategy form the basis for Dunedin City Council's application to renew its resource consents for stormwater discharge into the Otago Harbour.

The Mosgiel ICMP is a combined stormwater and wastewater ICMP. The ICMP's production is not driven by discharge consent requirements but instead by a need to understand future network development requirements in relation to expected growth; and identify opportunities to resolve existing and potential future flooding problems. Additional focus has been placed on aspects of planning (land use changes, growth projections and options for planning controls), emergency wastewater discharges, and flood risk.

The Mosgiel ICMP has been developed to identify these system deficiencies and test potential solutions in line with the DCC 3 Waters Strategic Objectives relating to stormwater and wastewater management. These objectives are described further in Section 2.6.4.

1.3 Scope

The scope of works for this ICMP was developed to collect sufficient information about current stormwater and wastewater management in the catchment and the effects of current practices. Objectives for stormwater and wastewater management have been set by the 3 Waters Strategic Direction Statement in conjunction with objectives for water supply management. Recommendations for future stormwater and wastewater management are required to meet these objectives based around avoiding, remedying or mitigating any adverse effects of stormwater and wastewater management practices on both the catchment itself and the receiving environment.

Integration of stormwater, wastewater and water supply management was undertaken at a macro level during Phase 1 of the 3 Waters Project. The opportunities for integration of the three waters increased as the water supply and wastewater studies moved through Phase 2 of this project, which was a more detailed study of problem areas. This ICMP considers integration of the stormwater and wastewater networks on a catchment scale.

The scope of this ICMP focuses on the effects of current stormwater and wastewater network management practices. However, there is network interaction and known issues with the watercourses running through the Mosgiel catchment. Information relating to the effects of watercourses, notably fluvial flooding, whilst outside the scope of this ICMP, have been included for completeness and to assist in future catchment planning.

It should be noted that the Resource Management Act (1991) (RMA), creates a statutory situation of 'shared responsibility' for water management including the avoidance or mitigation of actual or potential flood hazard, which in practice may be exercised in different ways. The ways in which this balance is achieved in a practical sense may be through advocacy, negotiation, or prescription, potentially depending as much on the political, financial and physical circumstances as well as



statutory duty. Thus highlighting that any adverse effects relating to natural watercourses are not solely the responsibility of the DCC to avoid, remedy or mitigate. This is discussed further in Section 2.

Figure 1-1 presents the scope of work for the Mosgiel ICMP component of the 3 Waters Strategy.

1.4 Overview

This ICMP comprises six parts:

Part 1 – Introduction. This provides the background to the study, and outlines the planning and statutory requirements of DCC with respect to stormwater and wastewater discharge management.

Part 2 – Baseline. This describes the study catchment as it is now; topography, land use, receiving environments, discharge quality. The stormwater and wastewater networks are also described and current operational issues discussed.

Part 3 – Analysis. Stormwater and wastewater management problems and issues are identified in this section, by analysing the results of quality investigations, network modelling, flood hazard mapping and other information collated in previous sections.

Part 4 – Targets. Catchment stormwater and wastewater management approaches and SMART targets are outlined in this section, as determined by the priority of each issue, and DCC's stormwater and wastewater management objectives.

Part 5 – Solutions. This section describes a number of potential solutions to the issues identified (stormwater and wastewater quantity and discharge quality).

Part 6 – Way Forward. A prioritised programme of works is outlined, based on the Optimised Decision Making Framework (ODM) developed for the DCC 3 Waters Strategy.

Figure 1-2 provides a process diagram of the ICMP process used for this project. The figure also indicates the position and influence of stakeholder consultation within this process. Ongoing consultation ensures that the project advances in a way that meets the needs and expectations of all parties involved. It can also significantly benefit the project by providing invaluable local knowledge and assist in identifying significant issues. Furthermore, successful consultation during development stages can often assist implementation of the ICMP.

An ICMP document is designed to accommodate a number of changes during its useful life, via monitoring and review processes (refer Section 16). Changes within the catchment, results of monitoring, or improved system knowledge are a number of things that may prompt a change in the ICMP.

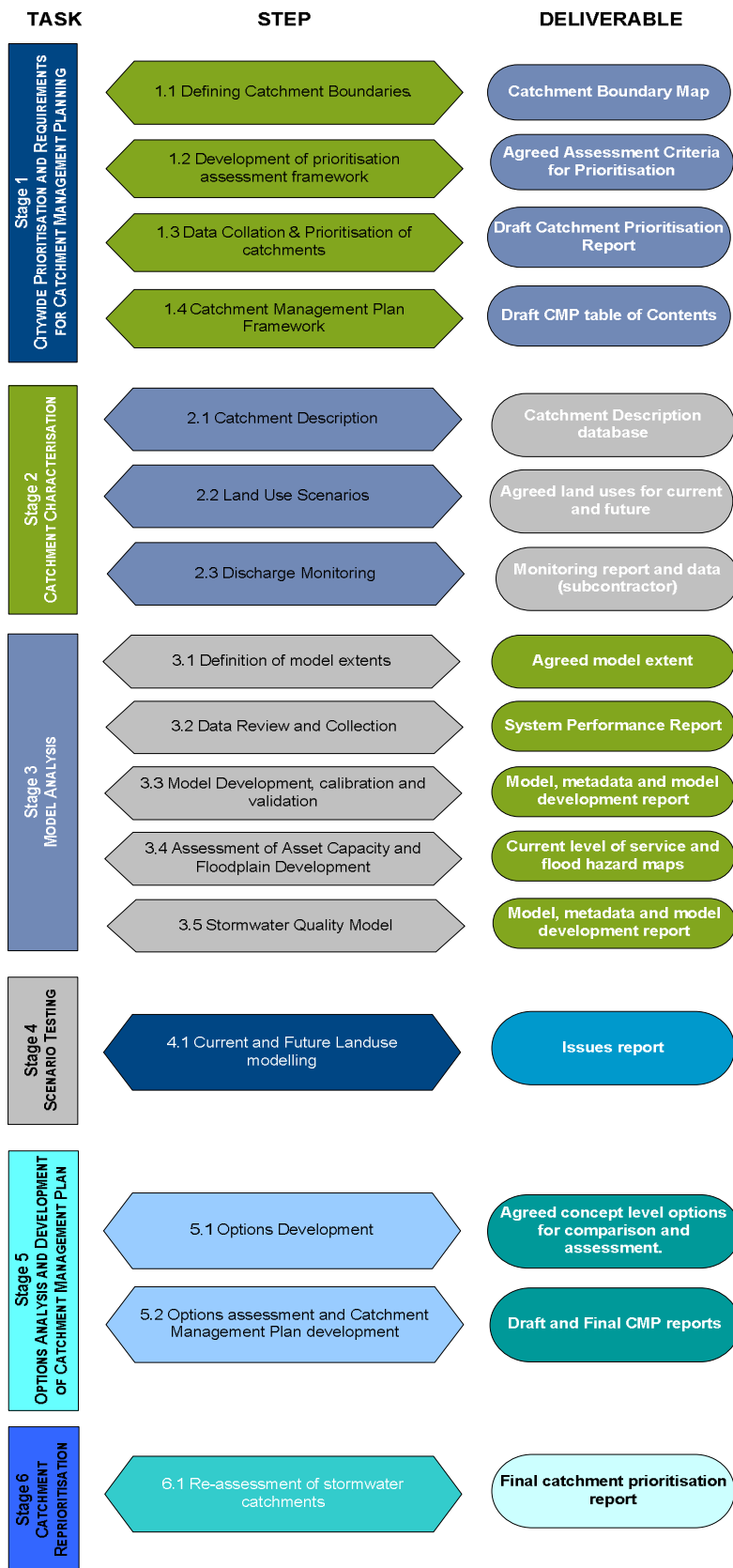


Figure 1-1 Scope of Work

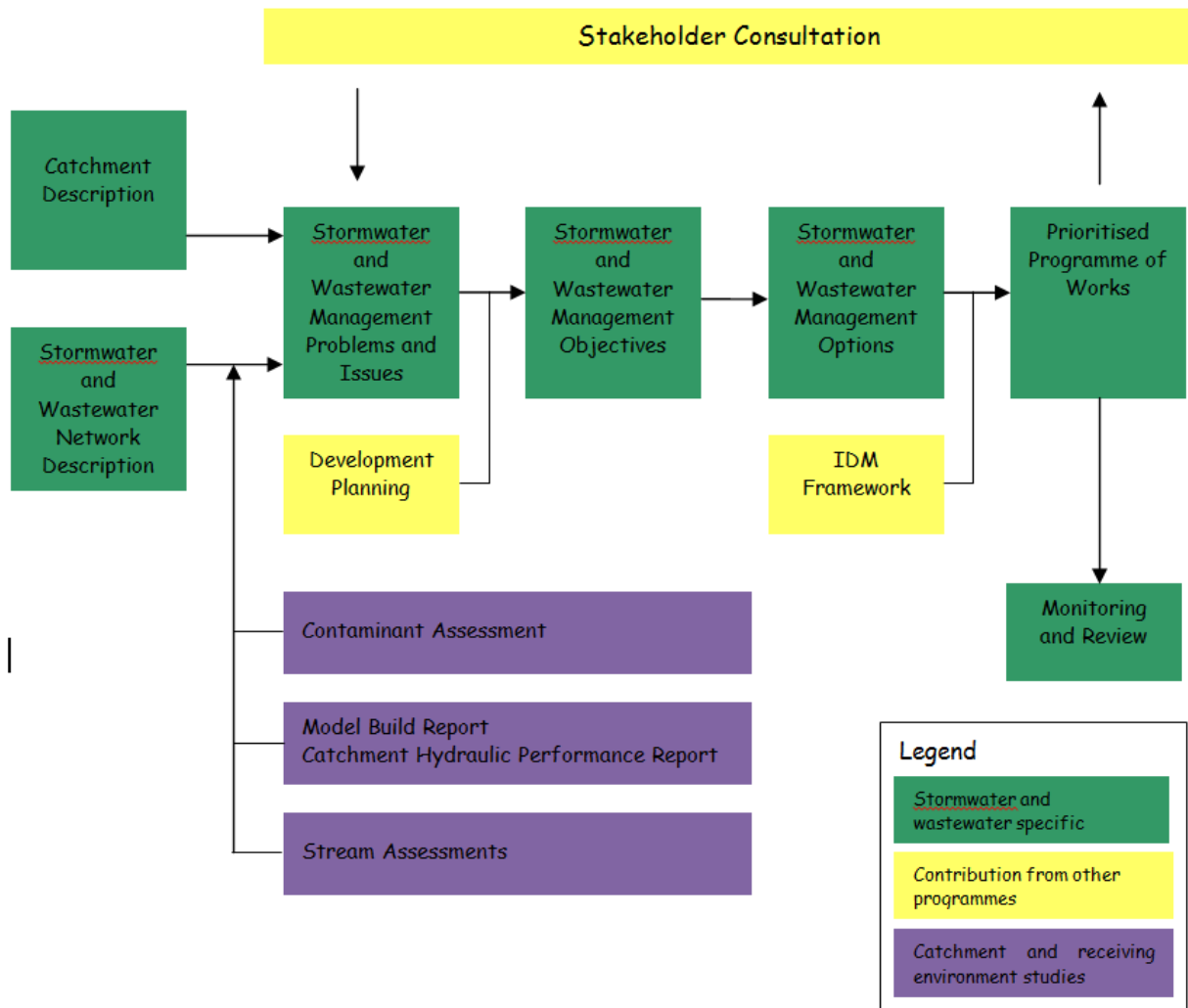


Figure 1-2: ICMP Development Process



2.2 The Local Government Act (2002)

The purpose of the Local Government Act 2002 (LGA) is to provide for democratic and effective local government that recognises the diversity of New Zealand communities and, to that end, this Act—

- (a) *States the purpose of local government; and*
- (b) *Provides a framework and powers for local authorities to decide which activities they undertake and the manner in which they will undertake them; and*
- (c) *Promotes the accountability of local authorities to their communities; and*
- (d) *Provides for local authorities to play a broad role in promoting the social, economic, environmental, and cultural wellbeing of their communities, taking a sustainable development approach.*

There are a number of responsibilities outlined within the LGA which are relevant to the ICMP. These include:

- Section 93, Long Term Plan (LTP);
- Section 95 Annual Plan; and
- Compliance with performance measures set by the Secretary of Local Government. .

These are discussed below.

An ICMP needs to be consistent with the LGA. This can be achieved by promoting consultation with all parties affected by stormwater management decisions and accounting for and managing the stormwater infrastructure for Dunedin City in a manner that provides for the present and future needs of the public and the environment.

2.2.1 Long Term Council Community Plan (LTP)

Section 93 of the LGA requires a local authority to produce a LTP for the following purposes:

“to describe the activities of the local authority; to describe community outcomes; to provide integrated decision making and co-ordination of resources; to provide a long term focus for decisions and activities; and provide a basis for the accountability of the local authority to the community.”; and to provide an opportunity for participation by the public in decision making processes.”

2.2.2 Annual Plan

The Annual Plan required under Section 95 of the LGA supports the LTP by providing for the co-ordination of local authority resources, contributing to the accountability of the local authority to the community, and extending the opportunities for participation by the public in decision making relating to costs and the funding of local authority activities.



Section 126 of the LGA is more prescriptive and requires a Council to assess and report on the status of water resources including potable supply, stormwater and wastewater. As well as assessing Council owned services, councils are obliged to assess services owned by others, and also areas that are not reticulated. This is driven by the importance of water and sanitary services to the public health of the community.

2.2.3 Performance Measures

The Secretary of Local Government is required to provide regulations that establish rules specifying performance measures for water supply; sewerage treatment/disposal; stormwater; flood protection and the provision of roads and footpaths. The performance measures relating to stormwater, wastewater and flood protection will need to be taken into account when developing solutions under the ICMP.

2.2.4 Trade Waste Bylaw

The Dunedin City Council Trade Waste Bylaw 2008 regulates the discharge of trade waste to a sewerage system operated by DCC. The purpose of the Bylaw is:

“to control and monitor trade waste discharges into public sewers in order to ...

(iii) protect the sewerage system infrastructure...

(v) protect the stormwater system...”

Schedules 1A, and 1B outline the characteristics of trade waste that are accepted on a permitted or conditional basis. Schedule 1C outlines trade waste characteristics that are prohibited from being discharged to the sewerage system. The characteristics outlined in these schedules provide an indication of the level of treatment that may be required when assessing options under the ICMP.

Section 4A of the Bylaw states that it is an offence to discharge stormwater into the stormwater system that does not satisfy the discharge acceptance standards outlined in Schedule 1E of the Bylaw. Schedule 1E contains a number of acceptance standards, including limitations on the quality of the stormwater.

2.3 Resource Management Act (1991)

The purpose of the RMA as defined in Section 5 of the Act, is to promote the sustainable management of New Zealand's natural and physical resources. This is to be achieved by managing the use of resources, in a manner that allows for people and communities to provide for their social, economic and cultural wellbeing, while sustaining the potential of natural and physical resource to meet the needs of future generations; safeguarding the life supporting capacity of air, water, soil and ecosystems; and avoiding, remedying or mitigating adverse effects of activities on the environment.

Section 6: Matters of National Importance, Section 7: Other Matters and Section 8: Treaty of Waitangi, outline values which all persons exercising functions and powers under the RMA shall recognise and provide for, have particular regard to and take into account when achieving the purpose of the RMA.



Sections 14 and 15 of the RMA place restrictions on taking and using water, and on the discharge of contaminants into the environment.

In relation to stormwater and wastewater management, the RMA addresses the following:

- The need to sustainably manage our water resources to meet the needs of future generations;
- The need to preserve the natural character of our coastal environment, wetlands, lakes, rivers and their margins;
- Recognising and providing for the relationship of Māori with their ancestral lands and water;
- The control of the use of land for the purpose of the maintenance and enhancement of the quality of water in water bodies and coastal water;
- The control of discharges of contaminants and water into water;
- The control of the taking, use, damming and diversion of water, and the control of the quantity, level and flow of water in any water body, including:
 - i) The setting of any maximum or minimum levels or flows of water;
 - ii) The control of the range, or rate of change, of levels or flows of water.

It is considered that the development and implementation of an ICMP that is consistent with the purpose and principles of the RMA will allow for the identification of in-catchment values, such as drainage patterns and sensitive receiving environments. Management recommendations are then made based on the best practicable option to ensure that the natural and physical environment within a stormwater or wastewater catchment and its receiving environment are managed sustainably. This approach helps to ensure that the natural and physical resources within Dunedin's stormwater and wastewater catchments are used in a way that provides for the communities social, economic and cultural wellbeing.

Duties under the RMA

Under Section 30 of the RMA, the statutory functions of regional councils include responsibility for water quality and quantity, including (but not limited to) the control of the use of land for the maintenance and enhancement of water quality and quantity (s30(1)(c)(ii)) and for the avoidance or mitigation of natural hazards (s30(1)(c)(iv)).

Under Section 31 of the RMA, the statutory functions of territorial local authorities include responsibility for the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards (s31(1)(b)(i)).

This creates a statutory situation of 'shared responsibility' for water management. For example, a regional council may control the construction and maintenance of flood control structures such as stopbanks on rivers and controls on land use in proximity to those. They may set objectives and policies for district councils to implement in terms of zoning and the types of land use and subdivision that should be permitted in proximity to those, as well as minimum floor heights that may be imposed on building and resource consents for development in proximity to those.

A regional council may also impose controls on stormwater management through resource consents for stormwater discharge that requires stormwater reticulation constructed by district councils and



developers to have a minimum level of stormwater retention, capacity, and rate and point of discharge (as well as potentially treatment also) at the time of its construction.

In turn, a district plan may include zoning, and objectives, policies, rules and standards controlling the type of development in relation to flood hazard areas identified in district or regional planning maps. A district council may also require provision of minimum floor heights that may be imposed on building and resource consents for development in proximity to those identified flood hazard areas. A district council may also have ongoing responsibility for management and maintenance of stormwater infrastructure (unless within a state highway designation in which case the New Zealand Transport Agency (NZTA) may prefer to retain control).

2.3.1 National Policy Statement for Freshwater Management (2011)

The National Policy Statement (NPS) for Freshwater Management provides high level guidance for local authorities when considering freshwater management objectives, policies and methods for inclusion in statutory planning documents. Objective A2 of the NPS requires that the overall quality of fresh water within a region is maintained or improved while; protecting the quality of outstanding fresh water bodies and the significant values of wetlands, and improving the quality of freshwater in water bodies that have been degraded by human activities to the point of being over-allocated. Over-allocation is defined in terms of water quantity and water quality.

The NPS does not outline the specific outcomes to be achieved for water quality and water quantity by local authorities. However, the NPS does specify that specific targets shall be included in planning documents. The ICMP provides one method of attaining the specific outcomes outlined in the NPS. Consequently the objectives of this NPS should be considered when reporting any solutions and recommendations in the ICMP in relation to stormwater and in relation to wastewater issues that could impact on freshwater quality. An example of how the ICMP may direct the specific outcomes required is via the monitoring to complete the ICMP; the results of monitoring can contribute to the understanding of stormwater and wastewater issues, and assist with the development of future water quality and quantity objectives, that may be included in statutory plans.

2.3.2 National Environmental Standards

While there are currently no National Environmental Standards (NES) relevant to this ICMP, it is assumed that NES will be developed in time for the type of activities covered. As local or regional councils must enforce standards imposed by an NES, the ICMP must be flexible enough to incorporate these standards.

2.3.3 The Otago Regional Policy Statement (1998)

The Otago Regional Policy Statement (ORPS) is an operative document giving effect to the RMA. The ORPS discusses issues, objectives and policies relating to managing the use, development and protection of the natural and physical resources of the region. The ORPS identifies regional issues and provides a policy framework for managing environmental effects associated with urban and rural development.

The ICMP is influenced by the ORPS and the planning documents which sit below it (i.e. Regional Plans). There are a number of policies contained within the ORPS which are relevant to the ICMP. Of particular relevance are Policies 6.5.5, 7.5.3 and 9.5.4 which seek to reduce the adverse effects



on the environment of contaminant discharges through the management of land use, air discharges and the built environment. The management options discussed include adopting baseline water quality standards and where possible improving the quality of water to a level above these baselines. The policies mentioned give general guidance to any stormwater or wastewater management initiatives within the region by identifying anticipated environmental outcomes. This general guidance is the main starting point for determining the direction of the ICMP.

The ORPS also addresses natural hazards in Policies 11.5.2, 11.5.3 and 11.5.4. These policies give direction to hazard management through outlining steps that should be taken to avoid or mitigate the effects of natural hazards. These overarching policies may play a significant role in providing direction for the ICMP if natural hazards (such as flooding) are determined to be a priority.

The ORPS was due for full review in October 2008 however at the time this report was written the review process has not been initiated.

2.3.4 The Regional Plan: Water for Otago

The operative Regional Plan: Water for Otago (Water Plan) considers the use, development and protection of the fresh water resources of the Otago region, including the beds and margins of water bodies. Chapter 7 of the Water Plan outlines objectives and policies to address those issues relating to water quality and discharges.

Policies 7.7.1, 7.7.2, 7.7.3, 7.7.4, 7.7.5 and 7.7.7 outline matters which need to be considered when assessing resource consents for point source discharges including; discharge location (land or other), cumulative effects, the sensitivity of the receiving environment and any relevant standards. Policies 7.7.10 and 7.7.11 address stormwater systems directly, identifying required outcomes for new systems and requiring the progressive upgrade of older systems. These policies provide both general and specific guidance for any stormwater or wastewater system or associated discharge within the Mosgiel catchment and play a strong role in determining the suitability, consentability and priority of any management option chosen under the ICMP.

2.3.5 The Dunedin City District Plan

The operative Dunedin City District Plan identifies issues and states objectives, policies and methods to manage the effects of land use activities on the environment.

The Dunedin City District Plan applies to all users of land and the surface of water bodies within the city; it is concerned with all areas above the line of mean high water springs (MHWS). Issues pertaining to those areas below the line of MHWS, including coastal waters, are addressed in the Coastal Plan and the NZCPS.

Policy 21.3.1 seeks to protect the harvest potential and quality of water within catchments. Policy 21.3.8 seeks to avoid or otherwise remedy or mitigate the adverse effect of activities which discharge to water, land or air. While standards relating to water quality are the jurisdiction of the Otago Regional Council (ORC), the policies contained within The Dunedin City District Plan address the effects of land use on water quality for example through the consideration of matters such as stormwater runoff from subdivisions.



The Dunedin City District Plan also uses land use zoning as a method of regulating activities under DCC jurisdiction. These land uses will play an integral part in determining the quantity and quality of any stormwater runoff. The Mosgiel catchment consists of 8 different land use zones. These are: Rural, Rural Residential, Residential 1, 2 and 6, Industrial 1, Local Activity Zone 1 and Special Development Zone.

Careful consideration will need to be given to these land use zones and any potential changes to the zones when looking at management options under the ICMP, as different land uses produce different stormwater quantities and quality outputs. It may also be that data obtained during the development of the ICMP provides input into future land use zoning within The Dunedin City District Plan.

The only policy relevant to the management of wastewater is Policy 21.3.6 that relates to the management of wastewater on land. All wastewater from the Mosgiel reticulated area is treated at the Mosgiel WWTP before being piped to the Green Island WWTP prior to discharging to the Pacific Ocean via the Green Island outfall. The provisions of the Dunedin City District Plan assert some control over the management of the treatment facilities through land use controls. While these facilities are already consented, if any modifications to the system are required this policy will need to be considered.

2.3.6 The Dunedin City Council Spatial Plan

The DCC is working to create a spatial plan (Dunedin Towards 2050) to set the strategic direction for Dunedin's growth and development for the next 30 years. The plan, when complete, will outline a broad set of principles, objectives, policies and actions and visually illustrate how the city could develop in the future. It will be used to guide land-use planning in the city, as well as how future infrastructure and services may be provided.

The Spatial Plan will provide direction for a second generation District Plan and inform the Transportation Strategy review.

Outcomes of the Mosgiel ICMP will inform the planning process in terms of influencing future development areas within Mosgiel.

2.4 Building Act (2004)

The Building Act 2004 includes Sections 71 to 74 which relate to limitations and restrictions on building consents and the construction of buildings on land subject to natural hazards.

The Building Regulations 1992 include the Building Code within Schedule 1, which provides guidance as to the implementation of the Building Act. Section E of the Building Code includes various performance criteria relating to stormwater systems which are relevant to the ICMP. These criteria are specific to managing natural hazards and include drainage system design and inundation probability criteria. The ICMP will need to reference the performance criteria outlined within the code when identifying management options.

Section G13 of the Building Code outlines standards in relation to the disposal of wastewater. This includes standards for the construction of drainage systems. These standards will need to be adhered to when developing any wastewater treatment or conveyance solution under this ICMP.



2.5 Civil Defence Emergency Management Act (2002)

The Civil Defence Emergency Management Act 2002 (CDEMA) addresses the management of emergencies including flooding. Section 64(1) of the CDEMA outlines the duties of local authorities and states:

“A local authority must plan and provide for civil defence emergency management within its district.”

Producing flood maps as part of the ICMP process may be one method of providing for civil defence emergency management however this method is not specifically prescribed by the CDEMA and therefore is at the discretion of the local authority concerned.

2.6 Non Statutory Documents

2.6.1 Kāi Tahu Ki Otago Natural Resource Management Plan

Kāi Tahu Ki Otago Natural Resource Management Plan (Kāi Tahu Plan) provides a background to Kāi Tahu's resource management issues in the Otago Region. The Kāi Tahu Plan contains management guidelines and objectives relating to freshwater fisheries and coastal resources. Kāi Tahu are particularly concerned with the destruction of the freshwater resource as a result of piping and channelisation, the mauri and life supporting capacity of water being compromised by structures and point source discharges, and the depletion of coastal fisheries due to discharges to the CMA.

Mosgiel is within Taieri River catchment within the Kai Tahu Plan. Specific policies for this catchment include: the discouragement of cross-mixing of water, and requiring structures do not impede or obstruct flows or fish migration.

General policies in the Kai Tahu Plan of relevance include:

- To promote the cultural importance of water to Kāi Tahu ki Otago in all water management.
- To protect and restore the mauri of all water.
- To promote to the ORC and Environment Canterbury minimum flow levels,
- To require land disposal for human effluent and contaminants.
- To require consideration of alternatives and use of new technology for discharge renewal consents.
- To encourage all stormwater be treated before being discharged.
- To encourage identification of non-point source pollution and mitigate, avoid or remedy adverse effects on Kāi Tahu ki Otago values.
- To encourage Kāi Tahu ki Otago input into the development of monitoring programmes.
- To require monitoring of all discharges be undertaken on a regular basis and all information, including an independent analysis of monitoring results, be made available to Kāi Tahu ki Otago.



- To encourage Management Plans for all discharge activities that detail the procedure for containing spills and including plans for extraordinary events.
- To require all discharge systems be well maintained and regularly serviced. Copies of all service and maintenance records should be available to Kāi Tahu ki Otago upon request.
- To oppose all river and instream work if near a nohoaka site during the months of August to April.
- To require that any works be undertaken either before or after spawning season of potentially affected species as identified by the affected Papatipu Runaka.
- To require that all practical measures are taken to minimise sedimentation or discharge of sediment.
- To require that all practical measures are undertaken to minimise the risk of contamination to the waterway.

2.6.2 Code of Subdivision and Development

Chapter 18, Subdivision, of The Dunedin City District Plan, contains Method 18.4.1 which makes reference to the Dunedin Code of Subdivision and Development. This code is not part of The Dunedin City District Plan but does contain guidelines, including levels of service, for any physical works (such as kerb and channel design, and wastewater pipe standards) associated with subdivision activity, which are considered when assessing consent applications. Stormwater and wastewater targets and management approaches proposed by the ICMP should ensure this code is complied with. It is also likely that the content of the ICMP may also help shape the future direction of the Code of Subdivision and Development.

2.6.3 The Dunedin City Council Sustainability Framework

The DCC Sustainability Framework is a relatively new non-statutory document which has an overarching influence on all aspects of DCC's operations and decision making through the following sustainability principles:

- Affordable: reasonable cost, value for money, today / future costs;
- Environmental Care: clean energy, bio-diversity, safe;
- Enduring: forward looking, whole of life, long term, future generations;
- Supporting People: social connectivity, social equity, quality of life, safe;
- Efficient: using less, creating less waste, smarter use.

These sustainability principles will influence the content of this ICMP and any recommendations with regard to future capital works.

2.6.4 3 Waters Strategic Direction Statement and 3 Waters Strategic Plan

The purpose of the 3 Waters Strategic Direction Statement is to align the management of Dunedin's three waters activities with the city's sustainability principles. This document provides direction for



the detailed 3 Waters Strategic Plan which will be largely influenced by the content of all of the ICMPs. It is through the 3 Waters Strategic Plan that the ICMPs will provide input to long term community planning objectives and ultimately, Activity Management Plans (AMPs) and capital works programmes for stormwater and wastewater.

The overarching strategic statements and associated strategic management objectives of the 3 Waters Strategic Direction Statement are shown in Table 2-1.

2.6.5 Activity Management Plans

The DCC stormwater, wastewater and water supply Activity Management Plans (AMPs) contain objectives, levels of service, methods for delivering this service, asset management and levels of funding in relation to each activity. These plans are developed through the long term community planning process. The ICMP provides input to the content of the AMPs through its contribution to the 3 Waters Strategic Plan.



Table 2-1: 3 Waters Strategic Management Objectives

Strategic Statement	Strategic Management Objectives
<i>We will meet the water needs of the City for the next 50 years from existing water sources.</i>	- The Council will lead the way by reducing system losses to economic levels. - The Council will help, educate and incentivise customers to waste less water.
<i>We will be able to adapt to a variety of future scenarios for climate change and fluctuations in population.</i>	- We will increase the flexibility and resilience of our infrastructure to reduce the risk of prolonged service interruptions. - We will ensure that where possible, new infrastructure is scalable to allow for increases or decreases in demand.
<i>We will reduce our reliance on non-renewable energy sources and oil based products.</i>	- We will prioritise the use of energy efficient technology. - We will generate renewable energy from our network, catchments and other resources where it is cost effective to do so. - We shall reduce the reliance of our supply chain on oil based products.
<i>We will improve the quality of our discharges to minimise the impact on the environment.</i>	- We will resolve all known cross connections between the foul and stormwater networks by 2015, and have an ongoing programme to disconnect the systems as new issues are identified. - We will reduce the contaminant load in our stormwater. We will use source control where practical, or otherwise consider effective stormwater treatment. - We will reduce the number of foul sewer overflows arising as a result of capacity. - We will assess the long term feasibility of wastewater treatment plant locations prior to individual consent renewal and consider alternatives such as land-based disposal.
<i>We will ensure that, as a minimum, key service levels are maintained into the future.</i>	- We will invest adequately in renewals to maintain the performance of our infrastructure. - We will plan our renewals effectively to avoid sharp increases in costs. - We will continue with our planned programme of water upgrades and once completed, maintain our drinking water quality at those levels. - There will be no increase in the number of residential or commercial properties at risk of sewer flooding, despite increasing pressure on the network. - We will prioritise our investment based on the community's willingness to pay for improvements and what they are willing to sacrifice as a result.



2.7 Resource Consents

This section outlines the classifying rules in the Dunedin City District Plan and the Regional Plan: water for Otago, which are relevant to the activities likely to occur under the ICMP.

While there are no rules within the Dunedin City District Plan classifying the discharge of stormwater, the ICMP needs to be consistent with the policies and objectives of the Dunedin City District Plan as described in Section 2.3.7, by incorporating further investigations of the system and environment and monitoring any discharges that are occurring.

All consent requirements will be addressed by the Regional Plan: Water for Otago. The Dunedin City District Plan however, contains methods addressing water quality issues through investigations, monitoring, education, consultation and the creation of management plans such as this ICMP.

2.7.1 Stormwater Discharges

Rules 12.4 and 12.5 of the Regional Plan: Water for Otago classifies the discharge of stormwater and the discharge of drainage water to water.

Rule 12.4.1 classifies the discharge of stormwater to water as a permitted activity provided that certain conditions are met. These conditions, among others include that; the discharge does not contain any human sewage, the discharge does not cause flooding of any other person's property, erosion, land instability, sedimentation or property damage and does not produce any conspicuous oil or grease films, scums or foams, or floatable or suspended materials or objectionable odours.

Should the conditions outlined in this rule not be met then the discharge of stormwater to water will be classified as a restricted discretionary activity requiring resource consent.

Rule 12.5.1 classifies the discharge of drainage water to water as a permitted activity provided the discharge does not cause flooding of any other person's property, erosion, land instability, sedimentation or property damage and does not produce any conspicuous oil or grease films, scums or foams, or floatable or suspended materials or objectionable odours.

If the conditions outlined in Rule 12.5.1 cannot be satisfied, then the discharge of stormwater to water will be classified as a restricted discretionary activity requiring resource consent.

The objectives of the ICMP should be aligned as closely as possible to the stormwater discharge permitted activity rules to enable the objectives of the Water Plan to be met where possible.

2.7.2 Wastewater Discharges

All wastewater from the Mosgiel catchment is treated at the Mosgiel WWTP then pumped to the Green Island WWTP, where it is treated further prior to discharging via the Green Island ocean outfall. Any discharge is therefore authorised by the resource consent associated with this outfall facility and no further resource consents are required.

2.8 Strategic Catchment Management Objectives

The strategic objectives of catchment management are outlined in Table 2-1 and provide the overarching objectives that guide the development of this ICMP in relation to stormwater and



wastewater management within the Mosgiel catchment. These objectives stem from the 3 Waters Strategic Direction Statement and are at the core of the relevant statutory and non-statutory documents addressing stormwater and wastewater management. These objectives have been developed with the aim of achieving benefits across the four wellbeings (environmental, social, economic and cultural), and have been set within the context of a 50 year timeframe.

Table 2-2: Strategic Catchment Management Objectives

Strategic Objectives
Development: Adapt to fluctuations in population while achieving key levels of service and improving the quality of discharges. Ensure new development provides a 1 in 10 year level of service, and avoids habitable floor flooding during a 1 in 50 year event in relation to stormwater. Ensure there are no wastewater overflows during events of 1 in 10 yr ARI and greater.
Levels of service: Maintaining key levels of service of the stormwater and wastewater networks into the future by adapting to climate change and fluctuations in population, while meeting all other objectives.
Environmental outcomes: Improve the quality of discharges to minimise the impact on the environment and reduce reliance on non-renewable energy sources and oil based products.
Tangata whenua values: Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of catchment discharges.
Natural hazards: Ensure there will be no increase in the numbers of properties at risk of flooding from the stormwater and wastewater networks.
Affordability: To meet strategic objectives while limiting cost increases to current affordability levels where practical.

2.8.1 Activity Management Plan/LTP Objectives and Targets

Levels of service statements for are contained within the DCC AMPs. These statements represent DCC's performance objectives for each of the three waters.

Level of service statements representing DCC's performance objectives for **wastewater** are:

- The extent of the reticulated network meets community needs.
- Services are affordable.
- Services are managed at lowest cost for required level of service.
- The wastewater service is reliable.
- Service calls are responded to promptly.



- Sewage is managed without adversely affecting the quality of the receiving environment.
- Appropriate wastewater services will be available to future generations.
- Sewage is managed without risk to public health.

Level of service statements representing DCC's performance objectives for **stormwater** are:

- Stormwater services are clean and safe.
- Service availability is appropriate to community needs.
- Stormwater is managed without adversely affecting the quality of the receiving environment.
- Appropriate stormwater services will be available to future generations.
- Services are affordable.
- Services are managed at lowest cost for required level of service.

Further to the level of service statements, shorter term objectives, performance measures and targets derived from DCC's stormwater and wastewater Activity Management Plans (AMP) and LTP are outlined in Tables 2-3 and 2-4 respectively. These objectives are to be reviewed annually but are set within the context of a 10 year timeframe. Therefore the measures and targets below may be subject to development or change based on findings from the ICMP development process. Influencing factors may include modelling results, or further research into costs surrounding changes to levels of service.

DCC also hope to begin reporting on a number of additional measures and targets relating to service provision. The ICMP development should inform this process, and help to identify the most appropriate measures and provide baseline information. It is hoped that the following areas will be able to be reported on following the ICMP completion if appropriate and necessary:

- Number of written complaints;
- Percentage of customers experiencing a public sewerage system problem in any one year;
- Percentage of customer emergency response times met;
- Percentage of customers with stormwater provision that meets current design standards;
- Percentage of the network predicted to overflow;
- Percentage of modelled networks able to meet a 1 in 10 yr ARI rainfall event;
- Number of properties at risk of habitable floor network flooding; and
- Number of properties at risk of network flooding in a 1 in 10 year event.


Table 2-3: Stormwater Activity Management Plan Measures and Targets

Objective	Performance Measure	2011/2012 Target	2021 Target
Stormwater Quality	Residents' satisfaction with the stormwater collection service*	≥ 60 %	≥ 70 %
	Number of blockages in the stormwater network per 100 km of mains per annum	< 15	< 10
	Number of beach closures	0	0
Service Availability	Percentage of customer emergency response times met (stormwater)	≥ 95 %	≥ 95 %
Demand Management	Completion of stormwater catchment management plans	as plan	X (should be completed by 2013)
Environmental Consent Compliance	Percentage compliance with stormwater discharge consents	≥ 75 %	tbc
	Number of prosecutions or infringement notices for non-compliance with resource consents	0	0
	Number of recorded breaches of Resource Management Act conditions	0	0
Asset Serviceability	Number of breaks per 100 km of stormwater sewer per annum	< 1	< 1
	< x % of critical network assets in condition grade 4 or 5	To increase % of known data	tbc
Supply Cost per m ³	Drainage uniform annual charge as a percentage of median income	≤ 1 %	≤ 1 %
	Total operational cost of stormwater service per rated household	\$ 76.70	tbc

*Based on Residents Opinion Survey (ROS)

tbc – to be confirmed


Table 2-4 Wastewater Activity Management Plan Measures and Targets

Objective	Performance Measure	2011/2010 Target	2021 Target
Wastewater Quality	Residents' satisfaction with the city's sewerage system*	≥ 65 %	≥ 70 %
	Number of odour complaints (wastewater)	< 21	<1 7
	Number of foul sewer blockages per 100 km of mains per annum	< 29	< 20
Service Availability	Percentage of customer emergency response times met (wastewater)	≥ 95 %	≥ 95 %
Environmental Compliance	Wastewater discharges comply with consent conditions	100 %	100 %
	Number of recorded breaches of Resource Management Act conditions	0	0
	Number of prosecutions or infringement notices for non-compliance with resource consents	0	0
Asset Serviceability	Number of breaks per 100 km of sewer main	< 2	< 1.5
	<x % of critical network assets in condition grade 4 or 5	To increase % of known data	tbc
Supply Cost per m3	Drainage UAC as % of median income	≤ 1 %	≤ 1 %
	Total cost of wastewater service per cubic metre (1000 litres)	tbc	tbc
Health and Safety Standards	Number of lost time accidents	≤ 5	≤ 5
Training and Development	% training objectives completed	≥ 90 %	≥ 90 %
Employee Satisfaction	Sickness levels	≤ 3 %	≤ 3 %
	% staff satisfied / very satisfied	≥ 65 %	≥ 65 %
	Staff turnover	< 6 %	< 6 %

*Based on Residents Opinion Survey (ROS)

tbc – to be confirmed



3 Consultation

Through Annual Plan consultation and through specific consultation in relation to the 3 Waters Strategy, a number of stakeholders have been identified as affected by, or interested in stormwater and/or wastewater management in Dunedin. The following provides a summary of values identified through the consultative processes mentioned. These values have been considered when developing objectives and options for stormwater and wastewater management of identified issues.

3.1 3 Waters Strategy Consultation- Stakeholder Workshops and Community Survey

For specific consultation relating to the 3 Waters Strategy, stakeholders were divided into three groups; environmental, economic/business and social/cultural. The outcomes of the specific consultation workshops were used to inform a community telephone survey to gauge the views of the wider community including catchment residents. Specific groups were also consulted directly, including: Kāi Tahu Ki Otago, ORC and East Otago Taiapure Management Committee.

The summary of consultation findings for the 3 Waters services included:

- More focus on Council-driven systems that could be used to encourage better outcomes.
- Better systems design could enable improved quality at minimal extra long-term expenditure.
- Financial incentives for 'good' businesses, households and developers, active Council assistance is expected along with careful use of legislation.
- Options to consider include rates rebates, user-pays systems, variable use-specific water quality (and thus prices), and subsidies.
- That desired improvements in asset capabilities should be paid for through improved 'smart' (i.e. cost effective) technologies and initiatives.
- Integrate holistic catchment ecosystem principles into water stewardship.
- More focus on joint/common approach between the ORC and DCC when developing strategies and plans.

3.1.1 Stormwater Management

From all consultation relating to the 3 Waters Strategy there was a general recognition that stormwater requirements and standards will need to increase, in terms of both quality and volume management.

A coordinated approach to stormwater management between ORC and DCC is desired; with the responsibilities for each organisation being clarified.

Overall, increasing the sustainability and efficiency of the network is also desired.

Views Relating to Quality

- A high awareness that stormwater contains many contaminants, and thus its management is not just a matter of transportation to the coast;



- That quality involves household drains and farm runoff as well as road runoff and sewage contamination;
- Recognise that the stormwater system does include recreational places, which underlines the need for better quality stormwater;
- Improving quality of disposed stormwater is a key issue – the higher the quality, the better.

Views Relating to Volume

- Recognition that climate change may result in more frequent storm events, thus putting a greater episodic demand on the system; and thus likely to require increased capacity. This may be compounded by decreases in permeable land resulting from increased property development in certain areas.
- That managing volumes (which is partially related to quality) requires a more encompassing view of the system and its management.

In summary, the consultation identified that the key points in relation to stormwater management were:

- Legislative changes, e.g. changing planning or building consents standards to further reduce the impact of new developments on stormwater;
- Passive changes, e.g. increasing the use of swales and soakholes to better manage storm events; using landscaping to reduce the visual pollution of outfalls;
- Active changes, e.g. increasing outfall pipe numbers to reduce the impact in any given area; increasing treatment standards; installing low-flow regulators;
- Doing more than simply increasing pipe capacity – i.e. review requirements for new property developments, in order to reduce runoff volumes and minimise the loss of permeable land; and
- Consideration of sustainable options e.g. stormwater captured and used by households; implementing alternative energy sources for pump stations (such as wind turbines or micro hydro-electricity generators). In rural areas, also capture stormwater in detention ponds, both to slow flows and prevent flooding but also to balance with demand for other water-use activities e.g. irrigation.

During the development of the 3 Waters Strategic Direction Statement, objective setting took the results of the community consultation into account, for example by incorporating statements relating to the use of source control for stormwater management. The ICMP approach to stormwater management also considers a range of management options for stormwater, described as 'legislative, passive and active' changes above.

3.1.2 Wastewater Management

Feedback highlighted the desire for improvements to the current wastewater system, especially to improve the discharge quality and reduce the volumes. A summary of the key points:

- A desire for overall wastewater system efficiency and managing energy needs (e.g. energy needs for running the systems in the face of energy shortages and the impact on the system of rising sea levels).



- Actively maintaining and enhancing aquatic ecosystems to protect and support all parts of the life-cycle of fish, eels, shellfish.
- Concerns regarding impacts to the health of the environment and people:
 - o The impact of fisheries and kaimoana from discharging wastewater to the harbours and oceans (and for human waste to be returned to Papatūānuku in the first instance).
 - o Location of wastewater treatment and disposal sites in near proximity to water ways and salt marshes (a desire for these sites to be re-located away from such areas).
 - o Cumulative effects of discharges (and water takes).
- Recognition of the role of the Council in improving the wastewater system, and the variety of benefits to be gained from this (e.g. quality eco-tourism cultural values, re-using waste for fertiliser).
- Initiatives such as re-using waste for energy and other uses - the desire for better system-wide initiatives like composting toilets, grey-water use etc. Recognition that technological development is also likely to have significant contribution to advancing this.
- Future-proofing the capabilities and standards of the treatment plants; sludge management costs and transportation; and wastewater-stormwater sewer separation (i.e. eliminate cross-connections).
- Managing wastewater at a household level, e.g. through better septic tank management (especially in low-lying areas likely to have a rising water table level); householder education.
- An holistic approach is required to improve the entire system. For example, introduce metering to encourage water use reduction, provide incentives to encourage better waste management, future proofing the capabilities and standards of the wastewater system.

3.2 Mosgiel Community Board Consultation

Consultation was carried out with the Mosgiel Community Board during the development of this ICMP in August, 2011. Feedback indicated that the community wishes to see an improvement in the current level of service within Mosgiel in relation to network flooding and that Council should be able to demonstrate to the community that network problems within Mosgiel are fully understood and that the development of solutions to mitigate the effects is underway.

Particular concerns raised by the Community Board include: frequent surface flooding occurs in a number of areas when it rains. This presents problems in locations where the road surface levels have been raised over the years and are now above the level of property foundations. Rainwater then flows overland across property boundaries. Church Street/Green Street, Gordon Road and Glasgow Street were noted as areas of frequent surface flooding during rainfall.

3.3 Annual Plan Submissions

A number of submissions were made with respect to stormwater issues through the 2009 Annual Plan consultation process. These submissions mainly centred on the maintenance and upgrade of the existing system to ensure adequate treatment and filtration of the stormwater prior to it being discharged. The issue of infrastructure capacity was also raised.



4 Catchment Description

4.1 Catchment Location

Mosgiel township covers an area of approximately 600 ha and lies to on the north-eastern extremity of the Lower Taieri Plains. The town centre is approximately 11 km directly west of the main urban centre of Dunedin. Figure 4-1 shows the location of the Mosgiel study catchment.

The wastewater and stormwater catchments for the Mosgiel township cover the urbanised area of Mosgiel, which is almost entirely located on flat land, with a small area on hillside to the east of the town centre. The ICMP study catchment extends some distance from the urban area, in an effort to quantify flows at the receiving environment discharge points on the Silver Stream and the Owhiro Stream.

4.2 Topography and Geology

Figure 4-2 provides a contour map of the Mosgiel catchment using 2 m contours. As discussed, the majority of the Mosgiel township is located on the relatively flat Taieri Plains.

Figure 4-3 shows the geology of the catchment (Bishop and Turnbull, 1996, revised 2004). There are a number of different geological features in the Mosgiel area; the predominant surficial geology of the Taieri plains was formed during the Quaternary period by alluvial processes (Q1a), and comprises well sorted gravel and sand from sandstone schist. Minor mud and peat may also be present. Tertiary age schist, with pockets of basalt, and sandstone, forms the geology of the hills to the south east of the township.

Soakage potential in the flatter part of Mosgiel is likely to be good in areas where gravels and sand dominate. However, drainage capabilities are expected to be influenced by groundwater levels and the interactions of groundwater with the river systems during flood conditions. Groundwater is discussed further in Section 4.6. Drainage through tertiary age deposits on the hills is likely to be poor, but will be dependent on the extent of fractures in the rock.

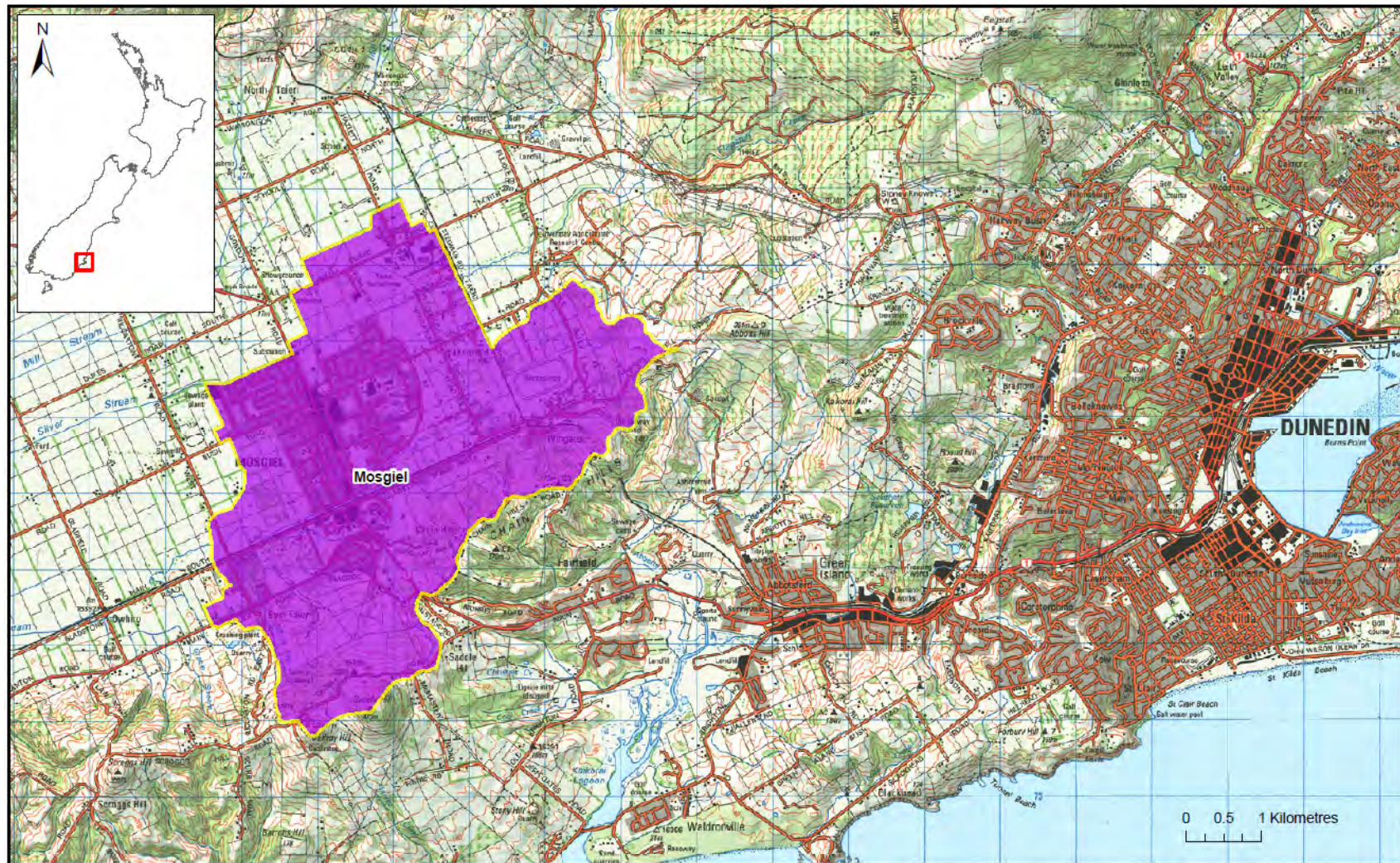


Figure 4-1: Mosgiel Catchment Location

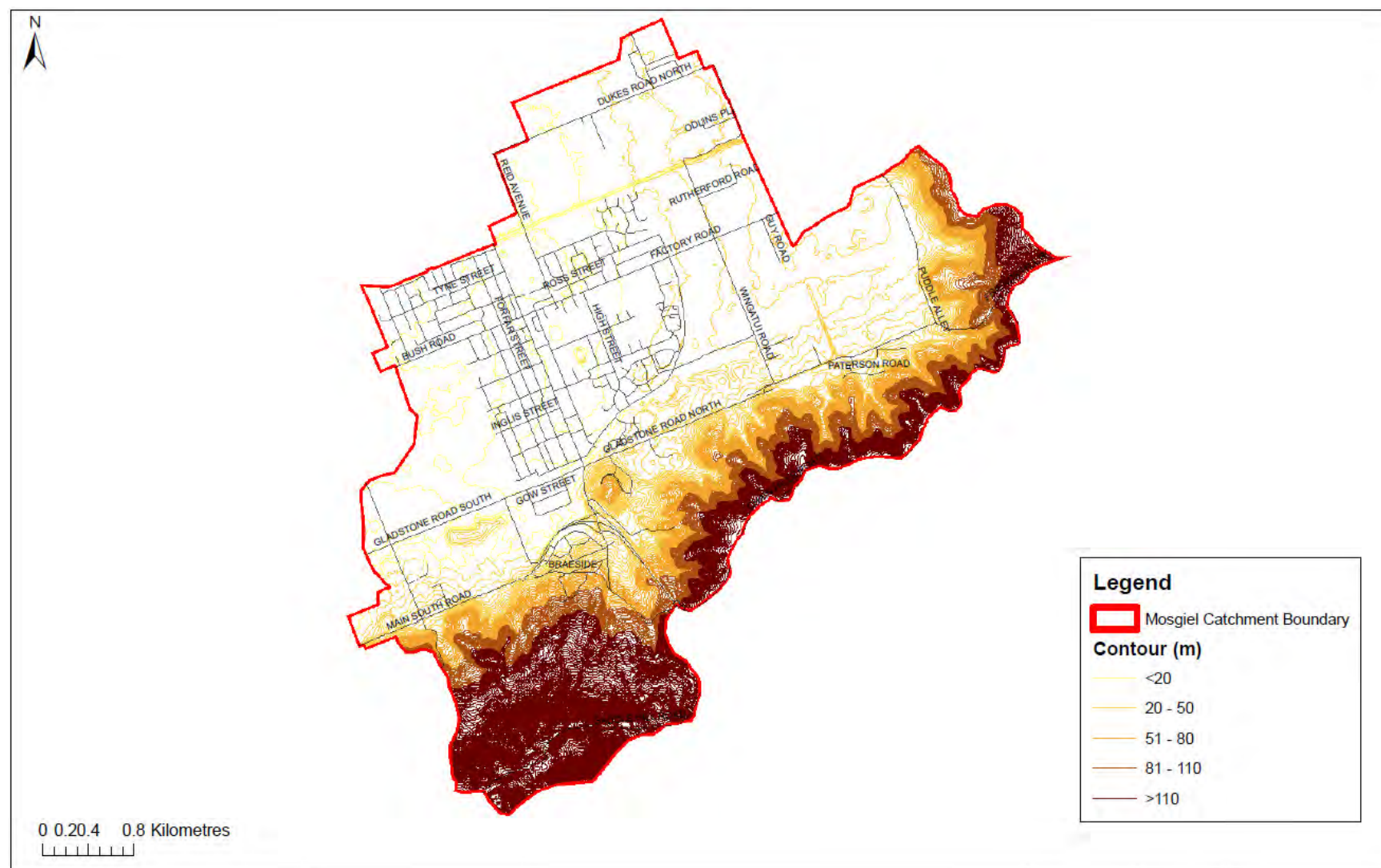


Figure 4-2: Mosgiel Catchment Contour Map

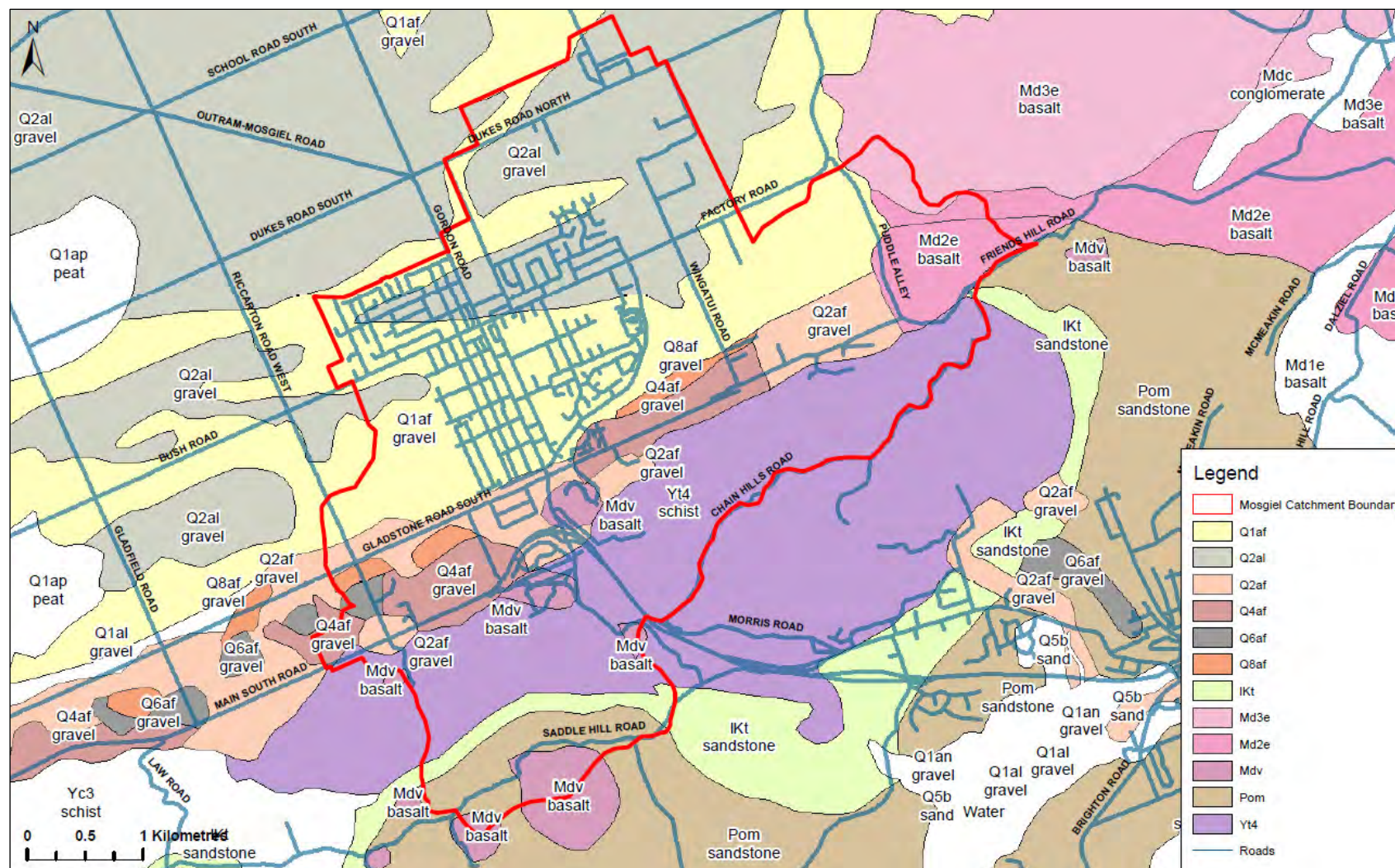


Figure 4-3: Mosgiel Catchment Geology Map



4.3 Land Use

4.3.1 Historical and Current Land Use

Mosgiel was first settled around 1850 and a road built to the Otago gold fields in 1861, intersecting the site of the future town.

The establishment of the Mosgiel Woollen Company and mill in 1871 brought further settlement of workers in cottages and much of the economy of the area focused on this industry until recent years. The woollen mill closed in 1980 and in 2008 Fisher and Paykel's Mosgiel factory also closed.

Mosgiel now derives its commercial income from local shops and by continuing its role as a rural service town, forming an important service centre for the farming community of the Taieri Plains and is the location of one of New Zealand's largest agricultural research institutes, Invermay.

As a consequence of the completion of the Fairfield Bypass road, residential development in Mosgiel has increased. Due to the reduction in industrial activity and the shortened commuting times to the city centre, the majority of land in Mosgiel is used for residential purposes.

Table 4-1 below provides a breakdown of the land use in the study area. Aside from the area of rural land included for modelling purposes, the majority of the land use in Mosgiel is Residential 1. There is also a significant area (approximately 170 ha) of industrial land use.

Table 4-1: Current Land Use in the Mosgiel Catchment

DCC Zone	Area (ha)	% of Study Area
Industrial 1	168	6.6 %
Large Scale Retail Zone	2	0.1 %
Local Activity Zone 1	12	0.5 %
Residential 1	493	19.5 %
Residential 2	80	3.2 %
Residential 6	136	5.4 %
Rural	1595	63.1 %
Rural Residential	39	1.5 %
Special Development	4	0.2 %



4.3.1.1 Resource Consents and Designations within the Catchment

Information has been provided by ORC and DCC with respect to resource consents granted in Dunedin City and city-wide District Plan designations.

A number of consents have been granted, by the ORC and DCC within the Mosgiel catchment. These consents include water take and discharge permits granted by ORC. Of significance are the following:

- Discharge stormwater and wastewater to land in circumstances where it may enter water for the purpose of disposing of stormwater and process wastewater from the concrete batching plant. Location: Morris Road.
- Discharge contaminants into or onto land in a manner that may result in that contaminant or any other contaminant emanating as a result of natural processes from that contaminant entering water. Location: Puddle Alley.
- Discharge stormwater to the Owhiro Stream for the purpose of disposal of stormwater from a development site (including roading and buildings) at the Birchleigh Retirement Home. Location: 100 m east of the formed end of Hagart Alexander Drive.

DCC has granted a number of land use consents, the effects of which have been incorporated into the future catchment imperviousness calculations.

A number of district plan designations exist within this catchment. Some are for transport purposes and include the Fairfield to Mosgiel Interchange (State Highway 1), State Highway 87 and the Main South Railway. There are a number of other designations scattered throughout the catchment including education facilities, a police station, wastewater treatment plant, and a number of water reservoirs and pumping stations. Figure 4-4 provides the location of the resource consents granted by DCC and District Plan designations within the Mosgiel catchment.

4.3.1.2 Cultural / Heritage Sites and Designations

According to DCC records of significant archaeological and heritage sites within Dunedin City, the Mosgiel catchment contains a number of heritage structures; these are shown in Figure 4-5. There are no archaeological sites, heritage facades or Townscape and Heritage precincts within Mosgiel.

Many of the heritage structures within the catchment are industrial and commercial buildings apart from two residential dwellings. The heritage structures within the catchment are scattered throughout the catchment towards the edge.

Kai Tahu have been identified as a key stakeholder. It should be noted that freshwater environments hold particularly high values for Kai Tahu (refer Section 2.6.1).

Views of key stakeholders throughout Dunedin's community are discussed in Section 3.

4.3.1.3 Contaminated Land

Data was collected from both the ORC and DCC with respect to contaminated land around Mosgiel. It should be noted that the information available on contaminated land sites may be incomplete and the extent of the remediation unknown in some instances. Figure 4-6 provides the location of the



known contaminated land sites within the Mosgiel catchment.

The ORC lists the following locations in Mosgiel as currently 'contaminated' (source Otago Daily Times, 2009), although it should be noted that it was reported that sites listed as contaminated typically have low-level problems, because sites with more serious spills are dealt with quickly:

- Wingatui closed landfill site, Gladstone Road North;
- North Taieri landfill, Milners Road;
- Mobil petrol station, Factory Road; and
- Coronation Hall petrol station, Gordon Road.

Other contaminated sites highlighted within the catchment include a 'managed' site (the Shell petrol station and a wood treatment plant on Stedman Road that is a 'managed' contaminated site.

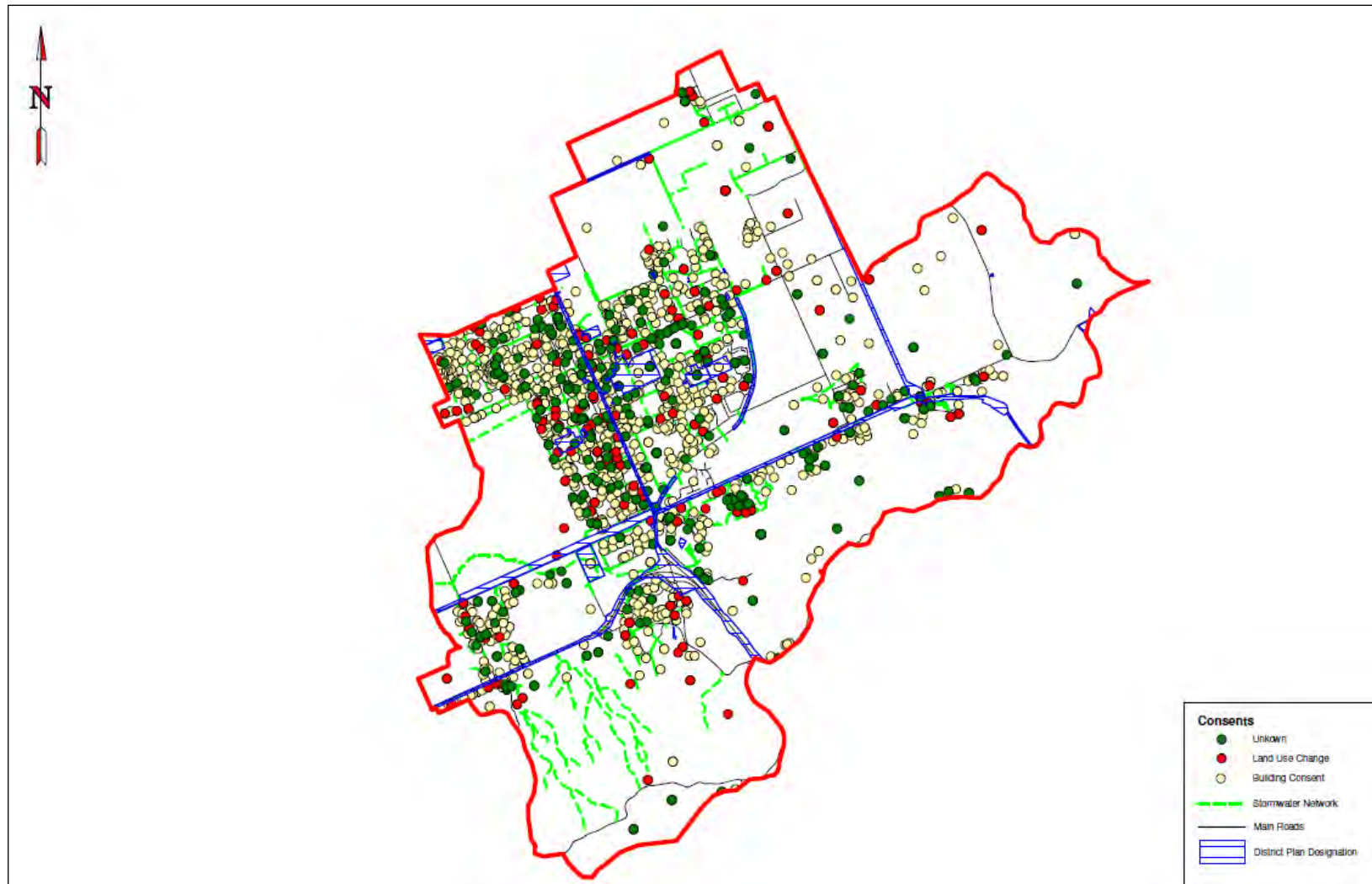


Figure 4-4: Resource Consents Granted by DCC and Designations within the Mosgiel Catchment

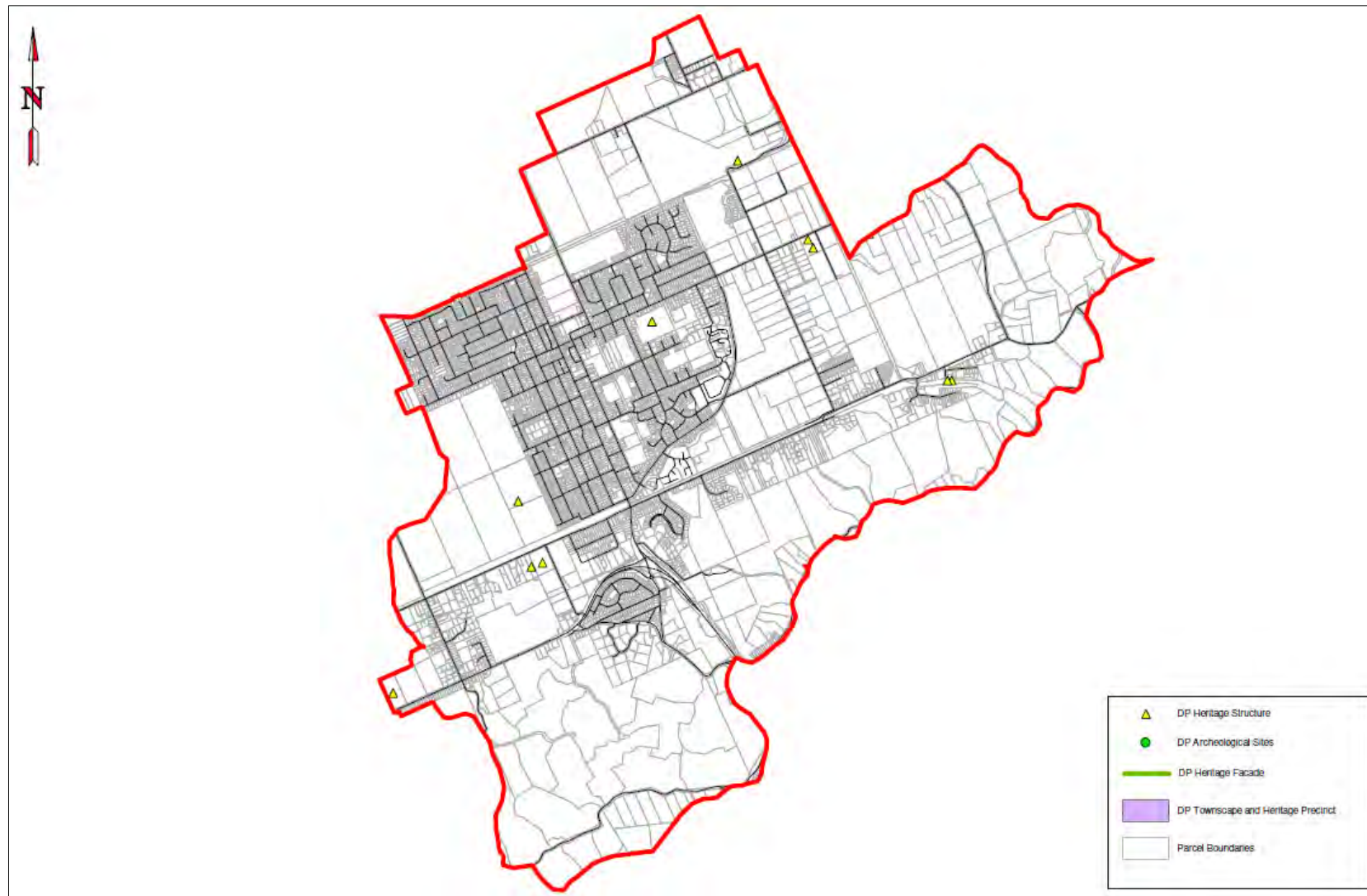


Figure 4-5: Archaeological and Heritage Sites within the Mosgiel Catchment

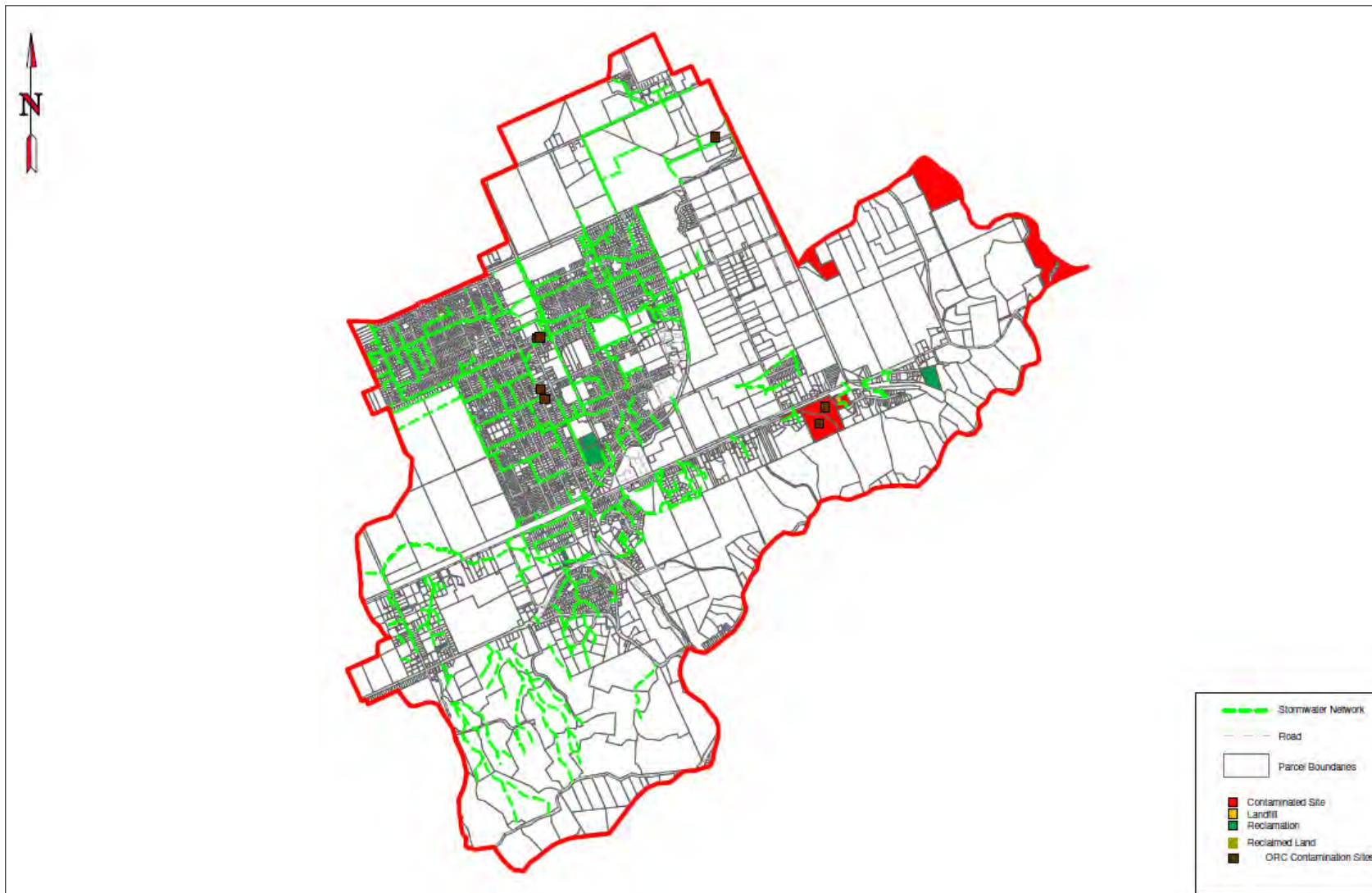


Figure 4-6: Contaminated Land Sites within the Mosgiel Catchment



4.3.2 Future Land Use

Several future land use scenarios are being considered within the DCC 3 Waters Strategy along with the current situation. The scenarios are: 2008 (current), 2031 and 2060.

For the purposes of modelling in this ICMP, the only future land use scenario (and population data) that was considered was the 2031 scenario. This is consistent with the planning horizon for Mosgiel within the current District Plan. Growth and therefore land use beyond this date is currently unplanned.

The 2031 land use scenario contains the maximum allowable imperviousness for each zone, consistent with the current District Plan.

Future land use in Mosgiel is controlled by three main factors. Large subdivision consents, private plan changes and changes to the Dunedin City District Plan including the Mosgiel East and East Taieri structure plans. Figure 4-7 displays the projected future land use (based on Dunedin City District Plan zoning).

4.4 Catchment Imperviousness

Figure 4-8 provides a map of current imperviousness for the Mosgiel catchment (refer Appendix A for calculation methods). Overall, including roads and land parcels, the Mosgiel study area is estimated to have a current imperviousness of approximately 15 %. However, if the large area of rural land use is excluded, current imperviousness of the urban area is approximately 34 %. The imperviousness study calculated that Residential 1 zones typically had a total imperviousness of approximately 39 %, of which about 23 % was estimated to be houses and driveways (with the remainder representing areas such as unconnected paving etc.).

The maximum future imperviousness has been calculated for each land parcel, based on the maximum allowable imperviousness for each land use, as per the Dunedin City District Plan rules, with exceptions for land parcels that, although in a particular zone, are currently (and likely to remain) in use for other purposes such as schools, parks, and recreational reserves.

The maximum possible imperviousness of the catchment has been applied for the 2060 land use scenario. In 2060 the Residential 1 zone has a maximum allowable imperviousness of 49 %. The study estimates that imperviousness in the Mosgiel study area may go up to approximately 23 % for the whole study area, with some of that due to increase in imperviousness for currently residential land, but some due to land changing from rural to residential land use.

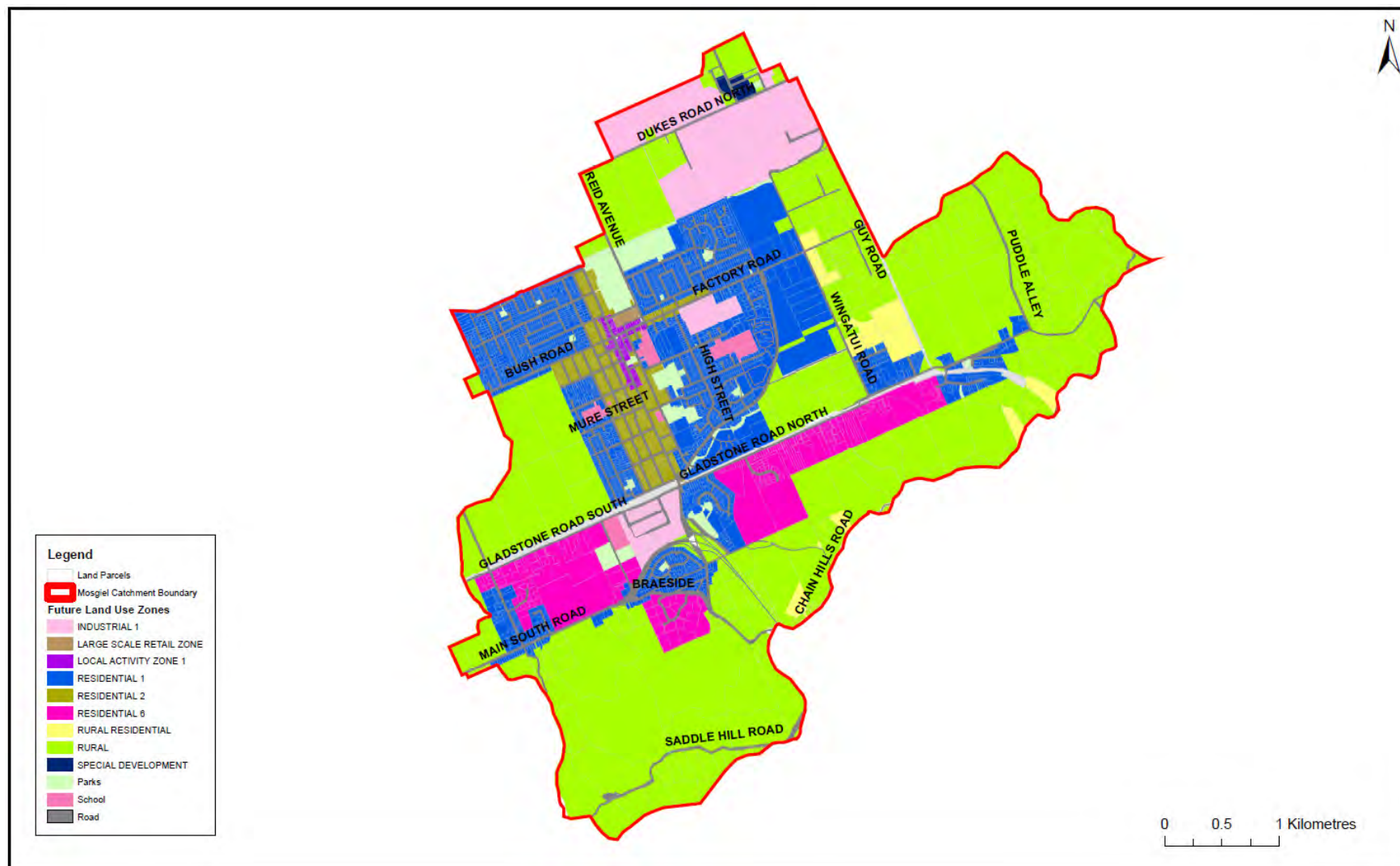


Figure 4-7: DCC District Plan Land Use Zones for the Mosgiel Catchment

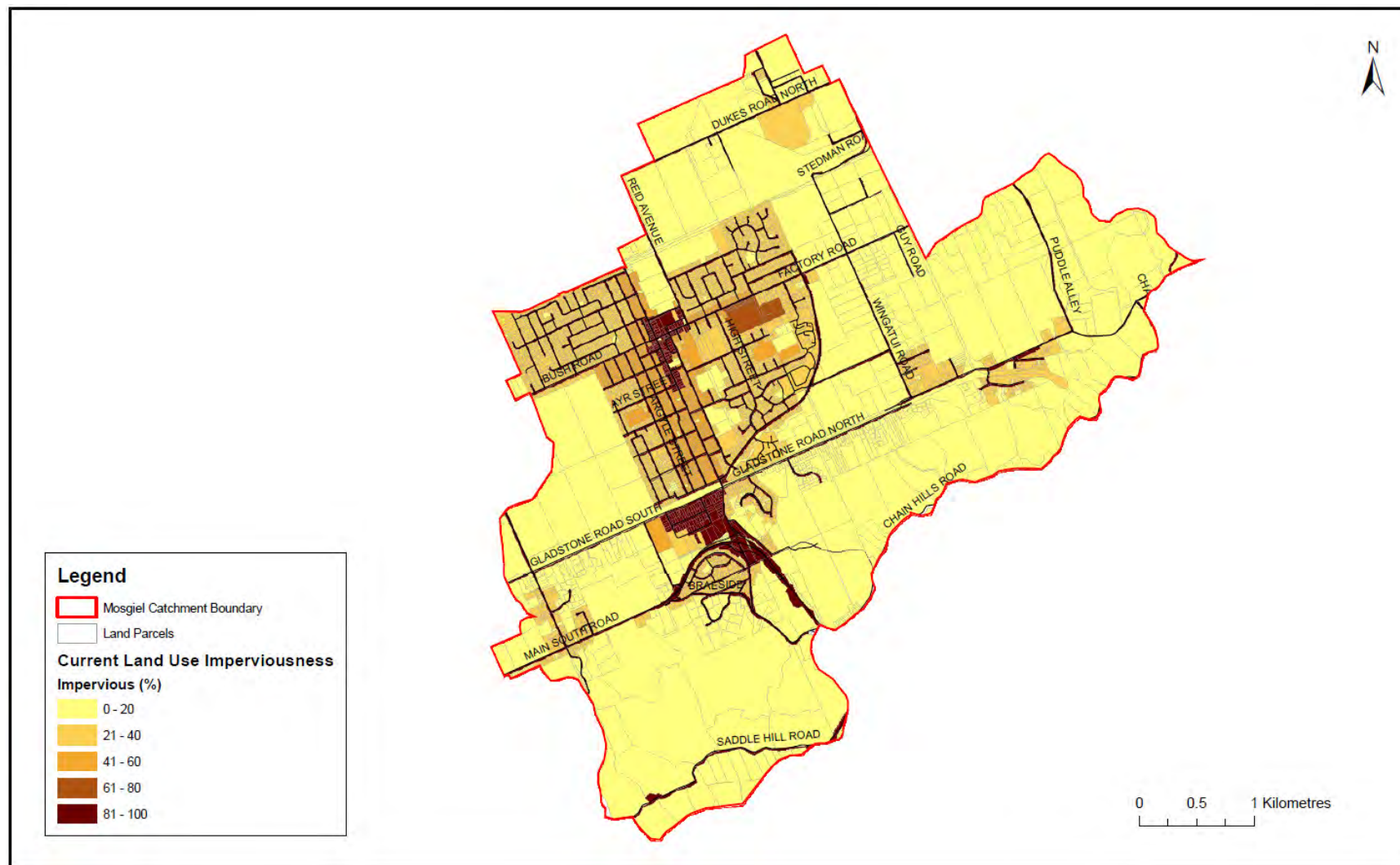


Figure 4-8: Current Imperviousness of the Mosgiel Catchment



4.5 Surface Water

The township of Mosgiel is bounded by two watercourses, the Silver Stream to the north and the Owhiro Stream to the south. Both are tributaries of the Taieri River. The smaller Quarry Creek, a tributary of the Owhiro Stream, flows through the southern part of the study catchment. All three watercourses flow in an east-west direction and ultimately drain to the Taieri River downstream of Mosgiel which in turn flows into the Pacific Ocean.

There are also a number of open channels within the catchment to convey stormwater and additional 'drains' crossing the Taieri Plains, mostly serving as drainage for farm land.

All stormwater from the urban area of Mosgiel is reticulated towards either the Silver Stream to the north of the catchment, the Owhiro Stream to the south, or an unnamed field drain west of Lanark Street. Wastewater overflows also discharge to the watercourses of the catchment. The locations of stormwater and wastewater outfalls are shown in Figure 4-14 (Section 4.8) and Figure 4-17 (Section 4.9).

Development on the outskirts of Mosgiel, south of Gladstone Road, discharge through both open channel and pipework to either the Owhiro Stream or the Quarry Creek.

Further information relating to the quality of the watercourses of the catchment is contained within Section 5 of this report. Surface water within the catchment is shown in Figure 4-14 (Section 4.8).

4.5.1 Silver Stream

The Silver Stream rises in the hills north-east of Mosgiel and flows through the Taieri Plain to its confluence with the Taieri River upstream of Allanton.

Parts of the Silver Stream have been modified over time as part of the Lower Taieri Flood Protection Scheme. Key modifications include:

- Silver Stream straightening (Late 1800's);
- Silver Stream right bank spillway (1970's); and
- Silver Stream stopbanking (1980's).

The reaches of the Silver Stream adjacent to Mosgiel currently comprise a straight engineered channel with stopbanks.

There are nine direct stormwater outfalls to the Silver Stream and one wastewater emergency overflow at the Mosgiel WWTP.

4.5.2 Owhiro Stream

The Owhiro Stream follows the base of the hills south and east of Mosgiel collecting flows from a number of steep hill catchments until it meets the Taieri River near Allanton.

The Owhiro Stream has also been modified as part of the Lower Taieri Flood Protection Scheme. The middle reaches, which flow through Mosgiel, are highly modified, having been subjected to channel straightening and bank realignment for flood protection purposes. In addition to these



modifications, flood gates were installed on the Owhiro Stream, at the Taieri River confluence in the 1970's. The purpose of which was to enable the reduction of flows to the Taieri River and utilise Owhiro Stream flood plain storage at times of high flow within the Taieri River.

There are 14 stormwater outfalls direct to the Owhiro Stream and one wastewater emergency overflow direct to the stream at Gladstone Road North.

4.5.3 Quarry Creek

The Quarry Creek is one of the many tributaries draining to the Owhiro Stream.

The Quarry Creek catchment rises to an elevation of approximately 470 m at Saddle Hill, with Saddle Hill Road forming the upper boundary of the catchment. It then falls steeply until about 1 km from its confluence with the Owhiro Stream at Gladstone Road south west of Mosgiel. The lower reach of the Quarry Creek is gentler in grade and has been modified from its original path, having been realigned to suit construction of the Dunedin Southern Motorway and the Gow Street industrial area.

There are eight stormwater outfalls direct to the Quarry Creek, but no wastewater emergency overflows.

4.5.4 Fluvial Flooding

Assessment of fluvial flooding is outside the scope of this ICMP. However, a desk top review of available literature and prior modelling data has been carried out for the three main watercourses of the catchment. A description of fluvial flood occurrence and risk is included in this section for completeness and to assist in developing suitable catchment management approaches for Mosgiel.

The data used to provide this information is as follows:

- *ORC, 2006. Review of the Capacity of the East Taieri Tributary Channels – The Owhiro Stream. June 2006.*
- *URS 2008. Lower Taieri Floodplain Flooding Risk Assessment. February 2008.*
- *Opus, 2009. Investigation of Silver Stream Flood Mitigation Options. February 2009.*
- *ORC, 2010. Engineering and Hazards Agenda 9 June 2010 (Figure 2. Residual Flood Risk for the East Taieri) June 2010.*
- *Opus 2011. Mosgiel Integrated Catchment Management Plan – Hydraulic Performance Report. July 2011.*

4.5.4.1 Silver Stream

The modifications to the Silver Stream (spillway and stop banking), have been designed so that the land to the north of the watercourse is sacrificed in order to protect the township to the south (refer Figure 4-9).

The stop banks of the true right bank (the north bank), are lower than the opposite bank and there is a spillway south of Gordon Road. When the flows are high flows spill to the north and form a



secondary flow path conveying flood waters towards the Taieri flood plain.

The stop banking of the true left bank (the south bank), provides protection to the Mosgiel urban area during high flows.

Modelling work undertaken on behalf of the ORC (URS, 2008), predicts that the level of protection of the true right bank of the Silver Stream is as follows:

- Between Gordon Road and Riccarton Road - approximately 1 in 10 yr ARI. (This is the first area to overtop, spilling to the farmland to the north, in order to relieve the main channel during high flows and protect the urban area to the south).
- Upstream of Gordon Road – between 1 in 10 yr and 1 in 50 yr ARI.

Modelling predicts that the true left bank of the Silver Stream provides the following levels of protection:

- Between Gladfield Road and Gordon Road - 1 in 10 yr to 1 in 50 yr ARI.
- Upstream of Gordon Road - between 1 in 50 yr and 1 in 100 yr ARI.

The review of the data indicates that areas of urban Mosgiel (south of the Silver Stream) to the east of Gordon Road are protected to a reasonably high standard (1 in 50 yr Average Recurrence Interval (ARI) or higher), whilst areas to the west, including the Mosgiel WWTP, are protected to a lower level, but still greater than a 1 in 10 yr ARI event.

4.5.4.2 Owhiro Stream

The Owhiro Stream is not known to be a source of flooding in urban Mosgiel, but is known to flood farmland downstream of Mosgiel relatively frequently. This is in part due to the Owhiro Stream being closed via a gate to reduce flows into the Taieri River and utilise any available Owhiro flood plain storage. Closure of the flood gates results in the stopbanks overtopping and flooding to the adjacent farmland for extended periods of time.

The ORC (2006) reported that the Owhiro Stream upstream of Gladfield Road has the capacity to convey a rainfall event of between a 1 in 20 and 1 in 50 yr ARI. This section of the channel is primarily within rural land on the outskirts of the main urban area.

The Owhiro Stream channel and culverts through the urban area of Mosgiel were designed to a 1 in 100 yr ARI standard, but recent modelling undertaken by ORC (ORC, 2006), predicts that the channel through Mosgiel could be overtopped during a 1 in 50 yr ARI event. The modelling predicted that the watercourse would first overtop its banks, during a 1 in 50 yr ARI rainfall event, upstream of the Balmoral Avenue crossing and approximately 600 m downstream of the Gordon Road crossing. However, this is predicted to be to a minor extent during this event (max 30 mm). The section of watercourse between Balmoral Avenue and Gordon Road is predicted to remain within its channel up to the 1 in 100 yr ARI event, with a minimum freeboard of 380 mm.

The review of the data indicates that the main urban area of Mosgiel is protected to a reasonably high standard from the Owhiro Stream.



4.5.4.3 Quarry Creek

Historic flooding is recorded in the lower reaches of the Quarry Creek and is also believed to contribute to other nearby historic flooding issues. The Quarry Creek is known to flood the car park of a pre-school on Cemetery Road and to also overtop Cemetery Road itself, restricting access to the pre-school.

No prior analysis of the Quarry Creek has been undertaken, however, basic analysis was carried out using the hydraulic model developed for this ICMP. No surveys of the watercourse were carried out and the modelling used only a 'typical' channel cross section, the confidence in the model in this location is therefore relatively low. However the model was able to replicate the flooding of the pre-school car park and the overtopping of the bridge/culvert as reported, during one of the historic rainfall events known to have occurred. However, the true return period for which this flooding occurs is unknown.

The modelling also predicted that the Quarry Creek catchment's critical duration was 12 hours and that high flows in the watercourse could be exacerbating network flooding within the Gow Street industrial area. The modelling, however, was not of sufficient detail to assess, with any confidence, the potential for the Quarry Creek to overtop into the industrial area. Overtopping could potentially occur during events greater than 1 in 10 yr ARI, However, further work would be required to confirm the likelihood and scale.

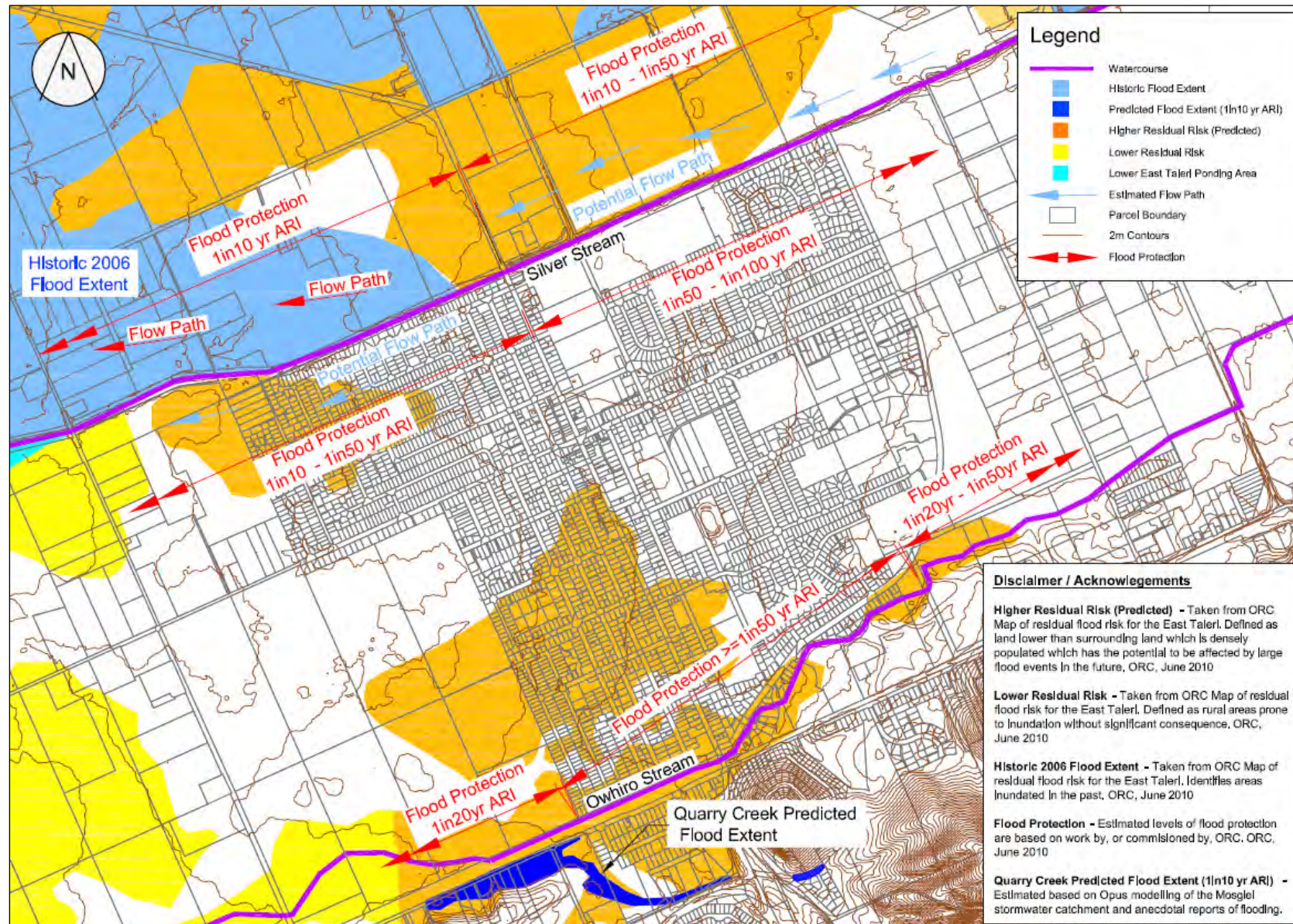


Figure 4-9: Mosgiel Fluvial Flood Risk



4.6 Groundwater

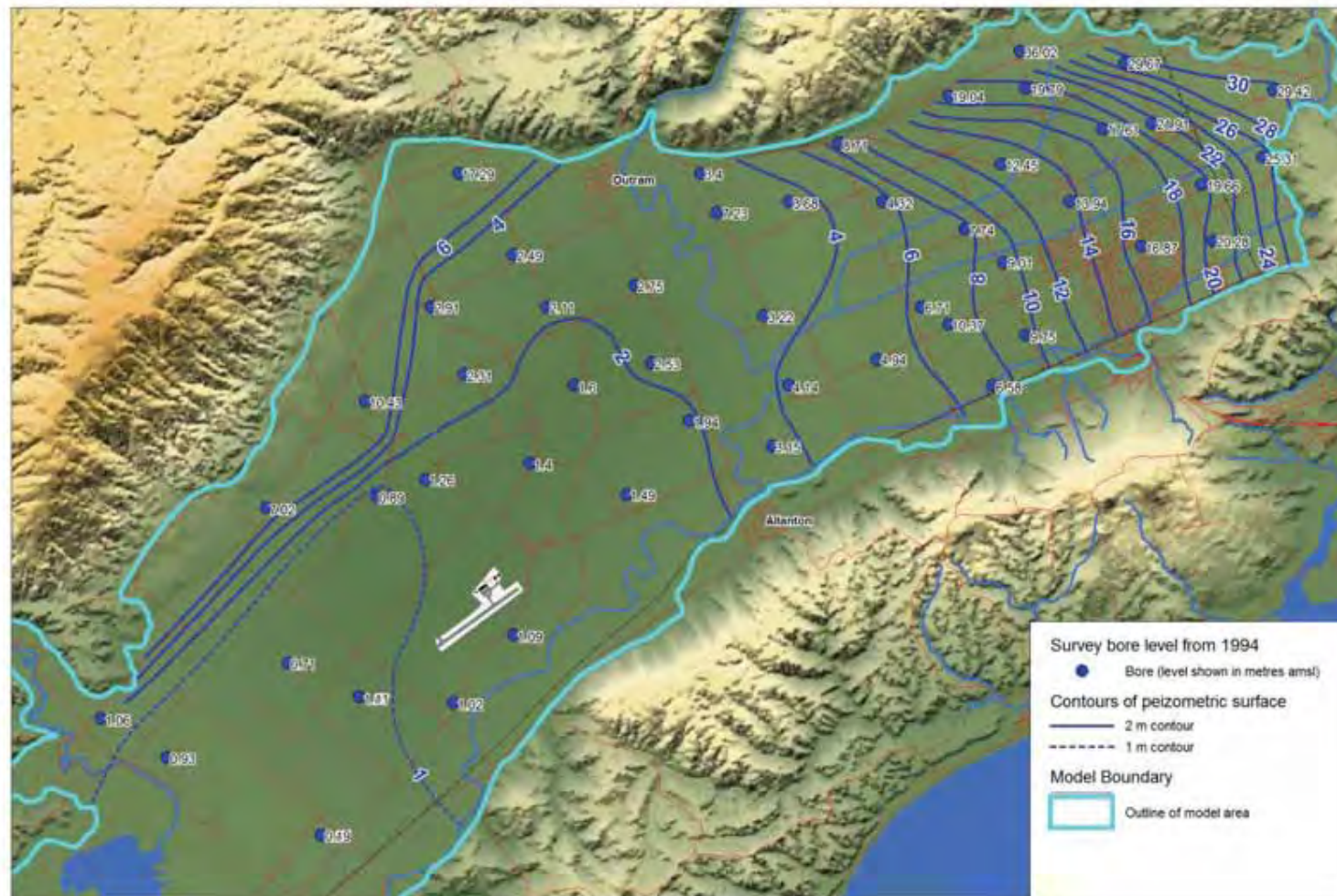
The ORC undertook a study of groundwater in the Mosgiel area during 2008 and 2009. The report, entitled the '*Lower Taieri Groundwater Allocation Study*' (ORC, 2010) provides information regarding the aquifers and groundwater availability in the area. The study illustrates that the aquifer directly below Mosgiel is stratified rather than confined, and that aquifer recharge occurs from the Mosgiel area. Response to rainfall suggests that aquifer recharge occurs during rainfall, and the study also suggests a strong interaction between the Silver Stream and the aquifer.

Limited groundwater quality impacts were noted by the report, with a small area of the basin around Mosgiel being susceptible to elevated nitrate concentrations. However, nitrate does not figure highly in typical stormwater runoff so it is much more likely to arise from rural sources.

Groundwater levels in the vicinity of Mosgiel township are indicated by Figure 4-10, taken from the ORC (2010) report.

Ground levels in Mosgiel fall in a south westerly direction and range from approximately 20 m above mean sea level (AMSL) in the north east of the catchment to approximately 12 m AMSL in the south west. Ground water levels over this area vary from 18 m AMSL in the north east to approximately 12 m AMSL in the south west. This indicates that groundwater depths below ground surface vary across Mosgiel from approximately 4.2 m – 0.6 m below ground.

Soil types and geology in the Mosgiel area indicate that direct stormwater discharge to ground may be an option for stormwater management, However the groundwater system in the area must be well understood. The impacts of groundwater levels (influenced by the Taieri River levels) on the effectiveness of infiltration practices, along with the effects of stormwater discharge on the quality of potable water abstracted are key issues, particularly given the un-confined nature of the aquifer in this area.



Groundwater flow direction is perpendicular to the contours

Figure 4-10: Mosgiel Ground Water Levels 1994 (ORC, 2010)



4.7 Water Supply Network

The following is a description of the water supply system within this catchment. Issues identified in Phase 1 and 2 of the 3 Waters investigations are summarised.

The Mosgiel water supply, under normal operation, is separate from the main Dunedin water supply. The Mosgiel supply is sourced from seven groundwater abstraction bores, which pump to five water treatment plants (WTPs) serving the Mosgiel area. From the WTPs the water supply is pumped into the network and also to the Quarry Hill reservoir. The Mosgiel network also supplies the East Taieri rural water supply to the south-west of Mosgiel, adjacent to the Wingatui and Taieri Industrial areas, which are supplied from the Mount Grand WTP.

The Mosgiel bores have a combined consented take of 5 ML/day. Peak demand for Mosgiel is estimated to be 5.2 ML/day by 2031. The Mosgiel treatment plants have a capacity to treat up to 10.6 ML/day.

There are approximately 95 km of water supply pipes within the Mosgiel catchment, with pipe diameters ranging from 15 mm to 500 mm diameter. The majority of the supply pipes in this catchment are constructed from asbestos cement and PVC, with PE and steel being the next most common material types.

A Public Health Risk Management Plan (PHRMP) is in place with respect to the Mosgiel Water Supply System, with the most recent issue of this plan being in July 2010. The bores in the area are considered secure bore heads according to the requirements set out in the New Zealand Drinking Water Standards 2005 (Revised 2008) for a *confined* aquifer. Given the more recent study by the ORC (2010), (refer Section 4.6) this status may need to be re-evaluated for unconfined or semi/confined aquifers. Monitoring of the water quality is undertaken on a regular basis by DCC to monitor this risk.

Recent reports from the DCC Water and Waste Services Business Unit, have identified faecal coliform counts in the water reticulation. If sourced from the groundwater, rather than via some other source, this may indicate groundwater contamination. Figure 4-11, taken from the PHRMP (2010), describes the actions to be followed in the event of contamination of the source water.

Event – Contaminates Entering Source Water	
Due to – unsealed bore head or casing, pipe ingress, flooding, or leachate from poor management of the aquifer	
Indicators	• Sampling programme identifies elevated levels above typical in tested chemical parameters (i.e. nitrates, positive E.coli). • Complaints from consumers. • Notification of contamination by others. • Visible deterioration of water
Actions	• Increase sampling to identify source of contamination and nature of problem. • Shut down identified bore and use alternative bore (if not contaminated) until event is past • If bacteriological, then issue boil water notice to consumers • Inform DWA of event • Consider supplying water from Mt Grand System • Follow requirements of Section 4.5.3 of DWSNZ:2005 (Revised 2008)

Figure 4-11: Contingency Plan for Contaminants in Groundwater Supply (from Mosgiel PHRMP, 2010)



Phase 2 water supply investigations concluded that the Mosgiel water supply system generally performs satisfactorily under normal operating conditions, however a number of issues were identified for 'active management' in the Mosgiel area:

- Customers local to reservoirs receiving low pressure;
- Leakage;
- Boil water notices;
- Provision of alternative supply;
- Supply to future growth areas; and
- Some mains operating above rated pressure.

Options were developed to resolve the boil water issues, along with city-wide approaches for assessing and managing leakage and resolving low pressures for customers local to reservoirs.

If water take consent conditions are not adjusted to accommodate future growth, Mosgiel can be supplied water from the Wingatui Reservoir if required. The Wingatui Reservoir accepts water from the Mount Grand WTP, which sources raw water from both Deep Stream and Deep Creek raw water intakes.

Much of the city of Dunedin relies on the Mount Grand WTP for water supply. Security of supply issues have been identified, in that the main source of raw water to Mount Grand relies on a single pipeline route from Deep Stream and Deep Creek to the city, however a number of options have been identified to manage this risk. The Taieri Bores have been identified as a key source of raw water for Dunedin during drought conditions.

Figure 4-12 provides a layout of the 3 waters networks in the Mosgiel catchment.

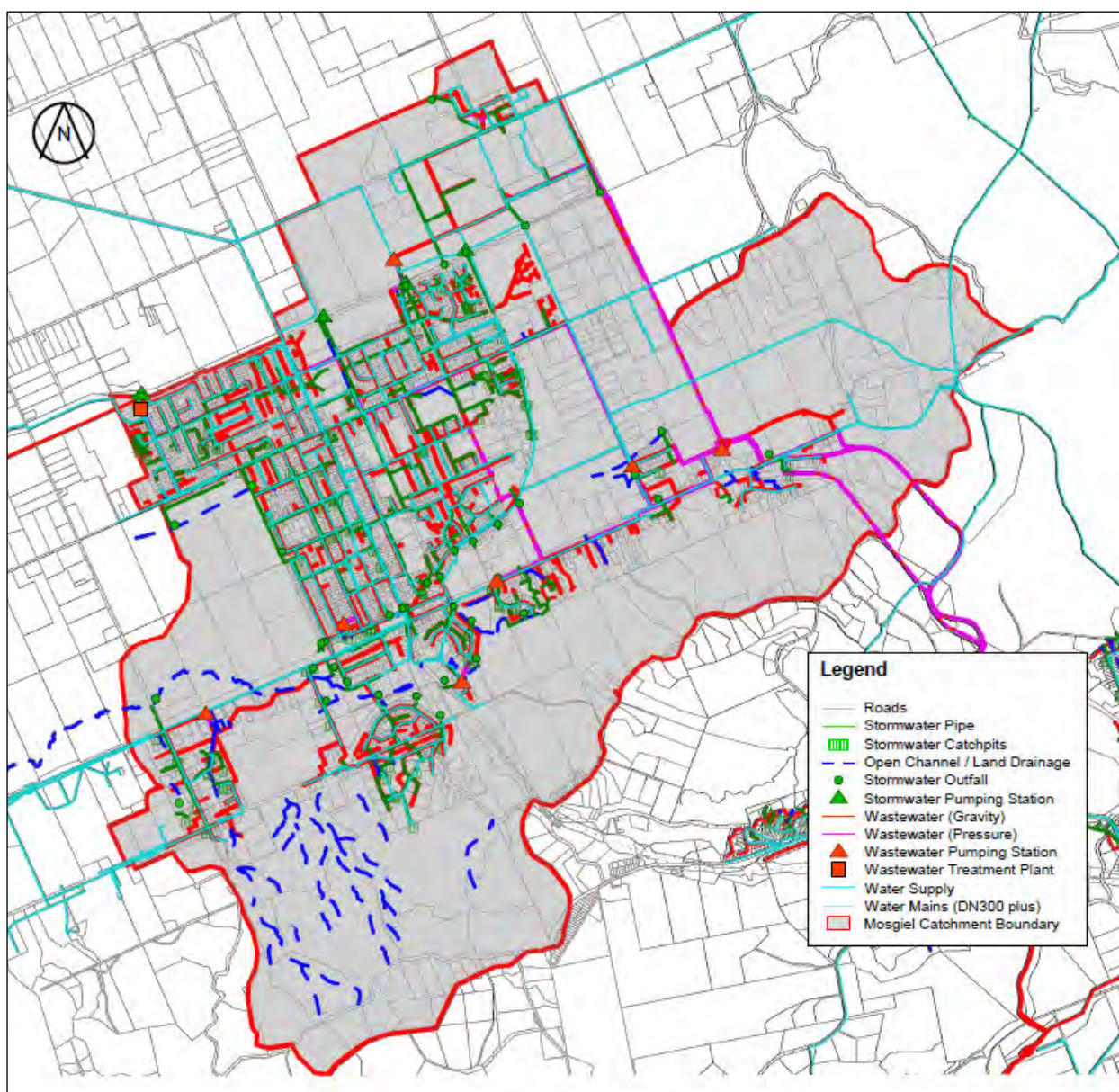


Figure 4-12: 3 Waters Networks in the Mosgiel Catchment



4.8 Stormwater Network

The stormwater network collects flows intercepted by the road drainage network and from down pipes (the majority of which discharge to kerb). Catchpits intercept the kerb and channel flows and direct them into the piped network. Once flows have entered the pipes, they are conveyed under gravity to one of several outfalls which discharge to watercourses. Several of the discharges are pumped when the downstream watercourse is in flood. Figure 4-14 provides details of the stormwater network within the catchment.

The stormwater network, to the south of the catchment in the steeper areas, utilises both pipes and open channels to convey flows to the receiving environment. These areas however, are not the focus of the study; they were included within the hydraulic model though to assess flow rates to lower areas of the catchment.

Details of the stormwater network can be found in the document: *Mosgiel Integrated Catchment Management Plan - Model Build Report* (Opus 2011). The key stormwater features have been identified as follows:

- The Silver Stream - this forms the boundary to a large portion of the Mosgiel stormwater network, and was therefore included in the hydraulic model to form a boundary condition for the pumped and combined gravity / pumped outfalls.
- Silver Stream Stormwater pump stations (PSSs) and Outfalls – Due to the boundary effect of the Silver Stream, the parts of the stormwater network draining to the Silver Stream have either pumped outlets or pump assisted gravity outlets. The operation of these outlets is crucial to maintain stormwater conveyance when the watercourse is flowing high. The outfalls consist of:
 - o Carlyle Road Outfall - pump assisted gravity outfall
 - o Reid Avenue Outfall - pump assisted gravity outfall
 - o Cherry Drive Outfall - pump assisted gravity outfall
 - o Hagart Alexander Outfall – two pumped outfalls
- The Owhiro Stream – this runs along the foot of the hills south and east of Mosgiel intercepting a number of small but steep hillside catchments. The Owhiro Stream bounds the southern extent of the town and forms a boundary to the localised stormwater network and the Quarry Creek.
- Reid Avenue Swale - this acts as both a conveyance and a storage facility should the stormwater main or PS flows exceed their capacity.
- Woodland Avenue Intake Structure – A small culvert intake screen located to the rear of a subdivision. This screen intercepts flows from the hills above.
- Bush Road Pipe Bifurcations – there are several bifurcations along Bush Road. Flows at these points are split between two stormwater lines which then rejoin downstream.
- Tyne Street Bifurcation – The flows are split between two main stormwater lines and rejoin



upstream of the Tyne Street outfall.

- Mure Street Overflow – this is a high level overflow to an adjacent drainage channel.

Figure 4-13 provides the distribution of known pipe diameters in the stormwater network. The data indicates that 150 mm, 225 mm and 300 mm diameter pipes make up a large portion of the network (9 %, 22 %, and 17 % respectively), with the remaining network spread over a range of pipe sizes from 100 mm up to 1800 mm. It should be noted that the use of small pipes is somewhat unusual in a flat catchment; the original design of the Mosgiel stormwater system included the use of the roads as secondary flood storage, with the pipes designed to convey a 10 mm (approximately 1 in 2 yr ARI) rainfall event.

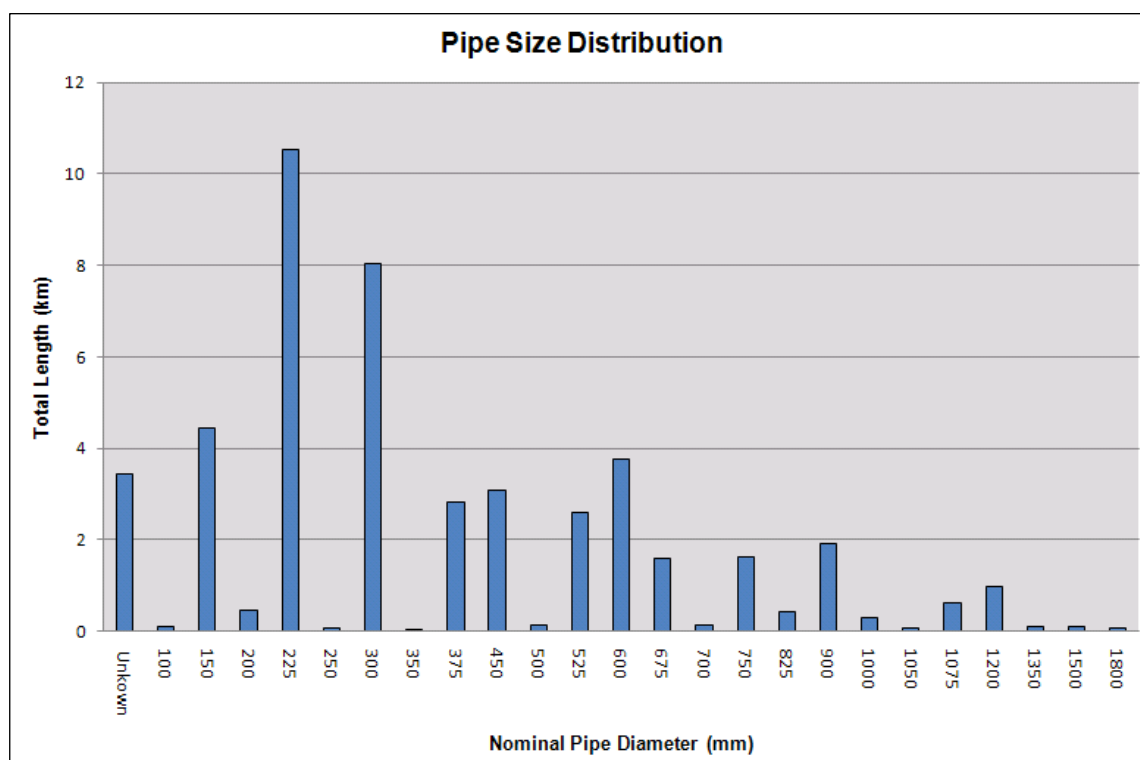


Figure 4-13: Stormwater Pipe Diameter Frequency Distribution

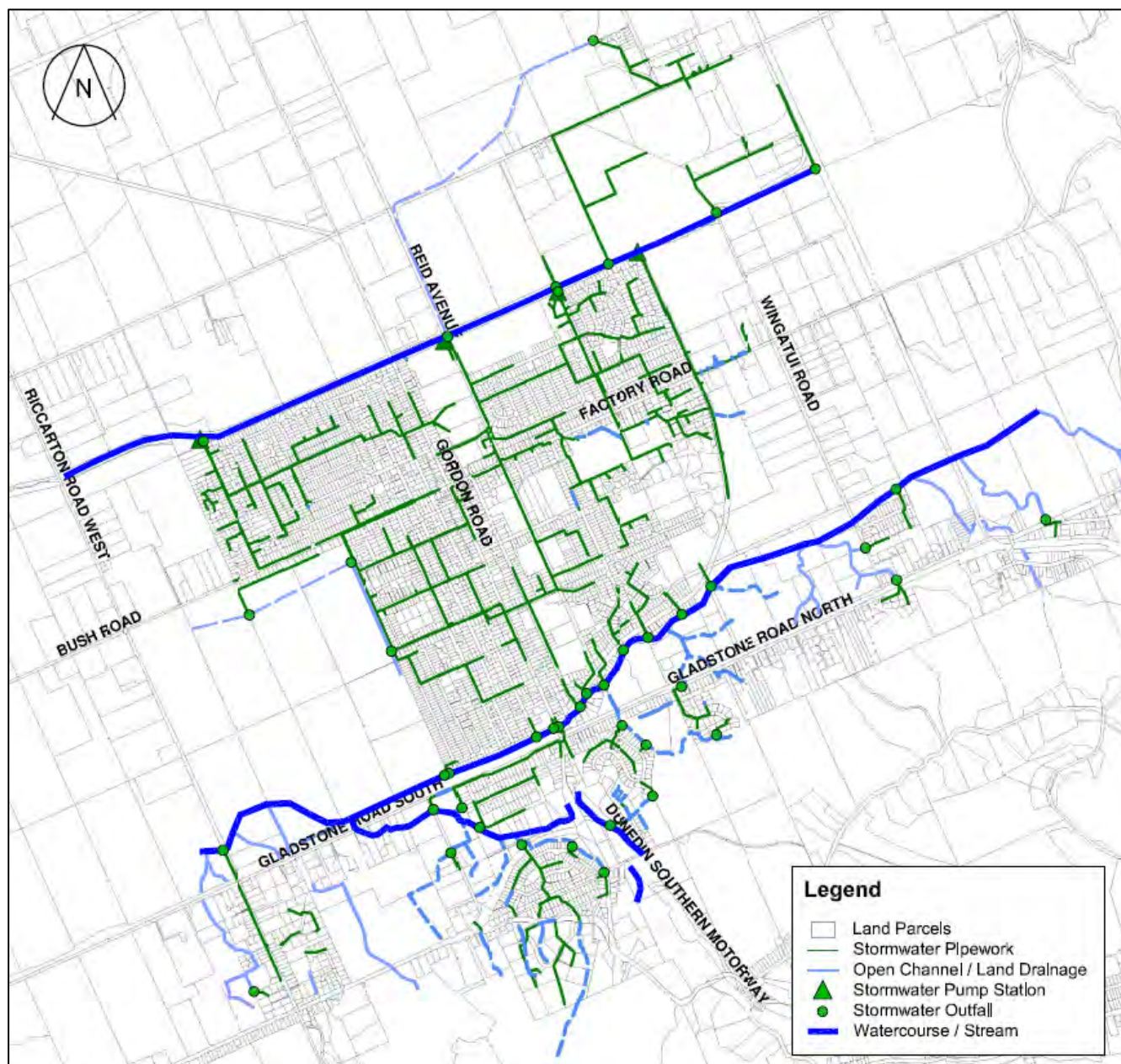


Figure 4-14: Stormwater Drainage Network



4.8.1 Network Age

Table 4-2 provides a breakdown of pipe age in the Mosgiel stormwater catchment, based on information held in DCC's GIS (geographic information system) database, which held installation dates for every pipe in the network. Figure 4-15 provides a map of pipe age based on location. As can be seen in the table and on the map, the data indicates that the age of the catchment varies from 1940's to post 2000, with the pipe age spread relatively evenly across the range. However, there is uncertainty surrounding the accuracy of this data. It is expected that there would be older pipes within the catchment.

Based on the current forecasts of theoretical asset life for stormwater mains, the majority of which have been assumed a theoretical life of 100 years, approximately 34 % of the network will be subject to inspection / condition assessment or renewal by 2060. Remaining life forecasts will be improved based on condition assessment and related work on refining expected lives, and renewals planning adjusted accordingly. Using this process, it is likely that a large portion of the network will be found to be in reasonable condition upon inspection. Therefore, it is unlikely that 34 % of the wastewater network will need to be renewed within the next 50 years.

Table 4-2: Stormwater Pipe Network Age and Length Composition

Installation Date	Approx. Age (years)	Number of Pipes	Length of Pipe (m)	% of Pipe Length
Pre-1900	>110	-	-	-
1901 - 1920	90-110	-	-	-
1921 - 1940	70-90	23	1,150	2.85 %
1941 - 1960	50-70	253	13,980	34.66 %
1961- 1980	30-50	199	12,600	31.24 %
1981-2000	10-30	184	4,770	11.83 %
Post 2000	<10	154	7,830	19.41 %

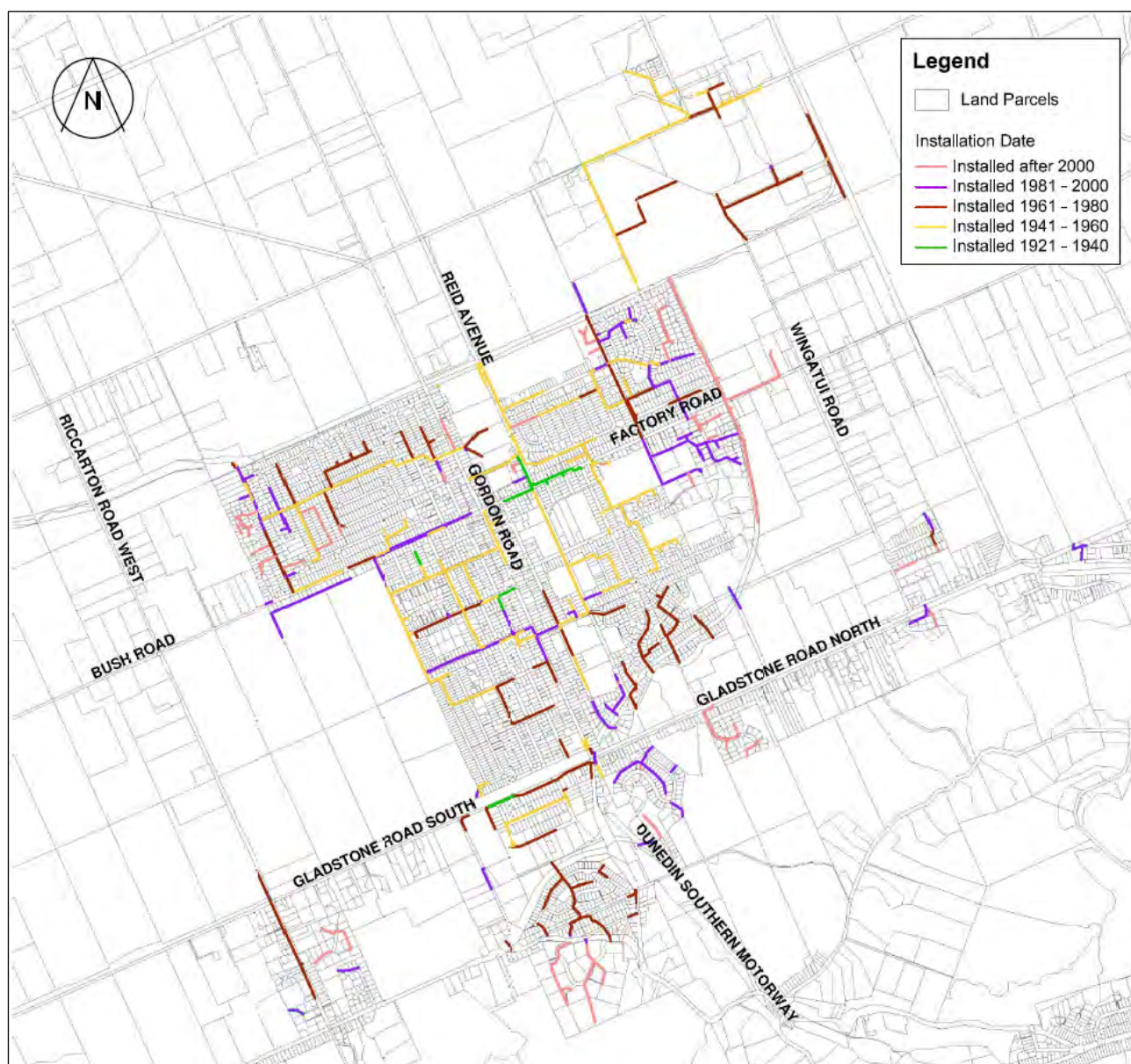


Figure 4-15 : Stormwater Pipe Network Age



4.8.2 Operational Issues

Discussions were held with DCC Water and Waste Services Business Unit personnel during the catchment walkover (December 2010) in order to identify known operational issues or locations of historical flooding. The stormwater related operational issues identified are detailed in Table 4-3; these highlight the issues raised during the walkover, plus any subsequent issues raised by DCC.

Table 4-3: Stormwater Operational Issues

Location	Issue
General	Blockage of catchpit
General	Blockage of screens
Gordon Road commercial area	Modification of kerb and channel has altered the flowpath and caused flooding
Reid Avenue	Flooding issues, storm channel smells of sewage
Green Street/Church Street	Flooding issues
Glasgow Street/Forfar Street	Flooding issues
Cherry Drive	Surface flooding, possibly issues with the stormwater PS
Gow Street/McGlashan Street	Flooding - Quarry Creek thought to cause or exacerbates the issue

4.8.3 Network Maintenance and Cleaning

The maintenance of stormwater catchpits and inlet screens is perceived to be a general issue across Dunedin City according to the Water and Waste Services Business Unit staff. It was noted by the network maintenance team that during autumn months heavy rainfall can result in blocked catchpits or inlet screens regardless of how well maintained they are. Given the low level of service of the piped network in Mosgiel, and the frequent ponding of stormwater in the road corridor, it is essential that catchpits are maintained in order to ensure ponded stormwater re-enters the network as quickly as possible following a rainfall event. Failure to remove silt and gravel from the catchpits can also lead to siltation and hence capacity reduction of the pipe network. Siltation has been identified as an issue in some areas of Dunedin by the Network Management and Maintenance team, and this is currently being investigated as part of a city wide CCTV programme.

The responsibility for the cleaning and maintenance of stormwater catchpits and other structures is divided between three DCC departments, Network Management (Water and Waste Services Business Unit), Transportation Operations and Community and Recreation Services (CARS).

Network Management

Stormwater structures under Network Management supervision are inspected on a weekly basis, after a rainfall event and before forecast bad weather. The specification for these inspections is as follows:

- Check access to the site with respect to Health and Safety requirements.
- Check the screen intake to ensure screen is 95 % or more clear.



- Check upstream channel is clear of debris (approximately first five metres).
- Check for any recent signs of overflow since last visit.
- If debris blocking intake screen, remove to achieve 95 % clearance. Type of material and approximate volume and weight to be recorded on the Screen/Intake Checklist.

In addition to the weekly inspections, condition assessments are completed every six months.

Transportation Operations

DCC Transportation Operations are responsible for stormwater structures within the road reserve (except State Highway, which are the responsibility of the New Zealand Transport Agency (NZTA)).

The cleaning and maintenance of these structures is contracted to a main contractor, managed by Transportation Operations. The main contractor then subcontracts the work to a third party.

Under the Transportation Operations cleaning and maintenance contract, with the main contractor, the asset cleaning and frequency levels of service are listed as follows:

- At any time at least 95 % of mud tanks shall have available 90 % of their grate waterway area clear of debris.
- At least 95 % of mud tanks, catchpits and catchpits shall have at least 150 mm below the level of the outlet invert clear of debris.
- At least 95 % of culverts shall have at least 90 % of their waterway area clear of debris throughout the entire length of the structure including 5 m upstream and downstream.
- At least 90 % of all other stormwater structures shall have 90 % of the waterway area clear of debris.

Included in the contract is an initial six month cycle to bring all stormwater structures up to specification. Once up to specification, they must be maintained to the specified level of service. Information relating to the way that compliance with the required level of service is measured was unavailable.

The cleaning and maintenance of stormwater structures in the road is currently perceived by Water and Waste Services Business Unit maintenance team to be inadequate. DCC have concerns that the cleaning and maintenance contract is not specific enough and therefore the stormwater structures within the roads are not maintained to a satisfactory standard.

Communities and Recreation Services (CARS)

The maintenance and cleaning of stormwater structures located within parks and reserves, other than those listed under Network Management supervision, are the responsibility of CARS.

At the time of writing this plan, CARS did not have a maintenance schedule for stormwater structures within parks and reserves. They were unable to confirm the location of such stormwater structures or whether any existed within the parks and reserves.



4.9 Wastewater Network

4.9.1 Network Description

There are two wastewater schemes within the boundary of the Mosgiel ICMP. The Mosgiel wastewater scheme and the Winagatui wastewater scheme. This ICMP focuses on the Mosgiel scheme.

The Winagatui wastewater scheme is separate from the Mosgiel scheme and consists of over 17 km of pipework and three PS's. The pump stations allow wastewater to be pumped directly to the Green Island WWTP for treatment.

The Mosgiel wastewater scheme provides wastewater services for industrial and residential customers in Mosgiel, including certain parts of the Taieri Industrial Estate and sections of the Taieri Plains. Wastewater collected in the system is treated at the Mosgiel wastewater treatment plant (WWTP) with treated effluent then pumped to the Green Island WWTP for disinfection by ultra violet light (UV) with subsequent discharge via the ocean outfall.

The Mosgiel wastewater system consists of the Mosgiel WWTP, 6 individual pump stations (PS) and over 57 km of pipelines of up to 1050 mm diameter. Figure 4-17 provides details of the wastewater network within the catchment.

The Mosgiel WWTP's operation in normal conditions allows for flow to enter the WWTP via the control room's basement where it is screened and then split into two separate inlet pump chambers which pump wastewater through the treatment process. Treated effluent is then stored in the treated effluent wet well before being pumped to the Green Island WWTP. In wet weather events, should the flows entering Mosgiel WWTP be high enough to pose a flooding risk to the basement of the control room, an isolation valve at the screens is shut, rerouting flows over a weir on the inlet line to the inlet pump chambers. Throughout this process, the inlet pumps work as per normal. When the treated effluent wet well's storage capacity is exceeded, flow is then diverted to a storm storage well which activates a separate diesel pump to assist in the transfer of treated effluent to the Green Island WWTP.

In worst case (emergency) scenarios, when the capacity of the inlet pump chambers or the treated effluent storage is exhausted, separate pumps will be utilised and the excess flow is pumped to the Silver Stream.

There are no known constructed wastewater overflows to the stormwater network in the Mosgiel wastewater system with the exception of the Mosgiel WWTP which overflows to the Silver Stream, as described above.

Details of the wastewater network can be found in the document: *Mosgiel Integrated Catchment Management Plan - Model Build Report* (Opus 2011). The key wastewater network features have been identified as follows:

- Mosgiel WWTP Basement Isolation Valve - this valve acts to divert flows away from the WWTP inlet screens during times of high flow. When the valve closes, flows back up until the WWTP inlet weir is overtopped, allowing flows to by-pass the inlet screen. The valve is currently manually operated during rain events when necessary.



- Mosgiel WWTP Inlet Weir - this allows flows to bypass the inlet screen and be directed to the pump stations downstream. The weir consists of a steel plate stoplog.
- Mosgiel WWTP Outfall - this outfall allows flows to be discharged direct to the Silver Stream in emergency situations, such as when all available storage at the WWTP has been utilised.
- Wingatui Wastewater PS Overflow – An emergency overflow in case of pump station failure (Wingatui Scheme). Set up unknown.
- Gladstone Road Wastewater PS Overflow - An emergency overflow in case of pump station failure (Wingatui Scheme). Flap valve installed.
- Soper Road Wastewater PS Overflow - An emergency overflow in case of pump station failure (Wingatui Scheme). Flap valve installed.
- Tyne Street Wastewater PS – This is a proposed pump station not yet constructed at the time of writing this plan. This pump station has been included in the hydraulic model as it is currently being progressed through to construction. The pump station is being constructed to alleviate an existing wastewater overflow issues on Tyne Street. The pump station is intended to eliminate the backwater affect caused by the main when it surcharges.

Figure 4-16 provides the distribution of known pipe diameters in the wastewater network. The data indicates that over half of the pipes (51 %) in the network are 150 mm diameter, with a further 26 % of pipes 225 mm or 300 mm diameter (13 % each), and 8 % being 500 mm diameter (comprising the pressure main to Green Island).

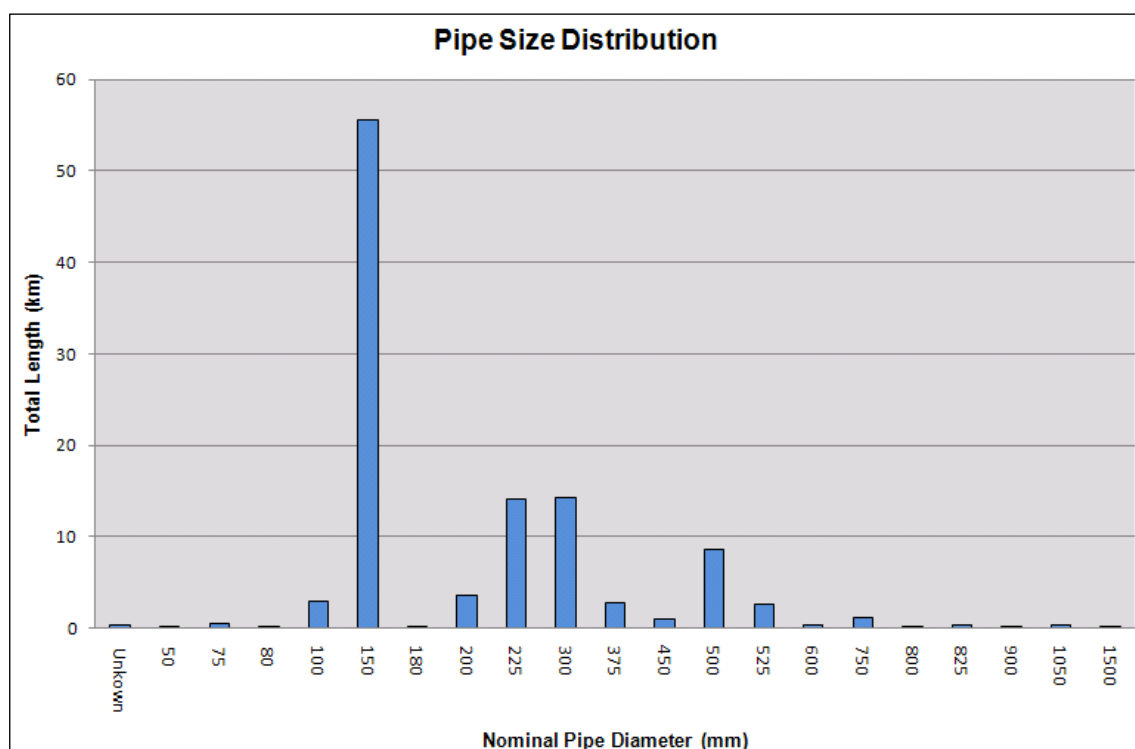


Figure 4-16: Wastewater Pipe Diameter Frequency Distribution

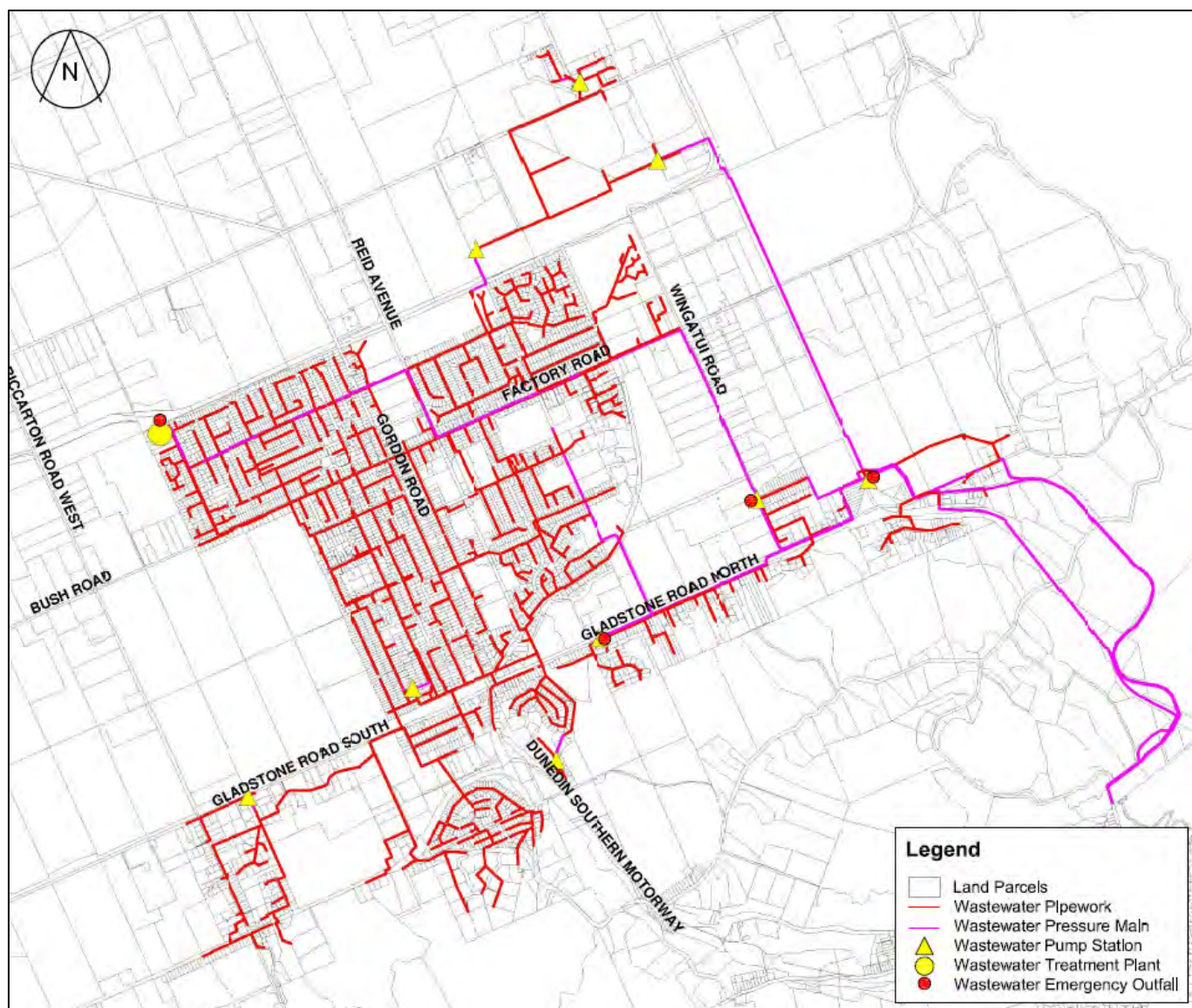


Figure 4-17: Wastewater Drainage Network



4.9.2 Network Age

Table 4-4 provides a breakdown of pipe age in the Mosgiel wastewater catchment, based on information held in DCC's GIS database, which held installation dates for every pipe in the network. Figure 4-18 provides a map of pipe age based on location. As can be seen in the table and on the map, the data indicates that the majority of the network was installed between 1940 and 2000, a period of 60 years, over which approximately 82 % of the network was installed. No pipes installed prior to 1937 are recorded in the data.

The wastewater network in Mosgiel was initially installed in 1880 so it is expected that there would be a proportion of pipes significantly older than the records indicate. It is known that there is inaccuracy in the GIS data relating to pipe age due to missing historic data with many pipe ages 'assumed' only.

However, based on the data available and the current forecasts of theoretical asset life for wastewater mains, the majority of which have been assumed a theoretical life of 100 years, approximately 31 % of the network will be subject to inspection / condition assessment or renewal by 2060. Remaining life forecasts will be improved based on condition assessment and related work on refining expected lives, and renewals planning adjusted accordingly. Using this process, it is likely that a large portion of the network will be found to be in reasonable condition upon inspection.

Table 4-4: Wastewater Pipe Network Age and Length Composition

Installation Date	Approx. Age (years)	Number of Pipes	Length of Pipe (m)	% of Pipe Length
Pre-1900	>110 years	-	-	-
1900 - 1920	90-110	-	-	-
1920 - 1940	70-90	100	60	0.1 %
1940 - 1960	50-70	392	29,060	26.80 %
1960- 1980	30-50	414	27,720	25.60 %
1980-2000	10-30	498	43,000	39.70 %
Post 2000	<10	180	8,460	7.8 %

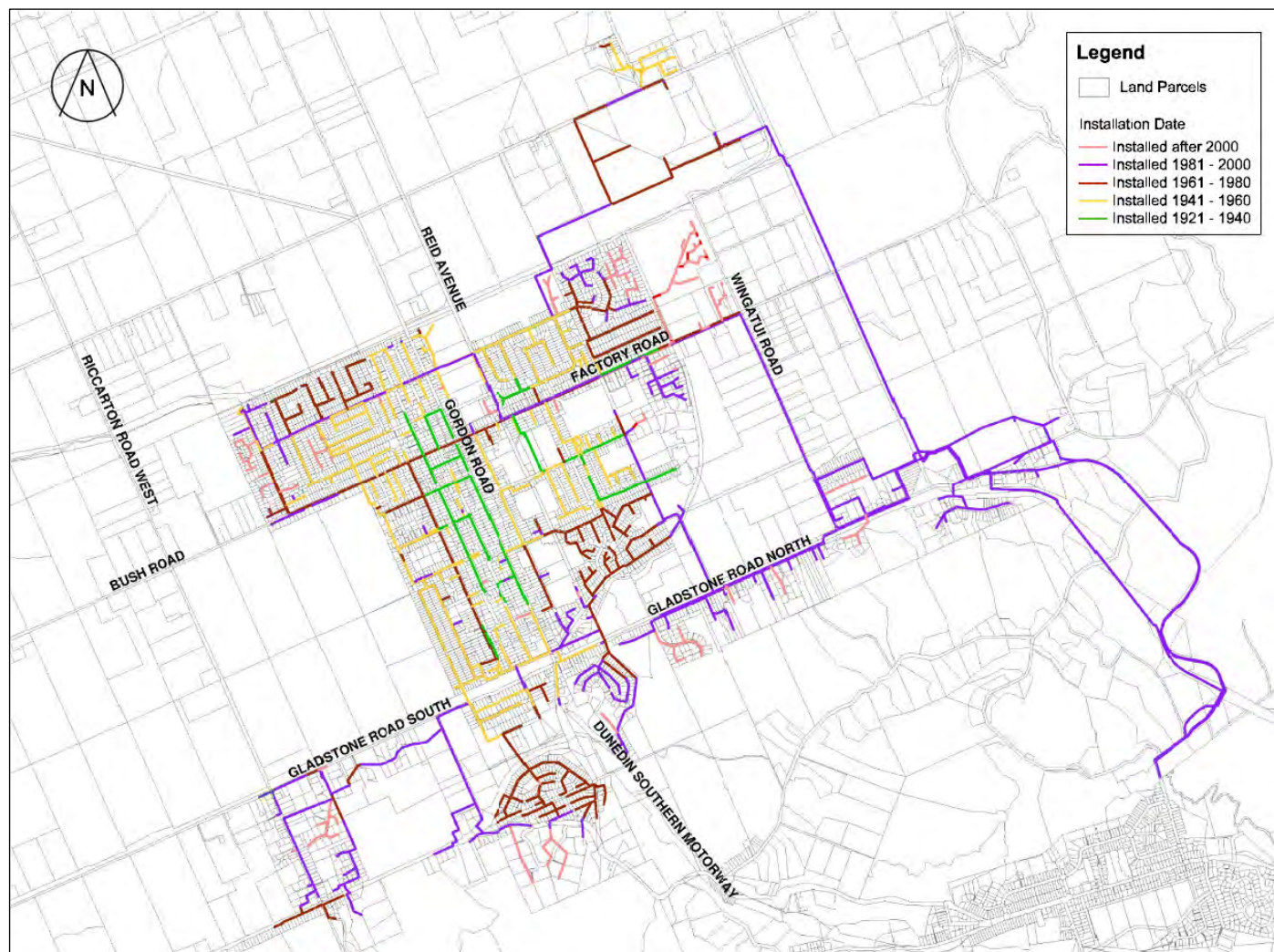


Figure 4-18: Wastewater Pipe Network Age



4.9.3 Operational Issues

Discussions were held with DCC Network Maintenance personnel during the catchment walkover in order to identify known operational issues or locations of historical flooding. The wastewater related issues identified during the catchment walkover, plus any subsequent issues raised by DCC are detailed in Table 4-5.

Table 4-5: Wastewater Operational Issues

Location	Issue
General	Blockage of sewers
General	Overflowing of property boundary traps and gully traps
Tyne Street	Foul manhole overflow
Carlyle Road	Overflowing manholes in the area
Silverstream Drive	Backing up of household toilets during storm event

4.9.4 Network Maintenance and Cleaning

No planned maintenance is undertaken for the wastewater network. Maintenance is instead carried out when required on a reactive basis, following customer complaints or issues identified through monitoring of the pump stations and treatment plant processes.

4.10 Asset Condition and Criticality

DCC has developed and applied a first cut criticality assessment to all water, wastewater, and stormwater network assets across the city. The criticality score has been calculated based on three weighted criteria: extent, cost, and location. For the full version of the methodology used, the DCC methodology document (available on request) should be referred to. Note that the stormwater intakes were rated slightly differently to remaining assets, with 20 % of the weighting assigned to cost and 20 % to each of the four wellbeings, given that the consequences of failure of an intake would be largely localised in nature due to area flooding.

Table 4-6 summarises the first cut version used for stormwater and wastewater network assets as of November 2010.

Figures 4-19 and 4-20 show a map of the Mosgiel catchment, with stormwater and wastewater criticality and well-being locations identified respectively. The maps shows pipe criticality only. Pipe condition assessment (via CCTV) is currently being undertaken throughout the city on selected pipes, however to date no information is available on pipes in the Mosgiel catchment.

There are a small number of wellbeing locations identified in the Mosgiel catchment, and the majority of the stormwater assets score a '1' for criticality. Pipes with a score of '2' tend to be located near major transport routes, or adjacent to school or parks/reserve sites. Similarly, the majority of the wastewater network score a '1' for criticality. Pipes with a score of '2' are predominantly those on major transport routes, or again, adjacent to school or parks/reserve sites. Of note, however, is that the rising main transferring wastewater to Green Island WWTP from Mosgiel, crosses an area of 'major environmental' value, with landslide risk.



Table 4-6: Asset Criticality Score Criteria

Factor	Score	Rating Scale	Proxy Used - Pipes	Proxy Used - Manholes	Proxy Used - Outlets
Extent (20 %)	1	Insignificant function failure			Assigned same rating as upstream pipe
	2	Minor (delivery) failure – Small population	<= 600 mm diameter	Manholes on non-pressurised pipes	Assigned same rating as upstream pipe
	3	Major (delivery) failure – Large population	> 600 mm diameter	Manholes on pressurised pipes	Assigned same rating as upstream pipe
	4	Major (safety, supply, containment) failure – Small population			Assigned same rating as upstream pipe
	5	Major (safety, supply, containment) failure – Large population			Assigned same rating as upstream pipe
Cost (20 %)	1	Up to \$20,000	All pipes	< 3.5 m deep	< 3.5 m deep
	2	\$20,000 - \$150,000		> 3.5 m deep	> 3.5 m deep
	3	\$150,000 - \$400,000			
	4	\$400,000 - \$1,000,000			
	5	Over \$ 1 m			
Location (15 % to each wellbeing)	1	Within 10 m of a ‘minor’ social, environmental, cultural, or economic wellbeing location			
	2	Within 5 m of a ‘minor’ social, environmental, cultural, or economic wellbeing location			
	3	Within 10 m of a ‘major’, or within 1 m of a ‘minor’ social, environmental, cultural, or economic wellbeing location			
	4	Within 5 m of a ‘major’ social, environmental, cultural, or economic wellbeing location			
	5	Within 1 m of a ‘major’ social, environmental, cultural, or economic wellbeing location			
Weighted Criticality Score	= (Extent Rating x 20 %) + (Cost Rating x 20 %) + (Social Rating x 15 %) + (Environmental Rating x 15 %) + (Cultural Rating x 15 %) + (Economic Rating x 15 %) = Criticality Rating				

Criticality 1 = Not Critical

Criticality 5 = Very Critical

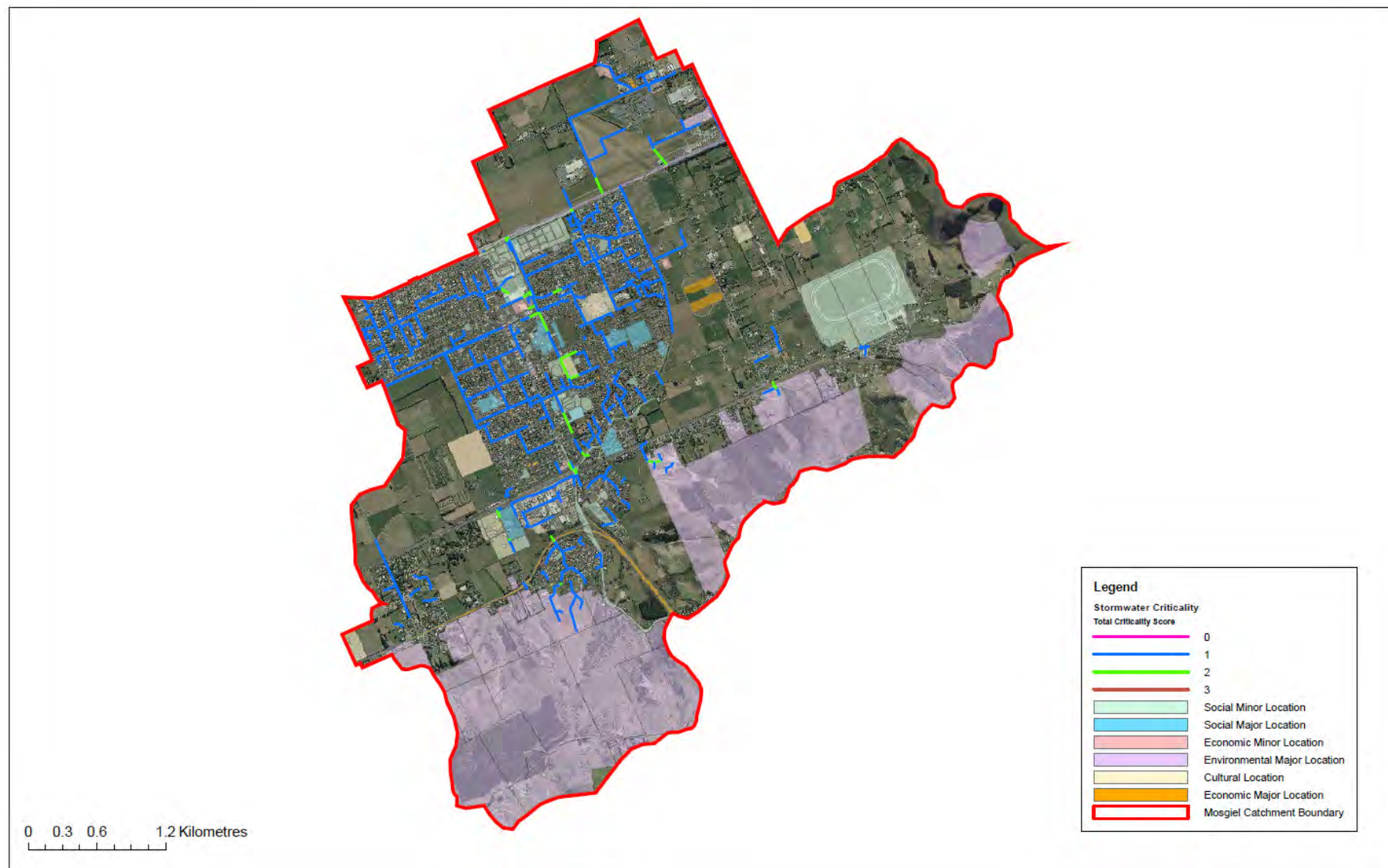


Figure 4-19: Stormwater Network Criticality

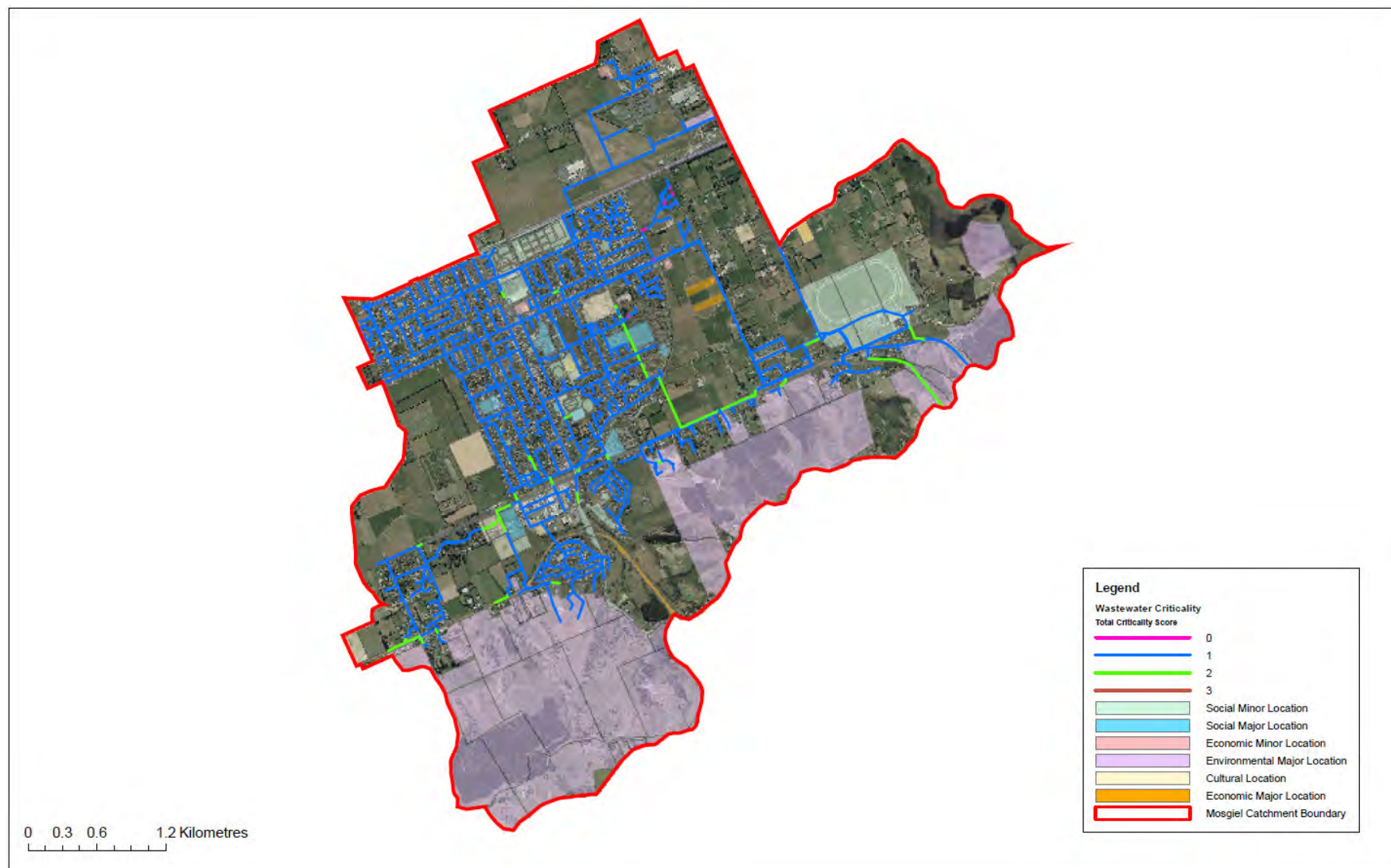


Figure 4-20: Wastewater Network Criticality



4.11 Catchment Complaints

Based on DCC customer complaints information collated between 2005 and 2010, there were a number of reported flooding incidents in the Mosgiel catchment. Figure 4-21 displays the stormwater complaints received, and Figure 4-22 displays the wastewater complaints received, in this five year period.

4.11.1 Stormwater Customer Complaints

There were numerous stormwater flooding complaints recorded between 2005 and 2010 that relate to blockages, overflows, leakages or that are unspecified. A significant number of complaints were recorded for Mosgiel, on average higher than received for other ICMP catchments. The key recorded flood complaints are summarised in Table 4-7. In addition to the key complaints highlighted, a number of one-off complaints were recorded. A full list of the stormwater complaints can be found in Appendix C.

Table 4-7: Key Stormwater Flood Complaints

Location	Year and Description
Gordon Road	34 complaints 2005 - widespread flooding along road. 1 complaint 2008
Shaw Street	2005, 2007, 2005 - "severe flooding" catchpits fail to deal with the flows"
Tyne Street/ Carlyle Road	2006, 2008, 2009 relating to stormwater PS and point of discharge
Gladstone Road	2005, 2007, 2008. 2005 – watercourse and blocked drains. 2008 – "blockage"
Woodland Avenue	2 complaints 2007 -blocked culvert intake resulted in properties flooding
Clyde Street	2005 - water running from the road caused a hole in the footpath to develop. Water then ran onto a wall and ponded on the foot path, contributing to the wall collapsing
Forfar Street/ Glasgow Street	2005 - whole street under water due to blocked catchpit. flowed into Glasgow Street and into a property
Cemetery Road	2005 -Quarry Creek rose and flooded residential property and East Taieri Preschool
Kinmont Crescent	2007- flooding onto property up to 0.5 m deep. 2008 - stormwater blockage
McGlashan Street	2007 -business flooded
Gow Street	2007 -business flooded
Centre Street	2008, 2009 - stormwater complaints
Glenbrook Drive	2008 , 2009 - stormwater lamp hole overflow
Factory Road	2008, 2009 – stormwater complaint
Argyle Street	2009 - stormwater overflowed and entered property

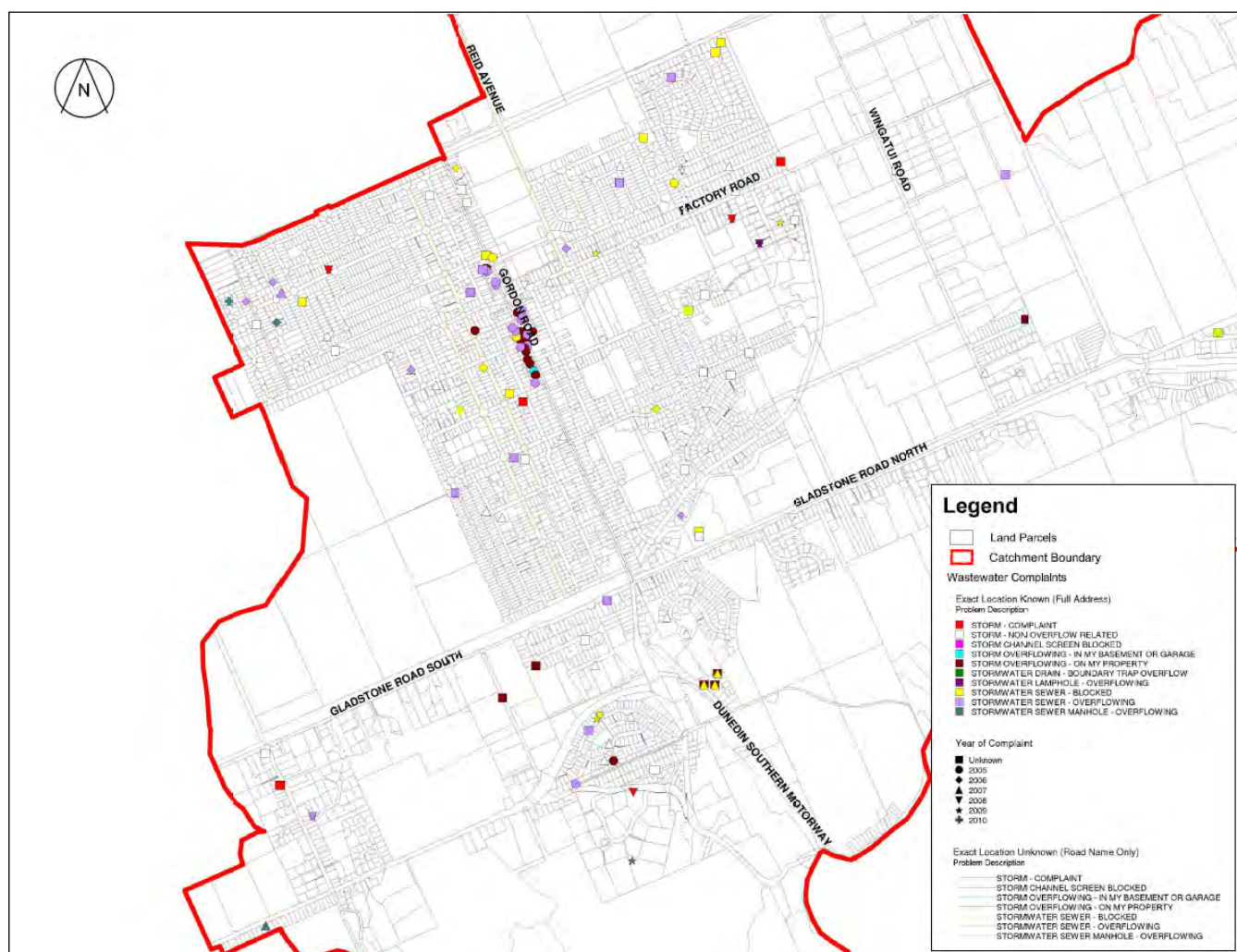


Figure 4-21: Mosgiel Stormwater Customer Complaints



4.11.2 Wastewater Customer Complaints

There were numerous wastewater flooding complaints recorded between 2005 and 2010 that relate to blockages, overflows, leakages or that are unspecified. The key recorded complaints are summarised in Table 4-8. A significant proportion of the complaints recorded are to the west of Gordon Road. In addition to the key complaints highlighted, a number of one-off complaints were recorded. A full list of the wastewater complaints can be found in Appendix C.

Table 4-8: Key Wastewater Customer Complaints

Location	Year and Description
Tyne Street / Carlyle Road	2006, 2007, 2009, 2010 – wastewater flood complaints
High Street	2007 to 2010 – wastewater overflow
Hazlett Road	2006, 2009 – wastewater overflows relating to the flooding and failure of the Hazlett Road PS
Argyle Street	Several complaints 2009 – wastewater overflows relating to a drain gully trap overflowing in the same location for all complaints
Ayr Street	2008, 2010 - wastewater boundary trap overflow
Forfar Street	2008, 2009, 2010 – wastewater overflow
Gebbie Street	2008, 2010 – wastewater overflow
Goodall Street	2008, 2010 – wastewater overflow
Mure Street	2008, 2010 – wastewater overflow
Shaw Street	2008, 2009 – wastewater overflow

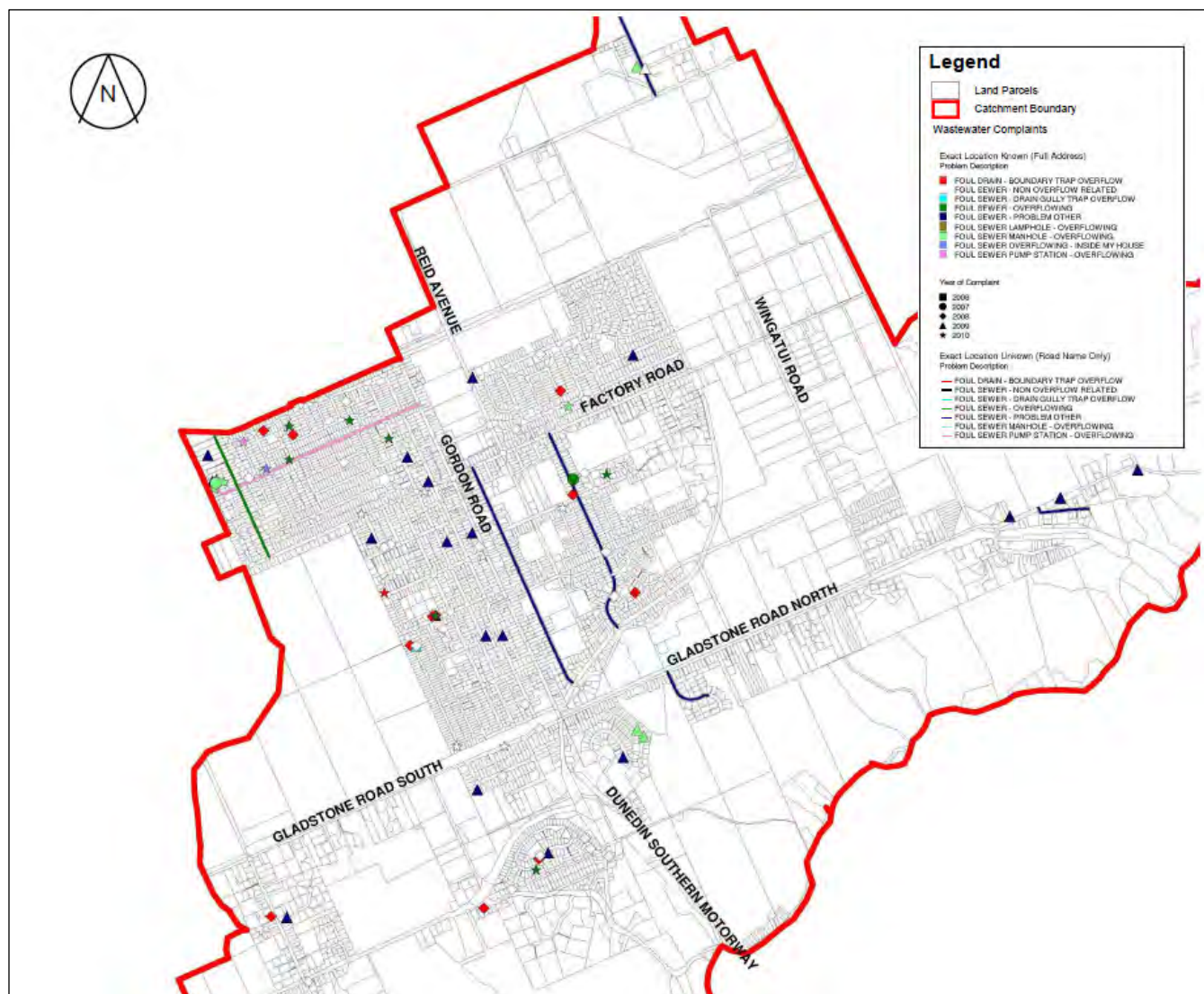


Figure 4-22: Mosgiel Wastewater Customer Complaints



5 Receiving Environment

This section identifies and describes the freshwater receiving environment for the Mosgiel catchment. An overview of the quality and value of the receiving environment is provided, acknowledging that both historical and current stormwater and wastewater network management, as well as many other activities not related to network management within the catchment, have contributed to the state of this environment.

Part 3 of this report identifies and analyses the effects that specific network management practices are considered to be having on the receiving environment of the catchment. Where the effects are considered to be unacceptable, options for avoiding remedying or mitigating the effects are discussed in Part 5 of this report.

5.1 Introduction

The effects of stormwater and wastewater discharge on streams can take a number of forms; physical effects (e.g. erosion, substrate changes) changing the natural hydrological flow regime of the catchment; whereas chemical changes result from the quality of the discharges. Each of these changes has an effect on the habitat, and hence the stream ecology. Modification of the stream environment through physical works also results in changes to the flow dynamics, and incorporation of fish barriers, in some instances.

It is difficult to distinguish between the effects of specific point source discharges and other influences on/input to the freshwater environment such as stream management, diffuse runoff and other activities in upstream reaches. The surrounding rural land uses in particular can be expected to have a measureable impact on stream water quality.

DCC have published a watercourse information sheet (May 2010), for property owners with a watercourse. It includes the following information:

"In Dunedin, watercourse is defined as any natural, modified or artificial channel through which water flows or collects, either continually or intermittently, or has the potential to do so, and includes rivers, streams, gullies, natural depressions, ditches and drainage channels. This also includes any culvert or stormwater pipe that replaces a natural channel. A watercourse is owned by the property owner through which the watercourse passes through from the point of entry to the exit point of the property boundary."

"Property owners are responsible for the following:

- Ensuring that there are no obstructions or impediments in the watercourse which may inhibit the flow of water; and*
- Ensuring that any grates or outlets within your property are kept clear of debris at all times."*

In general, alterations to watercourses require consent from both DCC and ORC.

5.1.1 Stream Assessments

An assessment of the freshwater receiving environment (Silver Stream and Owhiro Stream) was completed by Ryder Consulting Ltd (Ryder, May 2011) (Appendix D) as part of the Mosgiel catchment investigations. The assessment was carried out for the purpose of identifying the current



state of the streams and identifying the potential effects of current network discharges on stream health. The study comprised an assessment of the physical quality, values, water quality and ecology of the streams. The results also take into consideration a review of the literature and previous work undertaken in the catchment, including ORC State of the Environment (SOE) reporting.

Historic water quality data was analysed and compared against ANZECC and ARMCANZ (1992, 2000) water quality guidelines. This document provides a summary of the water quality guidelines proposed to protect and manage the environmental values supported by watercourses. This includes guideline/trigger levels for physico-chemical indicators of water quality that will protect the ecological health of aquatic ecosystems.

The ecological assessment of the streams involved the survey of aquatic plants, benthic macroinvertebrates and fish.

Benthic algal cover and aquatic plants were recorded and the relative abundance of diversity of species assessed.

Macroinvertebrates were sampled from a representative area of the stream bed using a kicknet. The abundance and diversity of taxa was assessed and the macroinvertebrate community health index (MCI) score was calculated to give an indication of stream health. The MCI score generally increases as water quality and habitat diversity increases. A semi-quantitative macroinvertebrate community health index (SMCI) score was also calculated. This can be used to determine the level of organic enrichment in a stream.

In order to assess the fish population electric fishing was carried out at locations representative of the different habitats within the stream. Where electric fishing was not able to be carried out effectively, spotlighting was used to visually identify the fish present.

A total of seven sites were selected for assessment in the catchment in consultation with DCC and ORC staff: three sites on the Silver Stream and four on the Owhiro Stream. All sites were assessed in April 2011. The location of the streams and assessment sites are shown in Figure 5-1.

The results of the ecological assessments and ORC data are summarised in the following sections. A number of different benchmarks were used to assess the significance of the findings.

5.2 Location and Description

Within the Mosgiel area there are two main watercourse catchments: Silver Stream and Owhiro Stream. These catchments contain residential, commercial, industrial and pastoral land uses. Stormwater and wastewater from the land uses are discharged to stream via stormwater outfalls or emergency overflows from the wastewater network.

The stormwater network in the Mosgiel catchment discharges to the freshwater environment via 48 outfalls of various sizes, nine discharge directly to the Silver Stream, 14 discharge directly to the Owhiro Stream and the remainder discharge to tributaries of these main streams or to unnamed field drains within the catchment.

The wastewater network discharges to the freshwater environment via emergency overflow which only operates in extreme circumstances. This is located at the Mosgiel WWTP and discharges to



the Silver Stream.

The network discharges are described in further detail in Section 6. The location of the outfalls and overflows are shown in Figure 4-14 (Section 4.8) and Figure 4-17 (Section 4.9)

Silver Stream is a major tributary of the Taieri River with its headwaters in the Silver Peaks (Powder and Whare Creeks) and hill catchments that border the west of Dunedin City to the west (McQuilkans and Flagstaff Creeks). From the hill catchments the stream crosses the East Taieri Plain, flows past Mosgiel and converges with the Taieri River upstream of Allanton.

Owhiro Stream is a much smaller tributary of the Taieri River. Its headwaters are in the lower slopes of Abbotts Hill above Wingatui. Tributaries from Saddle and Scroggs Hills flow into the middle and lower reaches. The Owhiro Stream converges with the Taieri River on the East Taieri Plain at Allanton.

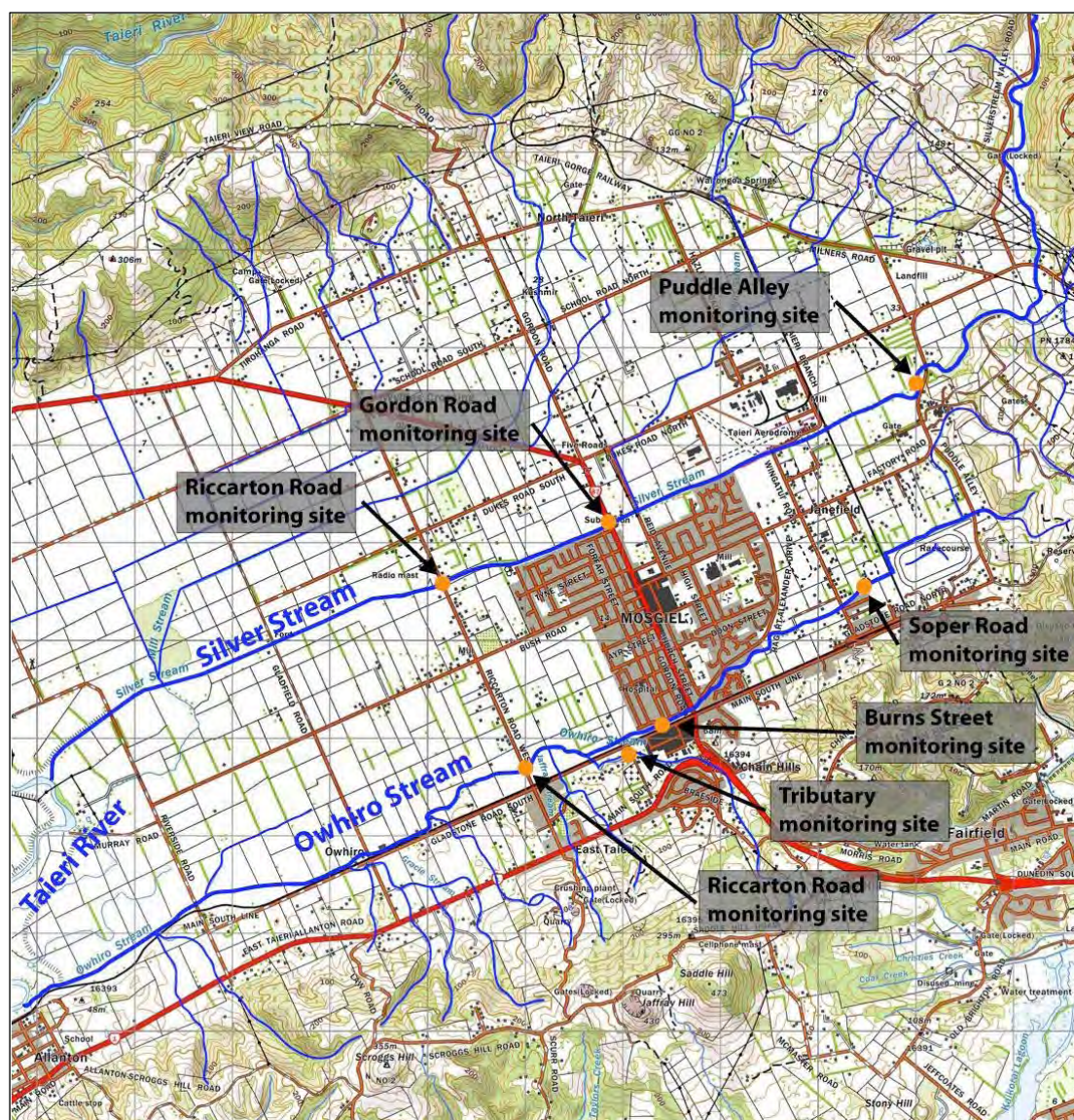


Figure 5-1: Freshwater Receiving Environment and Stream Assessment Sites



5.3 Silver Stream

Stream assessments were carried out at three sites on the Silver Stream (Figure 5-1):

- Puddle Alley;
- Gordon Road; and
- Riccarton Road.

The findings of these assessments are described in the following sections along with ORC SOE monitoring data from the Riccarton Road site.

5.3.1 Water Quality

Water quality data from the April 2011 surveys and historical ORC SOE monitoring have been assessed.

Historical ORC SOE data (taken between 2005 and 2010) from the Silver Stream catchment (measured at Riccarton Road) is summarised in Table 5-1. (These samples were taken predominantly during dry weather and therefore without the immediate influence of the stormwater discharges). The results are compared with ANZECC and ARMCANZ (1992, 2000) water quality guideline levels.

The ORC monitoring found that water quality is generally within guideline levels, with low turbidity, suspended solids and nutrient levels. The pH level is generally within the range (6.5 to 9) typically cited as being appropriate for freshwater bodies in New Zealand (ANZECC 1992). Dissolved oxygen levels are generally well above the 80 % acceptable minimum standard for lowland river environments. Conductivity levels are also low. A higher conductivity indicates higher levels of nutrient enrichment.

Instream faecal contaminant levels often exceed guideline levels for recreational activities with levels generally higher during low river flows. Direct recreational activity in Silver Stream is probably confined to low flow conditions although the lower reaches are not suitable for bathing.

It should be noted however, that monitoring undertaken by ORC in the upper Silver Stream catchment, upstream of Mosgiel, revealed that faecal contamination levels were also high indicating some contamination in the upper catchment. This is a common feature of lowland rural streams, notably where land uses include livestock.

Cyanobacteria have been regularly recorded in the reaches of the Silver Stream flowing through Mosgiel, including species able to produce cyanotoxins. This gives an indication that nutrient levels, at certain times of year, may be high in the stream.

The 2011 monitoring undertaken by Ryder Consulting showed similar conditions in Silver Stream, with high dissolved oxygen levels and low conductivity levels. Water temperature increased downstream, which was possibly the result of reduced shading from riparian vegetation.



Table 5-1: Summary of Silver Stream Water Quality 2005-2010 (dry weather), Riccarton Road SOE Site (ORC)

Parameter	Range (2005 – 2010)	Guideline Level
Temperature (°C)	4.6 – 25.3	< 15
pH	6.9 – 9.5	6.5 – 9.0
Dissolved Oxygen (%)	43.5 – 137.5	> 80 %
Conductivity (mS/cm)	0.08 – 0.22	-
Turbidity (NTU)	0.5 – 7.5	-
Suspended Solids (g/m ³)	1.5 – 24	-
E.coli (mpn/100ml)	4 – 1920	260 / 550 ¹
Faecal coliforms cfu/100ml)	4 - 1500	< 150 / < 1000 ²
Ammoniacal Nitrogen (g/m ³)	0.005 – 0.100	< 0.021 / < 0.9 ³
Nitrate/Nitrite Nitrogen (g/m ³)	0.007 – 0.720	< 0.444
Total Nitrogen (g/m ³)	0.17 – 0.97	< 0.614
Dissolved Reactive Phosphorus (g/m ³)	0.005 – 0.016	< 0.010
Total Phosphorus (g/m ³)	0.005 – 0.044	< 0.033
Guideline levels are taken from ANZECC and ARMCANZ (1992, 2000), Ministry for the Environment (1993, 2003). ^{1,2} guidelines for recreation only. ³ <0.021 guideline for nutrient enrichment, <0.9 guideline for toxicity		

The water quality in the Silver Stream was also monitored, by ORC, during rainfall events in 2004 and 2005. It was measured upstream and downstream of the Wingatui Place stormwater outfall; at Wingatui Place, and Titri Place respectively. (The Titri Place water quality was measured upstream of the Titri Place outfall). These results provide a limited indication of the overall health of the watercourse, providing just a 'snap-shot', and are likely to be influenced by several factors such as intensity and duration of rainfall. During rainfall there is also likely to be a significant amount of diffuse runoff entering the watercourse. The influence on water quality, of the diffuse runoff, cannot be distinguished from that of any point source inputs such as stormwater.

The results can be summarised as follows:

- The majority of contaminants were not found to exceed ANZECC guideline trigger levels or be significantly elevated downstream of the outfall when compared to upstream. In some cases contaminant were measured at lower levels downstream. However, there are some exceptions.
- Microbial contaminant levels were generally found to be higher downstream of the stormwater outfall. The levels were significantly higher in 2004. However, E.coli, faecal coliforms, and dissolved reactive phosphorus were measured above the ANZECC trigger level for 95 % species protection both upstream and downstream of the stormwater outfall in 2004 and 2005.
- Zinc was found to be higher downstream of the outfall in 2005 and was measured above the ANZECC trigger level for 95 % species protection.
- Nitrate/Nitrite, Copper and Nickel levels were found to be higher downstream of the outfall in 2005, however the increases were generally minor and the contaminant levels remained below ANZECC trigger levels.



5.3.2 Habitat

The habitat characteristics of the Silver Stream, at the three sites assessed, are summarised in Table 5-2 and the following text.

At Puddle Alley the stream is visible from the road and can be accessed from a public carpark and picnic area. A natural stream channel meanders under the road bridge. It appears the area may be popular for 4WD vehicles as tracks were observed. Land use within the area is predominately rural.



Figure 5-2: Puddle Alley Assessment Site

The Gordon Road site has a more defined channel with high flood banks. Surrounding land use is pastoral and industrial on the true right with the Mosgiel urban area is on the true left. The stream is accessible from a number of public areas.



Figure 5-3: Gordon Road Assessment Site

The Riccarton Road site is similar to Gordon Road with a modified channel and high flood banks along both banks. Land use on both sides of the stream is pastoral. The site is part of the ORC SOE monitoring programme.



Figure 5-4: Riccarton Road Assessment Site

Table 5-2: Silver Stream Assessment Site Characteristics

Characteristic	Silver Stream Sites		
	Puddle Alley	Gordon Road	Riccarton Road
Channel width	25 m	20 m	10-15 m
Channel depth	10-50 cm	10-30 cm	25-50 cm
Bank height	0.5-2 m	1.5-2 m flood banks 4-9 m	1-2 m flood banks 4-5 m
Bank stability	Moderate, reinforced areas, right bank	Stable	Stable
Wetted width	6-8 m	4-9 m	3-5 m
Clarity	High	High	High
Dominant riparian vegetation	Crack willow, ivy, blackberry	Exotic grasses	Exotic grasses
In-stream characteristics	Shallow riffles and runs, some pools	Runs with occasional shallow riffles	Runs with occasional shallow riffles
Bed substrate	Cobbles and gravels dominate, moderate to high stable bed	Gravels dominate, moderately stable bed	Gravels dominate, moderate-highly stable bed
Other instream	Woody debris and leaf litter common. Some aquatic plants	Some aquatic plants	Some aquatic plants, sparse woody debris
Other	Natural channel	Modified channel with high flood banks	Modified channel with high flood banks



5.3.3 Freshwater Ecology

A summary of the ecological assessment for the Silver Stream is as follows:

- **Aquatic Plants:** most of the sites were relatively clean of algae at the time of survey with only small patches on larger substrates. Cyanobacteria are regularly recorded the lower reaches flowing through Mosgiel upstream of the WWTP, with large mats present when water temperatures are high and flows low.
- **Macroinvertebrates:** Taxonomic diversity is generally higher further up the catchment and decreases with distance downstream. A total of 31 different taxa were identified within the Silver Stream catchment sites (April 2011 data). The number of taxa ranged from 14-24 when compared with a median of 18 taxa found in a long term nationwide survey of 66 sites (Scarsbrook et. al. 2000).
- **Macroinvertebrate communities** were generally dominated by oligochaete worms and Potamopyrgus snails however the Puddle Alley site was dominated by Deleatidium mayflies.
- **SMCI scores** generally decreased moving downstream, with average scores of 5.6 at Puddle Alley, 4.8 at Gordon Road and 4.8 at Riccarton Road. The Riccarton Road site is downstream of the WWTP overflow, it should be noted that there is little change in the effects of organic enrichment on the macroinvertebrate community upstream and downstream of this overflow.
- **Freshwater crayfish** have been found at the Riccarton Road site during ORC SOE fish surveys and in Whare Creek. The Department of Conservation list freshwater crayfish as 'chronically threatened – gradual decline' (Hitchmough et al, 2007).
- **Fish:** the catchment contains a diverse fish community dominated by native longfin eels and common bullies and introduced brown trout. The stream provides important spawning and nursery habitat for brown trout. Migratory species are in the lower reaches. Giant kokopu are in the tributaries but have not been recorded in the Silver Stream itself for almost 50 years. Fish distribution is shown in Figure 5-5.

In summary, there are increased algal blooms and a reduction in abundance and diversity of macroinvertebrate communities moving downstream from the upper catchment. However, the fish community remains diverse throughout all sites.

The increased algal blooms in the lower catchment may be due to optimum conditions for this to occur, such as slower flows, increased temperatures (due in part to slower flows and reduced riparian vegetation), and inputs of nutrients from rural runoff from the upper and lower catchment.

The decrease in macroinvertebrate abundance and diversity may be attributed to lack of riparian vegetation and significant modifications to the habitat in the lower catchment flowing through Mosgiel.

The quality of the watercourse overall could be considered moderate to good as the water and habitat is of a sufficiently high quality to support the fish community.

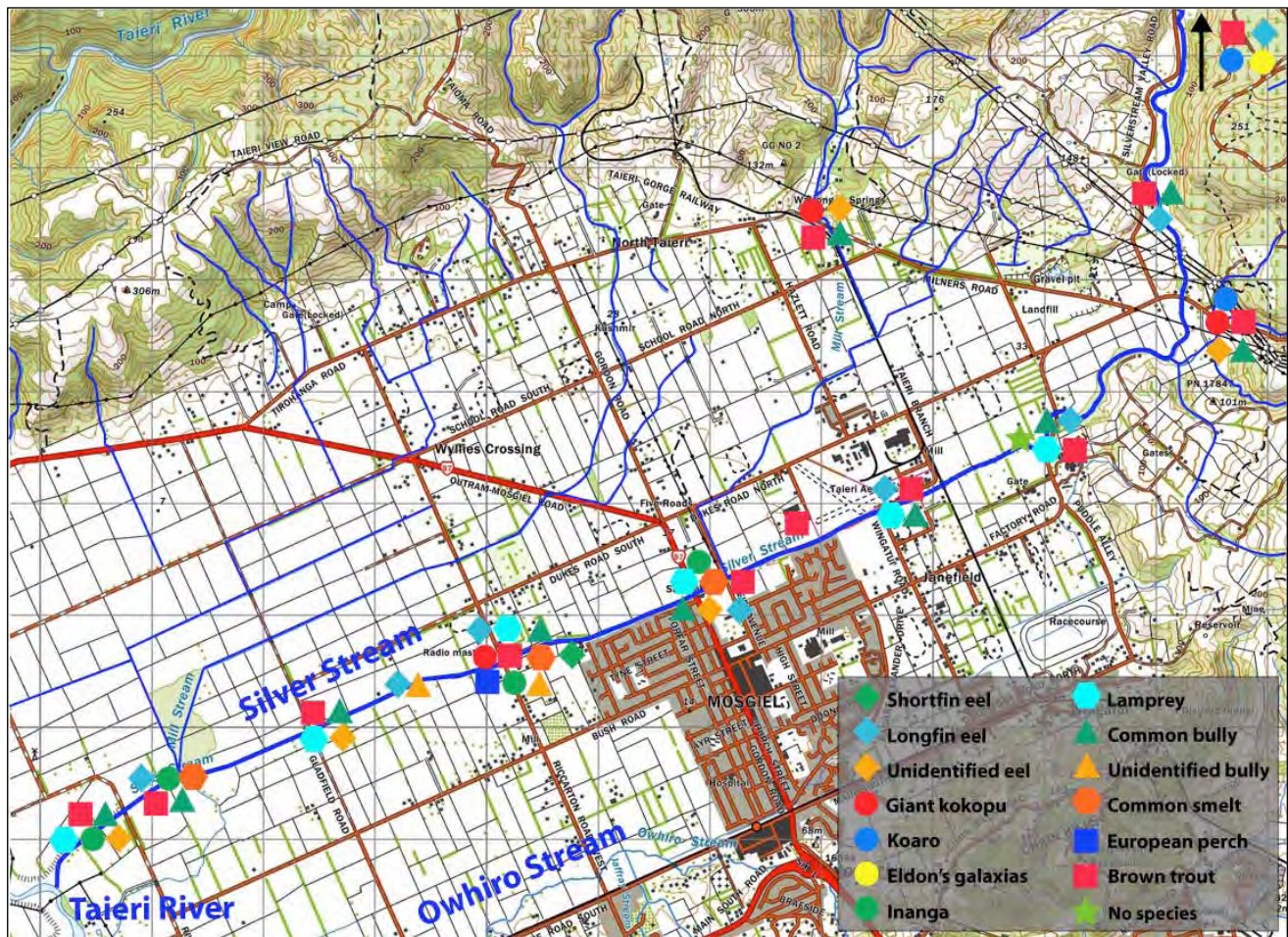


Figure 5-5: Fish Distribution Records in the Silver Stream Catchment (Sourced from NZFFD and Ryder (2011))

5.3.4 Culture and Amenity

The Silver Stream has been identified as having a number of amenity and cultural values.

The Silver Stream is not popular with anglers despite being open for fishing during the fishing season. The upper stream catchment has a number of walking routes. In the lower catchment surrounding Mosgiel there is a public access track along the Silver Stream Bank Reserve. This track is used for bike riding, walking, running and dog exercising. There is access to the stream for horse riders at the ford on Gladfield Road. The stream is visible from several road bridges.

The ORC Regional Plan: Water for Otago (2004) identifies Kai Tahu values for the Silver Stream. A variety of mana and access/customary uses are highlighted, shown in Table 5-3. These include the provision of food resources, the presence of significant spawning and nursery areas for native birds and/or fish, and the location of traditional routes.


Table 5-3: Kai Tahu Values for the Silver Stream, Schedule 1D, ORC Regional Plan: Water for Otago

Silver Stream	Beliefs, Values and Uses	Explanation
Mana Interests	MA1: Kaitiakitanga	The exercise of guardianship by Kai Tahu in accordance with tikanga Maori in relation to Otago's natural and physical resources; and includes the ethic of stewardship.
	MA2 : Mauri	Life Force; for example the mauri of a river is most recognisable when there is abundance of water flow and the associated ecosystems are healthy and plentiful: a most important element in the relationship that Kai Tahu have with the water bodies of Otago.
	MA3 : Waahi tapu and/or Waiwhakaheke	Sacred Places; sites, areas and values associated with water bodies that hold spiritual values of importance to Kai Tahu.
	MA4 : Waahi taoka	Treasured Resource; values, sites and resources that area valued and reinforce the special relationship Kai Tahu have with Otago's water resources.
Access/ Customary Use Interests	MB1 : Mahika kai	Places where food is procured or produced.
	MB2 : Kohanga	Important nursery/spawning areas for native fisheries and/or breeding grounds for birds.
	MB3 : Trails	Sites and water bodies which formed part of traditional routes.

5.4 Owhiro Stream

Stream Assessments were carried out at four sites on the Owhiro Stream (Figure 5-1):

- Soper Road;
- Burns Street;
- Quarry Creek (Owhiro Stream tributary); and
- Riccarton Road.

The findings of these assessments are described in the following sections along with ORC SOE monitoring data from the Burns Street site.

5.4.1 Water Quality

Water quality data from the April 2011 surveys and historical ORC SOE monitoring have been assessed.

Historical ORC SOE data (taken between 2001 and 2010) from the Owhiro Stream catchment (measured at Burns Street) is summarised in Table 5-4. The ORC monitoring found that the water quality of the Owhiro Stream is characterised by high turbidity, suspended sediments and nutrient levels. Dissolved oxygen levels were less than the recommended 80 % and conductivity was high particularly in the upper reaches. The pH values are within the range (6.5 to 9) typically cited as being appropriate for freshwater bodies in New Zealand (ANZECC 1992). Faecal contamination



concentrations are high and often exceed guideline levels. While the catchment is not known for its recreational values, exceedance of the guidelines is indicative of poor water quality.

Table 5-4: Summary of Owhiro Stream Water Quality 2005-2010, Burns Street SOE Site (ORC)

Parameter	Range (2005 – 2010)	Guideline Level
Temperature (°C)	2.2 – 22.1	< 15
pH	6.6 – 9.0	6.5 – 9.0
Dissolved Oxygen (%)	11.3 – 157.5	> 80 %
Conductivity (mS/cm)	0.08 – 0.39	-
Turbidity (NTU)	0.95 – 40.00	-
Suspended Solids (g/m ³)	1.5 – 27	-
E.coli (mpn/100ml)	5 – 5700	260 / 550 ¹
Faecal coliforms cfu/100ml)	6 - 5000	<150 / <1000 ²
Ammoniacal Nitrogen (g/m ³)	0.005 – 0.150	<0.021 / <0.9 ³
Nitrate/Nitrite Nitrogen (g/m ³)	0.003 – 1.47	<0.444
Total Nitrogen (g/m ³)	0.24 – 2.77	<0.614
Dissolved Reactive Phosphorus (g/m ³)	0.003 – 0.060	<0.010
Total Phosphorus (g/m ³)	0.04 – 0.86	<0.033
Guideline levels are taken from ANZECC and ARMCANZ (1992, 2000), Ministry for the Environment (1993, 2003).		
^{1,2} guidelines for recreation only.		
³ <0.021 guideline for nutrient enrichment, <0.9 guideline for toxicity		

Similar water quality conditions were found in the April 2011 sampling. Dissolved oxygen levels were low, especially at the downstream sampling locations where levels of less than 80 % were observed.

The water quality in the Owhiro Stream was also monitored, by ORC, during rainfall events in 2004 and 2005. It was measured upstream and downstream of the stormwater outfall discharging to the Quarry Creek (Owhiro Stream tributary). These results provide a limited indication of the overall health of the watercourse, providing just a 'snap-shot', and are likely to be influenced by several factors such as intensity and duration of rainfall. During rainfall there is also likely to be a significant amount of diffuse runoff entering the watercourse. The influence on water quality, of the diffuse runoff, cannot be distinguished from that of any point source inputs such as stormwater.

The results can be summarised as follows:

- Several contaminants were found to be higher downstream of the outfall, this includes microbial contaminants, suspended solids, heavy metals, nitrate/nitrite and phosphorus.
- Several contaminants were found to exceed ANZECC guideline trigger levels for 95 % species protection. However, where trigger levels were exceeded, it occurred both upstream and downstream of the stormwater outfall and thus cannot be solely attributed to stormwater input.



5.4.2 Habitat

The habitat characteristics of the Owhiro Stream, at the four sites assessed, are summarised in Table 5-5 and the following text.

The Soper Road site is downstream of Wingatui Racecourse. The stream is inaccessible to the public as it is behind private property or on farmland and is incised. The surrounding land use is pastoral.



Figure 5-6: Soper Road Assessment Site

Approximately 2.5 km downstream of Soper Road is the Burns Street site. By this stage the stream has flowed from pastoral land use along the eastern edge of the residential and industrial area of Mosgiel. The site is alongside the main trunk railway line. This site is part of the ORC State of the Environment monitoring programme.



Figure 5-7: Burns Street Assessment Site



The Quarry Creek tributary assessment reach flows through church and school land. Two pedestrian footbridges cross the stream and it is culverted under Cemetery Road. The channel is incised and has been straightened. This section of the stream is fully fenced.



Figure 5-8: Quarry Creek Assessment Site

The most downstream site is at Riccarton Road. From the Quarry Creek tributary site the stream has flowed through predominately pastoral land to this point. The stream is incised with large sections of bank having slumped and scoured. The stream is within private land.



Figure 5-9: Riccarton Road Assessment Site


Table 5-5: Owhiro Stream Assessment Site Characteristics

Characteristic	Owhiro Stream Sites			
	Soper Road	Burns Street	Quarry Creek Tributary	Riccarton Road
Channel width	9-10 m	10 m	5-6 m	4-10 m
Channel depth	5-20 cm	5-30 cm	20-30 cm	10-100 cm
Bank height	2-2.5 m	2-3 m	2-3 m	3-4 m
Bank stability	Mostly stable	Mostly stable, some undercutting	Generally stable	Mostly stable, large areas of slumping, some undercutting
Wetted width	1-2 m	1-2 m	0.8-1 m	0.5-5 m
Clarity	Moderate	Moderate	Moderate	Moderate
Dominant riparian vegetation	Exotic grass, gorse, gum trees on right bank	Exotic grasses	Exotic grasses	Pasture grass and thistles
In-stream characteristics	Runs with occasional shallow riffles	Runs with occasional shallow riffles	Runs with some shallow riffles	Shallow riffles with some short runs and larger pools
Bed substrate	Fine silts and sands dominate, highly unstable bed	Cobbles dominate, moderately stable bed.	Fine silts and sand dominate, highly unstable bed	Fine gravels dominate, highly unstable bed
Other instream	Some aquatic plants, sparse woody debris	Some aquatic plants, sparse woody debris	Some aquatic plants, sparse woody debris	Some aquatic plants, sparse woody debris
Other	Deeply incised straightened channel	Incised straightened channel	Incised straightened channel	Incised channel

5.4.3 Freshwater Ecology

A summary of the ecological assessment for the Owhiro Stream is as follows:

- Aquatic Plants: Communities are generally restricted to exotic plants. Sparse diatom mats and filamentous algae are found but limited as the bed substrates are unsuitable for supporting diverse benthic algal communities.
- Macroinvertebrates: Taxonomic diversity is low. A total of 19 different taxa were identified within the Owhiro Stream sites (April 2011 data). The number of taxa ranged from 8-11 when compared with a median of 18 taxa found in a long term nationwide survey of 66 sites (Scarsbrook et. al. 2000).
- Macroinvertebrate communities were generally dominated by worms and snails.
- SMCI scores for the Owhiro Stream were generally low and decreased moving downstream; with average scores of 4.6 at Soper Road, 2.6 at Burns Street and 2.4 at Riccarton Road. The Quarry Creek tributary had an average SMCI score of 3.2.



- Freshwater crayfish were been found at the Soper Road site (April 2011). The Department of Conservation list freshwater crayfish as 'chronically threatened – gradual decline' (Hitchmough et al, 2007).
- Fish: the catchment contains a fish community with moderate diversity but relatively low density. Native longfin eels and introduced brown trout have been found in lower reaches. Giant kokopu have been found but have a fragmented distribution with poor recruitment. Fish distribution is shown in Figure 5-10.

In summary, the aquatic community health in the Owhiro Stream is reasonably poor with sparse aquatic plant communities and macroinvertebrate communities of low diversity showing to deteriorate downstream.

In summary, the overall aquatic community health throughout the Owhiro Stream catchment is low. Plant and algal communities are restricted, macroinvertebrate communities are of low quality and dominated by taxa associated with streams of poor water quality. This may be attributed to habitat quality, with the channel being highly modified, lacking in riparian vegetation and with poor substrate.

Whilst freshwater crayfish have been found in the upper reaches of the stream, and freshwater fish are present throughout the stream, the population is of low to moderate diversity and with fragmented distribution.

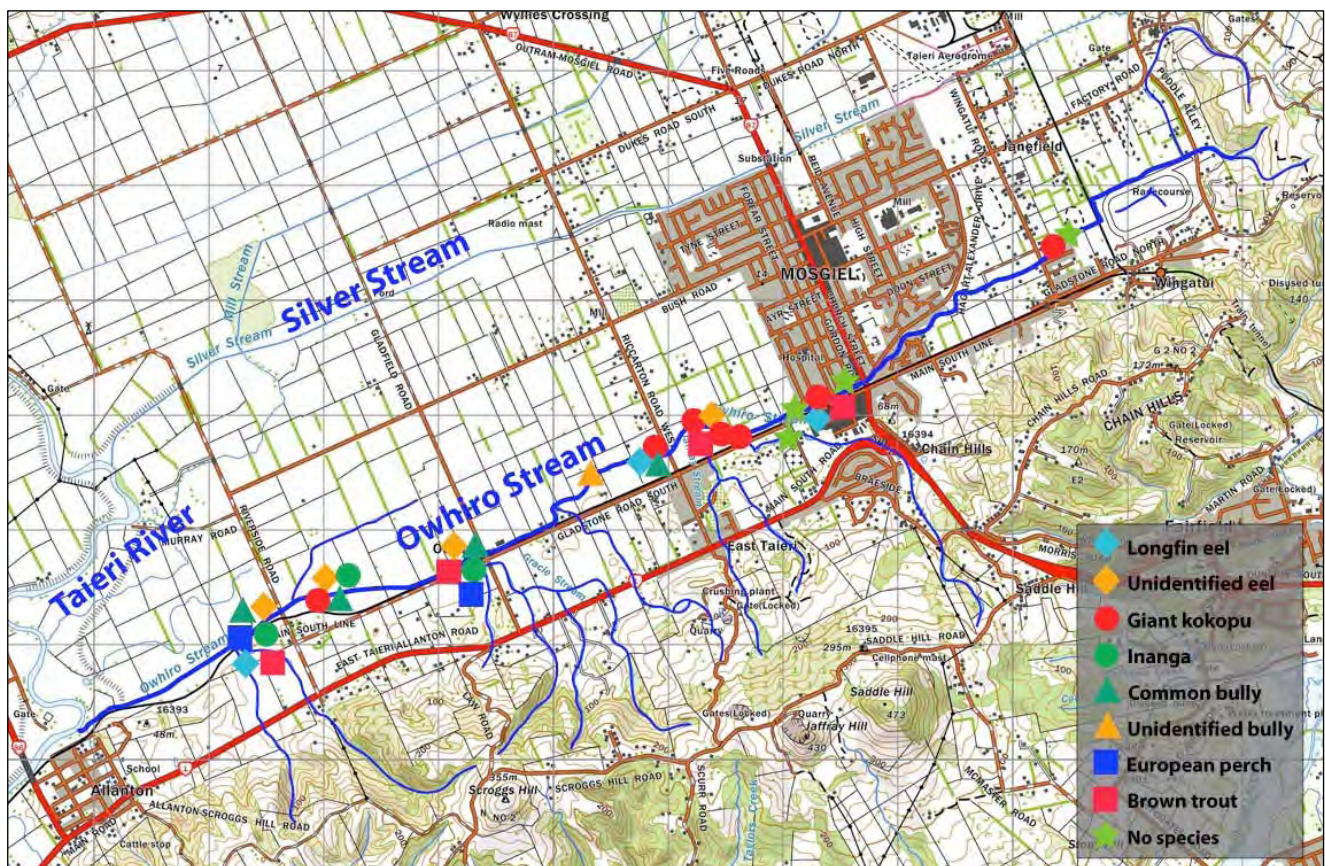


Figure 5-10: Fish Distribution Records in the Owhiro Stream Catchment. (Sourced from NZFFD, David et al. (2002) and Ryder (2011))



5.4.4 Culture and Amenity

The Owhiro Stream has been identified as having a number of amenity and cultural values.

The Owhiro Stream is also not popular with anglers despite the stream containing brown trout. Community groups have a strong involvement with the Owhiro Stream with various riparian planting and fencing projects having taken place along the stream. The stream is visible from the numerous bridges that cross it and also from Hagart Alexander Drive and Burns Street.

The ORC Regional Plan: Water for Otago (2004) identifies Kai Tahu values for the Owhiro Stream. A variety of mana and access/customary uses are highlighted, shown in Table 5-6. These include the provision of food resources, the presence of significant spawning and nursery areas for native birds and/or fish, and the location of traditional routes. In addition, the Owhiro Stream is a traditional source of weaving materials and medicines.

Table 5-6: Kai Tahu Values for the Owhiro Stream, Schedule 1D, ORC Regional Plan: Water for Otago

Silver Stream	Beliefs, Values and Uses	Explanation
Mana Interests	MA1: Kaitiakitanga	The exercise of guardianship by Kai Tahu in accordance with tikanga Maori in relation to Otago's natural and physical resources; and includes the ethic of stewardship.
	MA2 : Mauri	Life Force; for example the mauri of a river is most recognisable when there is abundance of water flow and the associated ecosystems are healthy and plentiful: a most important element in the relationship that Kai Tahu have with the water bodies of Otago.
	MA4 : Waahi taoka	Treasured Resource; values, sites and resources that area valued and reinforce the special relationship Kai Tahu have with Otago's water resources.
Access/ Customary Use Interests	MB1 : Mahika kai	Places where food is procured or produced.
	MB2 : Kohanga	Important nursery/spawning areas for native fisheries and/or breeding grounds for birds.
	MB3 : Trails	Sites and water bodies which formed part of traditional routes.
	MB4 : Cultural Materials	Water bodies that are sources of traditional weaving materials and medicines.

5.5 Receiving Environment Summary

This section summarises the freshwater receiving environment within the Mosgiel catchment. Further to the use of national classification systems, the different habitat and ecosystem features of the streams surveyed in the wider Dunedin stormwater catchments as part of this study have been interpreted relative to each other to summarise the receiving environment within the catchment. The features have been given an overall value of between 'poor' and 'excellent' based on the findings of the site assessments. This is shown in Table 5-7.

The aquatic ecosystems within the catchment were generally found to be of good to poor quality with the exception of the headwaters of the Silver Stream and the Puddle Alley site. The habitat



quality is generally limited with modified channels, poor riparian vegetation and instream cover. The Owhiro Stream is a smaller catchment that is entirely modified for urban and pastoral land use activities and this is reflected in its overall health.

Of note is the fish community of the Silver Stream which is very diverse and provides important spawning and nursery habitat for brown trout as well as several migratory species.

Whilst there some deterioration in the receiving environment moving downstream, it is unlikely that it is solely due to the effects of stormwater discharges. Pastoral land use activities will have contributed to the state of the streams as will modifications to the channels.

Table 5-7: Summary of Habitat and Ecosystem Quality in the Mosgiel Catchment
(Values are 'poor', 'good', and 'excellent')

Feature	Silver Stream	Owhiro Stream
Riparian vegetation	Poor	Poor
Bank stability	Good	Poor
Flow variability	Good	Poor
Bed substrate	Good	Poor
Instream cover	Poor	Poor
Water quality	Good	Poor
Invertebrates	Good	Poor
Fish	Excellent	Poor



6 Network Discharges

This section of the report provides a description of the stormwater and wastewater network discharges from the Mosgiel catchment based on the information available.

6.1 Stormwater Quality

Details of the quality of stormwater from the Mosgiel catchment are described in this section.

Urban stormwater can contain a wide range of contaminants, ranging from suspended sediments and micro-organisms to metals and petroleum compounds, amongst others. The sources of these contaminants are wide-ranging in urban environments and anthropogenic activities significantly contribute to runoff quality. Table 6-1 indicates the typical sources of urban stormwater contaminants.

Table 6-1: Sources of Stormwater Contaminants

Contaminant	Potential Sources
Suspended Solids (TSS)	Erosion, including streambank erosion. Can be intensified by vegetation stripping and construction activities.
Arsenic (As)	Naturally occurring in soils/rocks of New Zealand; combustion of fossil fuels; industrial activities, including primary production of iron, steel, copper, nickel, and zinc.
Cadmium (Cd)	Zinc products (Cd occurs as a contaminant), soldering for aluminium, ink, batteries, paints, oils spills, industrial activities.
Chromium (Cr)	Pigments for paints & dyes; vehicle brake lining wear; corrosion of welded metal plating; wear of moving parts in engines; pesticides; fertilisers; industrial activities.
Copper (Cu)	Vehicle brake linings; plumbing (including gutters and downpipes); pesticides and fungicides; industrial activities.
Nickel (Ni)	Corrosion of welded metal plating; wear of moving parts in engines; electroplating and alloy manufacture.
Lead (Pb)	Residues from historic paint and petrol (exhaust emissions), pipes, guttering & roof flashing; industrial activities.
Zinc (Zn)	Vehicle tyre wear and exhausts, galvanised building materials (e.g. roofs), paints, industrial activities.
Polycyclic aromatic hydrocarbons (PAH)	Vehicle /engine oil; vehicle exhaust emissions; erosion of road surfaces; pesticides.
Faecal coliforms / E.coli	Animals (birds, rodents, domestic pets, livestock), sewage.
Fluorescent Whitening Agents (FWAs)	Constituent of domestic cleaning products, indicator of human sewage contamination.
References: ARC, 2005; ROU, 2002; Williamson, 1993.	



6.1.1 Stormwater Monitoring

Stormwater quality monitoring is not carried out within the Mosgiel catchment on a regular basis. For the purposes of this study time-proportional monitoring was carried out on 13th September 2010, during a 2.6 mm rainfall event following several hours of dry weather. Samples were taken from the outfall at the end of Lanark Street, which discharges into an unknown field drain. The sub-catchment for this outfall is predominantly residential. The results of this analysis give an indication of the range of contaminants found in the stormwater discharges from residential areas of Mosgiel.

The ORC has completed some stormwater quality monitoring in Mosgiel. It should be noted that the ORC monitoring locations were likely chosen to monitor the mixed industrial activities served by those particular outfalls. They are not representative of most of the Mosgiel urban area. For this monitoring, grab samples were taken in attempt to capture the first flush. Stormwater from outfalls at three locations were monitored, Wingatui Road (Silver Stream), Titri Place (Silver Stream), and the Quarry Creek (Owhiro Stream), during rainfall events in November 2004 and February 2005.

The Wingatui Road and Titri Place pipe outfalls discharge stormwater from the north to Silver Stream from a rural/industrial sub-catchment which includes the Taieri Aerodrome and a timber treatment plant which is known to be a 'managed' contaminated site. The Quarry Creek outfall discharges stormwater runoff from rural hill catchments to the south and light industrial/residential land uses. The state highway also runs through the sub-catchment.

The results of stormwater quality monitoring in Mosgiel are presented in Table 6-2.

Three time-proportional stormwater quality samples were taken across Dunedin as part of the 3 Waters Strategy; one at South Dunedin (2009), one at Bauchop Street (2009), and one at Port Chalmers (2010). These three sites provide stormwater quality representing industrial/residential, commercial/residential, and residential land uses respectively. Table 6-3 presents these results.

There are no specific guidelines for stormwater discharge quality, nationally or internationally, however Table 6-4 presents stormwater quality data from a variety of sources. This information provides an indication of 'typical' stormwater contaminant concentrations that might be expected from urban catchments.

6.1.2 Stormwater Quality Results

The monitoring results from all sites indicate that the level of contaminants in the stormwater is variable between the sites and years monitored. Considerable variability can be expected in stormwater sampling due to antecedent conditions (the number of dry days prior to rainfall) and event characteristics (intensity and duration of rainfall) affecting the amount of sediment (and hence contaminants) present in the stormwater. Additionally, the grab-sampling technique, where employed, may have taken a sample at any point during the event.

The time-proportional monitoring results (2010) indicate contaminant levels within, or below, the range typically observed in urban stormwater, when compared with stormwater data from the variety of sources listed in Table 6-3 and 6-4. This may be because the sub-catchment is predominantly residential and therefore yields low levels of contaminants or could be due in part to a rainfall event only a few hours prior to sampling flushing a percentage of the contaminants from the catchment surface.

It should be noted that a single time-proportional sample, whilst giving an indication of the range of



contaminants in a single event, is not sufficient to give a clear picture of any trends in stormwater contaminants over time.

The ORC monitoring results from 2004 and 2005 also indicate variable results across the locations and years. The majority of contaminants are within the ranges typically observed for stormwater when compared with stormwater data from the variety of sources listed in Table 6-2 and 6-3. There are however, some exceptions.

Arsenic levels were slightly elevated in the Quarry Creek outfall samples during both years monitored; copper levels were found to be slightly elevated in the stormwater from the Quarry Creek outfall (2005) and the Wingatui Road outfall (2004, 2005); nickel; was also slightly elevated in samples from the Wingatui Road outfall (2004) when compared with stormwater data from the variety of sources listed in Table 6-3.

The majority of contaminants measured at the Titri Place outfall were within the range typically observed for stormwater. However, the levels of E.coli and faecal coliforms, measured in the grab samples, were at the upper end or exceeded the typical range for urban stormwater (1,000 – 21,000 MPN/100 ml) (Metcalf & Eddy, 1991).

There is no wastewater flood complaint data for Mosgiel for 2004 or 2005, so it is unclear whether wastewater flooding incidents within the catchment may have caused peaks in microbial contamination in the stormwater. There are no known cross connections between the stormwater and wastewater networks in Mosgiel in the sub-catchments monitored. There are a number of predicted wastewater manhole overflows but again, none in the vicinity of the stormwater outfalls monitored.

However, the sub-catchment for the Titri Place stormwater outfall is partly rural and landuse includes livestock grazing. Runoff from the rural land may be resulting in high microbial contamination in the stormwater.

The potential source of the microbial contamination in the stormwater is difficult to distinguish. The data is also limited and historic so the results do not allow any conclusion to be drawn as to whether it is an ongoing occurrence or not.

It should be noted that at present the stormwater discharges from Mosgiel are a permitted activity under the ORC Regional Plan: Water for Otago. However, the conditions for this permitted activity require that the discharges do not contain any human sewage, amongst others. Currently there is a risk of contamination, however discharge quality information is not sufficient to confirm this.



Table 6-2: Mosgiel Stormwater Quality Monitoring Results

Contaminant		pH	As	Cd	Cr	Cu	Ni	Pb	Zn	TSS	Oil & Grease	E.Coli	Faecal coliforms
Location	Date		g/m ³									MPN/100 ml	cfu/100 ml
Lanark Street (t-proportional range)	2010	6.8 - 7.3	≤0.021	≤0.00110	≤0.011	0.014 – 0.039	≤0.011	<0.002 – 0.006	0.51 – 0.82	3 - 15	8 - 17	3 - 40	5 - 40
Quarry Creek Outfall (ORC)	2004	7.3	0.019	0.00069	-	0.1060	0.0121	0.0576	2.170	270	-	1,600	2,000
	2005	6.4	0.010	0.00051	-	0.0650	0.0082	0.0505	1.660	360	-	5,200	5,000
Wingatui Road (ORC)	2004	7.0	0.004	0.00158	-	0.1450	0.1620	0.0318	1.670	150	-	550	550
	2005	6.5	0.002	0.00048	-	0.0370	0.0500	0.0074	1.230	31	-	3100	2700
Titri Place (ORC)	2004	7.1	0.003	0.00037	-	0.0306	0.0105	0.0358	0.936	480	-	21,400	21,400
	2005	6.9	0.001	0.00029	-	0.0149	0.0033	0.0169	0.566	73	-	20,900	20,900



Table 6-3: Dunedin City Time Proportional Stormwater Monitoring Results, Contaminant Ranges

Contaminant	As	Cd	Cr	Cu	Ni	Pb	Zn	pH	SS	Oil & Grease	E.Coli	Faecal coliforms
Location	g/m ³										MPN/100ml	Cfu/100ml
South Dunedin Industrial/Residential (2009)	0.0012-0.0052	0.00007-0.00041	0.001-0.0074	BDL-0.064	0.0067-0.073	0.00083-0.0044	0.23-0.84	7-7.67	17-160	26-42	3900-14000	5400-20000
Bauchop Street Commercial/Residential (2009)	BDL-0.0038	BDL-0.00054	BDL-0.05	0.04-0.23	BDL-0.007	BDL-0.087	0.05-2.5	6.71-7.91	26-330	7-53	-	-
Port Chalmers Residential (2010)	BDL	BDL	BDL	BDL	BDL – 0.108	0.0024 – 0.0077	0.108–0.26	7.60 – 7.90	8-47	6-18		320-1000
BDL = below detection limit												

Table 6-4: Comparison of Mosgiel Stormwater Quality with Other Stormwater Quality Data

Contaminant (g/m ³)	Time Proportional Dunedin (city-wide)	Christchurch Recommended Provisional Mean Values ¹	Pacific Steel, Auckland ²	Brookhaven Subdivision ³	Australian Stormwater Mean ⁴	Urban Highway, USA ⁵	New Zealand Data Range ⁶	Mosgiel
	Residential/Industrial	Christchurch	Industrial	Residential	Australian sites	Highway	Urban	Mixed use
TSS	8 - 330	33 - 200	124	5 - 49	164	142	-	50-86
Zinc	0.05- 2.50	0.40	2.80	0.003 - 0.260	0.910	0.329	0.09 – 0.80	0.136-0.24
Copper	BDL - 0.23	0.05	0.08	0.002 - 0.031	0.08	0.054	0.015 – 0.110	0.00162-0.0058
Lead	BDL - 0.087	0.075	0.23	0.003 - 0.007	0.25	0.4	0.06 – 0.19	BDL-0.121

¹ Christchurch City Council, 2003. ² NIWA, 2005. ³ Zollhoefer, 2008. ⁴ Wendelborn *et al*, 2005. ⁵ U.S. Department of Transportation Federal Highway Administration (1990) ⁶ Williamson, 1993.



6.2 Wastewater Emergency Overflows

There are three wastewater PS emergency overflows within the Mosgiel catchment and a further overflow from the Mosgiel WWTP.

The PSs with emergency overflows are located at:

- Wingatui Road – overflow to drainage ditch which flows into the Owhiro Stream.
- Soper Road - overflow to drainage ditch which flows into the Owhiro Stream.
- Gladstone Road – overflow to stormwater manhole which discharges via outfall to Owhiro Stream.

The emergency overflow from the Mosgiel WWTP discharges directly to the Silver Stream. This is designed to operate when the capacity of the inlet chambers or treated effluent storage is exhausted. When the capacity is exceeded excess volumes are pumped to the Silver Stream.

6.2.1 Operation

There are no records of operation of the emergency overflows from the wastewater pump stations.

Table 6-5 summarises the operation of the emergency overflow from the WWTP in Mosgiel between 2000 and 2009.

The overflow from the WWTP to the Silver Stream operates on average once a year during heavy rainfall events. The volumes spilling vary depending on the nature of the rainfall event and WWTP flows.

A high capacity diesel pump was installed in the WWTP in 2010 to pump flows to Green Island WWTP. Since the commissioning of this new pump, overflows to the Silver Stream occur less frequently as flows into the WWTP can now be transferred more quickly and the risk of capacity being exceeded is reduced.

6.2.2 Quality

The quality of the emergency overflow from the WWTP is not monitored. The effluent can be pumped to the Silver Stream from a number of points within the treatment plant, namely the inlet PSs, the secondary clarifier and the filter well PSs. If it is being pumped from the inlet PSs then it is untreated but all overflows are at least screened before being discharged. Normal DCC practice is to ensure overflows from the WWTP are as highly treated as practicable.

However, on the infrequent occasions when the wastewater overflow is operating (i.e. at periods of very high flows due to prolonged/heavy rainfall events), dilution factors may be such that the quality of the receiving water will only be affected to a minor extent and for a relatively short duration only.

The Stream Assessment Report (Ryder, 2011) concludes that “adverse environmental effects due to the emergency wastewater discharges would appear to be negligible”.


Table 6-5: Mosgiel WWTP Overflow Operation (2000 – 2009)

Year	Date	Total Rainfall (mm)	Length of Event	Plant Flow* (m ³ /day)	Increase in Flow (compared to ADWF)	Overflow Volume (m ³)	Comments
2000	18/08/00 – 19/08/00	92.1	2 days	17,229	5.4	6,678	Flow estimated to have bypassed plant for 37 hrs.
2004	11/05/04 – 13/05/04	65.8	2 days	5,412	1.5	6,678	Drizzle, Mosgiel WWTP operations remained normal.
2005	07/02/05	25.6	<20 mins	6,155	1.4	25,000	Flash flooding. Basement flood to 300-400 mm due to sudden surge of water.
2005	11/02/05 – 12/02/05	49.8	2 days	9,945	1.8	2,653	Heavy drizzle. Effluent PS tank overflowing into storage tanks.
2006	25/04/06 – 26/04/06	170.4	1 day	15,197	4.1	15,534	Steady rain, heavy drizzle. Silver Stream western banks breached. Basement flooded.
2007	30/07/07	82	12 hrs	20,430	5.5	10,962	Basement partially flooded.
2008	31/07/08 – 01/08/08	57.8	24 hrs	24,939	6.0	12,564	Muddy coloured water entering plant.
*Average Dry Weather Flow (ADWF) 3,700 m ³ /day							



7 Model Results

7.1 Introduction

A linked 1 and 2-dimensional hydrological and hydraulic model of the Mosgiel wastewater and stormwater networks was developed to replicate the performance of each system, assess any interactions between them, and to predict flood extents during a range of different scenarios.

Two different storm durations were assessed, a short duration event (30 minutes) which resulted in the greatest predicted extent of stormwater flooding and a long duration event (24 hour) which resulted in the highest predicted wastewater flows. The short duration event yielded the greatest flood extent from the stormwater network due to the high intensity of the rainfall, whilst the longer duration event provided sufficient time for the catchments soils to become saturated triggering the infiltration of water into the sewer system via leaky joints, pipe cracks etc.

To represent the different manner in which the stormwater and wastewater systems react to rainfall intensity and duration, rainfall falling on the catchment was routed between the two systems. The majority of surface runoff was routed directly to the stormwater network and rainfall infiltrating through pervious surfaces in the catchment was routed to the wastewater system, via a Ground Infiltration Module (GIM). This represents the saturation of the upper soils and the infiltration of the moisture into the wastewater network. The way rainfall was routed within the model is represented in Figure 7-1.

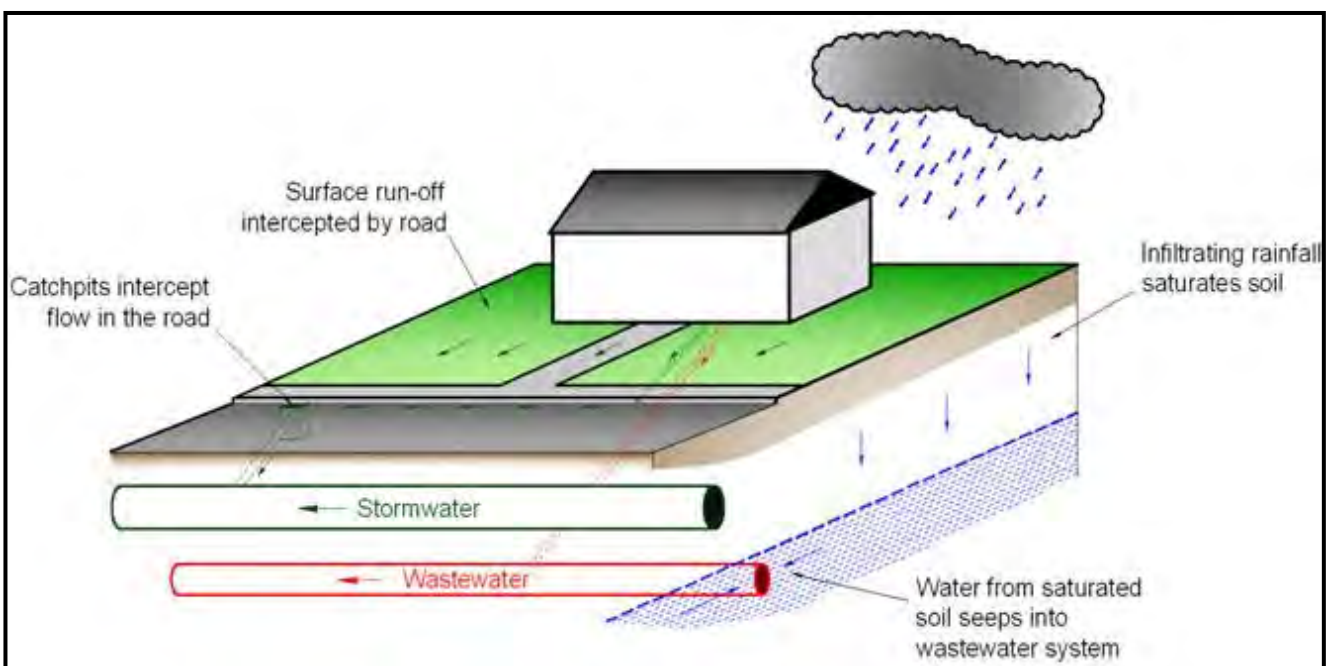


Figure 7-1: Rainfall Routing for Mosgiel's Stormwater and Wastewater System Model

Two modelling reports were produced for DCC detailing this analysis; the Mosgiel Model Build Report (Opus 2011a) and the Mosgiel Catchment Hydraulic Performance Report (Opus 2011b). The information presented in this section is sourced from these reports. Figures 4-14 and 4-17 (Sections 4.8 and 4.9) provide a diagram of the model extent for each system respectively. Figure 7-2 shows the combined model extent in the context of the study catchment.



The modelling analysed a number of influences of each system as follows:

- Two alternative catchment imperviousness figures; one for current land use, and one for the future, representing estimated imperviousness for 2031.
- Three different boundary conditions for the Silver Stream; a free discharge, a Mean Annual Flood (MAF) event and a 1 in 10 yr ARI rainfall event.
- Two different boundary conditions for the Owhiro Stream; a 1 in 10 yr ARI rainfall event, and a smaller event with an ARI of less than 1 in 10 yr.
- Five different rainfall events; 1 in 2 yr, 1 in 5 yr, 1 in 10 yr, 1 in 50 yr and 1 in 100 yr ARI events (refer Rainfall Analysis, Appendix B).
- Three climate change scenarios; no climate change (current conditions), mean forecast climate change and extreme forecast climate change (for 2031 and 2060 design horizons).

A number of flow monitors were installed across the catchment for both the wastewater and stormwater networks, in order to establish flow rates and system operation over a 3 month period.

The model relied for the most part on DCC GIS and Hansen (database) information regarding network configuration and detail. Site visit information, operational knowledge, as-built drawings, LiDAR (light detecting and ranging) and survey data were also incorporated into the model. Catchment hydrological parameters (runoff) were estimated based on the observed flow data and estimated imperviousness data.

Confidence in the model outputs is considered overall to be moderate, based on the level of model calibration and the correlation with known flooding locations, with some areas being of higher or lower confidence. The model has been built using accepted sound methodology by experienced modellers and engineers. The model output is considered to be of sufficient confidence for use as a tool for indicating areas with potential to flood and allowing for comparative effects of different rainfall events and climate change to be assessed.

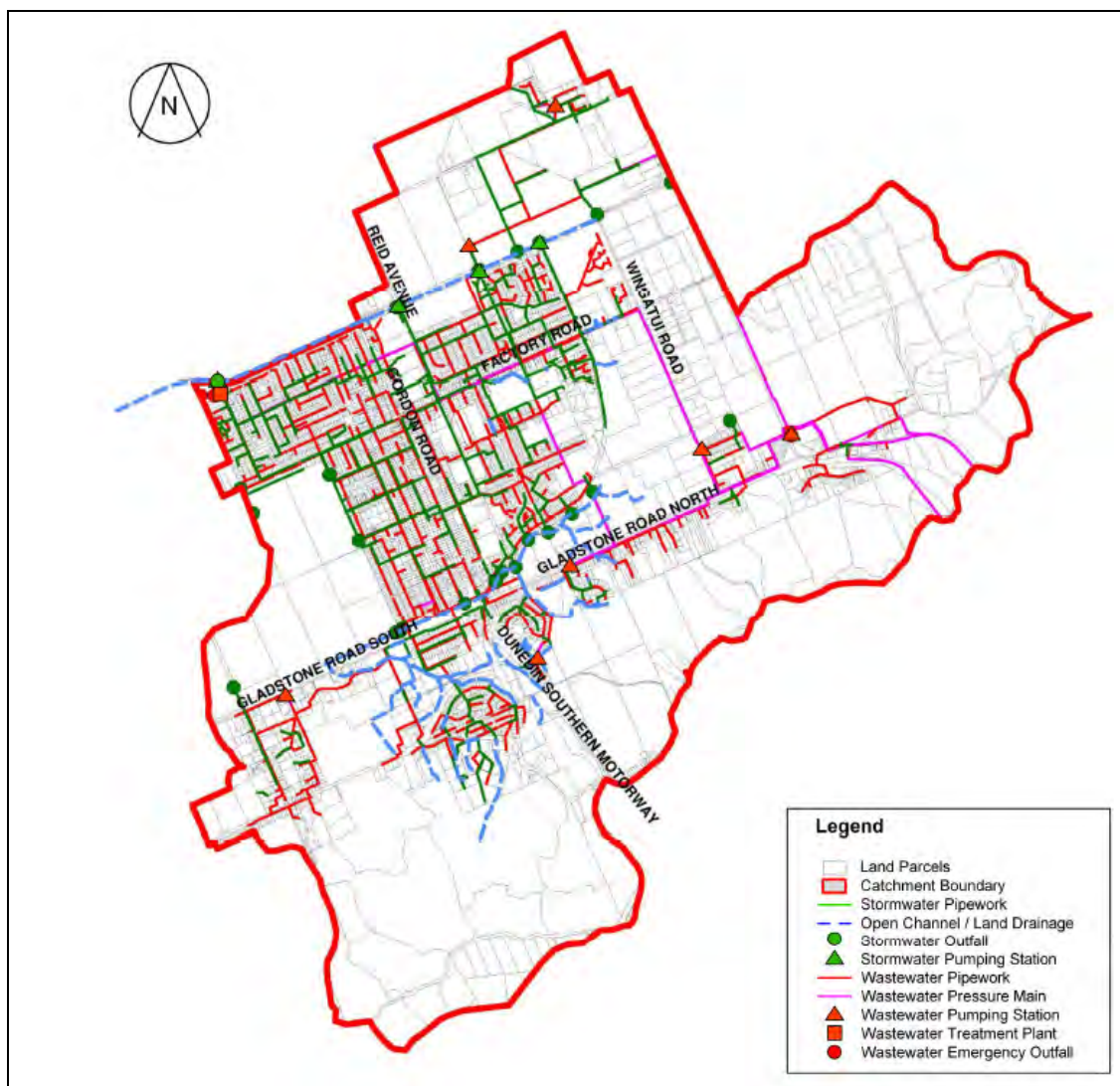


Figure 7-2: Mosgiel Study Catchment and Combined Model Extent



7.2 Model Results

The results from the combined model have been used to assess the performance of the stormwater and wastewater systems in relation to the following:

- Stormwater network capacity;
- Wastewater network capacity (dry weather flow (DWF) and wet weather flow (WWF));
- Catchment overflows and flooding; and
- Performance of key structures.

Unless otherwise stated all stormwater modelling results are based on a 30 minute duration rainfall event and wastewater modelling results on a 24 hour rainfall event.

Detailed model results can be found in: *Mosgiel Integrated Catchment Management Plan – Hydraulic Performance Report (Opus 2011)*.

7.2.1 Dry Weather

Wastewater current DWF performance is detailed in Table 7-1. The analysis relates only to pipelines designed to operate under gravity and the associated access structures such as manholes and lamp holes, which are not sealed. Values expressed as % of network relate to the total length of the wastewater network without the inclusion of pressure pipes.

Table 7-1: Wastewater Current DWF Performance

Wastewater Network Performance Measure	DWF Results	DWF Results (% of Network)
Surcharged pipe (km)	1.1 km	1.6 %
Number of manholes with free water level less than 300 mm from ground level	6	0.4 %
Number of manholes with free water level at or above ground level	0	0 %
Number of operating overflows	0	0 %
Pipes with peak daily velocities below 0.55 m/s	54 km	69.2 %
Pipes with peak daily velocities below 0.3 m/s	48 km	61.5 %

To assess dry weather infiltration/exfiltration within the wastewater system, dry weather wastewater discharge data per capita per day for each catchment was compared to water demand, per capita per day, data. It was considered that if the wastewater discharge rate was within a certain range of the water demand rate (-30 % to +20 %) then the dry weather rate was considered normal. If the wastewater discharge rate was more than 20 % higher than the water demand rate, then this indicated that there is potentially infiltration occurring in the catchment. If the wastewater discharge



rate was more than 30 % lower than the water demand rate, then it was considered that there is potential for exfiltration to be occurring in the catchment. Results of the analysis are displayed in Table 7-2.

The analysis indicates that significant dry weather infiltration is occurring in sub-catchment WW6. This finding is backed up by CCTV footage from Murray Street, which lies in catchment WW6, and shows water pouring through pipe joints.

The DWF in sub-catchment WW6 is estimated to be approximately 408 % greater than expected based on water consumption data. This equates to approximately 1,815 m³ per day. The sub-catchment accounts for 12 % of the geographical area in Mosgiel and 17 % of the population, however, the wastewater flows from this sub-catchment account for approximately 46 % of the total DWF from the network. Baseflows from this sub-catchment are approximately 20 L/s.

High DWF volumes are also observed, although to a lesser extent, in sub-catchment WW3.

Overall, it is estimated that DWF in Mosgiel is elevated by approximately 2,360 m³/day when compared with water consumption data. This is attributed to dry weather flow into the wastewater network. DWF infiltration is discussed further in Section 8.2.2.

Table 7-2: Model Results – Wastewater Dry Weather Flow (DWF).

Flow Monitor Catchment	Approximate Flow Monitor Location	Dry weather Infiltration / Exfiltration indication	Difference DWF and Water Consumption (%)	Difference DWF and Water Consumption (m ³ /day)
WW1	Outside 69 Carlyle Road	Normal	-15 %	-10.8
WW2	Outside 90 Tyne Street	Normal	-21 %	-94.9
WW3	Outside 25 Carlyle Road	Infiltration	97 %	293.5
WW5	Outside 120 Argyle Street	Normal	8 %	81.8
WW6	In Memorial Park between Gordon Road and Reid Avenue	Infiltration	408 %	1815.9
WW7	At intersection of Dey Street and Factory Road	Exfiltration	-39 %	-16.6
WW9	At intersection of McDonald Street and Ashton Street	Normal	-8 %	-1.2
WW10	At intersection of Argyle Street and Burns Street	Normal	-10 %	-32.0



7.2.2 Wet Weather

Eighteen scenarios representing different land use, rainfall, climate change and river level boundary conditions have been modelled. Tables 7-3a, 7-3b and 7-4 provide results of the stormwater and wastewater modelling, in relation to information required to assess the performance of the systems during these scenarios and enable the environmental affects to be determined.

Section 8 of this report analyses the modelling results in order to identify key issues relating to system capacity and flooding. In general, DCC are particularly concerned with the point at which overflows occur and cause flooding; however the pipe surcharge state, and manholes that are 'almost' overflowing, are of relevance when considering available capacity in the systems.

Table 7-3a: Model Results –Stormwater, Current Landuse

System	Hydraulic Performance Measure	ARI (yr)	Current Land Use
Stormwater (30 minute duration)	Percentage of manholes overflowing	1 in 2 ¹	16 %
		1 in 5	24 %
		1 in 10	29 %
	Number of parcels with flood depth >= 300 mm	1 in 2 ¹	2
		1 in 5	5
		1 in 10	10
	Flood Extent (% of catchment with flood depth >= 50 mm)	1 in 2 ¹	0.07 %
		1 in 5	0.18 %
		1 in 10	0.30 %
	Percentage (by km) of pipes surcharging	1 in 2 ¹	50 %
		1 in 5	60 %
		1 in 10	67 %
	Percentage of manholes with free water level within 300 mm of cover	1 in 2 ¹	28 %
		1 in 5	38 %
		1 in 10	44 %

¹ 1 in 2.33 year event (mean annual flood)

² On all or part of a land parcel, or against a building void in the 2D surface


Table 7-3b: Model Results – Wastewater, Current Landuse

System	Hydraulic Performance Measure	ARI (yr)	Current Land Use
Wastewater (24 hour duration)	Percentage of manholes overflowing	1 in 2 ¹	0.10 %
		1 in 5	0.40 %
		1 in 10	1.00 %
	Number of parcels with flood depth >= 300 mm contaminated with wastewater	1 in 2 ¹	0
		1 in 5	3
		1 in 10	9
	Flood Extent* (% of catchment with flood depth >= 50 mm)	1 in 2 ¹	0.20 %
		1 in 5	0.20 %
		1 in 10	0.60 %
	Percentage (by km) of pipes surcharging	1 in 2 ¹	11 %
		1 in 5	20 %
		1 in 10	37 %
	Percentage of manholes with free water level within 300 mm of cover	1 in 2 ¹	1.20 %
		1 in 5	1.80 %
		1 in 10	4.90 %
	Number of overflow structures operating	1 in 2 ¹	0
		1 in 5	1
		1 in 10	1
	Predicted total discharge volume from overflow structures (m ³)	1 in 2 ¹	0
		1 in 5	690 m ³
		1 in 10	3672 m ³
	Pipes (by km) with peak daily velocities below 0.55 m/s	1 in 2 ¹	35 km
		1 in 5	29 km
		1 in 10	26 km

¹ 1 in 2.33 year event (mean annual flood)

² On all or part of a land parcel, or against a building void in the 2D surface



Table 7-4: Model Results – Future Landuse / Climate Change

System	Hydraulic Performance Measure	ARI (yr)	Planning Scenario				
			Current	2031 Growth			
				Growth Only	2031 Mean Climate Change	2060 Mean Climate Change	2060 Extreme Climate Change
Stormwater (30 minute duration)	Percentage of manholes overflowing	1 in 10	29 %	32 %		37 %	
	Number of parcels with flood depth ≥ 300 mm ¹	1 in 10	10	12		19	
		1 in 50	22			33	
		1 in 100	29				76
	Flood extent (% of catchment area)	1 in 10	0.3 %	0.38 %		0.49 %	
		1 in 50	0.62 %			1.05 %	
		1 in 100	0.81 %				1.55 %
	Percentage (by km) of pipes surcharging	1 in 10	67 %	74 %		78 %	
Wastewater (24 hour duration)	Percentage of manholes with free water level within 300 mm of cover	1 in 10	44 %	48 %		54 %	
	Percentage of manholes overflowing	1 in 10	1.0 %	1.6 %	2.1 %	2.4 %	
	Number of parcels with flood depth ≥ 300 mm contaminated with wastewater	1 in 10	9	17	30	30	
	Flood Extent* (% of catchment with flood depth ≥ 50 mm)	1 in 10	0.6 %	1.1 %	1.3 %	1.6 %	
	Percentage (by km) of pipes surcharging	1 in 10	37 %	44 %	46 %	47 %	
	Percentage of manholes with free water level within 300 mm of cover	1 in 10	4.9 %	9.4 %	10.4 %	11.7 %	
	Number of overflow structures operating	1 in 10	1	1	1	1	
	Predicted total discharge volume from overflow structures (m ³)	1 in 10	3672 m ³	5312 m ³	6183 m ³	7282 m ³	
	Pipes with peak daily velocities below 0.55 m/s	1 in 10	26 km	26 km	26 km	26 km	

¹ On all or part of a land parcel, or against a building void in the 2-D surface.

² Includes 1 in 20 yr ARI storm surge (model run 14), which inundates 30 % of the catchment under dry weather conditions



7.2.2.1 Wastewater Wet Weather I&I

The percentage of catchment contributing to wastewater inflow (impervious response) is a model parameter used for calibration and represents the likely percentage of the flow monitor catchment that is impervious area directly connected to the wastewater system. This is the portion of the rainfall response that is not affected by soil saturation, but which responds quickly to rainfall and stops contributing fairly quickly after the cessation of rainfall. The impervious response percentages are not high in relation to the total rainfall, indicating direct connections to the wastewater system are not a major problem for the wastewater system. The larger problem is the infiltration of water through pipe joints and ponding of stormwater over wastewater manholes.

Another more “real world” measure for inflow and infiltration (I&I) is to calculate the percentage of rainfall falling on the catchment that is entering the wastewater system. Review of I&I reduction projects conducted in New Zealand and Australia has concluded that system rehabilitation is generally not warranted for responses less than 12-15 % of total rainfall.

Results of the I&I analysis for a 1 in 10 yr ARI rainfall event are shown in Table 7-5.

Table 7-5: Model Results – Wastewater I&I Results (1 in 10 yr ARI)

Flow Monitor Catchment	Approximate Flow Monitor Location	% total rainfall entering wastewater system	Volume rainfall entering wastewater system (m ³)
WW1	Outside 69 Carlyle Road	9 %	981
WW2	Outside 90 Tyne Street	8 %	6,196
WW3	Outside 25 Carlyle Road	6 %	2,681
WW5	Outside 120 Argyle Street	6 %	2,999
WW6	In Memorial Park between Gordon Road and Reid Avenue	3 %	2,392
WW7	At intersection of Dey Street and Factory Road	3 %	2,939
WW8	In the grass at the end of Carncross Street	1 %	543
WW9	At intersection of McDonald Street and Ashton Street	1 %	2,641
WW10	At intersection of Argyle Street and Burns Street	5 %	2,845

7.3 Sensitivity Analysis

7.3.1.1 Quarry Creek

Historic flooding has been observed on Gow Street/McGlashan Street; however the model results do not replicate the extent of flooding observed at these locations. Sensitivity analysis was carried out to assess the influence of the downstream watercourses (Quarry Creek and Owhiro Creek), on



the flooding in this area. Table 7-6 indicates the model scenario runs carried out to assess the influence.

The model was run with a variety of different rainfall durations for a 1 in 10 yr ARI event in order to assess the critical duration of the Quarry Creek catchment, to define the boundary condition during model build. A 12 hour storm was the duration which resulted in the highest flows within the Quarry Creek.

Table 7-6: Model Results – Quarry Creek Sensitivity Analysis

Model Scenario	ARI (yr)	Duration	Predicted Flood Level - Gow Street (m MSL)	Predicted Flood Depth - Gow Street (mm)
Quarry Creek Boundary Condition (include Owhiro) effect of Quarry Creek	1 in 10	12 hr	116.713	315
Owhiro Stream Boundary Condition (no Quarry Creek) – effect of Owhiro only	1 in 10	12 hr	116.690	211
No Boundary Condition - Quarry Creek & Owhiro Stream. Effect of pipe capacity only	1 in 10	12 hr	116.690	211
No Boundary Condition - Quarry Creek & Owhiro Stream. Effect of pipe capacity only	1 in 10	30 min	116.582	103

Results from the model indicates that even when no boundary condition is applied to the downstream end of the stormwater network at this location, surface flooding still occurs in Gow Street, indicating that the pipework is undersized to convey the flows predicted. However, the scale of the flooding is greatly reduced when compared to that with the Quarry Creek boundary condition applied.

When the Owhiro Stream boundary level (based on ORC modelling of the Owhiro Stream), is applied without any Quarry Creek influence, the predicted flood level remains the same as when no boundary conditions are applied, indicating that the level of the Owhiro Stream alone does not affect the flooding in Gow Street.

The model results indicate that when the boundary condition of the Quarry Creek is applied, flood depths and extents in Gow Street are significantly elevated as indicated in Table 7-6. Note however, that the Quarry Creek has been modelled simplistically and may contain additional hydraulic controls not represented in the model.

7.3.1.2 Reid Avenue Swale

In order to assess how well the model was representing the flow regime in the Reid Avenue area, the May 2010 flood event was run with the model. In order to look at the area in greater detail, the 2D surface detail was increased and the swale represented in the model as a 2D flow channel. The May 2010 rainfall event is estimated to be between a 1 in 10 yr and 1 in 50 yr ARI.

During the May 2010 the model predicts the following:

- swale completely full with water; and
- flooding across the park to Gordon Road, south to Hartstonge Avenue adjacent to the



supermarket and in one location across Reid Avenue itself and overland flow and ponding in the vicinity of Oban Street, Ross Street and Nairn Street.

The model was also run with the downstream outlet of the Reid Avenue swale blocked with debris and an amount of leakage at the outfall flap gate to assess the impact should the flap gate not seal correctly or the swale outlet screen become blocked. Results from the model during this scenario indicate the following:

- Increased flood extents towards Gordon Road and flooding across the full width of Reid Avenue, once the swale is completely full.

The 1 in 10 yr ARI, 30 minute and 24 hour duration events were also run with the more detailed 2D surface for Reid Avenue incorporating the swale as a 2D channel. The 24 hour duration event included a static boundary condition in the Silver Stream equivalent to the peak observed in May 2010. Results of this run predict flooding similar in nature to that predicted for the May 2010 event, with flooding out to Gordon Road and Hartstonge Avenue, on Oban Street and overland flow across Reid Avenue.

Results indicate that the 30 minute duration event does not represent the worst case duration for the Reid Avenue area, as the high intensity short duration event does not produce flow volumes large enough to fill the Reid Avenue swale and the free discharge condition means no backwater effect from the outlet. Therefore, during the 30 minute duration, the model does not predict the level of flooding previously observed on Reid Avenue, but does so when run with the May 2010 event. This suggests that the model is likely to be correctly representing the hydraulic flow regime at this location.

7.3.1.3 Woodland Avenue Stormwater Pipe

The invert level of the stormwater pipe on Woodland Avenue (downstream of intake) was not included in the DCC GIS data, hence a level was assumed. Initially the gradient of the pipe was conservatively assumed to be relatively flat. As a result, the flooding predicted at this location could have been a consequence of the pipe gradient assumed within the model. In order to assess whether the gradient was causing the flooding artificially, the grade of the pipe was amended to provide a steeper grade and the model re-run.

The revised model still predicted flooding at the same location, therefore, it appears that the pipe grade has only a minor impact on the flooding predicted by the model. However, the scale and depth of the flooding predicted will vary subject to the gradient applied in the model.



8 Assessment of Environmental Effects

This section identifies and summarises the actual and potential effects of stormwater and wastewater quantity and quality on the catchment networks and the natural environment.

The effects are summarised based on the interpretation of the outcomes of the network hydraulic modelling; the stream assessments; information gathered during catchment walkovers; DCC customer complaint records; and workshops with DCC Water and Waste Services Business Unit staff.

8.1 Network Benefits

8.1.1 Benefits of the Stormwater Network

Urban development significantly increases the area of impervious surfaces from which rainfall quickly runs off. These surfaces include building roofs, paved areas, roads and carparks, and they can also include, but to a lesser extent, grassed and garden areas. In Dunedin, the stormwater network controls the urban runoff, collecting the flows within the system and directing it to the receiving environment. The stormwater network therefore provides a number of benefits to the community.

The Dunedin City Council is responsible for managing the stormwater system in order to provide the best system possible at a reasonable cost to the ratepayer. The objectives set for stormwater management by the Council are outlined in the Stormwater AMP as follows:

'The key objective of the Stormwater Activity is to protect public health and safety by providing clean, safe and reliable stormwater services to every customer connected to the network with minimal impact on the environment and at an acceptable financial cost. In addition to ensuring effective delivery of today's service, we also need to be planning to meet future service requirements and securing our ability to deliver appropriate services to future generations.'

The stormwater activity is particularly focused on providing protection from flooding and erosion, and controlling and reducing the levels of pollution and silt in stormwater discharge to waterways and the sea, and the overall objective is broken down into the individual activity objectives of:

- Ensuring stormwater discharges meet quality standards;
- Ensuring services are available;
- Managing demand;
- Complying with environmental consents;
- Strategic investment;
- Maintaining assets to ensure serviceability; and
- Managing costs.

8.1.2 Benefits of the Wastewater Network

Urban areas require a means for managing, treating and disposing of wastewater. The Dunedin City Council is responsible for operating and maintaining the wastewater system from the main



sewer to the point where treated effluent is discharged to the environment. Every community needs an efficient, economic, and sustainable means of wastewater disposal to provide for the health, wellbeing and safety of the residents.

In the Mosgiel area wastewater is piped and pumped to the Mosgiel WWTP for initial treatment and then to Green Island WWTP for further treatment before discharging via an ocean outfall. In Allanton there is a pressurised wastewater system.

The objectives set for wastewater management by the Council are outlined in the Wastewater AMP as follows:

'The key objective of Wastewater Service provision is to protect public health and safety by delivering effective and targeted wastewater services to every customer connected to the network with minimal impact on the environment and at an acceptable financial cost.'

The wastewater activity is particularly focused on:

- ensuring the health of the community where urban housing exists, eliminating the need for individuals to provide their own wastewater system (which carries much higher health risks);
- providing a cost-effective trade waste disposal system for commercial and industrial users;
- providing a high-quality, efficient and environmentally acceptable collection, treatment and disposal system that functions in a controlled and regulated manner; and
- providing services for present needs, while ensuring there is potential for sustainable growth at the desired levels of service.

8.2 Quantity Effects

8.2.1 Infrastructure Capacity

Network analysis and flood mapping were undertaken for current and future land use scenarios in the Mosgiel catchment to predict the level of service of the stormwater and wastewater networks.

DCC are particularly concerned with the point at which a manhole is predicted to overflow and cause flooding. The pipe surcharge state and manholes that are 'almost' overflowing are also of relevance when considering available capacity in the system. In the case of the wastewater system, a manhole overflow has the potential to contaminate any stormwater that is ponded in the area.

With respect to flooding of private property, model results are presented as a 'number of land parcels with flood depth potentially ≥ 300 mm, and are based on a GIS assessment of DCC cadastral maps overlaid with modelled flood extents. When targets for protection of private property are set (Section 11) these are set to limit the flood risk to private property and habitable floors. As discussed further in Section 8, the modelled deep flooding of part of a parcel does not necessarily mean that the entire property is inundated; further detail (including survey) is generally required to confirm the risk to habitable floors.

8.2.1.1 Stormwater Network Capacity

In relation to stormwater, flooding is of particular concern when it poses a potential risk to habitable



floors. Surface flooding from the stormwater network is also of concern in this catchment when it is located in areas where it may be able to enter the wastewater network (e.g. via manholes), increasing the flows/reducing capacity in the wastewater system.

The network analysis and flood mapping undertaken for the current land use show that the predicted level of service provided by the stormwater network in the Mosgiel catchment is variable (refer Tables 7-3a and 7-4). Overall, it is predicted to be less than a 1 in 5 yr ARI rainfall event in most of the catchment, with many areas having a lower level of service, less than a 1 in 2 yr ARI.

However, it should be noted that the older parts of the stormwater network in Mosgiel (pre 1960's) have been designed to a lower standard than current best practice and consequently have a lower level of service. Workshop discussions and DCC records indicate that parts of the stormwater network in Mosgiel were "designed to flood in the kerb and channel" during rainfall events above approximately a 1 in 2 yr ARI.

Based on the results presented in Section 7 (manholes overflowing), during a 30 minute storm, the modelling estimates that the percentage of the stormwater network able to accept flows is as follows:

- 84 % of the network can accept a 1 in 2 yr ARI rainfall event;
- 71 % of the network can accept a 1 in 10 yr ARI rainfall event; and
- 56 % of the network can accept a 1 in 100 yr ARI rainfall event.

A 30 minute storm represents the worst case scenario for the stormwater network, with more manholes overflowing during events of this duration than shorter or longer events of the same ARI.

It should be noted however, that when the stormwater system is able to accept the flows, they may not immediately be conveyed by the network.

There are some system restrictions in the stormwater network during a 1 in 2 yr ARI rainfall event; current modelling indicates that 50 % of the pipes are flowing full and manhole overflows are predicted due to insufficient network capacity (Refer Figure 8-1).

A number of hydraulic bottlenecks exist, causing restrictions within the stormwater network and in some cases manhole overflows. However, the majority of the manhole overflows are predicted to result from inadequate capacity of the network to convey the stormwater flows. A large percentage of the network comprises relatively small diameter pipes, approximately 50 % of the pipes in the stormwater network are between 150 mm and 300 mm diameter.

The model also predicts that manhole overflows are exacerbated in some locations due to a backwater effect caused by levels in the watercourses into which the stormwater network discharges. It should be noted however, that the extent to which the watercourses influence the capacity of the stormwater network is dependent upon the watercourse boundary conditions applied within the model. This is discussed further in Section 8.2.4.

In many cases the network restrictions were verified during workshop discussions with Water and Waste Services Business Unit staff.

The Mosgiel catchment is not yet fully developed and imperviousness is predicted to increase by



approximately 8 % by 2031. When this future land use scenario and projected climate change (2060) are applied to the model, the level of service of the stormwater network is predicted to reduce.

The model predicts that the percentage of the network able to accept flows during a 1 in 10 yr ARI event reduces from 84 % in the current scenario to 63 % when a 2031 future growth with 2060 mean climate change scenario is modelled. Further to the increased manhole overflows, the percentage of pipes flowing full is predicted to increase from 67 % currently to 78 % indicating that in this scenario the stormwater network is close to capacity.

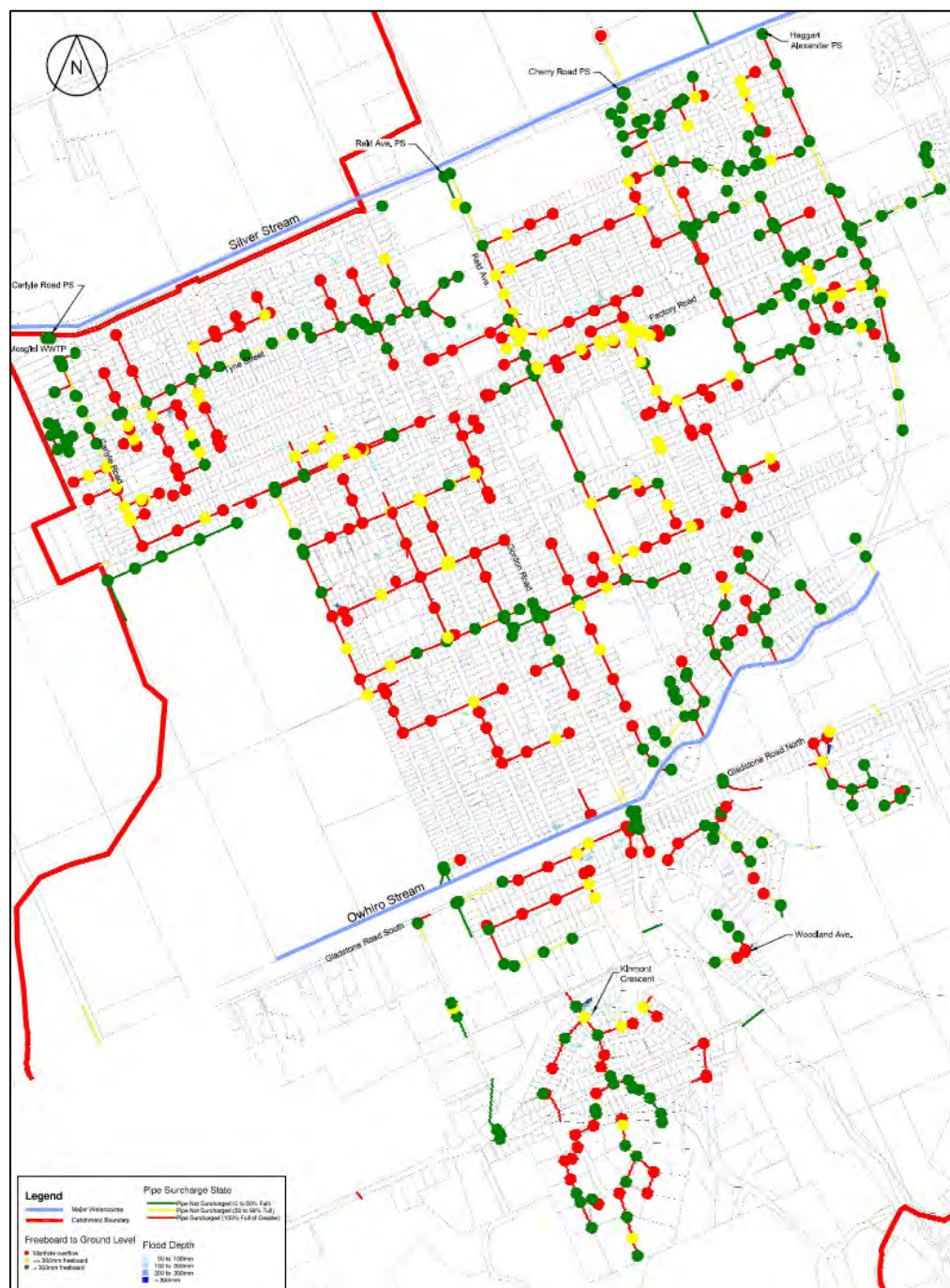


Figure 8-1: Current (30 min) 1 in 10 yr ARI (Stormwater Model Results)



8.2.1.2 Wastewater Network Capacity

When considering the level of service of the wastewater network, any overflows from the system during events up to and including a 1 in 10 yr ARI event are of concern.

The modelling results indicate that there are generally no problems with the capacity of the wastewater network during dry weather. No manhole overflows are predicted and only 1.6 % of the modelled pipes are predicted to be flowing full. This was verified by DCC Water and Waste Services Business Unit staff. The model also predicts that there will be no capacity problems with the network during dry weather in the future (2031).

However, the current dry weather flows (DWF) observed in two sub-catchments are significantly elevated, above that expected, when compared with water consumption data. This is discussed further in Section 8.2.2.

The wastewater network analysis undertaken for the current land use, shows that whilst there are some areas of the wastewater network that perform well during a 1 in 10 yr ARI rainfall event, the overall level of service is predicted to be between a 1 in 2 yr ARI and a 1 in 5 yr ARI rainfall event.

Based on the results presented in Section 7 (wastewater overflows), during a 24 hour rainfall event, the modelling estimates that the wastewater network performs as follows:

- 0.1 % of the manholes are predicted to overflow, no discharges from overflow structures during a 1 in 2 yr ARI rainfall event;
- 0.4 % of the manholes are predicted to overflow, and 690 m³ discharged from overflow structures during a 1 in 5 yr ARI rainfall event; and
- 1 % of the manholes are predicted to overflow, and 3,672 m³ discharged from overflow structures during a 1 in 10 yr ARI rainfall event.

A 24 hour storm represents the worst case scenario for the wastewater network, with more manholes overflowing during events of this duration than shorter or longer events of the same ARI.

The capacity problems and resulting overflows predicted during rainfall events are primarily due to the predicted influence of wet weather inflow and infiltration (I&I). There is also some influence on capacity from the WWTP which, under current operation, is predicted to have limited ability to accept elevated flows. This acts as a bottleneck causing a backwater effect in the pipes upstream. Interactions with the stormwater network, such as stormwater flooding over wastewater manholes, further exacerbate the capacity problems predicted within the wastewater network. These issues are discussed in further detail in the following sections.

When the future growth scenario (2031) and projected climate change (2060) is applied to the model the results indicate that Mosgiel's wastewater network has no spare capacity for future growth, based on network surcharging and the frequent operation of the WWTP emergency overflow to the Silver Stream.

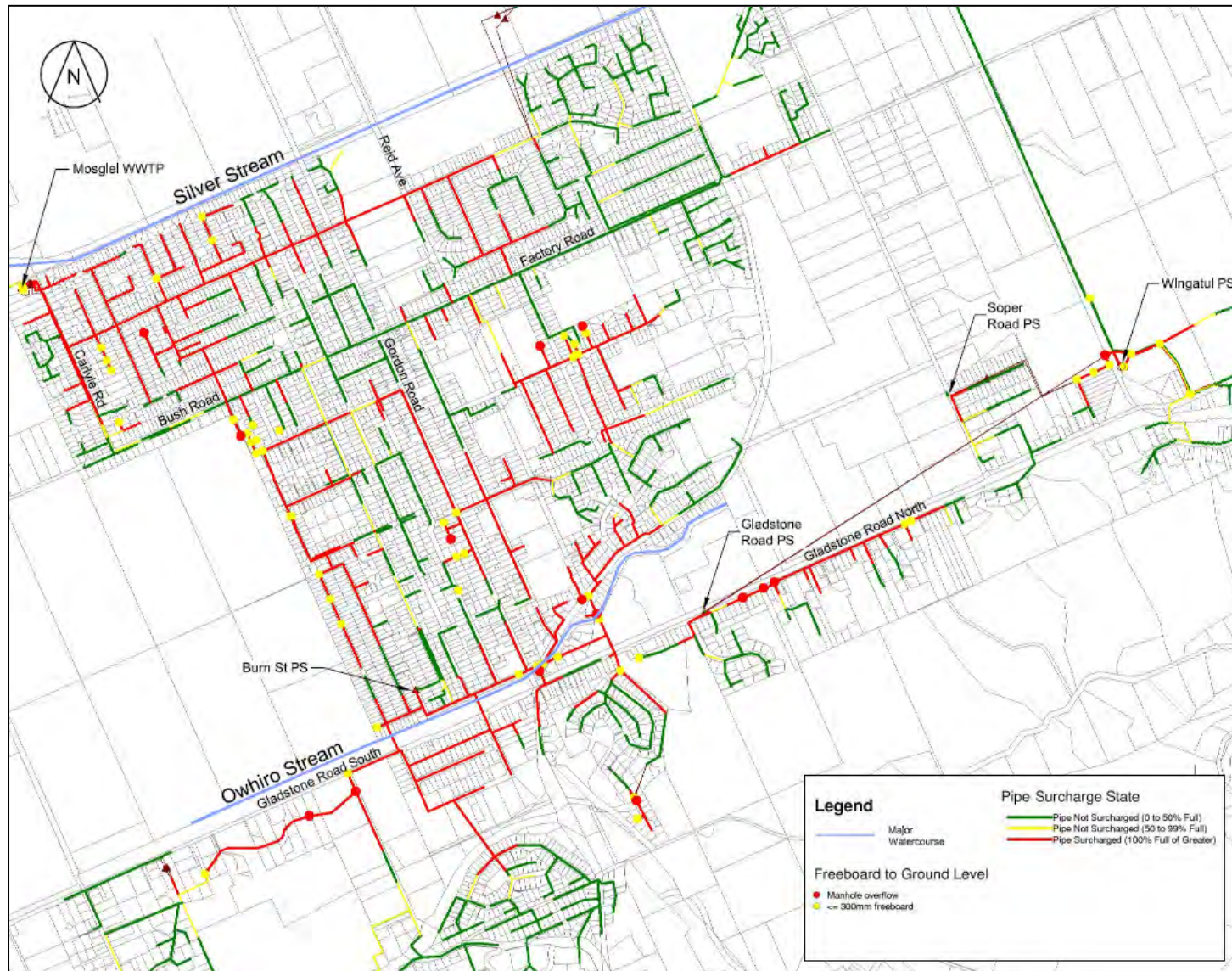


Figure 8-2: Current (24 hr) 1 in 10 yr ARI (Wastewater Model Results)



8.2.2 Dry Weather Infiltration

When compared with water demand per capita per day, the wastewater dry weather flow (measured by flow monitoring) for some network sub-catchments was found to be significantly elevated (refer Section 7.2.1). Where wastewater flows are more than 20 % higher than the water demand rate, then this indicates that there is potentially infiltration occurring in the sub-catchment.

Of note were the elevated flows from two sub-catchments monitored, the locations of which are shown in Figure 8-3.

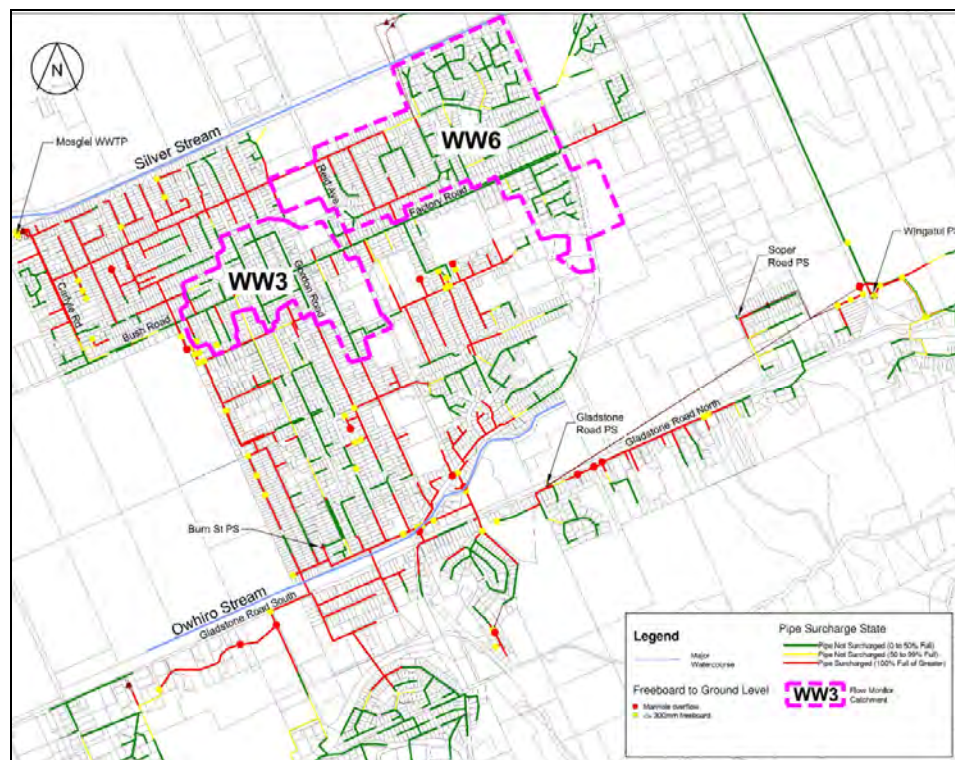


Figure 8-3: Wastewater Flow Monitoring Sub-Catchments with High Groundwater Infiltration

The flows were found to be elevated as follows:

- WW3 – DWF approximately 97 % (294 m³/day) higher than expected, with a baseflow of approximately 3 L/s.
- WW6 – DWF approximately 408 % (1,816 m³/day) higher than expected with a baseflow of approximately 20 L/s.

These findings are backed up by CCTV footage from Murray Street (WW6), which shows water pouring through pipe joints.

The results indicate that the most likely cause of the elevated DWF is groundwater infiltration into the wastewater reticulation. Groundwater across Mosgiel is known to be particularly high and analysis indicates that in sub-catchment WW6 in particular, wastewater pipes are likely to be 'below groundwater level' groundwater particularly in winter months and after prolonged wet weather. It is known that the older pipes in the network were designed to promote a certain amount of infiltration. This was to assist in flushing the pipes as they are laid at a relatively flat gradient.



Whilst this infiltration does not cause capacity problems during dry weather, it results in increased volumes of wastewater being treated at the Mosgiel WWTP and pumped to Green Island WWTP with cost implications. The elevated baseflows also exacerbate the capacity problems predicted within the piped network and at the Mosgiel WWTP during wet weather.

Analysis has indicated that should the DWF in the wastewater network be reduced, i.e. groundwater infiltration prevented, capacity problems within the pipes and WWTP operational problems are reduced.

8.2.3 Wet Weather Inflow and Infiltration

During wet weather, flow rates and volumes are observed to increase notably above DWF rates, particularly during longer duration events that saturate the catchment soils or from rainfall events falling onto an already saturated catchment, as typically occurs during winter months. This rainfall then enters the wastewater network via illegal connections or flooded gully traps (inflow) and cracked pipes or faulty pipe joints (infiltration), increasing wastewater network flows during rainfall events.

In general the response of the wastewater system to rainfall indicates direct inflow is not a major problem in Mosgiel, the larger problem is infiltration. The volume of infiltration observed in the wastewater system during wet weather, as an average over the entire catchment, is equivalent to 8 % of the total rainfall falling on the catchment. Whilst 8% sounds relatively small, 8% of the volume of rainfall falling onto the catchment is a much larger volume when compared to the volume of the average DWF (aDWF).

The additional volume of inflow to the system results in flow rates in excess of 6 times aDWF (the flow rate typically used for current sewer design) across much of the catchment, with some areas having flow rates elevated to 20 times aDWF. Flow rates exceeding 6 times aDWF would exceed both current and past design standards and result in surcharging of the system. If the surcharging were significant enough, it could potentially result in manhole overflows or gully trap overflows, as predicted by the model in several locations. They may also result in capacity problems at the WWTP and result in wastewater discharges to the Silver Stream.

8.2.4 Network Flooding

The hydraulic model has been used to indicate areas within the catchment potentially at risk of flooding from the stormwater and wastewater networks during a variety of planning scenarios. This includes a range of storm events, current and future land use scenarios and climate change projections, generally modelled with boundary conditions applied for watercourses within the catchment (adjusted for rainfall events and climate change where necessary). These predictions have been validated, where possible, with anecdotal evidence from the DCC Water and Waste Services Business Unit staff, and observations made on the catchment walkovers. As outlined in Section 4.8, a number of flood complaints have been made by the public in the catchment in recent years which have also been used to validate flooding predictions.

Predicted nuisance flooding, habitable floor flooding, flood hazard ratings and wastewater overflows within the catchment have been assessed, and are discussed in the following sections.

Nuisance flooding constitutes predicted flood depths generally between 50 mm and 300 mm, or flooding in locations unlikely to cause habitable floor flooding or serious transport disruption. New stormwater systems are designed to avoid nuisance flooding during rainfalls up to and including a 1



in 10 yr ARI event.

Predicted flood depths equal to or greater than 300 mm present a risk of habitable floor flooding. Habitable floor flooding is the flooding of 'useful floor space' for any zoning (including industrial). This is defined as the floor space of a dwelling or premises inside the outer wall, excluding cellars and non-habitable basements. Since surveyed floor levels were not available for this study, land parcels (properties) have been defined as 'at risk' of habitable floor flooding where the property boundary is intersected by a flood plain depth of equal to or greater than 300 mm.

New stormwater systems are designed to avoid habitable floor flooding during a 1 in 50 yr ARI rainfall event. For existing systems, analysis of a variety of rainfall events is undertaken in order to assess the risk of flooding.

It should be noted that although the model predicts that a number of land parcels will experience deep flooding (>300 mm), particularly during a 1 in 50 yr ARI rainfall event, some may arise from limitations in the LiDAR data and the model may therefore incorrectly predict flooding in certain locations. Not all buildings are included in the ground model and the model may incorrectly predict flooding of building footprints. Additionally, flood predictions in gully areas are usually related to open channels, and therefore do not pose a flooding risk to buildings. Information gathered on catchment walkovers, data analysis and engineering judgement has been applied in these situations, as well as model analysis, and those areas within the catchment that are considered at risk of deep flooding are described below.

8.2.4.1 Stormwater Network Flooding

Appendix E contains a summary of the stormwater flooding predicted in the Mosgiel catchment. The identification of 'confirmed' locations is based on model outputs combined with verification from customer complaints and/or DCC Water and Waste Services Business Unit staff. The model also predicts that a number of other areas may experience flooding but these events are unconfirmed by customer complaints or anecdotal evidence at this stage.

The effects of flooding from the stormwater network are predicted (and verified) to be significant in a number of locations. These are summarised in Table 8-1 and discussed in further detail in the following sections.

Table 8-1: Summary of Significant Stormwater Flooding

Location	Description	Min Rainfall Event (yr ARI)
Catchment-Wide	Nuisance Flooding / Deep Flooding	1 in 2
Gordon Road/Lanark Street	Nuisance Flooding / Deep Flooding	1 in 2
Kinmont Crescent	Deep Flooding	1 in 5
McGlashan Street, Gow Street, Gladstone Road South	Deep Flooding	1 in 10
Carlyle Road, Mallard Place, Bush Road, Tyne Street	Nuisance Flooding / Deep Flooding	1 in 2
Woodland Avenue	Deep Flooding	1 in 2
Reid Avenue Swale	Nuisance Flooding / Deep Flooding	<1 in 10
Gladstone Road	Deep Flooding	1 in 2



Catchment-Wide Nuisance and Deep Flooding

Since nuisance (50 – 300 mm) and deep flooding (>300 mm) frequently occur in the same location for different storm events, both are discussed in the following text.

Widespread nuisance flooding is predicted throughout the catchment during events as small as a 1 in 2 yr ARI. The model predicts that the majority of flooding remains within the road and flood depths are relatively low (<200 mm) in most locations and therefore the effects are considered to be relatively minor. Some locations where deep flooding is predicted are discussed individually in the following sections.

The nuisance flooding predicted matches well with that observed throughout the catchment during rainfall. It arises as a result of the network having insufficient capacity to convey the stormwater flows due to a large proportion of the network being designed to a low level of service, utilising the roading network as a secondary storage.

Whilst in many locations the effects of the nuisance flooding are probably relatively minor in terms of traffic and pedestrian disruption, reports from the community indicate a low level of tolerance with comments that numerous locations throughout the catchment experience nuisance flooding “every time it rains.” The community also advised that due to the low levels of house foundations and gradual increases in road levels due to successive resurfacing, stormwater spreads from the roadway across property boundaries in many locations. Modern style buildings with a concrete slab on the ground are perceived to be more susceptible to surface flooding.

Areas considered to be particularly affected by nuisance flooding include:

- Tay Street;
- Forfar Street/Glasgow Street;
- Reid Avenue; and
- Church Street/Green Street.

When future land use scenarios and climate change projections are applied to the model, nuisance flooding is predicted to become more extensive throughout the catchment. Flood extents increase from 0.3 % of the catchment during a 1 in 10 yr ARI rainfall event for the current scenario to 0.5 % of the catchment during the future scenario. Whilst the increase appears to be relatively small, the nuisance flooding is mostly confined to the central, urban area of the catchment. In some locations flooding is predicted to extend the width of the road but in most locations flood depths remain below 300 mm (Refer Figure 8-1).

During a 1 in 50 yr ARI event the model predicts an increase in depth and extent in flooding over the 1 in 10 yr ARI event. Deep flooding (>300 mm) is predicted on approximately 22 land parcels during the current scenario, rising to 33 land parcels during the future scenario. This may pose a risk to habitable floor flooding in certain locations:

It should be noted however, that the exact location of buildings and corresponding floor levels are not documented so it is not known whether flooding will actually affect the building, other than in those locations where it is already confirmed. Confirmed deep flooding is discussed in further detail in the following sections.



Gordon Road/Lanark Street

During a 1 in 2 yr ARI rainfall event the model predicts that the main stormwater line on Lanark Street is flowing full causing a backwater effect resulting in manhole overflows on Gordon Road where ponding occurs and flows overland to Lanark Street.

Predicted nuisance flooding in the kerb of Gordon Road and Lanark Street becomes deep flooding in Gordon Road (>300 mm), posing a risk to habitable floors, during a 1 in 5 yr ARI event or greater. The nuisance flooding is also predicted to be exacerbated during this event on Lanark Street (Figure 8-4).

Predicted flooding in this location has been verified by workshop discussions and flood complaints. The location of which matches deep flooding shown in photographs provided by DCC. The depth of flooding predicted on Gordon Road is sufficient to enter adjacent shops, which has been reported in the past.

Anecdotal evidence from the workshops with Water and Waste Services personnel indicated that some channelling works may have recently been carried out in this location to send overland flow down Lanark Street and reduces the deep flooding. There was uncertainty regarding the residual extent of flooding at this location following the training works. Further site investigation may reveal more.

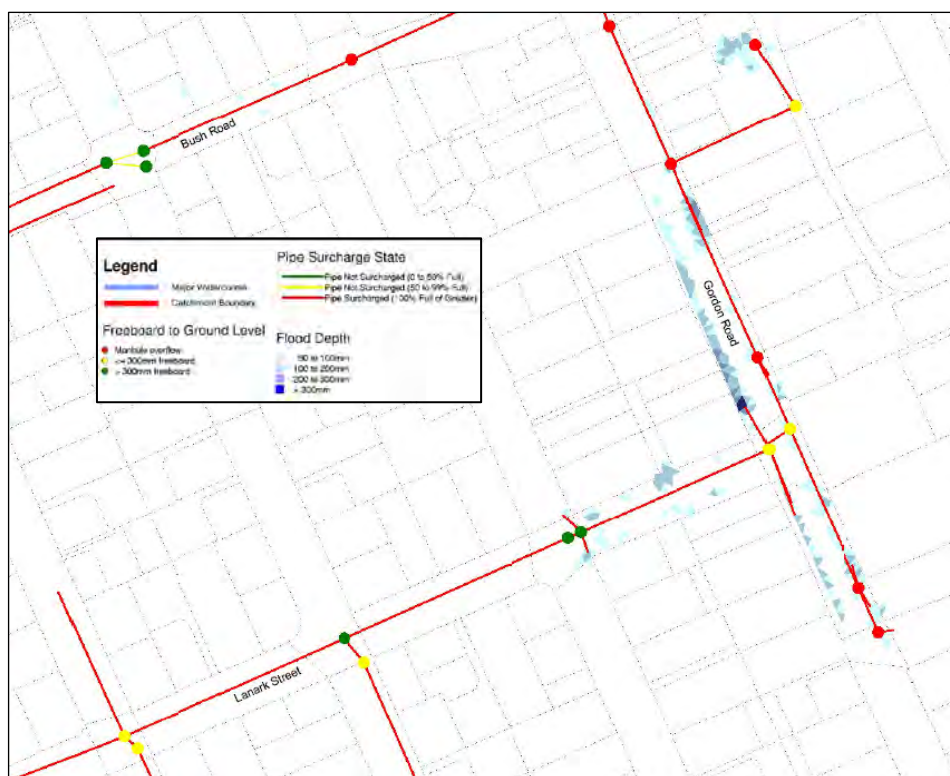


Figure 8-4: Current (30 min) 1 in 5 yr ARI (Stormwater Model Results)

During a 1 in 50 yr ARI event, the extent of deep ponding (>300 mm) is predicted to increase on Gordon Road and occur on Lanark Street.

The flooding in these locations is predicted to become worse when future land use scenarios and climate change projections are applied to the model.



Kinmont Crescent

During a 1 in 2 yr ARI event the stormwater pipes in the vicinity of Kinmont Crescent and Gebbie Street are predicted to be flowing full due to insufficient pipe capacity. This results in manhole overflows and overland flow from Gebbie Street and Kinmont Crescent. Flows are predicted to be channelled through several properties towards the low point in Kinmont Crescent. They are unable to return to the piped network due to inadequate inlet capacity and pond in the low point and to the rear of Kinmont Crescent.

The ponding in this location is predicted to exceed 300 mm deep during a 1 in 5 yr ARI event affecting approximately 1 property with the extent of ponding increasing with rainfall events of increasing severity (Figure 8-5). During a current 1 in 50 yr ARI event, it is predicted that approximately three properties experience deep flooding, posing a potential risk to habitable floors.

The overland flow and deep ponding was verified through workshop discussions and customer complaints. Flooding on a property in this location was reported to be up to 500 mm deep in 2007. Flooding was also reported again in 2008 due to a “stormwater blockage”.

Flows can be directed under the state highway via the stormwater network or a small culvert. The culvert under the state highway is designed to convey flows under the road into an open channel. It is predicted to be undersized and therefore causes flows to back up and exacerbates the deep ponding resulting from overland flows and inadequate inlet capacity on Kinmont Crescent.

The culvert and stormwater pipe under the state highway may also be influenced by a backwater effect from the Quarry Creek into which the flows are conveyed downstream. However, there is some uncertainty with model data relating to the culvert invert levels and behaviour of the Quarry Creek.

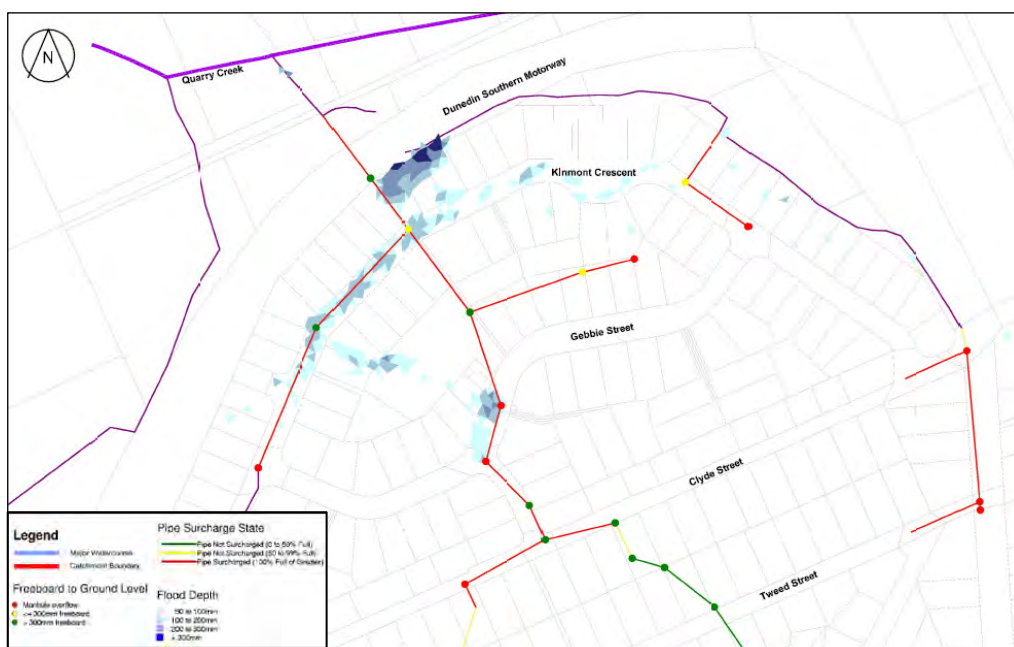


Figure 8-5: Current (30 min) 1 in 10 yr ARI (Stormwater Model Results)

The deep flooding in this location is predicted to become worse when future land use scenarios and climate change projections are applied to the model. During a future 1 in 10 yr ARI rainfall event the model predicts deep flooding on 3 properties, rising to 5 properties during a future 1 in 50 yr ARI event.



McGlashan Street, Gow Street, Gladstone Road South

During a 1 in 2 yr ARI rainfall event, the model predicts that the pipe capacity on Gow Street, McGlashan Street and Gladstone Road South is insufficient to convey flows resulting in manhole overflows. Nuisance flooding is predicted on Gow Street, McGlashan Street and Gladstone Road South/Quarry Road. The effects are predicted to be minor during storm events of 30 minute duration, up to and including a 1 in 50 yr ARI event.

However, this is an area of known flooding which is confirmed by customer complaints. Workshop discussions revealed that inundation of Gow Street is a long standing problem and the area floods “every year”.

Downstream of these locations the network discharges, via two outfalls, to the Quarry Creek. Sensitivity analysis relating to the Quarry Creek boundary condition (refer Section 7.1) indicated that the boundary effect of the Quarry Creek significantly affected flood depths and extents in these locations.

The flooding effects are predicted to be significantly worse during longer duration storm events when the flows in Quarry Creek are high. For example, during a 12 hour, 1 in 10 yr ARI event deep flooding is predicted (>300 mm) with the risk of habitable floor flooding on Gow Street, thus replicating flooding effects that have been observed (Figure 8-6).

Nuisance flooding <300 mm) is predicted as a result of pipe capacity alone, however, deep flooding (>300 mm) results when the boundary effects of the downstream watercourse are applied (refer Table 7-6).

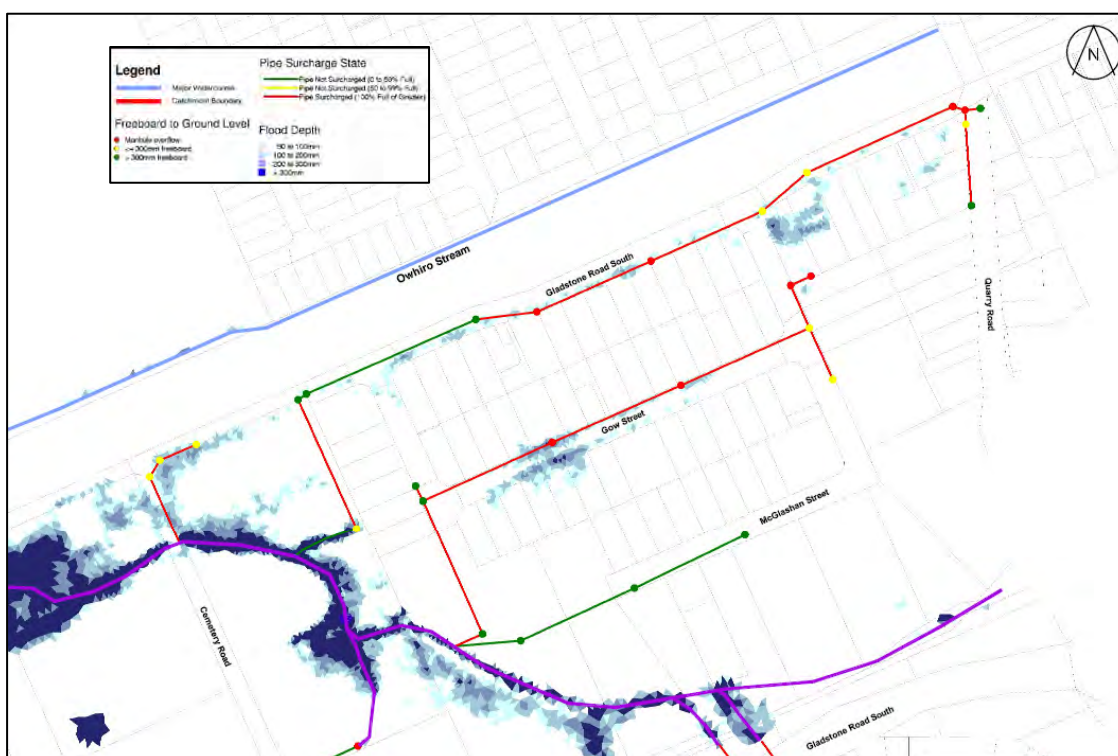


Figure 8-6: Current (12 hr) 1 in 10 yr ARI (Stormwater Model Results)

The deep flooding from the piped network, predicted during a 12 hour 1 in 10 yr ARI rainfall event, poses a threat to habitable floors of approximately four properties. Customer complaints verify that



businesses have been flooded in these locations in the past.

Whilst the model does not predict flood depths of greater than 300 mm in this location when future land use scenarios and climate change projections are applied to the model for a 30 minute, 1 in 50 yr ARI rainfall event, deep flooding and the risk to habitable floors is likely to significantly increase during longer duration rainfall events (12+ hours) in the future.

Carlyle Road, Mallard Place, Bush Road, Tyne Street

Carlyle Road, Mallard Place, Bush Road and Tyne Street is an area of known flooding problems. Workshop discussions indicated that flooding up to 1 m deep has been recorded in the Tyne Street subdivision in the past. These flows may have been combined with flows from the wastewater system as wastewater flooding has also been a significant problem in this location in the past (refer Section 8.2.4.2).

The model was unable to replicate this occurrence and therefore the extent and depth of flooding predicted by the model in this area is likely to be underestimated. It is predicted that stormwater from manhole overflows on Carlyle Road and Mallard Place flows overland to Tyne Street where ponding occurs at the low point in the road.

During a 1 in 2 yr ARI rainfall event nuisance flooding is predicted on Carlyle Road, Tyne Street, Mallard Place and Bush Road. The model predicts that flood depths remain below 200 mm during a 1 in 10 yr ARI event. The flooding is due to insufficient pipe capacity to convey the flows on Carlyle Road, which is further exacerbated by an hydraulic bottleneck at this location. This results in manhole overflows.

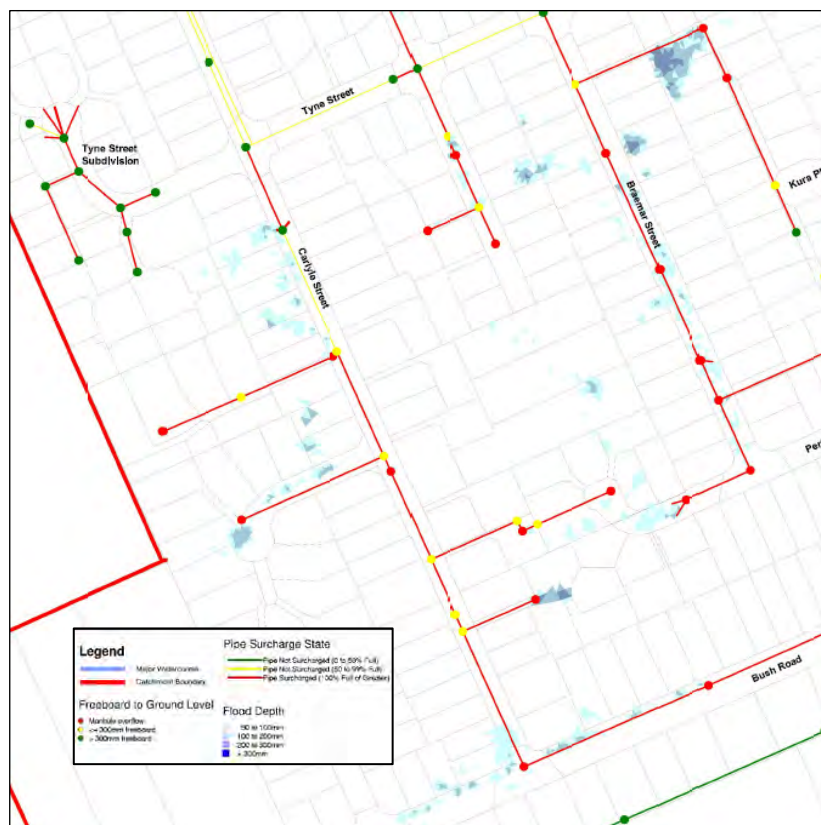


Figure 8-7: Current (30 min) 1 in 10 yr ARI (Stormwater Model Results)



Workshop discussions also indicated that the previous deep flooding observed was believed to be due to operational issues at the Carlyle Road PS downstream of the overflows. Blinding of the screen at the pump station inlet had caused the pumps to cycle on and off too frequently during a rainfall event, which had resulted in the pumps being shut off, causing flows to back up in the network.

When the model was run with the Carlyle Road PS shut off, in conjunction with the May 2010 rainfall event, significant flooding was predicted in the subdivision with a maximum depth of approximately 900 mm, similar to that reported as having occurred. Based on the model results, it would imply that the significant stormwater flooding observed in the past in the Tyne Street subdivision was not due to hydraulic capacity issues, but operational issues at the PS downstream. The model predicted that when the PS is shut off, (or the screen is blocked), the resulting backwater effect causes flooding on Carlyle Road adjacent to the subdivision. The flooding on Carlyle Road then flows overland and into the Tyne Street subdivision, where the lack of overland flow paths results in deep ponding. Workshop discussions also revealed that the previous overland flow path, directing flows to open land to the west of Tyne Street has been blocked since development has taken place in this location which now exacerbates any ponding that occurs.

When future land use scenarios and climate change projections are applied to the model, during a future 1 in 10 yr ARI event, the nuisance flood extents are predicted to increase with flood depths increasing to greater than 300 mm to the rear of Carlyle Road, affecting approximately two properties which may pose a risk of habitable floor flooding.

Woodland Avenue

During a 1 in 2 yr ARI rainfall event deep flooding (>300 mm) is predicted in the vicinity of the intake structure off Woodland Avenue. Since development of the subdivision, there is no overland flow path for stormwater overtopping the intake structure until flood depths exceed the kerb of the road downstream. This creates a significant risk to habitable floor flooding of properties in this location as the building floor levels are lower than the road.

Flows from the hill sub-catchment are conveyed by two open channels into the intake structure. The pipework downstream of the intake structure has insufficient capacity, which causes a backwater effect and overtopping of the intake structure. Blockage of the intake structure would further reduce capacity. It should be noted that in this location, maintenance of the open channels and the intake is the responsibility of the landowner. The scale of effects in this location is also dependent on the downstream Quarry Creek boundary condition and rainfall duration.

There are a number of areas of uncertainty regarding the predicted flooding at this location. There is low confidence in the GIS data at this location. The gradient of the pipe downstream of the intake is uncertain and the extent of flooding predicted is dependent on the gradient of the pipe. However, even with a steeper pipe gradient assumed, flooding is still predicted at this location. In addition, the sub-catchment upstream of the intake is predominantly rural. No flow monitoring has been completed in the rural areas of the catchment so there is a higher level of uncertainty in the predicted flow rates for rural sub-catchments.

Notwithstanding the uncertainties surrounding flooding predictions at this location, this is an area of known problems. Flooding was reported at this location in 2007 involving overtopping of the culvert intake screen. Workshop discussions confirm that this is a known problem area and when water levels in the Quarry Creek are high, flows back up and overtop the intake structure.



The deep flooding is predicted to become worse with rainfall events of increasing intensity, posing a significant risk of habitable floor flooding. This is exacerbated further when future land use scenarios and climate change projections are applied to the model, during a future 1 in 10 yr ARI event, the nuisance flood extents are predicted to increase with flood depths greater than 300 mm posing a risk of habitable floor flooding to two properties.

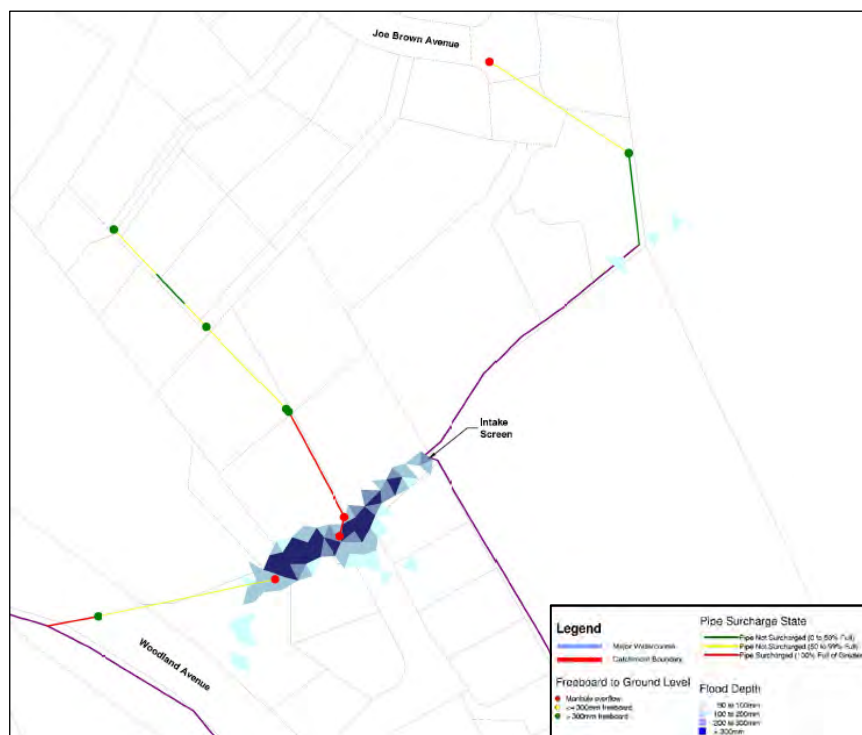


Figure 8-8: Stormwater Flooding Current (30 min) 1 in 10 yr ARI (Model Results)

Flooding from the wastewater system is also verified in this location. Stormwater overtopping the intake structure and ponding is predicted to enter the wastewater PS on Woodland Avenue. The model predicts that the PS becomes inundated with stormwater, the pumps are overwhelmed with flows greater than their capacity, and wastewater spills from the wet well. Wastewater complaints indicate “blocked sewers” in this location in the past.

Reid Avenue Swale

Significant flooding from the swale on Reid Avenue was observed following the May 2010 rainfall event (estimated to be between a 1 in 10 yr and 1 in 50 yr ARI event). Reports from the community indicate that the area around the swale, in particular Reid Avenue, is prone to flooding most years indicating that the flooding is likely to occur during events less than a 1 in 10 yr ARI.

Sensitivity analysis of the model indicated that a 30 minute duration storm event does not represent the worst case effects for the swale as this does not involve enough storm volume to fill the swale. However, a 24 hour, 1 in 10 yr ARI rainfall event with a static boundary condition on the Silver Stream replicates the flooding observed during the May 2010 event quite well.

During a 24 hour, 1 in 10 yr ARI rainfall event, the extent of flooding in this location is significant. Deep flooding is predicted (>300 mm) and poses a risk to habitable floors of approximately five properties. Flooding across the full width of the road on Reid Avenue and overland flows in the vicinity of Hartstonge Avenue, Oban Street, Ross Street and Nairn Street is also predicted (Figure



8-9). The model also indicates that a section of stormwater pipe on Hartstonge Avenue, connecting to the swale is undersized to convey flows during this event resulting in manhole overflows.

Should the swale inlet and outlets become blocked with debris or the flap valve to the Silver Stream not seal correctly the extent of flooding towards Gordon Road and across Reid Avenue would be significantly increased.

However, confidence in the way the swale behaves is low, as, the attenuation effect of flow through the swale may not be correctly represented by the model. Whilst the model does replicate the flooding reported, it does not necessarily mean the modelled swale is correctly replicating the cause.

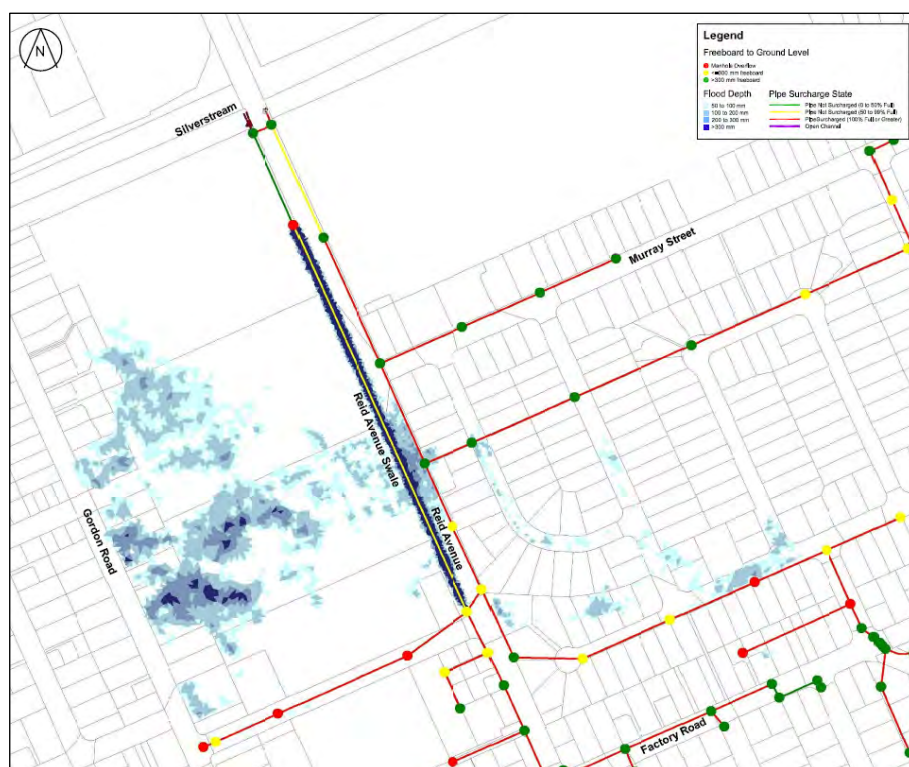


Figure 8-9: Current (24hr) 1 in 10 yr ARI (Stormwater Model Results)

Gladstone Road

During a 1 in 2 yr ARI rainfall event deep flooding (>300 mm) is predicted in the vicinity of the culvert under the railway off Gladstone Road North (in the vicinity of Irwin Logan Drive). During a 1 in 10 yr ARI event, a significant increase in the extent of deep flooding is predicted.

The culvert has insufficient capacity to convey the predicted flows. Flood depths are predicted to exceed 300 mm and potentially pose a risk to habitable floor flooding of approximately three properties.

The predicted flooding was verified by workshop discussions which indicated that ponding in this location is regularly observed. However, there are no customer complaints associated with these locations, therefore ponding may remain within drainage channels and the road, away from buildings.



8.2.4.2 Wastewater Network Flooding

Appendix E contains a summary of the wastewater network flooding predicted in the Mosgiel catchment, during events up to 1 in 10 yr ARI. The identification of 'confirmed' overflow locations is based on model outputs combined with verification from customer complaints and/or workshop discussions with DCC Water and Waste Services Business Unit staff. The model also predicts that a number of other areas may experience overflows but these events are unconfirmed by customer complaints or workshop discussions.

Predicted flooding from the wastewater network, is summarised in Table 8-2 and discussed in further detail in the following sections.

Table 8-2: Summary of Wastewater Flooding

Location	Description	Min Rainfall Event (yr ARI)
Gladstone Road North, Gladstone Road South, Cemetery Road, Henderson Street, Kura Place, Arran Street, High Street, Gordon Road	Unconfirmed manhole overflows	1 in 2
Lanark Street	Manhole overflow predicted, corresponding with complaint	1 in 10
Tyne Street/Silverstream Drive	Confirmed manhole overflows	1 in 10
Woodland Avenue Pump Station	Confirmed manhole overflow	1 in 5
Catchment Wide	Confirmed Gully trap / boundary trap overflows	unknown
Tyne Street subdivision	Historic wastewater flooding	n/a

Unconfirmed Manhole Overflows

The hydraulic model predicts that approximately 37 % of the wastewater network is surcharged during a 24 hour, 1 in 10 yr ARI rainfall event resulting in manhole overflows (1 % of total) in a number of locations (refer Table 8-2).

However, these do not correspond with anecdotal evidence or historic customer complaints, though this does not necessarily mean they do not occur. Many of the overflows predicted occur within reserves, rural land or to the rear of properties and therefore DCC Water and Waste Services Business Unit staff were unable to confirm whether these overflows have occurred in the past.

The model predicts that insufficient network capacity, primarily due to wet weather I&I and/or the operation of Mosgiel WWTP, results in the pipes flowing full, causing manholes to overflow. These issues are discussed in further detail in the following sections.

During a future 24 hour, 1 in 10 yr ARI rainfall event, it is predicted that capacity problems will worsen due to increased population and that approximately 2.4 % of all wastewater manholes in the catchment will overflow.

Confirmed Manhole Overflows

Manhole overflows predicted by the hydraulic model have been verified by workshop discussions and historic complaints in the following locations:



- Lanark Street; and
- Tyne Street / Silverstream Drive.

Manhole overflows are predicted on private property to the rear of Lanark Street, this corresponds with wastewater complaints for this location. The wastewater pipes downstream of Lanark Street are predicted to be surcharged during a 24 hr, 1 in 10 yr ARI rainfall event; causing manholes on Lanark Street to overflow. Sediment blockage of the pipe in Lanark Street was observed during flow monitoring and as such the blockage was replicated in the model. It should be noted that without the blockage, pipes are predicted to be surcharged but no overflows occur.

Workshop discussions indicated that there was a blockage removed from this location. This is likely therefore, to be an isolated incident.

The model predicts overflows from wastewater manholes on Tyne Street and Silverstream Drive due to surcharging of the wastewater network. The network surcharging is in part related to the operation of the inlet PSs at the Mosgiel WWTP causing a backwater effect in the network upstream. This is described in further detail in Section 8.2.6.

In the future scenario, an increased number of manholes are predicted to overflow as a result of the inlet PSs causing a backwater effect in the network. However, with increased wastewater flows predicted in the future, simply reducing the wastewater levels in the PSs would not resolve the issues.

Woodland Avenue PS

The model predicts that, during rainfall events of 1 in 5 yr ARI or greater, overflows occur from the wet well of the Woodland Avenue wastewater PS (refer also Section 8.2.4.1).

Stormwater flows overtopping the intake structure upstream of the PS are predicted to enter the wastewater network via manhole. The PS cannot pump the increased flows and is predicted to overflow as a result. Flooding in this location is therefore likely to be a combination of stormwater and wastewater.

The flooding is predicted to be more significant during longer duration events and in winter months due to the predominantly Greenfield stormwater catchment upstream.

Workshop discussions confirmed that this is an area of known stormwater flooding. However, whilst there are corresponding wastewater customer complaints indicating flooding for this location they refer to “blocked sewers”. Therefore there is some uncertainty regarding the nature and extent of wastewater overflow in this location.

Gully Trap/Boundary Trap Overflows

A number of customer complaints exist relating to gully trap and/or boundary trap overflows catchment wide. These however are not included within the hydraulic model as they are not DCC assets and remain the responsibility of the property owner.

It is possible that many of the complaints received were isolated incidents caused by blockages on private or public wastewater lines. However, as the model predicts widespread surcharging of the wastewater network during a 24 hour 1 in 10 yr ARI event, it is also possible that the surcharging of the pipes is sufficient to cause flows to back up and overflow from private property gully traps and boundary traps in some instances.



Tyne Street Sub-Division

The Tyne Street sub-division is an area of historic and significant wastewater flooding with numerous customer complaints relating to this location.

At the time of development of this ICMP, DCC was in the process of investigating design requirements for a new wastewater PS to serve the sub-division. Results from the Mosgiel hydraulic modelling indicated that the development of a PS in this location would serve to mitigate some of the flood effects.

The hydraulic model and this ICMP will be updated (as described in Section 16) when the PS development has been finalised.

It should be noted however that the sub-division is still at risk of wastewater manhole overflows during significant rainfall events until commissioning of the PS is complete.

8.2.4.3 Flood Hazard

The hydraulic model has been used to predict flooding during two 'emergency planning' events: a 30 minute duration, 1 in 100 yr ARI rainfall event with current land use, and a 30 minute, 1 in 100 yr ARI rainfall event with 2031 land use extreme (2060) climate change scenario. Flooding from both the stormwater and wastewater networks are considered under these scenarios, however the 30 minute event is the critical duration for the stormwater network.

The results from the extreme planning scenario will allow DCC to put emergency planning measures in place to avoid future catastrophic effects within the catchment, and to identify where overland flow paths lie.

A predicted flood hazard rating has been calculated for the current and future (extreme) planning scenario during a 1 in 100 yr ARI event. A flood hazard rating is a factor of velocity and depth calculated from the hydraulic model results. It indicates the likely degree of flood hazard for a given area and the associated risk to the public. A definition of each Rating can be found in Table 8-3.

Table 8-3: Flood Hazard Rating

Flood Hazard Rating	Degree of Flood Hazard	Flood Hazard Description
<0.75	Low	Caution – flood zone with shallow flowing water or deep standing water
0.75 – 1.25	Moderate	Dangerous for some – (i.e. children). Flood zone with <250 mm water, fast flowing water
1.25 – 2.0	Significant	Dangerous for most – flood zone with deep, 250 mm - 400 mm, fast flowing water
>2.0	Extreme	Dangerous for all – flood zone with deep, 400+ mm, fast flowing water

The maximum flood hazard rating for the catchment during a current 1 in 100 yr ARI rainfall event is 'Moderate to Significant'. This occurs in a small number of areas in the catchment, the main locations being: Kinmont Crescent, Woodland Avenue and Gladstone Road North. Of significance



to the flood hazard rating in these locations is the deep ponding predicted during this event. High velocity flows are not predicted due to the flatness of the catchment.

During a future 1 in 100 yr ARI rainfall event when the extreme planning scenario is applied, it is predicted that the total flood area will comprise approximately 1.6 % of the catchment; this however is confined to the flat, urban parts of the central catchment. The boundary condition applied to the watercourses has little effect on predicted flood hazard, particularly on the Silver Stream as the majority of discharges are pumped.

During this event the maximum flood hazard rating remains 'Moderate to Significant' with an increase in the number of locations predicted to experience this Rating; these include: Gordon Road, Factory Road, Watt Street to Braemar Street, Ross Street, Irvine Street and Ayr Place. This is shown in Figure 8-10.

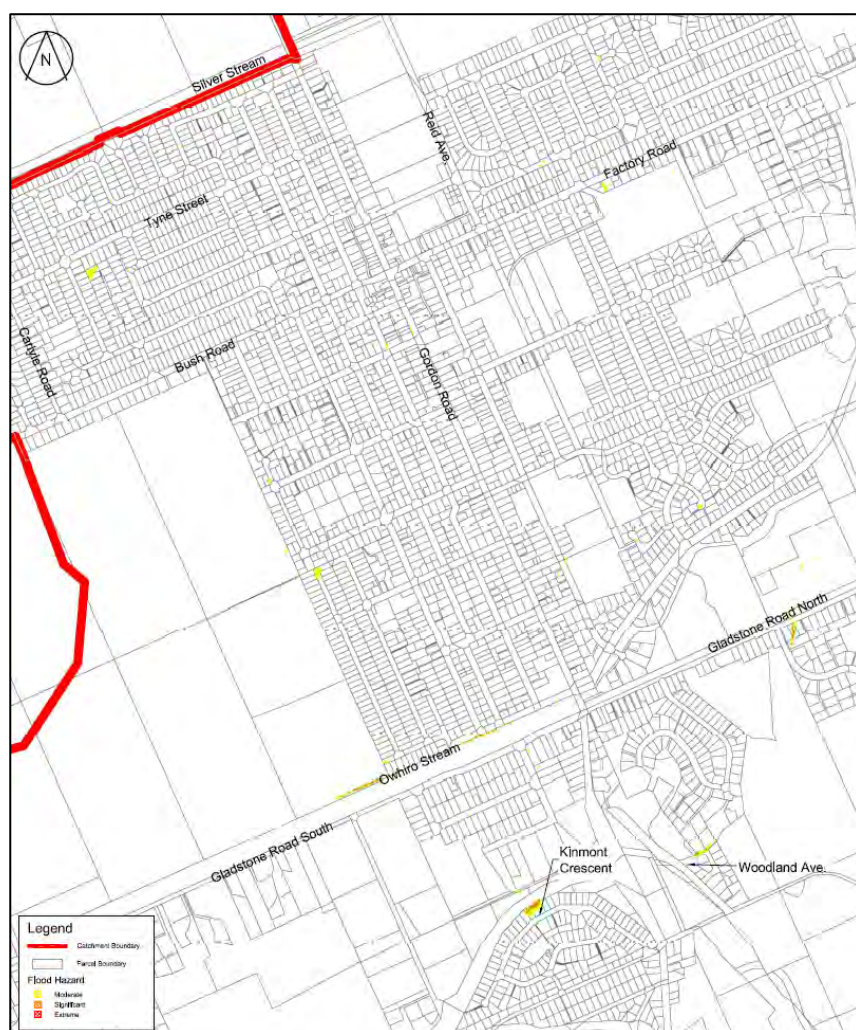


Figure 8-10: Flood Hazard Future (30 min) 1 in 100 yr ARI (Model Results)

It is unlikely that any major transport routes will be significantly disrupted during this event. Some residential roads may experience flooding across the full width but flood depths are likely to remain relatively shallow (< 300 mm). The areas of significant effect are those which are already predicted to experience flooding problems in the current scenario, during smaller rainfall events as described above.



8.2.5 Fluvial Flooding

Fluvial flooding is flooding arising from the external watercourses such as the Silver Stream and Owhiro Stream. Whilst the analysis of fluvial flooding is outside the scope of this ICMP it has been included in this section as it is a recognised issue within the Mosgiel catchment (refer also Section 4.5.4).

There are recorded incidents of fluvial flooding within the catchment and areas have been identified by studies with a high risk of fluvial flooding.

8.2.5.1 Quarry Creek

Historic flooding is recorded in the lower reaches of the Quarry Creek, which is also believed to contribute to other nearby historic stormwater network flooding issues. The flooding in this location is reported by both the community and DCC Water and Waste Services Business Unit staff to have been occurring at least annually in recent years.

The Quarry Creek is known to flood with the following effects:

- Flooding of East Taieri School car park on Cemetery Road;
- Flooding of Cemetery Road;
- Cemetery Road inaccessible and therefore closure of the school; and
- Flooding in pre-school grounds results in direct inflow into wastewater gully traps putting additional strain on the wastewater network.

Basic model analysis of the Quarry Creek revealed that a 12 hour storm event is the critical duration for the Quarry Creek. The model was able to replicate observed flooding in this location during a current 12 hour, 1 in 10 yr ARI event.

It would appear that the lower reaches of the Quarry Creek have insufficient capacity to convey the flows from upstream. This may be a result of the channel size but may also be as a result of poor watercourse management. Meeting notes from a site visit attended by DCC and ORC indicated that there was evidence of scour on the banks of the watercourse, in certain locations the channel was constricted by tree roots, and long grassy vegetation was noted down to water level.

It should be noted that at present the Quarry Creek (and Owhiro Stream) are designed (and managed) to a rural flood protection standard. It could be considered however that the adjacent areas in Mosgiel are now sufficiently developed requiring that flood protection should now be raised to an urban standard. Communications between DCC and ORC regarding this matter have been carried out. DCC will continue these discussions in order to reach a resolution on this issue.

8.2.5.2 Silver Stream / Owhiro Stream

A review of available literature and data was carried out to assess the flood risk from the Silver Stream and Owhiro Stream.

Modifications to the Silver Stream have been designed so that the land to the north of the watercourse serves as a flood plain in order to protect the township to the south. This land should



not be developed further without caution.

The review of the data indicates that areas of urban Mosgiel (south of the Silver Stream) to the east of Gordon Road are protected to a reasonably high standard (1 in 50 yr ARI or higher), whilst areas to the west, including the Mosgiel wastewater treatment plant (WWTP), are protected to a lower level, but still greater than a 1 in 10 yr ARI event.

The Owhiro Stream is not known to be a source of flooding in urban Mosgiel, but is known to flood farmland downstream of Mosgiel relatively routinely.

Whilst the Owhiro Stream channel and culverts through the urban area of Mosgiel were designed to a 1 in 100 yr ARI standard, recent modelling undertaken by ORC (ORC, 2006), predicts that the channel through Mosgiel could be overtopped during a 1 in 50 yr ARI event.

The review of the data indicates that the main urban area of Mosgiel is protected to a reasonably high standard from the Owhiro Stream.

In relation to future landuse planning and development consents in Mosgiel the flood risks from the watercourses should be taken in to account.

8.2.6 WWTP Operation

Under normal dry weather operation wastewater is screened as it enters the WWTP and then pumped via the two inlet PSs through the treatment plant. Treatment consists of sedimentation and trickling filters. Once treated, effluent is then pumped to the Green Island WWTP, via the effluent transfer PS, for UV disinfection and is then discharged via the Waldronville ocean outfall.

During rainfall events, if the wastewater level at the WWTP inlet PSs becomes too high this causes a backwater effect and results in the upstream pipes surcharging (with manhole overflows predicted). This could be because the pumps do not have the capacity for the inflow or simply because the pump start levels are set too high. Workshop discussions indicated that the most likely cause of the surcharging is the levels at which the pumps are set to start. Modelling indicates that reducing the pump start levels would alleviate the manhole overflows but would result in increased overflows from the WWTP to the Silver Stream.

The WWTP has been designed to a maximum treatment capacity of 10,000 m³/day and has approximately 2,000 m³ of additional storage. In the past the WWTP was limited to transferring a maximum of approximately 12,000 m³/day to the Green Island WWTP by the effluent transfer PS and the overflow to the Silver Stream has been operating at least annually.

Heavy rainfall will increase wastewater flows. If flows exceed the capacity of the transfer pumps then the WWTP storage will be utilised. Once the storage is full the remaining flow must be discharged to the Silver Stream.

The installation of a diesel pump in 2010 in the effluent transfer PS has increased the transfer capacity. The diesel pump design flow is 25,920 m³/day (300 L/s). However the pump rate is restricted to 225 L/s (19,440 m³/day) due to concerns about the pressure rating of the rising main to Green Island WWTP. Further investigation into the pressure rating of the rising main would confirm the need to restrict the pump rate.

The pressure main to Green Island WWTP is a 500 mm ID PN10 PE pipe. In the past with the low



capacity of the effluent transfer PS the velocities in the pressure main were low resulting in sedimentation. This sediment restricts the flow capacity of the pipeline but DCC are now using the diesel pump to flush the pipeline and improve the performance of the effluent transfer PS.

8.2.6.1 Emergency Overflow to Silver Stream

In wet weather events when flow into the WWTP plant exceeds the effluent transfer PS and storage capacity available wastewater is discharged to the Silver Stream. Prior to 2010 this has been a near annual occurrence. Now that the effluent transfer PS capacity has been increased with the installation of the diesel pump in 2010 the overflow to the Silver Stream is predicted to operate in events greater than a 1 in 5 yr ARI.

Quality effects of overflows are discussed in further detail in Section 8.3.

8.2.7 Network Operation, Maintenance and Risks

8.2.7.1 Intake Structures

As outlined in Section 4.8.3, depending on the location, catchpit and inlet maintenance is undertaken by a number of different teams with variations in inspection specification. This means that city-wide, there are variations in catchpit levels of service. During autumn months in particular, heavy rainfall can result in debris blocking the catchpits and inlet screens. A reduction in catchpit capacity due to silt build up can lead to extension of ponding durations and extents during a rainfall event. Similarly, blocking of inlet screens (of culverts or catchpits) prevents flow entering the network, also resulting in extended ponding, as well as increasing overland flow to other locations. This was verified by Water and Waste Services Business Unit staff as a potential issue during walkovers and workshops.

Within the Mosgiel catchment there are a number of key intake structures. Of particular importance are those where no overland flow path exists and blockage could result in habitable floor flooding.

Key structures in the Mosgiel catchment have been identified as:

- Woodland Avenue intake;
- Reid Avenue swale;
- Kinmont Crescent/State Highway culvert;
- Carlyle Road stormwater PS inlet screen.

Blocking of these structures could significantly exacerbate flooding predicted in these locations.

8.2.7.2 Stormwater Pump Station Failure

A failure in the operation of one of the stormwater PSs presents a significant flood risk in the catchment. Failure of each of the following pumps stations was assessed:

- Cherry Drive;
- Reid Avenue; and
- Carlyle Road.



The model was run with the May 2010 rainfall and corresponding Silverstream boundary level data. The model predicts that should any of the PSs fail, stormwater would back up in the PS and main stormwater lines until the hydraulic gradeline was high enough to allow flows to discharge under gravity via the gravity outfalls adjacent to the PSs. The flood effects predicted due to the failure of each PS are shown in Table 8-4 and described in the following text.

Table 8-4: Flood Effects, PS Failure

PS Failure	Parcels with predicted flood depth >300 mm	Predicted flood extent (ha)	Predicted volume of flooding (m ³)
Cherry Drive	15	18.3	4986
Reid Avenue	12	21.7	8482
Carlyle Road	20	22.5	6895

Cherry Drive PS

Pipe surcharging and manhole overflows would result following PS failure. Flooding of the lowest lying areas of the catchment, namely Maple Grove, Walnut Place, Peat Place and Lorne Street is predicted. Overland flows from Lorne Street would cause flooding to the west in Stirling Crescent, Nairn Street, Oban Street and Ross Street before being cut off by the Reid Avenue swale. Deep flooding (>300 mm) is predicted on Maple Grove, Walnut Place, Peat Place, Lorne Street, Stirling Crescent and Ross Street. Approximately 15 properties are predicted to be at risk of flood depths greater than 300 mm. The predicted effects are shown in Figure 8-11.

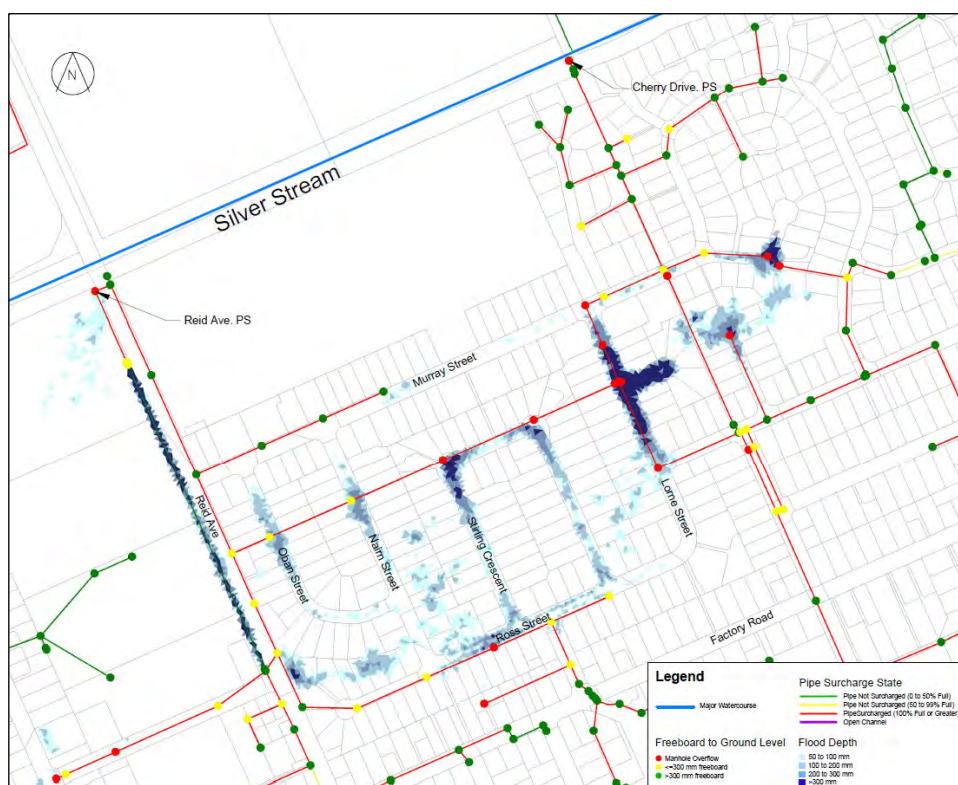
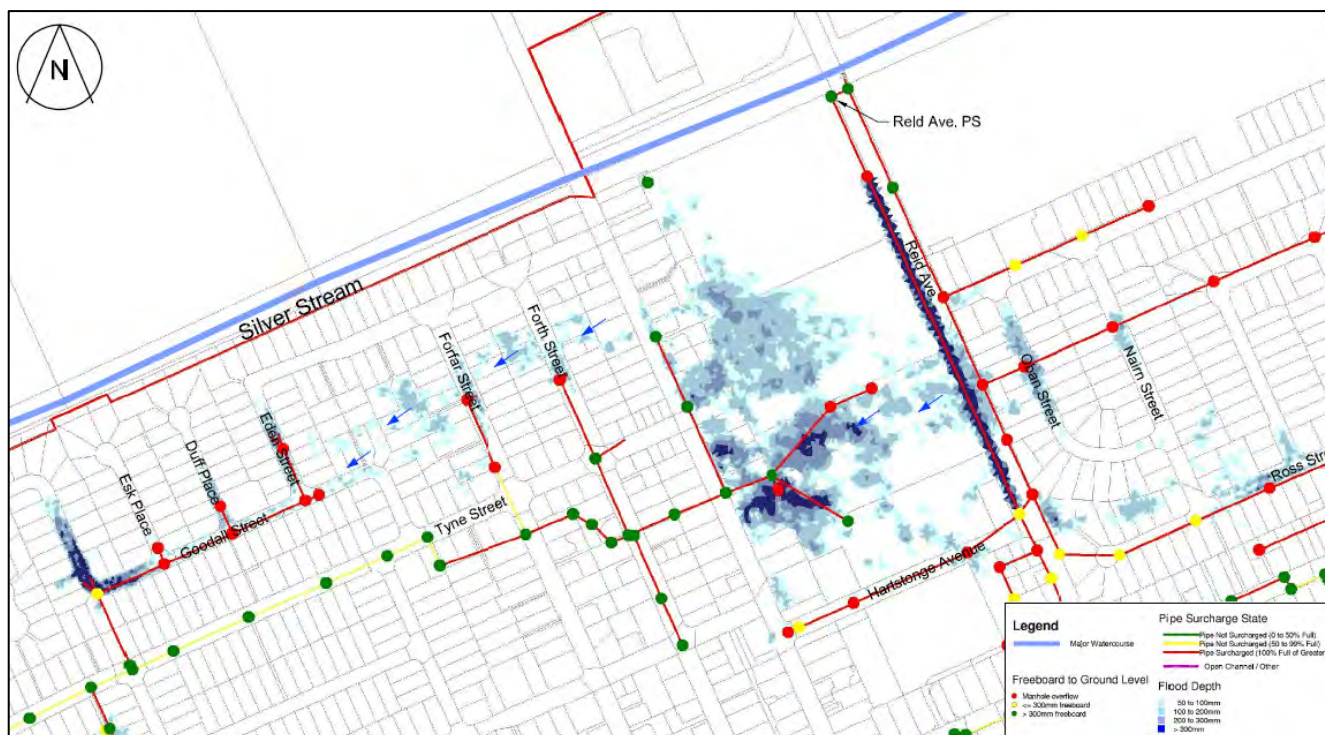


Figure 8-11: Flood Risk Cherry Drive Stormwater PS Failure (May 2010 event) (Model Results)



Reid Avenue PS

The backwater effect caused by PS failure would cause the Reid Avenue swale to overtop and flood part of Reid Avenue. Overland flows through the park towards Gordon Road and on to Goodall Street, Duff Place and Eden Street are predicted where deep flooding (>300 mm) occurs due to a lack of overland flow path. Manhole overflows are also predicted causing ponding in Ross Street, Oban Street and Nairn Street. Deep flooding is predicted on Ross Street, to the rear of Gordon Road adjacent to the park and at the low point in Goodall Street. Approximately 12 properties are predicted to be at risk of flood depths greater than 300 mm. The predicted effects are



shown in Figure 8-12

Figure 8-12: Flood Risk Reid Avenue Stormwater PS Failure (May 2010 event) (Model Results)

Carlyle Road PS

The backwater effects resulting from PS failure would cause pipe surcharging and manhole overflows to flood Carlyle Road, Tyne Street, Silverstream Drive, Goodall Street, Duff Place and Eden Street; with deep flooding (>300 mm) in the Tyne Street, Silverstream Drive and off Kura Place. Approximately 20 properties are predicted to be at risk flood depths greater than 300 mm. The effects are shown in Figure 8-13.

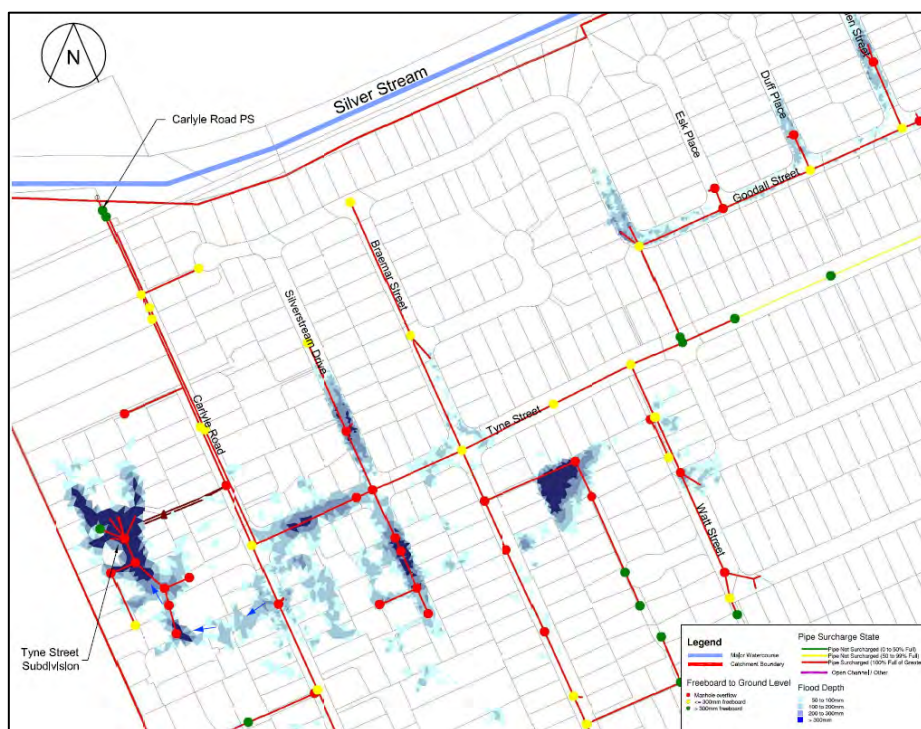


Figure 8-13: Flood Risk Carlyle Road Stormwater PS Failure (May 2010 event) (Model Results)

Blinding of the inlet screens at this PS also present a risk of pump failure and significant flooding (refer Section 8.4.2.1).

8.2.7.3 Stormwater Outfalls to the Silver Stream

When the Silver Stream is flowing high there is a risk that areas of Mosgiel could be inundated where land is at or below the level of the stopbanks as a result of flap valves, on the gravity outfalls linked to the PSs not being fully sealed.

Should the flap valves not fully seal, the efficiency of the PS will be greatly reduced as they will draw in fluvial flows, effectively creating a loop where the PS is merely returning river water to the Silver Stream. This would cause the stormwater network upstream to surcharge and flood, creating a similar effect to that described above when the PSs fail. Catchment walkovers revealed that at present the flap valves on the gravity outfalls may not fully seal and are at risk of becoming lodged open. The installation of appropriate flap valves and manually operated valves upstream of the outfall would significantly reduce this risk.

8.2.7.4 Wastewater Blockages

There is a relatively high risk of blockages in the wastewater network due to the flat nature of the catchment and therefore low gradient of the wastewater pipes. The flat pipes result in relatively low flow velocities in some areas, which increases the risk of sediment dropping out of flows and build up of fat, etc.

Several customer complaints exist which relate to “blockages” but until recently the complaints reporting procedures have not allowed for incidents such as blockages to be recorded against a specific asset so it has been difficult to determine problem areas.



Blockages/partial blockages significantly reduce the capacity of the network. This risk could be reduced by a better understanding of problem areas and regular cleaning/maintenance of those areas at greatest risk of blockage.

8.2.8 Summary of Quantity Effects

A summary of the quantity effects in the Mosgiel catchment is as follows:

- The modelling indicates that the stormwater network has a level of service of between a 1 in 2 yr and a 1 in 5 yr ARI rainfall event, with 71 % of the network able to accept runoff from a 1 in 10 yr ARI event.
- The modelling indicates that the wastewater network has sufficient capacity to accommodate future flows during dry weather but that DWF is elevated in certain sub-catchments due to the infiltration of groundwater.
- The wastewater network is predicted to have a wet weather level of service of between a 1 in 2 yr and a 1 in 5 yr ARI rainfall event, with 1 % of manholes predicted to overflow and the WWTP emergency overflow predicted to discharge approximately 3,670 m³ to the Silver Stream during a 1 in 10 yr ARI event.
- During wet weather events, wastewater flow rates and volumes are significantly increased above DWF indicating I&I within the pipes. This has been identified as contributing to capacity issues within the wastewater network resulting in manhole overflows, capacity problems at the WWTP and emergency discharges to the Silver Stream.
- Nuisance flooding from the stormwater network is predicted and (verified) catchment-wide during events of 1 in 2 yr ARI and greater. This is due to insufficient pipe capacity, lack of overland flow paths and historic design standards.
- Deep flooding from the stormwater network is predicted in some locations during events as small as a 1 in 2 yr ARI, which poses a risk of flooding to habitable floors. This is due to insufficient network capacity and/or inadequate inlet/culvert structures.
- Wastewater manhole overflows are predicted during events of 1 in 2 yr ARI or greater, caused by insufficient network capacity resulting from elevated DWF, wet weather I&I and WWTP capacity and operation.
- A maximum flood hazard rating of 'moderate to significant' has been assigned to the catchment during current and future 1 in 100 yr ARI events.
- Fluvial flooding is reported from the Quarry Creek and is known to have occurred annually in recent years. Studies have indicated a fluvial flood risk from the Silver Stream during events greater than a 1 in 10 yr ARI and from the Owhiro Stream during events of 1 in 50 yr ARI or greater.
- Inefficient WWTP operation, including operation of the inlet PS and, effluent transfer PS and storage capacity, contributes to wastewater overflows and network surcharging.
- The emergency overflow from the WWTP discharged to the Silver Stream on average once per year until 2010. Modelling indicates that approximately 3,670 m³ will be discharged during



a 1 in 10 yr ARI event.

- Inconsistencies in the standard and frequency of cleaning and maintenance of stormwater structures could exacerbate or transfer predicted flooding. Key structures in the Mosgiel catchment include those where no overland flow path exists and where blockage could result in habitable floor flooding.
- Failure of the key stormwater PSSs, individually or all, presents a significant flood risk within the catchment.
- Inadequate flap valves on the stormwater gravity outfalls linked to the PSSs increases the risk of catchment flooding.
- There is a risk of blockage in the wastewater pipes due to the flat nature of the catchment which would further reduce network capacity and cause overflows. There has been a lack of adequate reporting procedures historically and therefore no routine maintenance in problem areas to reduce this risk.



8.3 Quality Effects

8.3.1 Stormwater Quality

Stormwater quality is discussed in detail in Section 6.1. Stormwater quality monitoring is not carried out in the Mosgiel catchment on a regular basis. For the purposes of this study, a single time-proportional sample set was taken (2010) and a review of available historic grab-sample data (2004, 2005) completed in order to assess the quality of stormwater from the catchment.

The following is a summary of the stormwater quality data:

- The time-proportional results (2010 from the Lanark Street outfall indicate that the levels of contaminants measured within the stormwater from this catchment are within or below the range typically observed in urban stormwater.
- The historic grab-sample results (2004, 2005) indicate that the levels of the majority of contaminants in the stormwater analysed were within the range typically observed in urban stormwater at the Quarry Creek, Wingatui Road and Titri Place outfalls. There were however some exceptions.
- Arsenic and copper levels were slightly elevated in the samples from the Quarry Creek outfall (2004, and 2004/ 2005 respectively).
- Copper and nickel levels were slightly elevated in samples from the Wingatui Road outfall (2004/2005, and 2004 respectively).
- E. coli and faecal coliform levels were at the upper end or exceeded the range typically observed in urban stormwater in the samples from the Titri Place outfall (2004, 2005).
- Insufficient data exists to be able to gain a clear picture of stormwater quality trends over time.

The Lanark Place outfall discharges stormwater from a predominantly residential sub-catchment, it is expected that stormwater contaminant levels would be relatively low from a sub-catchment of this nature.

Wingatui Road and Titri Place outfalls discharge stormwater from the north of the Silver Stream from a rural/industrial sub-catchment which includes the Taieri Aerodrome and a timber treatment plant which is known to be a 'managed' contaminated site.

Whilst levels of copper and nickel were only slightly elevated above the typical range for urban stormwater from the Wingatui Road outfall, the elevated levels may be as a result of the land use activities in this location. Typical sources of copper and nickel include: vehicles/engines wear and a variety of industrial activities. Copper is a standard timber preservative which is likely to be used at the timber treatment plant in this catchment.

The potential source of microbial contamination in the stormwater from the Titri Place outfall is difficult to identify. Wastewater and animals (birds, rodents, livestock) are the common sources of microbial contamination. There are no customer complaints relating to wastewater overflows during the years that samples were analysed from this outfall or any known cross connection/predicted manhole overflows in the vicinity. However, an area of the sub-catchment discharging to the Titri Place outfall is rural and livestock grazing occurs in this area. A likely source of the high microbial



contamination is runoff from the rural sub-catchment.

As the data indicating high microbial contamination in the stormwater is historic, it is unknown if these microbial levels persist in the stormwater from the Titri Place outfall today. However, as stormwater discharges to watercourses are a permitted activity under the Regional Plan provided that they are free from wastewater contamination the extent of and potential source of microbial contamination should be investigated further to determine whether this is an historic or ongoing occurrence.

The Quarry Creek outfall discharges stormwater runoff from rural hill catchments to the south and light industrial/residential landuses. The state highway also runs through the sub-catchment.

Arsenic is naturally occurring in the soils and rocks of New Zealand and also results from the combustion of fossil fuels and industrial activities amongst others.

It is likely that the slightly elevated arsenic and copper levels measured in the stormwater from the Quarry Creek outfall are as a result of land use activities also. It may be that runoff from the hill catchments carries naturally occurring arsenic and that vehicle use in the sub-catchment (on residential roads and the state highway) contribute to the arsenic and copper levels within the stormwater.

Further to the high microbial results in the stormwater discharge monitored, stormwater flooding in a different part of the catchment, on Woodland Avenue, is predicted to inundate the wastewater PS resulting in overflow of wastewater. The wastewater overflows mixing with the stormwater flooding and may lead to contamination of the stormwater. Whilst significant dilution is likely to take place, stormwater discharges from this sub-catchment have not been monitored therefore likelihood and extent of contamination remains uncertain.

8.3.2 Wastewater Discharge

Wastewater from the Mosgiel WWTP discharged, via an emergency overflow, to the Silver Stream on average once per year until 2010. The model predicts overflows during rainfall events of 1 in 5 yr ARI and greater.

It can be pumped to the Silver Stream from a number of points within the treatment plant, namely the inlet PSs, the secondary clarifier and the filter well PSs. All wastewater is at least screened before it is discharged.

The quality of the discharge is not monitored. However, as the overflow only operates during heavy/prolonged rainfall events during which time the Silver Stream will be flowing high and as such significant dilution will take place in the receiving environment.

8.3.3 Water Quality

Water quality data, from the April 2010 surveys and historical ORC SOE monitoring, relating to the Silver Stream and Owhiro Creek, has been assessed. A summary and discussion of the data is as follows:

- Silver Stream:
 - Water quality is generally within ANZECC/ARMCANZ guideline levels for lowland rivers.



- Low turbidity, suspended solids, nutrients, and conductivity.
- pH within the range appropriate for freshwater bodies in New Zealand.
- Dissolved oxygen above the acceptable minimum standard for lowland rivers.
- Faecal contamination levels often exceed guidelines for recreation.
- Cyanobacteria regularly recorded in the Silver Stream (upstream of the WWTP).

Overall, the water quality in the Silver Stream has been assessed as good. Whilst faecal contamination levels have been measured above guideline levels for recreation, the lower reaches of the Silver Stream flowing through Mosgiel are not suitable for bathing.

It is noted that the upper catchment of the Silver Stream is rural, and high faecal contamination levels have also been measured in the upper catchment. Whilst there were reasonably high levels of microbial contamination measured in the stormwater discharging to the Silver Stream from one outfall, a significant amount of dilution of stormwater would occur within the stream and as such the levels in the stormwater are unlikely to be the cause of the high microbial levels in the stream. It is more likely that faecal contamination is due to livestock in the upper catchment rather than stormwater inputs in the lower reaches flowing through Mosgiel.

Cyanobacterial blooms recorded in the Silver Stream may indicate high level of nutrient input (nitrogen, phosphorus) at certain times of year. Whilst cyanobacteria is naturally occurring in freshwaters, high nutrient levels and optimum instream conditions result in algal blooms of this type. They can pose a health risk when taxa producing cyanotoxins occur. However, high nutrient levels are not a common component of urban stormwater. Furthermore, the upper catchment for the stream is rural. Rural activities, including fertiliser use, are likely to contribute to high nutrient levels in runoff from the upper catchment. This is the most likely source of the high nutrient levels in the lower reaches.

- Owhiro Stream:

- High turbidity, suspended solids, nutrients and conductivity.
- pH within the range appropriate for freshwater bodies in New Zealand.
- Dissolved oxygen generally below the minimum standard for lowland rivers.
- Faecal contamination levels often high, exceeding guidelines for recreation.

Overall the water quality of the Owhiro Stream has been assessed as being poor. The Owhiro Stream catchment is relatively small and is entirely modified for urban and farm land use activities.

Stormwater was analysed from a tributary of Owhiro Stream (Quarry Creek) flowing through Mosgiel. However, stormwater contaminant levels were not sufficiently high as to be the cause of the overall poor water quality assessed in the Owhiro Stream.

The small catchment of the Owhiro Stream means that less instream dilution will occur and the modifications to the channel (straightening, removal of riparian vegetation, and therefore the removal of shade), and land uses in both the upper and lower reaches are likely to be factors contributing to the poor water quality.



8.3.4 Habitat Quality

Habitat quality of the Silver Stream and Owhiro Stream were assessed in 2011.

The Silver Stream habitat quality through Mosgiel was found to be moderate to poor. The reaches flowing through Mosgiel have been heavily modified with channelisation and high stop banks. Riparian habitat is relatively poor; dominated by pasture grass with riparian shading considerably reduced as a result of the modifications. Instream habitat diversity and quality of bed substrate also declines with distance downstream which may be as a result of the modifications and also the high flows experienced in the lower reaches during heavy/prolonged rainfall events.

The Owhiro Stream habitat quality through Mosgiel was found to be poor. The entire catchment has been modified for rural or urban use. The reaches flowing through Mosgiel have been straightened and incised. Riparian habitat is poor, dominated by pasture and exotic grasses with little/no shading. Instream habitat diversity is low and the quality of the bed substrate poor, due to the channel being incised.

Community groups have a strong involvement with the Owhiro Stream and a planting project on a 900 m section of the lower stream near Allanton was completed in 2010. This will serve to improve the habitat quality in this location.

8.3.5 Ecology

The ecology in the Silver Stream was found to be good to excellent. Aquatic plants were restricted to mainly exotic plants in the stream bed, but a range of benthic algal and diatom taxa has been recorded. Macroinvertebrate communities are more diverse in the upper reaches, upstream of Mosgiel but were found to be fair at sites within Mosgiel.

The Silver Stream supports a diverse fish community dominated by longfin eels and common bullies. The stream provides important spawning and nursery habitats for brown trout. Inanga have been recorded in the lower reaches, and lamprey are common throughout.

The ecology within the Silver Stream in Mosgiel, whilst generally good, is less diverse than found in the upper reaches. This is likely to be due in part to the modifications of the channel and removal of riparian vegetation in the lower reaches which also affect water and habitat quality.

The ecology of the Owhiro Stream was found to be poor. Aquatic plants were restricted to mainly exotic plants along the banks and stream bed and instream substrate was unsuitable for supporting diverse benthic algal communities. Macroinvertebrate communities were of low quality, dominated by taxa found in streams of poor water quality or habitat dominated by soft bottom sediments.

Longfin eel, brown trout, giant kokopu, european perch, inanga and common bullies have been recorded in the Owhiro Stream which suggests that the overall quality of the stream is sufficient to support a fish population. However, the fish community is considered to be of reasonably low diversity in general.

The ecology in the Owhiro Stream is considered to be poor throughout the upper and lower reaches. This is likely to be a result of the relatively poor water and habitat quality of this stream due to channel modifications affecting instream habitats, lack of riparian vegetation and point source



and diffuse inputs from both rural and urban landuses.

8.3.6 Culture and Amenity

The Silver Stream has public access via a walking track along the Silver Stream Bank Reserve. It is open for fishing during the fishing season but it is not particularly popular with anglers.

The Owhiro Stream is also not popular with anglers but community groups have a strong involvement with the stream in particular with respects to habitat/amenity enhancement.

The Silver Stream and Owhiro Stream have a number of cultural values and freshwater resources are particularly important to Kai Tahu. The Kai Tahu Ki Otago Natural Resource Management Plan contains management guidelines and policies relating to the Taieri River catchment, to which the Silver Stream and Owhiro Stream contribute.

The continued operation of the WWTP emergency overflow in particular, is in conflict with Maori cultural values.

The cyanobacterial algal blooms recorded in the Silver Stream may present a health risk and affect the amenity value of the watercourse at certain times of year.

Whilst the quality of the streams in the Mosgiel catchment has an influence on the associated amenity and cultural values, there is little evidence at present to indicate that there is a continuing deterioration of the quality of these streams over time as a result of stormwater/wastewater inputs.

8.3.7 Summary of Quality Effects

A summary of the quality effects in the Mosgiel catchment is as follows:

- The majority of contaminants measured within the stormwater from the catchment are generally within the range typically observed for urban stormwater.
- The slightly elevated levels of arsenic, copper and nickel were measured in the stormwater (2004, 2005) are likely to be a result of surrounding land uses
- Elevated levels of microbial contamination were measured in stormwater from the Titri Place outfall (2004, 2005). The potential source of contamination is difficult to identify. Further investigation would identify whether these elevated levels persist to date.
- Potential wastewater contamination of stormwater due to Woodland Avenue wastewater PS overflows predicted to be caused by stormwater inundation of the PS.
- There is insufficient data available to determine trends in stormwater contamination over time.
- Wastewater emergency overflow from the Mosgiel WWTP discharges to the Silver Stream on average once per year until 2010. It is predicted to overflow during rainfall events of 1 in 5 yr ARI and greater. Some of the effluent discharged, whilst at least screened, may be otherwise untreated prior to discharge. The overflow only operates during heavy/prolonged rainfall events and as such significant dilution will take place in the receiving environment.



- Water quality was found to be good in the Silver Stream and poor in the Owhiro Stream. Poor water quality may be as a result of the small catchment, modifications to the channel, and land uses in both the upper and lower reaches.
- Cyanobacterial blooms recorded in the Silver Stream may pose a health risk. However, primary sources of nutrients are likely to be in the upper catchment and it is unknown if stormwater is contributing to this occurrence.
- The ecology within the Silver Stream running through Mosgiel is generally good, but less diverse than found in the upper reaches. This is likely to be due in part to the modifications of the channel and removal of riparian vegetation in the lower reaches which also affect water and habitat quality.
- The ecology in the Owhiro Stream is considered to be poor throughout the upper and lower reaches. This is likely to be a result of the relatively poor water and habitat quality of this stream which probably results from significant modifications to the channel.
- The streams that flow through Mosgiel have important cultural values and are also used for recreational purposes. The results of investigations do not indicate that the quality of the streams is deteriorating as a result of network discharges in Mosgiel.



9 Catchment Problems and Issues Summary

Following the Assessment of Environmental Effects (AEE), a number of key problems and issues can be identified in the Mosgiel catchment, and prioritised for action. These are discussed below. Section 10 prioritises these issues, and the remainder of this ICMP involves target setting and development of options to manage the stormwater and wastewater from this catchment. Figure 9-1 presents the key issues for the catchment.

9.1 Quantity Issues

9.1.1 Low Level of Service – Stormwater Network

Modelling predicts that approximately 71 % of the network can accept rainfall from a 1 in 10 yr ARI rainfall event but that overall the level of service of the stormwater network is between a 1 in 2 yr and 1 in 5 yr ARI rainfall event.

The effect of the low level of service is predicted nuisance flooding in numerous locations around the catchment during rainfall events as small as a 1 in 2 yr ARI primarily caused by insufficient pipe capacity. In many locations the nuisance flooding is contained within the kerb of the road and as such the effects are considered to be minor. However, there are some locations within the catchment where network capacity causes more significant flooding problems.

9.1.2 Low Level of Service – Wastewater Network

Modelling predicts that there is sufficient capacity on the wastewater network during dry weather. During wet weather however, whilst some areas of the network are predicted to perform well during a 1 in 10 yr ARI rainfall event, the overall level of service of the wastewater network is predicted to be between a 1 in 2 yr and 1 in 5 yr ARI event.

The effect of the low level of service is widespread surcharging of the pipes, resulting in manhole overflows in some locations and wastewater discharge direct to the Silver Stream from the WWTP emergency overflow. The low level of service results from a combination of issues including dry weather infiltration, wet weather I&I and WWTP operation.

9.1.3 Stormwater Flooding

Flooding from the stormwater network occurs during rainfall events as small as a 1 in 2 yr ARI and, in a number of locations, the flooding is predicted to become deep (> 300 mm) during events of 1 in 10 yr ARI and greater and may pose a risk to habitable floors. This is mainly due to insufficient pipe capacity, hydraulic bottlenecks and backwater effects from the watercourses in the catchment.

Flooding from the network is predicted and verified in the following locations:

- Catchment-wide (effects unacceptable to the local community);
- Gordon Road/Lanark Street;
- Kinmont Crescent;
- Gow Street/McGlashan Street/Gladstone Road South;



- Carlyle Road/Mallard Place/Bush Road/Tyne Street;
- Woodland Avenue;
- Reid Avenue; and
- Gladstone Road North.

9.1.4 Wastewater Flooding/Overflows

Flooding from the wastewater network is predicted (and in some cases verified) to occur during rainfall events as small as a 1 in 2 yr ARI with the effects becoming worse during a 1 in 10 yr ARI event. This is mainly due to insufficient network capacity resulting from dry weather groundwater infiltration during dry weather contributing to baseflows, wet weather I&I and WWTP capacity and operation.

Flooding/overflows from the network is predicted in the following locations:

- Catchment-wide – 1 % of all manholes predicted to overflow (unconfirmed);
- Catchment-wide – private property gully trap/boundary trap overflows;
- Tyne Street/Silverstream Drive - manhole overflows;
- Woodland Avenue wastewater PS - manhole overflow; and
- WWTP emergency overflow to the Silver Stream – predicted to operate during a 1 in 5 yr ARI rainfall event.

9.1.5 Flood Hazard

The model predicts that during a 1 in 100 yr ARI rainfall event the maximum flood hazard rating for the catchment is 'moderate to significant' due to deep ponding affecting in particular Kinmont Crescent, Woodland Avenue and Gladstone Road North. With the extreme climate change scenario applied to the model there is an increase in the extent of flooding and locations with a 'moderate to significant' Rating. However, it is unlikely that major transport routes will be adversely affected but some residential roads may become inundated with relatively shallow (<300 mm) flood depths.

9.1.6 Fluvial Flood Risk

Historic flooding has occurred from the lower reaches of the Quarry Creek, and has been reported to have occurred at least annually in recent years. Significant effects are observed when this happens including road closure and disruption to a pre-school in the vicinity. This is considered to be caused by insufficient channel capacity and exacerbated by poor watercourse management.

Studies completed to date predict that the Silver Stream presents a flood risk to the urban area of Mosgiel, to the west of the catchment during rainfall events of between a 1 in 10 yr and 1 in 50 yr ARI.

Studies also indicate that the Owhiro Stream may present a flood risk to urban Mosgiel during rainfall events of 1 in 50 yr ARI or greater.



9.1.7 Stormwater Network Maintenance

City-wide inconsistencies in frequency and standards of cleaning and maintenance of stormwater structures (inlets and catchpits) can lead to discrepancies in levels of service. This has the potential to exacerbate or transfer flooding.

Maintenance of stormwater structures is critical to optimal operation of the hydraulic network. Key structures within the catchment have been highlighted, of particular importance are those where no overland flow path exists and blockage could result in habitable floor flooding. These include the Woodland Avenue intake; Reid Avenue swale; Kinmont Crescent/State Highway culvert; and Carlyle Road PS inlet screen.

9.1.8 Stormwater Pump Station Failure

Significant flooding within the catchment is predicted should the stormwater PSs fail, for example due to power cut, during a significant rainfall event such as that experienced during May 2010.

Failure of any one of the PSs, Cherry Drive, Reid Avenue or Carlyle Road, would cause flows to back up in the stormwater network and cause wide-spread flooding including overland flow and deep ponding in the low lying areas in the vicinity. This would pose a risk to habitable floor flooding of a number of properties and may cause traffic disruptions should roads become flooded across their full width.

9.1.9 Wastewater Network Maintenance

There is a risk of blockages in the wastewater pipe network due to the flat nature of the catchment, resulting in decreased network capacity. An understanding and regular cleaning/maintenance of problem areas would significantly reduce this risk.

9.2 Quality Issues

9.2.1 Ongoing Stormwater Discharge

In general, the monitoring results indicate that the stormwater quality discharged from the Mosgiel catchment is largely typical of urban, mixed land use catchments with some contaminants slightly elevated in certain samples.

The stormwater quality data is fragmented with a large percentage being relatively dated (2004, 2005). It is therefore difficult to establish with any certainty current contaminant levels or to ascertain and stormwater quality trends over time.

There is uncertainty surrounding the sources of microbial and nutrient input into the Silver Stream. However, at present, the data does not indicate that the stormwater discharges are having an obvious adverse effect on the receiving environment but there is limited confidence in this information. Further data is required to validate this.



9.2.2 Potential Wastewater Contamination of Stormwater

The ORC monitoring results, from 2004 and 2005, indicate microbial contamination in the stormwater discharged from the Titri Place outfall at levels at or above the level typical of stormwater. This may indicate wastewater contamination of the stormwater from the northernmost part of the catchment.

There is little evidence to suggest wastewater ingress into the stormwater system in this location and the more likely source is runoff from rural land use. It is likely however, that wastewater enters the stormwater in other parts of the catchment where wastewater flooding is predicted. For example, stormwater flooding on Woodland Avenue is predicted to inundate the wastewater PS resulting in overflow of wastewater with a potential for stormwater contamination. The effects in this location have not been monitored

Given the uncertainty as to whether the microbial contamination is historic or persisting, that the sources of contamination remain unclear, and that wastewater in the stormwater discharge is in breach of permitted activity conditions within the Regional Plan: Water for Otago, this issue should be investigated further.

9.2.3 Wastewater Emergency Overflow

The WWTP emergency overflow is predicted to operate in rainfall events of 1 in 5 yr ARI or greater, with screened (but not necessarily treated) wastewater discharging to the Silver Stream.

Whilst the discharge is not considered to be having a significant adverse effect on the watercourse, due to significant dilution that will take place instream, the frequent operation of this overflow does not allow DCC to meet its strategic objectives for wastewater management and is contrary to Māori cultural values.

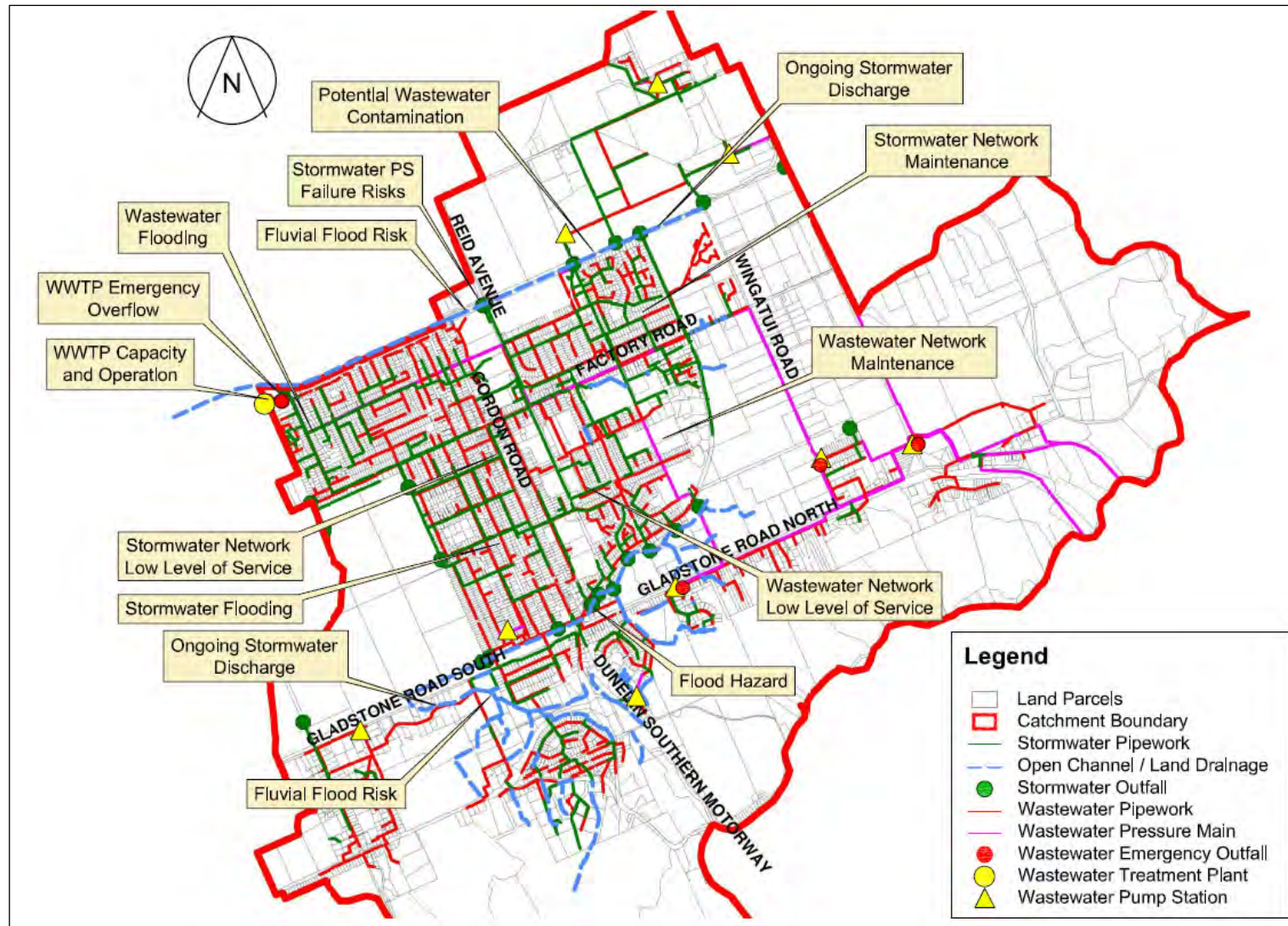


Figure 9-1: Mosgiel Catchment Issues



10 Issues Prioritisation

DCC have developed a decision making framework (refer Appendix F) in line with the New Zealand and Australian risk management framework AS/NZS 4360 to enable the comparison of issues and options. A Consequence and Likelihood rating has been applied to each of the issues identified to provide a risk matrix score, leading to a definition of problem management. Figure 10-1 below shows the risk matrix used in this scoring. Other information relating to definitions for Consequence and Likelihood are provided in the analysis of each issue, and the guidelines on this are provided in Appendix F.

Table 10-1 below provides a list of the main issues identified for the Mosgiel catchment, and a risk and consequence score for each, resulting in a 'Manage Passively' or 'Manage Actively' categorisation. The passive or active management categorisation then drives the catchment specific management approach for each issue, and later the options considered. Active management indicates that DCC will seek to implement changes to stormwater and wastewater management in the catchment, whereas passive management would tend more towards monitoring and review of existing management practices to ensure that the targets set can be met or clarification/confirmation of issues where significant uncertainty exists.

RISK LIKELIHOOD	CONSEQUENCE				
	Negligible (1)	Minor (10)	Moderate (40)	Major (70)	Catastrophic (100)
Almost Certain (5)	Low (5) Manage Passively	Moderate (50) Manage Passively	Very High (200) Manage Actively	Extreme (350) Manage Actively	Extreme (500) Manage Actively
Likely (4)	Low (4) Manage Passively	Moderate (40) Manage Passively	Very High (160) Manage Actively	Very High (280) Manage Actively	Extreme (400) Manage Actively
Possible (3)	Negligible (3) Manage Passively	Moderate (30) Manage Passively	High (120) Manage Actively	Very High (210) Manage Actively	Very High (300) Manage Actively
Unlikely (2)	Negligible (2) Accept	Low (20) Manage Passively	High (80) Manage Actively	High (140) Manage Actively	Very High (200) Manage Actively
Rare (1)	Negligible (1) Accept	Low (10) Accept	Moderate (40) Manage Passively	High (70) Manage Actively	High (100) Manage Actively
Note The Risk Matrix includes an indication of the minimum acceptable treatment strategy. In all cases the option of avoiding the risk should be considered first.					

Figure 10-1: Risk/Consequence Matrix for Issues Prioritisation



Table 10-1: Issues Prioritisation

Issue	Consequence Rating	Likelihood Rating	Discussion	Risk Matrix Score	Management Approach
Fluvial Flood Risk	70	3	It is outside the scope of this Management Plan to manage fluvial flooding. However, significant fluvial flood risk occurs in the catchment from the three largest watercourses and therefore management is necessary. Risk predicted to be during events of 1 in 10 yr ARI and greater. Road closures, disruption to the community, potential habitable floor flooding and risk to public health and safety known to occur. Level of flood protection set to rural standards in areas now significantly developed. Risks increased in the future with further catchment development and climate change.	210	Manage Actively
Stormwater & Wastewater Flooding- Woodland Avenue	40	5	Deep flooding predicted and verified during 30 minute events of 1 in 2 yr ARI and greater with a risk to habitable floor flooding of one property, rising to two properties during a future 30 minute 1 in 10 yr ARI event. Development of adjacent land may increase habitable floor flooding risk. Stormwater flooding, during events of 1 in 5 yr ARI and greater, is predicted to inundate wastewater PS in this location resulting in wastewater overflows. Wastewater overflows present potential public health risk. Flood extents and overflows become worse during longer duration rainfall events and when future scenarios are applied to the model. Combined effects are considered significant.	200	Manage Actively



Issue	Consequence Rating	Likelihood Rating	Discussion	Risk Matrix Score	Management Approach
Wastewater Flooding/Overflows	40	5	Wastewater manhole overflows predicted during events as small as a 1 in 2 yr ARI, 1 % of all manholes in catchment predicted to overflow during a 1 in 10 yr ARI. Overflows on Tyne Street/Silverstream Drive verified. 2.4 % of manholes predicted to overflow in future 1 in 10 yr ARI event Overflows from WWTP to Silver Stream predicted to operate during events of 1 in 5 yr ARI and greater. Prior to 2010 operation was approximately yearly. Overflows result from insufficient network capacity. I&I and WWTP operation contribute to capacity problems which result in the predicted overflows. Overflows are contrary to DCC Strategic Objectives, major stakeholder issue, resource consent implications.	200	Manage Actively
Potential Wastewater Contamination	40	4	Limited monitoring results and model predictions indicate potential wastewater contamination of stormwater in two locations. Uncertainty whether historic or persisting. Major stakeholder issue and risk to public health and safety where wastewater contamination of stormwater flooding may occur.	200	Manage Actively
Stormwater Flooding (Nuisance) – Catchment-Wide	40	4	Widespread nuisance flooding predicted during events of 1 in 2 yr ARI and greater. Effects may be minor in many cases, and uncertainty relating to flow paths across properties etc. Effects considered unacceptable by community thus elevating the consequence rating of this issue.	160	Manage Actively
WWTP Emergency Overflow	40	4	Overflow from WWTP to Silver Stream predicted to operate during events of 1 in 5 yr ARI and greater. High flows in receiving environment during operation results in significant dilution. No evidence to date to suggest detrimental effects on receiving environment. Major Stakeholder issue.	160	Manage Actively



Issue	Consequence Rating	Likelihood Rating	Discussion	Risk Matrix Score	Management Approach
Stormwater Flooding - Gow Street/McGlashan Street/Gladstone Road South	40	3	Nuisance flooding with minor effects predicted during a 30 minute storm event of up to 1 in 50 yr ARI. However, during longer duration events (12 hours), due to backwater effect of the Quarry Creek, deep flooding is predicted during a 1 in 10 yr ARI event posing a risk to habitable floor flooding of approximately four light industrial properties. Customer complaints indicate businesses have been subject to flooding in this location in the past. Flooding during longer duration events is likely to worsen during rainfalls of increasing ARI and in the future.	120	Manage Actively
Stormwater Flooding - Kinmont Crescent	40	3	Deep flooding is predicted during a 1 in 5 yr ARI event posing a risk to habitable floor flooding of one property. Three properties predicted to be at risk during a 1 in 50 yr ARI event. Corresponding complaints for this location. Properties at risk rises to five when future land use scenarios and climate change projections are applied during a 1 in 50 yr ARI event.	120	Manage Actively
Stormwater Flooding – Reid Avenue Swale	40	2	Community reports that swale is prone to flooding at least every year. The model predicts that longer duration rainfall events (24 hrs) result in the worst case flooding effects from the Reid Avenue swale. During a 1 in 10 yr ARI event (24 hrs), significant flooding and overland flow is predicted with flooding across the full width of local roads and a risk of habitable floors of approximately five properties. This would be further exacerbated should the swale inlets and outlets be partially blocked with debris.	80	Manage Actively
Stormwater Flooding – Gordon Road	40	2	Deep flooding is predicted during a 1 in 5 yr ARI event on Gordon Road, posing a risk to habitable floors with nuisance flooding also occurring on Lanark Street. Known problem area in the past but recent training works may have alleviated the problems. Uncertainty regarding the ongoing flooding effects during smaller events. During a 1 in 50 yr ARI event, extent of deep ponding on Gordon Street increases and also occurs on Lanark Street, worsened further with future land use scenarios and climate change projections.	80	Manage Actively



Issue	Consequence Rating	Likelihood Rating	Discussion	Risk Matrix Score	Management Approach
Stormwater Network Maintenance	10	5	Inconsistencies in frequency and standards of cleaning and maintenance of stormwater structures. Potential to exacerbate flooding effects.	50	Manage Passively
Wastewater Network Maintenance	10	5	High risk of blockages in pipe network due to flat catchment and low flow velocities. Maintenance/cleaning currently on an ad hoc basis only when blockages give rise to adverse effects (overflows etc.). Historic complaints reporting not sufficiently robust to allow incidents to be recorded against assets. Problem/blockage prone areas therefore currently unrecorded.	50	Manage Passively
Ongoing Stormwater Discharges	10	5	Ongoing discharge of stormwater (and associated contaminants) to the catchment watercourses. The extent of contamination is unconfirmed, but available data indicates that contaminants discharged are typical of land use, and the consequences are minor. Lack of historic/temporal data.	50	Manage Passively
Wastewater Flooding – Private Property Boundary/Gully Traps	10	4	Customer complaints relating to gully trap or boundary trap overflows, not DCC assets. Rainfall event during which this occurs unknown. May be due to isolated incidents/blockages or surcharging of the network causing flows to back up.	40	Manage Passively
Low Level of Service – Stormwater Network	10	4	Current level of service is predicted to be between a 1 in 2 yr and 1 in 5 yr ARI event. This is below DCC's target for new infrastructure as a result of network capacity. Approximately 71 % of the network can convey a 1 in 10 yr ARI rainfall event, in those parts of the catchment unable to convey this event adverse effects are predicted in some cases. Options to manage the effects of low level of service will also be addressed under the stormwater flooding issues. Effects of low level of service are predicted to be exacerbated by climate change. Adaptation is required to meet long term objectives. The ROS indicates that > 60 % of residents are satisfied/very satisfied with the stormwater service.	40	Manage Passively



Issue	Consequence Rating	Likelihood Rating	Discussion	Risk Matrix Score	Management Approach
Low Level of Service – Wastewater Network	10	4	Current level of service does not meet DCC Strategic Objectives or targets for new infrastructure. There is sufficient network capacity during dry weather but during a 1 in 10 yr ARI rainfall event widespread surcharging of the pipe network occurs resulting in wastewater overflows. The ROS indicates that 65 % of residents are satisfied/very satisfied with the stormwater service. Options to manage the effects of low level of service will be set under the catchment-wastewater flooding and overflow issues. Effects of low level of service are a key issue for stakeholders.	40	Manage Passively
Stormwater PS Failure Risk	40	1	Significant deep flood risk should stormwater PS failure occur, for example due to power outage. Effects predicted to be significant during longer duration events of greater than a 1 in 10 yr ARI events becoming worse with greater/prolonged rainfall events. Likelihood rating is low as the risk is present only when PS failure occurs during a rainfall event.	40	Manage Passively
Stormwater Flooding - Gladstone Road North	10	4	Deep flooding is predicted during events as small as a 1 in 2 yr ARI in the vicinity of the railway culvert. Uncertainty exists relating to the severity of effects. Flows are predicted to backup in an open channel which runs through two properties. It is unknown however, whether the open channel has the capacity to retain the flows or whether the properties are at risk of habitable floor flooding. No historic complaints exist. Deep flooding is predicted to become worse in the future. Consequence rating reflects uncertainty of effects.	40	Manage Passively



Issue	Consequence Rating	Likelihood Rating	Discussion	Risk Matrix Score	Management Approach
Flood Hazard – 1 in 100 yr ARI	40	1	Areas of moderate to significant flood hazard currently in roadways. Deep flooding predicted in locations within the catchment under current conditions. Future extreme climate change effects pose further threat. It is predicted that by 2060 during extreme weather there will be a moderate to significant hazard across a larger extent of the catchment. The extent of the threat is uncertain as there is unknown certainty around climate change predictions.	40	Manage Passively



11 Catchment Specific Targets and Approaches for Network Management

Figure 11-1 below provides a breakdown of the link between network management issues identification, objectives development and the setting of targets.

The information presented in the assessment of environmental effects (AEE) section of this report has been used to identify the key network management issues for stormwater and wastewater in the Mosgiel catchment. These issues have been prioritised and ranked, according to DCC's risk matrix, which looks at the consequence and likelihood of each issue.

For each issue, DCC's commitment (in terms of strategic objectives) will be examined, and a catchment specific approach outlined depending on both the strategic objectives, and the issue's priority. SMART targets are then set to guide the design of options, and also to measure the success of the catchment management approach.

Following this section, network management options are developed to ensure targets are met.

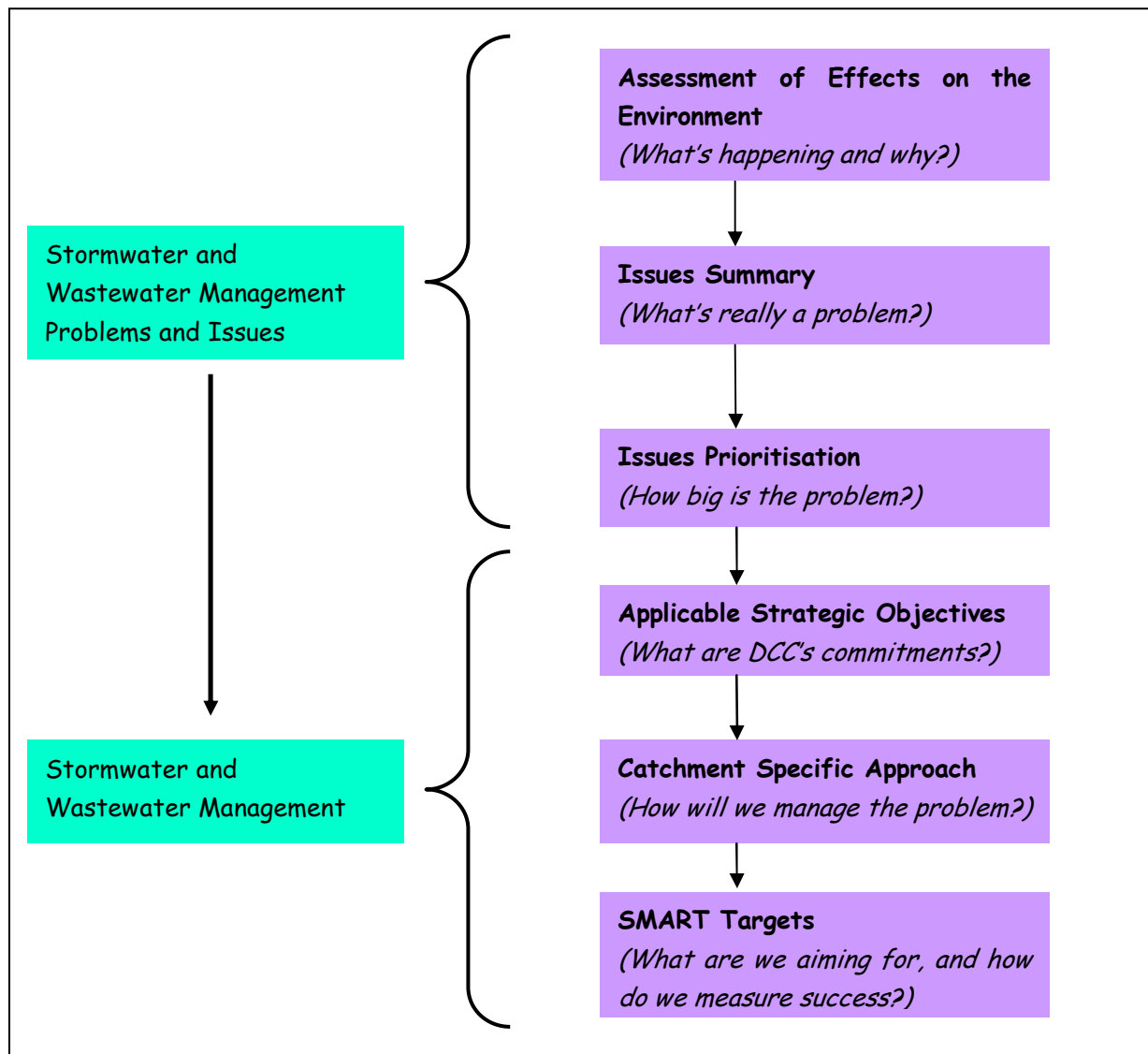


Figure 11-1: Target Development Process



Management approaches and targets are essential for providing information to ensure appropriate funding is made available for stormwater and wastewater management, and that the management options implemented provide the best value for money to the community. A number of other ICMPs have been prepared by DCC (for stormwater outfalls discharging to the harbour), and similar targets have been developed for these ICMPs, and ultimately, issues prioritisation will be used to compare and prioritise recommendations across the catchments.

The catchment specific management approaches are driven by the issues prioritisation, and strongly focused on the applicable long term (50 year) strategic objectives, outlined in Section 2. They provide guidance for options development in terms of a broad management approach for each issue, specific to the catchment.

Stormwater and wastewater 'SMART' targets are an important tool for DCC; these follow a set of guidelines to ensure that they are well-defined and attainable, as outlined below:

- **Specific** – well defined and clear targets, able to be understood;
- **Measurable** – to provide feedback to continually improve performance;
- **Achievable** – to ensure success;
- **Realistic** – within available resources, knowledge and time; and
- **Time-Bound** – to monitor progress on a number of timescales, and ensure time is available to achieve the goals.

Targets relate to both long and short term objectives outlined in Section 2, depending on the issue. For example, they may refer to maintenance of a certain level of service for the network, or commitments to minimise adverse effects on the receiving environment where appropriate. The assessment of environmental effects also guides the setting of targets. As some targets may be linked to monitoring information (e.g. stormwater quality), it is essential that these targets are open to review and adjustment over time.

Tables 11-1 and 11-2 outline catchment specific approaches and SMART targets for each of the key stormwater and wastewater issues identified in the Mosgiel catchment. These are discussed further in the following sections.

11.1 Quantity Targets and Approaches

Table 11-1 presents a summary of the key quantity effects and catchment specific targets set for stormwater and wastewater management in the Mosgiel catchment. Approaches and targets developed for 'active' and 'passive' management of quantity issues in the catchment are discussed in more detail below.

11.1.1 Fluvial Flood Risk

Studies to date indicate that the Mosgiel catchment is at risk of fluvial flooding from the three main watercourses flowing through the catchment, Silver Stream, Owhiro Creek and Quarry Creek. Depending on the watercourse and catchment location, flood risk is predicted during rainfall events as small as a 1 in 10 yr ARI. In some cases fluvial flooding has been observed in the past, and in



the case of the Quarry Creek, has been recorded at least annually in recent years suggesting that flooding may occur during events smaller than a 1 in 10 yr ARI.

Whilst it is outside the scope of this ICMP to manage the risks of fluvial flooding, this issue has been prioritised for 'active' management due to predicted and observed effects. Targets and approaches have been set to enable DCC to work towards a satisfactory outcome within the catchment in terms of fluvial flood risk.

It is not the responsibility of DCC to manage the watercourses or associated flood defences and satisfactory outcomes for the Mosgiel catchment will require inputs from the Regional Council. However, the information within this ICMP will enable DCC to ensure areas of new development are adequately protected from flood risk.

However, targets and approaches that have been set for this issue focus on the protection of properties against internal flooding during 1 in 100 yr ARI rainfall events, through adequate planning and development controls.

11.1.2 Stormwater Flooding

Stormwater flooding has been prioritised as a 'Manage Actively' issue due to the adverse effects predicted to occur. Flooding from the stormwater network occurs during events as small as a 1 in 2 yr ARI event and, in a number of locations is predicted to be deep (> 300 mm). Flooding from the network is predicted to cause significant effects in the following locations:

- Catchment-wide;
- Gordon Road/Lanark Street;
- Kinmont Crescent;
- Gow Street/McGlashan Street/Gladstone Road South;
- Woodland Avenue;
- Reid Avenue Swale; and
- Gladstone Road North.

Stormwater flooding in the catchment is a result of insufficient network capacity and therefore low level of service of the network. The flooding poses a risk to habitable floors; is predicted to inundate the wastewater network causing wastewater overflows, may pose a risk to public health and safety where ponding is predicted to be deep, and is considered to be unacceptable by the local community.

The model predicts that 10 land parcels in the Mosgiel catchment are estimated to be currently at risk of flood depths exceeding 300 mm during a current 1 in 10 yr ARI rainfall event, rising to 22 during a 1 in 50 yr ARI rainfall event. Deep flooding predicted during the current 1 in 100 yr ARI rainfall event is estimated to increase the depth and extent of flooding in already identified flood areas and affect 29 properties.



Targets and approaches for this particular issue provide consistency with the Building Act (which requires that habitable floors (or 'useful floor space' in relation to non-residential properties) should not be at risk of flooding during a 1 in 50 yr rainfall event); Dunedin Code of Subdivision and Development; and are aligned with objectives of the 3 Waters Strategy. They will seek to ensure that new stormwater network components are designed to a 1 in 10 yr ARI level of service; that habitable floor flooding is avoided under both current and future land use and climate change scenarios and that any increases in surface flooding of private properties are avoided during events up to and including a 1 in 50 yr ARI. They will also seek to reduce wastewater overflows resulting from network capacity problems.

It should be noted that DCC's targets are focused on avoiding habitable floor, or significant private property flooding. 'Land parcels' and 'properties' are both used to provide information within this ICMP. The model results only provide information in terms of 'land parcels'. Therefore actual numbers of properties / premises at risk is likely to be less than the number of land parcels reported. However, the modelled flood extents and analysis of aerial photographs do indicate that flooding has the potential to enter buildings in some cases. This is also confirmed by workshop discussions and customer complaints records.

11.1.3 Wastewater Flooding/Overflows

Wastewater overflows/flooding has been prioritised as a 'Manage Actively' issue due to the adverse effects predicted to occur. Overflows from the wastewater network occur during events as small as a 1 in 2 yr ARI event, mainly due to insufficient system capacity resulting from combined influence of elevated DWF, wet weather I&I and WWTP operation.

Overflows from the network are predicted in the following locations:

- Catchment-wide – 1 % of all manholes predicted to overflow (unconfirmed);
- Catchment-wide – private property gully trap/boundary trap overflows;
- Tyne Street/Silverstream Drive – confirmed manhole overflows;
- Woodland Avenue PS - manhole overflow; and
- WWTP emergency overflow to the Silver Stream.

Overflows from the wastewater network are a key stakeholder issue, pose a health risk to the public, may result in adverse environmental effects (where mixing with stormwater or discharging direct to the environment) and are contrary to DCC's Strategic Objectives.

Targets and approaches for this particular issue provide consistency with the Building Act and the Dunedin Code of Subdivision and Development, and are aligned with the Strategic Objectives of the 3 Waters Strategy. They will seek to reduce wastewater overflows resulting from network capacity problems, ensure that the risk of residential or commercial properties at risk of wastewater flooding does not increase into the future and ensure investment in renewals is adequate to maintain infrastructure performance.



11.1.4 Stormwater Network Maintenance

The maintenance and cleaning of catchpits and other stormwater structures is an essential part of maximising the efficiency and level of service of the stormwater network. As the owners of the network, DCC need to be certain that the asset is being maintained appropriately. The task of maintaining stormwater inlet assets is currently split between three DCC departments, and one national authority. Contracts for maintenance of catchpits and inlet structures have some differences in terms of performance criteria.

There would be benefit in identifying key assets as part of the catchment management process in order to focus maintenance and cleaning efforts further. Key structures that have been identified in the ICMP process are those with no overland flow path for stormwater flooding or where blockages could result in worsening of flooding effects. These include:

- Woodland Avenue intake;
- Reid Avenue swale;
- Kinmont Crescent/State Highway culvert;
- Carlyle Road PS inlet screens; and
- All stormwater network outfall flap valves.

The approaches and targets set for this issue require the development of an understanding of the current level of maintenance and cleaning, and then, where required, changes in order to focus efforts on key structures and optimise efficiency of the stormwater network.

11.1.5 Wastewater Network Maintenance

There is a relatively high risk of silt build up and blockages in the pipe network due to the flat nature of the catchment and low flow velocities. Blockages can significantly reduce the capacity of the network and therefore reduce efficiency and may contribute to wastewater overflows.

Maintenance/cleaning of the wastewater network is currently undertaken on an ad hoc basis, when problems arise. Historic reporting procedures have been insufficiently robust to enable problems to be recorded against a specific asset.

The approaches and targets set for this issue seek to improve the identification of problem locations/assets and where required, make changes to assign more regular cleaning in order to optimise network efficiency.

11.1.6 Level of Service – Stormwater Network

The current level of service of the stormwater network, in some parts of the catchment, is below DCC's target for new infrastructure, primarily as a result of inadequate network capacity, with some boundary influence from watercourses. The model predicts that 71 % of the network has the ability to accept rainfall from a 30 minute, 1 in 10 yr ARI event.



Historical data collection methods used for logging customer complaints have resulted in variable information on complaints. Improvements that have recently been made in complaints recording will result in a clearer picture of customer satisfaction in the future. The Residents Opinion Survey (ROS) has been running in its current format since 2003, and gauges Dunedin City residents' overall satisfaction with the stormwater collection service, amongst other council services. The Mosgiel catchment lies within the 'Mosgiel' group of this survey. The results of the 2011 survey indicate that 61 % of respondents were either 'very satisfied' or 'satisfied' with the stormwater collection service. As such this issue has been prioritised for 'Passive Management'. Specific targets, options and recommendations, for each of the effects resulting from the low level of service, are addressed individually under the stormwater flooding issues.

The recommended targets and approaches with respect to the level of service of the stormwater network focus on improving the existing level of service under current and future development and climate change scenarios. The strategic direction provided by the 3 Waters Strategic Direction Statement indicates that the main objective with respect to flooding is to ensure that the risk of flooding does not increase in the future as development occurs, or as climate change alters weather patterns. Therefore DCC will adopt a long term approach to improving network performance and adapting to climate change by ensuring that all new network components (for example, planned pipe renewals, or upgrades in specific locations) are designed to a 1 in 10 yr ARI level of service, using conservative design storms that incorporate projected changes in rainfall intensity, coupled with conservative watercourse boundary conditions. This is consistent with the Dunedin Code of Subdivision and Development, and also with the Building Act.

11.1.7 Level of Service – Wastewater Network

The current level of service of the wastewater network, in a large percentage of the catchment, does not meet DCC's performance objectives for wastewater level of service. It is also contrary to DCC's target of 'no wastewater overflows during events of 1 in 10 yr ARI or greater'.

The low level of service is due to a number of factors, predominantly I&I, which leads to capacity problems in the pipe network and the Mosgiel WWTP which results in wastewater overflows from the system. The model predicts that 1 % of manholes will overflow during a 24 hr, 1 in 10 yr ARI event and that the WWTP emergency overflow will operate during a 1 in 5 yr ARI. The model also predicts that during wet weather, there is no capacity within the system to accommodate future growth and climatic changes.

Historical data collection methods used for logging customer complaints have resulted in variable information on complaints. Improvements that have recently been made in complaints recording will result in a clearer picture of customer satisfaction in the future. The ROS has been running in its current format since 2003, and gauges Dunedin City residents' overall satisfaction with the city's sewerage system, amongst other council services. The Mosgiel catchment lies within the 'Mosgiel' group of this survey. The results of the 2011 survey indicate that 65 % of respondents were either 'very satisfied' or 'satisfied' with the sewerage system. As such this issue has been prioritised for 'passive management'. Specific targets, options and recommendations, for each of the effects resulting from the low level of service, are addressed individually under the wastewater flooding/overflow issues.

The recommended targets and approaches with respect to the level of service of the wastewater network focus on improving the existing level of service under current and future growth and climate



change scenarios. The strategic direction provided by the 3 Waters Strategic Direction Statement indicates that DCC are committed to ensuring that key service levels are maintained into the future and that the three waters networks are able to adapt to population fluctuations and climate change. Therefore, in addition to addressing specific wastewater issues (as described above), DCC will adopt a long term approach to improving network performance and adapting to climate change by ensuring that all new network components (for example, planned pipe renewals, or upgrades in specific locations) are designed to be consistent with the Building Act and “capable of carrying and treating the peak flows anticipated during the economic lifecycle of the system, with due allowance for ground and surface water inflow and infiltration” as described in the Dunedin Code of Subdivision and Development.

11.1.8 Stormwater PS Failure Risk

Failure in the operation of one of the stormwater PSs in the catchment presents a significant flood risk during longer duration rainfall events of greater than a 1 in 10 yr ARI. These are:

- Cherry Drive;
- Reid Avenue; and
- Carlyle Road.

Should any one of the three PSs fail during rainfall, for example due to a power outage, then widespread nuisance flooding, overland flows and deep flooding is predicted with numerous properties at risk of habitable floor flooding.

This issue has been prioritised for passive management only. This is because, whilst the effects are predicted to be significant, they are unlikely to occur with each rainfall event of greater than 1 in 10 yr occurs. The risk of a PS failure due to power failure is more likely to occur during rainfall events more severe than a 1 in 10 yr event.

The approaches and targets for this issue therefore, focus on DCC managing the risk of the PS failure and being prepared for this situation should it occur to avoid the predicted effects.

11.1.9 Flood Hazard (Current and Future)

Flood hazard is predicted to occur in the Mosgiel catchment as a result of the extent and depths of flooding in certain locations. A flood hazard rating of ‘Moderate to Significant’ is predicted to occur during a current 1 in 100 yr ARI rainfall event. This is predominantly due to insufficient capacity of the stormwater network, with some effect from watercourse boundary conditions. Stormwater flooding is predicted to pond in the low points of the predominantly flat catchment, affecting local roads and commercial and residential areas.

As the flood hazard is predicted to increase in the future, due to the timeframe of the extreme climate change scenario (2060), it is appropriate that the potential effects of climate change on this catchment be considered by the DCC's Climate Change Adaptation Plan (currently being developed).


Table 11-1: Mosgiel Catchment Management Targets – Quantity

Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Fluvial Flood Risk	Quarry Creek recorded to flood at least annually. Modelling predicts significant flood effects during a 1 in 10 yr ARI. Silver Stream predicted to flood, with a risk to urban Mosgiel, during current events of between a 1 in 10 yr and 1 in 50 yr ARI. Owhiro Stream predicted to flood, with a risk to urban part of the catchment, during current events of 1 in 50 yr ARI and greater. Current level of fluvial flood protection in Mosgiel to a rural standard only.	Ensure there will be no increase in the numbers of properties at risk of flooding	Manage Actively Ensure adequate planning controls so new development is not at risk of fluvial flooding during events up to and including 1 in 100 yr ARI. Avoid development of vulnerable sties / critical infrastructure in flood risk areas. Educate property owners to ensure private sections of watercourses are properly managed/maintained.	Develop adequate planning controls to reduce the risk of fluvial flooding to new development. No new development is at risk of interior flooding during events up to a 1 in 100 yr ARI.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Stormwater Flooding - Catchment-wide; - Gordon Road/Lanark Street; - Kinmont Crescent; - Gow Street/McGlashan Street etc. - Woodland Avenue; - Reid Avenue Swale; and - Gladstone Road.	During events as small as a 1 in 2 yr ARI, widespread nuisance flooding is predicted affecting approximately 0.07 % of the catchment, rising to 0.3 % during a 1 in 10 yr ARI. Effects are considered unacceptable to the local community. Deep flooding is also predicted in a number of isolated locations during high frequency events with a potential risk to building interiors. Catchment wide, modelling predicts approximately 10 parcels affected by deep flooding during 1 in 10 yr ARI rainfall event; rising to 22 during a current 1 in 50 yr ARI event. Potential of stormwater flooding to inundate wastewater network and result in wastewater overflows.	Ensure new development provides a 1 in 10 year level of service for stormwater, and avoids habitable floor flooding during a 1 in 50 yr ARI rainfall event. Invest adequately in renewals to maintain the performance of stormwater infrastructure. Ensure there will be no increase in the numbers of properties at risk of flooding. > 60 % residents' satisfaction with the stormwater collection service.	Manage Actively Ensure no increase in the number of stormwater manholes predicted to overflow in a 1 in 10 yr ARI rainfall event. Design new pipes with capacity to convey a 1 in 10 year storm event. Reduce the number of properties predicted to flood during a current 1 in 10 yr ARI rainfall event. Ensure new development does not increase potential for habitable floor flooding in events up to a 1 in 50 yr ARI rainfall event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment. Enhance understanding of effects of deep flooding, particularly on private property. Undertake works where required to reduce flood effects.	> 29 of stormwater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. < 0.07 % of catchment surface area predicted to flood during a 1 in 2 yr ARI rainfall event by 2060. < 10 properties at risk of deep flooding (> 300 mm) during a 1 in 10 yr ARI rainfall event by 2060. Undertake habitable floor survey and/or damage assessment of potentially flooded properties. No stormwater inundation of the wastewater network by 2060. > 60 % resident's satisfaction with the stormwater collection service (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Wastewater Flooding - Unconfirmed manhole overflows - Private property gully trap/boundary trap overflows; - Tyne Street/Silverstream Drive manhole overflow - Woodland Avenue PS manhole overflow	Flooding from the wastewater network is predicted to occur during events as small as a 1 in 2 yr ARI event, due to insufficient system capacity resulting from combined influence of elevated DWF, wet weather I&I and WWTP operation. 1 % of manholes in the catchment predicted to occur during a current 1 in 10 yr ARI rainfall event, rising to 2.4 % with future growth and climate change applied. Historic customer complaints indicate private property boundary/gully trap overflows occurs within the catchment although the cause is uncertain. Stormwater inundation of the wastewater system may also result in overflows.	Reduce the number of wastewater overflows arising as a result of capacity. Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives. Invest adequately in renewals to maintain the performance of wastewater infrastructure. Ensure there will be no increase in the numbers of properties at risk of wastewater flooding, despite increasing pressure on the network. Service calls are responded to promptly. Wastewater is managed without risk to public health. > 65 % residents' satisfaction with the sewerage system.	Manage Actively Improve existing level of service in the network. Ensure reduction in the number of wastewater overflows predicted during a 1 in 10 yr ARI rainfall event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment. Enhance understanding of effects of wastewater flooding, particularly on private property. Undertake works where required to reduce flood effects.	No wastewater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. > 63 % of wastewater pipes to convey a 1 in 10 yr ARI rainfall event by 2060. Ensure customer complaints recording highlights causes of any private property flooding issues and/or undertake site visits to confirm. > 65 % resident's satisfaction with the sewerage system (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Stormwater Network Maintenance	Flooding extents and durations in catchment potentially exacerbated by variations in the frequency and standards of cleaning and maintenance of stormwater structures (inlets and catchpits). City-wide inconsistencies in frequency and standards of cleaning and maintenance of stormwater structures can lead to discrepancies in level of service.	Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives.	Manage Passively Identify areas in catchment where more regular stormwater structure cleaning and maintenance could reduce flooding risk. Ensure consistency city-wide of stormwater structure cleaning and maintenance. Ensure cleaning and maintenance schedules and contracts are sufficiently robust.	Develop consistent cleaning and maintenance criteria for all stormwater assets (in conjunction with city-wide criteria) by 2013. Develop list of key stormwater assets in Mosgiel catchment requiring additional cleaning and maintenance by 2013. Document cleaning and maintenance responsibilities for catchment stormwater assets by 2013.
Wastewater Network Maintenance	High risk of blockages in pipe network due to flat catchment and low flow velocities. Blockage/partial blockages significantly reduce network capacity and increase the risk of overflow. Cleaning and maintenance of network currently carried out on ad hoc basis when problems arise.	Reduce the number of wastewater overflows arising as a result of capacity. Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives.	Manage Passively Identify areas in the network prone to blockage. Identify cleaning/maintenance requirements and frequency for pipes at higher risk of blockage. Ensure cleaning and maintenance schedules and contracts are sufficiently robust.	Ensure complaints and operational issues are reported with incident and asset details. Develop list of key areas of the wastewater network prone to blockage by 2013. Develop a cleaning and maintenance schedule for wastewater assets which require regular attention by 2013.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Low Level of Service – Stormwater Network	29 % of stormwater network cannot accept rainfall from a 1 in 10 yr ARI, primarily driven network capacity. This low level of service is currently occurring with no capacity for climate change effects. Effects include widespread nuisance flooding, deep flooding in isolated locations with risk of flooding of habitable floors and inundation of wastewater system causing overflows. Effects unacceptable to local community in some locations.	Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives. Ensure new development provides a 1 in 10 year level of service for stormwater, and avoids habitable floor flooding during a 1 in 50 yr ARI rainfall event. Invest adequately in renewals to maintain the performance of stormwater infrastructure. Ensure there will be no increase in the numbers of properties at risk of flooding. > 60 % residents' satisfaction with the stormwater collection service.	Manage Passively Improve existing level of service in network. Ensure no increase in the number of stormwater manholes predicted to overflow in a 1 in 10 yr ARI rainfall event. Design new pipes with capacity to convey a 1 in 10 year storm event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment.	<0.07 % of catchment surface area predicted to flood during a future 1 in 2 yr ARI rainfall event. < 29 % stormwater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event by 2060. Undertake survey of property owners to determine any occurrence of flooding on properties during high frequency events. > 60 % resident's satisfaction with the stormwater collection service (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Low Level of Service – Wastewater Network	1 % of wastewater manholes predicted to overflow during a 1 in 10 yr ARI. WWTP emergency overflow predicted to operate during a 1 in 5 yr ARI rainfall event. Effects driven by network capacity problems resulting from combined influence of elevated DWF, wet weather I&I and WWTP operation. This low level of service is currently occurring with no capacity for future growth or climate change effects. Effects include widespread network surcharging, overflows from manholes and private property boundary/gully traps, emergency overflow operation.	The extent of the reticulated network meets community needs. Reduce the number of wastewater overflows arising as a result of capacity. Maintain key levels of service into the future by adapting to climate change and fluctuations in population, while meeting all other objectives. Invest adequately in renewals to maintain the performance of wastewater infrastructure. Ensure there will be no increase in the numbers of properties at risk of wastewater flooding, despite increasing pressure on the network. > 65 % residents' satisfaction with the sewerage system.	Manage Passively Improve existing level of service in the network. Ensure reduction in the number of wastewater overflows predicted during a 1 in 10 yr ARI rainfall event. Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment.	No wastewater manholes predicted to overflow during a 1 in 10 yr ARI rainfall event. No occurrence of WWTP emergency overflow during events if 1 in 10 yr ARI or less by 2060. > 63 % of wastewater pipes to convey a 1 in 10 yr ARI rainfall event by 2060. > 65 % resident's satisfaction with the sewerage system (ongoing).



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Flood Hazard (1 in 100 yr ARI)	Areas of moderate to significant flood hazard are predicted during current event affecting local roads and commercial and residential areas. Extent of 'moderate to significant' flood hazard predicted to increase in the future (2060) event exacerbated by predicted climate change effects.	Ensure there will be no increase in the numbers of properties at risk of flooding from the stormwater network.	Manage Passively Ensure new development does not increase the number of properties predicted to flood due to the stormwater system in a 1 in 100 yr ARI rainfall event. Protect key and vulnerable infrastructure (e.g. pump stations, works depots, schools, hospitals, electricity supply etc.) from flood hazard. Avoid development of vulnerable sites / critical infrastructure in flood prone areas. Develop a better understanding of the likely effects and magnitude of climate change.	Provide modelled flood predictions to DCC Climate Change Adaptation Group to ensure information is taken into account during the development of a city-wide climate change adaptation plan.



11.2 Quality Targets and Approaches

A summary of key quality effects, and catchment specific approaches and targets set for the Mosgiel catchment are presented in Table 11-2. The catchment specific approaches and targets are discussed further in the following sections.

It should be noted that the Regional Plan: Water for Otago (2001) sets out objectives and policies relating to the quality of freshwater resources in Otago. Objective 7.5.1 seeks *‘to maintain or enhance the quality of water in Otago’s lakes and rivers so that it is suitable to support their natural and human use values and people’s use of water’*.

Relevant policies within the Regional Plan: Water for Otago (2001) relate to both the enhancement of water quality and point source discharges. Policy 7.6.1 states that water quality in a number of water bodies should be enhanced so that they *“become suitable to support primary contact recreation.”* This policy includes the lower Silver Stream (below Riccarton Road).

The rules of the Regional Plan: Water for Otago (2001) allow for the discharge of stormwater from a reticulated stormwater system to water, as a permitted activity, with several provisions including:

- The discharge does not contain any human sewage; and
- The discharge does not cause flooding of any other person’s property, erosion, land instability, sedimentation or property damage; and
- The stormwater discharged, after reasonable mixing, does not give rise to all or any of the following effects in the receiving water:
 - The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials; or
 - Any conspicuous change in the colour or visual clarity; or
 - Any emission of objectionable odour; or
 - The rendering of fresh water unsuitable for consumption by farm animals; or
 - Any significant adverse effects on aquatic life.

11.1.1 Potential Wastewater Contamination of Stormwater

The stormwater monitoring results for the Mosgiel catchment show microbial contaminant levels within grab samples obtained in 2004 and 2005 from the Titri Place outfall to be at or above the upper level that is typical of urban stormwater. However, it is acknowledged that there is low confidence in the grab-sample data as it is historic and it is not known if these contaminant levels persist.

Furthermore, there are no known or predicted issues with the wastewater network in this part of the catchment and no customer complaints relate to this location. The potential source of contamination is therefore unknown and may be as a result of surrounding land use for livestock grazing. As such the level of threat remains inconclusive.

Further to the high microbial results in the stormwater discharge monitored, stormwater flooding in a different part of the catchment, on Woodland Avenue, is predicted to inundate the wastewater PS resulting in overflow of wastewater. The wastewater PS overflows may lead to contamination of the



stormwater. Whilst significant dilution is likely to take place, stormwater discharges from this sub-catchment have not been monitored therefore the likelihood and extent of contamination remains uncertain. Management approaches to this particular issue are also addressed under stormwater and wastewater quantity issues.

However, as stormwater discharges to watercourses are a permitted activity under the Regional Plan provided that they are free from wastewater contamination the extent of and potential source of microbial contamination should be investigated further to determine whether this is an historic or ongoing occurrence and ensure that the DCC stormwater discharges from the Mosgiel catchment meet the requirements of a permitted activity.

The approach and targets for this issue are related to reducing uncertainty in the data and effects, identifying the levels of microbial contaminants in the stormwater and investigating potential sources of any problems. This will ensure any management options in the catchment, should they be required, are developed appropriate to the issue.

11.1.2 WWTP Emergency Overflow Quality.

The WWTP emergency overflow is predicted to operate in rainfall events of 1 in 5 yr ARI or greater, with screened (but not necessarily treated) wastewater discharging to the Silver Stream. Prior to 2010 it was known to operate at approximately once per year, however recent installation of diesel pumps to increase flows to Green Island WWTP have reduced the frequency of overflow.

The discharge is not considered to be having a significant adverse effect on the watercourse, due to significant dilution that will take place instream, but the operation of this overflow does not allow DCC to meet strategic objectives for wastewater management (quantity) and discharge of wastewater to freshwater is a key stakeholder issue.

However, a reduction in overflow operation will reduce contaminants entering the watercourse and therefore provide a benefit to water quality.

The approach and targets for this issue are related to recording the instances of overflow to gain a clear understanding of conditions under which it operates. This will enable DCC to determine the management approaches for the WWTP overflow issue (both quality and quantity) are effective.

11.1.3 Ongoing Stormwater Discharge

The stormwater monitoring data analysed does not indicate that the levels of contaminants in stormwater from the Mosgiel catchment are significantly high, with the exception is relatively high microbial contamination which is addressed as a separate issue (Section 11.2.2). However, historic grab-sample results (2004, 2005) indicate slightly elevated levels of arsenic, copper and nickel in the stormwater.

However, it is acknowledged that there is low confidence in the data set as not all outfalls have been monitored, the grab-sample data is historic and the single time-proportional sample from one sub-catchment, whilst providing up to date information, is insufficient to give a clear indication of stormwater quality or trends over time. As such, this issue is prioritised as 'Manage Passively'.

The approaches and targets for the management of this issue focus on preventing the deterioration of stormwater quality from this catchment through adequate control of land use and high contaminant risk activities.



DCC is committed to ensuring that stormwater quality does not deteriorate as a result of new development or land use changes in the catchment. Examples of this include:

- Considering the cost and benefit of incorporating stormwater treatment into flood mitigation works where practicable.
- Requiring source control or management of stormwater contaminants in high contaminant generating land uses by enforcing the Trade Waste Bylaw and working to educate occupiers of high risk sites with respect to stormwater discharge quality.
- The Dunedin Code of Subdivision and Development indicates that at source management of stormwater is desirable and Low Impact Design (LID) methods are preferred.


Table 11-2: Mosgiel Catchment Management Targets: Quality

Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Potential Wastewater Contamination of Stormwater	Potential wastewater contamination of stormwater in 2 locations. Unknown whether potential contamination persists (Titri Place). Extent of contamination unknown (Woodland Avenue).	Improve the quality of stormwater discharges to minimise the impact on the environment. Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of stormwater discharges. Ensure stormwater discharge quality does not deteriorate.	Manage Actively Investigate potential catchment wastewater contamination. Incorporate a feedback process to the ICMP if / when monitoring indicates potential wastewater contamination.	Improve data relating to levels microbial contamination and potential sources within the catchment by 2013.
WWTP Emergency Overflow Quality	WWTP emergency overflow is predicted to operate in rainfall events of 1 in 5 yr ARI or greater. Prior to 2010 it was known to operate at approximately once per year. Discharge is not considered to be having a significant adverse effect on the watercourse. Key stakeholder issue.	Reduce the number of wastewater overflows arising as a result of capacity. Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of discharges.	Manage Actively Monitor operation of overflow to enable better understanding of triggers and frequency of operation.	No wastewater overflows due to capacity during a 1 in 10 yr ARI rainfall event. Ensure adequate recording of frequency of overflow operation by 2013.



Issue (Problem Description)	Effects Summary	Strategic Objectives & Targets	Catchment Specific Approach	SMART Targets
Ongoing Stormwater Discharge	Uncertainty regarding stormwater quality throughout catchment. Based on available data, consequence currently believed to be minor. Key stakeholder issue.	Improve the quality of stormwater discharges to minimise the impact on the environment. Adopt an integrated approach to water management which embraces the concept of kaitiakitaka and improves the quality of stormwater discharges. Ensure stormwater discharge quality does not deteriorate.	Manage Passively Consider the cost / benefit of stormwater quality treatment as part of flood mitigation works where practicable. Require source control of stormwater contaminants in new development of high- contaminant generating land uses. Enforce the Trade Waste Bylaw, and educate occupiers of high-risk sites with respect to stormwater discharge quality.	Identify locations of high risk land uses within the catchment and implement an education programme targeting stormwater discharges. No deterioration of stormwater quality due to land use change or development in the catchment.



12 Catchment Management Options

12.1 Introduction

Options are presented below to manage the stormwater issues identified in the Mosgiel catchment. Options are generally capital work options, planning options, or operation and maintenance tasks. These have been developed in line with issues prioritisation and catchment specific targets and approaches set in Section 11.

When considering the options available for each issue, options considered to be 'deal breakers' are eliminated from the options to be evaluated. Example definitions of deal breakers are as follows:

- Option must be technically feasible;
- Option must meet relevant legislative requirements;
- Option must be consistent with the principles of the Treaty of Waitangi;
- Option must be aligned with the catchment specific objectives developed in Section 11 of this document;
- Option must not have greater negative environmental, social or cultural consequences than the 'do nothing' option;
- Option should not contravene any explicitly stated political objective;
- Option should not result in an increase in the risk category; and
- Option should not increase health and safety risks compared with the 'do nothing' option.

'Active management' indicates that DCC will seek to implement changes to network management in the catchment, whereas 'passive management' would tend more towards monitoring and review of existing management practices to ensure that the targets set can be met.

This section puts forward a number of options (where more than one exists) for each issue identified in the catchment. Following the elimination of deal breakers, information on the options for network management is collated. The options identified for 'Manage Actively' issues are then evaluated against the Quadruple Bottom Line (QBL) evaluation criteria outlined in Section 13, with the most favourable management option selected.

Following the identification of options for each management issue, and options evaluation using QBL methodology, a prioritised programme of capital works and additional investigations recommended in the Mosgiel catchment is then developed.

The implementation of the programme is expected to progressively improve network management in the catchment as part of the wider 3 Waters Strategic Plan, which incorporates programming of the outcomes recommended in all ICMPs developed across the city.



12.2 Potential Options

Outlined below are preliminary options identified for the key stormwater management issues present in the catchment. Option 'deal breakers' are eliminated and feasible options are described in further detail. Where an issue has been prioritised as 'Manage Passively', management options are discussed in more general terms, although planning based options may be presented where applicable. Where an issue is prioritised as 'Manage Actively', where applicable, a number of alternative options will be considered for further evaluation. Detailed descriptions of the alternative options and options evaluation can be found in Section 13. Additional option information is presented in Appendix G where applicable.

12.2.1 Fluvial Flood Risk – Manage Actively

Whilst it is outside the scope of this Management Plan to assess in detail or manage fluvial flooding, it remains a significant issue within the Mosgiel catchment and as such is prioritised for active management. It is documented within this plan and recommendations have been provided to manage the current risks and allow appropriate management approaches to be developed in the future.

It is noted that it is not the responsibility of DCC to manage the watercourses or associated flood defences and satisfactory outcomes for the Mosgiel catchment will require inputs from the Regional Council also.

Studies to date indicate that the Mosgiel catchment is at risk of fluvial flooding from the three main watercourses flowing through the catchment; the Silver Stream, Owhiro Creek and Quarry Creek. Depending on the watercourse and catchment location, flood risk is predicted during rainfall events as small as a 1 in 10 yr ARI. In some cases fluvial flooding has been observed in the past, and in the case of the Quarry Creek, has been recorded at least annually in recent years suggesting that flooding may occur during events smaller than a 1 in 10 yr ARI.

The catchment specific targets and approaches identified for this issue are as follows:

- Develop adequate planning controls to reduce the risk of fluvial flooding to new development during rainfall events up to and including 1 in 100 yr ARI.
- Work with Regional Council to ensure appropriate level of watercourse flood protection is provided.
- Educate property owners to ensure private sections of watercourses are properly managed/maintained.

The recommendations made under the stormwater flooding issue in relation to improving knowledge of the hydraulics of the Quarry Creek will also assist with management of this issue.

12.2.2 Stormwater Flooding: – Manage Actively

Stormwater flooding has been prioritised as a 'Manage Actively' issue in this catchment due to the adverse effects predicted to occur in a number of locations.

There are a number of catchment specific approaches for the management of the stormwater flooding issue; these include:



- Improve existing level of service in network;
- Ensure no increase in the number of stormwater manholes predicted to overflow in a 1 in 10 yr ARI rainfall event;
- Reduce number of properties predicted to flood during a current 1 in 10 yr ARI rainfall event;
- Ensure new development provides a 1 in 10 yr ARI level of service and avoids habitable floor flooding during a 1 in 50 yr ARI event;
- Invest adequately in renewals to maintain the performance of stormwater infrastructure;
- Enhance understanding of effects of deep flooding, particularly on private property; and
- Undertake works where required to reduce flood effects.

The strategic direction provided by the 3 Waters Strategic Direction Statement indicates that the main objective with respect to flooding is to ensure that the risk of flooding from the stormwater system does not increase in the future as development occurs, or climate change alters weather patterns.

Rules set for future development in the Dunedin Code of Subdivision and Development will ensure that into the future, new or re-development of sites will include the provision of stormwater detention or conveyance up to a 1 in 10 yr ARI storm event. This, along with planned pipe renewals, will assist in reducing the risk of stormwater flooding in the catchment but is unlikely to resolve the specific stormwater flooding issues prioritised for active management.

As development occurs, or pipe renewals are undertaken, the level of service of parts of the network will gradually improve. The pipe renewal process includes inspection and condition assessment, and potentially extends the useful life of an asset beyond 100 years if it is in good condition. It should be noted that the pipe age in the Mosgiel catchment is uncertain in some areas due to missing/assumed historic data.

The following catchment wide recommendations are presented to manage stormwater flooding, they are not presented as alternatives, but rather to assist with both the renewals programme and the further design and development of management options for stormwater flooding in the catchment. It is anticipated that they would be carried out in conjunction with the stormwater flooding management options identified in the following sections.

Improve quality of Stormwater Network Data

There would be benefit in improving the quality of data relating to the stormwater network, particularly age and condition. To augment the information gathered during the city-wide CCTV inspection programme (in progress at the time of writing this plan), improvements in GIS asset data would be beneficial. It is recommended that this be implemented in ahead of the renewals programming to provide better data relating to those pipes where the age is uncertain to assist in renewals prioritisation.

**Include Additional or Improved Catchpits in any Capital Works**

By ensuring any future capital works carried out on the stormwater network include either additional or improved catchpits, there would be better utilisation of hydraulic capacity better enabling surface flows into the piped network.

However, due to the adverse effects predicted resulting from the low level of service, local upgrades as part of the pipe renewals process alone are unlikely to significantly improve the level of service in many parts of the catchment. However, options investigated to resolve stormwater flooding issues in the catchment in conjunction with the renewals process are likely to significantly improve the overall performance of the network.

Investigate Risk to Flooding of Property Interiors

To fully understand the flood risk to the interior of properties in the catchment, properties identified as being at risk could be subject to property owner questionnaires and building footprint confirmation to confirm historic interior flooding. Floor level surveys would also be required to determine whether flood depths of less than 300 mm would in fact enter the building during high frequency events. It is recommended that this be carried out prior to the detailed development of capital works.

A damage assessment of affected properties that are commercial or industrial in nature is often useful in terms of identifying vulnerable premises. This would involve a topographical survey of building floor levels, and a report on the use of the premises by the occupant, and value of stock and/or fittings that would potentially be damaged by a flood event of a certain depth. An assessment would need to be undertaken with every change of use of the premises and potentially could be a requirement of the property owner.

Improve Understanding of Quarry Creek

The stormwater network performance may be significantly influenced in several locations by the boundary effects of the Quarry Creek. This watercourse was modelled in a simplified manner for the purposes of this ICMP so confidence in model results relating to the hydraulics of the Quarry Creek is low. Investigations into the behaviour of Quarry Creek and its influence on the stormwater network is necessary in order to enable the development of optimal mitigation options for the flooding problems in the catchment.

As a minimum, a better understanding of channel capacity, flood plain/catchment hydrology and watercourse behaviour during rainfall events would be required and would probably require additional survey and modelling.

It should be noted that management of the watercourses in the catchment are outside the remit of the DCC. Any investigations therefore, relating to the Quarry Creek therefore would need to be developed in conjunction with ORC.

Further to the catchment wide recommendations, a number of alternative management options have been developed for each specific stormwater flooding issue; the details of which are provided in the following sections.



12.2.2.1 Catchment Wide Flooding

During rainfall events as small as a 1 in 2 yr ARI widespread nuisance flooding is predicted throughout the catchment with more significant effects in isolated locations. Options to manage the effects in those isolated locations are presented under the individual issue.

During a 1 in 10 yr ARI event, 29 % of manholes are predicted to overflow and 0.3 % of the catchment (concentrated in the central urban part), is predicted to experience flooding.

The nuisance flooding effects, due to insufficient capacity of the stormwater network, may be minor in many cases. However, it is unknown whether flows cross property boundaries and the associated effects are considered unacceptable to the local community.

Alternative management options have been considered to alleviate the nuisance flooding issues and improve the level of service of the stormwater network catchment wide. These options were assessed at a high level only, using a variety of assumptions, in order to provide some comparison in terms of costs and benefits of differing approaches to a catchment wide solution.

It is unknown the extent to which the deep stormwater flooding issues identified in other isolated locations would be resolved by these solutions.

Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacities

This option involves upsizing 29 km pipework, and upgrading Carlyle Road PS, to resolve nuisance flooding throughout the catchment during a future 1 in 10 yr ARI rainfall event.

Option Mo2: New Stormwater Relief Main and Terminal PS

This option comprises the installation of a new stormwater main to bisect several sub-catchments, with a new terminal PS to discharge flows to the Silver Stream. This would relieve capacity issues in a number of existing stormwater pipes.

Option Mo3: Retrofit Swales to Local Roads

This option involves the retrofitting of swales to suitable local roads throughout the catchment to provide formal storage for stormwater flows to prevent nuisance flooding within the road and across properties.

Section 13 contains further information and evaluation of the above options.

12.2.2.2 Stormwater Flooding: Gordon Road

This is an area of historic flooding problems and the model predictions align with anecdotal evidence, flood complaints and deep flooding shown in photographs provided by DCC.

During a 1 in 2 yr ARI rainfall event the model predicts that the main stormwater line on Lanark Street is flowing full, causing a backwater effect and resulting in manhole overflows on Gordon Road where ponding occurs and flows overland to Lanark Street. Predicted nuisance flooding in the kerb of Gordon Road and Lanark Street becomes deep flooding in Gordon Road (>300 mm), posing a risk to habitable floors, during a 1 in 5 yr ARI event and greater. The nuisance flooding is also predicted to be exacerbated during this event on Lanark Street. The deep flooding predicted on Gordon Road is sufficient to enter adjacent shops, which has been reported in the past.



There was however, some uncertainty as to the current extent of flooding at these locations following the training works that have been carried out. Evidence suggests that the works now result in overland flow down Lanark Street thus reducing the deep flooding on Gordon Road. Further site investigation would reveal the extent of any residual problems.

Prior to the implementation of any capital works in this location investigations should be carried out to reduce the uncertainty of current network behaviour. Notwithstanding the alternative capital works options presented, it is recommended that the following be carried out prior to further work in this location:

Investigate Surface Water Drainage on Gordon Road and Lanark Street

Insufficient information currently exists to analyse current surface drainage in this location. Prior to the development of capital works, including those as part of the renewals process, it is recommended that the following be investigated:

- Capacity of surface drainage;
- Kerb and channel flow paths;
- Catchpit capacity; and
- Adequacy of drainage at all low points.

This would confirm whether the training works to date have alleviated the historic problems and those predicted by the model, and enable the benefits of future renewals or capital works to be assessed with increased confidence.

Whilst there is some uncertainty surrounding the performance of the network in this location, and resulting effects, alternative options have been developed based on historic evidence and model outputs.

Option Mo4: Local Upgrade to Pipe Network on Gordon Road and Lanark Street

Upgrade of the stormwater pipework on Gordon Road and Lanark Street to relieve capacity problems and reduce flooding.

Option Mo5: Provide Storage on Gordon Road

Provision of storage in the form of an offline detention tank in the vicinity of Gordon Road to detain flows until the network has capacity for conveyance.

Section 13 contains further information and evaluation of the above options.

12.2.2.3 Stormwater Flooding: Kinmont Crescent

During a 1 in 2 yr ARI event and greater the stormwater pipes in the vicinity of Kinmont Crescent and Gebbie Street are predicted to be flowing full due to insufficient pipe capacity. This results in the following effects:

- Manhole overflows and overland flow from Gebbie Street and Kinmont Crescent;
- Overland flows channelled through several properties towards the north of Kinmont Crescent;



- Flows unable to return to the piped network due to inadequate inlet capacity and pond at low point adjacent to the state highway;
- Deep (>300 mm) ponding during a 1 in 5 yr ARI event; approximately one property is at risk of habitable floor flooding;
- Approximately three properties at risk of habitable floor flooding during a current 1 in 50 yr ARI event;
- Effects may be exacerbated by backwater effects from Quarry Creek (note that confidence in data is low); and
- Effects verified by workshop discussions and customer complaints. Property flooding reported in 2007 to be up to 500 mm deep. Flooding was also reported in 2008.

The catchment wide recommendations for the management of stormwater flooding, detailed in Section 12.2.4, are particularly applicable to this issue where confirmation of behaviour of the Quarry Creek and extent of risk to habitable floors would significantly aid detailed option development.

In addition to these recommendations, a number of alternative options have been developed to mitigate the flooding effects in this location.

Option Mo6: Local Pipe Upgrades

Upsize local pipework to minimise manhole overflows upstream and, therefore, overland flows to the low point in Kinmont Crescent.

Option Mo7: Additional Catchpits

Provide high capacity catchpits at low point in road to capture overland flow before it flows across adjacent properties.

Option Mo8: Provide Storage Kinmont Crescent

Provide offline storage for flows at the low point of Kinmont Crescent, adjacent to the culvert and properties at risk of flooding.

Option Mo9: Purchase Properties Kinmont Crescent

Explore options to purchase properties prone to flooding on Kinmont Crescent and convert the land into a reserve to provide a dedicated flow path through the area and a formalised ponding area.

Section 13 contains further information and evaluation of the above options.

12.2.2.4 Stormwater Flooding: Gow Street/McGlashan Street/Gladstone Road South

This is an area of known stormwater flooding, which is confirmed by customer complaints. Workshops revealed that inundation of Gow Street is a long-standing problem and floods “every year”.

Modelling predicts that during a 1 in 2 yr ARI rainfall event, the pipe capacity on Gow Street, McGlashan Street and Gladstone Road South is insufficient to convey flows. The effects are predicted to be minor during short duration (30 minute) events up to a 1 in 50 yr ARI. However during a 1 in 10 yr ARI event of longer duration (12 hours) significant deep flooding (> 300 mm)



effects are predicted with a with risk to property interiors on Gow Street. This replicates observed historic flooding.

Nuisance flooding (<300 mm) is predicted as a result of pipe capacity alone, however, deep flooding (>300 mm) results when the boundary effects of the downstream watercourse are applied to the model.

The catchment wide recommendations for the management of stormwater flooding, detailed in Section 12.2.4, are particularly applicable to this issue where confirmation of behaviour of the Quarry Creek and extent of risk to habitable floors would significantly aid detailed option development.

In addition to these recommendations, a number of alternative options have been developed to mitigate the flooding effects in this location.

Option Mo10: Upsize Local Pipework Gow Street

Upsize the pipework on Gow Street to improve network capacity and reduce the backwater effects from the Quarry Creek. This could be combined with the provision of a pumped outlet.

Option Mo11: Provide Storage Gow Street

Provide offline storage tank to detain stormwater until the network has capacity to convey the flows.

Section 13 contains further information and evaluation of the above options.

12.2.2.5 Stormwater Flooding: Reid Avenue Swale

Significant flooding from the swale and piped network on Reid Avenue was observed following the May 2010 rainfall event (estimated to be between a 1 in 10 yr and 1 in 50 yr ARI event). Reports from the community indicate that the area around the swale, in particular Reid Avenue, is prone to flooding most years, indicating that the flooding is likely to occur during events less than a 1 in 10 yr ARI.

During a 24 hour, 1 in 10 yr ARI rainfall event, the effects are as follows:

- Overtopping of swale;
- Manhole overflows on Hartstonge Avenue;
- Extent of nuisance flooding significant;
- Deep flooding (>300 mm) posing a risk to habitable floors of approximately six properties;
- Flooding across the full width of the road on Reid Avenue;
- Overland flows towards Hartstonge Avenue, Oban Street, Ross Street and Nairn Street; and
- Effects exacerbated should swale inlet / outlet become blocked or outfall flap valve become jammed open.

The catchment wide recommendations for the management of stormwater flooding, detailed in Section 12.2.4, are applicable to this issue where confirmation of the extent of risk to habitable floors would aid detailed option development.



Furthermore, options presented for stormwater network maintenance and cleaning will also assist with the management of this issue as blockages to the swale inlet/outlet significantly increases the flood risk in this location.

Option Mo12: Upsize Main Reid Avenue

Upsize stormwater main on Reid Avenue to increase capacity and reduce surcharging upstream.

Option Mo13: Increase Volume of Reid Avenue Swale

Increase the volume of the Reid Avenue swale, thus reducing risk of overtopping.

Section 13 contains further information and evaluation of the above options.

Two further options have been developed. They are not presented as alternatives as they are not designed to entirely mitigate the flooding issue at this location. It is likely that they will increase the efficiency of the swale and therefore reduce the risk of flooding. These options should also be considered alongside any capital works to resolve the flooding issues in this location.

Improve Screen and Flap Valve Reid Avenue Swale

Visual inspection of the swale outlet screen indicates it could be prone to blockage and the Reid Avenue gravity outlet flap valves could provide a poor seal, particularly if debris has collected behind it, as has been reported to occur in the past.

This option includes improvement of the screen to reduce the potential for blockage and installing rubberised inline check valves (or similar) in the gravity outlet pipes to replace the current flap valves. This would provide a better outfall seal and the flap valves would be less likely to become jammed open. Worthwhile added security from fluvial flooding could be achieved by installing a penstock valve or stop logs upstream of the non-return valves.

Whilst this option would not alleviate the predicted flooding effects, it would reduce flood risk and therefore should be considered in conjunction with other options to mitigate this issue.

Increase Outlet Capacity of Reid Avenue Swale

This option involves the provision of a high level overflow on the swale outlet to increase the flow delivered to the PS downstream of the swale.

During larger rainfall events, additional inflow to the swale results in a flow rate greater than the than outlet can cope with. Headlosses associated with the swale outlet and outlet screen also act to further reduce the capacity of the outlet pipe to deal with the predicted flow rates.

A high level overflow on the outlet structure would increase the conveyance capacity to the downstream PS once flood levels reach a certain height within the swale. This would increase outflow from the swale.

12.2.2.6 Stormwater Flooding: Gladstone Road North

Stormwater flooding at this particular location has been prioritised for Passive Management due to the uncertainty surrounding the actual adverse effects.

During a 1 in 2 yr ARI rainfall event deep flooding (>300 mm) is predicted adjacent to Gladstone Road North due to the limited capacity of the culvert under the railway.



Whilst the predicted flooding was verified by workshop discussions, there are no customer complaints associated with this location, therefore ponding may remain within drainage channels and the road, away from buildings.

Prior to the detailed development and implementation of management options for this issue, confirmation of the adverse effects and risk to property interiors should be confirmed.

Notwithstanding the uncertainty surrounding the adverse effects, the following management option has been developed to mitigate this potential issue:

Option Mo14: Upsize Existing Culvert Gladstone Road North

Upsize existing culvert under Gladstone Road North and railway to improve conveyance of flows.

Section 13 contains further information on the above option.

12.2.2.7 Stormwater Flooding: Woodland Avenue

This is an area of known problems with flooding reported in 2007. Workshop discussions confirm that problems exist and are worse when water levels in the Quarry Creek are high.

During a 1 in 2 yr ARI rainfall event deep flooding is predicted in the vicinity of the intake structure off Woodland Avenue. There is no overland flow path for stormwater overtopping the intake structure until flood depths exceed the kerb of the road downstream. This results in the following effects:

- Deep flooding (> 300 mm) with risk of habitable floor flooding to one property during current 1 in 10 yr ARI event, rising to three during a 1 in 50 yr ARI.
- Undeveloped lots in this location - further risk of habitable flood flooding should flooding not be accounted for / mitigated.
- Stormwater flooding inundates wastewater PS on Woodland Avenue causing wastewater overflow.
- Scale of effects in this location dependent on the downstream Quarry Creek boundary condition and rainfall duration and may be exacerbated by inlet blockage.

The catchment wide recommendations for the management of stormwater flooding, detailed in Section 12.2.4, are particularly applicable to this issue where confirmation of behaviour of the Quarry Creek and extent of risk to habitable floors would significantly aid detailed option development.

In addition to these recommendations, a number of alternative options have been developed to mitigate the flooding effects in this location.

Option Mo15: Upsize Pipework Woodland Avenue

Upsize existing pipeline to prevent flooding during a 1 in 10 yr ARI 30 minute duration storm events allowing for 2060 climate change and a 1 in 10 year flood level in the Quarry Creek (based on the current level of modelling).

**Option Mo16: Provide Offline Storage Woodland Avenue**

Provide offline storage to detain stormwater until network has capacity to convey flows.

Option Mo17: Provide Formal Overland Flow Path Woodland Avenue

Provide a formal overland flow path to convey stormwater flooding from the inlet structure to the Quarry Creek.

Section 13 contains further information and evaluation of the above options.

12.2.3 Wastewater Flooding/Overflows – Manage Actively

A number of problems within the catchment are interrelated, with more than one source contributing to the adverse effects. For example, elevated flows (dry weather infiltration and wet weather I&I) create capacity problems with respect to both the pipe network and the WWTP which in turn results in predicted manhole overflows and WWTP emergency overflow to the Silver Stream; in addition to increasing the pumping and treatment costs associated with the wastewater system in Mosgiel.

The catchment specific approaches and targets for the management of wastewater flooding/overflows in the wastewater network, include:

- Improve existing level of service in network;
- Reduce number of wastewater overflows predicted to occur during 1 in 10 yr ARI rainfall event;
- Ensure no increase in the number of properties at risk of wastewater flooding; and
- Invest adequately in renewals to maintain the performance of wastewater infrastructure.

A number of alternative management options have been developed to resolve each overflow issue. These options have been designed to meet the catchment specific approaches and targets and align with DCC's Strategic Objective of no wastewater overflows in a 1 in 10 yr ARI rainfall event.

12.2.3.1 Manhole Overflows

A number of wastewater manhole overflows are predicted during a 1 in 10 yr Ari rainfall event. However, many are unconfirmed as there are no customer complaints for the corresponding locations or they are not known to overflow based on discussions with DCC Water and Waste Services Business Unit staff. Workshop discussions revealed however that they may be unknown simply because of their location, for example, to the rear of private properties or on parks/reserves where effects would go unnoticed.

During 1 in 10 yr ARI rainfall events, confirmed manhole overflows occur on Tyne Street and Silverstream Drive due to surcharging of the wastewater network. The surcharging is a result of the WWTP inlet PS's maximum operational level and lack of pipe capacity on Tyne Street.

For those manhole overflows that are confirmed an 'active' approach to management is required. However, a 'passive' approach is recommended for those predicted to overflow but unconfirmed, until such time as they can be verified.



The following management options have been developed to mitigate the adverse effects from the 'confirmed' manhole overflows:

WMo1: Renew Pipelines (Sub-catchment WW6)

Replace or rehabilitate pipelines in sub-catchment WW6 (refer Figure 8-3), to prevent groundwater infiltration, in order to reduce flows and surcharging in Tyne Street.

WMo2: Lower Groundwater Levels (Sub-catchment WW6)

Reduce the local groundwater levels below the wastewater pipe invert levels to prevent infiltration in order to reduce flows and surcharging in Tyne Street.

WMo3: Reduce Operation Level of Pump Station

Lowering the operating level in the WWTP inlet pump station to prevent backwater effect and surcharging of the network.

WMo4: Upsize Wastewater Pipes on Tyne Street

Upsize pipeline on Tyne Street to provide sufficient capacity to cater for flows and mitigate surcharging.

WMo5: Reduce Wet Weather Infiltration

Reduce wet weather I&I through relining of pipes and therefore reduce flows in Tyne Street pipeline.

The approach to management of the unconfirmed manhole overflows in the first instance should be to verify the problem. Following verification, active management approaches can be applied where necessary.

Confirm Manhole Overflows Predicted By the Model

It is recommended that those manhole overflows predicted but unconfirmed are investigated. Checks could be carried out in the predicted locations during rainfall to investigate further. Management approaches within the ICMP would then be amended as required.

Section 13 contains further information and evaluation of the above options.

12.2.3.2 WWTP Overflow to Silver Stream

The WWTP emergency overflow to the Silver Stream is predicted to operate during a 1 in 5 yr ARI rainfall event.

During wet weather the capacity of effluent transfer system to Green Island WWTP is the limiting factor at the Mosgiel WWTP. When flows exceed the capacity of the effluent transfer system and storage at the Mosgiel WWTP, flows are by-passed to the Silver Stream.

DCC have already installed a new high capacity diesel pump, and are progressively optimising it's operation.

The following management options have been developed to mitigate the capacity problems and reduce emergency overflow:

**WMo1: Reduce Baseflow: Renew Pipeline Murray Street**

Replace or rehabilitate pipelines in sub-catchment WW6 (refer Figure 8-3) to prevent groundwater infiltration, and therefore reduce flows to the WWTP.

WMo2: Lower Groundwater Levels (Sub-catchment WW6)

Reduce the local groundwater levels below the wastewater pipe invert levels to prevent infiltration, and therefore reduce flows to the WWTP.

WMo5: Reduce Wet Weather Infiltration

Reduce wet weather I&I through relining of pipes and therefore reduce flows to the WWTP.

WMo6: Divert Wastewater Flows (Burns Street PS)

Divert parts of the Mosgiel wastewater catchment to the old Fortex pipeline (Wingatui system), thereby reducing flows to the WWTP.

WMo7: Divert Wastewater Flows (Old Mill PS)

Divert parts of the Mosgiel wastewater catchment to the Wingatui system, reducing flows to the WWTP.

WMo8: Increase Capacity of Effluent Transfer

Increase the effluent transfer rate to Green Island WWTP relieving capacity problems at the Mosgiel WWTP.

WMo9: Provide Storage

Provide additional storage at Mosgiel WWTP to buffer flows that are greater than the effluent transfer pump capacity to prevent overflow.

Section 13 contains further information and evaluation of the above options.

12.2.3.3 Woodland Avenue Wastewater Flooding

Stormwater flooding within the Woodland Avenue subdivision can enter the wastewater system via gully traps, manhole lids and pump station lids. The resulting high flow overwhelms the wastewater pump station resulting in wastewater overflows.

Alleviating stormwater flooding at this location would prevent inundation of the wastewater system. Management options developed to alleviate stormwater flooding are detailed under the 'Stormwater Flooding - Woodland Avenue' issue.

12.2.3.4 Private Property Boundary Trap/Gully Trap Overflows

A number of customer complaints exist relating to private property boundary/gully trap overflows. In many cases the overflows result from problems within the property, blockages etc. Overflows such as these are dealt with on a case by case basis when a complaint is reported. Maintenance within a private property is the responsibility of the owner.

However, as the model predicts widespread surcharging of the wastewater network during a 1 in 10 yr ARI rainfall event, there may be instances where this manifests as overflows on private property. Should this be the case then DCC would be responsible for mitigation of the effects.



Management options developed for wastewater flooding/overflow issues will go some way to alleviating the risks of private property overflows due to main surcharging where they are designed to increase network capacity.

In addition, a robust complaints reporting procedure, documenting incidents against assets and responses/actions taken, would allow DCC to gain a better understanding of any mains with recurring problems of this nature and assign a management approach to mitigate effects.

An understanding of assets and associated problems would also allow the development of a cleaning/maintenance schedule for the wastewater network, ensuring it remains free from blockages that may cause property overflows.

12.2.4 Potential Wastewater Contamination of Stormwater – Manage Actively

Microbial contamination of the stormwater from the Mosgiel catchment was measured at or above the upper level that is typical of urban stormwater, within grab samples obtained in 2004 and 2005 from the Titri Place outfall. However, this data is historic and it is not known if these contaminant levels persist. There are no known issues with the wastewater system in this part of the catchment and the potential source of contamination is unknown. As such the level of threat remains inconclusive.

Further to the high microbial results in the stormwater discharge monitored, stormwater flooding in a different part of the catchment, on Woodland Avenue, is predicted to inundate the wastewater PS resulting in overflow of wastewater. The wastewater overflows mixing with the stormwater flooding and may lead to contamination of the stormwater. Contamination cannot be verified as stormwater from this sub-catchment has not been monitored to date.

However, as stormwater discharges to watercourses are a permitted activity under the Regional Plan provided that they are free from wastewater contamination; the extent of and potential source of microbial contamination should be investigated further. This would determine whether this is an historic or ongoing occurrence and ensure that DCC stormwater discharges from the Mosgiel catchment meet the requirements for a permitted activity.

In order to enable DCC to maintain or improve stormwater quality, and implement appropriate management options to remediate any potential threat from microbial contamination relevant monitoring data and identification of potential contaminant source/s is required, which can be gained through further investigation into this issue.

The catchment specific approaches recommended for this issue in this catchment are related to those associated with the 'Ongoing Stormwater Discharge' issue, and are as follows:

- Use monitoring to gather a baseline dataset to enable better understanding of potential catchment contamination.
- Incorporate a feedback process to the ICMP if / when monitoring indicates potential wastewater contamination. Include new information, management approaches and ongoing monitoring protocols.

Despite a 'Manage Actively' classification, the extent and source of microbial contamination in the catchment remains unclear. The first step in management of this issue must therefore be to define



the levels and sources of contamination in the catchment via the data collection. Consequently, only one option alternative is presented:

Design a Framework for Stormwater Quality Baseline Data Collection

The implementation of a framework, to provide a baseline dataset of stormwater quality in Mosgiel, would allow the identification of stormwater quality for this catchment with a level of confidence. Improved level of confidence in the data would allow DCC to:

- Improve knowledge of stormwater quality;
- Identify any stormwater contaminants of concern;
- Provide sufficient quality information to ensure suitable management approaches for quality are implemented;
- Ensure stormwater discharges meet criteria for permitted activity under the rules of the Regional Plan: Water for Otago; and
- Provide a stormwater quality baseline dataset for any future resource consent applications that may be required from this catchment.

The results of the monitoring undertaken according to the framework will allow the following targets to be met:

- Develop greater understanding of nature of stormwater discharges.
- Improve data relating to levels of microbial contamination and potential sources of contamination within the catchment.

Implementation of the targets following the outcomes of the monitoring framework will be via the monitoring and continuous improvement of the ICMPs, as described in Section 16. The improved data confidence will allow the prioritisation of stormwater management recommendations based on the significance of stormwater quality issues.

12.2.5 WWTP Emergency Overflow Quality – Manage Actively

Evidence to date does not suggest that the WWTP emergency overflow is having a detrimental effect on the quality of the receiving environment. However, it is acknowledged that overflows from the wastewater network are a key stakeholder issue, may pose a health risk to the public and are contrary to DCC's Strategic Objectives.

Mitigation measures to reduce the quantity and frequency of overflow operation will also address quality concerns. Active management approaches and options to reduce the overflow operation have been set under the wastewater flooding/overflows issue.

As such, targets and approaches for this particular issue therefore are more general and relate to monitoring the overflow frequency as a means of gauging the effectiveness of the approaches to wastewater management throughout the catchment. The catchment specific approaches and targets for this issue are as follows:



- Monitor operation of overflow to enable better understanding of triggers and frequency of operation.
- No wastewater overflows due to capacity during a 1 in 10 yr ARI rainfall event.

12.2.6 Stormwater Network Maintenance – Manage Passively

Flooding extents and durations in the Mosgiel catchment could potentially be exacerbated should critical stormwater structures not be adequately cleaned. A number of structures have been identified as prone to blockage and in some cases this is known to exacerbate flooding issues within the catchment or present a risk to flooding of properties, particularly where no overland flow path exists.

These include:

- Woodland Avenue intake;
- Reid Avenue swale;
- Kinmont Crescent/State Highway culvert; and
- Carlyle Road PS inlet screens.

Regular cleaning and maintenance of catchpits and stormwater structures is essential across the city, and city-wide inconsistencies in frequency and standards of cleaning and maintenance of stormwater structures (inlets and catchpits) can lead to discrepancies in level of service. The following catchment approaches have been developed for this issue:

- Identify areas in the catchment where more regular stormwater structure cleaning and maintenance could reduce flooding risk.
- Ensure consistency city-wide of stormwater structure cleaning and maintenance.
- Ensure cleaning and maintenance schedules and contracts are sufficiently robust.

It is recommended that the following be carried out to address this issue:

Develop an inventory of key stormwater structures in the catchment

An inventory of the key structures and specific maintenance/cleaning requirements for each, within the Mosgiel catchment would assist in reducing the flood risk at these locations.

Develop consistent cleaning and maintenance criteria for all stormwater assets (in conjunction with city-wide criteria)

A review of schedules and methods used across the city could be undertaken to ensure that all possible sources of contaminants (e.g. catchpits) and flood risk (e.g. inlet structures) are cleaned regularly, and the flood risk is reduced as much as possible. Alignment of contracts for this maintenance (currently with a number of agencies) would provide confidence that catchpit and stormwater structures were operating optimally.

As part of the contracts, key structures identified in each catchment plan could be incorporated as requiring additional or more frequent attention.



Management options developed to mitigate other stormwater effects will in some cases reduce the risk of flooding from key structures. However, regular maintenance would still be required.

12.2.7 Wastewater Network Maintenance – Manage Passively

As the Mosgiel catchment is relatively flat, velocities within the wastewater pipes are generally quite low, therefore there is a high risk of partial blockage should sediments fall out and build up.

The capacity of the wastewater network could be significantly reduced by blockages and may result in overflows if they are significant. Regular cleaning and maintenance of pipes particularly prone to blockage would significantly reduce the risks.

To date, cleaning and maintenance of the wastewater network is carried out on an ad hoc basis when incidents occur. Furthermore, until recently the complaints reporting procedure within the catchment did not allow for the recording of incidents (such as blockages) to be recorded against an asset.

An understanding of assets and associated problems would allow the development of cleaning/maintenance schedule for the wastewater system, enabling a proactive approach targeting those parts of the network at greatest risk or with recurring problems.

The following management approaches are recommended for this issue:

Develop Inventory of Wastewater Assets Prone to Blockage

The documentation of incidents against assets, through customer complaints recording and the reporting of operational issues would allow a catchment wide inventory of problem areas/pipes to be developed.

Develop Cleaning/Maintenance Schedule for Wastewater Network

Using the inventory of problem areas/assets a cleaning/maintenance schedule would be developed to ensure assets at highest risk of blockage received regular attention.

12.2.8 Ongoing Stormwater Discharges – Manage Passively

The stormwater quality data at present indicates that the levels of many contaminants in stormwater from the Mosgiel catchment are not significantly high (with the exception of microbial levels which are addressed in a separate issue). Therefore based on the best available information at this time, the prioritisation of this issue has resulted in a 'passive management' prioritisation.

The following catchment approaches have been developed for this issue:

- Identify the location of high risk land uses within the catchment and implement an education programme targeting stormwater.
- Consider the cost / benefit of stormwater quality treatment as part of flood mitigation works where practicable.
- Require source control of stormwater contaminants in new development of high- contaminant generating land uses.



- Identify locations of high risk land uses within the catchment and implement an education programme targeting stormwater discharges.
- No deterioration of stormwater quality due to land use change or development in the catchment.
- Enforce the Trade Waste Bylaw, and educate occupiers of high-risk sites with respect to stormwater discharge quality.

The development and implementation of a monitoring framework (under the potential wastewater contamination issue) to collect a baseline dataset of stormwater quality for this catchment will mitigate the uncertainty in the stormwater quality data from this catchment. There is also potential in the future for stormwater discharge consents for Mosgiel to be required. Should this be the case then baseline data relating to catchment stormwater quality would be needed. The approach to stormwater quality management in this catchment would be revised following the outcomes of the proposed monitoring. This will be implemented by updating the ICMP and the continuous monitoring and improving of SMART targets.

In the meantime, the management of stormwater discharges to ensure that quality is maintained or improves can be undertaken using several mechanisms:

- **Development Controls:** DCC have a preference for at-source management and low impact stormwater design as outlined in the draft Dunedin Code of Subdivision and Development. This document also requires a minimisation of damage to the environment from the adverse effects of stormwater runoff; that habitat requirements are taken into account; that stormwater treatment is put into place where practical and that road drainage applies appropriate stormwater treatment.
- An amendment to the business processes used to manage subdivision and development. This would be aimed at ensuring that the developer/DCC representative review the appropriate ICMP for the area of development, in order to direct stormwater treatment based on catchment specific requirements.
- **Trade Waste Bylaw:** The Trade Waste Bylaw currently includes standards for stormwater discharge quality. Enforcement of this Bylaw would result in an improved quality of stormwater discharge leaving industrial or commercial sites. The Bylaw currently includes standards for stormwater discharge relating to the ANZECC (2000) guidelines for Fresh and Marine quality. Following improved understanding of stormwater discharge quality and its effects, this Bylaw may require review.
- **Education and Assistance:** Also under the Trade Waste Bylaw, inspections of industrial premises could be undertaken to ensure that adequate on site management practices are being applied. Assistance could be provided by DCC to help achieve higher stormwater quality. It is anticipated that ORC would be involved in this type of scheme for consented discharges, and potentially have resources available to assist in city-wide education.
- Regular network maintenance and cleaning (particularly of catchpits) will serve to maintain stormwater quality.



12.2.9 Low Level of Service Stormwater Network – Manage Passively

The current level of service in parts of the catchment is below DCC's target for new infrastructure primarily as a result of infrastructure capacity with some boundary effects from the catchment watercourses contributing also.

Currently 71 % of the stormwater network is predicted to have the capacity to accept rainfall from a 1 in 10 yr ARI event. In those areas where the capacity is less, some adverse effects are predicted to occur. Management options for those adverse effects are addressed under the 'Stormwater Flooding' issues.

The results of the ROS (2011) indicate that Mosgiel residents/building owners are not dissatisfied with the stormwater service; however Community Board feedback indicates that the adverse effects due to the low levels of service of the stormwater network is unacceptable in several locations. There are a number of catchment specific approaches for this issue, these include:

- Improve existing level of service in network.
- Ensure no increase in the number of stormwater manholes predicted to overflow in a 1 in 10 yr ARI rainfall event.
- Design new pipes with capacity to convey a 1 in 10 yr ARI rainfall event.
- Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment.
- Use customer complaints, ROS and Community Board feedback to gauge satisfaction with the stormwater service.

DCC can achieve these approaches in the following ways:

The Dunedin Code of Subdivision and Development is used by the DCC to set requirements for land development and subdivision, but is also used by the DCC to guide design of network upgrades undertaken by DCC. Table 12-1 outlines the design criteria required by DCC for new stormwater work. Compliance with this document ensures that new pipes to convey a 1 in 10 yr ARI rainfall event, and that secondary protection is provided up to a 1 in 100 yr ARI rainfall event.

As development occurs, or pipe renewals are undertaken, the level of service of parts of the network will gradually improve. The pipe renewal process includes inspection and condition assessment, and potentially extends the useful life of an asset beyond 100 years if it is in good condition. It should be noted that pipe ages in Mosgiel are relatively young compared to other parts of Dunedin, with only 34 % of the network due for condition assessment or renewal by 2060. There is also some uncertainty surrounding some of the stormwater pipe ages due to missing/assumed historic data.

In the interim, the ROS and Community Board feedback can be used to gauge satisfaction with the stormwater services. The ROS provides a city wide impression of satisfaction with the stormwater services and is used to measure progress against a target of 60 % satisfaction. In 2011, 61 % customer satisfaction with the service in Mosgiel was recorded.


Table 12-1: Stormwater Design Criteria

Function	AEP %	Return Period (yr ARI)
Primary protection	10	10
Primary protection in areas where secondary flow paths are not available or are through private property	1	100
Secondary protection	1	100

12.2.10 Low Level of Service Wastewater Network – Manage Passively

The current level of service in parts of the catchment is below DCC's target for new infrastructure primarily as a result of infrastructure capacity with some boundary effects caused by the WWTP.

The current level of service in the wastewater network does not meet DCC's performance objectives in a large percentage of the catchment.

Currently 1 % of wastewater manholes are predicted to overflow during a 1 in 10 yr ARI rainfall event and the WWTP emergency overflow is predicted to operate during a 1 in 5 yr ARI rainfall event.

Management options for the adverse effects resulting from the low level of service are also addressed under all other wastewater issues.

The results of the ROS (2011) indicate that Mosgiel residents/building owners are not dissatisfied with the sewerage service.

There are a number of catchment specific approaches for this issues; these include:

- Improve existing level of service in the network.
- Ensure reduction in the number of wastewater overflows predicted during a 1 in 10 yr ARI rainfall event.
- Undertake pipe renewals programme as scheduled and prioritise to focus on poorly performing areas of the catchment.
- Use customer complaints and ROS to gauge satisfaction with the sewerage service.

DCC can meet these approaches in the following ways:

The Dunedin Code of Subdivision and Development is used by DCC to set requirements for land development and subdivision, but is also used to guide the design of network upgrades undertaken by DCC. Compliance with this document ensures that the wastewater network is designed to be "capable of carrying and treating the peak flows anticipated during the economic lifecycle of the system, with due allowance for ground and surface water inflow and infiltration".

As development occurs, or pipe renewals are undertaken, the level of service of parts of the network will gradually improve. The pipe renewal process includes inspection and condition



assessment, and potentially extends the useful life of an asset beyond 100 years if it is in good condition. It should be noted that the pipe age in the Mosgiel catchment is uncertain in many areas due to a large amount of missing historic data. The following is therefore recommended:

Improve quality of Wastewater Network Data

To assist with both the renewals programme and the further design and development of wastewater management options in the catchment, there would be benefit in improving the quality of data relating to the wastewater network, particularly age and condition. To augment the information gathered during the city-wide CCTV inspection programme (in progress at the time of writing this plan), improvements in GIS asset data would be beneficial. It is recommended that this be implemented ahead of the renewals programming to provide better data relating to those pipes where the age is uncertain to assist in renewals prioritisation.

Due to the adverse effects predicted resulting from the low level of service, local upgrades as part of the pipe renewals process alone are unlikely to significantly improve the level of service in many parts of the catchment. However, options investigated to actively resolve wastewater network issues in the catchment in conjunction with the renewals process are likely to improve the overall performance of the network.

In the interim, the ROS and Community Board feedback can be used to gauge satisfaction with the stormwater services. The ROS provides a city wide impression of satisfaction with the sewerage services and is used to measure progress against a target of 65 % satisfaction. In 2011, 65 % customer satisfaction with the service in Mosgiel was recorded.

12.2.11 Flood Hazard (1 in 100 yr ARI) – Manage Passively

A flood hazard rating of 'moderate to significant' is predicted to occur during a current 1 in 100 yr ARI rainfall event in certain locations. Stormwater flooding is predicted to pond in the low points of the predominantly flat catchment affecting local roads and commercial and residential areas. The flood hazard is predicted to increase in the future.

Small benefits may be gained, during current and future (extreme) events, from other management approaches seeking to alleviate flooding and improve network capacity. The catchment specific targets and approaches identified for this issue are as follows:

- Ensure new development does not increase the number of properties predicted to flood due to the stormwater system in a 1 in 100 yr ARI rainfall event.
- Protect key and vulnerable infrastructure (e.g. pump stations, works depots, schools, hospitals, electricity supply etc.) from flood hazard. Avoid development of vulnerable sites / critical infrastructure in flood prone areas.
- Develop a better understanding of the likely effects and magnitude of climate change.

In terms of ensuring that development does not further exacerbate flooding, management of the effects of new development would be as per the requirements of the Dunedin Code of Subdivision and Development.

Flooding and flood hazard extents in this catchment are predicted to intensify in the future due to climate change impacts; therefore the management approach presented reflects this driver by ensuring that these effects are incorporated into climate change planning.



Develop Climate Change Adaptation Plan

In order to develop a better understanding of the likely effects and magnitude of climate change, there needs to be an ongoing re-visitation of new information regarding climate change predictions, and the implications of these for the Mosgiel catchment. The hydraulic model developed for this study would be a key tool in assessing the impacts of a range of further climate change scenarios. A climate change adaptation plan for the whole of Dunedin City would incorporate findings in terms of a plan for all catchments, including Mosgiel. This plan may affect the options chosen in terms of on-going provision of level of service of the network. Damage assessment of critical and vulnerable sites (such as the State Highway and electricity substations) would form part of this work.

12.2.12 Stormwater PS Failure Risk – Manage Passively

Failure in the operation of one of the stormwater PSs in the catchment, for example due to power failure, presents a significant flood risk during longer duration rainfall events of greater than a 1 in 10 yr ARI. These are:

- Cherry Drive;
- Reid Avenue; and
- Carlyle Road.

Should any one of the three PSs fail during rainfall, for example due to a power outage, then widespread nuisance flooding, overland flows and deep flooding is predicted with numerous properties at risk of habitable floor flooding.

It should be noted that if any of the seals on the gravity outfalls linked to the PSs are ineffective then this will reduce the efficiency of the pumps and therefore present a flood risk during longer duration or low frequency events as this would cause flows to back up in network.

The approaches for the management of this issue focus on DCC managing the risk of the PS failure and being prepared for this situation should it occur in order to avoid the predicted effects.

It is recommended that the following be carried out to manage this issue:

Develop a Response Plan for the Event of Stormwater PS Failure

Development of a response plan for PS failure would allow DCC to manage the flooding risks of PS failure. In response to managing the risk of PS failure the following could be considered:

- Ensure adequate warning system is in place to alert personnel of PS failure.
- Installation of diesel generators at each PS that can be set to operate in the event of power failure.
- Document particular cleaning/maintenance requirements to ensure optimal operation. (For Example, regular cleaning and maintenance of PS inlet screens at Carlyle Road PS where blinding is known to potentially result in pump failure).



Review of Gravity Outfalls to the Silver Stream and Improvement of Outfall Seals

Due to the potential flood risks associated with poor outfall seals, a review of all gravity outfalls to the Silver Stream and the quality of the seal provided between the flap valve and the pipe and the potential for it to become jammed open or damaged during a flood event is recommended.

Where outfalls seals are deemed to be inappropriate, installation of inline rubberised check valves is recommended. This would likely provide a better seal and be less prone to damage or being jammed open.

Additional security in the form of manually operated penstock valves or stop logs could also be considered.



13 Options Evaluation

13.1 Options Evaluation Criteria & Methodology

Where more than one option has been developed for an issue identified as requiring 'active management', these options have undergone a preliminary evaluation. This included further screening combining the use of the hydraulic model and engineering judgement, to determine technical feasibility and the likelihood of meeting the targets set for this catchment.

The option was then either 'shortlisted', and taken forward for further evaluation or categorized as a 'dealbreaker' based on inability to meet the catchment targets, or the 'dealbreaker' criteria as listed in Section 12. Where options were found to be 'deal breakers' they were not taken forward further evaluation.

The shortlist of options comprised those options that are deemed to be technically feasible and likely to meet the objectives and targets set for this catchment.

The shortlist options were then further evaluated using QBL analysis. The evaluation criteria have been developed based on objectives and decision making criteria set in the following:

- The 3 Waters Strategic Direction statement;
- DCC's Optimised Decision Making Matrix; and
- DCC's LTP.

Stormwater specific criteria have been developed for the QBL (economic, social, cultural and environmental) analysis, with an additional two risk categories, Implementation Risk and Effectiveness (risk reduction) separated from the core QBL by DCC and given significant weighting; the first to ensure that operationally, capital works installed will work, and the second to highlight the benefits of each option in terms of reduction of current risk and levels of service. The scoring framework is presented in Appendix G. Weighting for each of the criteria has been assigned by DCC.

Multiple options were not developed for all issues identified as requiring 'active management', as often the assessment of a number of issues resulted in only a single management option being identified, or the need for further study. Option evaluation was not carried out in these cases.



13.2 Options Comparison

Several issues identified for 'active management' have more than one management option developed and therefore have prompted an options evaluation. Those issues requiring an options evaluation are as follows:

- Stormwater Flooding – Catchment Wide
- Stormwater Flooding – Gordon Road
- Stormwater Flooding – Kinmont Crescent
- Stormwater Flooding – Gow Street/McGlashan Street/Gladstone Road South
- Stormwater Flooding – Reid Avenue Swale
- Stormwater Flooding – Woodland Avenue
- Wastewater Flooding/Overflows

For each issue identified, the outcomes of the preliminary evaluation and short list (QBL) evaluation are presented in the following sections.

13.2.1 Stormwater Flooding – Catchment Wide

Options developed have been designed to alleviate catchment wide nuisance flooding and improve the overall level of service in the catchment during current and future (2060) 1 in 10 yr ARI rainfall events.

These options were assessed at a high level only, using a variety of assumptions, in order to provide some comparison in terms of costs and benefits of differing approaches to a catchment wide solution.

It is unknown the extent to which the deep stormwater flooding issues identified in other isolated locations would be resolved by these solutions.

13.2.1.1 Preliminary Option Evaluation

Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacities - Shortlist

This option involves upsizing 29 km pipework, and upgrade to the Carlyle Road PS, to resolve nuisance flooding throughout the catchment during a future 1 in 10 yr ARI rainfall event.

In order to assess the extent of the network requiring an upgrade to meet current design standards and alleviate flooding, the theoretical flow rate was calculated for each pipe and compared with the modelled pipe capacity. Where the theoretical flow rate exceeded the modelled pipe capacity, the modelled pipe was upsized based on the Manning's equation until it had sufficient capacity. This resulted in approximately 29 km of pipework requiring an upgrade.

Figure 13-1 shows the pipework that was modelled as upsized within the urban area of Mosgiel, based on the methodology applied.

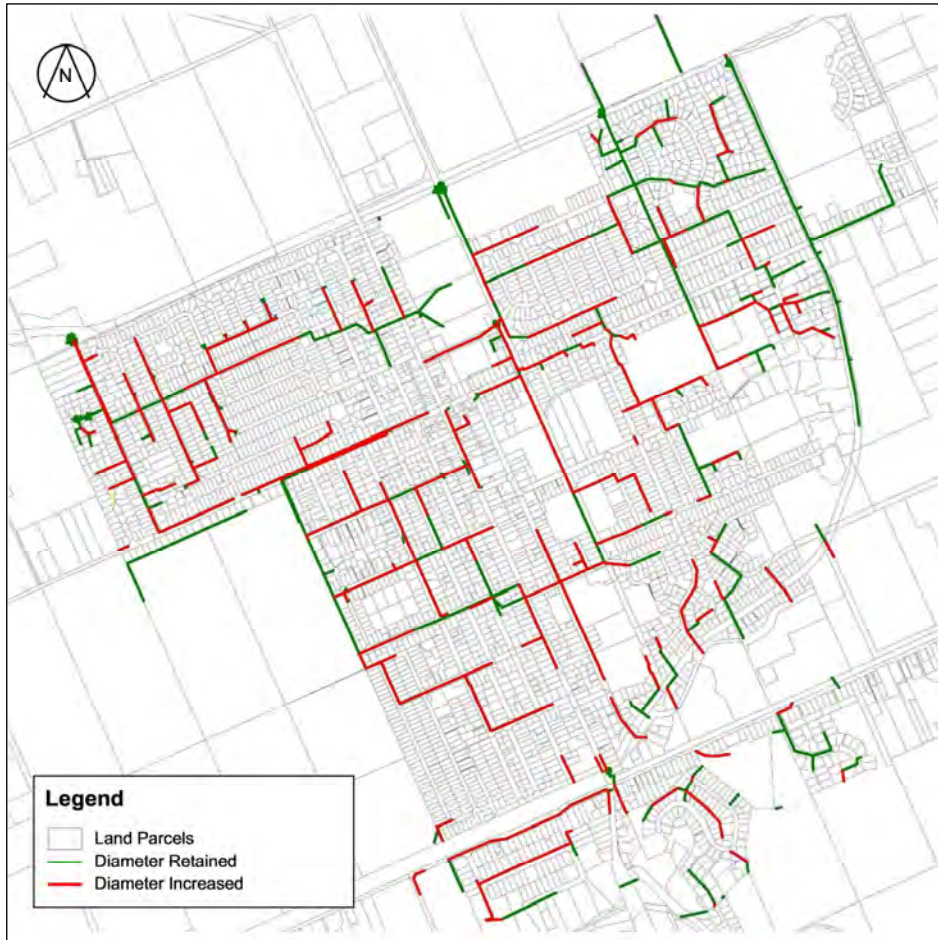


Figure 13-1: Option Mo1: Catchment Wide Network Upgrade (Stormwater)

The model was then re-run with the amended pipe sizes. The results indicated that upsizing the pipework increased the peak flow rate to the Carlyle Road PS sufficiently to exceed its pumping capacity and surcharge the Carlyle Street main causing flooding upstream. The modelling indicated that the pipe upgrades would need to be combined with an increase in pump capacity at the Carlyle Road PS.

This option is predicted to resolve all nuisance flooding during a future (2060) 1 in 10 yr ARI rainfall event. The model results are shown in Table 13-1.

Table 13-1: Option Mo1: Model Results

Hydraulic Performance Measure	Future (2060) 1 in 10 yr ARI Rainfall Event	
	Existing	Upgraded System
Percentage of manholes predicted to overflow	37 %	0 %
Estimated flood extent (ha)	35.0	0 %
Modelled percentage (by number) of pipes surcharging	78 %	48 %
Percentage of manholes predicted to be close to overflowing (free water level within 300 mm of cover)	54 %	13 %



The estimated cost for this option is likely to be in the range of \$60 million, based on DCC asset valuation rates. (Network costs approximately \$45 million, PS costs approximately \$15 million).

A staged approach could be carried out for this option with a percentage of upgrades programmed each year moving towards alleviating all catchment flooding by 2060. The use of the model allows assessment of those pipes targeted for upgrading.

It is likely that this option would also provide some benefit through alleviation of deep flooding in the catchment, particularly where management options for the deep flooding issues include pipe upgrades.

Option Mo2: New Stormwater Relief Main and Terminal PS – Dealbreaker

This option comprises the installation of a new stormwater main to bisect several sub-catchments, with a new terminal PS to discharge flows to the Silver Stream. This would relieve capacity issues in a number of existing stormwater pipes. It should be noted that a new PS discharge to the Silver Stream would require resource consent.

Within the model a new main was created in order to bisect several catchments and alleviate flows in several key points in the system. The main that was modelled ran from Gordon Road through to Carlyle Road (see Figure 13-2) and out to a new terminal PS west of the WWTP. Several other pipes were also included to link the new main with nearby existing mains.

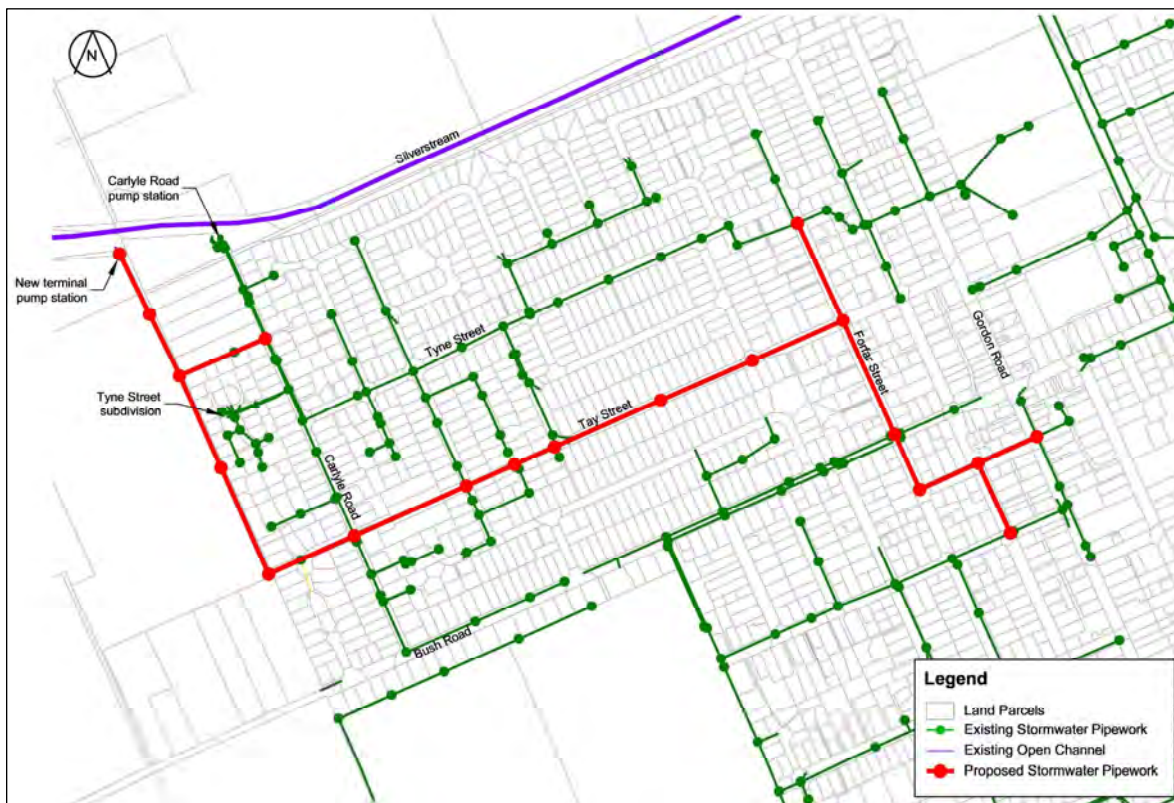


Figure 13-2: Option Mo2: New Stormwater Relief Main and Terminal PS

Table 13-2 shows the modelled results for this option. The proposed option resulted in a reduction of 18 manhole overflows, and a 2.3 % reduction in predicted flooding for the catchment as a whole



during a current 1 in 10 yr ARI event. The option would not however, prevent surface flooding from occurring, only reduce its scale.

The estimated cost for this option, based on DCC asset valuation rates, is approximately \$18 million. (Network costs approximately \$3.5 million, PS costs approximately \$14.5 million).

Table 13-2: Option Mo2: Model Results

Hydraulic Performance Measure	Future (2060) 1 in 10 yr ARI Rainfall Event	
	Existing	Relief Main
Percentage of manholes predicted to overflow	37 %	35 %
Estimated flood extent (ha)	35.0	34.2
Modelled percentage (by number) of pipes surcharging	78 %	79 %
Percentage of manholes predicted to be close to overflowing (free water level within 300 mm of cover)	54 %	51 %

As this option does not resolve the issue throughout the catchment in a current or future 1 in 10 yr ARI rainfall event, it is therefore considered to be a dealbreaker.

Option Mo3: Retrofit Swales to Local Roads - Shortlist

Historically, the road corridors in Mosgiel were utilised to store stormwater during events greater than the design capacity of the piped network.

The use of swales to provide formal storage for excess stormwater was investigated as an alternative to upgrading the piped network. Swales have the advantage of providing stormwater quality benefits, as well as stormwater quantity management, and can provide green space within the road corridor.

Many of Mosgiel's roads have a wide corridor. The Dunedin Code of Subdivision and Development provides a minimum carriage way, berm and footpath width to be provided. For residential local roads, the requirement is for a 6 m traffic lane, with two 2 m footpaths, and two 3 m berms. This sums to a total road corridor of 16 m. A review of some of Mosgiel's roads indicates that some of the local roads have widths greater than 20 m.

Based on the assumption that most of the local roads would be able to accommodate a 3 m wide swale within the road corridor or the berm, an option has been developed based on the installation of 59 km of swale.

In order to assess the effect of retrofitting existing minor roads with swales, the model hydrology was modified to allow a surface infiltration loss for impervious areas, based on an infiltration rate of 25 mm/hr which was equivalent to a 6 mm/hr loss over all impervious areas. Additional to this, the initial loss value was increased to represent the depression storage the swales would provide. Based on a 3 m wide swale with 1:4 side slopes over 59 km of road, an overall depression storage depth of 8 mm was applied. The results of modelling the swales are shown in Table 13-2.


Table 13-3: Option Mo3: Model Results

Hydraulic Performance Measure	Future (2060) 1 in 10 yr ARI Rainfall Event	
	Existing Roads	With Swales
Percentage of manholes predicted to overflow	37 %	4 %
Estimated flood extent (ha)	35.0	2.9
Modelled percentage (by number) of pipes surcharging	78 %	27 %
Percentage of manholes predicted to be close to overflowing (free water level within 300 mm of cover)	54 %	8 %

The cost of implementing this option could be in the range of \$25 million, including swale formation and vehicle crossings, together with some footpath re-builds and deepening of utility services. There would also be additional annual maintenance costs.

Maintenance of swales consists primarily of mowing the grass cover. Periodic litter collection may also be required and repair work as required, should grass cover become damaged, for example due to vehicles driving into them.

The annual maintenance cost for the 59 km of swale is estimated to be approximately \$110,000 (at today's rates). If the swales were planted as opposed to grassed, the annual maintenance cost would likely be doubled to approximately \$220,000 (at today's rates) as well as increasing the initial outlay required. However, planted swales may provide better community outcomes and would discourage vehicles entering them.

A staged approach could be carried out for this option with a percentage of roads programmed each year. It could also be aligned with any scheduled road resurfacing. This would allow movement towards alleviating all catchment flooding by 2060.

This option would potentially require major changes to the road corridor to accommodate the swales, they may not be acceptable to the community and would introduce a substantial maintenance cost for Mosgiel. However, this option has been shortlisted as it provides numerous quality and quantity benefits. The temporary disruption during construction may not be as unacceptable to the community as the existing nuisance flooding.

Community consultation and/or a pilot programme could be carried out targeting a small area, to better determine effectiveness and community opinion relating to this type of option.

It is unlikely that this option will alleviate deep flooding issues in the catchment and further management of those issues may be required in addition to this option. It is unknown at this stage whether the high groundwater within the catchment would impact on the success of this option. Further investigation would reveal whether this option provided satisfactory benefits.

13.2.1.2 Options Shortlist Evaluation

The results of the preliminary evaluation identified two 'shortlist' options. QBL analysis has been undertaken for direct comparison, a summary of this comparison is shown in Table 13-4. Full details of the QBL analysis can be found in Appendix G


Table 13-4: Stormwater Flooding: Catchment Wide – Shortlist Comparison

QBL Assessment Criteria Total Score	Option Mo1 : Network Upgrade	Option Mo3: retrofit Swales
Environment (20)	-25.05	41.75
Social (10)	0	50
Cultural (10)	0	0
Economic (10)	12.5	-12.5
Implementation Risk (20)	200	100
Effectiveness (Risk Reduction (30)	262.5	187.5
TOTAL	450	317

The results of the QBL analysis indicate that **Option Mo1: Catchment Wide Network Upgrade** is the more favourable option. This is mainly due to the relatively low risks associated with implementation and effectiveness in comparison to Option Mo3.

Whilst Option Mo3: Retrofit Swales to Local Roads would provide both quality and quantity benefits as well as having a lower capital cost, significant annual maintenance costs would be associated with this option.

However, both these options would provide significant long term benefits in relation to this issue. Further investigation would be required to determine the most poorly performing sections of the catchment and locations where nuisance flooding is particularly unacceptable to the community; for example where flooding flows across properties. This would enable a programme of works to be scheduled, focussing on the most poorly performing areas first.

Community consultation may provide useful information to assist in determining poorly performing areas and also to determine the acceptability of each option to the community.

The following catchment wide recommendations should be considered alongside these management options:

- Improve quality of stormwater network data; and
- Include additional or improved catchpits in any capital works.



13.2.2 Stormwater Flooding – Gordon Road

Options developed have been designed to alleviate the predicted deep flooding on Gordon Road during current and future (2060) rainfall events up to and including a 1 in 50 yr ARI.

13.2.2.1 Preliminary Option Evaluation

Option Mo4: Local Upgrade to Pipe Network Gordon Road and Lanark Street - Shortlist

This option involves the upgrade of the stormwater pipework on Gordon Road and Lanark Street to relieve capacity problems and reduce flooding.

Modelling of increased pipework along Carlyle Road and Bush Road indicates that upsizing the main would drop the hydraulic grade line sufficiently to prevent manhole overflows and flooding on Gordon Road.

During a future 1 in 50 yr ARI event, no deep flooding is predicted on Gordon Road with the upsized main, though nuisance flooding (<300 mm) is predicted. However, further work is required to assess the current road layout and surface drainage prior to advancing this option any further.

Based on DCC asset valuation rates, this option is likely to cost in the range of \$2.4 million.

Option Mo5: Provide Storage Gordon Road - Shortlist

This option involves the provision of storage in the form of an offline detention tank in the vicinity of Gordon Road to detain flows until the network has capacity for conveyance.

Based on the volume of flooding predicted in this area, approximately 400 m³ of storage would be required. There is land nearby in the form of amenity space which may be able to accommodate storage of this type.

An offline detention tank containing pumps would be constructed within the amenity space which would return stormwater to the system once flows in the main have dropped. With the provision of storage, during a future 1 in 50 yr ARI event, no deep flooding is predicted on Gordon Road.

However, further work is required to assess the current road layout and surface drainage prior to advancing this option any further.

The capital cost of this option would be in the range of \$1.5 – 2.0 million, with ongoing pumping and maintenance costs.

13.2.2.2 Options Shortlist Evaluation

The results of the preliminary evaluation identified two 'shortlist' options. QBL analysis has been undertaken for direct comparison, a summary of this comparison is shown in Table 13-5. Full details of the QBL analysis can be found in Appendix G.


Table 13-5: Stormwater Flooding: Gordon Road – Shortlist Comparison

QBL Assessment Criteria Total Score	Option Mo4: Local Upgrade Gordon Road	Option Mo5: Storage Gordon Road
Environment (20)	-33.4	-33.4
Social (10)	50	50
Cultural (10)	0	0
Economic (10)	25	0
Implementation Risk (20)	200	200
Effectiveness (Risk Reduction (30)	262.5	262.5
TOTAL	454	429

The results of the QBL analysis indicate that **Option Mo4: Local Upgrade to Pipe Network Gordon Road and Lanark Street** is the more favourable option. This is mainly due to the comparatively lower capital cost of this option.

As uncertainty exists surrounding the current surface drainage in this location, investigations to remove uncertainty should be carried out in the first instance. Following the outcomes, should further mitigation be required, the outcomes of this evaluation can be used to develop the appropriate management option.

In the first instance the following is recommended:

- Investigate surface water drainage Gordon Road.

The following catchment wide recommendations should be considered alongside any active management options developed following investigation:

- Improve quality of stormwater network data; and
- Include additional or improved catchpits in any capital works.



13.2.3 Stormwater Flooding – Kinmont Crescent

Options developed have been designed to alleviate overland flow through properties and flooding during current and future (2060) rainfall events of 1 in 10 yr ARI and deep flooding during current and future (2060) rainfall events of 1 in 50 yr ARI.

13.2.3.1 Preliminary Option Evaluation

Option Mo6: Reduce Overland Flows to Kinmont Crescent – Shortlist

This option involves the upsizing of pipework, as shown in Figure 13-3, to minimise manhole overflows upstream and, therefore, overland flows to the low point in Kinmont Crescent. This option would also include new high capacity catchpits at the low points in the road which would discharge to the DN1050 main (conveying flows under the state highway) in order to capture any overland flow before it can overtop the kerb and flow across adjacent properties.

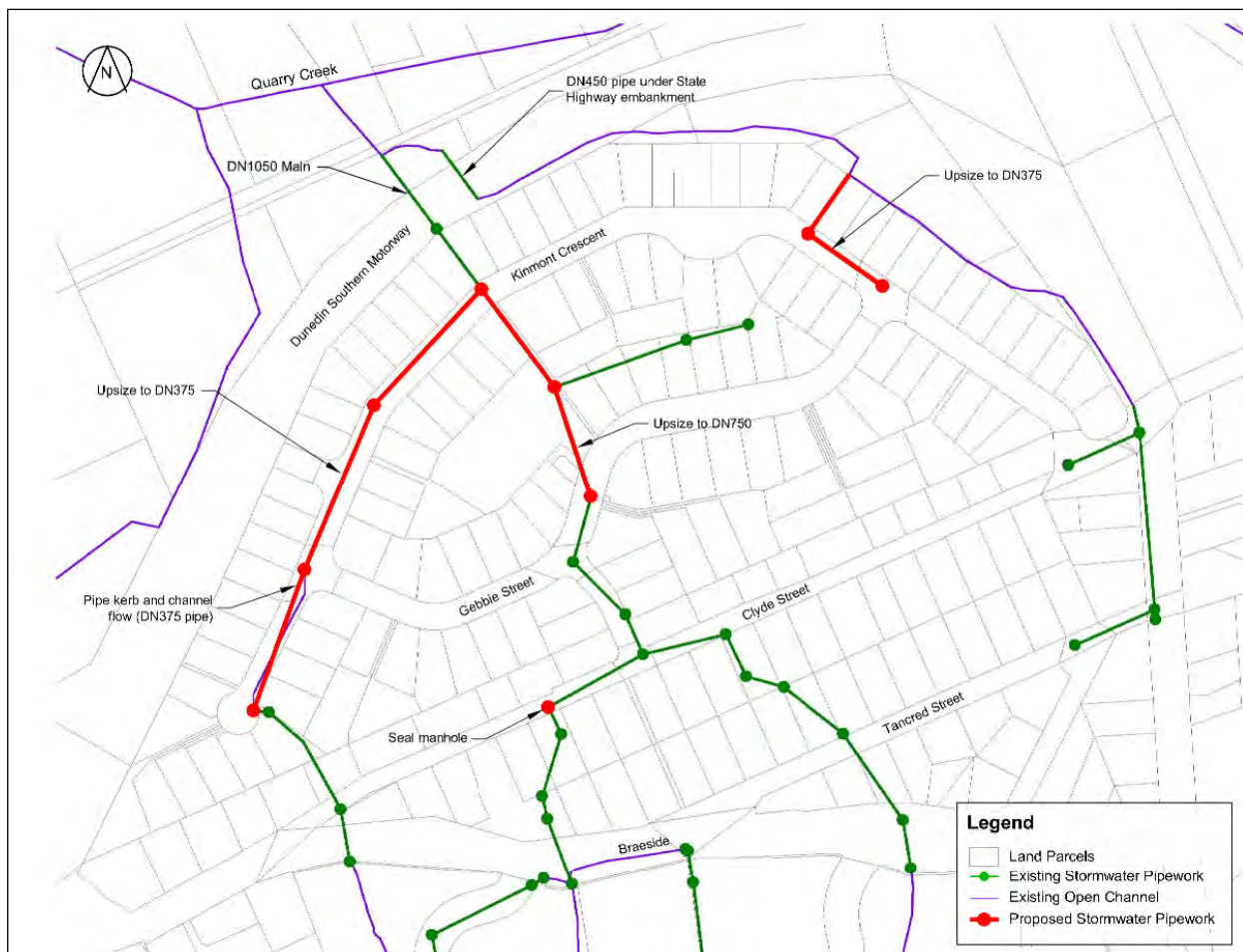


Figure 13-3: Option Mo6: Reduce Overland Flows to Kinmont Crescent

This option would prevent flooding in current and future (2060) events up to 1 in 10 yr ARI.

When this option was assessed against a 30 minute duration 2060 1 in 50 yr event, the model results indicate a reduction in 7 manhole overflows on Kinmont Crescent/Gebbie Street and reduction in risk of habitable floor flooding to three properties north of Kinmont Crescent.



Overland flow through properties (from Gebbie Street and upstream on Kinmont Crescent) would be almost entirely stopped. There would still be some ponding in the Kinmont Crescent road corridor up to 300 mm deep, but to a lesser extent than currently predicted. Deep flooding was still predicted at the rear of the properties on Kinmont Crescent, but the ponding appeared to be isolated to the culvert inlet and did not pose any risk to the adjacent properties.

Further assessment would be required to confirm the capacity of the open channel downstream of the network on Kinmont Crescent and whether or not this would also need to be improved to prevent backwater effects. Confidence in the model in this area is low as no flow calibration was undertaken and there is potential for road runoff to overshoot catchpits upstream due to the steep road grades.

The extent of deep flooding during a future 1 in 50 yr ARI is reduced but not eliminated. It reduces the risk of habitable floor flooding, during future 1 in 50 yr ARI events, at the rear of Kinmont Crescent,

The cost of this option, based on DCC asset valuation rates, would be in the range of \$1.7 - \$2.2 million.

Option Mo7: Intercept Overland Flow at Kinmont Crescent – Shortlist

This option involves the provision of high capacity catchpits at low point at the bottom of Kinmont Crescent.

This option would not prevent overflows from occurring down Kinmont Crescent within the road or flowing through properties above Kinmont Crescent, during a future 1 in 10 yr ARI. It would act to intercept the flows before they flow from the low point in Kinmont Crescent overland through the properties to the rear and pond in this location.

Modification to surrounding levels, such as lowering the road locally or modifying the kerb may be required, to further prevent the entry of overland flows in the adjacent properties at the low point on Kinmont Crescent.

During a future (2060) 1 in 50 yr event, this option would result in reduction in risk of habitable floor flooding to three properties at the rear of Kinmont Crescent. This option could be implemented as a useful first step to Option Mo6.

The cost of this option, based on DCC asset valuation rates, would be in the range of \$100k.

Option Mo8: Provide Storage Kinmont Crescent – Dealbreaker

This option involves the provision of offline storage for flows at the low point of Kinmont Crescent, adjacent to the culvert and properties at risk of flooding, and the inclusion of a high capacity catchpit.

Flows would be intercepted via a new catchpit located in the low point of the road and directed to the offline detention tank. Due to the location any storage tank would likely be deeper than groundwater levels. The depth of the tank would therefore require a pump fitting within it to pump flows back to the gravity network. A storage volume of at least 400 m³ would be required.



The cost of this option would likely to be in the range of \$1.5 – 2.0 million.

This option would not resolve overland flows upstream of the low point in Kinmont Crescent, it would only resolve the deep flooding predicted at the low point of Kinmont Crescent. Furthermore, there is insufficient land available for detention in this location. This option is therefore considered to be a dealbreaker.

Option Mo9: Purchase Properties Kinmont Crescent - Dealbreaker

This option involves the purchase of the two properties at risk of habitable floor flooding to the rear of Kinmont Crescent. The land could be converted into a reserve to provide a dedicated flow path through the area and a formalised ponding area.

This option would not prevent the overland flow or deep ponding from occurring, but would contain the ponding within an uninhabited area with minimal consequence. The cost of purchasing the properties would likely be in the range of \$600k – \$700k.

Whilst this option would resolve the risk of habitable floor flooding it would not prevent nuisance overland flows through properties upstream. Furthermore, this option could be considered to have greater negative social consequences than the 'do nothing' option. It is therefore considered to be a dealbreaker.

13.2.3.2 Options Shortlist Evaluation

The results of the preliminary evaluation identified two 'shortlist' options. QBL analysis has been undertaken for direct comparison, a summary of this comparison is shown in Table 13-6. Full details of the QBL analysis can be found in Appendix G.

Table 13-6: Stormwater Flooding: Kinmont Crescent - Shortlist Comparison

QBL Assessment Criteria Total Score	Option Mo6: Reduce Overland Flows	Option Mo7: Intercept Overland Flows
Environment (20)	-41.75	-41.75
Social (10)	0	0
Cultural (10)	0	0
Economic (10)	37.5	62.5
Implementation Risk (20)	200	200
Effectiveness (Risk Reduction (30)	225	225
TOTAL	421	466

The results of the QBL analysis indicate that **Option Mo7: Intercept Overland Flows at Kinmont Crescent** is the more favourable option. This is mainly due to the comparatively lower capital cost of



this option.

As there is uncertainty relating to the effects of the Quarry Creek on the network in Kinmont Crescent and also the actual effects of deep flooding, prior to further development of a management option, and to increase certainty, the following are recommended:

- Improve understanding of Quarry Creek; and
- Investigate risk to flooding of property interiors.

The following catchment wide recommendations should be considered alongside any active management options developed:

- Improve quality of stormwater network data; and
- Include additional or improved catchpits in any capital works.



13.2.4 Stormwater Flooding – Gow Street/McGlashan Street/Gladstone Road

Options developed for this issue have been designed to alleviate deep flooding on Gow Street during current and future (2060) long duration (12 hour) rainfall events up to 1 in 50 yr ARI.

13.2.4.1 Preliminary Option Evaluation

Option Mo10: Upsize Local Pipework Gow Street - Shortlist

This option comprises the upsizing of pipework on Gow Street to improve network capacity and reduce backwater effects from the Quarry Creek during longer duration (12 hr) events up to 1 in 50 yr ARI. This is shown in Figure 13-4.

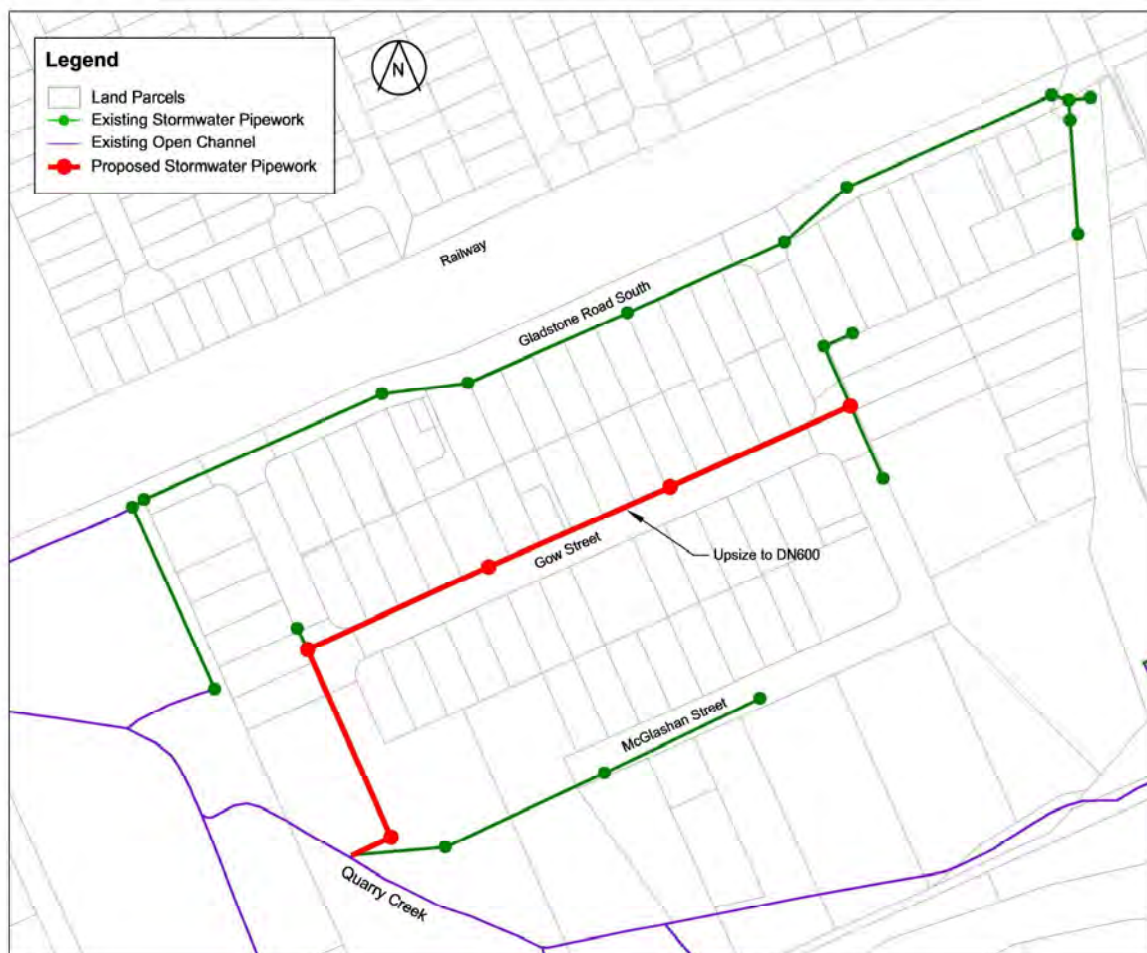


Figure 13-4: Option Mo10: Upsize Local Pipework Gow Street (Stormwater)

Modelling of this option indicates that this would be an effective way of resolving the flooding issues predicted on Gow Street. The larger pipe diameter reduces the impact of the backwater effect from the Quarry Creek by reducing the hydraulic grade line.

When the future (2060) 12 hour duration 1 in 50 yr ARI scenario was run, the results predicted flood depths in Gow Street to remain below 300 mm, therefore reducing the number of properties at risk of habitable floor flooding by three to zero. However it should be noted that the modelling was



based on assumed river levels only.

The cost of this option, based on DCC asset valuation rates, would be in the range of \$600k – \$700k.

Should the backwater effects of the Quarry Creek be more significant than currently estimated, the provision of a pumped outlet in combination with the pipe upgrade would further assist in relieving the backwater effects. With the addition of a pumped outlet the cost of this option is estimated to be in the range \$3 - \$6 million.

Confidence in the Quarry Creek flood level at this location is low. Further investigation is required by the ORC (with input from DCC), to confirm the likely level of the Quarry Creek during a flood event. This investigation should also assess the effectiveness and likely cost of improving the channel downstream. Improvements to the hydraulic capacity of the Quarry Creek downstream would be a more cost effective solution than modifying the stormwater network. Outcomes of the investigations would allow DCC to assess with greater accuracy, the potential for fluvial flooding of McGlashan and Gow Street.

Option Mo11: Provide Storage Gow Street - Dealbreaker

In order to mitigate the predicted flood volume, during longer duration (12 hr) events up to 1 in 50 yr ARI, offline storage to detain stormwater could be provided which would then pump or gravitate flows back into the network once there is capacity to convey the flows.

Modelling results show that at least 450 m³ of storage would be required. To provide such a storage volume within Gow Street, a 300 m long, 1.5 m x 1.0 m box culvert or similar would be required.

When the future (2060) 12 hour duration 1 in 50 yr ARI scenario was run, the results predicted flood depths in Gow Street to remain below 300 mm, therefore reducing the number of properties at risk of habitable floor flooding by three to zero.

The cost of this option would be in the range of \$1.7 – \$2.2 million.

However, this option is not feasible as there is limited land available in the area to accommodate this volume of storage. The only viable location would be under the road. However, this would likely clash with existing services. This option is therefore considered to be a dealbreaker.

13.2.4.2 Options Shortlist Evaluation

The results of the preliminary evaluation identified a single 'shortlist' option. As such no QBL comparison has been carried out.

The option identified is **Option Mo10: Upsize Local Pipework Gow Street**. QBL scoring has however been completed for this option (details in Appendix G) to enable this option to be compared with other options catchment wide should the need arise. The evaluation resulted in a total score of 396.

This option could be incorporated into any programme for a catchment wide network upgrade (Option Mo1).

However, prior to the further development of a management option in this location there would be merits to better understanding the effects of the downstream watercourse on network performance



in this location. In the first instance the following options are recommended:

- Improve Understanding of Quarry Creek.

The following catchment wide recommendations should also be considered alongside any active management options developed for this issue:

- Improve quality of stormwater network data; and
- Include additional or improved catchpits in any capital works.



13.2.5 Stormwater Flooding – Reid Avenue Swale

Two options developed for this issue have been designed to alleviate the predicted overtopping of the Reid Avenue swale and manhole overflows in the vicinity during current and future (2060) 12 hour duration events of up to a 1 in 50 yr ARI. Longer duration events are predicted to have the most significant effects in relation to flooding in this area.

A further two options have been developed, not to alleviate flooding but to increase efficiency and reduce the risk of the swale overtopping.

13.2.5.1 Preliminary Option Evaluation

Options to alleviate flooding are as follows:

Option Mo12: Upsize Main Reid Avenue – Shortlist

This option involves upsizing the stormwater main on Hartstonge Avenue/Reid Avenue to increase local network capacity and reduce surcharging and manhole overflows.

It is proposed that the stormwater mains on Hartstonge Avenue and Reid Avenue be upgraded as shown in Figure 13-6.

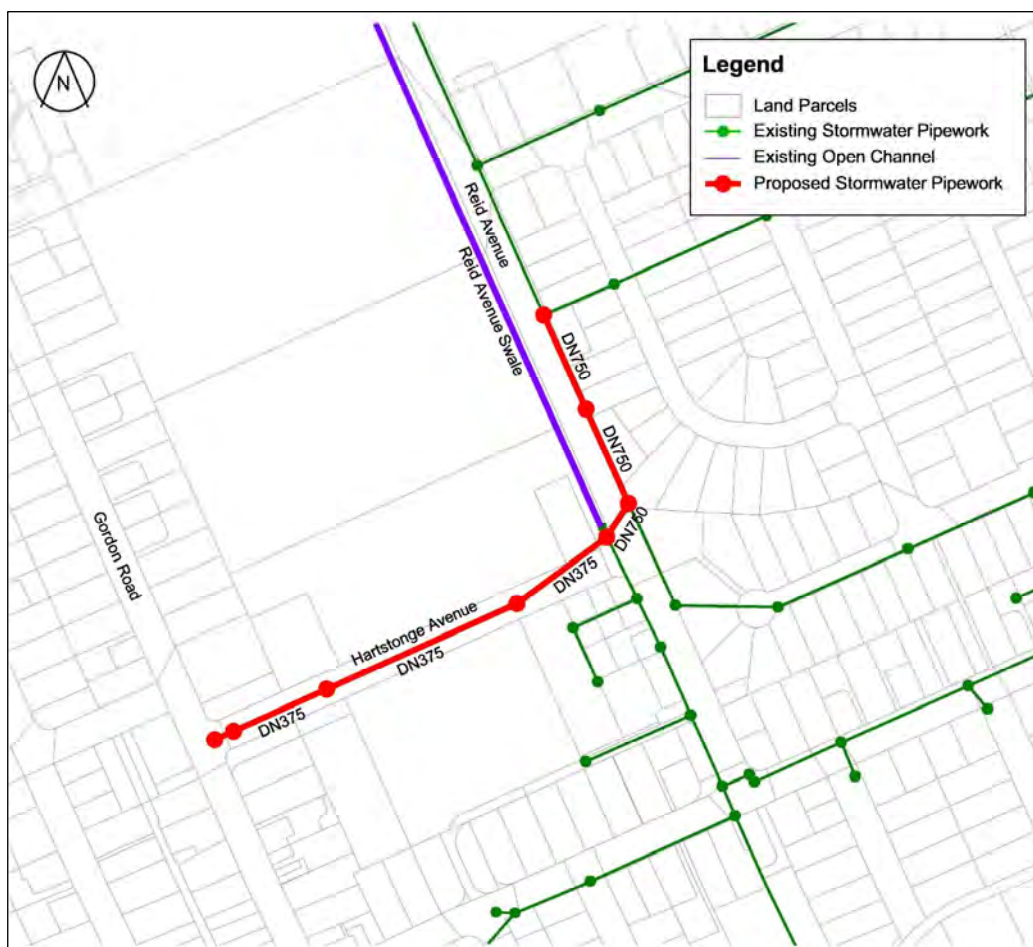


Figure 13-5: Option Mo12: Upsize Main Reid Avenue (Stormwater)



Modelling of this option predicts that during a future (2060) 24 hour, 1 in 10 yr ARI rainfall event the upgrade reduces the volume and water levels within the swale and reduces predicted flooding on Hartstonge Avenue. During a future (2060) 24 hour, 1 in 50 yr ARI rainfall event the model predicts that the upgrade is not as effective. The model results are shown in Table 13-7.

The cost of this option would be in the range of \$600k – \$1 million.

Table 13-7: Option Mo13: Model Results

Hydraulic Performance Measure	Future (2060) Rainfall Event			
	1 in 10 yr ARI		1 in 50 yr ARI	
	Existing	Upsize Main	Existing	Upsize Main
Number of manholes predicted to overflow	14	12	No reduction	
Estimated flood extent (ha)	6.55	4.64	14.35	13.21
Number of land parcels with flood depth potentially > 300 mm	6	2	21	20

Option Mo13: Increase Volume of Reid Avenue Swale – Shortlist

To reduce the risk of the swale overtopping during long duration rainfall events, the volume of storage within the swale could be increased. Preventing overtopping of the swale would reduce the number of properties at risk of habitable floor flooding by 6 to zero and prevent disruption that may be caused due to flooding of local roads.

At least 4000 m³ of additional storage (widening of the swale) would be required to prevent the swale from overtopping during events of a similar magnitude to the May 2010 event. This storage would have to be provided over a length of approximately 250 m, which equates to additional swale widening by 16 m.

Whilst there is open land to the west of the swale it contains sports pitches. The extension of the swale may encroach upon this area which may be unacceptable to the local community.

The permanent loss of amenity value of the sports fields, should the swale be extended, could be considered to be a greater negative social consequence than the 'do nothing' option which may result in the swale overtopping and flooding the sports area once a year.

There may be merit however, in increasing the volume as much as practical/as space would allow without adverse effects on amenities to provide an incremental benefit in this area. Other options could be implemented in conjunction with this to further reduce the risk in this location.

Further options have been developed to reduce the flood risk presented by the Reid Avenue swale. They are not presented as alternatives as they are not designed to entirely mitigate the flooding issue at this location. It is likely that they will increase the efficiency of the swale and therefore



reduce the risk of flooding occurring.

It is recommended that these options be considered alongside any capital works to manage this issue.

Improve Screen Reid Avenue Swale and Downstream Flap Valve

Installation of an improved inlet screen to reduce the potential for blockage and installation of improved flap valve on the outfall to the Silver Stream, downstream of the swale, to provide a better seal. The cost of this option is estimated to be <\$100k

Increase Outlet Capacity of Reid Avenue Swale

Provide high level overflow/weir on swale outlet to increase conveyance capacity to the downstream PS and outfall to the Silverstream. The cost of this option is estimated to be <\$200k

13.2.5.2 Options Shortlist Evaluation

The results of the preliminary evaluation identified two 'shortlist' options. QBL analysis has been undertaken for direct comparison, a summary of this comparison is shown in Table 13-8. Full details of the QBL analysis can be found in Appendix G.

Table 13-8: Stormwater Flooding: Reid Avenue Swale – Shortlist Comparison

QBL Assessment Criteria Total Score	Option Mo12 Upsize Main Reid Avenue	Option Mo13 Increase Volume Swale
Environment (20)	-33.4	-16.7
Social (10)	50	50
Cultural (10)	0	0
Economic (10)	37.5	37.5
Implementation Risk (20)	200	100
Effectiveness (Risk Reduction (30)	262.5	262.5
TOTAL	467	383

The results of the QBL analysis indicate that **Option Mo13: Upsize Main Reid Avenue** is the more favourable option.

There is uncertainty surrounding the causes of the swale flooding during May/October 2010 events/longer duration events. Whilst Option Mo13 appears to be more favourable based on QBL analysis, this is primarily due to confidence in the benefits of this option (implementation risk) in comparison with increasing the volume of the swale.

Option Mo13 provides benefits during long duration high frequency events but the benefits provided



during low frequency events are minimal.

It is recommended that in the first instance options to reduce flood risk in this location be considered, particularly in light of reports that the swale overtops at least annually. These include:

- Improve outlet screen of Reid Avenue swale;
- Increase outlet capacity of Reid Avenue swale;
- Review gravity outfalls to the Silver Stream and improvement of outfall seals; and
- Develop Response Plan for event of stormwater PS failure.

Further investigation to assess the benefits which may result within the network should the swale volume be increased, but to a lesser extent in combination with other catchment wide management approaches is recommended also.



13.2.6 Stormwater Flooding – Woodland Avenue

Options have been developed to alleviate stormwater flooding during current and future (2060) 1 in 10 yr ARI rainfall events and alleviate deep flooding during current and future (2060) 1 in 50 yr ARI rainfall events.

Alleviating stormwater flooding in this location will reduce the risk of habitable floor flooding of properties and also mitigate the wastewater overflows occurring in this location.

13.2.6.1 Preliminary Option Evaluation

Option Mo14: Upsize Pipework Woodland Avenue - Shortlist

This option involves upsizing the existing pipeline from the intake structure to the Quarry Creek as shown in Figure 13-6.

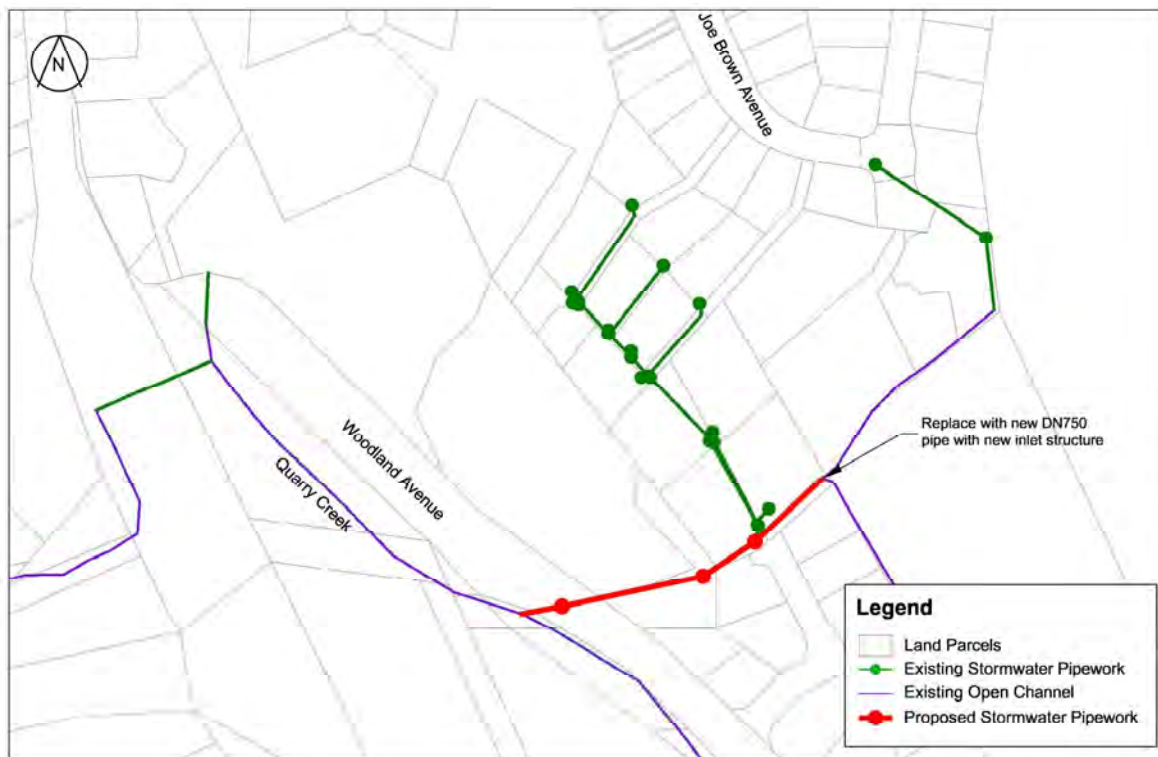


Figure 13-6: Option Mo14: Upsize Pipework Woodland Avenue (Stormwater)

The model results predict that this is sufficient to prevent flooding during a future (2060) 1 in 10 yr (with a 1 in 10 year flood level in the Quarry Creek, based on the current level of modelling).

This would resolve the deep flooding issues currently occurring in this location during high frequency events and reduce the risk of habitable floor flooding during a 1 in 10 yr ARI to zero. It would also mitigate the wastewater overflows in this location by preventing stormwater ponding and therefore inundating the wastewater PS.

During a future (2060) 1 in 50 yr ARI event, the upgraded pipe had sufficient capacity to convey the flows predicted. However, deep flooding (> 300 mm) was isolated to low points in the LiDAR over



the pipe route and posed no threat to nearby properties. Catchpits installed in the low points of the land to capture flows and direct them to the upgraded pipe would resolve this problem.

However, the upstream catchment is likely to generate more significant flows during longer duration events as it's predominantly greenfield and, therefore, there could still be some risk of flooding during a 1 in 50 yr event.

The cost of this option, based on DCC asset valuation rates, would be in the range of \$400k – \$500k

Option Mo15: Provide Offline Storage Woodland Avenue - Dealbreaker

This options comprises the provision of storage to capture the predicted flood volume and pump it back into the system once levels drop sufficiently

Assuming offline detention was provided, a storage volume of at least 400 m³ would be required to detain flows and prevent flooding during a short duration 1 in 10 yr ARI event.

Land lots in this location have been subdivided for future development, and groundwater levels are likely to be high.

The cost of this option would be in the range of \$1.5 – \$2.0 million,

During larger or longer duration events, there will be increased flows from the upstream hill catchment and increased backwater effects from the Quarry Creek downstream. The significantly larger volume of storage required under these circumstances is likely to be prohibitive. This is therefore considered to be a dealbreaker.

Option Mo16: Provide Formal Overland Flow Path Woodland Avenue - Shortlist

This option comprises the provision of a formal overland flow path to convey stormwater flooding from the inlet structure on Woodland Avenue to the Quarry Creek.

To provide an overland flow path a shallow swale would be formed following the alignment of the pipeline.

To convey flows from the swale to the Quarry Creek a section of Woodland Avenue would need to be lowered to allow flows to cross the road to the Quarry Creek. This option would likely require several hundred metres of road to be re-graded and potentially re-aligned.

Alternatively, a cheaper solution would be to install a new culvert / culverts under the existing road, sized to deal with the predicted flow rate during a future (2060) 1 in 50 yr ARI event. However, this option would not be as effective as lowering the road.

If a formal overland flow path to the Quarry Creek was provided, the risk of habitable floor flooding during a future (2060) 1 in 50 yr ARI would be reduced to zero but some flows would pond within the swale.

Providing a lower level flow path in this manner would prevent flooding at this location from becoming deep and posing a risk of habitable floor flooding to the low lying properties.



Provision of a swale and lowering the road would cost in the range of < \$500k.

Provision of a swale with culverts would cost in the range of < \$200k.

13.2.6.2 Options Shortlist Evaluation

The results of the preliminary evaluation identified two 'shortlist' options. QBL analysis has been undertaken for direct comparison, a summary of this comparison is shown in Table 13-9. Full details of the QBL analysis can be found in Appendix G.

Table 13-9: Stormwater Flooding: Woodland Avenue – Shortlist Comparison

QBL Assessment Criteria Total Score	Option Mo14: Upsize Pipe Woodland Avenue	Option Mo16: Provide Overland Flow Path
Environment (20)	-25.05	-25.05
Social (10)	50	50
Cultural (10)	0	0
Economic (10)	37.5	0
Implementation Risk (20)	200	200
Effectiveness (Risk Reduction (30)	225	225
TOTAL	437	400

The results of the QBL analysis indicate that **Option Mo14: Upsize Pipe Woodland Avenue** is the more favourable option.

In line with the development of this option, the following investigations are recommended to improve understanding regarding the current risk to properties in this area and to improve certainty relating to the benefits this option would provide:

- Investigate risk to flooding of property interiors; and
- Improve understanding of Quarry Creek.



13.2.7 Wastewater Flooding/Overflows

Options have been developed for this issue to meet the catchment specific approaches and targets and align with DCC's Strategic Objective of no wastewater overflows during a 1 in 10 yr ARI rainfall event.

A number of alternative options have been developed to actively manage the following flooding/overflows:

- Tyne Street/Silverstream Drive manhole overflow; and
- WWTP emergency overflow to Silver Stream.

Wastewater flooding/overflows are caused by insufficient capacity both in the pipe network and at the Mosgiel WWTP. As such, management options have been developed to provide efficiency benefits within the system and improve the overall level of service within the wastewater network.

All management options have been assessed during a 1 in 10 yr ARI rainfall event.

13.2.7.1 Preliminary Option Evaluation

Preliminary evaluation of the management options developed to address the wastewater flooding/overflow issues indicated that no single option was likely to provide sufficient benefits, if it were to be implemented as a stand-alone option, to meet the catchment specific targets and approaches or align with the Strategic Objective of no wastewater overflows during a 1 in 10 yr ARI rainfall event.

Where an option was not technically feasible and/or met the dealbreaker criteria it was considered to be a 'dealbreaker' and no further evaluation was undertaken.

However, those options which were assessed as being technical feasible and able to provide incremental benefits to the wastewater system were then assessed in combination. These combinations of options form the 'shortlist for this issue.

The options shortlist evaluation for this issue comprises QBL analysis on each group/combination of options, when implemented together, are able to meet the catchment specific targets and approaches and align with DCC's Strategic Objectives.

Details and outcomes of the preliminary evaluation of alternative options are presented below.

WMo1: Reduce Baseflow - Renew Pipeline Murray Street

This option has been developed to reduce groundwater infiltration (and therefore baseflows) in sub-catchment WW6. It comprises the replacement or rehabilitation of 490 m of DN375 trunk sewer and 70 m DN300 trunk sewer along Murray Street. Refer Figure 13-7.

Flow monitoring indicates that the main potential location of infiltration in wastewater sub-catchment WW6 is the section of DN375 pipe along Murray Street. This section has been CCTVed and the pipelines that are in groundwater display severe infiltration. Therefore lining or replacement of this section of pipeline should reduce the baseflow from this catchment.

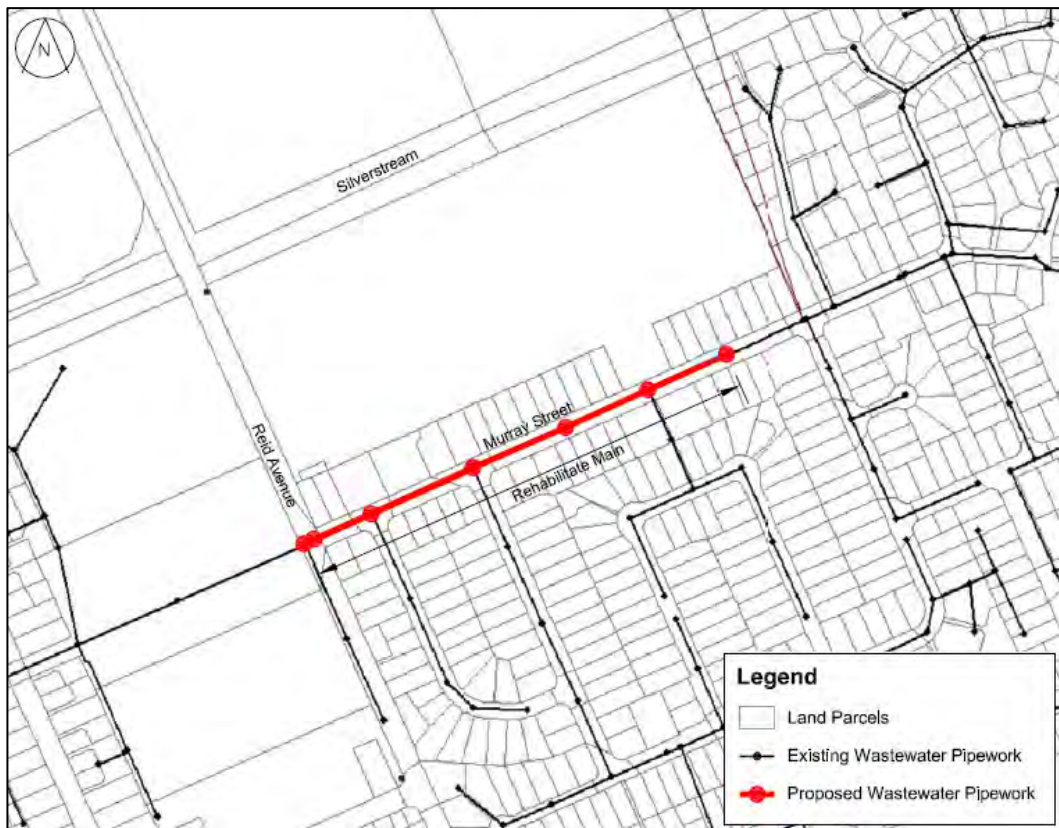


Figure 13-7: Option WMo1: Reduce Baseflow: Renew Pipeline Murray Street (Wastewater)

There is some risk that removing the infiltration into the sewer will result in higher groundwater levels in the area which then may find higher level sewer pipes to infiltrate into or cause nuisance for residents in the area. It is recommended that DCC monitor the area after works are undertaken.

Based on a desktop study of the existing DCC services in this area it would appear that replacement of the pipeline on a similar alignment to the existing would not result in significant clashes with other existing services. Therefore lining or renewing the pipeline should be considered because for a one off project, establishment cost of a lining contractor (based in Auckland) may make replacement of the pipeline just as cost effective.

DCC were unable to supply Mosgiel WWTP operational costs to allow the cost savings of reducing the daily volume of flow to the WWTP to be calculated. However cost savings of over \$10,000 per year have been estimated for the reduction in effluent transfer pumping hours alone due to the reduction in flows. This direct cost saving to DCC's operational budget serves as an additional benefit provided by this option and should not be overlooked.

The removal of dry weather infiltration does not prevent overflows upstream of the WWTP if the start levels of the inlet pumps are too high. However if PS levels are lowered then infiltration reduction does prevent manhole overflows. The rough order cost estimate for this option is \$770,000.

WMo2: Lower Groundwater- Dealbreaker

Lowering the groundwater to levels below the wastewater pipe inverts would reduce the dry weather infiltration and provide capacity benefits to the network.



Tile or field drains to lower groundwater to reduce the infiltration into the sewer are difficult to assess with the current level of information available. Further information is required on actual groundwater levels, soil type and depth, and hydraulic conductivity.

There is also a risk that if the tile drains were successful at lowering the groundwater exfiltration could occur from the sewer network when the system is surcharged (i.e. there is pressure available to drive wastewater out of the joints which are known to be “leaky”). It is considered that repair or replacement of the wastewater pipe that is known to be defective is the better option. Due to risks and current level of uncertainty surrounding this option is considered to be a dealbreaker.

WMo3: Reduce Operation Level of WWTP Inlet PSs

This option proposes a change to the pump start levels in the two inlet PSs of the WWTP. This would serve to keep the level within the PSs under 111.2 RL. The result would be a reduction in the backwater effect on the pipe network upstream, therefore relieving some surcharging.

The inlet pumps have the capacity for peak flows, however reducing the maximum level in the PSs results in a slight increase in flow discharged to the Silver Stream, as effectively the storage within the system has been decreased.

It is assumed that this will be completed ‘in house’ by DCC operations personal and therefore the cost is zero.

WMo4: Upsize Pipes on Tyne Street

This option involves upsizing of the wastewater pipe on Tyne Street to cater for flows, to reduce network surcharging, as shown in Figure 13-8.



Figure 13-8: Option WMo5: Upsize Pipes on Tyne Street (Wastewater)



Upsizing the 260m of existing DN450 trunk sewer on Tyne Street (between Carlyle Road and Braemar Street) to a DN600 pipe does not prevent overflows upstream of the WWTP if the start levels of the inlet pumps are too high. However if PS levels are lowered then this upgrade does prevent manhole overflows.

The rough order cost estimate for this option is \$580k.

WMo5: Reduce Wet Weather I&I - Dealbreaker

Wet weather I&I contributes to the overflows before and within the WWTP. Analysis of the model data has revealed that the highest percentage of rainfall falling on the catchment that is entering the wastewater system is in catchment WW2.

However a review of I&I reduction projects has concluded that system rehabilitation should not be considered for responses less than 12-15 %. Therefore no catchments in Mosgiel are considered suitable for I&I reduction.

WMo6: Divert Flows (Burns Street PS)

To reduce flows to the Mosgiel WWTP the Burns Street PS could be redirected to pump to the Tunnel pipeline or to the old Fortex pipeline (Wingatui system).

The peak wet weather flow required to be diverted is approximately 100 L/s. The Tunnel pipeline is a DN225 Class B uPVC pipeline and does not have capacity for this peak flow. The old Fortex pipeline is a DN300 Class C uPVC pipeline and could accept this peak flow rate.

This option involves an upgrade to the Burns Street PS and construction of a new DN300 pressure main from Burns Street PS to connect to the old Fortex pipeline in Wingatui.

The rough order cost estimate for this option is \$5.1 million.

WMo7: Divert Flows (Old Mill PS) - Dealbreaker

This option involves utilising the disused Old Mill PS and DN200 Class B uPVC rising main to divert flows, relieving capacity in the existing network and reducing flows to the WWTP.

The Old Mill PS could be upgraded to divert a peak wet weather flow of 20 L/s to the Wingatui system. A new 200 m DN300 gravity main is required to divert flows from Factory Road to the existing Old Mill PS. This option does not divert enough flow away from the WWTP to contribute to significant improvements and is therefore considered to be a dealbreaker.

WMo8: Increase Capacity of Effluent Transfer

Increasing the effluent transfer rate, from the WWTP, to 300 L/s by improving the rising main performance would relieve some capacity issues.

The diesel pump at the WWTP, used for effluent transfer, has the potential to significantly reduce the overflow to Silver Stream should the effluent transfer rate be increased. To ensure the diesel pump is most effective, regular maintenance of the rising main from the Mosgiel WWTP to the Green Island WWTP is required. Operation of the diesel pump has started to flush the pipeline and is improving performance however it is recommended that swabbing or pigging of the pipeline is



undertaken to increase the cleaning process. Currently capacity of the diesel pump is being restricted due to concerns about rising main strength and pressure rating. It is recommended that further work is undertaken on the pipe condition to determine the appropriate derating values to apply in pressure calculations.

WMo9: Provide Storage

Increasing storage at the WWTP could reduce the volume of overflow to the Silver Stream.

Approximately 7,000 m³ of additional storage is required to at the WWTP to remove the overflow to the Silver Stream. To incorporate this volume of storage into the WWTP site a mixture of above and below ground storage is likely to be required. The estimated rough order cost for this option is \$13.4 million.

This option is very expensive but could be coupled with other options which decrease the amount of storage required. Should the storage volume be decreased then the estimated costs would also be reduced.

13.2.7.2 Options Shortlist Evaluation

Preliminary evaluation of the management options indicated that no single option was likely to provide sufficient benefits, if it were to be implemented as a stand-alone option. Therefore those options which were assessed as being technical feasible and able to provide incremental benefits to the wastewater system have been considered in combination.

The combined options form the basis of the shortlist evaluation and have undergone QBL analysis to determine the optimal recommendations for this issue. Full details of the QBL analysis undertaken can be found in Appendix G.

Table 13-10 indicates the shortlisted combinations of options that have been developed to meet catchment specific targets and objectives and align with DCC's Strategic Objective during a current 1 in 10 yr ARI rainfall event.


Table 13-10: Wastewater Flooding/Overflows – Options Shortlist

Shortlist Option	Combined Approach
Option WMoA ROC \$770k	WMo8: Increase Capacity of Effluent Transfer to 300 L/s WMo3: Reduce Operation Level of WWTP Inlet PSs WMo1: Reduce Baseflow - Renew Pipeline Murray Street
Option WMoB ROC \$5.9 million	WMo6: Divert Flows (Burns Street PS) WMo3: Reduce Operation Level of WWTP Inlet PSs WMo1: Reduce Baseflow - Renew Pipeline Murray Street
Option WMoC ROC \$3.3 million	WMo9: Provide Storage at WWTP (2,500m ³) WMo3: Reduce Operation Level of WWTP Inlet PSs WMo1: Reduce Baseflow - Renew Pipeline Murray Street
Option WMoD is \$4.1 million	WMo9: Provide Storage at WWTP (3,400m ³) WMo3: Reduce Operation Level of WWTP Inlet PSs WMo4: Upsize Pipes on Tyne Street

A summary of the results of the shortlist comparison are presented in Table 13-11. Full details of the QBL analysis can be found in Appendix G.

Table 13-11: Wastewater Flooding/Overflows – Shortlist Comparison

QBL Assessment Criteria Total Score	Option			
	Option WMoA	Option WMoB	Option WMoC	Option WMoD
Environment (20)	37.5	12.5	25	-37.5
Social (10)	50	50	50	50
Cultural (10)	0	0	0	0
Economic (10)	50	25	37.5	37.5
Implementation Risk (20)	100	100	100	200
Effectiveness (Risk Reduction (30))	150	187.5	75	75
TOTAL	388	375	288	325



Based on the shortlist evaluation, to address the issues for the current 1 in 10 yr ARI rainfall event the preferred grouping of options is:

Option WMoA:

- **WMo8:** Increase Capacity of Effluent Transfer to 300 L/s;
- **WMo3:** Reduce Operation Level of WWTP Inlet PSs; and
- **WMo1:** Reduce Baseflow - Renew Pipeline Murray Street.

A phased approach could be carried out with the less expensive and quicker solutions (WMo8, WMo3) carried out first.

To meet the catchment specific approaches and targets in the future due to growth and climate change, further works will be required. The recommended alternative options to meet the future scenario are:

WMo6: Divert flows (Burns Street PS)

This option greatly increases the capacity of the system and has spare capacity for growth and climate change, greater than that predicted to be required. Rough order cost of \$5.1 million.

WMo9: Provide Storage at WWTP (reduced volume)

To cater for predicted growth and climate change a storage volume of 1,100 m³ is required. The rough order cost is \$1.3 million. (Note: this is a reduced cost when compared with Option WMo9 in Section 13.2.7.1. This is because when in combination with other options, Option WMo9 requires less storage volume and therefore indicative costs are less also.)



14 Option Selection

14.1 Approaches for Active Management

A number of issues have been prioritised in the Mosgiel catchment as requiring 'active management' (Section 10).

Options were identified to manage each of these issues (Section 12). They include capital works options, planning options, investigations and operation and maintenance tasks. Where more than one alternative was identified, the options were further evaluated to determine the optimal approach for each issue (Section 13).

Table 14-1 presents a summary of the issues requiring 'active management' in the Mosgiel catchment and the corresponding management approaches that have been identified.

Table 14-1: Active Management Issues and Approaches – Mosgiel Catchment

Active Management Issue	Management Approach
Fluvial Flood Risk	- Improve understanding of flood levels and hydraulic capacity of the Quarry Creek (investigations by ORC in collaboration with DCC) - DCC to work with ORC to ensure appropriate level of fluvial flood protection is provided by ORC - Amend business processes to manage land use planning and subdivision and development controls to ensure new development/growth areas are not at risk of fluvial flooding - Educate property owners to ensure private sections of watercourses are appropriately managed
Stormwater Flooding – Woodland Avenue	- Improve understanding of flood levels and hydraulic capacity of the Quarry Creek (investigations by ORC) - Investigate risk of habitable floor flooding (floor level survey and damage assessment) - Option Mo4: Upsize Pipe Woodland Avenue (detailed development following outcome of investigations)
Wastewater Flooding/Overflows	- Option WMoA: detailed development, programming, implementation - Confirm manhole overflows predicted by the model (where not verified) and develop management approach where necessary - Ongoing assessment of system performance, develop /amend capital works options to address future growth as required
Potential Wastewater Contamination	- Design and implement framework for stormwater quality baseline data collection - Investigate potential sources of microbial contamination
WWTP Emergency Overflow Quality	Monitor WWTP overflow to enable better understanding of triggers and frequency of operation



Active Management Issue	Management Approach
	<i>(further management approaches to reduce overflow operation are presented under other wastewater Manage Actively issues)</i>
Stormwater Flooding – Catchment Wide (nuisance)	• Improve quality of stormwater network data • Include additional or improved catchpits in any capital works • Investigate risk of habitable floor flooding (floor level survey and damage assessment) • Feasibility study, consultation and programming – catchment wide upgrade (pipes or swales)
Stormwater Flooding – Gow Street/McGlashan Street/Gladstone Road	• Improve understanding of flood levels and hydraulic capacity of the Quarry Creek (investigations by ORC in collaboration with DCC) • Investigate risk of habitable floor flooding (floor level survey and damage assessment) • Develop /amend capital works option Mo10 following outcomes of investigations • Include additional or improved catchpits in any capital works
Stormwater Flooding – Kinmont Crescent	• Improve understanding of flood levels and hydraulic capacity of the Quarry Creek (investigations by ORC in collaboration with DCC) • Investigate risk of habitable floor flooding (floor level survey and damage assessment) • Develop /amend capital works Option Mo7 following outcomes of investigations • Include additional or improved catchpits in any capital works
Stormwater Flooding – Reid Avenue Swale	• Improve outlet screen – Reid Avenue Swale • Increase outlet capacity – Reid Avenue Swale • Review gravity outfalls to the Silver Stream and improve outfall seals • Develop a response plan for event of stormwater PS failure
Stormwater Flooding – Gordon Road	• Investigate current surface water drainage on Gordon Road and Lanark Street and update management approach • Include additional or improved catchpits in any capital works

Recommendations for the management of stormwater and wastewater in the Mosgiel catchment are presented and prioritised in Section 15.



14.2 Approaches for Passive Management

A number of issues have been prioritised in the Mosgiel catchment as requiring 'passive' management.

Management options have been identified for these issues (Section 12). 'Passive Management' will achieve catchment specific targets and objectives through measures already in place, via the options identified for other issues in the catchment or via non-infrastructure options such as planning and investigations.

Table 14-2 presents a summary of the issues requiring 'passive management' in the Mosgiel catchment and the corresponding management approaches that have been identified.

Table 14-2: Passive Management Issues and Approaches – Mosgiel Catchment

Passive Management Issue	Management Approach
Stormwater Network Maintenance	- Develop an inventory of key stormwater structures in the catchment - Identify key structures and incorporate into priority list for more regular catchment inspection and cleaning. (Include: Woodland Avenue intake, Reid Avenue swale; Kinmont Crescent/state highway culvert; and Carlyle Road PS inlet screens) - Develop consistent cleaning and maintenance criteria for all stormwater assets (in conjunction with city-wide criteria)
Wastewater Network Maintenance	- Ensure robust complaints/operational incident reporting procedures to allow documentation of incidents against assets - Develop an inventory of wastewater assets prone to blockage - Develop cleaning and maintenance schedule for the wastewater network
Ongoing Stormwater Discharges	- Identify locations of high risk land uses within the catchment and implement an education programme targeting stormwater discharges - Design and implement framework for stormwater baseline data collection
Wastewater Flooding – Private Property Boundary/Gully Traps	- Ensure robust complaints/operational incident reporting procedures to allow documentation of incidents against assets - Develop an inventory of wastewater assets prone to blockage - Develop cleaning and maintenance schedule for the wastewater network
Low Level of Service – Stormwater Network	- Improve quality of stormwater network data - Utilise stormwater complaints information, ROS and Community Board feedback to continually gauge customer satisfaction with the stormwater service - Ensure new pipes (renewals and development) are designed to accommodate a



Passive Management Issue	Management Approach
	1 in 10 yr ARI rainfall event
Low Level of Service – Wastewater Network	• Improve quality of wastewater network data • Utilise wastewater complaints information and ROS to continually gauge customer satisfaction with the sewerage services
Stormwater Flooding PS Failure Risk	• Develop a response plan for event of stormwater PS failure (Cherry Drive, Reid Avenue, Carlyle Road) • Review gravity outfalls to the Silver Stream and improve outfall seals
Stormwater Flooding – Gladstone Road North	• Investigate risk of habitable floor flooding (floor level survey and damage assessment) • Develop /amend capital works options following outcomes of investigations
Flood Hazard (1 in 100 yr)	• Develop climate change adaptation plan

Recommendations for the management of stormwater and wastewater in the Mosgiel catchment are presented and prioritised in Section 15.



15 Recommendations

The following tables provide a list of recommendations relating to stormwater and wastewater network management in the Mosgiel catchment. An indicative cost and work period for each recommendation is provided.

Recommendations are split into further studies, planning and education, operation and maintenance, and capital works tasks. Further studies recommended will assist in improving certainty around catchment management targets, or where further information is required in order to develop options.

The recommendations are prioritised, based on the risk matrix score (Section 10). However, it should be noted that some recommendations with lower risk matrix scores, particularly those prioritised for passive management, may provide 'quick wins' for DCC in terms of benefits or may be relatively cheap to implement. For example, there would be merits implementing those recommendations that have been developed to manage flood risk sooner rather than later.

The intention is that as each task is carried out, the influence on catchment management targets is assessed through the ICMP review process (Section 16) and further tasks are undertaken as necessary to achieve targets.

Where a cost of \$0 has been applied, it is intended that DCC staff will undertake the work. Delivery dates have been identified where available, however a number of the recommendations will have their delivery dates set by the 3 Waters Strategic Plan, yet to be developed. Refer to the following Section regarding implementation of the Plan.


Table 15-1: Further Study Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
210	Improve understanding of flood levels and hydraulic capacity of the Quarry Creek (investigations by ORC in collaboration with DCC).	\$100-150k	12 months
200	Design framework to investigate stormwater quality, in particular the extent of microbial contamination.	\$8-\$15k	2-4 months
200	Implement framework for investigating stormwater quality with focus on extent of microbial contamination within catchment.	\$20-\$30k	8-10 months
200	Improve quality of wastewater network data through (level survey, GIS confirmation, CCTV).	\$0	Ongoing
160	Improve quality of stormwater network data through (level survey, GIS confirmation, CCTV).	\$0	Ongoing
160	Community consultation followed by feasibility study for catchment-wide stormwater network upgrade (pipes or swales).	\$100 - \$200k	12 months
120	Identify and undertake floor level survey and damage assessment of properties potentially affected by deep (habitable floor) flooding up to a 1 in 50 yr ARI event prior to detailed development of options for Gow Street.	\$20-40k	3-6 months
120	Identify and undertake floor level survey and damage assessment of properties potentially affected by deep (habitable floor) flooding up to a 1 in 50 yr ARI event prior to detailed development of options for Kinmont Crescent.	\$20-40k	3-6 months
80	Investigate current surface water drainage on Gordon Road and Lanark street and update management approach as required.	\$5-\$10k	2-4 months
40	Develop Response Plan for event of stormwater PS failure.	\$10-\$20k	3-6 months
40	Utilise stormwater and wastewater complaints, ROS and Community Board feedback information to continuously gauge customer satisfaction with the stormwater and wastewater services.	\$0	Ongoing
40	Review/amend capital works options for Gow Street/McGlashan Street stormwater flooding issues following outcomes of catchment investigations (Quarry Creek/Habitable floor flooding).	\$0	6 months
40	Ongoing assessment of wastewater system performance, develop/amend capital works options to address future growth as required.	\$0	ongoing
40	Review/amend capital works options Gladstone Road North stormwater flooding issues following outcomes of catchment investigations (Habitable floor flooding).	\$0	6 months


Table 15-2: Planning and Education Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
210	Collaborate with ORC to ensure appropriate level of fluvial flood protection is provided in Mosgiel.	\$0	6-12 months
210	Review/amend business processes (landuse planning, subdivision and development) to ensure new development/growth areas are not at risk from fluvial flooding.	\$0	12 months
210	Review the education/advice provided to property owners responsible for watercourses to ensure adequate information and assistance is provided.	\$0	3-6 months
50	Identify locations of high risk land uses within the catchment and implement an education programme targeting stormwater discharges.	\$10-20	3-6 months
40	Include the Mosgiel catchment in the development of a city-wide Climate Change Adaptation Plan.	\$0	6-12 months

Table 15-3: Operation & Maintenance Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
50	Review/amend wastewater complaints logging/incident reporting procedures to enable recording of incidents against assets.	\$0	3 months
50	Compile an inventory of wastewater assets prone to blockage or other problems. Update regularly using complaints/incident reporting.	\$0	ongoing
50	Develop a cleaning and maintenance schedule for the wastewater network documenting locations, nature of cleaning/maintenance and frequency.	tba	Ongoing
50	Compile an inventory of stormwater structures including asset condition, ownership and identify sensitive locations for more frequent cleaning and maintenance.	\$20k	3-6 months
50	Develop consistent cleaning and maintenance criteria for all stormwater assets (in conjunction with city-wide criteria).	\$20k	2 months


Table 15-4: Capital Works Recommendations

Risk Matrix Score	Task	Budget Cost	Work Period
200	Option WMoA (wastewater) - detailed development, programming, implementation (staged approach).	\$800K - \$1.5M	12-24 months
200	Option Mo4: Upsize Stormwater Pipe Woodland Avenue- Identify and undertake floor level survey and damage assessment of properties potentially affected by deep flooding up to a 1 in 50 yr ARI, detailed option development, implementation.	\$400-\$600k	tba
160	Include additional or improved catchpits in stormwater capital works.	tba	ongoing
80	Improve outlet screen – Reid Avenue Swale.	\$50-\$100k	tba
80	Increase outlet capacity – Reid Avenue swale.	\$100-\$200k	tba
40	Review gravity outfalls to the Silver Stream and improve outfall seals.	\$50-\$100k	tba
40	Implement works resulting from the development of the Response Plan for stormwater PS failure.	\$1M-\$2M	tba



16 Implementation, Monitoring and Continuous Improvement of the ICMP

16.1 Implementation

As detailed in Section 1 of this report, a number of DCC documents are linked to the outcomes of this ICMP. These include the Dunedin Code of Subdivision and Development, the Dunedin City District Plan, and the 3 Waters Strategic Plan. A number of other documents are also influenced by this ICMP.

The DCC 3 Waters Strategic Plan pulls together the recommendations from all ICMPs, as well as other 3 Waters work prepared by DCC. Currently, 11 ICMPs are under development, and the recommended options presented by each ICMP will need to be managed in a coordinated manner.

Targets set within each ICMP, and issue prioritisation will be used to determine the programme for commitment of staff resources, and both operational and capital funds for recommended works across the city over the coming years.

16.2 Monitoring and Continuous Improvement

The continuous monitoring and reporting with respect to the SMART targets developed for each of the critical stormwater and wastewater issues ensures that the success of this ICMP will be measurable.

Recommendations presented in Section 15 above have been prioritised, and provide the opportunity for DCC to progressively work towards these targets. It also ensures that when targets have been reached, DCC can re-evaluate recommended works appropriately.

A revision of the ICMP will be completed at least once every five years.

This ICMP is intended to be a 'live' document and as such, updates may also be required at a number of milestones, and may either be minor updates or major changes as follows:

1. When further stormwater quality data has been collated and assessed to confirm any key stormwater quality issues requiring management;
2. When the recommended investigations have been completed, a review of the issues, targets and management approaches may be necessary.
3. Due to changes in climate change predictions.



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Appendix A

A1 Dunedin City Imperviousness Report

Dunedin City Imperviousness

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Table of Contents

Executive Summary	1
1 Introduction.....	4
2 Land Use Zones	5
2.1 Residential 1	7
2.2 Residential 2	7
2.3 Residential 3	8
2.4 Residential 4	8
2.5 Residential 5 (Un-serviced or Semi-serviced Residential).....	9
2.6 Residential 6 (Special Areas).....	9
2.7 Activity Zones.....	9
2.8 Industry	10
2.9 Rural and Residential.....	10
2.10 Port	10
2.11 Campus.....	11
3 Estimating Current Imperviousness	12
3.1 Methodology	12
3.2 Final Estimates – Current Imperviousness.....	17
4 Estimating Future Imperviousness.....	19
4.1 Data	19
4.2 Methodology and Assumptions	21
4.3 Results - Final Imperviousness Figures	21
5 Conclusions	27



List of Figures

Figure 2-1: Land Use Zones	6
Figure 3-1: Sample Areas	16
Figure 3-2: Current Land Use Imperviousness over Dunedin Region	18
Figure 4-1: Future Imperviousness 2031 and 2060	26

List of Tables

Table ES 1: Estimated Imperviousness in Dunedin City	2
Table ES-2: Current Land Use Zoning in Dunedin	3
Table 3-1: Current Estimated Imperviousness Sampling Results – Dunedin City	13
Table 3-2: Current Imperviousness Estimates – Non-sampled Parcels.....	14
Table 3-3: Current Estimated Imperviousness for each Land Use Zone	17
Table 4-1: Permitted Residential Densities	20
Table 4-2: Useable Residential Land 2005	20
Table 4-3: Building Consents Issued for New Dwelling Units by zone, 2000-2005.....	20
Table 4-4: Current and Future Imperviousness for Dunedin Catchments	22



Executive Summary

Land use in Dunedin is classified into six zones: Rural, Rural Residential, Port, Campus and a number of 'Activity Zones' which include light industry, recreation and commercial areas (as specified in the Dunedin City District Plan). For the 3 Waters Strategy Project, the Dunedin area has been split into 11 stormwater management catchments, each of which contains a number of these land use zones. All of the catchments (except Mosgiel) are currently considered by DCC planners to be approaching a fully developed state. Mosgiel is expected to have the most potential for development among all the 3 Waters Catchments.

Current imperviousness estimates for parcels within each land use zone in the city were made by calculating or estimating the imperviousness in a number of sample areas within Dunedin City. This imperviousness assumption was then applied to each land parcel within the stormwater model extents, excluding those parcels identified as vacant, a park or a school (as indicated by DCC information), and roads.

Three future land use scenarios are being considered within the DCC 3 Waters Strategy along with the current situation. The scenarios are: 2008 (current), 2021, 2031 and 2060. For the purposes of stormwater modelling, the 2031 scenario contains the maximum allowable imperviousness for each zone, consistent with the planning horizon of the district plan (2036), and little development was expected by 2021, based on the current development present in most areas. The 2060 scenario also uses the maximum allowable imperviousness. The following information was used to estimate future imperviousness:

- Areas in Dunedin where vacant land, or large lots of land have been identified as potential areas for subdivision;
- Resource and Building consents granted by DCC recently;
- Plan changes proposed; and
- Maximum allowable imperviousness permitted in the Dunedin City District Plan.

The average estimated imperviousness is summarised for each catchment in Table ES-1 overleaf, for the current scenario, and for two future scenarios.

Table ES-2 summarises the amount of land allocated to each land use zone as a percentage of the overall catchment area.

It was found that for most of the catchments, there is relatively little change from the current figure to the future maximum imperviousness expected / allowed by 2060. Population growth, land development and consequently, imperviousness, are expected to increase slightly in some, mainly outlying, Dunedin areas. While there is some in-fill development expected in built up areas due to the majority of Dunedin City being zoned Residential 1, Residential 2, or Commercial / Industrial, imperviousness is already at or above the maximum allowable by the DCC district plan for some catchments.



Table ES 1: Estimated Imperviousness in Dunedin City

Catchment	Average Impervious Area as Percentage of Total Catchment		
	Current	2031	2060
Halsey Street	60	61	61
Kitchener Street	70	72	72
Mason Street	56	57	57
Mosgiel	16	25	25
Orari Street	47	49	49
Port Chalmers	34	36	36
Portsmouth Drive	98	98	98
Ravensbourne Road	48	48	48
Shore Street	49	50	50
South Dunedin	56	57	57
St Clair	41	44	44



Table ES-2: Current Land Use Zoning in Dunedin

DCC Land Use Zone	Proportion of Catchment within Land Use Zone (%)										
	Halsey Street	Kitchener Street	Mason Street	Mosgiel	Orari Street	Port Chalmers	Portsmouth Drive	Ravensbourne Road	Shore Street	South Dunedin	St Clair
Campus	8										
Central Activity Area	9	3	13								
Industrial 1	9	22	9	7		1	100	41		17	
Industrial 2	1										
Large Scale Retail	1	11	2								
Local Activity Zone 1				1	1	6			1	2	
Local Activity Zone 2											
Port 1						1					
Port 2	7	16	2					4			
R1	50	28	57	22	97	43			97	17	88
R2				4	2				3	64	2
R3	11										
R4	4	19	17								
R5											
R6				6							
Rural				59		49		55			10
Rural Residential				2							
Special Development											



1 Introduction

The amount of impervious surface in a catchment is one of the major influences on both the quantity of stormwater runoff generated in a catchment and the contaminants carried by the stormwater.

Changes in imperviousness over time are therefore a critical factor in determining the effects of development on stormwater issues. An imperviousness study has been undertaken for Dunedin City as part of the 3 Waters Strategy Project. To support stormwater hydrological modelling, the study needed to provide an imperviousness estimate for each land parcel in the city under current and future scenarios.

An assessment of the current imperviousness was carried out for the whole of Dunedin City using the following information:

- Aerial photographs (2007);
- Land Use zones (DCC, 2005);
- Assessment of vacant land (DCC Residential Capacity Study, 2005);
- Parks and Reserves information (DCC); and
- Schools database (DCC).

Future Imperviousness was then calculated for two future scenarios - 2031 and 2060, based on a variety of information including the following:

- Areas in Dunedin where vacant land, or large lots of land, have been identified as potential areas for subdivision;
- Resource and Building consents granted by DCC recently;
- Plan changes proposed; and
- Maximum allowable imperviousness permitted in the Dunedin City District Plan.

The 2031 and 2060 scenarios use the maximum allowable imperviousness in the DCC District Plan which includes potential subdivision and plan changes. The planning horizon of the district plan only extends to 2036 and hence the imperviousness for the 2060 scenario is identical to the 2031 scenario; changes in the modelling scenario have been made to reflect estimated climate change effects.



2 Land Use Zones

Investigation into the characteristics of each land use zone was completed to enable the imperviousness of each property parcel within the stormwater catchment boundaries to be estimated.

Figure 2-1 illustrates the varying land use zones (as per the Dunedin City District Plan) in central Dunedin and Mosgiel. According to the Dunedin City District Plan Specifications, most of the central Dunedin area is classified as Residential 1 (R1) with Residential 2 (R2) (for the most part in the South Dunedin Catchment) also contributing to a large area of the Dunedin land use. The Mosgiel catchment is dominated by Rural and R1 land use. The 11 stormwater catchment boundaries are illustrated in Figure 2-1 below to provide a visual comparison of the land use zones in each catchment.

The sections following outline the dominant characteristics of each land use zone that would be likely to influence imperviousness. Residential 1, 2 and 3 are described in some detail; however the remainder of the zones play a less significant role in the imperviousness of Dunedin and these descriptions are therefore included in brief. For more detail refer to the Dunedin City District Plan.

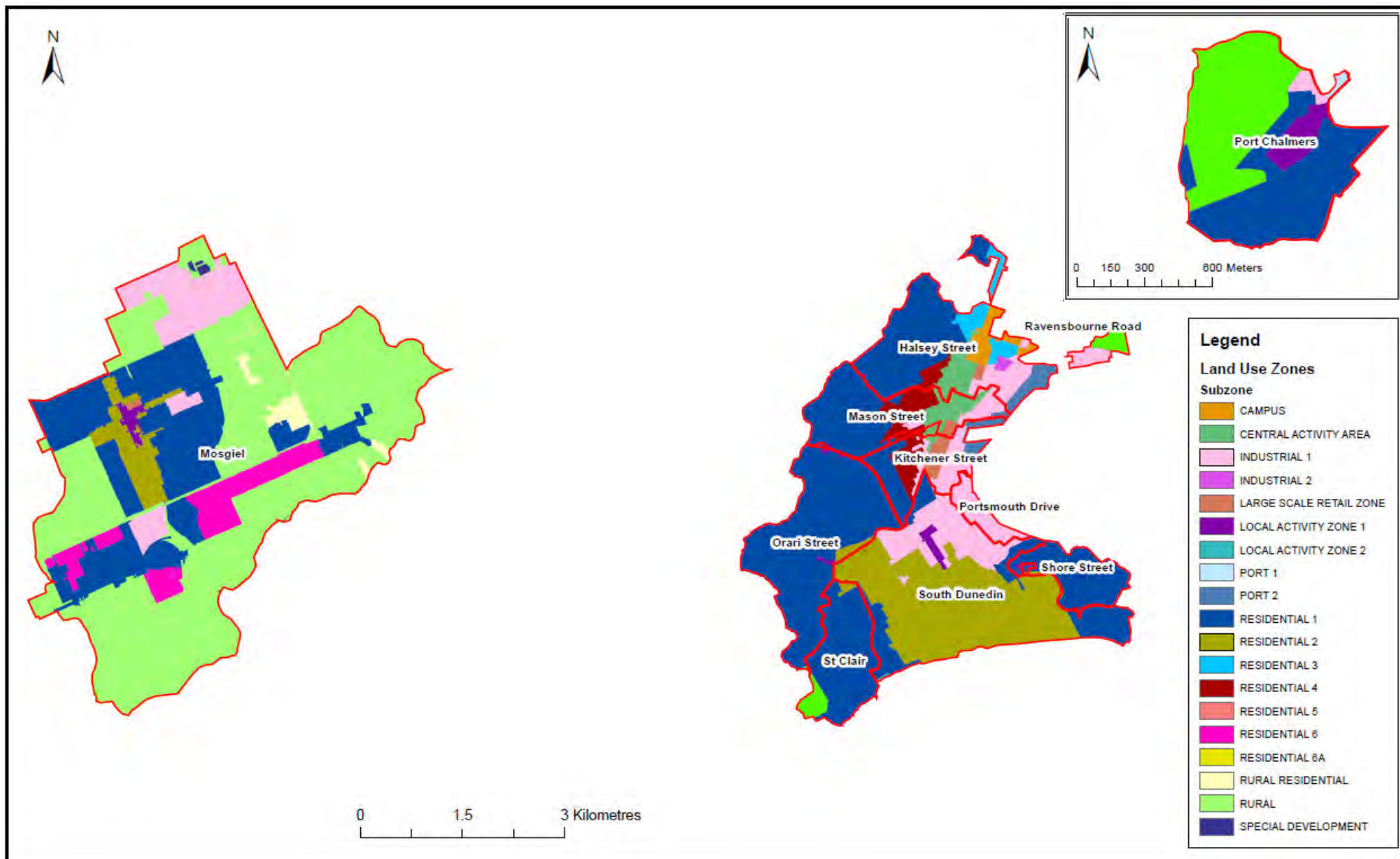


Figure 2-1: Land Use Zones



2.1 Residential 1

Residential 1 zoning consists of land parcels that are reasonably uniform in shape and size, typically one or two storey houses surrounded by lawn and garden. This category includes much of Dunedin's middle suburbs and most of the outer areas. Single dwelling developments dominate, and density is relatively low enabling significant open areas which have been landscaped and are used for on-site recreation. Recent demand for development has increased pressure on areas to be infilled but has not yet significantly impacted on the area's residential character.

Housing in Residential 1 typically has:

- Front yards more than 4.5 m deep, usually landscaped with trees and / or gardens.
- Side yards of at least 1.8 m, giving a reasonable space between buildings.
- Single-storeyed, single-unit developments.
- Rear yards capable of accommodating large trees.
- Low site coverage (25 %).
- A variety of dwelling sizes and styles reflecting the era they were constructed in.

2.2 Residential 2

Areas closely settled during the early period of Dunedin's development are largely classified as Residential 2 land. These properties are distinctly different from those in the north of the city, with much of the Residential 2 area being on flat land.

The average size of Residential 2 sites is smaller than those in other residential zones. This area has some narrower streets with sites having a smaller front and rear yard. Side yards of 900 mm to 1 m are common. The domination of single-storied structures keeps development in scale. Small areas of amenity open space and some narrow roads impact on the amount of space available for recreation.

Key points for Residential 2 classification include:

- Medium to small front yards, generally up to 3 m deep.
- Side yards less than 1 m giving little space between buildings.
- Large number of small sites.
- Medium number of multi-unit developments.
- Medium to high site coverage (40 %).
- Smaller dwelling size.
- High population density.
- Lack of off-street parking.



2.3 Residential 3

A smaller area north of the city surrounded by educational facilities, light industrial and service activities, this area has developed as a key area for student housing in the form of high density blocks of flats. Much of the original housing was built prior to 1920. Despite considerable replacement, repair, modification and additions to these buildings, many of the sites that had large areas of open space have been redeveloped and this has significantly increased the overall density of development in this zone. Some developments have site coverage of 45 %.

Development in the Residential 3 Zone is characterised by:

- Small to medium sized front yards, generally less than 3 m deep.
- Side yards of up to 1 m giving little space between buildings.
- Large number of small sites.
- Medium to high site coverage (45 %).
- High number of multi-unit developments.
- A variety of dwelling sizes.
- High population density.
- High proportion of dwellings occupied by short and medium term tenants.
- Severe lack of off-street parking.
- Competition for on-street parking.
- Parking pressure from non-residential uses.

2.4 Residential 4

Development in the Residential 4 Zone is characterised by:

- Large front yards, generally more than 4.5 m deep.
- Side yards of up to 1 m giving little space between buildings.
- Large number of small sites.
- High site coverage (60 %).
- Very high population density.
- Intense building development.
- Multi-unit development.
- Lack of off-street parking.
- Competition for on street parking.
- Parking pressure from non-residential uses.
- Steep topography.



2.5 Residential 5 (Un-serviced or Semi-serviced Residential)

Development in the Residential 5 Zone is characterised by:

- Large front yards, generally more than 6 m deep.
- Side yards 2 m or more giving good space between buildings.
- Generally large sites greater than 1000 m².
- Low site coverage (20 %).
- Smaller dwelling size.
- Low population density.
- Number of vacant sites.
- No or limited infrastructure.

2.6 Residential 6 (Special Areas)

Within the Residential 6 Zone are special areas which need conditions to protect the special amenity, the urban service infrastructure from the adverse effects of development or redevelopment. These areas are:

- East Taieri south of Cemetery Road;
- East Taieri between McFadden Drive and Wingatui;
- Doctors Point;
- Hawksbury;
- Braeside;
- Momona Airport Village;
- Outram;
- Leith Valley;
- Cove Extension;
- North-East Valley;
- Waldronville;
- Mission Cove; and
- Wakari.

2.7 Activity Zones

Primarily located within the central business area, Activity Zones consist of three sub categories; Central Activity Zone, Large Retail Zone and Local Activity Zones 1 and 2. The inner city is a hub of retail, recreation, entertainment, light industry, hotel and other residential activity.

The large retail zone is of also of significance in terms of the high volume of traffic it creates.



2.8 Industry

Industrial importance in Dunedin has changed determined by varying influences in each era. In the last decade or so manufacturing has proved more important for the city's economy. The location of industries in the Dunedin area is largely determined by the availability of the natural and physical resources which are required for efficient industrial activities. The resources include purpose-built buildings, correspondingly large areas of flat land, adequate urban service infrastructure, proximity to transportation routes, proximity to ports, and in some cases proximity to source materials.

The location of industries in the City is focused around a number of key areas including:

- Ravensbourne;
- Port Chalmers;
- State Highway 88 and Parry Street;
- Dunedin Wharf Area;
- Strathallan Street / Andersons Bay Road / Portobello Road / Portsmouth Drive;
- Hillside Road;
- Kaikorai Valley Road / Donald Street;
- Burnside Corner;
- Fairfield;
- Abbotsford to Lambert Street; and
- Mosgiel.

The small Industrial 2 zone is an area of historically mixed land use, and includes some high technology based industries. The purpose of this zone is to enable the development of activities which generate few adverse effects in areas close to sites such as the University or to allow activities to operate alongside what may normally be considered incompatible land uses. Activities in this zone are likely to have a higher stormwater quality than traditional industrial land uses.

2.9 Rural and Residential

Outside the city lie Rural and Rural Residential Zones which cover more than 318,000 ha, equating to approximately 95 % of the city area. For most of the catchments, these areas are not of major significance as they are predominantly outside the study area; however, the Mosgiel catchment has a large area of rural land. Rural imperviousness is generally estimated to be insignificant, and runoff from rural residential areas is unlikely to reach the stormwater reticulation, in most instances.

2.10 Port

Port zonings are either Port 1 (Port Chalmers only), or Port 2 (Kitchener Street, Mason Street and Halsey Street catchments).

While the Port 1 zone is restricted to port and recreational activities, the Port 2 zone also permits industrial, service and related retail activities along with activities specific to a port such as the unloading and storage of cargo.



2.11 Campus

The Campus is a unique area in the north of the city hosting 3 educational institutions. Bounded on several sides by residential accommodation the housing is mainly dense accommodation blocks.

As a historic and valuable site in Dunedin, land use here is not expected to change in the foreseeable future.



3 Estimating Current Imperviousness

3.1 Methodology

Current imperviousness estimates for parcels within each land use zone in the city were made by calculating or estimating the imperviousness in a number of sample areas within each zone (Identified in Figure 3-1). This imperviousness assumption for each zone was then applied to each land parcel within the stormwater model extents, excluding those parcels identified as vacant, a park or a school (as indicated by DCC information), and roads. In each case, all land parcels intersected by a 50 m x 75 m sample 'square' were assessed. Sampled areas have an average size of approximately 6,500 m². Imperviousness was categorised as impervious – connected (i.e. roofs and roads), impervious – unconnected (driveways, areas of paving), and pervious area.

A number of the individual industrial areas were analysed by a visual assessment, as there was a large amount of variability and no 'typical' industrial land use that could be used as an estimate of imperviousness for other areas. Additionally, some variation in residential density was noticed amongst different suburbs, and slightly different estimates were applied. Table 3-1 provides the details of the imperviousness calculated for each sampled area. Table 3-2 provides the imperviousness estimates for the non-sampled areas (i.e. industry and some commercial areas).


Table 3-1: Current Estimated Imperviousness Sampling Results – Dunedin City

Land Use (Zone)	Suburb / Area	Sample No.	Area Connected (m ²)	Area Unconnected (m ²)	Total Area (m ²)	Total % Impervious	Total % Impervious Estimate For zone
R1	Broad Bay	1	1108	559	7450	22 %	39 %
	Dunedin	2	1110	652	6526	27 %	
	Mosgiel	3	1591	1115	6351	43 %	
	Dunedin	4	1569	1191	5778	48 %	
	Dunedin	5	2029	1573	9455	38 %	
	Fairfield	6	2003	1231	6917	47 %	
	Dunedin	7	526	333	3803	23 %	
	Dunedin	8	1418	961	5020	47 %	
R2	South Dunedin	1	1918	1043	5144	58 %	56 %
	South Dunedin	2	2804	2199	7777	64 %	
	Mosgiel	3	1466	1009	5434	46 %	
R3	City	1	1746	1537	4681	70 %	61 %
	City	2	2250	2189	8521	52 %	
R4	City Rise	1	1944	1408	7901	42 %	53 %
	City Rise	2	2054	1229	5138	64 %	
R5	Waitati	1	481	259	5407	14 %	18.5%
	Harrington Place	2	514	110	2755	23 %	
R6	Braeside	1	901	2037	15353	19 %	16 %
	Doctor's Point	2	335	711	8465	12 %	
Campus	Campus	1	82277	0	142065	58 %	58 %

* Broad Bay, due to its distance from the major Residential 1 area, has used the imperviousness of the sample area, rather than the average.



Table 3-2: Current Imperviousness Estimates – Non-sampled Parcels

Zone	Location	Impervious – Connected	Impervious – Unconnected	Comments
CA (Central Activity Zone)		100 %		Commercial area. Small (negligible) amount of landscaping.
I1 (Industry 1)	Burnside	70 %		Next to motorway with large rural areas / vegetation belts. Mainly impervious with large areas of landscaping.
	Andersons Bay	100 %		100 % impervious except for Carisbrook park.
	Fairfield	30 %		Largely undeveloped.
	Green Island	50 %		Early industrial site. Still to be developed.
	Kaikorai Valley	60 %		Large pervious areas due to slope.
	MacLaggan St	90 %		Small area. Appears to be engineered platforms with sloping land around.
	Middlemarch	5 %	5 %	Undeveloped site.
	Mosgiel Central	70 %		Large buildings. Large pervious areas still to be developed. Some residential units within the area.
	Mosgiel North	20 %		Largely undeveloped site, flat land.
	Mosgiel South	90 %		Most of area impervious.
	North Dunedin	100 %		
	Old Brighton Road	30 %		Timber yard. Mainly trees. Impervious area not sealed – hard-packed gravel / soil.
	Princes Street	50 %		
	Sawyers Bay	50 %		Treatment Plant.
	Waikouaiti	10 %		Large unsealed areas. Mainly undeveloped.
I2 (Industry 2)		100 %		Small inner city area.
LA 1 (Local Activity Area 1)	Green Island	90 %		Some car parks, bowling green, amenity areas. Residential houses.
	Mornington	90 %		Minimal landscaping. Flat to 10 % gradients. Small Area. Some residential units within area.
	Mosgiel	95 %		Flat, large buildings, car parks and residential houses.
	Port Chalmers	60 %		Flat to 10 % gradient. Shops, sports fields, residential units.
	Roslyn	95 %		Fully developed. Small Area.
	South Dunedin	100 %		Impervious with minimal landscaping.
	Waikouaiti	15 %	35 %	Older small scale shopping centre. Next to rural land. Large unsealed areas of land.



Zone	Location	Impervious – Connected	Impervious – Unconnected	Comments
LSR (Large Scale Retail)	Mosgiel	25 %		Much of the area is still to be developed. Some landscaping. Flat.
	Central City	100 %		Minimal landscaping. Variable slope.
	Crawford Street	100 %		No landscaping. Flat.
Port 1	Port Chalmers	100 %		
Port 2	Downtown Dunedin	100 %		
R2	Mosgiel	25 %	15 %	Not as intensely urbanised as South Dunedin.

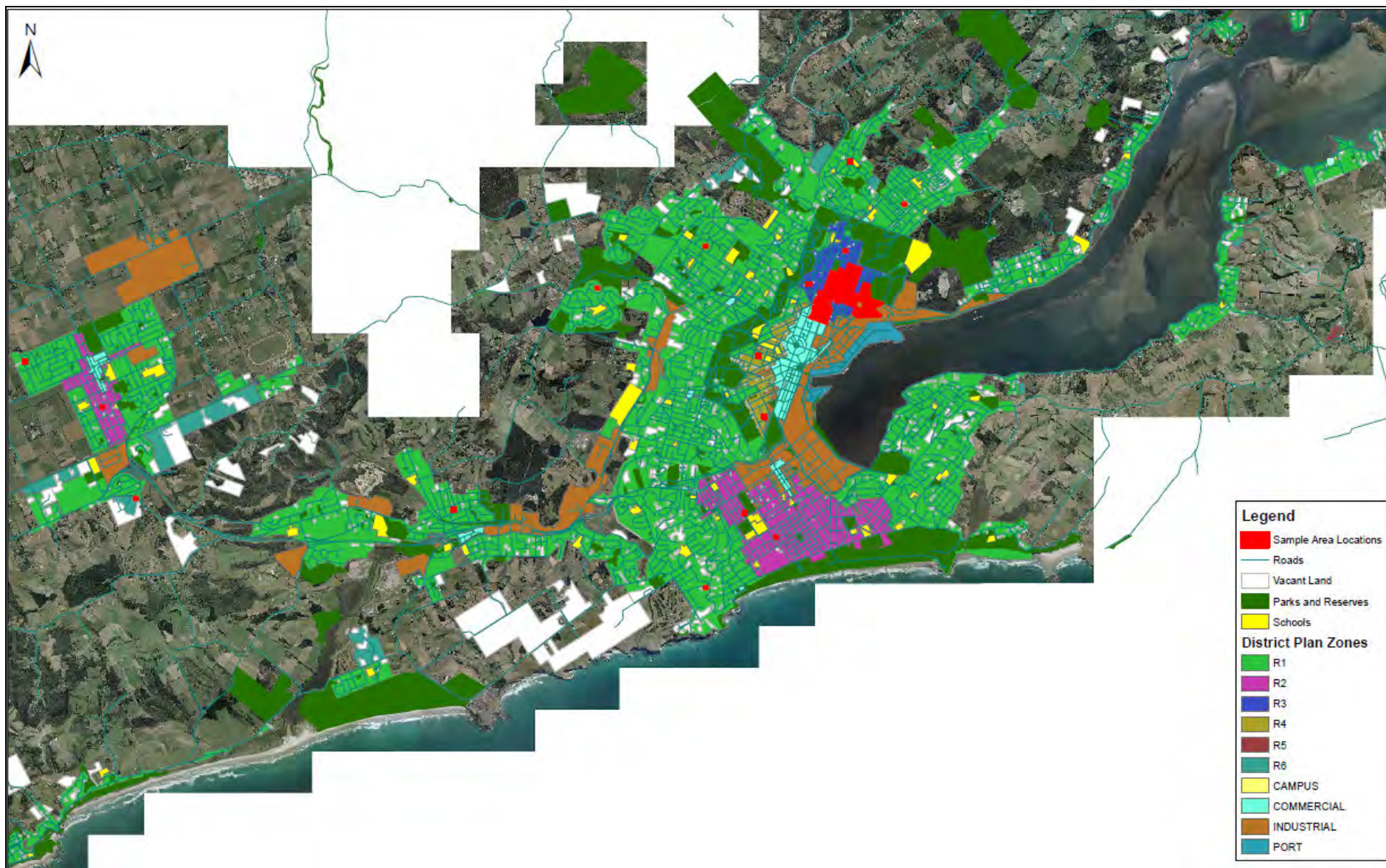


Figure 3-1: Sample Areas



3.2 Final Estimates – Current Imperviousness

Table 3-3 provides the final estimated figures applied to each parcel of a specific land use, as summarised from the GIS shapefile produced, and mapped as Figure 3-3. Note that for individually assessed parcels a unique land use type has been developed based on the parcel's zone and the estimated imperviousness of the specific parcel.

It should be noted that the current imperviousness figures generated are used as an initial estimate only – imperviousness is one of the key calibration parameters adjusted during stormwater model calibration. Final imperviousness figures for each stormwater catchment model are not necessarily consistent with the estimates provided here.

Table 3-3: Current Estimated Imperviousness for each Land Use Zone

Land Use Zone	Number of Parcels	Impervious % Connected	Impervious % Unconnected	Total % Impervious	Total % Pervious
Campus	788	58	0	58	42
CAZ	928	100	0	100	0
In1	1512	100	0	100	0
In2	70	100	0	100	0
LA1	245	100	0	100	0
LA2	15	80	0	80	20
LSR	275	100	0	100	0
Ocean	10	0	0	0	100
Parks & Reserves	2090	0	0	0	100
Port2	203	100	0	100	0
R1	34265	23	16	39	61
R2	4815	36.5	19.5	56	44
R3	1559	31.5	29.5	61	39
R4	1207	32.5	20.5	53	47
R5	23	14	4.5	18.5	81.5
R6	396	5	11	16	84
RR	498	0	0	0	100
Road	7142	100	0	100	0
Rural	2350	0	0	0	100
SD	7	3	7	10	90
School	733	25	2.5	27.5	72.5
Vacant	125	0	0	0	100

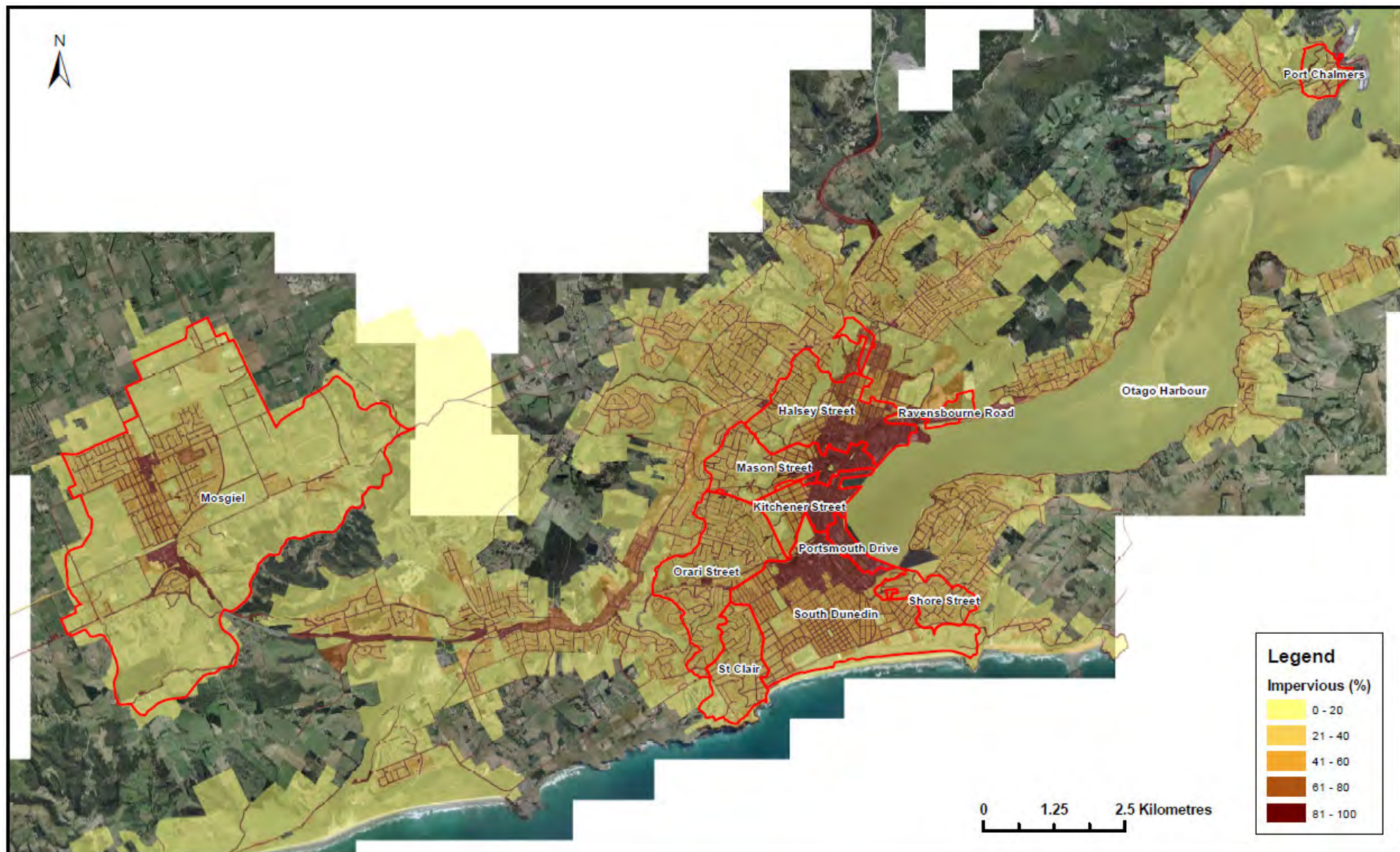


Figure 3-2: Current Land Use Imperviousness over Dunedin Region



4 Estimating Future Imperviousness

4.1 Data

For the purposes of the Three Waters ICMP Future Imperviousness was calculated for two future scenarios 2031, and 2060, based on a variety of information including the following:

- Areas in Dunedin where vacant land, or large lots of land have been identified as potential areas for subdivision;
- Resource and Building consents granted by DCC recently;
- Plan changes proposed; and
- Maximum allowable imperviousness permitted in the Dunedin City District Plan.

As a primarily residential area, the issues surrounding an increase in capacity are of particular significance for Dunedin City, including the impact on each network of the three Waters system. For the period 2000-2005, records show that there were approximately 1500 building consents issued for new dwelling units.

From the Dunedin City Residential Capacity Study, 2006 (District Plan Monitoring series) the following tables illustrate the restrictions around density and development, and although from 2005, these provide a useful indication of the useable land area for potential development.

Table 4-1: Permitted Residential Densities, highlights the regulation in terms of site area, applicable to the development of any residential land. Table 4-2 shows that the zone with the most land for development is in Residential 1, however of this amount, only 69 % is potentially available for development.

Table 4-3, with the exclusion of 2005 data, demonstrates a clear increasing trend in the number of Residential 1 consent applications. The rest of the zones show a fairly constant pattern in application numbers which fits with the predictions for the future imperviousness discussed later in this section.


Table 4-1: Permitted Residential Densities

Zone	Minimum Site Area (per unit)	Development Permitted on Existing Sites of Any Size?
Residential 1	500 m ²	Yes
Residential 2	300 m ²	Yes
Residential 3	45 m ² per habitable room	Yes, but habitable room density still applies
Residential 4	200 m ²	Yes
Residential 5	1000 m ²	Aramoana Residential 5 Zone only
Residential 6	Various, from 500 m ² to 5000 m ²	East Taieri (Wingatui) Residential 6 Zone only
Rural Residential	2 ha	No

Table 4-2: Useable Residential Land 2005

Zone	Area (ha)	% of Total Useable Residential Land	% Useable Land in Zone
Residential 1	3,245	47.0	69.0
Residential 2	269	3.9	54.7
Residential 3	59	0.9	52.2
Residential 4	48	0.7	64.0
Residential 5	332	4.8	75.6
Residential 6	244	3.5	92.4
Rural Residential	2,700	39.1	95.6
Total:	6,897	100.0	77.0

Table 4-3: Building Consents Issued for New Dwelling Units by zone, 2000-2005

Zone	2000	2001	2002	2003	2004	2005*	%
Residential 1	91	70	118	166	195	102	52.8
Residential 2	26	11	25	31	22	18	9.5
Residential 3	19	16	10	33	19	8	8.0
Residential 4	4	16	3	3	4	11	2.5
Residential 5	6	3	5	8	12	10	2.8
Residential 6	2	2	5	17	20	8	3.8
Rural Residential	12	20	15	25	19	12	7.5
Rural	14	19	18	36	44	26	10.8
Other Zones		1	1	7	49	10	2.3
Total Dwelling Units:	174	158	200	326	384	205	100

* 2005 data for the first half year only, Consents are for new construction only, does not include conversion of existing buildings to dwellings.



4.2 Methodology and Assumptions

The future imperviousness of each parcel within the stormwater catchments was estimated using GIS analysis that 'layered' the information available on current imperviousness, building consents, vacant lots etc. To enable the calculation of future imperviousness, three fundamental high level assumptions were established;

1. All building consents, plan changes and subdivision consents were included as fully developed in 2031.
2. Parks and Schools remain undeveloped and therefore stay at current imperviousness. (Figure 3-1 shows the current areas allocated to these land uses).
3. The maximum imperviousness (for 2031) was set at the following, as per the maximum allowable imperviousness limits set by the District Plan (horizon: 2036):
 - Res 1 – 40 %
 - Res 2 – 50 %
 - Res 3
 - (a) 40 % of the site area where the site is located to the west of George Street and south of Warrender Street, except for front sites on George Street where the maximum site coverage in (b) will apply.
 - (b) On all other sites 50 % of site area.
 - Res 4 – 60 %
 - Res 5 – 30 %
 - Res 6
 - (a) For all sites except the Abbotsford Residential 6 Zone, the maximum site coverage shall be 30 % of site area.
 - (b) For the Abbotsford Residential 6 Zone, the maximum site coverage shall be 40 % or, alternatively, 60 % within the regions marked 'Subzone A' on the annexed Grandvista Estate Structure Plan, provided that the units proposed at this alternative density comprise attached, multi-level dwellings.
 - Central Activity Zone – 100 %
 - Industrial 1 and 2 – 100 %
 - Port 1 and 2 – 100 %
 - Campus – remains as current in 2031. 2060 model to include complete in-fill.

4.3 Results - Final Imperviousness Figures

Current and future imperviousness, assessed on an individual land parcel basis, were summarised for each land use within each catchment. The results are presented in Table 4-1 following, and mapped in Figure 5-1.



Table 4-4: Current and Future Imperviousness for Dunedin Catchments

Catchment	Land Use Zone	Current			2031			2060		
		Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious
Halsey Street	Campus	18.35	27.36	67.10	18.35	27.36	67.10	18.35	27.36	67.10
	Central Activity Area	28.94	29.07	99.54	28.94	29.07	99.54	28.94	29.07	99.54
	Industrial 1	30.11	30.11	100.00	30.11	30.11	100.00	30.11	30.11	100.00
	Industrial 2	3.41	3.43	99.48	3.41	3.43	99.48	3.41	3.43	99.48
	Large Scale Retail Zone	2.96	2.96	100.00	2.96	2.96	100.00	2.96	2.96	100.00
	Local Activity Zone 1	0.26	0.26	98.30	0.26	0.26	99.35	0.26	0.26	99.35
	Port 2	22.38	22.38	100.00	22.38	22.38	100.00	22.38	22.38	100.00
	Residential 1	59.62	166.91	35.72	60.99	166.91	36.54	60.99	166.91	36.54
	Residential 3	26.71	37.68	70.90	26.85	37.68	71.26	26.85	37.68	71.26
	Residential 4	8.50	13.43	63.31	9.17	13.43	68.25	9.17	13.43	68.25
	Rural	0.00	0.08	0.00	0.00	0.08	0.00	0.00	0.08	0.00
	Total	201.25	333.67	60.31	203.43	333.67	60.97	203.43	333.67	60.97
Kitchener Street	Central Activity Area	4.62	4.62	100.00	4.62	4.62	100.00	4.62	4.62	100.00
	Industrial 1	26.81	30.05	89.19	28.58	30.05	95.10	28.58	30.05	95.10
	Large Scale Retail Zone	14.63	14.63	100.00	14.63	14.63	100.00	14.63	14.63	100.00
	Port 2	22.19	22.19	100.00	22.19	22.19	100.00	22.19	22.19	100.00
	Residential 1	10.32	38.20	27.01	10.44	38.20	27.32	10.44	38.20	27.32
	Residential 4	16.16	26.25	61.56	17.50	26.25	66.67	17.50	26.25	66.67
	Rural	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.15	0.00
	Total	94.73	136.10	69.61	97.97	136.10	71.98	97.97	136.10	71.98

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Catchment	Land Use Zone	Current			2031			2060		
		Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious
Mason Street	Central Activity Area	26.63	27.66	96.27	26.68	27.66	96.46	26.68	27.66	96.46
	Industrial 1	17.88	18.52	96.52	18.10	18.52	97.69	18.10	18.52	97.69
	Large Scale Retail Zone	3.64	3.64	100.00	3.64	3.64	100.00	3.64	3.64	100.00
	Local Activity Zone 1	0.55	0.60	90.86	0.60	0.60	99.08	0.60	0.60	99.08
	Port 2	4.83	4.83	100.00	4.83	4.83	100.00	4.83	4.83	100.00
	Residential 1	41.42	119.26	34.73	42.69	119.26	35.80	42.69	119.26	35.80
	Residential 4	21.94	35.24	62.24	23.61	35.24	66.98	23.61	35.24	66.98
	Total	116.88	209.76	55.72	120.15	209.76	57.28	120.15	209.76	57.28
Mosgiel	Industrial 1	43.29	167.79	25.80	160.41	167.79	95.60	160.41	167.79	95.60
	Large Scale Retail Zone	1.95	2.28	85.62	2.26	2.28	99.32	2.26	2.28	99.32
	Local Activity Zone 1	11.43	11.95	95.66	11.83	11.95	99.04	11.83	11.95	99.04
	Residential 1	193.94	493.53	39.30	232.18	520.22	44.63	232.18	520.22	44.63
	Residential 2	48.06	80.02	60.06	53.68	80.02	67.08	53.68	80.02	67.08
	Residential 6	13.68	135.51	10.09	54.22	174.71	31.03	54.22	174.71	31.03
	Rural	51.98	1353.70	3.84	42.08	1281.91	3.28	42.08	1281.91	3.28
	Rural Residential	1.53	38.52	3.96	1.73	44.41	3.91	1.73	44.41	3.91
	Special Development	0.46	4.35	10.69	4.04	4.35	93.05	4.04	4.35	93.05
	Total	366.33	2287.64	16.01	562.46	2287.64	24.59	562.46	2287.64	24.59

Continued next page...



Catchment	Land Use Zone	Current			2031			2060		
		Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious
Orari Street	Industrial 1	0.13	0.13	99.77	0.13	0.13	99.95	0.13	0.13	99.95
	Local Activity Zone 1	3.38	3.52	96.16	3.49	3.52	99.27	3.49	3.52	99.27
	Residential 1	151.07	329.23	45.89	160.39	329.23	48.72	160.39	329.23	48.72
	Residential 2	4.27	7.49	57.05	4.37	7.49	58.40	4.37	7.49	58.40
	Rural	0.22	0.85	26.57	0.22	0.85	26.57	0.22	0.85	26.57
	Total	159.08	341.21	46.62	168.61	341.21	49.41	168.61	341.21	49.41
Port Chalmers	Industrial 1	0.07	0.57	12.90	0.07	0.57	12.90	0.07	0.57	12.90
	Local Activity Zone 1	2.45	3.59	68.17	3.59	3.59	100.00	3.59	3.59	100.00
	Port 1	0.55	0.55	98.89	0.55	0.55	98.89	0.55	0.55	98.89
	Residential 1	12.06	25.15	47.97	12.09	25.15	48.08	12.09	25.15	48.08
	Rural	4.53	28.12	16.10	4.53	28.12	16.10	4.53	28.12	16.10
	Rural Residential	0.02	0.02	100.00	0.02	0.02	100.00	0.02	0.02	100.00
	Total	19.68	58.00	33.93	20.85	58.00	35.94	20.85	58.00	35.94
Portsmouth Drive	Industrial 1	38.58	39.28	98.20	38.58	39.28	98.21	38.58	39.28	98.21
	Residential 1	0.14	0.14	100.00	0.14	0.14	100.00	0.14	0.14	100.00
	Total	38.71	39.42	98.21	38.72	39.42	98.22	38.72	39.42	98.22
Ravensbourne Road	Industrial 1	9.41	12.46	75.54	9.41	12.46	75.58	9.41	12.46	75.58
	Port 2	1.29	1.29	100.00	1.29	1.29	100.00	1.29	1.29	100.00
	Rural	4.09	17.01	24.02	4.09	17.01	24.02	4.09	17.01	24.02
	Total	14.78	30.75	48.07	14.79	30.75	48.08	14.79	30.75	48.08

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Catchment	Land Use Zone	Current			2031			2060		
		Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious	Impervious Area (ha)	Total Area (ha)	% Impervious
Shore Street	Local Activity Zone 1	0.49	0.52	94.15	0.52	0.52	98.83	0.52	0.52	98.83
	Residential 1	47.32	98.17	48.20	48.24	98.17	49.13	48.24	98.17	49.13
	Residential 2	1.87	2.58	72.54	1.87	2.58	72.54	1.87	2.58	72.54
	Total	49.68	101.28	49.06	50.63	101.28	49.99	50.63	101.28	49.99
South Dunedin	Industrial 1	97.23	101.15	96.13	98.78	101.15	97.66	98.78	101.15	97.66
	Large Scale Retail Zone	0.32	0.32	100.00	0.32	0.32	100.00	0.32	0.32	100.00
	Local Activity Zone 1	9.55	9.59	99.67	9.58	9.59	99.94	9.58	9.59	99.94
	Local Activity Zone 2	0.38	0.69	55.33	0.38	0.69	55.33	0.38	0.69	55.33
	Port 2	1.12	1.12	100.00	1.12	1.12	100.00	1.12	1.12	100.00
	Residential 1	30.46	100.94	30.17	31.04	100.94	30.75	31.04	100.94	30.75
	Residential 2	191.50	375.68	50.97	196.81	375.68	52.39	196.81	375.68	52.39
	Total	330.57	589.49	56.08	338.03	589.49	57.34	338.03	589.49	57.34
St Clair	Residential 1	65.91	143.93	45.79	69.99	143.93	48.63	69.99	143.93	48.63
	Residential 2	0.94	3.16	29.76	0.94	3.16	29.76	0.94	3.16	29.76
	Rural	0.63	16.90	3.71	0.63	16.90	3.71	0.63	16.90	3.71
	Total	67.48	163.99	41.15	71.56	163.99	43.64	71.56	163.99	43.64

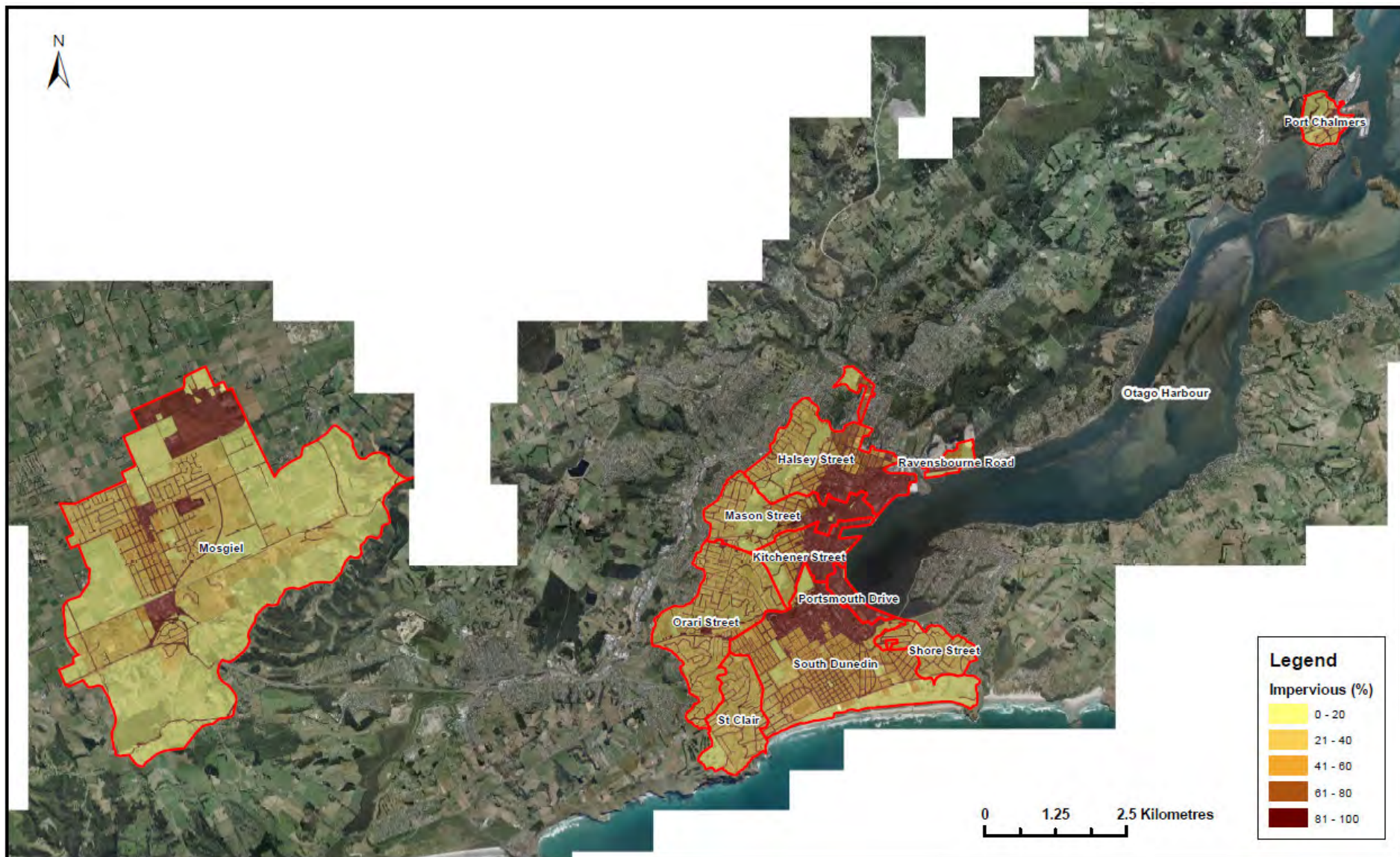


Figure 4-1: Future Imperviousness 2031 and 2060



5 Conclusions

It was found that for most of the catchments, there is very little change from the current imperviousness to the maximum possible future imperviousness estimated for the 2031 and 2060 scenarios. Population growth, land development and consequently, imperviousness, are expected to increase slightly in some, mainly outlying, Dunedin areas. While there is some in-fill development expected in built up areas, imperviousness is already at or above the maximum allowable by the Dunedin City District Plan for these areas due to the majority of the zoning being Residential 1 and 2, or Commercial / Industrial.

Based on current trends, the greatest increase in imperviousness would occur in the Mosgiel area as potential development takes place.

The imperviousness study for the Dunedin area has been carried out as a high level study and may be subject to variations depending on whether or not the assumptions discussed previously are changed, or within the model build process. For the purposes of the 3 Waters Strategy it is considered that this study provides imperviousness detail accurate enough to be included in further modelling studies, and act as a key component for the development of Integrated Catchment Management Plans for the region.



Appendix B

B1 Rainfall and Tidal Analysis Report

Dunedin Integrated Catchment Management Plans Rainfall and Tidal Analysis Report

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Table of Contents

Executive Summary	3
1 Report Introduction.....	5
2 Rainfall - Introduction	6
2.1 General	6
2.2 Use of Return Periods.....	6
3 Rainfall - Methodology.....	7
3.1 Introduction	7
3.2 Base Data (DDF).....	7
3.3 Climate Change	18
3.4 Climate Variability.....	20
3.5 Areal Reduction.....	22
3.6 Spatial Variation	22
3.7 Storm Shape	27
3.8 Summary.....	28
4 Rainfall - Results.....	29
4.1 Synthetic Design Storm Events.....	29
5 Tide – Introduction	31
5.1 General	31
5.2 Data Sources	31
5.3 Datums.....	31
5.4 Limitations on Use.....	32
6 Tide – Methodology.....	33
6.1 Overview	33
6.2 Calibration Data	33
6.3 Synthetic Extreme Tidal Events	33
7 Tide - Results	37
7.1 Synthetic Static Extreme Tide Values	37
7.2 Synthetic Cyclic Extreme Tide Values.....	37
8 Joint Analysis	38
9 References	41



Appendix A: Distribution Analysis

Appendix B: Data CD



Executive Summary

The aim of the Dunedin 3 Waters Strategy is to undertake a holistic and integrated investigation into the provision of potable water and the collection and disposal of storm and waste waters in Dunedin. The key objectives for the strategy are to determine the Level of Service provided by the 3 Waters infrastructure currently, and into the future. This allows planning of remedial works and new infrastructure such that levels of service and regulatory compliance can be ensured into the future.

Central to these investigations is the hydraulic modelling of the storm water and waste water conveyance infrastructure, and a critical part of the modelling is the boundary conditions used.

This report details the work undertaken to generate the rainfall data and tidal data used as boundary conditions within the modelling.

Subsequent to the production of this work the Mosgiel catchment was added to the project scope. This revision now includes the outcomes of analysis for Mosgiel.

Rainfall Data

The project requires the development of synthetic rainfall storms of defined return period to test the Level of Service provided by infrastructure now, and in the future, and to plan for capacity increases and new infrastructure.

Depth Duration Frequency (DDF) data was developed as a base for the information required by the project. For Mosgiel the DDF data was derived from the Silverstream at Taieri Depot long term rain gauge (1988 – 2011). For the remaining catchments DDF data was derived using data presented within *Raineffects (2006)*, and extended using data from the Musselburgh long-term raingauge (1986-2008). Supporting information was obtained for all catchments (excluding Mosgiel) from 8 short term (1 year) rain gauges installed across Dunedin City.

The base synthetic storms (developed for 2yr, 5yr, 10 yr, 50 yr and 100 yr events) were applied to each of the project catchments by undertaking a spatial analysis of Dunedin rainfall. This was undertaken using data from the short term rain gauges across Dunedin to produce an isohyet map. From this the rainfalls were weighted to take account of spatial variation, producing specific storms for each stormwater catchment studied within the 3 Waters Strategy Project. No spatial variation assessment was undertaken for Mosgiel, given the flat topography, limited area and central location of the raingauge used.

Final adjustments were made to account for the effects of climate change and climate variability. Climate change adjustments were made using *MfE (2008)* predictions for the likely change in rainfall intensity over time. Although climate variability was considered, no evidence of interdecadal shifts in rainfall could be found and therefore this was excluded.

The adjusted DDF information was applied to a synthetic storm profile, derived from profiles presented in *CCC (2006)* and verified by inspection of local storm shapes.

Tidal analysis

As much of Dunedin is low lying, its storm water and waste water infrastructure is susceptible to tidal influences which can reduce the capacity, and therefore level of service, of the system.

An assessment was made of the likely extreme tidal levels which could be expected at Dunedin. In addition to these extreme levels (i.e up to 1:100 yr tidal event), consideration was given to the impact of climate change and climate variability, with appropriate allowances being added for both.



Due to its distance from the coast, the Mosgiel catchment is not expected to be significantly influenced by tides, but rather by local stream levels. Please refer to *Mosgiel Integrated Catchment Management Plan – Model Build Report* (Opus, 2011) for details.

Joint Analysis

Neither the rainfall data nor the tidal/stream data can be used in isolation as there is a certain probability that any rainfall event will coincide with a tidal/stream condition which is also impacting the infrastructure. As such, a table of scenarios was developed which considers a number of rainfall-tidal/stream combinations such that the joint impacts can be determined. This provides the scenarios used in the hydraulic modelling.



1 Report Introduction

This report summarises the work undertaken to derive rainfall and tidal data sets for the hydraulic modelling of storm water and waste water infrastructure within each of the Dunedin 3 Waters Strategy catchments. The report is split into 3 parts (Table 1).

Table 1: Rainfall Information Required for Strategy

Part	Contents
Rainfall	Derivation of rainfall data used to calibrate hydraulic models, development of synthetic design rainfall events to test the Levels of Service (LoS) offered by infrastructure.
Tide	Derivation of tidal data used to calibrate hydraulic models and development of synthetic tidal cycles to test the Levels of Service offered by infrastructure.
Joint Analysis	The independent return periods considered by the rainfall analysis and the tidal analysis do not take into account the return period of these events coinciding. The return period of coincidence being far longer than the separate return periods.

The Joint Analysis, Part 3, provides the ultimate scenarios which are used by the hydraulic modelling.



2 Rainfall - Introduction

2.1 General

This part of the report provides information on the derivation of the rainfall events required by the Dunedin 3 Waters Strategy Project. Three broad types of event are required for the Strategy Project (Table 2) and are discussed within this report. This report influences the synthetic design events only; calibration / verification and communication events are covered within the individual catchment model build reports and are not considered further here.

Table 2: Rainfall Information Required for Strategy

Event Type	Purpose
Calibration / Verification Events	Used to determine the operation of the hydraulic model, ensuring that it is fit for purpose.
Communication Events	Used to convey the potential implications of mitigation options in a way which members of the public / media can understand.
Synthetic Design Events	Used to determine current and future LoS provided by stormwater and waste water infrastructure, and to plan for future upgrades and additions to these systems.

2.2 Use of Return Periods

Within this part of the report all return periods quoted refer to the return period of rainfall events. However, elsewhere within the Dunedin 3 Waters Strategy Project the return period of flow events within piped systems and/or water courses may be discussed.

Although not strictly correct, for the purpose of this study a 1:x year rainfall event has been considered to produced a 1:x year flow event within the systems under consideration.



3 Rainfall - Methodology

3.1 Introduction

Defining synthetic storm events is central to determining the current and future LoS provided by the infrastructure across Dunedin. The key part of developing synthetic storm events is the development of Depth-Duration-Frequency (DDF) data. The DDF data, which provides rainfall depths (in mm) for storm events of particular return period and duration, can then be manipulated to produce the required synthetic storm events.

The following are the main factors considered in the development of synthetic rainfall events for the Dunedin 3 Water Strategy:

- Base Data;
- Climate Change;
- Climate Variation;
- Areal Reduction;
- Spatial Variation; and
- Storm Profile.

3.2 Base Data (DDF)

3.2.1 Sources

The following sections outline the different data sources available for the development of DDF base data.

3.2.1.1 Previous Modelling

There appears to be a lack of previous work undertaken in Dunedin which derives synthetic storm events. Much of the historic work considers time series data, as summarised below, and hence cannot be used by this project.

Previous storm water modelling undertaken in Dunedin for DCC by AWT New Zealand (Mosgiel) and for ORC by OPUS (Water of Leith) used different hydrological approaches.

The Mosgiel study, undertaken in 2002, developed rainfall intensity tables using rain gauge information in the Mosgiel area (the Dunedin Airport rain gauge), and undertook time series modelling for particular periods, including the following:

- 26 Jan 1991 – 23 March 1991
- 14 Feb 1994 – 31 March 1994
- 10 Dec 1999 – 19 March 2000
- 8 August 2000 – 24 August 2000



The Mosgiel analysis is unsuitable for application in the Dunedin City 3 Waters Strategy catchments due to the distance between Dunedin City and Mosgiel, and across all areas due to the lack of appropriate DDF data.

Modelling for the Water of Leith undertaken by OPUS utilised historical stream flows, rather than rainfall for hydrological input, however they did identify a number of critical large storms, as follows:

- 18 Feb 1991
- 9 March 1968
- 5 June 1980
- 26 April 2006
- 19 March 1994
- March 1929
- April and May 1923

This information has been used to confirm the importance of historical events.

3.2.1.2 IDF Study

In 2006, Dunedin City Council commissioned the development of rainfall IDF (Intensity, duration, frequency) curves for the city. *Raineffects* completed this work (*Method for Calculating Rainfall Intensity and Duration Values for the Greater Dunedin City Area; Part 1: Method Development; Part 2: Method Application*), and generated curves based on analysis of rainfall data from the Musselburgh (1949-2005), Dunedin Airport (1962-1991) and Cherry Farm Hospital (1960-1989) rain gauges. Spatial variation of rainfall across the city was estimated based on elevation.

This study can provide much of the base data required for the 3 Waters Strategy Project work, however, is limited in its provision of data for long duration events, having a maximum duration of two hours.

3.2.1.3 Raingauges

There are a number of historic rain gauges in and around Dunedin City, with a variety of record lengths and recording intervals. Table 3 lists these gauges, and the year that each record commences. The location of these gauges, and those short term gauges listed below is provided in Figure 1.

Rainfall in and around Dunedin is anecdotally known to have significant geographical variation. As part of the DCC 3 Waters Strategy Project, eight short term (1 - 2 year) rain gauges have been installed across the city. These gauges (Table 4), along with the long term gauges, are used in subsequent sections to define this spatial variation.



Table 3: Long Term Rain Gauge Sites

Site	Start Date	End Date	Data Increment
Musselburgh	1 Jan 1918	30 Aug 2008	Daily
Musselburgh	1 Jan 1986	30 Aug 2008	Hourly
Leith at Sullivans Dam	4 Feb 2000	1 Jun 2008	15 min
Leith at Pine Hill	25 Apr 1979	13 Jun 2008	15 min
Botanical Gardens	3 Jan 1913	31 Jul 2008	Daily
Sawyers Bay STP	1980	2000	Daily
Sawyers Bay	1921	1979	Daily
Silverstream at Taieri Depot	26 Jul 1988	11 Jan 2011	15 min

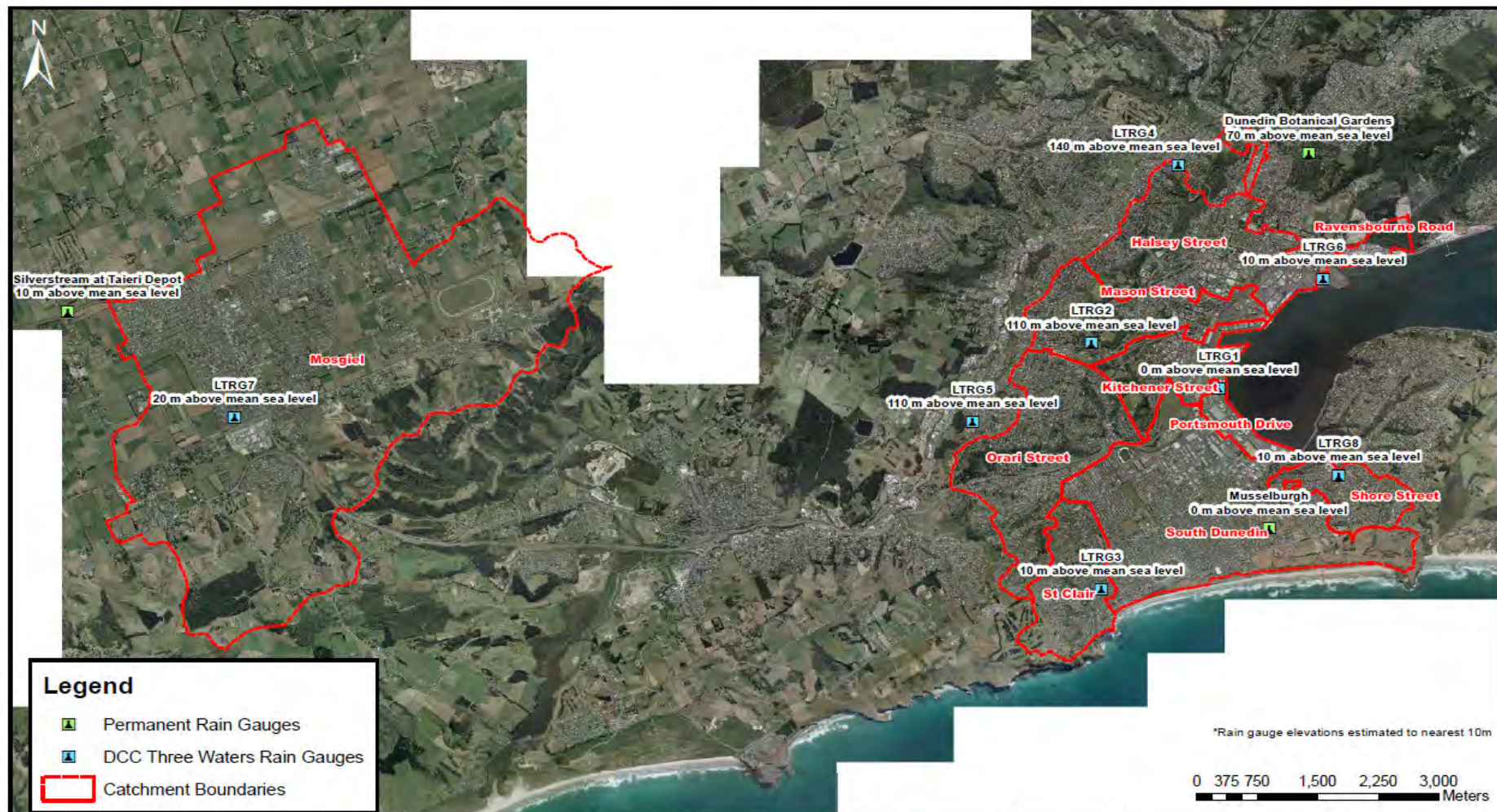
Table 4: Short Term Rain Gauge Sites

Site	Type	Data length
LTRG1 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG2 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG3 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG4 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG5 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG6 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG7 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
LTRG8 Rain gauge	Short Term Rain gauge	Rainfall data Sept 08 – Sept 09
Port Chalmers	Short Term Rain gauge	Rainfall data Mar 10 – May 10



Rainfall and Tidal Analysis Report

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3.2.1.3.1 Musselburgh

The Musselburgh rain gauge is located at the Musselburgh wastewater treatment plant. The gauge is located at 4 m above mean sea level. This gauge is located within the South Dunedin catchment.

Daily data was available at Musselburgh from 1918 onwards, with hourly data available from 1986. There is a degree of uncertainty surrounding the largest storm on record (April 1923), given the significantly elevated total depth when compared to the next largest storm. The five largest storms on record are as follows:

1. 22 April 1923 (229 mm)
2. 4 June 1980 (119 mm)
3. 3 December 1938 (113 mm)
4. 19 March 1929 (104 mm)
5. 8 March 1968 (91 mm)

This gauge offers the most suitable long term record for use in creating DDF information.

3.2.1.3.2 Sullivans Dam

The Sullivans Dam rain gauge is approximately 8 km from the Octagon, in the Leith Valley. The gauge is approximately 300 m above mean sea level. Hourly data was obtained for the period 4 Feb 2000 – 1 Jun 2008. No early records are available for this site, reducing the suitability of the gauge for return period estimates.

The five largest storms on record are as follows:

1. 25 April 2006 (218 mm)
2. 29 July 2007 (130 mm)
3. 11 February 2005 (121 mm)
4. 19 July 2001 (104 mm)
5. 9 January 2002 (98 mm)

3.2.1.1.1 Pine Hill

The Pine Hill rain gauge, located just off Campbells Rd, approximately 5 km from the Octagon, is about 250 m above mean sea level. Hourly data was obtained for the period 25 April 1979 – 13 Jun 2008, however two large gaps exist in the data from April 1980-July 1981 and May 1986-Feb 2000, with several smaller gaps in the earlier years. These gaps decrease the accuracy of the return period estimates.

The five largest storms on record are as follows:

1. 25 April 2006 (157 mm)
2. 29 July 2007 (110 mm)
3. 11 January 2002 (101 mm)
4. 11 February 2005 (96 mm)
5. 12 May 2004 (96 mm)



3.2.1.3.3 Botanical Gardens

The Botanical Gardens rain gauge is located 73 m above mean sea level. A long record of daily readings is available from the gauge from 3 Jan 1913 to 31 Jul 2008, however no hourly readings are available from this site. This information was used to preliminarily investigate spatial variability across Dunedin, and justified the development of spatial variability factors. The five largest storms on record are as follows.

1. 22 April 1923 (173 mm)
2. 3 December 1938 (138mm)
3. 19 March 1929 (134 mm)
4. 17 February 1991 (129 mm)
5. 25 April 2006 (116 mm)

3.2.1.3.4 Silverstream

The Silverstream rain gauge is located south of Mosgiel Township at the intersection of Riccarton Road and Silverstream. This instantaneous rain gauge, located approximately 11 m above mean sea level, provides rainfall records for every 15 minutes. The rainfall data, which covers the period of 26 July 1988 to 11 January 2011, shows that the five largest storms on record are:

1. 25 April 2006 (165 mm)
2. 25 May 2010 (116 mm)
3. 18 March 1994 (102 mm)
4. 2 January 2000 (94 mm)
5. 29 July 2007 (93 mm)

3.2.1.3.5 Short term gauges

These gauges have insufficient records to be useful in the derivation of return period statistics. They remain important, however, in estimating spatial variability of rainfall across Dunedin and in calibrating / verifying hydraulic model operation. The spatial variation is discussed later in this document.

3.2.2 Analysis

From the review of data in the section above no single source provides sufficient information to create the required set of DDF data.

For the Mosgiel catchment, only the Silverstream rain gauge data is used for analysis. For the remaining catchments, the DDF information generated by Raineffects is used as a base. Analysis of rainfall records, specifically the Musselburgh record, is then used to extend the DDF data.

3.2.2.1 DDF

The data provided in *Raineffects* (2006) is used as the base for the all the Dunedin 3 Waters Strategy catchments except Mosgiel (Table 5a). For the Mosgiel catchment, data from Silverstream at Taieri Depot rain gauge is used (Table 5b).



Table 5a: Rainfall Depth Duration Frequency Figures (mm) for All Catchments except Mosgiel

Source	Raineffects (2006)							
ARI	10 (min)	20 (min)	30 (min)	40 (min)	50 (min)	1 (hr)	1.5 (hr)	2 (hr)
10	11.69	13.52	15.22	16.78	18.23	19.6	23.35	26.72
50	16.28	18.35	20.36	22.23	23.97	25.61	30.1	34.13
100	18.16	20.38	22.55	24.56	26.43	28.2	33.04	37.38

Table 5b: Rainfall Depth Duration Frequency Figures (mm) for Mosgiel

Source	Silverstream at Taieri Depot Rain Gauge					
ARI	10 (min)	20 (min)	30 (min)	1 (hr)	2 (hr)	24 (hr)
2	4.1	6.8	8.2	10.8	15.1	58.9
5	5.4	8.9	10.7	13.6	18.7	84.4
10	6.4	10.6	12.7	15.9	21.6	105
50	8.7	14.3	17.2	20.9	27.9	150.6
100	9.7	15.9	19.1	23	30.6	169.8

3.2.2.2 Rain Gauge Analysis

Analysis of the Musselburgh and Mosgiel data set was conducted (using Hilltop Hydro software) to find the best fit distribution for the rainfall data in order to estimate the size of events with certain return periods. The software enabled a number of distributions to be analysed, including Gumbel, GEV, and Log Pearson 3; distributions commonly adopted for analysis of rainfall and river flows in New Zealand. Results of this analysis can be found in Appendix A. An effort was made to confirm return period estimates provided by a number of different publications for particular storms; for example, DCC flooding reports, however this was not always possible, as discussed below.

The distribution plots found the Gumbel distribution to best represent the Musselburgh rainfall: where the Pearson Log 3 and GEV distributions seem to underestimate the data, the Gumbel distribution is more conservative for the larger events and looks to best represent the data at low – mid range events.



To establish the design storm depths for all catchments except Mosgiel (to supplement the DCC IDF curves which only extend to a 2-hour duration), and in order to obtain a good match with DCC flooding reports, only the available hourly data at Musselburgh (1986-2008) was analysed for storm volume, to match the data used by Raineffects Ltd in the calculation of event return periods for DCC (*pers.comm, Dave Stewart*).

The storms of April 2006 and July 2007 stand out as significant recent storms across all catchments— this is supported by flooding reports across Dunedin. Sullivans Dam has the highest rainfall for each storm and is the highest in elevation. Musselburgh has the lowest rainfall and is also at the lowest elevation. This analysis gave a reasonable match for both of these storms (Return periods 10-12 years and 15-16 years respectively).

The distribution plots for the Silverstream rainfall show minimal variation between the various distribution types. The Gumbel distribution was used to represent the Mosgiel rainfall.



3.2.3 Combined Data Set

Adding the above analysis to the base DDF data set from Raineffects Ltd provides a complete data set (refer to Table 6a and Figure 2a) for all Dunedin 3 Water Strategy Project catchments except Mosgiel. Note that depths for the 10, 50 and 100 year ARI storms with durations up to 2 hours were generated by Raineffects (2006), with the remainder of data generated by URS (2010).

Table 6a – Complete DDF Data (Depth mm) for All Catchments except Mosgiel

ARI	10 (min)	20 (min)	30 (min)	40 (min)	50 (min)	1 (hr)	1.5 (hr)	2 (hr)	4 (hr)	6 (hr)	12 (hr)	24 (hr)
2	4.6	6.8	8.3			11.9		17.2		29.9	42	54
5	6.6	9.7	11.3			15.1		20.9		37.6	54.4	68
10	11.69	13.52	15.22	16.78	18.23	19.6	23.35	26.72	38.7	46.2	62.6	82.5
50	16.28	18.35	20.36	22.23	23.97	25.61	30.1	34.13	47.7	58.9	83.6	109
100	18.16	20.38	22.55	24.56	26.43	28.2	33.04	37.38	51.5	64.3	92.5	120.2

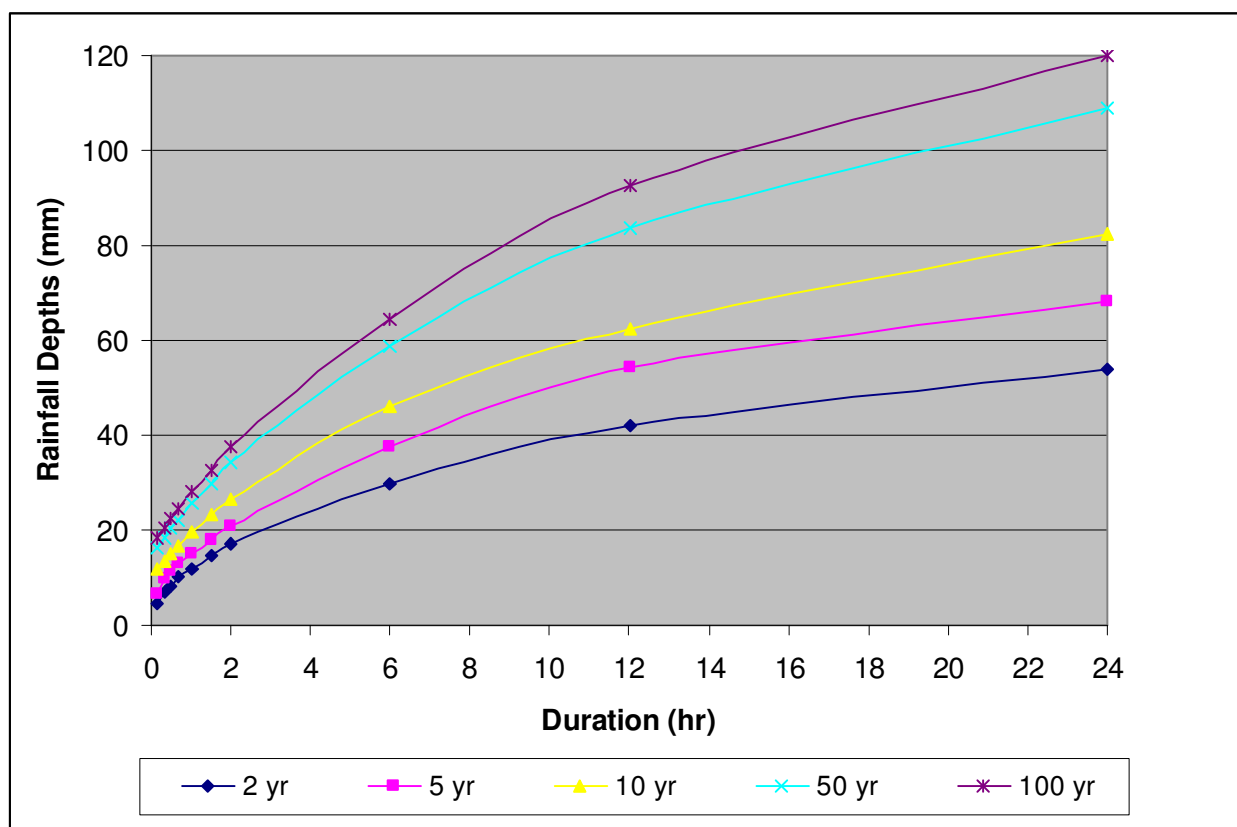


Figure 2a – Rainfall Depths (mm) for the Various ARIs for all catchments except Mosgiel



A complete data set for Mosgiel is shown in Table 6b and Figure 2b.

Table 6b – Complete DDF Data (Depth mm) for Mosgiel

Source	Silverstream at Taieri Depot Rain Gauge									
ARI	10 (min)	20 (min)	30 (min)	1 (hr)	2 (hr)	6 (hr)	12 (hr)	24 (hr)	2 (days)	3 (days)
2	4.1	6.8	8.2	10.8	15.1	29	43	58.9	71.9	77.9
5	5.4	8.9	10.7	13.6	18.7	37.9	60.1	84.4	104.1	111.2
10	6.4	10.6	12.7	15.9	21.6	45.2	74	105	130.3	138.2
20	7.4	12.2	14.7	18.1	24.3	52.2	87.4	124.9	155.5	164.2
50	8.7	14.3	17.2	20.9	27.9	61.3	104.7	150.6	188	197.7
100	9.7	15.9	19.1	23	30.6	68.1	117.6	169.8	212.4	222.9
200	10.6	17.5	21	25.1	33.2	74.8	130.5	189	236.6	248

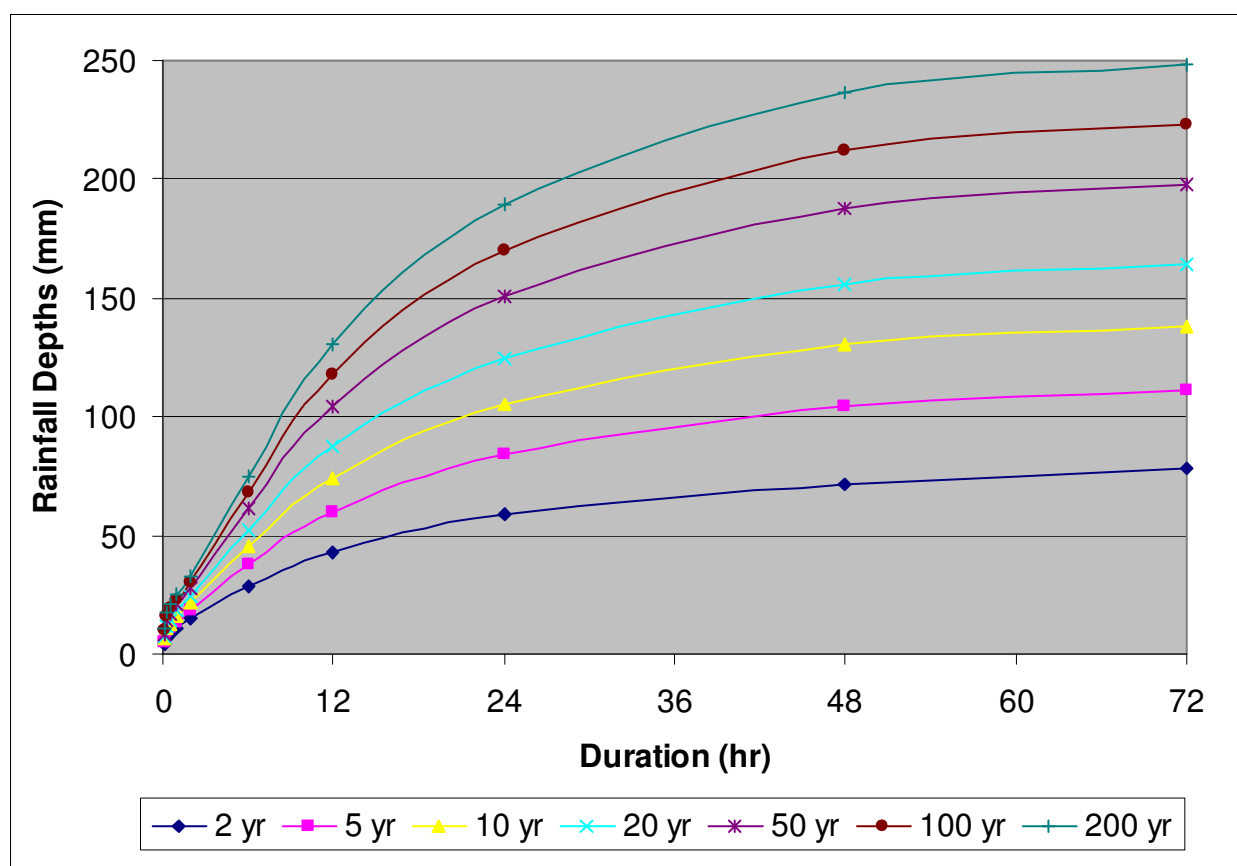


Figure 2b – Rainfall Depths (mm) for the Various ARIs for Mosgiel



3.2.4 Storm Durations and Events

Within the analysis key storm return periods were defined to allow the synthetic event data to be used in a meaningful way for ongoing planning and system maintenance. The key return periods chosen were:

- 1:100 year – Used for emergency planning purposes;
- 1:50 year – Used as a standard to assess the risk of habitable floor flooding;
- 1:10 year – Used as an indicator of the LoS provided by drainage infrastructure;
- 1:5 year – Used to determine the current infrastructure capacity; and
- 1:2 year – Used to determine the current infrastructure capacity.

For each of these return periods a series of storm durations were chosen to cover the likely critical durations (time of concentration) for the catchments considered. The durations used were:

- 20 minute;
- 30 minute (Mosgiel only);
- 40 minute;
- 60 minute; and
- 1440 minute (24 hr storm used as infiltration input for wastewater modelling).



3.3 Climate Change

As stated in *MfE (2008)*, 'Climate change effects due to the increase in greenhouse gases in the atmosphere will be felt over time at regional and local levels differently in various parts of New Zealand.' The uncertainty in the scale and spatial occurrence of effects presents a number of challenges for future infrastructure planning and management.

To assist development of realistic predictions of climate change impacts *MfE (2008)* provides guidance on the matter which forms the basis of the assessment of climate change impacts on rainfall for the Dunedin 3 Waters Strategy.

Predictions of temperature change (annual) were taken from *MfE (2008)* (Table 7 & 8) for the 2040 and 2090 horizons reported. Average and upper prediction limits for the scenarios considered by MfE were selected. These are referred to in this document as *mean* and *max* scenarios.

A linear interpolation was then used to obtain estimates of temperature increase for the DCC planning horizons of 2031 and 2060.

Table 7: Temperature Change Predictions 2040 (*MfE, 2008*)

Table 2.2: Projected changes in seasonal and annual mean temperature (in °C) from 1990 to 2040, by regional council area. The average change, and the lower and upper limits (in brackets), over the six illustrative scenarios are given.					
	Summer	Autumn	Winter	Spring	Annual
Northland	1.1 [0.3, 2.7]	1.0 [0.2, 2.9]	0.9 [0.1, 2.4]	0.8 [0.1, 2.2]	0.9 [0.2, 2.6]
Auckland	1.1 [0.3, 2.6]	1.0 [0.2, 2.8]	0.9 [0.2, 2.4]	0.8 [0.1, 2.2]	0.9 [0.2, 2.5]
Waikato	1.1 [0.2, 2.5]	1.0 [0.3, 2.7]	0.9 [0.2, 2.2]	0.8 [0.0, 2.0]	0.9 [0.2, 2.4]
Bay of Plenty	1.0 [0.3, 2.5]	1.0 [0.3, 2.7]	0.9 [0.1, 2.2]	0.8 [0.0, 2.1]	0.9 [0.2, 2.4]
Taranaki	1.1 [0.2, 2.4]	1.0 [0.2, 2.6]	0.9 [0.1, 2.2]	0.8 [0.0, 2.0]	0.9 [0.2, 2.3]
Manawatu-Wanganui	1.1 [0.2, 2.3]	1.0 [0.2, 2.6]	0.9 [0.2, 2.2]	0.8 [0.0, 1.9]	0.9 [0.2, 2.2]
Hawke's Bay	1.0 [0.2, 2.5]	1.0 [0.3, 2.6]	0.9 [0.1, 2.2]	0.8 [0.0, 2.0]	0.9 [0.2, 2.3]
Gisborne	1.0 [0.2, 2.6]	1.0 [0.3, 2.7]	0.9 [0.1, 2.2]	0.8 [0.0, 2.1]	0.9 [0.2, 2.4]
Wellington	1.0 [0.2, 2.2]	1.0 [0.3, 2.5]	0.9 [0.2, 2.1]	0.8 [0.1, 1.9]	0.9 [0.3, 2.2]
Tasman-Nelson	1.0 [0.2, 2.2]	1.0 [0.2, 2.3]	0.9 [0.2, 2.0]	0.7 [0.1, 1.8]	0.9 [0.2, 2.0]
Marlborough	1.0 [0.2, 2.1]	1.0 [0.2, 2.4]	0.9 [0.2, 2.0]	0.8 [0.1, 1.8]	0.9 [0.2, 2.1]
West Coast	1.0 [0.2, 2.4]	1.0 [0.2, 2.1]	0.9 [0.2, 1.8]	0.7 [0.1, 1.7]	0.9 [0.2, 1.8]
Canterbury	0.9 [0.1, 2.2]	0.9 [0.2, 2.2]	1.0 [0.4, 2.0]	0.8 [0.2, 1.8]	0.9 [0.2, 1.9]
Otago	0.9 [0.0, 2.4]	0.9 [0.1, 1.9]	1.0 [0.3, 2.1]	0.7 [0.0, 1.8]	0.9 [0.1, 1.9]
Southland	0.9 [0.0, 2.4]	0.9 [0.1, 1.9]	0.9 [0.2, 2.0]	0.7 [-0.1, 1.7]	0.8 [0.1, 1.9]
Chatham Islands	0.8 [0.2, 1.9]	0.9 [0.2, 2.0]	0.9 [0.1, 2.3]	0.7 [0.1, 1.8]	0.8 [0.2, 1.9]

Note 1: This table covers the period from 1990 (1980–1999) to 2040 (2030–2049), based on downscaled temperature changes for 12 global climate models, re-scaled to match the IPCC global warming range for six illustrative emission scenarios (B1, A1T, B2, A1B, A2 and A1FI). Corresponding maps (Figures 2.3, 2.4) should be used to identify sub-regional spatial gradients.

Note 2: If the seasonal ranges are averaged, the resulting range is larger than the range shown in the annual column, because of cancellation effects when summing over the year.

Note 3: Projected changes for the 15 regional council regions were the result of the statistical downscaling over mainland New Zealand. For the Chatham Islands, the scenario changes come from direct interpolation of the General Circulation Model grid-point changes to the latitude and longitude associated with the Chathams.



Table 8: Temperature Change Predictions 2090 (*MfE*, 2008)

Table 2.3: Projected changes in seasonal and annual mean temperature (in °C) from 1990 to 2090, by regional council area. The average change, and the lower and upper limits (in brackets), over the six illustrative scenarios are given.

	Summer	Autumn	Winter	Spring	Annual
Northland	2.3 [0.8, 6.6]	2.1 [0.6, 6.0]	2.0 [0.5, 5.5]	1.9 [0.4, 5.5]	2.1 [0.6, 5.9]
Auckland	2.3 [0.8, 6.5]	2.1 [0.6, 5.9]	2.0 [0.5, 5.5]	1.9 [0.4, 5.4]	2.1 [0.6, 5.8]
Waikato	2.3 [0.9, 6.3]	2.2 [0.6, 5.6]	2.1 [0.5, 5.2]	1.8 [0.3, 5.1]	2.1 [0.6, 5.6]
Bay of Plenty	2.2 [0.8, 6.2]	2.2 [0.6, 5.6]	2.0 [0.5, 5.2]	1.8 [0.3, 5.1]	2.1 [0.6, 5.5]
Taranaki	2.3 [0.9, 6.1]	2.2 [0.6, 5.3]	2.1 [0.5, 5.1]	1.8 [0.3, 4.9]	2.1 [0.6, 5.3]
Manawatu-Wanganui	2.3 [0.9, 6.0]	2.2 [0.6, 5.3]	2.1 [0.5, 5.0]	1.8 [0.3, 4.9]	2.1 [0.6, 5.3]
Hawke's Bay	2.1 [0.8, 6.0]	2.1 [0.6, 5.3]	2.1 [0.5, 5.1]	1.9 [0.3, 5.1]	2.1 [0.6, 5.4]
Gisborne	2.2 [0.8, 6.2]	2.2 [0.6, 5.6]	2.0 [0.5, 5.2]	1.9 [0.3, 5.2]	2.1 [0.6, 5.5]
Wellington	2.2 [0.9, 5.7]	2.1 [0.6, 5.1]	2.1 [0.6, 5.0]	1.8 [0.3, 4.8]	2.1 [0.6, 5.2]
Tasman-Nelson	2.2 [0.9, 5.6]	2.1 [0.6, 5.1]	2.0 [0.5, 4.9]	1.7 [0.3, 4.6]	2.0 [0.6, 5.0]
Marlborough	2.1 [0.9, 5.6]	2.1 [0.6, 5.0]	2.1 [0.6, 5.0]	1.8 [0.3, 4.8]	2.0 [0.6, 5.1]
West Coast	2.2 [0.9, 5.3]	2.1 [0.7, 5.0]	2.1 [0.6, 4.9]	1.7 [0.4, 4.5]	2.0 [0.7, 4.9]
Canterbury	2.1 [0.8, 5.2]	2.1 [0.7, 4.9]	2.2 [0.8, 5.1]	1.8 [0.4, 4.7]	2.0 [0.7, 5.0]
Otago	2.0 [0.7, 4.8]	2.0 [0.8, 4.6]	2.2 [0.8, 4.8]	1.7 [0.5, 4.3]	2.0 [0.8, 4.6]
Southland	2.0 [0.7, 4.7]	2.0 [0.8, 4.6]	2.1 [0.8, 4.7]	1.6 [0.5, 4.1]	1.9 [0.8, 4.5]
Chatham Islands	1.9 [0.8, 4.6]	2.1 [0.6, 4.9]	2.0 [0.3, 4.5]	1.8 [0.3, 4.6]	2.0 [0.5, 4.7]

Note 1: This table covers the period from 1990 (1980–1999) to 2090 (2080–2099), based on downscaled temperature changes for 12 global climate models, re-scaled to match the IPCC global warming range for six illustrative emission scenarios. Corresponding maps (Figures 2.3, 2.5) should be used to identify sub-regional spatial gradients.

Note 2: If the seasonal ranges are averaged, the resulting range is larger than the range shown in the annual column, because of cancellation effects when summing over the year.

Note 3: Projected changes for the 15 regional council regions were the result of the statistical downscaling over mainland New Zealand. For the Chatham Islands, the scenario changes come from direct interpolation of the General Circulation Model grid-point changes to the latitude and longitude associated with the Chathams.

To convert the temperature increases in Table 7 and 8 to a change in rainfall, the corresponding increases in rainfall intensity were also taken from *MfE* (2008) (Table 9). This analysis produced a set of amendments to the base DDF data to account for climate change impacts (Table 10).


Table 9: Extreme Rainfall Factors per 1 °C Warming (*MfE, 2008*)

Table 5.2: Factors for use in deriving extreme rainfall information for screening assessments.							
ARI (years) → Duration ↓	2	5	10	20	30	50	100
< 10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
30 minutes	7.2	7.4	7.6	7.8	8.0	8.0	8.0
1 hour	6.7	7.1	7.4	7.7	8.0	8.0	8.0
2 hours	6.2	6.7	7.2	7.6	8.0	8.0	8.0
3 hours	5.9	6.5	7.0	7.5	8.0	8.0	8.0
6 hours	5.3	6.1	6.8	7.4	8.0	8.0	8.0
12 hours	4.8	5.8	6.5	7.3	8.0	8.0	8.0
24 hours	4.3	5.4	6.3	7.2	8.0	8.0	8.0
48 hours	3.8	5.0	6.1	7.1	7.8	8.0	8.0
72 hours	3.5	4.8	5.9	7.0	7.7	8.0	8.0

Note: This table recommends *percentage* adjustments to apply to extreme rainfall per 1°C of warming, for a range of average recurrence intervals (ARIs.). The percentage changes are mid-range estimates per 1°C and should be used only in a screening assessment. The entries in this table for a duration of 24 hours are based on results from a regional climate model driven for the A2 SRES emissions scenario. The entries for 10-minute duration are based on the theoretical increase in the amount of water held in the atmosphere for a 1°C increase in temperature (8%). Entries for other durations are based on logarithmic (in time) interpolation between the 10-minute and 24-hour rates. Refer to the discussion in section 2.2.4.

Table 10: Dunedin 3 Waters Strategy Climate Change Scenarios

Scenario	Temp Increase (°C)	Intensity Increase (%)
2030 _{mean}	0.6	5
2030 _{max}	1.3	10
2060 _{mean}	1.3	11
2060 _{max}	2.9	23

3.4 Climate Variability

3.4.1 General

Climate variability is the natural variation of climate, driven by changes to large scale meteorological factors such as air pressure and sea surface temperature. These variations are generally cyclical in nature and operate over timescales of years / decades. Many of the processes behind these cycles are poorly understood.

The two key cyclic variations which impact upon New Zealand's climate are the Interdecadal Pacific Oscillation (IPO) and the El Niño-Southern Oscillation (ENSO).

Through the IPO (Figure 3) New Zealand experiences decadal climate variations. Research is still in progress on the cause and predictability of the IPO and its local climatic impacts. Historically, there was a shift to the 'negative phase' of the IPO around 1999, so more La Niña (and less El Niño)



activity may be expected compared to 1978–1998, with a period of higher temperatures for New Zealand. This is likely to favour reduced westerlies and southwesterlies, rainfall reductions in the southwest of the country but increases in the northeast, and faster rises in air temperature and sea level. These conditions could last for the next 20–30 years.

ENSO is a tropical Pacific-wide oscillation that affects pressure, winds, sea-surface temperature (SST) and rainfall. It is split into two opposite extremes of the cycle; the El Niño phase, where the easterly trade winds weaken and Sea Surface Temperatures (SST) in the eastern tropical Pacific can become several degrees warmer than normal, and the La Niña; essentially the opposite in the tropical Pacific; New Zealand experiences more north easterly flows, higher temperatures and wetter conditions in the north and east of the North Island.

The ENSO cycle, represented by the Southern Oscillation Index (SOI) (Figure 3) varies between about 3 and 7 years and there is large inter-annual variability in the intensity of individual events.

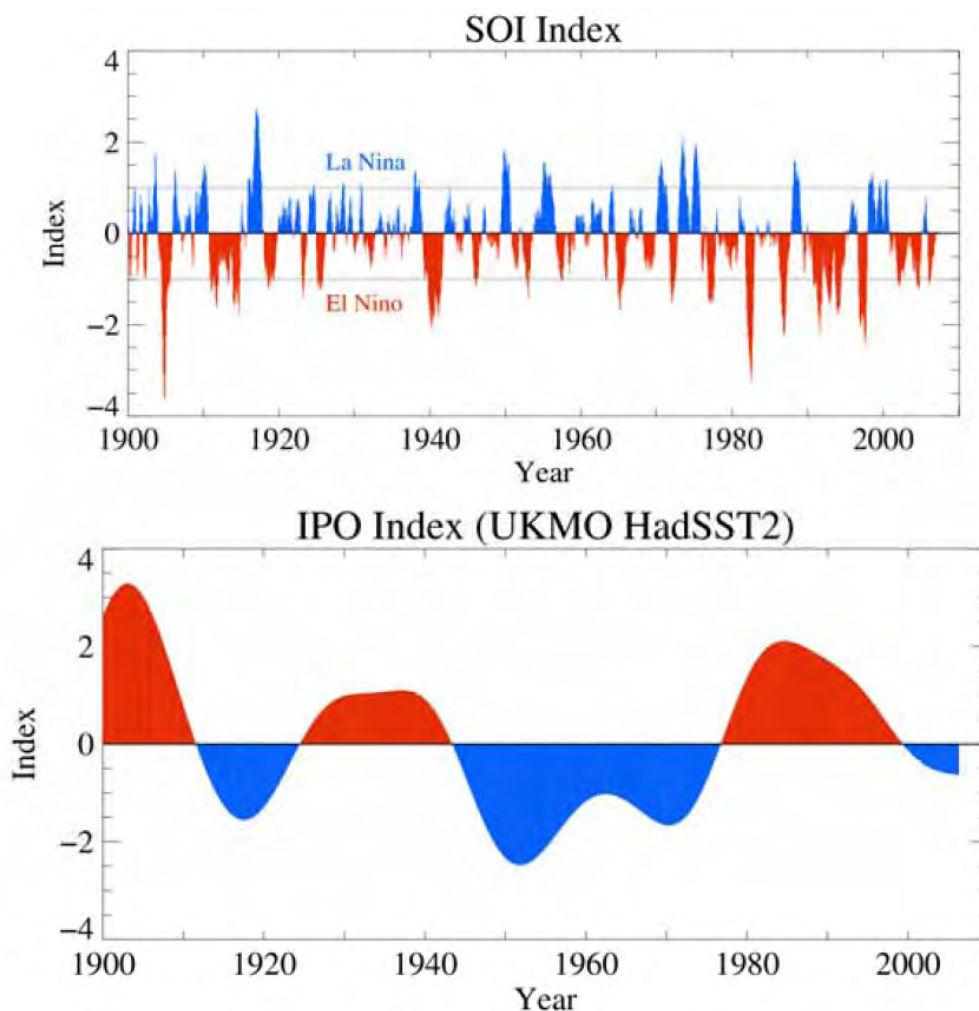


Figure 3: IPO and ENSO Index (MfE 2008)

The impact on New Zealand's weather by these cycles, in terms of prevailing winds, rainfall totals and ability for ex-cyclones to reach the islands, means that careful consideration must be given to the implications for Dunedin in terms of predicted future rainfall.



3.4.2 Implications for Dunedin

As discussed above, climatic variations have the potential to alter the intensity and occurrence of extreme rainfall events around Dunedin. A literature review was undertaken to determine the extent of the influence climate variability is likely to have on Dunedin's extreme rainfall.

A number of studies have been undertaken to assess the impact of ENSO / IPO on rainfall across New Zealand. In particular *McKerchar & Henderson (2003)* investigated the shifts in flood flow and low flow regimes in New Zealand rivers. It compared annual peak flows and annual minimum flows for two periods (1947-1977 & 1978-1999). This analysis was based on evidence that an IPO phase shift occurred in 1977.

The study found that for rivers in the north-east of the North Island and for those draining the Main Divide in the South Island interdecadal shifts were evident, however, no consistent pattern of shifts was evident elsewhere. Importantly the Taieri River was included in the study which drains the local area around Dunedin but does not extend towards the Main Divide. *McKerchar & Henderson* found no evidence of a phase shift in flows the Taieri River.

The pattern identified by *McKerchar & Henderson* of shifts in the north-east of the North Island and rivers draining the Main Divide of the South Island was also identified in *Mosley (2000)*, however, this study did not contain data which could be specifically related to Dunedin.

The results presented by *McKerchar & Henderson* and *Mosley*; that rainfall on the southern-east coast of the South Island is not affected by interdecadal shifts, is supported by studies undertaken in Timaru, which did not present any evidence of variability (*NIWA 13th September 2004, Pers. Comm.*).

Given the above it is considered unnecessary to include any allowances for climate variation within the rainfall analysis for Dunedin. It is noted that is not the case when considering tidal data.

As an aside, the lack of any climatic oscillation also supports the use of long historic records in estimating rainfall as it supports the requirement to have stationarity in the data when estimating probability distributions.

3.5 Areal Reduction

The rainfall data used by this study is based on the Musselburgh and Silverstream rain gauges, as amended by a number of factors. The data from the rain gauges are representative of the rainfall occurring in a very limited area around the rain gauge and the average rainfall depth over an entire catchment is likely to be less than that recorded by the gauge. An Areal Reduction Factor (ARF) can be used to account for the difference between point rainfall and catchment rainfall.

The use of ARF's was investigated in the Dunedin city urban area, but deemed to have a negligible impact upon the rainfall intensities derived for the project and as such these were not used within the analysis. The exclusion of what would have been at most a 5 % reduction in rainfall depth was considered to maintain a degree of conservatism within the work.

3.6 Spatial Variation

The rainfall across Dunedin is known anecdotally not to be uniform, but varies depending on location. This means that the DDF data from the Musselburgh rain gauge cannot be applied



elsewhere without considering the spatial variation in rainfall between the donor gauge (Musselburgh) and the subject catchment.

In Dunedin, spatial variation is driven primarily by topography, through orographic enhancement of rainfall, and this is evident in the increase of Average Annual Rainfall (AAR) (Table 11) between the low lying flat areas around Musselburgh and the higher ground around hill suburbs such as Mornington.

Table 11: Average Annual Rainfalls

Rain gauge	Catchment	ARR (mm)	Ground Elevation at gauge (to nearest 10m) m OD
LTRG1	Kitchener St	747	0
LTRG2	Mason St	906	110
LTRG3	St Clair	757	10
LTRG4	Halsey St	772	140
LTRG5	Orari	950	110
LTRG6	Halsey St	804	10
LTRG8	Shore St	721	10
Sawyers Bay	Port Chalmers	1037	70
Sawyers Bay STP	Port Chalmers	806	0
Musselburgh	South Dunedin	775	0

Although there is only a 4 km horizontal separation between the Musselburgh gauge and the LTRG2 gauge, the ~ 90 m difference in elevation results in a 17 % increase in annual rainfall. The limited distance over which such a large difference in rainfall occurs confirms that a single set of hyetographs, generated using data from the Musselburgh gauge, cannot be used to represent rainfall events in every catchment in Dunedin.

Rain gauge LTRG 4 was disregarded for the purposes of determining spatial variation. This gauge had considerably lower rainfall than would be expected for the elevation, with no obvious explanation. It is possible that due to its elevated and exposed position, wind shear across the top of the gauge has reduced the amount of water falling into the collection bucket, however, this could not be confirmed. Had this gauge been taken into account there would have been little effect on the weighted AAR of surrounding catchments.

In considering the spatial variation across the city it is assumed that the pattern and occurrence of rainfall remains constant. This is considered a reasonable assumption given the relatively small size of the city.

The AAR for each rain gauge in the city was plotted on a map and isohyets manually created. The isohyets (Figure 4) were used to determine a weighted average AAR for each catchment which was compared to the AAR for the donor gauge (Musselburgh). A factor used to modify the donor data was then created.



It should be noted that a number of these gauges were only installed during Phase 1 of the project and have, therefore, only been in operation for a short time (1 year). Consequently, it is possible that the data used may not be entirely typical of an average rainfall year but nevertheless are useful in establishing a scaling factor.

The factors applied to modify the donor data to represent variations in location are shown as Spatial Variation Factors (SVF) in Table 12.

Table 12: Spatial Variation Factors

Catchment	Total Area (km ²)	Weighted Catchment AAR Rainfall (mm)	Spatial Variation Factor (Base Musselburgh AAR: 775 mm)
Halsey	3.36	855	1.10
Mason	2.21	858	1.11
Kitchener	1.18	816	1.05
Portsmouth	0.38	725	0.94
Orari	3.46	898	1.16
St Clair	1.59	877	1.13
Ravensbourne	0.25	791	1.02
South Dunedin	5.69	750	0.97
Shore	0.99	725	0.94
Port Chalmers	0.58	921	1.19

For the Port Chalmers catchment isohyets were not created. A short term rain gauge was installed as part of the 3 Waters Strategy, however, at the time of analysis, this gauge provided only three months of data and as such does not fit within the methodology used, which considers annual rainfall statistics. This is not to say that the rain gauge is unnecessary; the assessment of spatial variation should be rechecked once the full data set from this gauge is available.

In lieu of data being available from the project gauge two long term rain gauges from nearby Port Chalmers were used to determine a suitable spatial variation factor for the catchment.

A gauge was present at Sawyers Bay from 1921 – 1979, located at 70 m above sea level. In 1980 it is understood that the gauge was moved to near sea level and restarted. The gauge recorded rainfall in this new location until 2000.

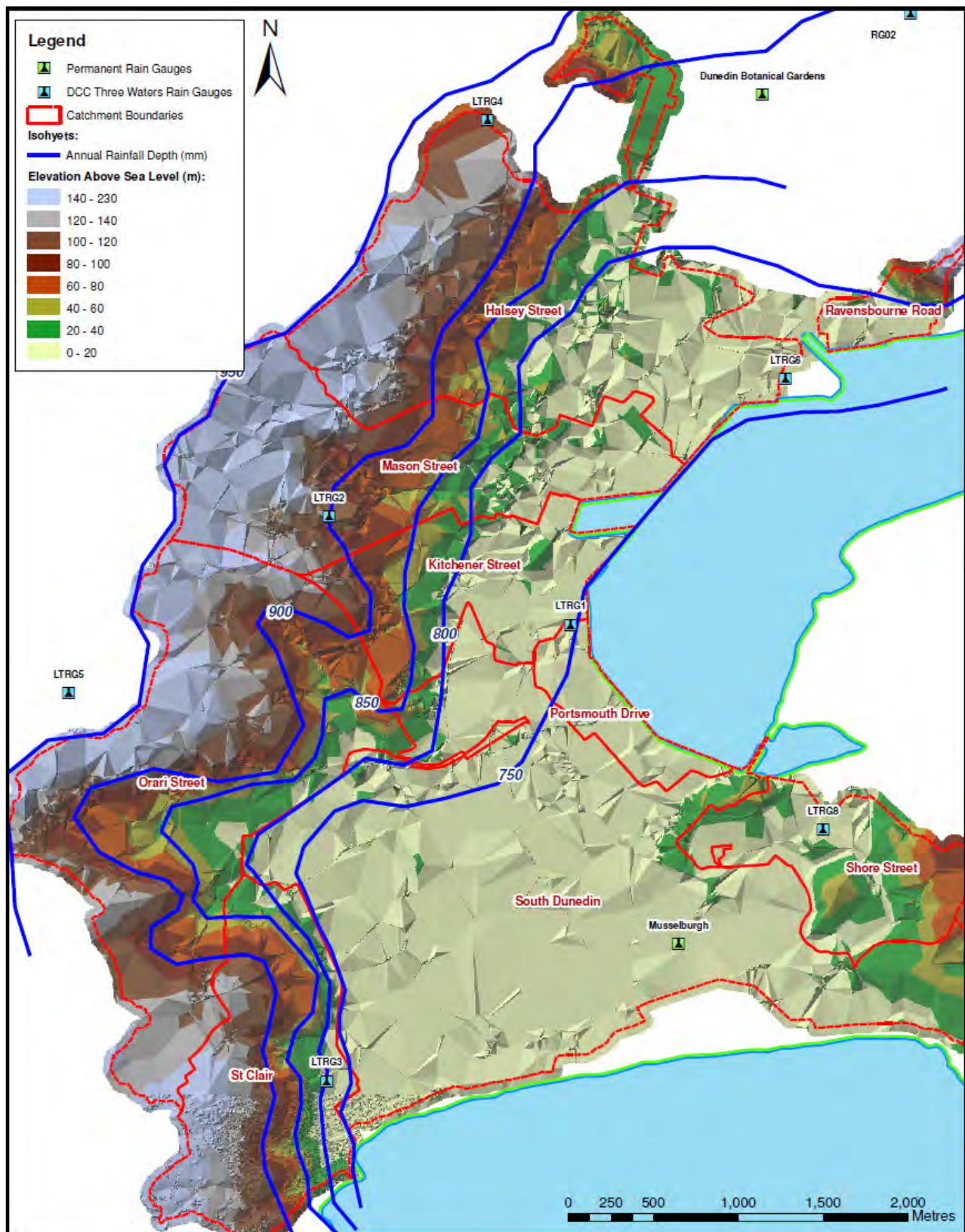
The AAR for the first installation was calculated as 1037 mm, with the later installation (at the lower elevation) having a calculated AAR of 806 mm.

Although these records do not overlap it is considered unlikely that the difference in annual average rainfalls can be as a result of climatic variability between the two periods. The difference, in this instance, is considered to relate to the change in elevation between the gauge locations. The scale of difference between the two gauges is not unrealistic; given similar differences exist in central Dunedin.



To create the spatial variation factor for Port Chalmers the mean of the two rainfall figures at Sawyers Bay was taken as being representative of the Port Chalmers area. This is considered valid given one raingauge was located at a low elevation, the other at a high elevation, level with the top of the Port Chalmers catchment.

For the Mosgiel catchment, the effect of spatial variation is expected to be negligible due to the uniform flat topography across the catchment.



						DCC 3 Water- Phase 2 Hydrology Rainfall Variability			
						File:	Designed: SEW	Status FINAL	
						Scale: 1:20,000	Drawn: SEW		
						Original Size: A3	Checked:	Drawing Number	Rev
						Date Created: 22/01/10	Approved:	Figure 4	A

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3.7 Storm Shape

A storm shape is required to transform adjusted total storm rainfall depths, as identified within the DDF analysis, into temporal patterns of rainfall which can be used by hydraulic models.

A standard dimensionless hyetograph has been adopted from CCC (2003) (Figure 5). In adopting this standard it has been assumed that Dunedin experiences a similar pattern of rainfall to Christchurch and as such the data from Christchurch is applicable to Dunedin. Within the confines of the project scope this is considered an appropriate assumption. Although a detailed investigation has not been undertaken, an inspection of storm shapes recorded around Dunedin broadly supports the use of this design storm shape.

It was determined that seasonal differences in storm shape, which are commonly reported between winter and summer storms, not be considered as part of this assessment.

The hyetograph used has a triangular form with peak intensity two times the average intensity, occurring 0.7 through the event (Figure 5 & Figure 6).

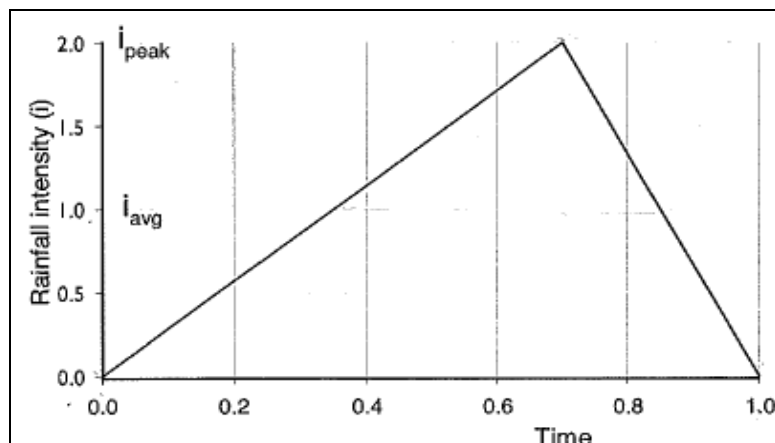


Figure 5: Dimensionless Hyetograph for Rainfall Intensity (CCC, 2003)

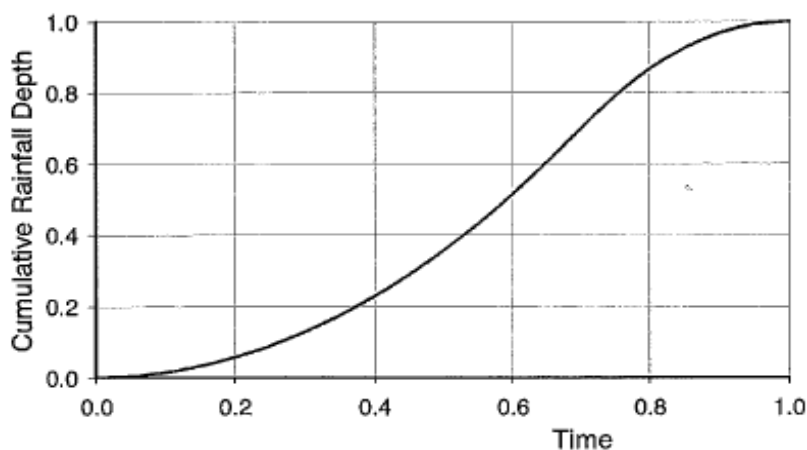


Figure 6: Cumulative Depth Hyetograph for Rainfall Intensity (CCC, 2003)



The dimensionless hyetograph was applied to each of the rainfall depths determined from the DDF analysis (as amended by the factors discussed herein). This produced 20, 30, 40 and 60 minute as well as 24 hour base hyetographs for the 2, 5, 10, 50 and 100 yr events for use in the hydraulic modelling.

3.8 Summary

To summarise the above analysis the following steps have been undertaken in preparing the rainfall data to be used for the Dunedin 3 Waters Strategy:

- Base Data derived using data from the Musselburgh and Silverstream rain gauges as analysed by URS and *Raineffects (2006)*;
- Climate change adjustments made to rainfall intensities using *MfE (2008)* mean and upper bound predictions for 2040 and 2090;
- Influence of ENSO / IPO considered and deemed insignificant;
- Spatial variation determined by isohyet analysis of local rain gauge records;
- Areal Reduction factors considered and deemed insignificant; and
- Dimensionless unit hyetograph from *CCC (2003)* used to represent storm profile.



4 Rainfall - Results

4.1 Synthetic Design Storm Events

The outcome of this work is a series of synthetic design storm events (Table 13) for each catchment under consideration. By way of example, a typical hyetograph is also provided (Figure 7). The full set of data is included in Appendix B – Data CD.

Table 13: Example Hyetograph Set (Halsey Street Catchment)

Catchment	Return Period	Duration	Climate Scenario
Halsey Street	1:10 yr	20 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
		40 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
		60 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
	1:50 yr	20 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
		40 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
		60 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
	1:100 yr	20 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
		40 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}
		60 mins	2010 _{current}
			2030 _{mean}
			2030 _{max}
			2060 _{mean}
			2060 _{max}

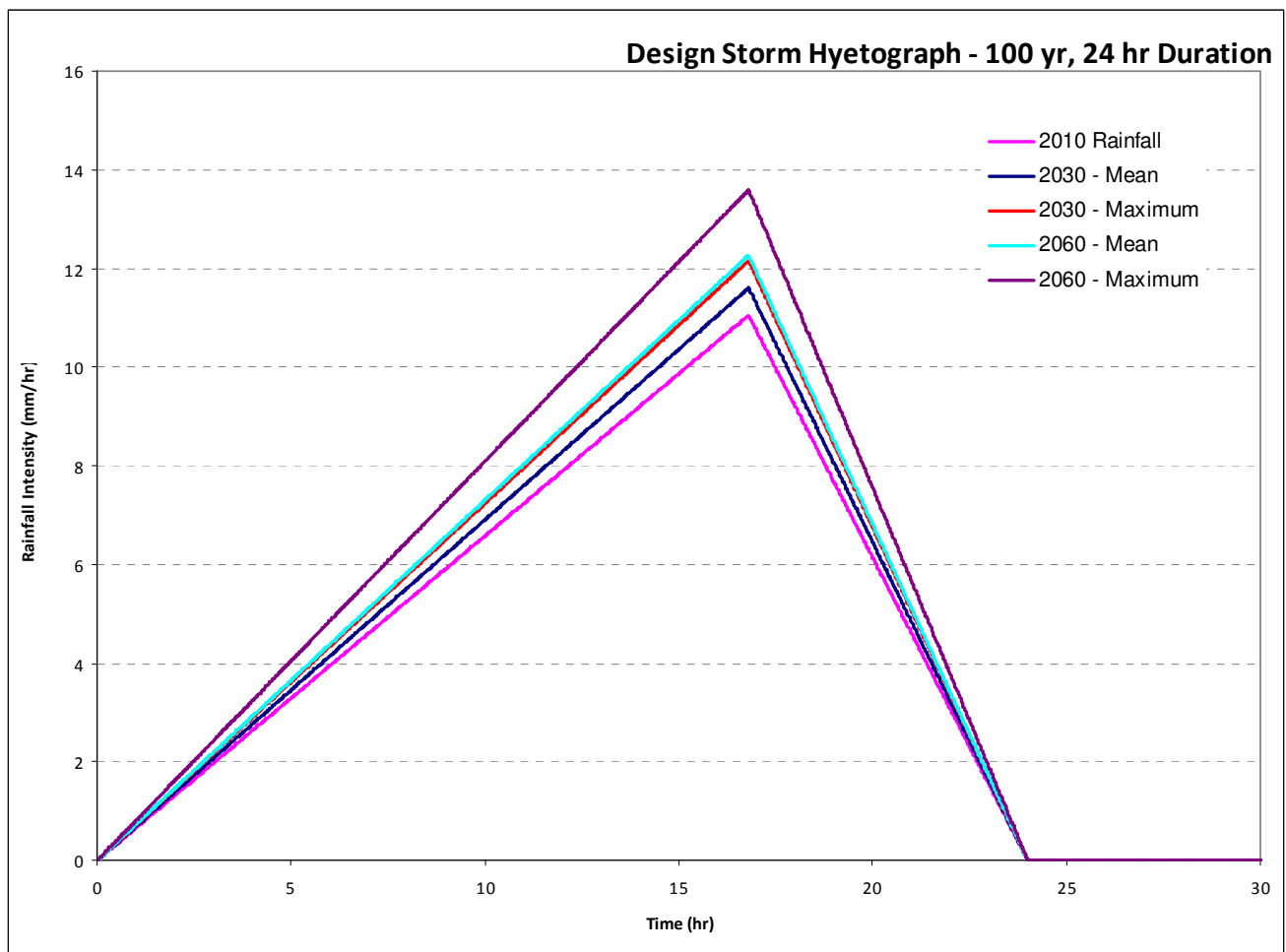


Figure 7: Example Hyetograph



5 Tide – Introduction

5.1 General

Parts of Dunedin and its drainage infrastructure are impacted by the tide. It is important, therefore, that tidal cycles be taken into account when considering the performance of storm water and waste water infrastructure throughout the low lying parts of the city. Of particular importance is consideration of how long term shifts in climate will impact on the tides experienced around Dunedin and how this will change LoS offered by infrastructure over time.

Within this part of the report the normal tidal cycles around Dunedin are identified, as are the levels for rare extreme tidal events. Consideration is then given as to how these would alter under scenarios of a changing climate.

An exception is the Mosgiel catchment which is not significantly influenced by tides due to its distance from the coast. As such, another form of downstream model boundary i.e. stream levels have been developed for Mosgiel as defined in the *Mosgiel Integrated Catchment Management Plan – Model Build Report* (Opus, 2011).

5.2 Data Sources

5.2.1 Calibration / Actual Data

The actual tidal data is sourced from long-term tidal gauges installed at Dunedin Port and Port Chalmers. This data was supplied by Land Information New Zealand (LINZ).

5.2.2 Synthetic Extreme Data

Extreme tidal data was extracted from *NIWA (2005) Otago Extreme Sea Level Analysis*. This report was prepared by the National Institute of Water & Atmospheric Research (NIWA) for Otago Regional Council (ORC) to determine extreme sea levels with return periods of 2, 5, 10, 20, 50 and 100 years at eight locations in Otago, including Dunedin Harbour and Port Chalmers. In this context an extreme tide accounts for the effect of the normal tidal cycle and storm surge. This document was used as the source of extreme tidal data for this project.

5.2.3 Additional Tidal Influences

To collate information on the other factors which influence tidal levels, a large number of references were reviewed. Factors such as climate change, climate variability and other factors were considered.

5.3 Datums

A number of different datums are used for defining the elevation of points around Dunedin. For the Dunedin 3 Waters Strategy the standard datum selected for use is the Otago Datum (OD). This datum sets Mean Level Of the Sea (MLOS) at 100.12 m so as to ensure negative values do not occur in any level data. For clarity the relationships between key datums in Dunedin are provided (Figure 8), however, unless otherwise stated, all levels quoted relate to OD.

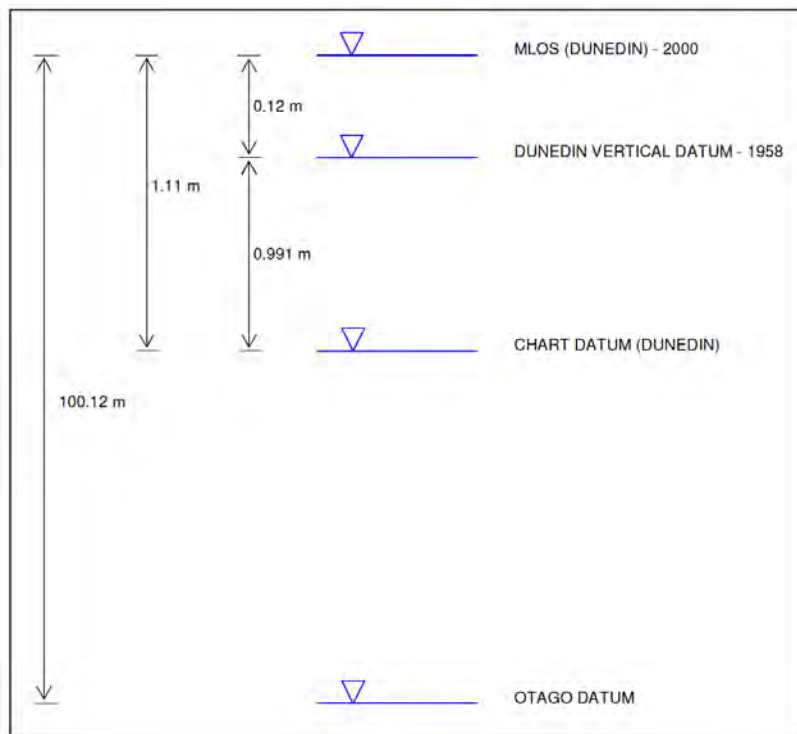


Figure 8: Relationship between Dunedin Datums

5.4 Limitations on Use

Within the work undertaken as part of the Dunedin 3 Waters Strategy the information gathered on tides is used to provide lower boundary conditions for the storm water and waste water hydraulic models. The tidal information is used for this purpose to determine the impact on flooding patterns within the city as a result of either system being impacted by the tide.

The scope of the Dunedin 3 Waters Strategy does not extend to consideration of surface flooding caused directly by tide levels (i.e. tides or surges which breach sea walls and wharfs to inundate adjacent land).

The tidal levels reported within this study should not be used for the design of coastal flood prevention schemes nor should they be used to define coastal hazard zones as they omit several important factors which must be considered for such work.



6 Tide – Methodology

6.1 Overview

The following are the main uses of tidal information for the Dunedin 3 Water Strategy:

- Calibration Data
- Synthetic Extreme Tidal Events (Static and Cyclic)

6.2 Calibration Data

A number of long-term tide gauges are present in the Dunedin area. Of particular interest to the catchments currently being studied under the 3 Waters Project are the gauges located at Port Chalmers and at Dunedin Harbour; these being the tide gauges closest to the outfalls under consideration.

Data from the gauges was provided by LINZ, for each location datum levels were checked and converted to OD.

6.3 Synthetic Extreme Tidal Events

6.3.1 Introduction

Extreme tidal data was extracted from *NIWA (2005)*. This report was prepared by NIWA for ORC to determine extreme sea levels with return periods of 2, 5, 10, 20, 50 and 100 years at eight locations in Otago, including Dunedin Harbour.

In this context, an extreme tide accounts for the effect of the normal tidal cycle and storm surge.

There are two ways in which this data can be used by the modelling work:

- As a static boundary condition allowing conservative estimates of flooding within Dunedin.
- As applied to a synthetic tidal cycle with amplitude equal to the extreme tidal value. This allows a more realistic representation of a storm and tide event coinciding.

6.3.2 Base Data Tide and Surge

6.3.2.1 Static Boundary Method

As the static boundary method is a constant (peak) level, when used in modelling it may not allow storm water and waste water infrastructure to drain during low tide, as it would in reality. For shorter duration rainfall events, up to around 1 – 2 hrs, this method serves as an acceptable conservative boundary condition. Storm events of this length occurring during high tide would be unlikely to benefit from low tide conditions, due to the brevity of the event.

The static boundary method uses *NIWA (2005)* predictions for a range of storm events. These were converted to OD. Table 14 depicts the extreme sea level rise values used for design purposes. This provided a basis for applying the 'mean' and 'extreme' planning limits for climate change established with DCC.



Table 14: Extreme Sea Levels ± 0.3 m NIWA (2005) [2 d.p. in parentheses]

Return Period	1:2 yr	1:5 yr	1:10 yr	1:20 yr	1:50 yr	1:100 yr
Otago Harbour (at Dunedin)	101.6 (101.66)	101.7 (101.74)	101.8 (101.81)	101.9 (101.87)	102.0 (101.96)	102.0 (102.02)
Port Chalmers	101.6 (101.60)	101.7 (101.66)	101.7 (101.72)	101.8 (101.78)	101.9 (101.86)	101.9 (101.92)

6.3.2.2 Synthetic Cyclic Method

By creating a synthetic tidal cycle actual conditions can be better represented and more detailed modelling can be undertaken. This is particularly true for longer duration rainfall events where the pattern of flooding is more vulnerable to misrepresentation by static tidal boundary conditions.

CCC (2003) provides a methodology to generate synthetic tidal cycles. Using this methodology creates a tidal cycle with a tidal period of 12.421 hr and amplitude which relates to the static sea levels given previously (Table 14).

This method provides tidal cycles (Figure 9) which are adequate for the intended uses of representing extreme boundary conditions for the hydraulic modelling.

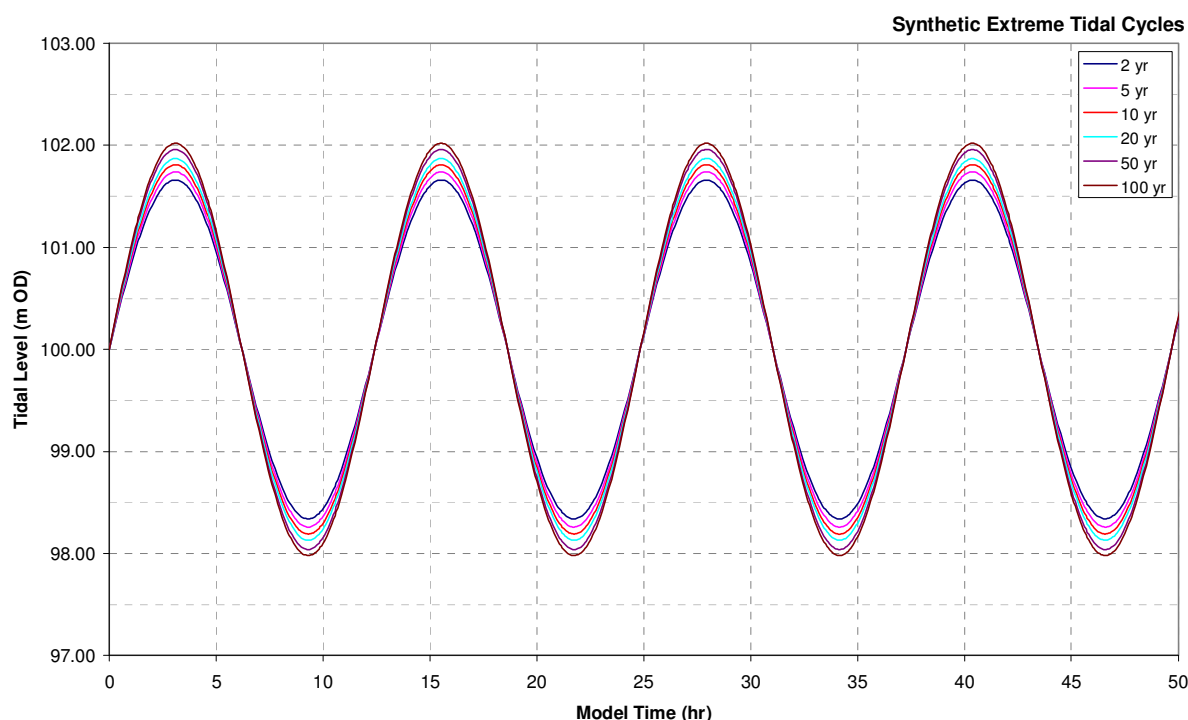


Figure 9: Synthetic Extreme Tidal Cycles for Otago Harbour (at Dunedin)

6.3.3 Climate Variability

It is important to make the distinction between climate change and climate variability. Climate variability refers to natural cyclical variations in climate which are driven by any number of processes many of which are not fully understood. This differs from climate change which, for the



purpose of this study, is considered as the increases in global temperatures as a result of anthropogenic discharges of greenhouse gases to the atmosphere.

This section of the report considers the impacts of various climate variability factors on tidal levels around Dunedin, focusing on IPO and ENSO as discussed previously in Section 3.4.1. *NIWA (2005)* provides predictions the impacts of these variations, as below:

- During negative phases of the IPO the mean level of the sea (MLOS) is likely to be approximately 0.05 m higher.
- Under strong La Niña conditions the MLOS can rise by 0.15 m, with a similar decrease during strong El Niño conditions.

The effects of the IPO and ENSO were added to give a worst case sea level rise through climate variability which assumes that a strong La Niña event would coincide with the trough of a negative phase IPO event. This gives a combined sea level rise of 0.2 m (Table 15).

Table 15 – Impact of Climate Variability on Sea Level

Year	Increase (m)
All Years	0.2

This figure was added to all modelling scenarios for the 2031 and 2060 planning horizons.

6.3.4 Climate Change

It is widely estimated that climate change will cause sea level to rise and number of predictions exist, providing different severities of sea level increase.

The defined planning horizons for the Dunedin 3 Waters Strategy are 2031 and 2060, and as such, the likely effect of climate change on sea level has been assessed for these points in time only. Predictions within *MfE (2008b)* were used as the basis for this assessment.

Values for 2031 have been interpolated from the 2040 MfE values assuming a linear trend (conservative) and values for 2060 have been interpolated from the 2090 MfE values also assuming a linear trend (Table 16).

Table 16: Sea Level Rise due to Climate Change

Year	Mean (m)	Max (m)
2031	0.12	0.2
2061	0.28	0.46

The increases are applied to both the extreme tidal figures and to a number of actual events to highlight how the outcomes of these events would change were they to have occurred under an altered climate.



6.3.4.1 Factors not Considered

Several factors which can influence tidal level were not included within this analysis. For clarity these are detailed below.

Wave set up: The average level of the water inside the surf zone to the beach is set up higher than the sea level offshore from the breaker zone.

Wave run-up: The extra height that broken waves reach as they run up the beach and adjacent coastal barrier (natural or artificial), until the wave energy is finally expended by friction and gravity.

Reason for exclusion: These were considered, but ultimately excluded from this analysis as they are not considered important in setting an offshore sea level for river (or in this case sewer) flood simulations, as discussed in *NIWA (2005)*.

It is important to note, however, that this makes the figures provided within the Dunedin 3 Waters Strategy work unsuitable for use in setting design levels for coastal protection works and in determining coastal hazard zones.

Thermal expansion: Seasonal cycles due to the thermal expansion and contraction of sea water due to summer and winter ambient temperatures.

Reason for exclusion: This effect was not considered significant enough for explicit inclusion. *NIWA (2005)* predicts a variability of +/- 0.03 m due to this factor.



7 Tide - Results

7.1 Synthetic Static Extreme Tide Values

The predicted rise in sea level for the mean and extreme scenarios, including planning guideline parameters, climate change and potential cyclical variations are provided below (Table 17 & 18).

Table 17: Dunedin Harbour - Climate Change & Climate Variability Sea Level Rise (m OD)

Long Term Record Dunedin Harbour	2009	2031 Mean	2031 Max	2061 Mean	2061 Max
Extreme 2 yr value	101.66	101.98	102.06	102.14	102.32
Extreme 5 yr value	101.74	102.06	102.14	102.22	102.40
Extreme 10 yr value	101.81	102.13	102.21	102.29	102.47
Extreme 20 yr value	101.87	102.19	102.27	102.35	102.53
Extreme 50 yr value	101.96	102.28	102.36	102.44	102.62
Extreme 100 yr value	102.02	102.34	102.42	102.50	102.68

Table 18 - Port Chalmers - Climate Change & Climate Variability Sea Level Rise (m OD)

Long Term Record Port Chalmers	2009	2031 Mean	2031 Max	2061 Mean	2061 Max
Extreme 2 yr value	101.60	101.92	102.00	102.08	102.26
Extreme 5 yr value	101.66	101.98	102.06	102.14	102.32
Extreme 10 yr value	101.72	102.04	102.12	102.20	102.38
Extreme 20 yr value	101.78	102.10	102.18	102.26	102.44
Extreme 50 yr value	101.86	102.18	102.26	102.34	102.52
Extreme 100 yr value	101.92	102.24	102.32	102.40	102.58

7.2 Synthetic Cyclic Extreme Tide Values

The synthetic cyclic extreme tide data is included in Appendix B – DATA CD.



8 Joint Analysis

It is an over simplification to consider, for example, a 1:10 year rainfall event without taking account of the probability that the rainfall event may coincide with a high tide (which occur twice a day) or high stream level (which is affected by rainfall events). Considering this, however, introduces a significant number of potential scenarios. As such, a number of scenarios were developed to allow the impact of tidal/stream extremes to be considered in conjunction with a small number of rainfall events within the analysis, without producing so many scenarios that the outcomes become lost in the data. Table 19a provides the modelling scenarios being used by all the 3 Waters Strategy catchments except Mosgiel while Table 19b provides the modelling scenarios for Mosgiel only.



Table 19a – Hydraulic Modelling Scenarios for All Catchments except Mosgiel

Model Run	Scenario			Rainfall Event					Climate Change ¹			Tide Level		Flood Maps			Scenario Application
	Current	2031 ²	2060	2yr ³	5yr	10yr	50yr	100yr	None	Mean	Extreme	MHWS ⁴	Extreme	LOS	Deep Flood ⁵	Hazard	
1	✓			Actual					✓			Actual		✓			Model confidence
2	✓			✓					✓			✓		✓			Current infrastructure capacity
3	✓				✓				✓			✓		✓			Current infrastructure capacity
4	✓					✓			✓			✓		✓			Current infrastructure capacity
5	✓						✓		✓			✓			✓		Current potential habitable floor flooding
6	✓							✓	✓				1 in 2yr			✓	Current Emergency planning
7		✓				✓			✓			✓		✓			2031 Infrastructure capacity
8		✓				✓				✓		✓		✓			2031 Infrastructure capacity
9		✓				✓					✓	✓		✓			2031 Infrastructure capacity
10		✓					✓			✓		✓			✓		2031 Potential habitable floor flooding
11			✓			✓				✓		✓		✓			2060 Infrastructure capacity
12			✓			✓					✓	✓		✓			2060 Infrastructure capacity
13			✓				✓			✓		✓			✓		2060 Potential habitable floor flooding
14			✓					✓			✓		1 in 20yr			✓	2060 Emergency planning

¹ For the same year associated with 'Scenario'

² Assumes 2031 population with maximum allowable development/imperviousness

³ 2.33 yr ARI, representing the 'mean annual flood' event

⁴ Mean high water springs (MHWS)

⁵ Only shows flooding > 300 mm deep



Rainfall and Tidal Analysis Report

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Table 19b –Mosgiel Hydraulic Modelling Scenarios

Model Run	Scenario			Rainfall Event					Climate Change			Storm Duration	Boundary (Silver Stream)	Flood Maps	Reporting / Analysis	Systems Run	Scenario Application
	Current	2031 ²	2060 ²	2yr	5yr	10yr	50yr	100yr	None	Mean	Extreme						
1	✓			DWF					N/A			24 hr	Free			Both	System Performance
2		✓		DWF					N/A			24 hr	Free		✓	Both	Capacity to accept future growth
3	✓					✓			✓	Both		30 min	Free	✓	✓	Both	Current infrastructure capacity
4	✓					✓			✓			24 hr	1 in 10 yr		✓	Both	Current infrastructure capacity
5		✓				✓			✓			30 min	Free	✓	✓	Both	2031 infrastructure capacity
6		✓				✓			✓			24 hr	1 in 10 yr		✓	Both	2031 infrastructure capacity
7 ¹		✓				✓				2031		24 hr	1 in 10 yr		✓	Both	2031 Growth + Climate change
8			✓			✓				2060		30 min	Free	✓	✓	Both	Potential 2060 infrastructure capacity
9			✓			✓				2060		24 hr	1 in 10 yr		✓	Both	Potential 2060 infrastructure capacity
10			✓				✓		✓			30 min	Free	✓	✓	Both	Current habitable floor flooding
11			✓				✓			2060		30 min	Free	✓	✓	Both	Potential 2060 habitable floor flooding
12	✓							✓	✓			30 min	Free	✓	✓	Both	Current emergency planning
13			✓					✓			2060	30 min	MAF	✓	✓	Both	Future emergency planning
14	Historic May 2010 Event (based on available data)													✓		Both	Model validation
15	✓			✓					✓			30 min	Free	✓	✓	Both	Current infrastructure capacity
16	✓			✓					✓			24 hr	1 in 10 yr			Both	Current infrastructure capacity
17	✓				✓				✓			30 min	Free	✓	✓	Both	Current infrastructure capacity
18	✓				✓				✓			24 hr	1 in 10 yr			Both	Current infrastructure capacity

¹ Future growth for the stormwater system is expected to be greenfield and designed to current standards, hence only the 2060 growth scenario is considered for the stormwater system.



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APPENDIX A – Distribution Analysis



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4.00 Hours Rainfall (mm) at Musselburgh-Hrly-1

From 1-Jan-1986 09:00:00 to 30-Aug-2008 24:00:00

Location = 19.3 Scale = 5.42 100yr/2.33yr = 1.971

-- Gumbel Distribution --

12 mth Par **4.00 Hours mean starts at** Measured maximum 1.96 std. d_k Prob. per y Return Period

			56.8	13.6	0.001	1000
			53	12.3	0.002	500
			48.1	10.4	0.005	200
			44.3	9.1	0.01	100
			40.5	7.7	0.02	50
1-Jan-91	18/02/1991 10:00	38	38	6.8	0.032	31.7
			35.4	6	0.05	20
1-Jan-07	30/07/2007 11:00	33.8	33.8	5.4	0.067	14.9
1-Jan-88	14/01/1988 6:00	31.6	31.6	4.7	0.099	10.1
			31.5	4.6	0.1	10
1-Jan-06	25/04/2006 22:00	30.5	30.5	4.3	0.12	8.3
			27.5	3.4	0.2	5
1-Jan-00	24/01/2000 1:00	27	27	3.3	0.216	4.6
1-Jan-98	7/02/1998 16:00	26.4	26.4	3.1	0.238	4.2
1-Jan-04	12/05/2004 23:00	25.9	25.9	3	0.258	3.9
1-Jan-05	7/02/2005 16:00	25.1	25.1	2.8	0.292	3.4
1-Jan-94	19/03/1994 12:00	23.9	23.9	2.6	0.35	2.9
			22.5	2.4	0.43	2.33
1-Jan-93	30/01/1993 5:00	21.8	21.8	2.3	0.47	2.1
1-Jan-86	13/02/1986 7:00	21.7	21.7	2.3	0.476	2.1
1-Jan-90	25/08/1990 11:00	21	21	2.3	0.521	1.9
1-Jan-02	8/09/2002 17:00	20.9	20.9	2.3	0.528	1.9
1-Jan-87	10/03/1987 13:00	20	20	2.3	0.587	1.7
1-Jan-03	28/12/2003 15:00	19.1	19.1	2.4	0.648	1.5
1-Jan-92	8/04/1992 18:00	19	19	2.4	0.655	1.5
1-Jan-08	30/04/2008 8:00	18.7	18.7	2.4	0.675	1.5
1-Jan-97	16/12/1997 7:00	17.8	17.8	2.5	0.735	1.4
1-Jan-96	31/10/1996 17:00	17.7	17.7	2.6	0.741	1.3
1-Jan-95	24/12/1995 15:00	16.4	16.4	2.8	0.821	1.2
1-Jan-99	13/12/1999 12:00	16.2	16.2	2.8	0.832	1.2
1-Jan-89	4/12/1989 12:00	15.1	15.1	3.1	0.888	1.1
1-Jan-01	9/06/2001 17:00	9.2	9.2	4.9	0.998	1

Mean = 22.5



Source is J:\Jobs\42166807\5 Technical\501 - Hydrology\Hiltop\DCC.hts

6.00 Hours Rainfall (mm) at Musselburgh-Hrly-1

From 1-Jan-1986 09:00:00 to 30-Aug-2008 24:00:00

Location = 24.0 Scale = 7.71 100yr/2.33yr = 2.090

-- Gumbel Distribution --

12 mth Par 6.00 Hours mean starts at Measured maximum 1.96 std. dev Prob. per y Return Period

			77.3	19.4	0.001	1000
			71.9	17.4	0.002	500
			64.8	14.9	0.005	200
			59.5	12.9	0.01	100
			54.1	11	0.02	50
1-Jan-91	18/02/1991 10:00	48.8	48.8	9.1	0.039	25.4
1-Jan-07	30/07/2007 11:00	47.2	47.2	8.6	0.048	20.8
			46.9	8.5	0.05	20
1-Jan-88	19/01/1988 8:00	41.6	41.6	6.7	0.097	10.3
			41.4	6.6	0.1	10
1-Jan-06	25/04/2006 21:00	40.3	40.3	6.3	0.114	8.8
			35.6	4.8	0.2	5
1-Jan-00	36549	35.2	35.2	4.7	0.209	4.8
1-Jan-98	7/02/1998 14:00	33	33	4.2	0.268	3.7
1-Jan-04	12/05/2004 21:00	32.5	32.5	4.1	0.283	3.5
1-Jan-94	19/03/1994 10:00	31.2	31.2	3.8	0.325	3.1
1-Jan-05	7/02/2005 15:00	29.9	29.9	3.6	0.372	2.7
1-Jan-90	25/08/1990 9:00	29.5	29.5	3.5	0.388	2.6
1-Jan-86	25/02/1986 13:00	29.3	29.3	3.5	0.395	2.5
			28.5	3.4	0.43	2.33
1-Jan-87	19/05/1987 3:00	26.6	26.6	3.3	0.51	2
1-Jan-03	28/12/2003 17:00	25.2	25.2	3.3	0.575	1.7
1-Jan-93	30/01/1993 5:00	24.1	24.1	3.3	0.628	1.6
1-Jan-08	2/03/2008 7:00	23.6	23.6	3.4	0.652	1.5
1-Jan-95	25/03/1995 16:00	22.5	22.5	3.5	0.704	1.4
1-Jan-92	8/04/1992 18:00	22.1	22.1	3.6	0.722	1.4
1-Jan-02	8/09/2002 15:00	21.4	21.4	3.7	0.754	1.3
1-Jan-97	11/02/1997 5:00	21.3	21.3	3.7	0.758	1.3
1-Jan-99	13/12/1999 12:00	21.2	21.2	3.7	0.763	1.3
1-Jan-96	31/10/1996 17:00	19.5	19.5	4.1	0.834	1.2
1-Jan-89	22/10/1989 16:00	17.5	17.5	4.5	0.902	1.1
1-Jan-01	19/07/2001 12:00	11	11	6.5	0.995	1

Mean = 28.5



Source is J:\Jobs\42166807\5 Technical\501 - Hydrology\Hiltop\DCC.hts

Twelve hourly Rainfall (mm) at Musselburgh-Hrly-1

From 1-Jan-1986 09:00:00 to 30-Aug-2008 24:00:00

Location = 33.9 Scale = 12.7 100yr/2.33yr = 2.240

-- Gumbel Distribution --

12 mth Par	12.00 Hours mean starts at	Measured maximum	1.96 std. d	Prob. per y	Return Period	
		121.8	32	0.001	1000	
		113	28.8	0.002	500	
		101.3	24.5	0.005	200	
		92.5	21.3	0.01	100	
		83.6	18.1	0.02	50	
1-Jan-07	30/07/2007 8:00	77.9	77.9	16.1	0.031	32.2
			71.7	14	0.05	20
1-Jan-91	18/02/1991 5:00	66.3	66.3	12.1	0.076	13.2
1-Jan-06	25/04/2006 20:00	63.9	63.9	11.3	0.091	11
			62.6	10.9	0.1	10
1-Jan-88	19/01/1988 4:00	59	59	9.7	0.13	7.7
1-Jan-98	7/02/1998 8:00	56.6	56.6	9	0.155	6.5
			53	8	0.2	5
1-Jan-94	19/03/1994 5:00	51.3	51.3	7.5	0.225	4.4
1-Jan-04	12/05/2004 16:00	49.4	49.4	7	0.257	3.9
1-Jan-86	25/02/1986 11:00	46.7	46.7	6.4	0.307	3.3
1-Jan-00	23/01/2000 22:00	45.2	45.2	6.1	0.338	3
1-Jan-87	19/05/1987 2:00	41.9	41.9	5.7	0.414	2.4
			41.3	5.6	0.43	2.33
1-Jan-90	25/08/1990 7:00	38.4	38.4	5.4	0.506	2
1-Jan-08	39509	36.9	36.9	5.4	0.547	1.8
1-Jan-03	28/12/2003 12:00	35	35	5.4	0.601	1.7
1-Jan-99	13/12/1999 10:00	33.4	33.4	5.6	0.648	1.5
1-Jan-96	12/10/1996 22:00	33.3	33.3	5.6	0.651	1.5
1-Jan-97	10/02/1997 23:00	33	33	5.6	0.659	1.5
1-Jan-05	7/02/2005 13:00	32.3	32.3	5.7	0.679	1.5
1-Jan-93	17/05/1993 9:00	30.6	30.6	5.9	0.728	1.4
1-Jan-02	9/01/2002 19:00	25.4	25.4	6.9	0.859	1.2
1-Jan-89	11/03/1989 22:00	25	25	7	0.867	1.2
1-Jan-92	4/02/1992 11:00	24.5	24.5	7.2	0.878	1.1
1-Jan-95	25/03/1995 14:00	24	24	7.3	0.887	1.1
1-Jan-01	19/07/2001 21:00	19.5	19.5	8.5	0.955	1

Mean = 41.3



Source is J:\Jobs\42166807\5 Technical\501 - Hydrology\Hiltop\DCC.hts

Daily Rainfall (mm) at Musselburgh-Hrly-1

From 1-Jan-1986 09:00:00 to 30-Aug-2008 24:00:00

Location = 46.4 Scale = 16.0 100yr/2.33yr = 2.161

-- Gumbel Distribution --

12 mth Par	1 Day	mean starts at	Measured maximum	1.96 std. d	Prob. per y	Return Period
			157.2	40.4	0.001	1000
			146.1	36.3	0.002	500
			131.3	30.9	0.005	200
			120.2	26.9	0.01	100
			109	22.9	0.02	50
1-Jan-91	17/02/1991 19:00	99.8	99.8	19.6	0.035	28.5
			94	17.6	0.05	20
1-Jan-07	29/07/2007 22:00	89.1	89.1	15.9	0.067	14.9
1-Jan-06	25/04/2006 10:00	82.5	82.5	13.7	0.1	10
			82.5	13.7	0.1	10
1-Jan-86	25/02/1986 2:00	74.7	74.7	11.3	0.157	6.4
1-Jan-94	18/03/1994 17:00	74	74	11.1	0.164	6.1
			70.4	10.1	0.2	5
1-Jan-98	7/02/1998 3:00	65.8	65.8	8.9	0.258	3.9
1-Jan-04	12/05/2004 9:00	65.3	65.3	8.8	0.264	3.8
1-Jan-88	18/01/1988 22:00	63	63	8.2	0.298	3.4
1-Jan-87	9/03/1987 23:00	63	63	8.2	0.298	3.4
1-Jan-08	31/07/2008 6:00	60.7	60.7	7.8	0.336	3
1-Jan-00	18/08/2000 15:00	58.2	58.2	7.4	0.38	2.6
			55.6	7	0.43	2.33
1-Jan-97	11/01/1997 15:00	51	51	6.8	0.527	1.9
1-Jan-90	24/08/1990 19:00	49.1	49.1	6.8	0.57	1.8
1-Jan-05	11/02/2005 10:00	48.7	48.7	6.8	0.579	1.7
1-Jan-93	34106	45	45	7.1	0.663	1.5
1-Jan-96	12/10/1996 18:00	41.8	41.8	7.5	0.735	1.4
1-Jan-99	13/12/1999 9:00	40	40	7.8	0.774	1.3
1-Jan-02	27/04/2002 22:00	38.7	38.7	8.1	0.8	1.2
1-Jan-03	28/12/2003 3:00	38	38	8.2	0.814	1.2
1-Jan-89	3/10/1989 21:00	36	36	8.7	0.852	1.2
1-Jan-01	19/07/2001 12:00	35.1	35.1	8.9	0.867	1.2
1-Jan-92	14/11/1992 22:00	33.7	33.7	9.2	0.889	1.1
1-Jan-95	13/03/1995 4:00	26.1	25.7	11.4	0.973	1

Mean = 55.6



Source is J:\Jobs\42173227\5 Works\501 - Hydrology\Updated Mosgiel Data
 \DR 240111 Frances Judge URS.hts

Rainfall (mm) at Silverstream at Taieri Depot

From 26-Jul-1988 00:00:00 to 11-Jan-2011 13:45:00

Location = 43.0 Scale = 27.6 100yr/2.33yr = 2.881

-- Gumbel Distribution --

12 mth

Partition starts	1 Day starts at	mean	Measured	maximum	1.96 std. dev.	Prob. per year	Return Period
				233.4	67.8	0.001	1000
				214.3	61	0.002	500
				189	51.9	0.005	200
				169.8	45.1	0.01	100
1-Jan-06	25/04/2006 10:15	164.5	164.5	164.5	43.3	0.012	82.6
				150.6	38.4	0.02	50
				124.9	29.6	0.05	20
1-Jan-10	25/05/2010 4:45	115.5	115.5	115.5	26.4	0.07	14.4
				105	23.1	0.1	10
1-Jan-94	18/03/1994 13:30	102	102	102	22.1	0.111	9
1-Jan-00	2/01/2000 15:00	94	94	94	19.7	0.146	6.9
1-Jan-07	29/07/2007 22:30	93	93	93	19.4	0.151	6.6
				84.4	16.9	0.2	5
1-Jan-97	11/01/1997 15:45	83	83	83	16.5	0.209	4.8
1-Jan-91	17/02/1991 21:15	79	79	79	15.5	0.237	4.2
1-Jan-01	19/07/2001 12:15	62	62	62	12.2	0.395	2.5
				58.9	11.8	0.43	2.33
1-Jan-08	31/07/2008 2:30	58	58	58	11.7	0.441	2.3
1-Jan-05	11/02/2005 10:45	57	57	57	11.7	0.452	2.2
1-Jan-98	6/02/1998 20:45	55.5	55.5	55.5	11.6	0.471	2.1
1-Jan-89	3/10/1989 21:15	54	54	54	11.5	0.489	2
1-Jan-02	28/04/2002 1:00	45	45	45	11.5	0.606	1.7
1-Jan-99	13/12/1999 3:15	44	44	44	11.6	0.619	1.6
1-Jan-93	24/09/1993 7:15	44	44	44	11.6	0.619	1.6
1-Jan-96	12/10/1996 17:45	43.5	43.5	43.5	11.6	0.626	1.6
1-Jan-92	14/11/1992 23:45	36	36	36	12.5	0.725	1.4
1-Jan-09	20/02/2009 11:45	33	33	33	13	0.763	1.3
1-Jan-95	6/09/1995 7:15	31.5	31.5	31.5	13.3	0.781	1.3
1-Jan-03	17/02/2003 9:15	29.5	29.5	29.5	13.6	0.805	1.2
1-Jan-04	21/12/2004 2:45	29	29	29	13.7	0.811	1.2
1-Jan-90	13/10/1990 8:00	24	24	24	14.8	0.864	1.2
1-Jan-11	2/01/2011 8:15	19.5	19.5	19.5	15.9	0.904	1.1
1-Jan-88	18/11/1988 7:00	18	18	18	16.3	0.916	1.1

Mean = 58.9



APPENDIX B – Data CD



Appendix C

C1 Mosgiel Wastewater Customer Complaints 2005-2010

Table C1-1: Mosgiel Wastewater Complaints (2005-2010)

C2 Mosgiel Stormwater Customer Complaints 2005-2010

Table C2-1: Mosgiel Stormwater Complaints (2005-2010)



C1: Mosgiel Wastewater Customer Complaints 2005 - 2010

Table C1-1: Mosgiel Wastewater Complaints (2005 - 2010)

Street Name	Description
Tyne Street / Carlyle Road	Wastewater flood complaints in 2006, 2007, 2009 and 2010.
High Street	Wastewater overflows in 2007 - 2010.
Hazlett Road	Wastewater overflows in 2006 and 2009. This appeared to relate to the flooding and failure of the Hazlett Road PS [Taieri septic wastewater PS] which had potential to contaminate surface flood water around the PS and associated manholes in the reticulation.
Argyle Street	Wastewater overflows in 2009. This is related to a drain gully trap overflowing in the same location for all complaints
Ayr Street	Wastewater boundary trap overflow in 2008 and 2010.
Braeside	Wastewater boundary trap overflow in 2008
Eden Street	Wastewater blocked sewer in 2008
Forfar Street	Wastewater overflows in 2008 – 2010
Gebbie Street	Wastewater overflows in 2008 and 2010
Gladstone Road	Wastewater overflows in 2008
Goodall Street	Wastewater overflows in 2008 and 2010
Gow Street	Wastewater boundary trap overflow in 2008
Lomond Place	Wastewater overflow in 2010
McFadden Drive	Wastewater overflow in 2009
Mure Street	Wastewater overflow in 2008 and 2010
Oak Place	Wastewater boundary trap overflow in 2008
Riccarton Road	Wastewater boundary trap overflow in 2008
Ross Street	Wastewater overflows in 2010
Silverstream Drive	Wastewater overflows in 2010 – reported as an overflowing pump station
Shaw Street	Wastewater overflows in 2008 and 2009
Stirling Crescent	Wastewater boundary trap overflow in 2008



C2: Mosgiel Stormwater Customer Complaints 2005 - 2010

Table C2-1: Mosgiel Stormwater Complaints (2005 - 2010)

Street Name	Description
Gordon Road	34 flood complaints in 2005. Widespread flooding along road. Single complaint in 2008.
Shaw Street	2 flood complaints in 2005 and 2007. 2005 recorded as "severe flooding". Operator comment that catchpits fail to deal with the flows.
Tyne Street / Carlyle Road	Flood complaint in 2006, 2008 and 2009. This relates to the recent subdivision and the stormwater PS and its point of discharge which floods.
Gladstone Road	Flooding complaints in 2005, 2007 and 2008. 2005 complaint relates to watercourse and blocked drains. The 2008 complaint also relates to a blockage.
Woodland Avenue	2 flood complaints in 2007. Appears to be blocked culvert intake which resulted in properties flooding.
Clyde Street	2005. Water running from the road caused a hole in the footpath to develop. Water then ran onto a wall and ponded on the foot path, contributing to the wall collapsing.
Forfar Street / Glasgow Street	2005. Whole street under water due to blocked catchpit. Water flowed into Glasgow Street and into a property.
Cemetery Road	2005. Quarry Creek a tributary to the Owhiro rose and flooded residential property and East Taieri Preschool.
Kinmont Crescent	2007, flooding onto property up to 0.5 m deep. 2008, stormwater blockage.
McGlashan Street	2007. Business flooded.
Gow Street	2007. Business flooded.
Centre Street	2008 and 2009. Stormwater complaints.
Glenbrook Drive	2008 and 2009. Stormwater lamp hole overflowed.
Factory Road	2008 and 2009. Stormwater complaint.
Argyle Street	2009. Stormwater overflowed and entered property.
Stirling Crescent	2009. Stormwater complaint.
Hall Street	2009. Stormwater complaint.
Braeside	2008. Stormwater complaint.



Appendix D

D1 Mosgiel Stream Assessment Report

Dunedin Three Waters Strategy

Mosgiel Stream Assessments



prepared by

Ryder Consulting

February 2012

Dunedin Three Waters Strategy

Mosgiel Stream Assessments

prepared by

Ben Ludgate, MSc.

Ryder Consulting

February 2012

Cover: Silver Stream upstream of Gordon Road, April 2011.

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Table of Contents

1. Introduction.....	4
1.1 Background.....	4
1.2 Purpose of report.....	4
2. The stream ecosystem - overview.....	5
2.1 General.....	5
2.2 Effects of urbanisation and stormwater	6
2.3 Effects of wastewater.....	11
3. Assessment Techniques	12
3.1 Literature and data review	12
3.2 Habitat surveys	12
3.2.1 General.....	12
3.2.2 Habitat characteristics.....	13
3.2.3 Water quality.....	14
3.2.4 Aquatic plants	14
3.2.5 Benthic macroinvertebrates	14
3.2.6 Fish.....	15
3.2.7 River flows and sampling conditions.....	15
4. Silver Stream catchment	18
4.1 Catchment information	18
4.2 Natural values (ORC Regional Plan: Water).....	20
4.3 Cultural values	21
4.4 Wetlands (ORC Regional Plan: Water)	23
4.5 Amenity values	23
4.6 Habitat characteristics.....	24
4.7 Water quality.....	29
4.8 Aquatic plants	37
4.9 Benthic macroinvertebrates	39
4.10 Fish.....	44
4.11 Summary of aquatic ecosystems.....	52
4.12 Issues associated with stormwater and wastewater	53
4.12.1 Stormwater.....	53
4.12.2 Wastewater.....	54
5. Owhiro Stream catchment	55
5.1 Catchment layout	55
5.2 Natural values (ORC Regional Plan: Water).....	56
5.3 Cultural values	56
5.4 Wetlands (ORC Regional Plan: Water)	58
5.5 Amenity values	58
5.6 Habitat characteristics.....	60
5.7 Water quality.....	68
5.8 Aquatic plants	76
5.9 Benthic macroinvertebrates	77
5.10 Fish.....	82
5.11 Summary of aquatic ecosystems.....	88
5.12 Issues associated with stormwater and wastewater	89
5.12.1 Stormwater.....	89
5.12.2 Wastewater.....	90
6. Overall summary and catchment comparison.....	92
7. References.....	94
Appendix One: Invertebrate data summaries and metric calculations	99
Appendix Two: Riparian vegetation data.....	102
Appendix Three: Habitat assessment data.....	110

1. Introduction

1.1 Background

The Dunedin City Council (DCC) has developed the 3 Waters Strategy to provide direction for effective and sustainable management of Dunedin's current and future water requirements.

The Mosgiel Integrated Catchment Management Plan (ICMP) is one of a number of ICMPs to be developed as part of DCC's 3 Waters Strategy. The Mosgiel ICMP is a combined stormwater and wastewater ICMP and is the eleventh to be developed for Dunedin. The ICMP's production is not driven by discharge consent requirements but instead by a need to understand future network development requirements and to identify system deficiencies and test potential solutions in line with the DCC 3 Waters Strategic Objectives relating to stormwater and wastewater management.

As a part of the ICMP development, the existing quality of the freshwater receiving environments, and potential effects of discharge quantity and quality in the Mosgiel catchment will be assessed.

Opus engaged Ryder Consulting to carry out assessments of the freshwater receiving environments of the Silver Stream, Owhiro Stream and Quarry Creek within the Mosgiel catchment.

1.2 Purpose of report

This report provides an assessment of ecosystems in the Silver Stream and Owhiro Stream catchments. Historic information is reviewed and habitat surveys were undertaken in April/May 2011 including assessments of physical habitat, water quality, benthic ecological components, and fish communities. Potential effects of stormwater and/or wastewater discharges on aquatic communities are also identified.

2. The stream ecosystem - overview

2.1 General

The principal living components of stream ecosystems can be divided roughly into three main groups: plants and algae (primary producers), macroinvertebrates and fish.

Light energy is utilised by benthic or epilithic algae (algae that live on the bed of a river, attached to the surfaces of stones, debris, and submerged plants) and submerged plants (macrophytes), in combination with nutrients and dissolved organic carbon supplied in surface runoff, groundwater, and sediments from the surrounding catchment. These 'primary producers', together with other aquatic microorganisms (e.g., benthic fungi and bacteria, which collectively are known as 'periphyton') and organic detritus (processed terrestrial vegetation) are the food source for small animals (mainly invertebrates) that live on the bottoms of rivers. However, under favourable conditions (i.e., plenty of sun and nutrients, and stable flows) periphyton can grow prolifically to the extent that they cover the entire surface of the river bed and become a nuisance to humans, taint the water, and produce undesirable habitat conditions for other aquatic organisms, particularly benthic invertebrates and fish.

Freshwater invertebrates comprise a range of different organisms. In 'unpolluted' New Zealand rivers, benthic (bottom dwelling) invertebrate communities are dominated by insect larvae (e.g., mayflies, stoneflies, midges, etc), and, to a lesser extent, by aquatic worms, snails, and small crustaceans.

'Benthic invertebrates' are usually abundant in rivers and play an important role in ecosystem processes. In particular, they contribute to the processing of organic carbon, thereby influencing periphyton growth, nutrients, and food availability for fish and birds through their secondary production (Quinn and Hickey 1990). In most unmodified rivers, benthic invertebrates are able to 'graze' periphyton on stone surfaces so that growths are kept to a minimum. However, when periphyton growth is accelerated, for example due to nutrient enrichment from the surrounding catchment, invertebrates adapted to graze thin periphyton layers (e.g., mayflies, stoneflies and many caddisflies) are unable to cope in this changing habitat and are replaced by more resilient, 'pollution-tolerant' species (e.g., snails, worms, and chironomid larvae). This is often accompanied by a reduction in species diversity.

In New Zealand, river benthic invertebrates are the dominant food source for native and introduced fish (Sagar and Eldon 1983, Richardson 1987). Thus, they represent an important link in the food chain of aquatic ecosystems and any change in their composition can impact upon the fish community. In addition, a number of invertebrate species are important components of the diet of native birds.

Detrimental changes are not only caused by increased inputs of nutrients; excessive inputs of other contaminants can cause similar effects. For example, sediment deposition can alter the benthic habitat, change the benthic invertebrate community to one dominated by sediment-tolerant species, affect fish spawning and degrade the visual quality river from a human perspective. Excessive inputs of contaminants in the form of organic-rich effluent can exert considerable oxygen demand, lowering the dissolved oxygen level in water and thus limiting the distribution of clean water species. Nutrient enrichment and sediment inputs also promote the growth of rooted macrophytes in slower reaches of rivers.

2.2 Effects of urbanisation and stormwater

General

Urbanisation typically results in modifications to stream environments. Direct effects include channel straightening, removal of obstructions and riparian vegetation, re-contouring of banks and concrete reinforcement of the channel. These modifications are made to allow the channel to convey flows more efficiently and prevent storm flows from overtopping the banks (Suren and Elliot 2004).

Urban stormwater is designed to reach receiving water streams quickly and efficiently through networks of gutters and pipes. This efficient conveyance system typically results in greater flood peaks. These flood peaks can affect the physical habitat of streams by eroding the stream banks, damaging riparian vegetation, removing obstructions and debris that provide habitat for invertebrates and fish, scouring the stream bed, and generally modifying instream habitat. The rapid change in water levels and flows can wash away invertebrates and can cause extensive substrate movement, which can have detrimental effects on invertebrate communities (Suren and Elliot 2004, and references therein). These higher flows can also have detrimental effects on the stream itself, with substrate disturbed and transported downstream, resulting in high levels of sedimentation in lower reaches.

Impervious surfaces, such as roads and driveways, produce greater volumes of stormwater runoff than pasture or bush-clad land. Impervious surfaces typically cover about 40% of the land area in urban residential areas, with 80% or more of the land area covered in commercial or light industrial areas (Suren and Elliot 2004). Baseflows can also be reduced due to reduced groundwater recharge beneath impervious surfaces, resulting in lower and slower stream flows.

Urban streams often have reduced riparian cover, which reduces shading, eliminates overhanging vegetation, and reduces habitat quality by reducing inputs of branches, logs and leaf litter to the stream. Peak water temperatures typically increase due to lack of shading.

Pollutants

Water quality generally decreases as a result of urbanisation due to increased runoff that transports pollutants. Major types of pollutants in urban stormwater are suspended sediments, toxicants, nutrients, bacteria and general rubbish (Williamson 1993, cited in Suren and Elliot 2004).

Stormwater transports pollutants that have accumulated on impervious surfaces, such as from transport infrastructure (roads, carparks, and railways), erosion and runoff from developing subdivisions, industrial spillages, roof run off, discarded rubbish, accidental or deliberate discharges into stormwater systems, and animal faeces in streets or parks (Suren and Elliot 2004). Stormwater can also contain varying amounts of other toxicants, such as pesticides (herbicides, insecticides, fungicides) and various types of hydrocarbons (e.g., polycyclic aromatic hydrocarbons (PAH)). Hydrocarbon contamination is most likely from direct runoff from service stations, parking lots and garages, of petrol and oil that drip from sumps, fuel lines and the like (Suren and Elliot 2004). Hydrocarbons are also sourced from roading, through asphalt wear and from vehicles using the road, through exhaust emissions, brake linings and tyre wear.

Nutrients

Rural environments, agricultural fertilisers, stock manure and urine are the major non-point-sources of the nutrients nitrogen and phosphorus. Wastewater overflows and earthworks are also major sources of these nutrients. These nutrients can enter water bodies relatively quickly if they are carried across the land surface by rainfall run-off,

particularly if there are drains such as the mole and tile drains (below-ground channels constructed to drain surplus water) that are common on farmed pasture in Otago. In recent years, the impact of agricultural land use on water quality has grown as a result of increased stocking rates and use of nitrogen fertilisers. Within the agricultural sector, there has also been a move away from low-intensity to high-intensity land use (for example, converting from sheep farming to dairy or deer farming). The net effect of most intensified land use is to increase the amount of nutrients, sediment and animal effluent dispersed into water bodies.

High nutrient levels can contribute to increased growth of algae and macrophytes. When these aquatic plants die, high numbers of bacteria are required for decomposition of the organic matter. These bacteria use dissolved oxygen, which depletes the oxygen levels in the water and can have adverse effects on fish communities. In addition, high levels of ammonia can have toxic effects on aquatic communities, affecting hatching and growth rates of fish, and result in changes to the development of gill, liver, and kidney tissues.

Suspended sediments

Suspended sediments can affect fish feeding and behaviour; reduce instream algal productivity by increasing light scatter within the water column; settle on the stream bed, smothering gravel and cobble substrates and filling interstitial spaces between particles, thus reducing the amount of habitat available to fish and invertebrates; and can settle in lower reaches, raising the bed and reducing the flood capacity of the stream (Suren and Elliot 2004).

These particles settle out of suspension onto the bed, with larger, heavier particles settling more quickly than smaller, lighter ones. Sedimentation occurs more rapidly in slower flowing reaches. Excessive sediment loads can affect physical stream characteristics, plants and algae, and invertebrates and fish, as well as human aesthetic, recreational, and spiritual attributes.

Coarser graded particles fill in the interstices between stones and cobbles, while finer graded particles smother or 'blanket' the bed. Increased water turbidity, caused by suspended sediments, can affect benthic algae and macrophyte growth by reducing light penetration through the water column. Fine sediments can also smother algae and plants

when they settle out, and can become ‘trapped’ by periphyton covering stone surfaces. The effect of this ‘entrapment’ is to lower the food quality of this periphyton.

Elevated sediment levels in rivers directly affect fish, including avoidance of turbid water by some fish, lower growth rates, impairment to visual feeding fish, and clogging of gills resulting in death (Alabaster and Lloyd 1982, Newcombe and McDonald 1991, Ryan 1991). Indirect effects include reduction in the invertebrate food source, avoidance of silted gravels for spawning by adult fish, and egg mortality due to reduced oxygen conditions in gravel caused by silt deposition.

Siltation affects aquatic invertebrates by five primary mechanisms: reduction of light penetration, abrasion, adsorbed toxicants, changes in substrate character, and reduction in food quality. Reduction of light penetration reduces periphyton production, which may result in limiting food supply for the invertebrates. Abrasion can act directly on benthic invertebrates by physical contact and indirectly by abrading periphyton (Cordone and Kelley 1961). Toxicants such as pesticides and heavy metals can be adsorbed to fine sediment particles, which may then become incorporated into invertebrate food sources such as periphyton. Siltation changes the physical characteristics of the substrate, which may then influence the benthic community. The infilling of the interstices may decrease the retention of organic material (Anderson and Cummins 1979, Ryder 1989), reduce the surface area of stones available for algae grazing by invertebrates (Ryder 1989), restrict the flow of water to the deeper substrates (Carling and McCahon 1987), and create instability (Nuttall 1972). These may in turn affect invertebrate distribution. Studies have shown that periphyton can accumulate silt even at low concentrations. Growth of invertebrates feeding on silted periphyton has been found to be significantly lower than for invertebrates that grazed on unsilted periphyton.

Heavy metals

Heavy metals in stormwater are derived from road runoff (from brake linings, tyre wear, and road markings), lead-based paints and petrol products, copper spouting and deteriorating zinc-coated, or galvanised, roofs and fences (Suren and Elliot 2004). Zinc is one of the more problematic heavy metals in streams.

Heavy metals can contribute to decreased diversity of invertebrate communities, with reduced abundance of more ‘sensitive’ taxa, such as mayflies, and increased abundance of

more ‘tolerant’ taxa, such as worms. Heavy metal contamination can also affect fish growth.

Dissolved metals can also accumulate in bed sediments and biofilms on the bed substrate, with subsequent detrimental effects on aquatic species. By retaining and releasing metal pollutants, biofilms play a key role in both the concentration of dissolved metals in the water column and the transfer of metal to invertebrates and fish grazing on them (Ancion *et al.* 2010). For example, Suren (unpublished data, in Suren and Elliott 2004) demonstrated that *Deleatidium* mayfly survival was low when exposed to metal-contaminated biofilms and sediments. Mayfly survival was also low with additional exposure to high sedimentation levels (Suren and Elliot 2004). In addition, biofilms have been found to release metals relatively slowly, which suggests biofilms may have a great influence on the transfer of metals to organisms feeding on them by quickly accumulating metals during storm events and retaining them for several days after the event (Ancion *et al.* 2010).

Macroinvertebrates

Urban streams typically have macroinvertebrate communities with very few ‘sensitive’ taxa such as mayflies and stoneflies, and are dominated by oligochaete worms, *Potamopyrgus antipodarum* snails, orthoclad and chironomid midges, ostracods and the blackfly *Austrosimulium* (Suren and Elliot 2004). High flows in urban streams can wash away invertebrates, especially in concrete-lined sections, and can also cause extensive substrate movement which has detrimental effects on invertebrate communities (Suren and Elliot 2004, and references therein). Low flows also affect invertebrate communities, as they can be associated with elevated water temperature, low dissolved oxygen levels and sediment deposition (Suren and Elliot 2004).

Fish

Piping and culvert construction can strongly influence fish communities by reducing available habitat and restricting fish passage, although pipes do not necessarily have negative impacts on fish fauna. For example, banded kokopu were found in Auckland streams well upstream of pipes and culverts (Suren and Elliot 2004, and references therein). Studies have shown that even artificial banks can provide good fish habitat if cover, such as undercut banks, is available (Suren and Elliot 2004, and references therein).

2.3 Effects of wastewater

Wastewater is liquid waste (and liquids containing waste solids) from domestic, commercial and industrial premises, including, but not limited to, toilet wastes, grey water (household wastewater from kitchens, bathrooms and laundries), trade wastes and gross solids. Human wastewater and sewage leaking from broken sewer pipes or being discharged into stormwater systems through faulty connections contributes high amounts of bacteria and nutrients (nitrogen and phosphorus) to urban streams. Untreated wastewater typically contains high levels of contaminants including disease-causing organisms that may indicate the presence of faecal material.

Untreated wastewater has potential to exert considerable adverse effects on stream ecosystems by degrading water quality, particularly through increasing oxygen demand, altering pH, increasing nutrient and sediment concentrations, and introducing potentially toxic substances. In addition to these potential characteristics that affect stream biota, faecal bacteria in wastewater degrades recreational opportunity and introduces a health risk to recreational users who come into contact with receiving water.

3. Assessment Techniques

3.1 Literature and data review

A literature and data review was undertaken, utilising information from a variety of sources including DCC and Otago Regional Council (ORC) reports and data, the New Zealand Freshwater Fish Database, unpublished research reports from the University of Otago, and published scientific journal papers. The Department of Conservation Otago Conservancy and Fish and Game Otago were also consulted for additional data.

3.2 Habitat surveys

3.2.1 General

Habitat surveys of the Silver Stream and Owhiro Stream catchments were undertaken in April/May 2011, to provide an up-to-date picture of current habitat values. Information from these sites was to complement that gathered during the literature and data review. Sites were selected to be representative of the aquatic ecosystems present in the Silver Stream and Owhiro Stream catchments. Sites were identified from topographical maps, followed by a site inspection to determine if safe access was possible and if sufficient water (i.e., water depth and flow, channel connectivity) was present for a robust assessment. Consultation with DCC and ORC staff was undertaken once suitable sites had been selected. Site locations are detailed in Table 1 and in Figure 1.

Table 1 *Location of April/May 2011 sampling sites within the Silver Stream and Owhiro Stream catchments.*

Site	Grid co-ordinates (NZTM)
Silver Stream at Puddle Alley	E1397002 N4918632
Silver Stream at Gordon Road	E1393873 N4917182
Silver Stream at Riccarton Road	E1392152 N4916576
Owhiro Stream at Soper Road	E1396492 N4916549
Owhiro Stream at Burns Street	E1394367 N4915138
Owhiro Stream tributary	E1394065 N4914858
Owhiro Stream at Riccarton Road	E1392979 N4914657

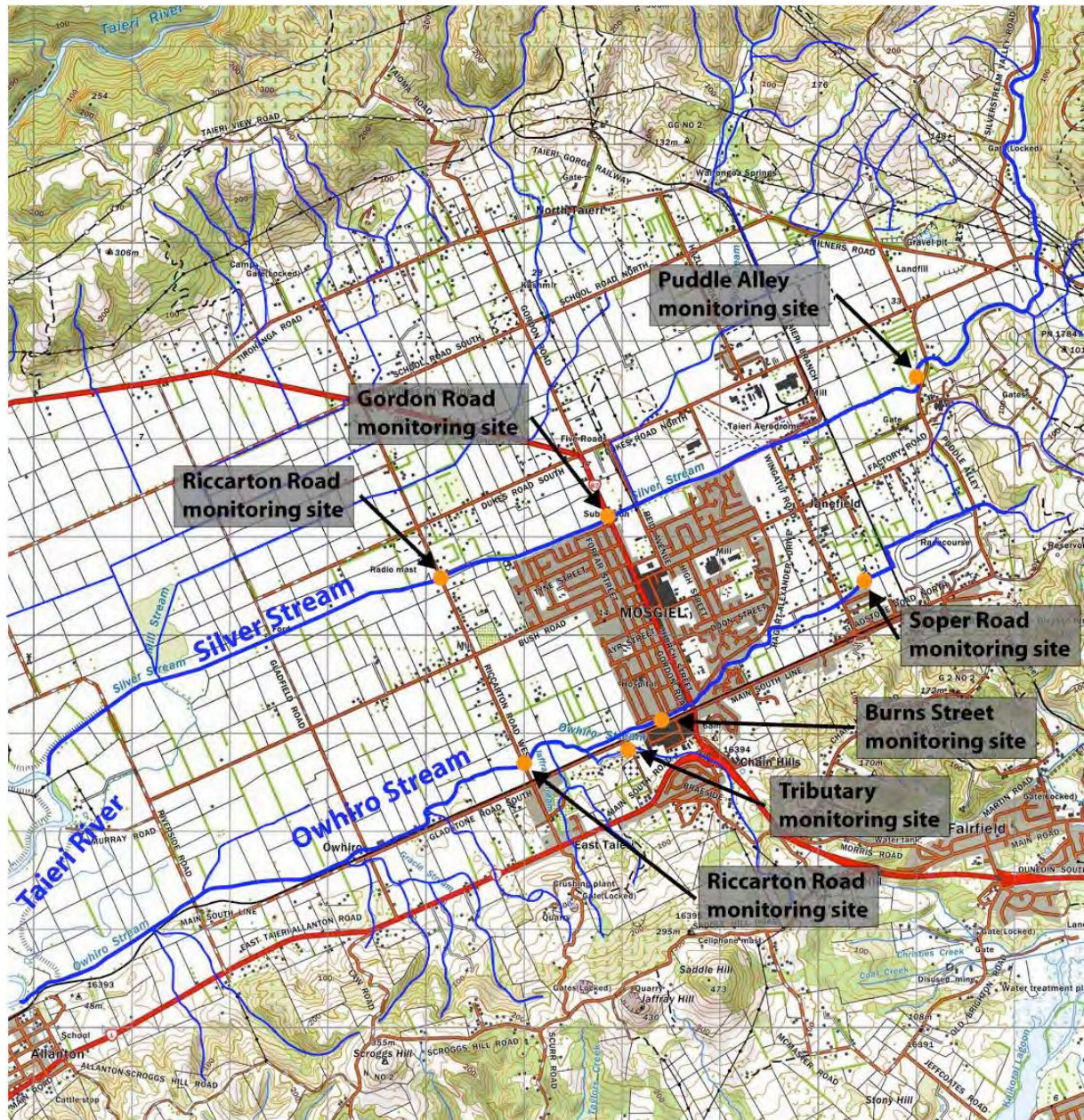


Figure 1 Map showing the lower Silver Stream catchment, Owhiro Stream catchment and April/May 2011 monitoring sites.

3.2.2 Habitat characteristics

Stream habitat assessments included observations of catchment and surrounding land use, riparian vegetation (with Marcia Dale), channel width and shape, channel modifications, bank stability, evidence of flooding, scour and erosion, instream habitat and flow type, bed substrate and stability and water depth. Any amenity values were also identified.

3.2.3 Water quality

Water quality measurements of pH, water temperature (°C), dissolved oxygen (% and mg/L), and conductivity (µS/cm) levels were taken at each site using a handheld YSI Professional Plus multi-probe field meter.

3.2.4 Aquatic plants

Periphyton (benthic algae) cover and composition was determined at each sampling site. The percentage of the stream bed covered by key algal groups (e.g., diatoms, filamentous green algae, cyanobacteria) was estimated and a representative sample collected. Samples were inspected microscopically in the laboratory under 200-400x magnification to determine the algal species present using the keys of Biggs and Kilroy (2000), Entwisle *et al.* (1988) and Moore (2000). Relative abundance of each taxa was scored using the scheme of Biggs and Kilroy (2000), which scores taxa from 1 (rare) to 8 (absolutely dominant/monoculture).

An assessment of macrophytes, including submerged, floating and emergent plant types, was also undertaken at each site.

3.2.5 Benthic macroinvertebrates

Benthic macroinvertebrates were sampled using a kicknet with a 500µm diameter mesh. Samples were collected by disturbing the substrate in a representative area immediately upstream of the net, and/or by sweeping the net through aquatic vegetation. Two replicate samples were collected from each sampling site. Samples were preserved with ethanol and returned to the laboratory.

In the laboratory the samples were passed through a 500µm sieve to remove fine material and residual ethanol. The contents of the sieve were then placed in a white tray and macroinvertebrates identified under a dissecting microscope (10-40X) using criteria from Winterbourn *et al.* (2000).

Appendix One contains a summary of data and metric calculations.

3.2.6 Fish

Electric fishing

Fish communities at each site were sampled qualitatively using a Kainga EFM 300 electric fishing machine. The machine operator moved through the site fishing to a second person with a downstream net. Multiple passes were undertaken to ensure all fish were detected in the sample area. Sampling sites were selected to be representative of the different fish habitats present. Stunned fish were captured and placed in a bucket to prevent further shock, and were later identified and measured before being returned to the area where they were captured.

Spotlighting

Spotlighting was used in areas unable to be electric fished efficiently (e.g., deep pools). The technique of spotlighting has been recognised as an effective method for detecting some of New Zealand's nocturnal native fish (e.g., David *et al.* 2002) and introduced brown trout (Hickey and Closs 2006). Spotlighting can be very efficient when observations can be made from the bank and where water surface disturbance is minimal. Spotlighting was undertaken using a single spotlight (35 W spotlight with 12 V battery). The operator moved through the area once identifying all fish seen and visually estimating length. When possible, fish were caught using a hand net and measured before being returned to the area in which they were captured.

3.2.7 River flows and sampling conditions

Rainfall in the Silver Stream and Owhiro Stream catchments during summer and autumn 2011 was high, and included several high rainfall events interspersed with lower rainfall events (Figure 2).

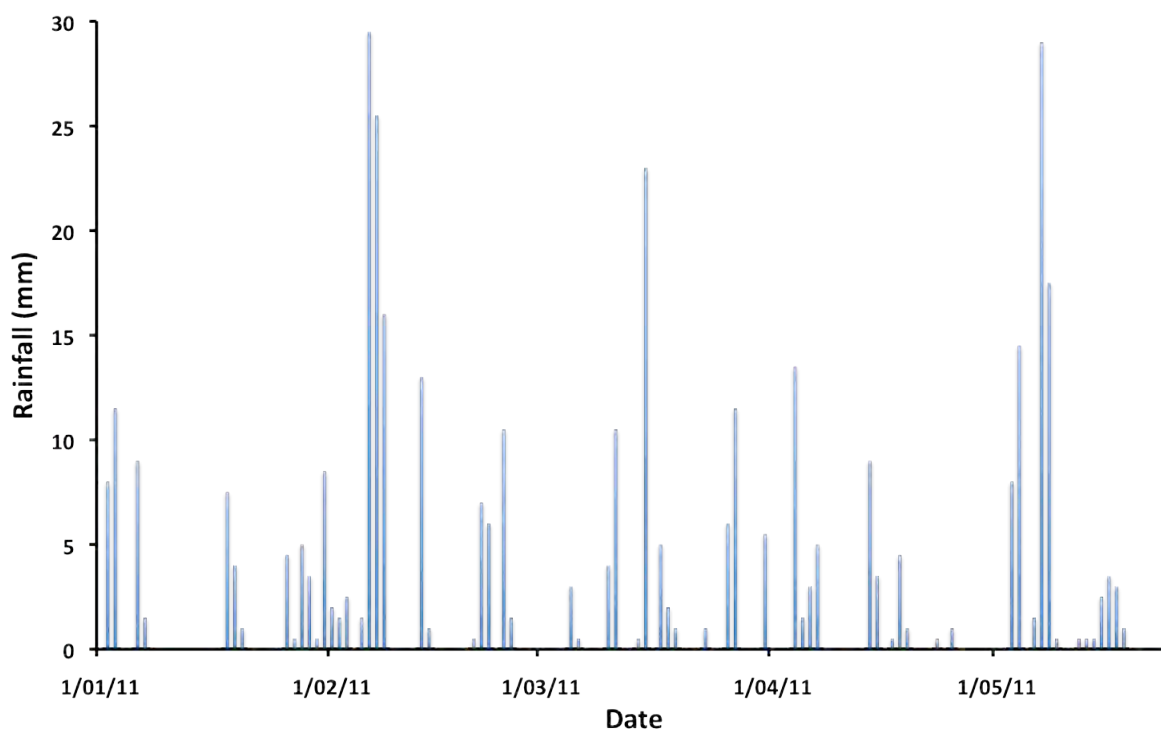


Figure 2 *Daily rainfall (mm) at Riccarton Road between January 2011 and May 2011. Data from ORC.*

River flows throughout much of Otago were at higher than normal levels for long periods in summer and autumn 2011. River flows in the Silver Stream were generally low, except for two high flow events: in early February and early May (Figure 3). Mean daily flows peaked at 10.8 m³/second in early February and 17.9 m³/second in early May (instantaneous flow records peaked at approximately 26 m³/second in early February and approximately 42 m³/second in early May).

Aquatic community assessments were undertaken in April and May 2011. Habitat descriptions, water quality measurements, macroinvertebrate sampling, and electric fishing were undertaken in both catchments on the 13-14th of April. Spotlighting for fish in the Silver Stream catchment was undertaken on the evening of the 3rd of May, while spotlighting in the Owhiro Stream catchment was delayed by a high flow event until the 18th of May. Sampling was undertaken under base flow conditions, except spotlighting in the Owhiro Stream catchment which was undertaken when flows were slightly higher.

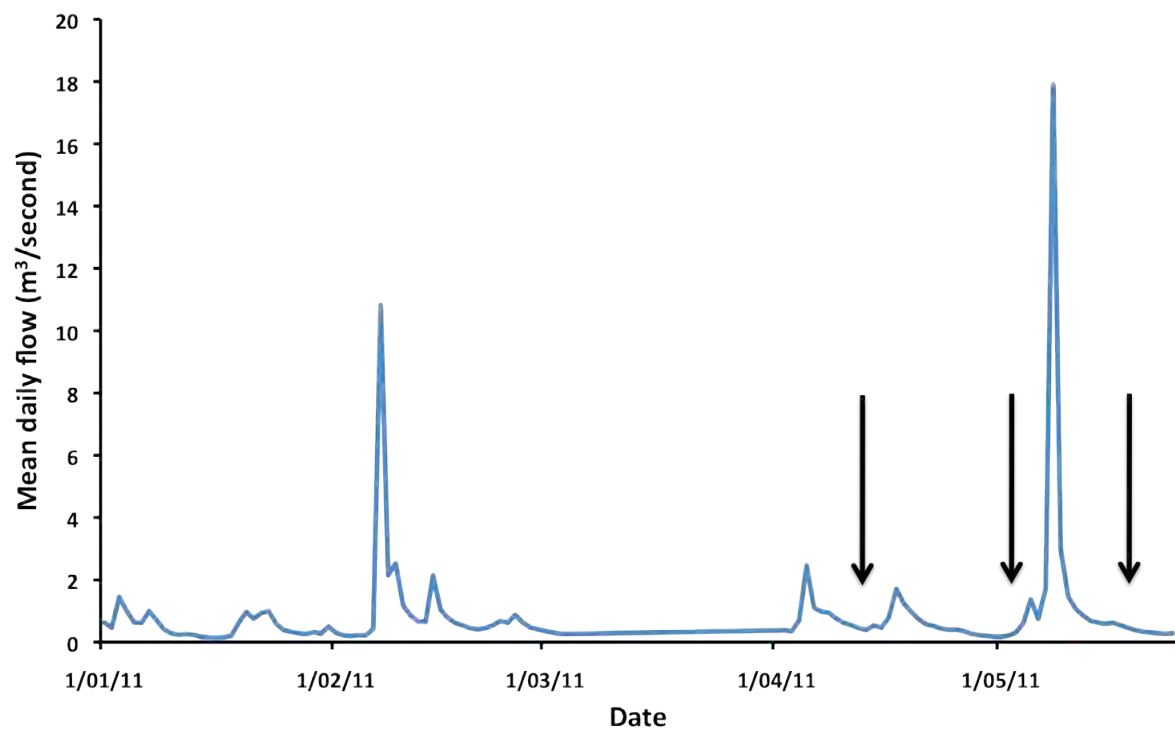


Figure 3 Mean daily flow (m³/second) in the Silver Stream at Riccarton Road between January 2011 and May 2011. Data from ORC. Arrows indicate sampling dates.

4. Silver Stream catchment

4.1 Catchment information

The Silver Stream is a major tributary of the Taieri River. It has its headwater in the Silver Peaks and hill catchments that border Dunedin City to the west (Figure 4). Several hill tributaries converge at or above Whare Flat before the stream spills out onto the East Taieri Plain. From thereon, the Silver Stream channel has been largely straightened as it flows across the plains, past Mosgiel, before converging with the Taieri River just upstream of Allanton.

Land cover is distinctly divided between the well vegetated hill catchment upstream of Whare Flat and the mainly grassed fertile land of the East Taieri Plain.

A large part of the hill catchment is protected from development and is used as a water supply reserve. Dunedin City Council water supply abstractions sites are found throughout the upper catchment, including structure on the Silver Stream, McQuilkans Creek, Sligos Creek and McKenzies Creek (Whare Creek).

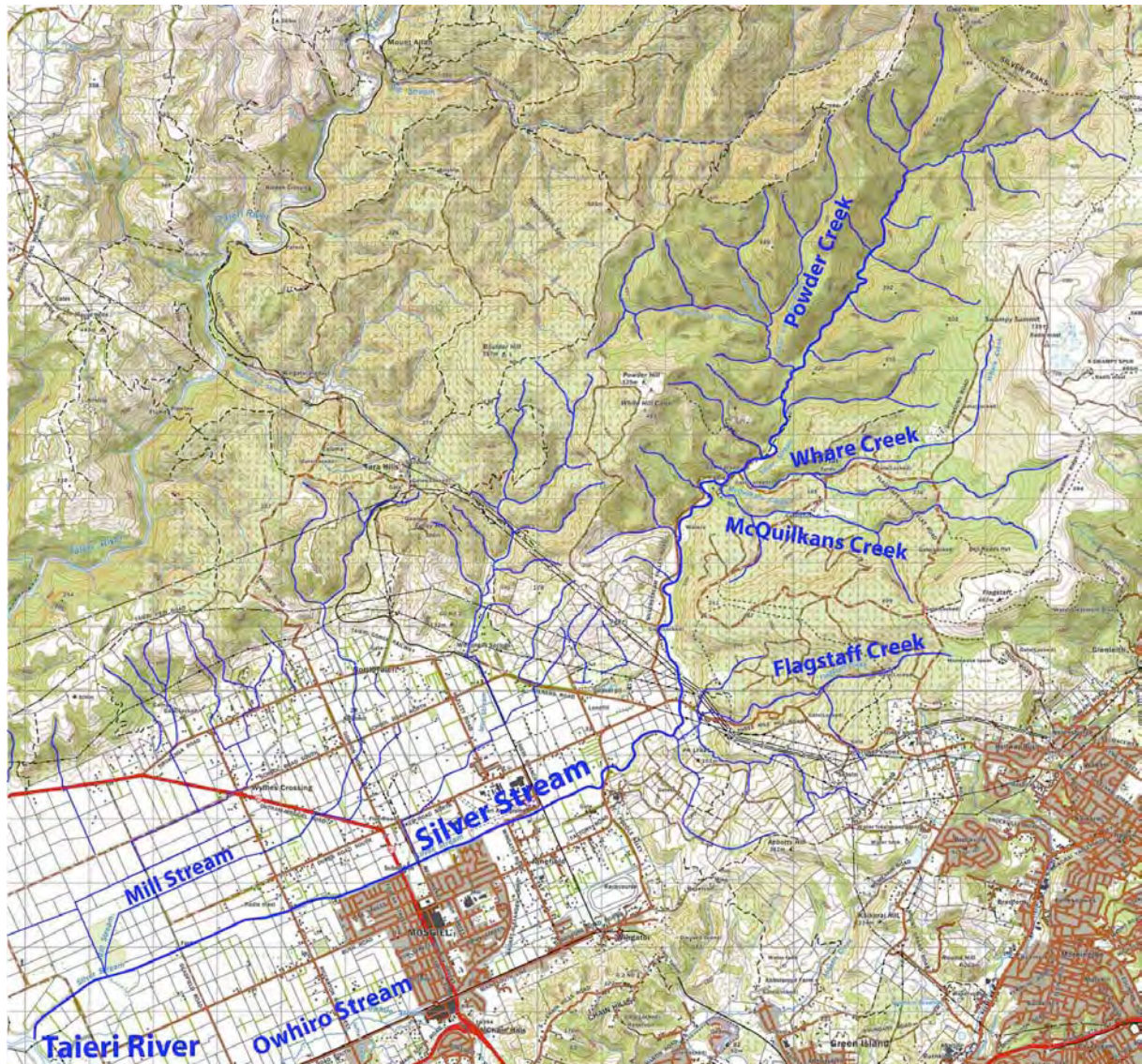


Figure 4 Map showing the Silver Stream catchment and significant tributary streams.

The ORC regularly undertakes monitoring in the Silver Stream at Riccarton Road and at Three Mile Hill Road, as part of the SOE programme (Figure 5). Ryder Consulting assessed three sites in the lower Silver Stream in April/May 2011 (Figure 5). Monitoring sites are all downstream of upper catchment areas with significant ecological values.

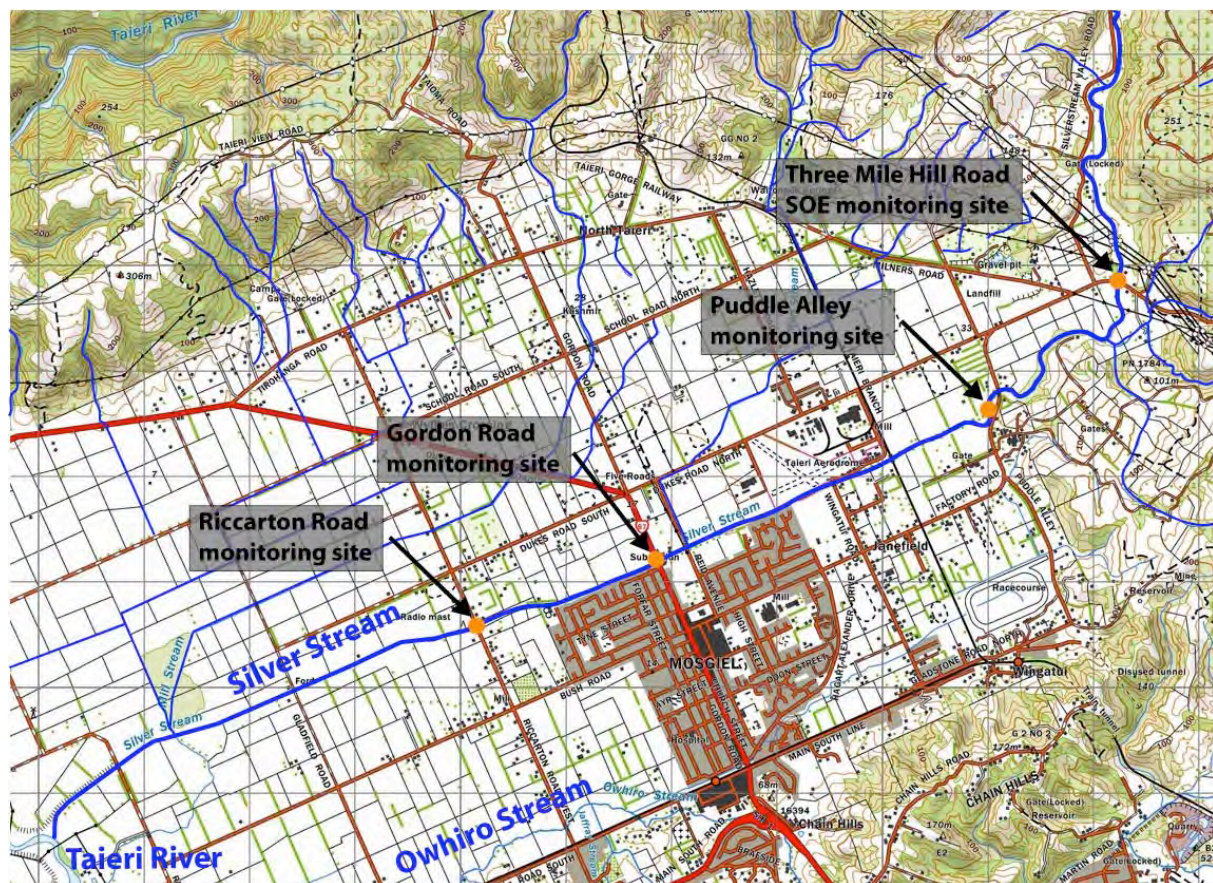


Figure 5 Map showing the lower Silver Stream catchment and monitoring sites. The Riccarton Road site is used for ORC SOE sampling, and was also used by Ryder Consulting in April/May 2011.

4.2 Natural values (ORC Regional Plan: Water)

According to the ORC Regional Plan: Water for Otago (2004) the Silver Stream catchment contains several significant natural values (Table 2). Most of these values are in the middle to upper catchment, including riparian vegetation, the presence of indigenous invertebrates and fish species threatened with extinction, and a high degree of naturalness above 900 metres above sea level (note this is likely meant to read '90' or '100 metres') and within a Scenic Reserve and a water reserve. The catchment is also free of aquatic pest plants, has a gravel bed and contains habitat for trout spawning and development, for koaro and for lamprey (Table 2).

In addition, Whare Creek, a tributary of the upper reaches of the Silver Stream, contains several significant values (Table 2). These include presence of indigenous fish species

and habitat for the ‘Lower Taieri galaxiid’. This galaxiid is the Eldon’s galaxias (*Galaxias eldoni*), recorded in the upper reaches of Whare Creek.

Table 2 Natural values for the Silver Stream catchment. Schedule 1A, ORC Regional Plan: Water for Otago (2004).

Water body	Ecosystem values	Significant indigenous vegetation and significant habitat of indigenous fauna	Areas with a high degree of naturalness
Silver Stream	Gravel bed composition No aquatic pest plants Significant presence of: - Eels - Trout Significant areas for/of: - Riparian vegetation in upper catchment - Trout spawning - Juvenile trout Presence of significant range of indigenous invertebrates in middle reaches Presence of indigenous invertebrates threatened with extinction, upstream of I44:144849 Presence of indigenous fish species threatened with extinction	Significant habitat for: - koaro upstream of I44: 114899 and including several tributaries - lamprey (uncommon in Otago)	A high degree of naturalness above 900 metres asl and within Scenic Reserve and water reserve
Whare Creek	No aquatic pest plants Significant presence of: - eels Presence of: - indigenous fish species threatened with extinction	Significant habitat for: Lower Taieri galaxiid	

4.3 Cultural values

The ORC Regional Plan: Water for Otago (2004) identified a variety of mana and access/customary use interests for the Silver Stream (Table 3). Mana interests involve the notions of guardianship, life force, sacred places and treasured interests, which together define the relationship that Kai Tahu have with the Silver Stream. Access and customary use interests include the provision of food resources, the presence of significant spawning and nursery areas for native birds and/or fish, and the location of traditional routes (Table 3).

Table 3 Kai Tahu values for the Silver Stream. Schedule 1D, ORC Regional Plan: Water for Otago (2004).

	Beliefs, values and uses	Explanation
Silver Stream		
Mana interests	MA1: Kaitiakitanga MA2: Mauri MA3: Waahi tapu and/or Waiwhakaheke MA4: Waahi taoka	The exercise of guardianship by Kai Tahu in accordance with tikanga Maori in relation to Otago's natural and physical resources; and includes the ethic of stewardship Life force; for example the mauri of a river is most recognisable when there is abundance of water flow and the associated ecosystems are healthy and plentiful; a most important element in the relationship that Kai Tahu have with the water bodies of Otago Sacred places; sites, areas and values associated with water bodies that hold spiritual values of importance to Kai Tahu. (Note: Kai Tahu should be consulted regarding the location of these places, sites areas and values for a river identified as MA3) Treasured resource; values, sites and resources that are valued and reinforce the special relationship Kai Tahu have with Otago's water resources
Access/customary use interests	MB1: Mahika kai MB2: Kohanga MB3: Trails	Places where food is procured or produced Important nursery/spawning areas for native fisheries and/or breeding grounds for birds Sites and water bodies which formed part of traditional routes

A Cultural Health Index (CHI) for streams has been developed by linking Western scientific methods and cultural knowledge about stream health (Tipa and Teirney 2003). The lower Silver Stream CHI score was ranked A-0 / 3.13 / 2.00 (Tipa and Teirney 2003), which indicates:

- It is a traditional site (A; versus B for non-traditional).
- Rūnanga members would not return to the site (0; versus 1 for will be used).

- Mahinga kai values are moderate (3.13; four factors are scored on a 1-5 scale and then averaged).
- It scores poorly for stream health (2.00; five factors are scored on a 1-5 scale and then averaged).

4.4 Wetlands (ORC Regional Plan: Water)

Schedule 9 of the ORC Regional Plan: Water for Otago (2004) does not include any wetlands of regional significance in the Silver Stream catchment.

4.5 Amenity values

The Silver Stream is open for fishing, using all legal methods, between the 1st of October and the 30th of April, with a bag limit of 3 fish per person. However, the stream is not popular with anglers. While the Taieri River catchment and the Taieri River itself are popular with anglers, few anglers use the Silver Stream (Table 4). Angler access is available throughout the lower catchment, including at Puddle Alley, Gordon Road and Riccarton Road.

Table 4 *Angler use of the Silver Stream and Taieri River catchment (Unwin 2009).*

	2001/02 angling days per year ($\pm$ 1 standard error)	2007/08 angling days per year ($\pm$ 1 standard error)
Silver Stream	20 $\pm$ 20	240 $\pm$ 220
Taieri River (Outram Bridge to Taieri Mouth)	13230 $\pm$ 2470	7610 $\pm$ 2360
Taieri River catchment	32860 $\pm$ 3090	24450 $\pm$ 3220

The upper catchment has an extensive network of walking tracks. The lower catchment has a public access track along the Silver Stream Bank Reserve, comprising a basic track/route along the east (true left) flood bank of the Silver Stream between Mosgiel and the confluence of the Silver Stream and Taieri River. The upper 600m section of the track, upstream of Wingatui Road, is on the west (true right) bank of the stream. This track is used for bike riding, walking, running and dog exercising. School and community groups use the track to study the Silver Stream environment (e.g., botany, geology, and freshwater ecology). A DCC bylaw prohibits horse riding along the banks of the Silver Stream, however access to the Silver Stream is available for horse riders at the ford on Gladfield Road. Several Mosgiel residents can access the stream bank reserve from their

properties. Public access is also available from Wingatui Road, Gordon Road, Riccarton Road, Gladfield Road and Riverside Road.

Several roads cross the Silver Stream in the lower catchment. The stream is visible from road bridges on Puddle Alley, Wingatui Road, Gordon Road, Riccarton Road, and Riverside Road. The Gladfield Road crossing consists of a vehicle ford with a pedestrian footbridge.

Additional amenity values specific to the April/May 2011 monitoring sites are described below.

Silver Stream at Puddle Alley

The stream is visible from Puddle Alley, and is accessible from a public carpark and picnic area. The area may be popular with 4WD enthusiasts; vehicle tracks are visible on the stream bed.

Silver Stream at Gordon Road

The stream is accessible from public amenities, including the Mosgiel public swimming pool, Mosgiel Caravan Park, Peter Johnstone Park and a carpark at the end of Reid Road.

Silver Stream at Riccarton Road

No additional amenity values have been identified.

4.6 Habitat characteristics

Riparian vegetation and habitat assessments were undertaken in April 2011. Riparian vegetation species lists are in Appendix Two, with habitat assessment data in Appendix Three.

Silver Stream at Puddle Alley

A natural stream channel meanders under the Puddle Alley road bridge into an open area with an exposed gravel bar along the true left edge and a steep bank along the true right (Figure 6). Surrounding land use is pastoral.

Crack willow trees dominate riparian vegetation along the steeper true right bank, with groundcover of ivy and blackberry. Crack willow, ivy and blackberry are all pest species.

Willow trees overhang the stream providing some shading to the channel. Exotic grasses (e.g., cocksfoot and tall fescue) and several weed species dominate vegetation in an open grassy area and carpark on the true left bank.

The stream is contained within a 25 m wide channel, with 0.5 to 2 m high stream banks. A steep bank, more than 10 m high, is along the true right bank. The banks are moderately stable, with reinforced areas along the true right bank (Figure 6). No bank undercutting was observed. The channel has a wetted width of 6 to 8 m, and is between 10 and 50 cm deep (under base flow conditions). Water clarity was high.

Shallow riffles and runs dominate instream habitat, with large pools upstream. Cobbles and gravels dominate bed substrate, with patches of fine sediments (silts and sands) in slower flowing areas and amongst willow roots. Bed substrate is moderately to highly stable, with mobile sediments only in slower flowing areas and amongst willow roots. The aquatic plants monkey musk (*Mimulus guttatus*), watercress (*Nasturtium microphyllum*) and floating sweetgrass (*Glyceria fluitans*) are along the stream edge. Woody debris (branches and small logs) is common, and moss is absent. Leaves are abundant throughout the stream, due to the high density of willow trees.



Figure 6 *Silver Stream at Puddle Alley.
Top: Assessment site, looking downstream.
Bottom: Bank reinforcing along the true right bank.*

Silver Stream at Gordon Road

The stream is contained within a modified channel with high flood banks (Figure 7). Surrounding land use is pastoral and industrial on the true right with the Mosgiel urban area on the true left.

Exotic grasses (e.g., cocksfoot and tall fescue) dominate riparian vegetation along both banks, with some small shrubs and flaxes. Riparian vegetation does not shade the stream, with limited shading from the Gordon Road bridge.

The stream is contained within a 20 m wide, u-shaped, straightened channel, with 1.5 to 2 m high lower stream banks, and 4 to 5 m high flood banks. The banks are stable, with vegetation covering both banks. No bank undercutting was observed. The channel has a wetted width of 4 to 9 m, and is between 10 and 30 cm deep (under base flow conditions). Water clarity was high.

Runs dominate the instream habitat, with occasional shallow riffles. Gravels dominate bed substrate, with patches of cobbles and fine sediments (silts and sands) in slower flowing areas and amongst aquatic vegetation. Bed substrate is moderately stable. The aquatic plants monkey musk (*Mimulus guttatus*), watercress (*Nasturtium microphyllum*) and floating sweetgrass (*Glyceria fluitans*) are along the stream edge. Woody debris (branches and small logs), moss and leaves are absent.



Figure 7 Silver Stream at Gordon Road, looking upstream.

Silver Stream at Riccarton Road

The stream has similar characteristics to the Gordon Road site, with a modified channel and high flood banks along both banks (Figure 8). Land use is pastoral on both sides of the stream, with the Mosgiel urban area upstream on the true left.

Exotic grasses (e.g., browntop and tall fescue) dominate riparian vegetation along both banks. Riparian vegetation does not shade the stream, with limited shading from the Riccarton Road bridge.

The stream is contained within a 10 to 15 m wide, u-shaped, straightened channel, with 1 m high lower stream banks, and 4 to 5 m high flood banks. The banks are stable, with vegetation covering both banks. No bank undercutting was observed. The channel has a wetted width of 3 to 5 m, and is between 25 and 50 cm deep (under base flow conditions). Water clarity was high.

Runs dominate the instream habitat, with occasional shallow riffles. Gravels dominate bed substrate, with patches of cobbles and fine sediments (silts and sands) in slower flowing areas and amongst aquatic vegetation. Bed substrate appears moderately to highly stable. The aquatic plants monkey musk (*Mimulus guttatus*), watercress (*Nasturtium microphyllum*) and floating sweetgrass (*Glyceria fluitans*) are along the stream edge. Woody debris (branches and small logs) is sparse, with some small logs collected around the bridge footing, while moss and leaves are absent.



Figure 8 *Silver Stream at Riccarton Road, looking upstream.*

4.7 Water quality

General

Otago Regional Council monitoring at Riccarton Road found water quality is generally within guidelines levels, with low turbidity, suspended sediment and nutrient levels (Table 5). pH is generally well within the range 6.5 to 9.0, which is typically cited as being appropriate for freshwater bodies of New Zealand (ANZECC 1992) (Table 5). Dissolved oxygen levels are generally well above 80%, which is an acceptable minimum standard for lowland river environments and protects trout, which is the fish species most sensitive to low dissolved oxygen in New Zealand waters (Third Schedule of the Resource Management Act 1991, Dean and Richardson 1999).

Table 5 Water quality parameters for the Silver Stream measured at Riccarton Road between January 2005 and June 2010. Data sourced from the ORC. Guideline levels from ANZECC and ARMCANZ (2000), Ministry for the Environment (1992) and Ministry for the Environment (2003). Guideline levels shown are the default trigger values for slightly disturbed lowland rivers.

Parameter	Minimum	Maximum	Median	Mean	n	Guideline levels
Temperature (°C)	4.6	25.3	13.6	13.0	33	<15
pH	6.9	9.5	7.8	8.1	25	7.2 – 7.8
Dissolved oxygen saturation (%)	43.5	137.5	98.7	100.3	32	98 – 105
Dissolved oxygen (g/m ³)	3.5	15.9	11.2	10.7	32	–
Conductivity (mS/cm)	0.08	0.22	0.16	0.16	31	0.125 – 0.3 ¹
Turbidity (NTU)	0.5	7.5	1.7	2.5	33	<5.6
Suspended solids (g/m ³)	1.5	24	1.5	3.7	33	–
<i>Escherichia coli</i> (mpn/100mL)	4	1920	80	241.6	34	260, 550 ²
Faecal coliforms (cfu/100mL)	4	1500	100	184.3	25	<150, <1000 ³
Ammoniacal Nitrogen (g/m ³)	0.005	0.1	0.005	0.01	33	<0.021, <0.9 ⁴
Nitrite/Nitrate Nitrogen (g/m ³)	0.007	0.72	0.23	0.25	34	<0.444
Total Nitrogen (g/m ³)	0.17	0.97	0.36	0.43	33	<0.614
Dissolved Reactive Phosphorus (g/m ³)	0.005	0.016	0.007	0.008	34	<0.010
Total Phosphorus (g/m ³)	0.005	0.044	0.016	0.018	33	<0.033

1. South-eastern Australian standard for lowland rivers

2. Acceptable/Green Mode: No single sample greater than 260 *E. coli*/100 mL, Alert/Amber Mode: Single sample greater than 260 *E. coli*/100 mL, Action/Red Mode: Single sample greater than 550 *E. coli*/100 mL.

3. <150 (primary contact e.g., swimming), <1000 (secondary contact e.g., boating, fishing)

4. <0.021 = guideline for nutrient enrichment, <0.9 = guideline for ammonia toxicity

Levels of faecal indicator bacteria (*E. coli* and faecal coliforms) are generally high during low river flows, with lower levels following periods of higher river flows due to increased dilution (Figures 9 and 10). Faecal contaminant levels often exceed guideline levels for recreational activities (Figures 9 and 10). The Ministry for the Environment Action/Red Mode level for *E. coli* is a single sample greater than 550 *E. coli* per 100 mL (Ministry for the Environment 2003). The ORC interprets this such that if this guideline is exceeded there could be a health-risk for swimming. For faecal coliforms, ANZECC and ARMCANZ (2000) states that for primary contact (e.g., swimming) over the bathing season there should not be more than 150 faecal coliform organisms per 100 mL. For secondary contact (e.g., boating, fishing) there should not be more than 1000 faecal coliform organisms per 100 mL. The primary contact guideline is regularly exceeded, while the secondary contact guideline has been exceeded on one occasion. These results indicate that safe recreation in the Silver Stream is likely to be limited by poor water quality. Direct recreational activity in the Silver Stream is probably confined to low flow

conditions, although the lower reaches of the stream are not considered suitable for bathing.

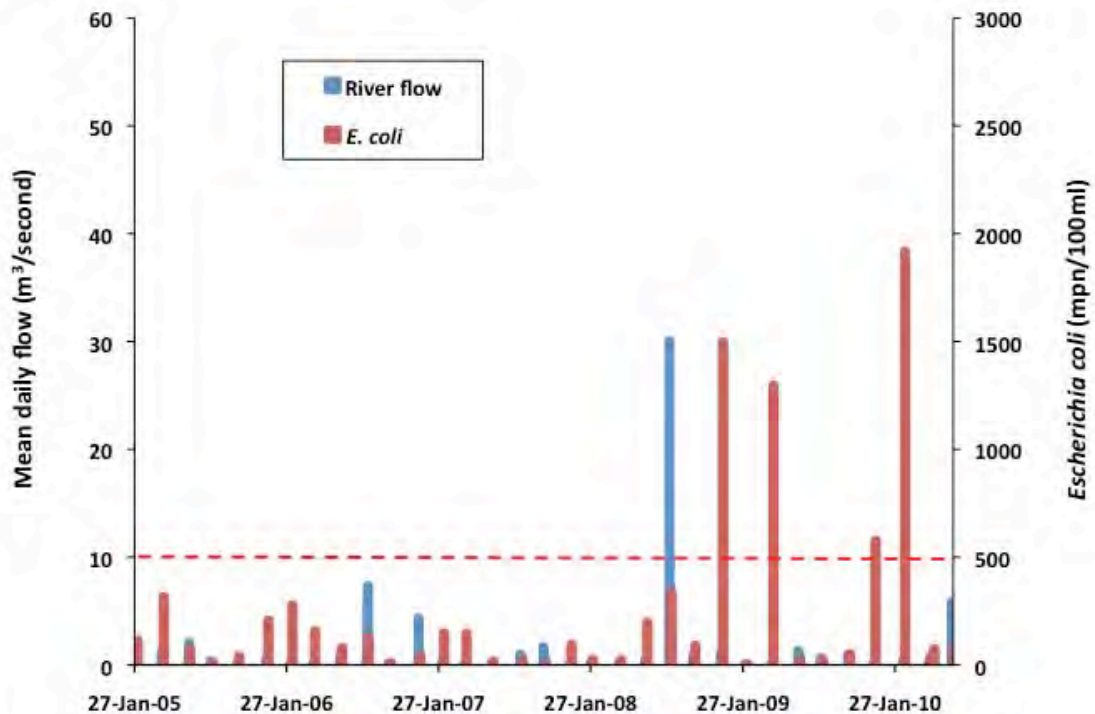


Figure 9 *E. coli* levels (red bars) and river flow for five days prior to water sampling (blue bars) between January 2005 and June 2010 for the Silver Stream at Riccarton Road. Data is only shown for dates when water sampling was undertaken. Data sourced from the ORC. Red dashed line indicates Ministry for the Environment action/red mode level, above which there could be a health-risk for swimming.

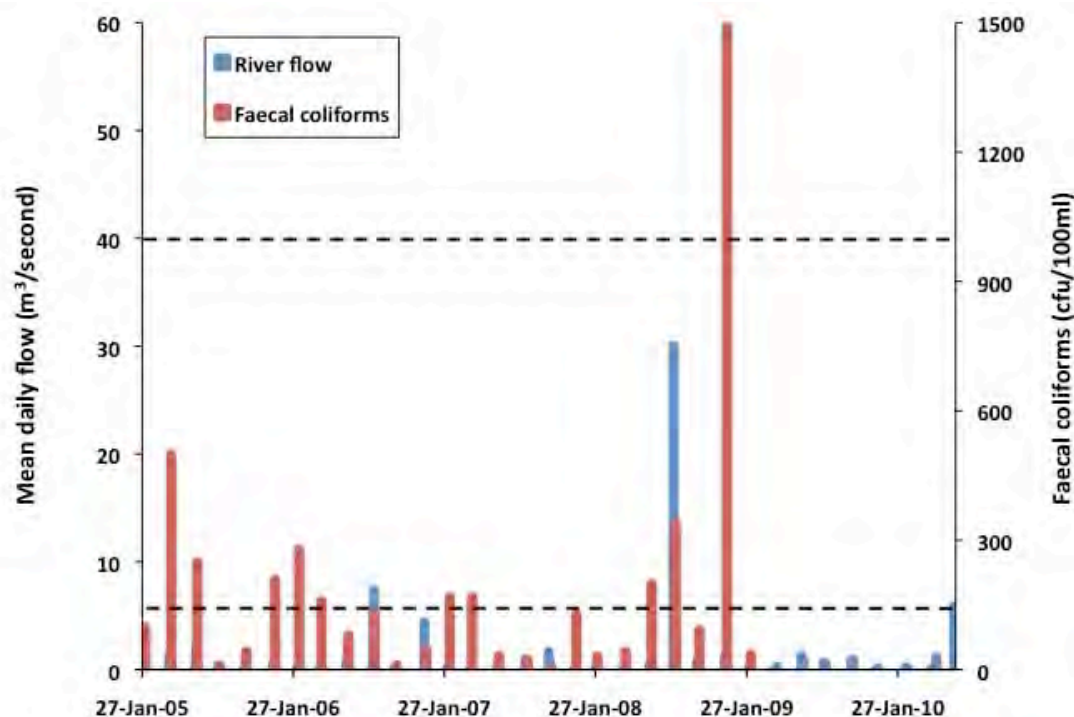


Figure 10 Faecal coliform levels (red bars) and river flow for five days prior to water sampling (blue bars) between January 2005 and June 2010 for the Silver Stream at Riccarton Road. Data is only shown for dates when water sampling was undertaken. Data sourced from the ORC. Black dashed lines indicate ANZECC and ARMCANZ (2000) trigger values for primary contact (e.g., swimming) (lower line) and secondary contact (e.g., fishing) (upper line).

Monitoring by the Otago Regional Council further upstream at Three Mile Hill Road found water quality to be generally high (Table 6), due to protection in the upper catchment (a water and scenic reserve). Water temperature, conductivity, nutrients, turbidity, and suspended solids levels are all low, while dissolved oxygen levels are high. However, faecal indicator bacteria levels are high, indicating some faecal contamination higher in the catchment.

Table 6 Water quality parameters for the Silver Stream measured at Three Mile Hill Road between June 1990 and August 2009. Data sourced from the ORC. Guideline levels from ANZECC and ARMCANZ (2000), Ministry for the Environment (1992) and Ministry for the Environment (2003). Guideline levels shown are the default trigger values for slightly disturbed lowland rivers.

Parameter	Minimum	Maximum	Median	Mean	n	Guideline levels
Temperature (°C)	2	18.3	10.5	10.7	36	<15
pH	6.1	7.9	7.2	7.2	35	7.2 – 7.8
Dissolved oxygen saturation (%)	75.5	91	86	84.5	6	98 – 105
Dissolved oxygen (g/m ³)	4.9	15.5	10.6	10.5	36	–
Conductivity (mS/cm)	0.08	0.37	0.17	0.17	35	0.125 – 0.3 ¹
Turbidity (NTU)	0.4	17	1.1	2.2	32	<5.6
Suspended solids (g/m ³)	1	30	2	5.4	25	–
<i>Escherichia coli</i> (mpn/100mL)	4	600	74	136.6	13	260, 550 ²
Faecal coliforms (cfu/100mL)	12	2100	63	273.9	21	<150, <1000 ³
Ammoniacal Nitrogen (g/m ³)	0.004	0.03	0.01	0.01	33	<0.021, <0.9 ⁴
Nitrite/Nitrate Nitrogen (g/m ³)	0.003	0.26	0.04	0.06	33	<0.444
Total Nitrogen (g/m ³)	0.08	0.44	0.14	0.18	19	<0.614
Dissolved Reactive Phosphorus (g/m ³)	0.0005	0.015	0.003	0.004	33	<0.010
Total Phosphorus (g/m ³)	0.002	0.07	0.01	0.01	33	<0.033

1. South-eastern Australian standard for lowland rivers

2. Acceptable/Green Mode: No single sample greater than 260 *E. coli*/100 mL, Alert/Amber Mode: Single sample greater than 260 *E. coli*/100 mL, Action/Red Mode: Single sample greater than 550 *E. coli*/100 mL.

3. <150 (primary contact e.g., swimming), <1000 (secondary contact e.g., boating, fishing)

4. <0.021 = guideline for nutrient enrichment, <0.9 = guideline for ammonia toxicity

Similar water quality conditions were found in April 2011, with high dissolved oxygen and low conductivity levels (Table 7). Water temperatures increased downstream, probably due to reduced shading from riparian vegetation. pH also increased downstream, and was above guideline levels but well within the range 6.5 to 9.0, which is typically cited as being appropriate for freshwater bodies of New Zealand (ANZECC 1992).

Table 7 Water quality in the Silver Stream catchment, April 2011.

Site	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	Conductivity (mS/cm)
Silver Stream at Puddle Alley	7.74	14.5	10.43	102.3	0.13
Silver Stream at Gordon Road	7.83	14.5	10.85	106.6	0.14
Silver Stream at Riccarton Road	8.20	15.4	11.32	113.5	0.14

Stormwater inputs

The ORC monitored the ‘first flush’ of stormwater to the Silver Stream in November 2004 and February 2005 during rainfall events. The ‘first flush’ of stormwater generally contains a high pollution load relative to subsequent discharges during a rain event. Monitoring was undertaken at stormwater outfalls and in the Silver Stream immediately upstream of the outfalls. Note that water quality trigger values and guidelines are usually developed for receiving waters and not for stormwater, hence stormwater quality is not compared to guideline values in this report.

Biochemical oxygen demand (BOD), a measure of the amount of oxygen consumed by microorganisms in decomposing organic matter in water, was high at each stormwater outfall, and exceeded the Ministry for the Environment guideline of 2 g/m³ at the Wingatui Road stream site in November 2004 (Table 8). Faecal indicator bacteria levels were high in the stream upstream of the stormwater outfalls and in the stormwater, with particularly high levels in Titri Place stormwater. For faecal coliforms, the ANZECC and ARMCANZ (2000) primary and secondary contact guidelines were exceeded at all stream sites. Suspended solids and turbidity levels were high in the stormwater. Nutrient concentrations were relatively low in the Silver Stream itself, but were very high in the stormwater. Ammonia concentrations in Titri Place stormwater in February 2005 were very high and potentially toxic without dilution.

Metal and metalloid contaminant concentrations can be compared with ANZECC and ARMCANZ (2000) toxicity trigger values. Protection levels are derived as chemical-specific estimates of contaminant concentrations that should have no adverse effects on aquatic ecosystems. The ‘protection of 95% of species’ level is most commonly applied to ‘slightly–moderately disturbed’ ecosystems (Table 9). ANZECC and ARMCANZ (2000) toxicity trigger values for metals are aimed at protection from sustained exposure (i.e., chronic toxicity), and exposure to stormwater-derived contaminants in stream waters is relatively short. However, short-term exposure to contaminants may have adverse effects on aquatic communities. The guidelines should not be used on a ‘pass’ or ‘fail’ basis (ANZECC and ARMCANZ 2000). If total contaminant concentrations exceed trigger values, further investigation is required to consider the fraction of the contaminant that is bio-available or can be transformed and mobilised in a bio-available form (ANZECC and ARMCANZ 2000). In this case, the bio-available metal fraction is better represented by the dissolved metal fraction.

Arsenic concentrations in the Silver Stream were lower than ANZECC trigger values and were also low in the stormwater discharge (Tables 8 and 9). Metal concentrations in the stream were also generally lower than trigger levels, with only zinc concentrations at Titri Place exceeding the 95% trigger level. However, cadmium, copper, lead, nickel and zinc concentrations were very high in the stormwater. Dissolved (i.e., bio-available) copper, nickel and zinc concentrations were very high in the stormwater. These metals are all derived from road runoff (from brake linings, tyre wear, and road markings), with lead also derived from lead-based paints and petrol products, and copper and zinc also from spouting and deteriorating zinc-coated, or galvanised, roofs and fences (Suren and Elliot 2004).

Industrial land and roading dominate the catchments drained by the two stormwater outfalls. Metal contaminant concentrations in the Silver Stream itself were generally low, with elevated concentrations only downstream of stormwater outfalls (i.e., high zinc levels at Titri Place, downstream of the Wingatui Road stormwater outfall, in February 2005).

Table 8 Water quality in the Silver Stream and stormwater during rainfall events in November 2004 and February 2005. Stream sites are upstream of stormwater outfalls; Wingatui Road is upstream of Titri Place. Data from the ORC. Metals and metalloids: bold values indicate higher than 95% trigger values, shaded values indicate higher than 80% trigger values (Table 9). Other parameters: bold values indicate breached guidelines listed in Tables 5 and 6. No guideline levels for suspended solids.

	Silver Stream							
	November 2004				February 2005			
	Wingatui Road	Stormwater	Titri Place	Stormwater	Wingatui Road	Stormwater	Titri Place	Stormwater
pH	7.77	7.03	7.76	7.11	7.59	6.45	7.51	6.87
Conductivity (mS/cm)	0.17	0.07	0.17	0.08	0.16	0.08	0.16	0.12
Turbidity (NTU)	1.9	36	1.2	60	1.4	16	1.4	21
Suspended solids (g/m ³)	2	150	2	480	2	31	3	73
Biochemical oxygen demand (5 day, g/m ³)	4	18	1	21	1	23	1	21
<i>Escherichia coli</i> (mpn/100mL)	1300	550	2400	21400	1800	3100	1800	20900
Faecal coliforms (cfu/100mL)	1300	550	2800	21400	1400	2700	1900	20000
Ammoniacal Nitrogen (g/m ³)	0.01	0.47	0.03	0.39	0.02	0.65	0.01	1.09
Nitrite/Nitrate Nitrogen (g/m ³)	0.087	0.256	0.085	0.491	0.035	0.293	0.039	0.31
Total Nitrogen (g/m ³)	0.37	2.75	0.27	3.35	0.29	2.52	0.24	3.13
Dissolved Reactive Phosphorus (g/m ³)	0.017	0.24	0.013	0.197	0.012	0.164	0.011	0.175
Total Phosphorus (g/m ³)	0.033	0.63	0.026	0.884	0.023	0.305	0.02	0.453
Dissolved Arsenic (g/m ³)	0.0005	0.001	0.0005	0.0005	0.0005	0.001	0.0005	0.0005
Total Arsenic (g/m ³)	0.0005	0.004	0.0005	0.003	0.0005	0.002	0.0005	0.0005
Dissolved Cadmium (g/m ³)	0.00003	0.0009	0.00003	0.00003	0.00003	0.00034	0.00003	0.00009
Total Cadmium (g/m ³)	0.00003	0.00158	0.00003	0.00037	0.00003	0.00048	0.00003	0.00029
Dissolved Copper (g/m ³)	0.00025	0.0236	0.0006	0.0031	0.0005	0.0217	0.0008	0.008
Total Copper (g/m ³)	0.0011	0.145	0.001	0.0306	0.0005	0.0375	0.0011	0.0149
Dissolved Lead (g/m ³)	0.00005	0.0009	0.00005	0.0005	0.0001	0.0012	0.00005	0.0019
Total Lead (g/m ³)	0.0003	0.0318	0.0003	0.0358	0.0003	0.0074	0.0002	0.0169
Dissolved Nickel (g/m ³)	0.0006	0.0716	0.0006	0.0032	0.0006	0.0428	0.0013	0.0022
Total Nickel (g/m ³)	0.0008	0.162	0.0007	0.0105	0.0007	0.0503	0.0019	0.0033
Dissolved Zinc (g/m ³)	0.003	1.39	0.003	0.116	0.002	1.13	0.019	0.432
Total Zinc (g/m ³)	0.007	1.67	0.007	0.936	0.002	1.23	0.027	0.566

Table 9 ANZECC and ARMCANZ (2000) toxicity trigger values for freshwaters. The 95% trigger values are most commonly applied to ‘slightly–moderately disturbed’ ecosystems.

Metals and Metalloids	Level of protection (% species)	
	95%	80%
Arsenic (g/m ³) ¹	0.013	0.140
Cadmium (g/m ³)	0.0002	0.0008
Copper (g/m ³)	0.0014	0.0025
Lead (g/m ³)	0.0034	0.0094
Nickel (g/m ³)	0.011	0.017
Zinc (g/m ³)	0.008	0.031

1. Trigger values for arsenic are conservative, as arsenic speciation was not determined.

4.8 Aquatic plants

The ORC collect periphyton samples for analysis of algae taxonomic composition. The periphyton community at Riccarton Road is generally dominated by filamentous green and red algae and diatoms (Table 10). The filamentous algae taxa are commonly found in a range of conditions, from clean rivers (e.g., *Audouinella*), clean or nutrient enriched rivers (e.g., *Stigeoclonium*) or nutrient enriched rivers (e.g., *Oedogonium*) (Biggs and Kilroy 2000, Moore 2000). The diatom community is very diverse, with dominant taxa commonly found in clean, low conductivity streams (e.g., *Achnanthisidium*), clean or degraded streams with high abundance under low flow conditions (e.g., *Cymbella*), and nutrient enriched waters (e.g., *Gomphonema*) (Biggs and Kilroy 2000, Moore 2000).

Cyanobacteria are regularly recorded in the Silver Stream, with large mats present when water temperatures are high and river flows low. *Phormidium*, a cyanobacterial taxon able to produce cyanotoxins, has been recorded in recent years. There have also been reports of dog deaths following consumption of cyanobacterial mats containing cyanotoxins in the Silver Stream.

Table 10 Periphyton taxa found during ORC SOE monitoring in the Silver Stream, 2007-2010. Relative abundance of each taxa was scored using the scheme of Biggs and Kilroy (2000), which scores taxa from 1 (rare) to 8 (absolutely dominant/monoculture).

	Silver Stream @ Riccarton Road				Silver Stream @ Three Mile Hill Rd
	2007	2008	2009	2010	2008
Filamentous Green Algae					
<i>Microspora</i>				3	
<i>Oedogonium</i>				5	
<i>Stigeoclonium</i>	2	5			
<i>Ulothrix</i>		3			
Filamentous Red Algae					
<i>Audouinella</i>	7	4	3		3
Cyanobacteria					
cf. <i>Phormidium</i> spp.				3	
<i>Oscillatoria</i>			3		
Filamentous Diatoms					
<i>Diatoma</i> cf. <i>tenuis</i>				2	
<i>Diatoma</i> cf. <i>vulgaris</i>				4	
<i>Fragilaria</i>			2	3	
<i>Melosira</i>			2	4	3
Diatoms					
<i>Achnantheidium</i>				6	
<i>Cocconeis</i>				3	
<i>Cymbella</i>	3	3	4	8	
<i>Encyonema</i>				7	3
<i>Frustulia</i>					3
<i>Gomphoneis</i>					4
<i>Gomphonema</i>	1		2		
<i>Gomphonema</i> cf. <i>minutum</i> (15 µm)				3	
<i>Gomphonema</i> cf. <i>parvulum</i>				4	
<i>Gomphonema</i> cf. <i>truncatum</i>				5	
<i>Meridion circulare</i>				1	
Naviculoid diatom				3	4
<i>Nitzschia</i>		3		2	6
<i>Reimeria</i> spp.				1	
<i>Rossithidium linearis</i>				3	
<i>Stauroneis</i>					2
<i>Surirella</i>			1		
<i>Synedra</i>		3	2		
<i>Synedra</i> cf. <i>acus</i>				5	
<i>Synedra ulna</i> var. <i>biceps</i>				2	
<i>Synedra ulna</i> cf. <i>ramesi</i>				3	
Single Celled Green Algae					
<i>Cosmarium</i>			2		
Colonial Green Algae					
<i>Scenedesmus</i>				4	

Most of the stream bed was relatively clean of algae in April 2011, with only small patches of algae on larger substrates; smaller gravels generally did not have any visible periphyton cover. Puddle Alley had occasional large cobbles with small patches (5 to 10% cover) of short (less than 1 cm long) filamentous algae (*Oedogonium* and *Melosira*) (Table 11). The filamentous red algae *Audouinella* was also present in small patches (2 to 5% cover) (Table 11). Some larger substrates at Gordon Road had between 5 and 100% cover of thin to medium cyanobacterial mats. Short filamentous algae (*Spirogyra* and

Melosira) was also present on larger substrates (5 to 30% cover). Small patches of filamentous algae (*Melosira*) were along the edges at Riccarton Road, with very small patches (less than 1% cover) of thin diatom mats.

Table 11 *Periphyton taxa found in the Silver Stream catchment, April 2011. Relative abundance of each taxa was scored using the scheme of Biggs and Kilroy (2000), which scores taxa from 1 (rare) to 8 (absolutely dominant/monoculture).*

	Silver Stream at Puddle Alley	Silver Stream at Gordon Road	Silver Stream at Riccarton Road
Filamentous Green Algae			
<i>Oedogonium</i>	2		
<i>Spirogyra</i>		3	
Filamentous Red Algae			
<i>Audouinella</i>	8		
Filamentous Yellow-Green Algae			
<i>Tribonema</i>			1
Cyanobacteria			
<i>Oscillatoria / Phormidium</i>		2	
Filamentous Diatoms			
<i>Melosira</i>	1	8	8
Diatoms			
<i>Cymbella</i>		4	4
<i>Encyonema</i>		3	
<i>Frustulia</i>		2	2
<i>Gomphoneis</i>	3		1
<i>Gomphonema</i>	4		2
Naviculoid diatom	2	3	3
<i>Nitzschia</i>		1	
<i>Pinnularia</i>			1
<i>Synedra</i>	4	3	2
Single Celled Green Algae			
<i>Closterium</i>		1	
<i>Cosmarium</i>		2	

The aquatic plants monkey musk (*Mimulus guttatus*), watercress (*Nasturtium microphyllum*), and floating sweetgrass (*Glyceria fluitans*) were along the stream edge at each of the April 2011 sites. These aquatic plants are all exotic species.

4.9 Benthic macroinvertebrates

Otago Regional Council macroinvertebrate monitoring at Three Mile Hill Road found the community dominated by *Deleatidium* mayflies, *Potamopyrgus* snails and midge larvae (e.g., Orthocladiinae) (Table 12). Further downstream at Riccarton Road, *Deleatidium* mayflies were considerably less abundant, with the community dominated by ostracods (seed shrimps) and several types of snails.

Table 12 Macroinvertebrate taxa in samples collected during ORC SOE monitoring in the Silver Stream, 2003 - 2010. Coded abundance scores after Stark (1998).

TAXON	MCI score	Silver Stream at Three Mile Hill Road				Silver Stream at Riccarton Road					
		2003	2003	2004	2008	2003	2004	2007	2008	2009	2010
ACARINA	5					A				R	VA
COLEOPTERA											
<i>Berosus</i> species	5									R	R
Elmidae	6	VA	VA	R	VA	VA	A	A	VA	VA	VVA
Hydraenidae	8										R
CRUSTACEA											
Copepoda	5				C						
Ostracoda	3	VA		A	C	VVA	VVA	R	R	VVA	VVA
<i>Paracalliope fluviatilis</i>	5	A		R				R		R	R
DIPTERA											
<i>Aphrophila</i> species	5	R			R						
<i>Austrosimulium</i> species	3			C	A			C	R		
Chironominae	2	VA	VA		C	A		R			
Empididae	3				C						
Ephydriidae	4					A					
<i>Maoriadamesa</i> species	3	A	A	A							
Muscidae	3	A	A	R		A					R
Orthocladiinae	2	VA	VVA	A	VVA	VA	C	A	C	A	VVA
Tanypodinae	5	A	A		C	A		R			A
EPHEMEROPTERA											
<i>Austroclima</i> species	9			R							
<i>Coloburiscus humeralis</i>	9	R	R								
<i>Deleatidium</i> species	8	VVA	VVA	VA	VVA			R	A	C	C
MEGALOPTERA											
<i>Archichauliodes diversus</i>	7	A	A	A	C			R			C
MOLLUSCA											
<i>Gyraulus</i> species	3						VVA			R	
<i>Physella</i> species	3	C		A		VVA	VVA	R	R	C	A
<i>Potamopyrgus antipodarum</i>	4	VVA	VVA	VVA	A	VVA	VVA	C	A	VVA	VVA
Sphaeriidae	3	C		R							
NEMATODA	3				R						
OLIGOCHAETA	1	VA	VA	VA	VA	A	VVA	C	A	VA	R
PLATYHELMINTHES	3						C				
PLECOPTERA											
<i>Austroperla cyrene</i>	9	C	R	R	R						
<i>Megaleptoperla</i> species	9	R									
<i>Stenoperla</i> species	10	C	R	R							
<i>Zelandoperla</i> species	10	A	A	C	A						R
TRICHOPTERA											
<i>Aoteapsyche</i> species	4	VVA	VVA	A	A	R					
<i>Costachorema xanthopterum</i>	7				R						
<i>Hudsonema alienum</i>	6	A	A								
<i>Hudsonema amabile</i>	6	A	A	A		A					
<i>Hydrobiosidae</i> early instar	5	A	A	A	A	A		R	R	R	
<i>Hydrobiosis clavigera</i> group	5				R						
<i>Hydrobiosis</i> species	5										C
<i>Hydrobiosis umbripennis</i> group	5					A			R		
<i>Hydroptilidae</i> instar	2				A						
<i>Neurochorema</i> species	6	C									
<i>Olinga</i> species	9	VA	VVA	VA	A					R	A
<i>Oxyethira albiceps</i>	2	VA	A	VA		A		R	R		VA
<i>Polypsectropus</i> species	8			C							
<i>Psilochorema</i> species	8	R	VA	C	A	R	R	R	C	R	A
<i>Pycnocentria</i> species	7	VA	VVA	VA	R	A					
<i>Pycnocentrodes</i> species	5	VVA	VVA	VVA	VA				R	C	R
Number of taxa		30	23	26	26	18	9	15	14	15	20
Number of EPT taxa		16	14	14	13	7	1	4	7	5	7
MCI score		110	114	110	102	83	73	85	87	97	104
SQMCI score		4.9	5.4	4.8	4.8	3.5	2.8	3.8	4.9	3.5	3.8

The highest quality invertebrate community was at Puddle Alley in April 2011. *Deleatidium* mayflies, which are typically found in streams with high water quality, dominated the community (Table 13). However, oligochaete worms and *Potamopyrgus* snails, invertebrates indicative of lower water quality, were also very abundant (Table 13). Elmid (riffle) beetles, midge larvae (e.g., Orthoclaadiinae), *Potamopyrgus* snails and oligochaete worms dominated communities at Gordon Road and Riccarton Road. *Deleatidium* mayflies were present, but were less abundant than at Puddle Alley.

Table 13 Macroinvertebrate taxa in samples collected in the Silver Stream catchment, April 2011. Coded abundance scores after Stark (1998).

TAXON	MCI score	Silver Stream at Puddle Alley		Silver Stream at Gordon Road		Silver Stream at Riccarton Road	
		1	2	1	2	1	2
COLEOPTERA							
Elmidae	6	C	A	VA	A	VA	VA
CRUSTACEA							
Ostracoda	3	C		A	C	R	C
<i>Paracalliope fluviatilis</i>	5		C		R		R
<i>Paraleptamphopus</i> species	5			R	R		
DIPTERA							
<i>Aphrophila</i> species	5	C	C	R			
<i>Austrosimulium</i> species	3	A	C	C	R	R	R
<i>Mischoderus</i> species	4			R			
Muscidae	3			R	R		R
Orthoclaadiinae	2	C	C	VA	VA	A	A
EPHEMEROPTERA							
<i>Coloburiscus humeralis</i>	9	C					
<i>Deleatidium</i> species	8	VVA	VVA	VA	VA	VA	A
MEGALOPTERA							
<i>Archichauliodes diversus</i>	7	A	C	R	R	R	R
MOLLUSCA							
Lymnaeidae	3			R	R	R	R
<i>Potamopyrgus antipodarum</i>	4	VA	VVA	VA	A	VA	A
Sphaeriidae	3	C			R		
OLIGOCHAETA	1	VA	VVA	A	A	VA	A
PLATYHELMINTHES	3			R			
PLECOPTERA							
<i>Austroperla cyrene</i>	9	C			R		R
<i>Megaleptoperla</i> species	9	C					R
<i>Stenoperla</i> species	10		C				
<i>Zelandobius</i> species	5	A	A	C	R	R	R
<i>Zelandoperla</i> species	10	C		R	R		
TRICHOPTERA							
<i>Aoteapsyche</i> species	4	A	A	R	R		
<i>Hudsonema amabile</i>	6	A	VA	C	R		R
<i>Hydrobiosis clavigera</i> group	5		C				
<i>Hydrobiosis umbripennis</i> group	5	A	A	R		R	R
<i>Olinga</i> species	9	VA	A	R	R		R
<i>Oxyethira albiceps</i>	2	C		R	R		C
<i>Psilochorema</i> species	8	A	A	C	C	C	C
<i>Pycnocentria</i> species	7	A	A	R			
<i>Pycnocentrodus</i> species	5	A	VA	R	R	R	
Number of taxa		23	19	24	22	14	19
Number of EPT taxa		14	11	11	10	6	9
MCI score		113	111	98	101	94	103
SQMCi score		6.5	4.6	4.8	4.8	4.7	5.0
Average MCI score		112		100		99	
Average SQMCi score		5.6		4.8		4.8	

Taxonomic diversity is generally higher at sites high in the catchment and decreases with distance downstream, with the lowest diversity at Riccarton Road (Figure 11). Diversity at Three Mile Hill Road, Puddle Alley and Gordon Road is higher than the median of 18

taxa per site found by Scarsbrook *et al.* (2000) in a nation-wide assessment of 66 long-term monitoring sites located throughout New Zealand. Diversity at Riccarton Road is generally lower than the national median.

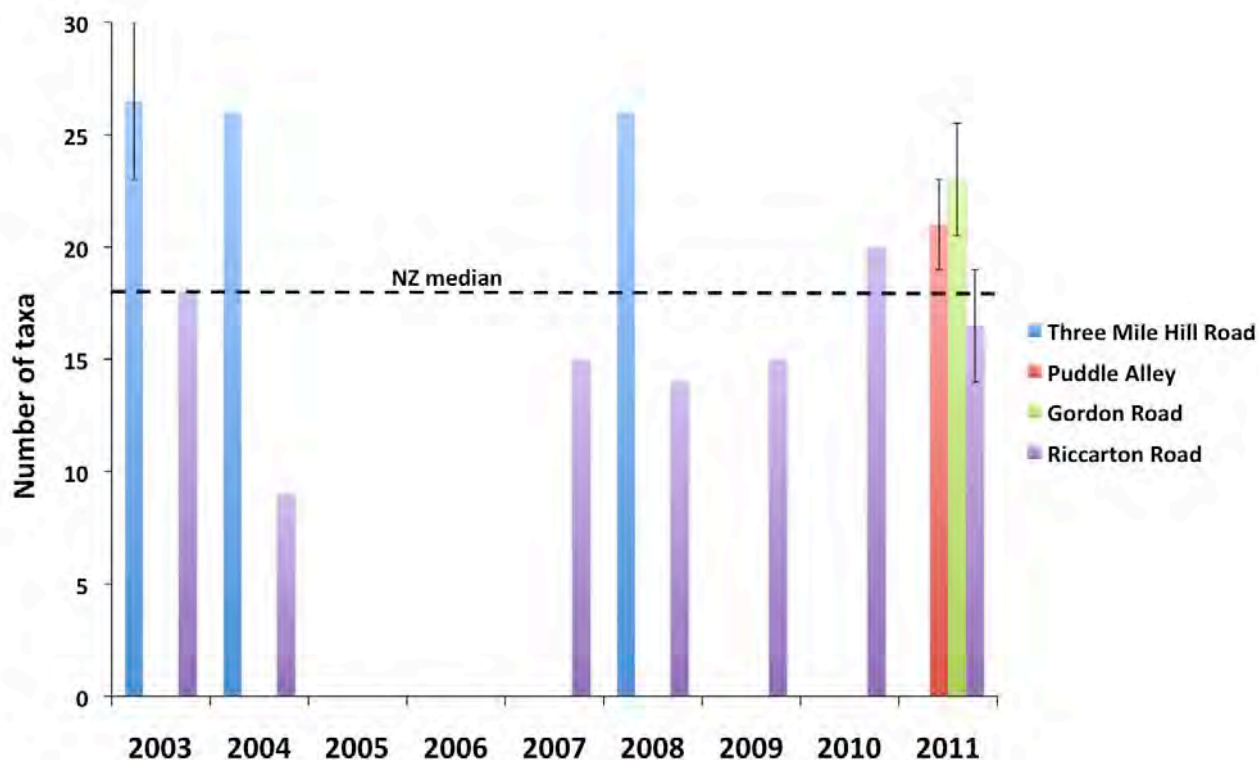


Figure 11 Diversity of the macroinvertebrate community in the Silver Stream. Data from ORC SOE monitoring (2003-2010) and Ryder Consulting (2011). The dashed line indicating the New Zealand median of 18 taxa per site is from Scarsbrook *et al.* (2000). Note that samples were not collected in 2005 and 2006. Where more than one sample was collected, averages are presented with error bars of +/- one standard error.

The number of EPT taxa (invertebrates typically indicative of higher water quality, e.g., mayflies) is relatively high at Three Mile Hill Road, Puddle Alley and Gordon Road, with between 10 and 16 taxa, but is lower at Riccarton Road with between one and nine taxa (Figure 12). Diversity of EPT taxa at Riccarton Road is lower than the median of 8 taxa per site determined by Scarsbrook *et al.* (2000) from their national assessment. Further upstream, diversity is considerably higher than the national median.

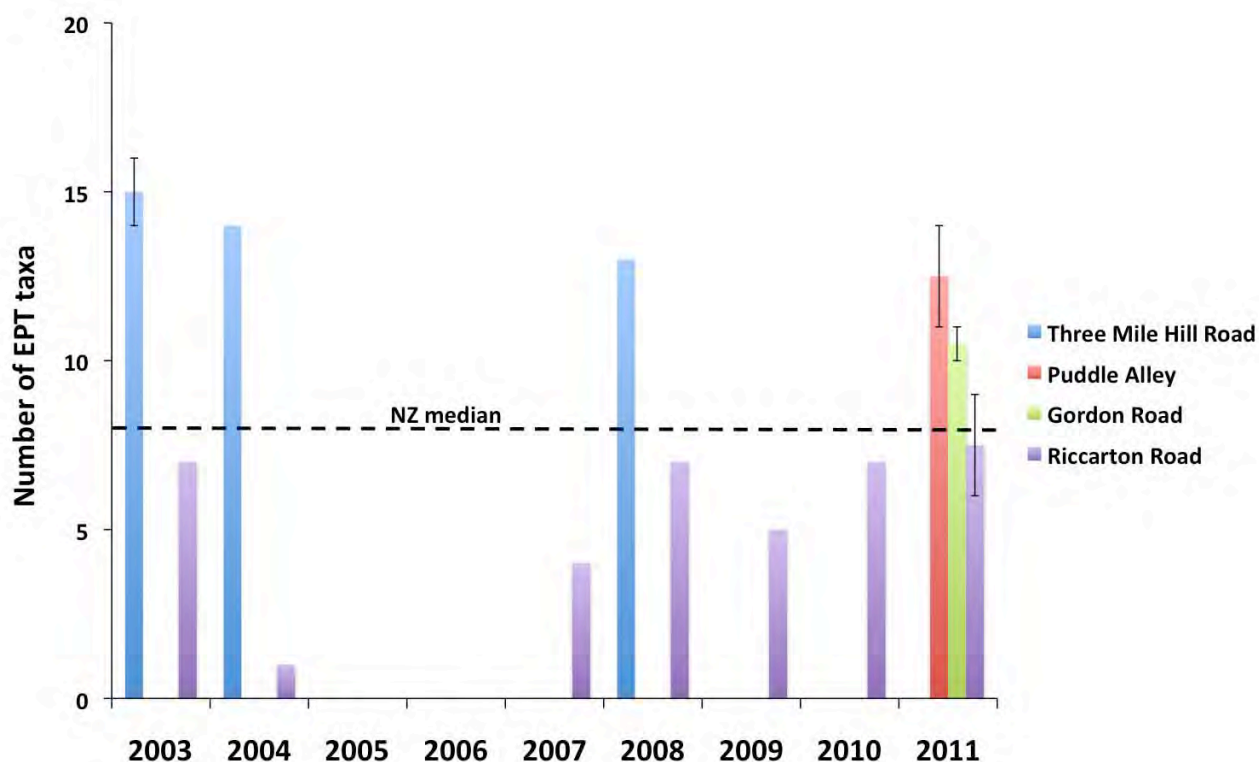


Figure 12 Diversity of EPT taxa in the Silver Stream. Data from ORC SOE monitoring (2003-2010) and Ryder Consulting (2011). The dashed line indicating the New Zealand median of 8 EPT taxa per site is from Scarsbrook et al. (2000). Note that samples were not collected in 2005 and 2006. Where more than one sample was collected, averages are presented with error bars of +/- one standard error.

Macroinvertebrate community health index scores (SQMCI; low scores represent ‘probable severe pollution’ and high scores represent very ‘clean’ conditions) are relatively low (Figure 13). Three Mile Hill Road and Puddle Alley scores are indicative of ‘fair’ to ‘good’ water quality, while scores are lower downstream and generally indicative of ‘poor’ to ‘fair’ water quality (Figure 13), using the narrative terminology of Stark and Maxted (2007).

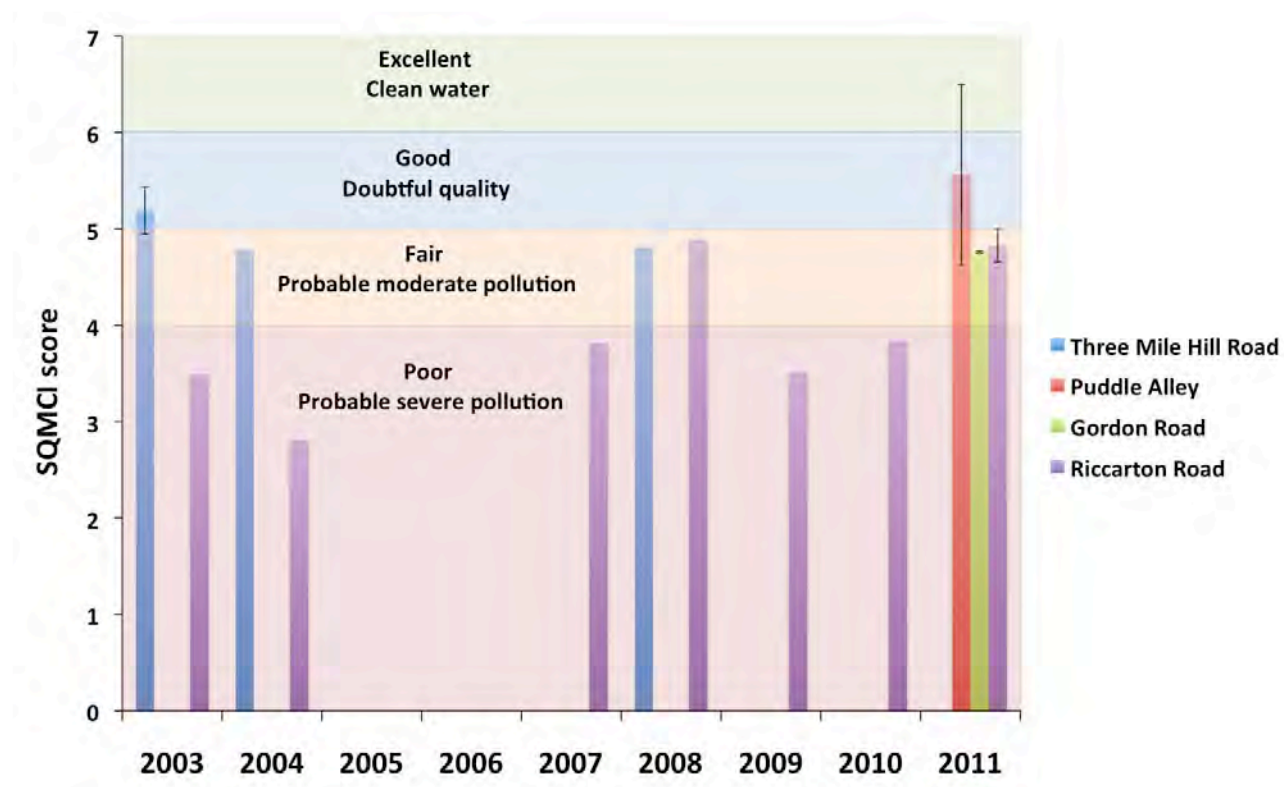


Figure 13 SQMCI scores in Silver Stream at Riccarton and Three Mile Hill Roads. Data from ORC SOE monitoring. Quality classes from Boothroyd and Stark (2000) and Stark and Maxted (2007). Note that samples were not collected in 2005 and 2006.

Freshwater crayfish (*Paranephrops zealandicus*) have been found at Riccarton Road during ORC SOE fish surveys. This species has also been found in Whare Creek, a tributary in the upper reaches of the catchment. The Department of Conservation, using the ‘threat of extinction’ classification (Molloy *et al.* 2002), has listed freshwater crayfish as ‘chronically threatened - gradual decline’ (Hitchmough *et al.* 2007).

4.10 Fish

An examination of the New Zealand Freshwater Fish Database (NZFFD) revealed 64 fish surveys have been undertaken in the Silver Stream catchment between 1964 and 2007. In addition, Ryder Consulting surveyed fish communities in April/May 2011. Nine native fish species and two introduced fish species have been found in the stream (Table 14, Figure 14).

Table 14 List of fish species identified as being present in the Silver Stream catchment.

Species	Common Name	Native	Migratory
<i>Anguilla australis</i>	Shortfin eel	Y	Y
<i>Anguilla dieffenbachii</i>	Longfin eel	Y	Y
<i>Galaxias argenteus</i>	Giant kokopu	Y	Y/N
<i>Galaxias brevipinnis</i>	Koaro	Y	Y/N
<i>Galaxias eldoni</i>	Eldon's galaxias	Y	N
<i>Galaxias maculatus</i>	Inanga	Y	Y
<i>Geotria australis</i>	Lamprey	Y	Y
<i>Gobiomorphus cotidianus</i>	Common bully	Y	Y/N
<i>Perca fluviatilis</i>	European perch	N	N
<i>Retropinna retropinna</i>	Common smelt	Y	Y
<i>Salmo trutta</i>	Brown trout	N	Y/N

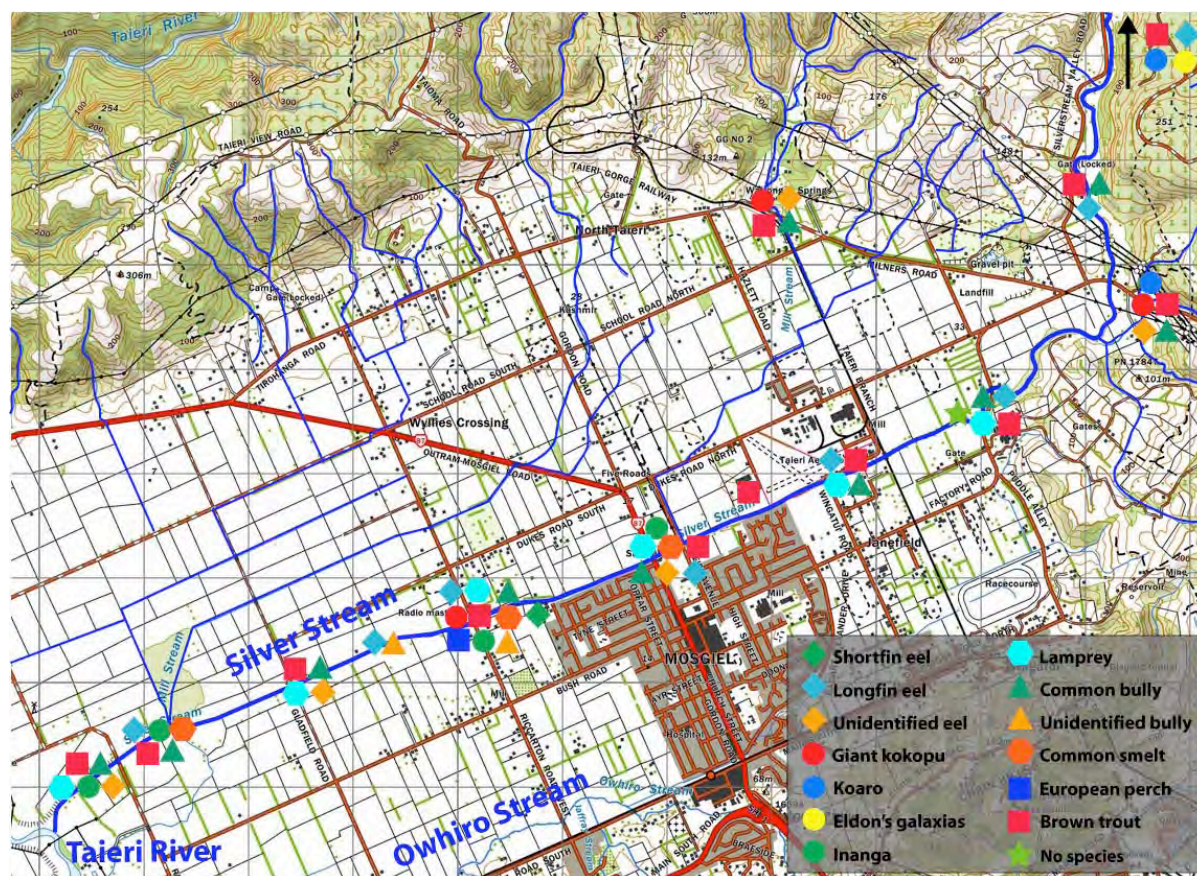


Figure 14 Fish distribution records in the Silver Stream catchment. Sourced from NZFFD and Ryder Consulting April/May 2011 surveys.

Longfin eels, common bullies and brown trout are most abundant and have been found throughout the lower reaches with shortfin eels, common smelt, inanga, and lamprey. However, common smelt and inanga have only been found downstream of Gordon Road. Common smelt and inanga are migratory and are typically found in the lower reaches of lowland streams. In the lower catchment, koaro have been found in Flagstaff Creek, a tributary of the Silver Stream.

Lamprey have been found throughout the lower reaches. Adults migrate upstream in winter and spring to unknown spawning sites that are suspected to be in small, cobbled, forested tributaries (McDowall 2000, James 2008). Adult lamprey do not feed while in freshwater and may spend up to 16 months in freshwater before spawning (James 2008). Following hatching, ammocoetes (larval lamprey) move downstream, feeding and growing, before metamorphosing into macrophthalmia (miniature adults) after four to five years. Their colouration changes from the dull grey-brown of the larvae to brilliant silver and blue. Macrophthalmia go to sea in winter, returning three to four years later as adults.

European perch have been found at Riccarton Road, however the only record from the NZFFD was from 1964. Perch were also found at Riccarton Road in April 2011, confirming the occasional presence of this exotic fish species in the catchment.

According to the NZFFD, giant kokopu have been found at Riccarton Road, and in two tributaries (Figure 14). However, the Riccarton Road record is from 1964, with no further records in the main stream. Surveys of Silver Stream tributaries (namely Mill Stream and Flagstaff Creek) in 1999 found healthy populations of giant kokopu (David *et al.* 2002). The 1999 surveys utilised spotlighting, whereas most other surveys in the catchment have used electric fishing. Giant kokopu are primarily nocturnal and reside deep in cover in pool habitat during the day, which may decrease the likelihood of sampling this species by electric fishing (David *et al.* 2002). The significant number of giant kokopu detected by spotlight in the 1999 survey highlights the importance of using alternate fish sampling techniques and taking into account the behavioural patterns of certain species (David *et al.* 2002).

The presence of giant kokopu in Silver Stream tributaries indicates that this species may occasionally be present in the Silver Stream. Giant kokopu have been known to move

large distances during high discharge events (David 2003). High discharge events may play an important role in re-distributing and re-organising populations in small streams, by providing opportunities for individuals restricted during base flow conditions to move to other stream locations (David 2003). However, the absence of giant kokopu from degraded (particularly channelised) reaches of streams, such as in the lower reaches of the Silver Stream, may be due to the lack of suitable habitat including extensive areas of shallow water and little cover. Such areas probably provide little or no refuge during high discharge periods and fish would be unable to move into low-velocity areas to avoid being displaced (David 2003).

Brown trout, longfin eels, koaro and Eldon's galaxias have been found in the upper Silver Stream catchment (Figure 14). Eldon's galaxias are a non-migratory species that live their entire life cycle in short sections of stream. These galaxiids have only been found in the upper reaches of Whare Creek. Koaro are migratory, and favour clear, swift flowing boulder/cobbles streams in forested catchments.

The April/May 2011 fish survey found low diversity overall, with the highest diversity occurring at Gordon Road and Riccarton Road (Table 15). Longfin eels and common bullies were found at Puddle Alley by electric fishing, with several large trout observed by spotlighting. Lamprey were found amongst soft sediments and aquatic plants at Gordon Road, with ammocoete and the larger and more brilliantly coloured macrophthalmia life stages observed (Figure 15). An individual inanga was also caught (Figure 15). Common bullies were the most abundant species at Gordon Road and were also abundant at Riccarton Road. An individual perch was also caught in a backwater area at Riccarton Road (Figure 16), and a large brown trout was observed during spotlighting.

Table 15 *Number and length range (mm, in brackets) of native fish caught/observed in the Silver Stream, April/May 2011.*

Site	Longfin eel	Lamprey	Inanga	Common bully	European perch	Brown trout
Silver Stream at Puddle Alley	5 (250-480mm)	–	–	5 (~40-~60mm)	–	10 (80-~500mm)
Silver Stream at Gordon Road	3 (270-650mm)	4 (82-118mm)	1 (78mm)	9 (48-92mm)	–	4 (~80-146mm)
Silver Stream at Riccarton Road	3 (310-~700mm)	–	1 (70mm)	19 (48-88mm)	1 (90mm)	10 (~80-~500mm)



Figure 15 Native fish species caught in the Silver Stream, April 2011.
Top left: Ammocoete life stage of lamprey, Gordon Road.
Top right: Macrophthalmia life stage of lamprey, Gordon Road.
Middle left: Inanga at Gordon Road.
Middle right: Longfin eel at Gordon Road.
Bottom: Common bully at Riccarton Road.



Figure 16 Exotic fish species caught in the Silver Stream, April 2011.
Left: European perch at Riccarton Road.
Right: Brown trout at Riccarton Road.

A threat ranking process has recently (June 2009) been applied to New Zealand freshwater fish (Allibone *et al.* 2010). These rankings supersede the rankings conducted under the system of Molloy *et al.* (2002), as listed in Hitchmough (2002) and Hitchmough *et al.* (2007). Under the new ranking system, longfin eel, giant kokopu, koaro, inanga and lamprey are classified as ‘declining’, with the qualifier of ‘partial decline’ for giant kokopu, ‘conservation dependent’ and ‘data poor’ for inanga, and ‘data poor’ for lamprey (Allibone *et al.* 2010). Eldon’s galaxias are classified as ‘nationally endangered’, but as they have only been found high in the Silver Stream catchment in Whare Creek, this species is not influenced by activities in the lower catchment.

Electric fishing at Riccarton Road by ORC, as part of the SOE monitoring programme, has found five fish species on each sampling occasion (Table 16). Freshwater crayfish have also been found on each sampling occasion.

Table 16 Number of fish found during ORC SOE fish monitoring in the Silver Stream at Riccarton Road. Data from ORC.

	2009	2010	2011
Longfin eel	25	16	18
Inanga	4	158	3
Lamprey (juvenile)	7	11	35
Common bully	160	175	53
Brown trout	30	114	12

The Silver Stream is an important trout spawning and nursery tributary of the lower Taieri River. Adult trout migrate upstream from the Taieri River, sometimes in large numbers. Spawning habitat can be found throughout the stream but is particularly important at sites upstream of Mosgiel. Spawning surveys in June 2005 in the Whare Flat area (in the upper reaches of the catchment) revealed at least 26 brown trout, with an additional large group of at least 50 trout found congregating in a large pool immediately downstream of the DCC water abstraction weir (Goldsmith *et al.* 2007). Approximately 22 redds were observed throughout the survey reach, with superimposition of some redds, perhaps indicating highly favourable spawning sites (Goldsmith *et al.* 2007).

A University of Otago study investigated population dynamics of juvenile brown trout in the Silver Stream (Kristensen and Closs 2008). Juvenile brown trout densities were highly variable between the upstream site (approximately 2km upstream of Three Mile Hill Road) and the downstream site (near Mosgiel), with the highest densities recorded downstream. Standard length and condition factors of juvenile brown trout from the downstream site were consistently higher than upstream (Kristensen and Closs 2008). However, trout densities in the downstream site declined to zero each year, while trout from the previous year remained at the upstream site when the new cohort emerged. River flows were positively correlated with loss rate of juvenile brown trout from the downstream reach in 2004–05, which indicates a negative effect of high discharge on fish numbers (Kristensen and Closs 2008).

Kristensen continued his studies of Silver Stream trout by investigating the spawning contribution of resident and anadromous (return to rivers from the sea to breed) female brown trout in the Taieri River and its tributaries (Kristensen *et al.* 2011). Within the Silver Stream, eggs from anadromous trout were predominantly collected from the downstream end of the sampled reach (Figure 17), adjacent to Mosgiel and in the vicinity of Three Mile Hill Road. Eggs from freshwater-resident trout were only collected at the upstream end of the sampled reach, upstream of Three Mile Hill Road.

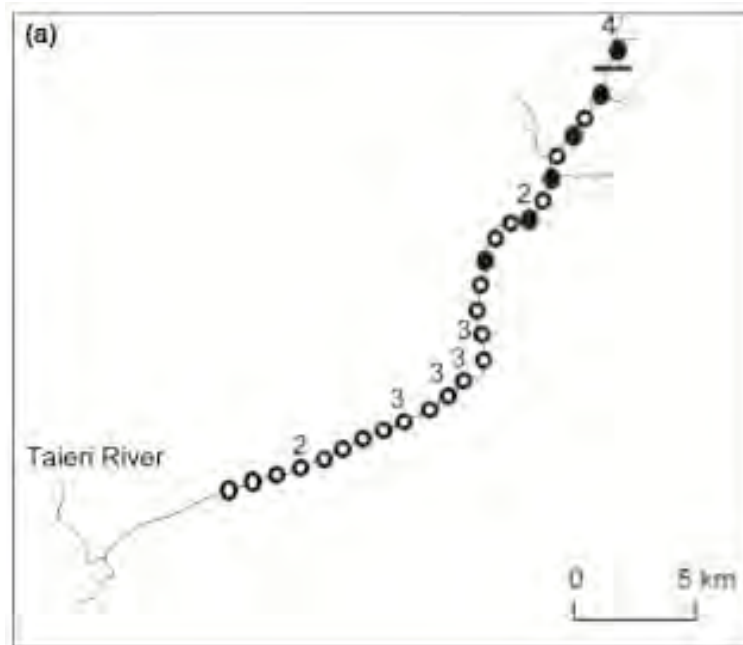


Figure 17 Distribution of redds from anadromous trout (open circles) and freshwater-resident trout (closed circles) along the Silver Stream. Numbers along stream indicate where >1 redds were sampled at a single location, and black bar indicates location of weir. From Kristensen et al. (2011).

The Silver Stream enters the Taieri River approximately 2 km upstream of the tidal limit and represents the first major spawning tributary entering the Taieri River upstream of the estuarine reaches. It might be expected that large numbers of anadromous fish would use this stream for spawning (Kristensen *et al.* 2011). However, the overlapping pattern of spawning by anadromous and freshwater-resident fish along the upstream section of Kristensen's sample reach suggests that the energetic costs of anadromous migration were beginning to outweigh the benefits along this section. These results help explain the observation by Kristensen and Closs (2008) of the decline to zero each year of trout densities in the lower reaches of the stream. Anadromous trout spawning in the lower reaches migrate into the area to spawn, while resident trout remain in the upper reaches following spawning, with no major migration undertaken.

The results of these surveys on trout in the Silver Stream demonstrate the importance of the Silver Stream as spawning habitat for Taieri River brown trout.

4.11 Summary of aquatic ecosystems

The Silver Stream catchment has high quality native forest and aquatic communities in its upper reaches. The lower reaches, in the vicinity of Mosgiel and further downstream, have been heavily modified with channelization and construction of high flood banks to prevent flooding of surrounding land. Riparian vegetation is dominated by pasture grass and stream shading is considerably reduced. Instream habitat diversity declines with distance downstream, with riffles, runs and pools in upstream areas but only runs and occasional riffles further downstream. Similarly, bed substrate size decreases, with fine gravels dominant throughout the lower reaches.

Overall, water quality in the lower reaches of the Silver Stream is relatively poor. While dissolved oxygen levels are high and conductivity and nutrient levels are low, faecal contaminant levels often exceed recreational guidelines, with elevated levels under low river flows. During rain events, stormwater discharges contain high faecal contaminant and nutrient levels. Stormwater discharges also contain very high concentrations of cadmium, copper, lead, nickel, and zinc. These contaminants are sourced from industrial land and road runoff.

Aquatic community health is expected to be considerably higher in the forested reserve reaches in the upper catchment than in the lower reaches. Community health decreases downstream with reduced habitat diversity and quality and poorer quality riparian vegetation and water quality. The upper reaches are generally clean of algae, however benthic cyanobacterial blooms have been recorded with increasing frequency in the lower reaches. Benthic macroinvertebrate communities are of high quality in the upper reaches, with high overall diversity and high abundance of mayflies. However, taxonomic diversity and mayfly abundance are reduced in the lower reaches. Macroinvertebrate communities are of high quality in upstream areas, such as at Puddle Alley, but are only of 'fair' to 'poor' quality in the lower reaches. The threatened freshwater crayfish has been found in Whare Creek, a tributary of the upper Silver Stream, but has only been found in the lower reaches at Riccarton Road.

The Silver Stream contains a diverse freshwater fish community, dominated by native longfin eels and common bullies, and the introduced brown trout. The stream provides important spawning and nursery habitats for brown trout. Migratory species, such as inanga and smelt, are in the lower reaches, while lamprey are throughout the stream. The

introduced European perch is also in the lower reaches at Riccarton Road. Giant kokopu are in Silver Stream tributaries, but have not been recorded in the Silver Stream itself for almost 50 years.

4.12 Issues associated with stormwater and wastewater

4.12.1 Stormwater

General

Physical habitat in the Silver Stream has historically been significantly modified. Examples include channel straightening, creation of high flood banks, and removal and modification of riparian vegetation. Flood flows occur regularly in the Silver Stream and are influential in affecting physical habitat. While urban stormwater contributes to these floods, the contribution from Mosgiel is minor compared to the high volumes sourced from the upper catchment. Of more concern are the pollutants carried by the stormwater and their potential effects on water quality and aquatic communities.

Stormwater inputs to the Silver Stream are from pastoral, urban and industrial land. The stormwater contains high faecal contaminant and nutrient levels; high BOD, suspended sediments, and turbidity; and very high concentrations of cadmium, copper, lead, nickel, and zinc.

Nutrients

Nutrient concentrations are relatively low in the Silver Stream itself, but are very high in the stormwater. Ammonia concentrations high enough to have toxic effects have been found in stormwater entering the Silver Stream. While stream water would likely dilute ammonia concentrations, there is the potential for adverse effects on aquatic communities.

Suspended sediments

Suspended sediment levels in stormwater entering the Silver Stream are very high. These particles settle out of suspension onto the bed, with larger, heavier particles settling more quickly than smaller, lighter ones. Sedimentation occurs more rapidly in slower flowing reaches. Excessive sediment loads can affect physical stream characteristics, plants and algae, and invertebrates and fish, as well as human aesthetic, recreational, and spiritual attributes.

Heavy metals

Dissolved metal concentrations are high in the Silver Stream during rainfall events. Contaminant concentrations may only be high for short periods during rain events, however this short-term exposure may have adverse effects on aquatic communities. Heavy metals can contribute to decreased diversity of invertebrate communities, with reduced abundance of more 'sensitive' taxa, such as mayflies, and increased abundance of more 'tolerant' taxa, such as worms. Heavy metal contamination can also affect fish growth.

4.12.2 Wastewater

The Mosgiel Wastewater Treatment Plant has an emergency wastewater overflow to the Silver Stream, which operates for emergency discharges only. Water quality in the Silver Stream, downstream of the emergency wastewater discharge point, is relatively poor. Water quality is especially poor with respect to microbial contamination at low flows. At high flows, levels of bacteria and other contaminants decrease due to dilution, but suspended sediment levels increase. On the infrequent occasions when the wastewater overflow into the Silver Stream is operating (i.e., at periods of very high flows as a result of prolonged rainfall events), dilution factors may be such that the quality of the receiving water will be affected only to a minor extent and for a relatively short duration only. Water in the stream at such times is highly unlikely to be used for either primary or secondary contact recreation and there are unlikely to be abstractions downstream of the discharge point for which water quality may be an issue (e.g., drinking water). Stock may have access downstream, but adverse effects are considered to be no worse than if the discharge were not occurring. Effects on aquatic communities in the Silver Stream would be minimal as the high discharge rate would quickly dilute and transport the contaminants downstream. High ecological values in the Silver Stream catchment are located in the upper reaches and are not affected by emergency wastewater discharges. Consequently, adverse environmental effects in the Silver Stream due to the emergency wastewater discharges would appear to be negligible.

5. Owhiro Stream catchment

5.1 Catchment layout

Owhiro Stream is a small tributary of the Taieri River, joining it on the East Taieri Plain at Allanton (Figure 18). Pastoral land dominates the upper catchment, with the Mosgiel urban area dominating the middle reaches, where the stream is highly modified and has been subjected to channel straightening and bank realignment for flood protection. Pastoral land also dominates the lower catchment, downstream of Mosgiel, where the channel has been straightened. Several tributaries draining the Saddle Hill and Scroggs Hill areas contribute to Owhiro Stream flows in the middle and lower reaches. Pastoral land dominates these tributary catchments, with industrial areas close to Mosgiel.

The ORC regularly undertakes monitoring in Owhiro Stream at Burns Street as part of the SOE programme (Figure 18). Ryder Consulting assessed four sites in the Owhiro Stream in April/May 2011 (Figure 18). The Burns Street and tributary sites are within the Mosgiel urban area; the other two sites are in pastoral areas. The tributary has historically been referred to as ‘Quarry Creek’, ‘Smith Creek’ or incorrectly as ‘Owhiro Stream’.

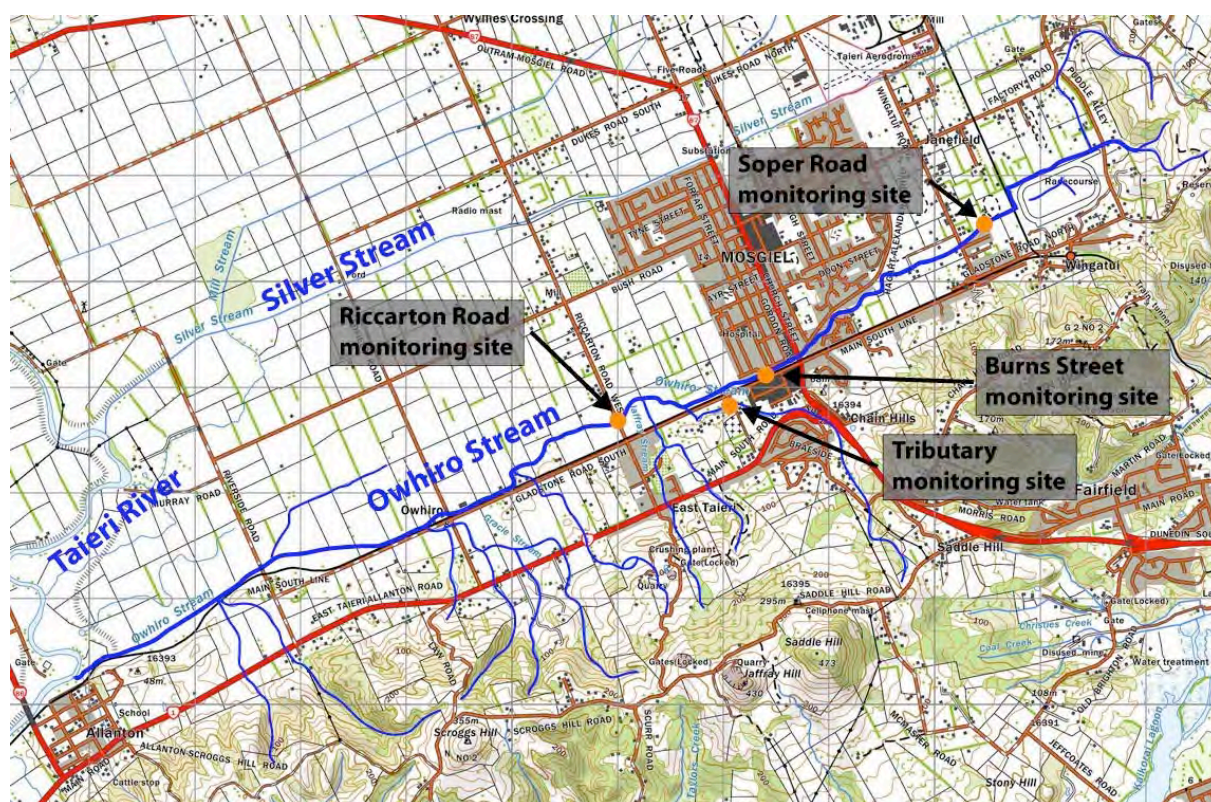


Figure 18 Map showing the Owhiro Stream catchment and monitoring sites. The Burns Street site is used for ORC SOE sampling, and was also used by Ryder Consulting in April/May 2011.

5.2 Natural values (ORC Regional Plan: Water)

According to the ORC Regional Plan: Water for Otago (2004), Owhiro Stream does not contain any significant values.

5.3 Cultural values

The ORC Regional Plan: Water for Otago (2004) identified a variety of mana and access/customary use interests for Owhiro Stream (Table 17). Mana interests involve the notions of guardianship, life force, and treasured interests, which together define the relationship that Kai Tahu have with Owhiro Stream. Access and customary use interests include the provision of food resources, the presence of significant spawning and nursery areas for native birds and/or fish, the location of traditional routes, and sources of weaving materials and medicines (Table 17).

Table 17 Kai Tahu values for Owhiro Stream. Schedule 1D, ORC Regional Plan: Water for Otago (2004).

	Beliefs, values and uses	Explanation
Owhiro Stream		
Mana interests	MA1: Kaitiakitanga	The exercise of guardianship by Kai Tahu in accordance with tikanga Maori in relation to Otago's natural and physical resources; and includes the ethic of stewardship
	MA2: Mauri	Life force; for example the mauri of a river is most recognisable when there is abundance of water flow and the associated ecosystems are healthy and plentiful; a most important element in the relationship that Kai Tahu have with the water bodies of Otago
	MA4: Waahi taoka	Treasured resource; values, sites and resources that are valued and reinforce the special relationship Kai Tahu have with Otago's water resources
Access/customary use interests	MB1: Mahika kai	Places where food is procured or produced
	MB2: Kohanga	Important nursery/spawning areas for native fisheries and/or breeding grounds for birds
	MB3: Trails	Sites and water bodies which formed part of traditional routes
	MB4: Cultural materials	Water bodies that are sources of traditional weaving materials and medicines

A Cultural Health Index (CHI) for streams has been developed by linking Western scientific methods and cultural knowledge about stream health (Tipa and Teirney 2003). The lower Owhiro Stream CHI score was ranked A-0 / 1.75 / 1.65 (Tipa and Teirney 2003), which indicates:

- It is a traditional site (A; versus B for non-traditional).
- Rūnanga members would not return to the site (0; versus 1 for will be used).
- Mahinga kai values are low (1.75; four factors are scored on a 1-5 scale and then averaged), due to:
 - a high score for access, but,
 - the site is so modified there were no mahinga kai species, aside from eel,

- it scores highly because it is traditionally a significant site for eels, and these are still present, but,
- it scores poorly because rūnanga members would not return to the site.
- It scores poorly for stream health (1.65; five factors are scored on a 1-5 scale and then averaged):
 - catchment 1
 - modification 1
 - riparian 1
 - flow visible 4
 - water quality 1.25

5.4 Wetlands (ORC Regional Plan: Water)

Schedule 9 of the ORC Regional Plan: Water for Otago (2004) does not include any wetlands of regional significance in the Owhiro Stream catchment.

5.5 Amenity values

Brown trout have been found in Owhiro Stream (see Section 5.10), however the stream is not popular with anglers. While the Taieri River catchment and the Taieri River itself are popular with anglers, there are no records of angler use in Owhiro Stream (Unwin 2009).

Community groups have strong involvement with Owhiro Stream. In 2010, a 900 m section of the lower Owhiro Stream near Allanton was fenced and planted. The 'Speight's Environmental Fund', private landowners, Fish and Game, the Mosgiel Scout Group, Task Force Green, and the Department of Conservation all contributed to the project. This followed an earlier riparian planting project, initiated by the Taieri Trust in 2003.

Several Mosgiel residents can access the stream banks from their properties. Public access is also available along Hagart-Alexander Drive and Burns Street. Several roads cross Owhiro Stream. The stream is visible from bridges on Puddle Alley, Wingatui Road, Balmoral Avenue, Brookside Place, Gordon Road, Riccarton Road, and Riverside Road.

Additional amenity values specific to the April/May 2011 monitoring sites are described below.

Owhiro Stream at Soper Road

The stream is inaccessible to the public, being contained in an incised channel behind private residential properties or on farmland. The stream is visible at the Wingatui Road bridge. As the stream is on private land, amenity values are limited to viewing from Wingatui Road.

Owhiro Stream at Burns Street

The channel is between roading / private property and railway land. The stream is visible from Gordon Road and from a Burns Street road verge. Railway land is used for bike riding, walking, running and dog exercising, with several small tracks leading to the stream edge and a small footbridge at the end of Burns Street.

Owhiro Stream tributary

The tributary is on private land (East Taieri Presbyterian Church) downstream of Cemetery Road, where two footbridges cross the stream. Pedestrians frequent the footbridge closest to Cemetery Road; the second footbridge is further downstream and appears to have infrequent use. The stream is visible from the Cemetery Road bridge, an adjacent carpark, and from the footbridges. The tributary is contained within primary school grounds (East Taieri School) upstream of Cemetery Road. The channel is fully fenced, with fenced footbridges crossing the stream. School groups may access the stream for studies (e.g., freshwater ecology). The stream is visible from the Cemetery Road bridge, and from the footbridges. The incised nature of the channel and the private land restricts access to the stream.

Owhiro Stream at Riccarton Road

The stream is in an incised channel on private farm land and is visible only from the Riccarton Road bridge; thick hedging is present along both sides of Riccarton Road. Riccarton Road is very narrow and bordered by narrow verges with steep ditches; areas for car parking or pedestrian activities are lacking. As the stream is on private land, amenity values are limited to restricted viewing from Riccarton Road.

5.6 Habitat characteristics

Riparian vegetation and habitat assessments were undertaken in April 2011. Riparian vegetation species lists are in Appendix Two, with habitat assessment data in Appendix Three.

Owhiro Stream at Soper Road

The stream is contained within a deeply incised, straightened channel through private land, downstream of the Wingatui Racecourse (Figure 19). Surrounding land use is pastoral.

Pasture grasses (e.g., cocksfoot) and gorse dominate riparian vegetation along the true left bank, with gum trees and groundcover of exotic grasses, gorse and occasional toetoe along the true right bank. Gorse is a pest species. The gum trees and gorse bushes overhang the channel, providing some shading of the stream bed.

The stream is contained within a 9 to 10 m wide, deeply incised and straightened channel, with 2 to 2.5 m high upper stream banks. The banks are mostly stable, with no bank undercutting observed. The channel has a wetted width of 1 to 2 m, and is between 5 and 20 cm deep (under base flow conditions). Water clarity was moderately high, with some discolouration in the water column. There was evidence of recent high flow events, with damaged vegetation along the lower stream banks.

Runs dominate instream habitat, with occasional shallow riffles. Fine silts and sands dominate bed substrate, with some clay and fine gravels. Bed substrate is highly unstable, with mobile sediments throughout the channel and deep beds of fine sediments (up to 20 cm deep). The aquatic plant monkey musk (*Mimulus guttatus*) is along the edges, with Canadian pondweed (*Elodea canadensis*) beds instream (Figure 19). Water starwort (*Callitriche stagnalis*) is also along the edges and instream. Woody debris (branches and small logs) and leaves are sparse, however moss is absent.



Figure 19 Owhiro Stream at Soper Road.
Top: Assessment site, looking upstream.
Bottom: Beds of *Elodea canadensis* and fine sediments.

Owhiro Stream at Burns Street

The stream sits in an incised, straightened channel in the Mosgiel urban area, and is bordered by railway land and roading (Figure 20). Surrounding land use is urban and industrial.

Exotic grasses (e.g., cocksfoot and tall fescue) dominate riparian vegetation along both banks, with isolated shrubs along the true right bank. Overhanging grasses provide very little shading of the channel.

The stream is contained within a 10 m wide channel with 2 to 3 m high upper stream banks. The banks are mostly stable, with some bank undercutting. On the day of survey (under base flow conditions), the stream had a wetted width of 1 to 2 m and was between 5 and 30 cm deep. Water clarity was moderate, with some discolouration in the water column. There was evidence of a recent high flow event, with damaged vegetation along the lower stream banks.

Runs dominate instream habitat, with occasional shallow riffles. Cobbles dominate bed substrate, with areas of gravels and fine silts and sands in slower flowing areas. Bed substrate appears moderately stable. The aquatic plant monkey musk (*Mimulus guttatus*) is along the edges, with water starwort (*Callitriche stagnalis*) along the edges and instream. Woody debris (branches and small logs) and leaves are sparse, and moss is absent.



Figure 20 *Owhiro Stream at Burns Street, looking upstream.*

Owhiro Stream tributary

The tributary sits in an incised and straightened channel through school grounds and private land and is culverted under Cemetery Road (Figure 21). Surrounding land use is urban and industrial land.

Exotic grasses (e.g., cocksfoot and tall fescue) dominate riparian vegetation along both banks. Poplar trees along the true left bank, and some overhanging grasses, provide limited shading of the channel.

The stream is in a 5 to 6 m wide channel with 2 to 3 m high upper stream banks. The banks are generally stable, with very small areas of undercutting. The stream has a wetted width of 0.8 to 1 m, and is between 20 and 30 cm deep (under base flow conditions). Water clarity was moderate. There was evidence of a recent high flow event, with damaged vegetation along the lower stream banks.

Runs dominate instream habitat, with shallow riffles immediately downstream of the Cemetery Road culvert (where the gradient of the bed was higher). Fine silts and sands dominated bed substrate, with some areas of gravels. Due to the fine nature of the silts,

bed substrate is highly unstable. The aquatic plants monkey musk (*Mimulus guttatus*) and floating sweetgrass (*Glyceria fluitans*) are along the edges of the stream. Water starwort (*Callitriche stagnalis*) and watercress (*Nasturtium microphyllum*) are along the edges and instream. Woody debris (branches and small logs) and leaves are sparse, and moss is absent.



Figure 21 Owhiro Stream tributary.
Top: Assessment site, looking downstream.
Bottom: Beds of aquatic plants, looking upstream.

Owhiro Stream at Riccarton Road

The stream is in an incised channel through farm land (Figure 22). Surrounding land use is pastoral.

Pasture grasses (e.g., perennial rye grass) and thistles dominate riparian vegetation along both banks. Bankside vegetation does not shade the stream, with limited shading from stream banks and a large black poplar tree.

The stream sits in a 4 to 10 m wide strongly sinuous channel, with 3 to 4 m high upper stream banks. The banks are mostly stable, however large areas have slumping and scouring (Figure 22), with bank undercutting also observed. The channel has a wetted width of 0.5 to 5 m, and is between 10 and 100 cm deep (under base flow conditions). Water clarity was moderate, but was discoloured in slower flowing areas. There was evidence of a recent high flow event, with damaged vegetation along the stream banks.

Shallow riffles dominate instream habitat, with short runs and some larger pools (Figure 22). Fine gravels dominate bed substrate, with some areas of silts and sands and some small cobbles. Bed substrate is highly unstable. The aquatic plants monkey musk (*Mimulus guttatus*) and floating sweetgrass (*Glyceria fluitans*) are along the stream edge, with water starwort (*Callitriche stagnalis*) along the edges and instream. Woody debris (branches and small logs) is sparse, with moss and leaves absent.



Figure 22 *Owhiro Stream at Riccarton Road.*
Top: Assessment site, looking downstream.
Bottom: Large pool with erosion of stream bank.

5.7 Water quality

General

Otago Regional Council monitoring at Burns Street found water quality is characterised by high turbidity, suspended sediments and nutrient levels (Table 18). Ammoniacal nitrogen, total nitrogen, dissolved reactive phosphorus and total phosphorus averages are all higher than guideline levels, indicating nutrient enrichment. pH is generally well within the range 6.5 to 9.0, which is typically cited as being appropriate for freshwater bodies of New Zealand (ANZECC 1992) (Table 18). Dissolved oxygen levels are low and often below 80%, which is an acceptable minimum standard for lowland river environments and protects trout, which is the fish species most sensitive to low dissolved oxygen in New Zealand waters (Third Schedule of the Resource Management Act 1991, Dean and Richardson 1999).

Faecal contaminant concentrations are high and often exceed guideline levels for recreational activities. The Ministry for the Environment Action/Red Mode level for *E. coli* is a single sample greater than 550 *E. coli* per 100 mL (Ministry for the Environment 2003). The ORC interprets this such that if this guideline is exceeded there could be a health-risk for swimming. This guideline is regularly exceeded in Owhiro Stream (Table 18). For faecal coliforms, ANZECC and ARMCANZ (2000) states that for primary contact (e.g., swimming) over the bathing season there should not be more than 150 faecal coliform organisms per 100 mL. For secondary contact (e.g., boating, fishing) there should not be more than 1000 faecal coliform organisms per 100 mL. The primary and secondary contact guidelines are regularly exceeded in Owhiro Stream (Table 18). These results indicate that safe recreation in Owhiro Stream is likely to be limited by poor water quality.

Table 18 Water quality parameters for Owhiro Stream measured at Burns Street between October 2001 and June 2010. Data sourced from the ORC. Guideline levels from ANZECC and ARMCANZ (2000), Ministry for the Environment (1992) and Ministry for the Environment (2003). The values shown are the default trigger values for slightly disturbed lowland rivers.

Parameter	Minimum	Maximum	Median	Mean	n	Guideline levels
Temperature (°C)	2.2	22.1	11.6	11.2	58	<15
pH	6.6	9.0	7.3	7.4	54	7.2 – 7.8
Dissolved oxygen saturation (%)	11.3	157.5	79.8	80.2	42	98 – 105
Dissolved oxygen (g/m ³)	1.3	16.1	9.3	9.1	55	–
Conductivity (mS/cm)	0.08	0.395	0.196	0.21	59	0.125 – 0.3 ¹
Turbidity (NTU)	0.95	40	9.8	12.1	59	<5.6
Suspended solids (g/m ³)	1.5	27	7	9.1	47	–
<i>Escherichia coli</i> (mpn/100mL)	5	5700	170	653.1	59	260, 550 ²
Faecal coliforms (cfu/100mL)	6	5000	170	533.9	39	<150, <1000 ³
Ammoniacal Nitrogen (g/m ³)	0.005	0.15	0.03	0.05	59	<0.021, <0.9 ⁴
Nitrite/Nitrate Nitrogen (g/m ³)	0.003	1.47	0.2	0.39	59	<0.444
Total Nitrogen (g/m ³)	0.24	2.77	0.92	1.06	59	<0.614
Dissolved Reactive Phosphorus (g/m ³)	0.003	0.06	0.02	0.025	59	<0.010
Total Phosphorus (g/m ³)	0.04	0.86	0.1	0.13	59	<0.033

1. South-eastern Australian standard for lowland rivers

2. Acceptable/Green Mode: No single sample greater than 260 *E. coli*/100 mL, Alert/Amber Mode: Single sample greater than 260 *E. coli*/100 mL, Action/Red Mode: Single sample greater than 550 *E. coli*/100 mL.

3. <150 (primary contact e.g., swimming), <1000 (secondary contact e.g., boating, fishing)

4. <0.021 = guideline for nutrient enrichment, <0.9 = guideline for ammonia toxicity

Similar water quality conditions were found in April 2011 (Table 19). Dissolved oxygen levels were relatively low, with the highest levels at Burns Street. Dissolved oxygen levels in the tributary and at Riccarton Road were less than 80%, indicating conditions were less than optimal for trout. Conductivity, an indicator of nutrient enrichment, was high, especially in the upper reaches and in the tributary. pH was well within the accepted range. Water temperatures increased downstream, due to reduced bankside shading.

Table 19 Water quality in the Owhiro Stream catchment, March 2011.

Site	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	Conductivity (µS/cm)
Owhiro Stream at Soper Road	7.30	13.5	8.59	82.6	0.25
Owhiro Stream at Burns Street	7.63	13.3	10.23	98.3	0.20
Owhiro Stream tributary	7.45	12.6	7.83	73.7	0.27
Owhiro Stream at Riccarton Road	7.35	12.4	7.20	67.5	0.20

Stormwater inputs

The ORC monitored the ‘first flush’ of stormwater to Owhiro Stream and a receiving tributary (the same tributary assessed in April 2011) in November 2004 and February 2005 during rainfall events. The ‘first flush’ of stormwater generally contains a high pollution load relative to subsequent discharges during a rain event. Note that water quality trigger values and guidelines are usually developed for receiving waters and not for stormwater, hence stormwater quality is not compared to guideline values in this report.

Monitoring was undertaken at a stormwater outfall and in the Owhiro Stream tributary immediately upstream and downstream of the outfall. Biochemical oxygen demand (BOD), a measure of the amount of oxygen consumed by microorganisms in decomposing organic matter in water, was high at each stormwater outfall, and exceeded the Ministry for the Environment guideline of 2 g/m³ at all stream sites (Table 20). Faecal indicator bacteria levels were high at all sites, with particularly high levels in the stream downstream of the stormwater outfalls. For faecal coliforms, the ANZECC and ARMCANZ (2000) primary and secondary contact guidelines were exceeded at all stream sites. Suspended solids and turbidity levels were very high, with turbidity higher than guideline levels in the stream. Nutrient concentrations were also very high at all stream sites and exceeded guideline levels.

Metal and metalloid contaminant concentrations can be compared with ANZECC and ARMCANZ (2000) toxicity trigger values. Protection levels are derived as chemical-specific estimates of contaminant concentrations that should have no adverse effects on aquatic ecosystems. The ‘protection of 95% of species’ level is most commonly applied to ‘slightly–moderately disturbed’ ecosystems (Table 21). ANZECC and ARMCANZ (2000) toxicity trigger values for metals are aimed at protection from sustained exposure (i.e., chronic toxicity), and exposure to stormwater-derived contaminants in stream waters is relatively short. However, short-term exposure to contaminants may have adverse effects on aquatic communities. The guidelines should not be used on a ‘pass’ or ‘fail’ basis (ANZECC and ARMCANZ 2000). If total contaminant concentrations exceed trigger values, further investigation is required to consider the fraction of the contaminant that is bio-available or can be transformed and mobilised in a bio-available form

(ANZECC and ARMCANZ 2000). In this case, the bio-available metal fraction is better represented by the dissolved metal fraction.

In the Owhiro Stream tributary, arsenic and nickel concentrations were generally lower than trigger values, while total cadmium and total lead levels were higher than 95% and 80% trigger values respectively (Tables 20 and 21). However, the bio-available (dissolved) fractions of cadmium and lead remained below all trigger levels. Total and dissolved copper and zinc concentrations were very high in the stormwater and exceeded the 80% trigger values in the tributary (Tables 20 and 21). Lead, copper and zinc are derived from lead-based paints and petrol products, road runoff (from brake linings and tyre wear), copper spouting, and deteriorating zinc-coated, or galvanised, roofs and fences (Suren and Elliot 2004).

Industrial land and roading dominate the tributary catchment. Metal contaminant concentrations in the tributary and the stormwater were very high, with contaminants in the stream water likely sourced from industrial land runoff further upstream.

Table 20

Water quality in the Owhiro Stream tributary and stormwater during rainfall events in November 2004 and February 2005. Data from the ORC. Metals and metalloids: bold values indicate higher than 95% trigger values, shaded values indicate higher than 80% trigger values (Table 21). Other parameters: bold values indicate breached guidelines listed in Table 18. No guideline levels for suspended solids.

	Owhiro Stream tributary					
	November 2004			February 2005		
	Upstream	Stormwater	Downstream	Upstream	Stormwater	Downstream
pH	8.68	7.27	7.24	7.21	6.40	6.87
Conductivity (mS/cm)	0.26	0.13	0.25	0.36	0.08	0.17
Turbidity (NTU)	60	60	75	25	70	50
Suspended solids (g/m ³)	150	270	310	48	360	150
Biochemical oxygen demand (5 day, g/m ³)	24	30	29	12	14	24
<i>Escherichia coli</i> (mpn/100mL)	1100	1600	12100	11900	5200	22800
Faecal coliforms (cfu/100mL)	1400	2000	12000	11900	5000	19800
Ammoniacal Nitrogen (g/m ³)	0.65	0.45	0.33	0.31	0.36	0.73
Nitrite/Nitrate Nitrogen (g/m ³)	1.14	0.53	1.46	1.19	0.34	0.94
Total Nitrogen (g/m ³)	4.68	4.17	4.23	3.43	3.15	4.64
Dissolved Reactive Phosphorus (g/m ³)	0.198	0.302	0.123	0.164	0.152	0.174
Total Phosphorus (g/m ³)	0.516	0.992	0.770	0.406	0.711	0.693
Dissolved Arsenic (g/m ³)	0.002	0.006	0.0005	0.002	0.003	0.002
Total Arsenic (g/m ³)	0.004	0.019	0.005	0.003	0.01	0.004
Dissolved Cadmium (g/m ³)	0.00014	0.00003	0.00003	0.00009	0.00011	0.00008
Total Cadmium (g/m ³)	0.00039	0.00069	0.00049	0.00018	0.00051	0.00039
Dissolved Copper (g/m ³)	0.0202	0.0111	0.0049	0.0127	0.0115	0.0134
Total Copper (g/m ³)	0.0521	0.106	0.0435	0.0214	0.0652	0.0439
Dissolved Lead (g/m ³)	0.0022	0.001	0.0008	0.001	0.0007	0.0025
Total Lead (g/m ³)	0.0234	0.0576	0.0444	0.0122	0.0505	0.0253
Dissolved Nickel (g/m ³)	0.0056	0.0038	0.0021	0.0023	0.0023	0.0029
Total Nickel (g/m ³)	0.01	0.0121	0.0073	0.0034	0.0082	0.0054
Dissolved Zinc (g/m ³)	1.34	1.15	0.154	0.632	0.895	1.31
Total Zinc (g/m ³)	1.95	2.17	1.36	0.835	1.66	1.71

Table 21 ANZECC and ARMCANZ (2000) toxicity trigger values for freshwaters. The 95% trigger values are most commonly applied to ‘slightly–moderately disturbed’ ecosystems.

Metals and Metalloids	Level of protection (% species)	
	95%	80%
Arsenic (g/m ³) ¹	0.013	0.140
Cadmium (g/m ³)	0.0002	0.0008
Copper (g/m ³)	0.0014	0.0025
Lead (g/m ³)	0.0034	0.0094
Nickel (g/m ³)	0.011	0.017
Zinc (g/m ³)	0.008	0.031

1. Trigger values for arsenic are conservative, as arsenic speciation was not determined.

The ORC monitored stormwater inputs to Owhiro Stream at two different outfalls: at Hagart-Alexander Drive and further downstream at the intersection of Gordon Road and Hagart-Alexander Drive. Monitoring was undertaken at the stormwater outfalls and in Owhiro Stream immediately upstream of the outfalls. BOD and faecal indicator bacteria levels were very high, with higher levels in the stream upstream of the stormwater outfalls than in the stormwater (Table 22). BOD levels exceeded Ministry for the Environment guidelines and faecal coliform levels exceeded ANZECC and ARMCANZ (2000) primary and secondary contact guidelines at all stream sites (Table 22). Suspended solids and turbidity levels were very high in the stream and the stormwater, with turbidity higher than guideline levels in the stream. Nutrient concentrations were also very high and exceeded guideline levels in the stream.

Arsenic, cadmium and nickel concentrations in Owhiro Stream were lower than ANZECC trigger values and were also low in the stormwater discharges (Tables 21 and 22). Total and dissolved copper concentrations were very high in the stream and stormwater and exceeded the 80% trigger level in the stream. Total zinc concentrations were also high in the stream and stormwater and exceeded the 80% trigger level in the stream. Dissolved zinc concentrations were high and exceeded the 95% trigger level in all stream samples and exceeded the 80% trigger level in one of the three stream samples. Total lead levels were high in the stream and stormwater and exceeded the 80% trigger

levels in the stream in November 2004 (Tables 21 and 22). However, the bio-available (dissolved) fractions of lead remained below trigger levels (Tables 21 and 22). These metal are all derived from road runoff (from brake linings, tyre wear, and road markings), with lead also derived from lead-based paints and petrol products, and copper and zinc also from spouting and deteriorating zinc-coated, or galvanised, roofs and fences (Suren and Elliot 2004).

Pastoral land dominates the upper catchment, with nutrients and faecal contaminants in Owhiro Stream likely sourced from pastoral land runoff. Wastewater discharges into the stream would also contribute to the elevated levels. Industrial land and roading dominate the catchments drained by the two stormwater outfalls. Metal contaminant concentrations in Owhiro Stream and the stormwater were very high, with contaminants in the stream water likely sourced from industrial land and road runoff further upstream.

Table 22 Water quality in Owhiro Stream and stormwater during rainfall events in November 2004 and February 2005. Hagart-Alexander Drive is upstream of Gordon Road/Hagart-Alexander Drive. Data from the ORC. Metals and metalloids: bold values indicate higher than 95% trigger values, shaded values indicate higher than 80% trigger values (Table 21). Other parameters: bold values indicate breached guidelines listed in Table 18. No guideline levels for suspended solids.

	Owhiro Stream					
	Hagart-Alexander Drive		Gordon Road / Hagart-Alexander Drive			
	February 2005		November 2004		February 2005	
	Upstream	Stormwater	Upstream	Stormwater	Upstream	Stormwater
pH	7.39	6.4	7.21	6.91	7.2	6.5
Conductivity (mS/cm)	0.17	0.05	0.18	0.04	0.24	0.05
Turbidity (NTU)	26	7.9	60	20	20	19
Suspended solids (g/m ³)	55	11	270	69	39	20
Biochemical oxygen demand (5 day, g/m ³)	9	9	13	9	21	7
<i>Escherichia coli</i> (mpn/100mL)	27600	5300	15500	1100	48400	22400
Faecal coliforms (cfu/100mL)	19400	3900	15600	1700	47000	24200
Ammoniacal Nitrogen (g/m ³)	0.28	0.4	0.63	0.64	0.42	0.62
Nitrite/Nitrate Nitrogen (g/m ³)	0.418	0.229	0.957	0.283	0.7	0.255
Total Nitrogen (g/m ³)	1.88	1.46	5.13	1.78	2.89	1.5
Dissolved Reactive Phosphorus (g/m ³)	0.136	0.104	0.078	0.158	0.117	0.15
Total Phosphorus (g/m ³)	0.3	0.167	0.778	0.32	0.299	0.235
Dissolved Arsenic (g/m ³)	0.002	0.0005	0.001	0.0005	0.002	0.0005
Total Arsenic (g/m ³)	0.003	0.0005	0.004	0.002	0.003	0.0005
Dissolved Cadmium (g/m ³)	0.00003	0.00003	0.00003	0.00005	0.00003	0.00006
Total Cadmium (g/m ³)	0.00003	0.00003	0.00012	0.00009	0.00005	0.00008
Dissolved Copper (g/m ³)	0.0043	0.0336	0.0042	0.0143	0.0103	0.0199
Total Copper (g/m ³)	0.0069	0.0398	0.0177	0.0276	0.0149	0.0274
Dissolved Lead (g/m ³)	0.0004	0.0007	0.0009	0.0005	0.0007	0.0008
Total Lead (g/m ³)	0.0047	0.0032	0.0166	0.015	0.0044	0.0076
Dissolved Nickel (g/m ³)	0.0009	0.0011	0.0013	0.001	0.0022	0.0012
Total Nickel (g/m ³)	0.0019	0.0014	0.0046	0.0024	0.0026	0.0018
Dissolved Zinc (g/m ³)	0.027	0.07	0.018	0.28	0.042	0.369
Total Zinc (g/m ³)	0.084	0.08	0.262	0.358	0.073	0.428

5.8 Aquatic plants

The ORC collect periphyton samples for analysis of algae taxonomic composition. The periphyton community at Burns Street is generally dominated by filamentous green and red algae (Table 23). The filamentous algae taxa are commonly found in a range of conditions, from clean rivers (e.g., *Audouinella*, *Microspora*) to nutrient enriched rivers (e.g., *Cladophora*, *Oedogonium*, *Rhizoclonium*) (Biggs and Kilroy 2000, Moore 2000). Many of these taxa can form large blooms under stable flow conditions in summer and autumn. Diatoms are also present, comprising taxa commonly found in lowland streams throughout New Zealand (e.g., *Rhoicosphenia*, *Synedra*) (Table 23).

Table 23 Periphyton taxa found during ORC SOE monitoring in Owhiro Stream, 2007-2009. Relative abundance of each taxa was scored using the scheme of Biggs and Kilroy (2000), which scores taxa from 1 (rare) to 8 (absolutely dominant/monoculture).

	Owhiro Stream @ Burns Street		
	2007	2008	2009
Filamentous Green Algae			
<i>Cladophora</i>		5	6
<i>Microspora</i>	3		6
<i>Oedogonium</i>			3
<i>Rhizoclonium</i>		4	
<i>Ulothrix</i>			3
Filamentous Yellow-Green Algae			
<i>Tribonema</i>	3		
Filamentous Red Algae			
<i>Audouinella</i>	5		
Filamentous Diatoms			
<i>Melosira</i>		2	
Diatoms			
<i>Frustulia</i>	2		
Naviculoid diatom			3
<i>Rhoicosphenia</i>	3	5	2
<i>Synedra</i>			3

Most of the stream bed was unsuitable for supporting diverse benthic algal communities in April 2011, due to the dominance of fine and mobile bed substrates. Benthic algae were not visible at Soper Road. Faster flowing areas at Burns Street, where a bed of cobbles and gravels was more common, supported filamentous algae (e.g., *Oedogonium*, *Audouinella*) and diatoms (Table 24). Long filamentous algae covered between 30 and 80% of the bed on the larger substrates, while slower flowing areas with fine sediments did not harbour any benthic algae. The tributary site supported some short filamentous algae on gravel substrate at the upstream end of the site. However, the community was

dominated by the diatom *Rhoicosphenia*, which is commonly found in small lowland streams and attached to aquatic plants (Biggs and Kilroy 2000, Moore 2000). Occasional diatom mats were observed at Riccarton Road.

Table 24 *Periphyton taxa found in the Owhiro Stream catchment, April 2011. Relative abundance of each taxa was scored using the scheme of Biggs and Kilroy (2000), which scores taxa from 1 (rare) to 8 (absolutely dominant/monoculture).*

	Owhiro Stream at Soper Road	Owhiro Stream at Burns Street	Owhiro Stream tributary	Owhiro Stream at Riccarton Road
Filamentous Green Algae				
<i>Cladophora</i>		3		
<i>Oedogonium</i>		8		
Filamentous Red Algae				
<i>Audouinella</i>		5	3	1
Filamentous Diatoms				
<i>Melosira</i>		3	3	
Diatoms				
Naviculoid diatom		2		
<i>Nitzschia</i>		4		
<i>Rhoicosphenia</i>		4	6	
<i>Synedra</i>		5		1

The aquatic plants monkey musk (*Mimulus guttatus*) and water starwort (*Callitriche stagnalis*) were at each of the April 2011 sites. Submerged beds of Canadian pondweed (*Elodea canadensis*) were at Soper Road, while floating sweetgrass (*Glyceria fluitans*) was in the Owhiro Stream tributary and at Riccarton Road. Watercress (*Nasturtium microphyllum*) was also in the Owhiro Stream tributary. These aquatic plants are all exotic species.

5.9 Benthic macroinvertebrates

Otago Regional Council macroinvertebrate monitoring at Burns Street found the community dominated by taxa typically found in streams with poor water quality and habitat with soft-bottomed areas, dominated by fine sediments. Dominant taxa included oligochaete worms, *Potamopyrgus* snails, midge larvae (e.g., Orthocladiinae) and crustaceans (e.g., ostracods) (Table 25). While Owhiro Stream at Burns Street is dominated by cobbles, finer substrates (e.g., fine silts and sands) are abundant and will also influence invertebrate community composition.

Table 25 Macroinvertebrate taxa in samples collected during ORC SOE monitoring in Owhiro Stream, 2003 - 2009. Coded abundance scores after Stark (1998).

TAXON	MCI-sb score	Owhiro Stream at Burns Street					
		2003	2004	2004	2007	2008	2009
ACARINA	5.2			C			
CNIDARIA							
<i>Hydra</i> species	1.6			A			
COLEOPTERA							
<i>Rhantus pulverosus</i>	1.0	R	R	R			
CRUSTACEA							
<i>Chiltonia</i> species	5.5			C			
Cladocera	0.7		VVA	VVA			R
Copepoda	2.4			VVA			
Ostracoda	1.9	VA	VVA	VA	A	VA	VA
<i>Paracalliope fluviatilis</i>	5.5		R	R		A	R
DIPTERA							
<i>Austrosimulium</i> species	3.9		R	R	A		
Chironominae	3.8	A					
<i>Chironomus zealandicus</i>	3.4	R	VA	R			
Muscidae	1.6						C
Orthoclaadiinae	3.2	VA	VVA	VA	VA	C	R
HEMIPTERA							
<i>Anisops</i> species	2.2			R			
<i>Sigara</i> species	2.4		VA	VA			R
MOLLUSCA							
<i>Gyraulus</i> species	1.7						R
Lymnaeidae	1.2			R			
<i>Physella</i> species	0.1	VA	A	VA	A	A	A
<i>Potamopyrgus antipodarum</i>	2.1	VVA	VVA	VVA	A	VVA	VVA
Sphaeriidae	2.9	VA	A	A		C	A
ODONATA							
Anisoptera	6.0						R
<i>Xanthocnemis zealandica</i>	1.2	R	R	A			
OLIGOCHAETA	3.8	VVA	VVA	VVA	VVA	VA	VVA
PLATYHELMINTHES	0.9						R
TRICHOPTERA							
Hydrobiosidae early instar	6.7				C		
<i>Oxyethira albiceps</i>	1.2		R				R
<i>Triplectides</i> species	5.7			R			R
Number of taxa		10	14	20	7	7	15
Number of EPT taxa		0	1	1	1	0	2
MCI-sb score		47	48	56	62	56	53
SQMCI-sb score		2.7	2.4	2.2	3.5	2.4	2.8

The highest quality invertebrate community was at Soper Road in April 2011, where amphipods and snails dominated the community (Table 26). Community composition at Burns Street was similar to ORC SOE results, with ostracods, orthoclad midges, snails and worms. Invertebrate communities in the tributary and at Riccarton Road were similar to those at Burns Street.

Freshwater crayfish (*Paranephrops zealandicus*) were found at Soper Road in April/May 2011. The Department of Conservation, using the ‘threat of extinction’ classification (Molloy *et al.* 2002), has listed freshwater crayfish as ‘chronically threatened - gradual decline’ (Hitchmough *et al.* 2007).

Table 26 Macroinvertebrate taxa in samples collected in the Owhiro Stream catchment, April 2011. Coded abundance scores after Stark (1998).

TAXON	MCI-sb score	Owhiro Stream at Soper Road		Owhiro Stream at Burns Street		Owhiro Stream tributary		Owhiro Stream at Riccarton Road	
		1	2	1	2	1	2	1	2
CRUSTACEA									
Ostracoda	1.9			VA	VA	VA	VA	A	A
<i>Paracalliope fluviatilis</i>	5.5	VVA	VVA		C		R	A	A
<i>Paraleptamphopus</i> species	5.5	VVA	VA						
<i>Paranephrops zealandicus</i>	8.4	R							
<i>Phreatoicus typicus</i>	4.5	A	C	C	C				
DIPTERA									
<i>Chironomus zealandicus</i>	3.4			C		C			
Muscidae	1.6				C		C	C	
Orthoclaadiinae	3.2		C	VA	A	C	C	A	A
<i>Paralimnophila skusei</i>	7.4	R	C						
Stratiomyidae	4.2				R				
HIRUDINEA	1.2			C	R				
MOLLUSCA									
Lymnaeidae	1.2		C	VVA	VA	A	VA	VVA	VA
<i>Potamopyrgus antipodarum</i>	2.1	A	VVA	VVA	VVA	A	VA	VVA	VVA
Sphaeriidae	2.9	A	VA	VVA	VA	A	VA	C	A
OLIGOCHAETA	3.8	A	VA	VVA	VVA	VVA	VVA	VA	VVA
PLATYHELMINTHES	0.9	C		R		C			
TRICHOPTERA									
<i>Hudsonema amabile</i>	6.5							R	C
<i>Oxyethira albiceps</i>	1.2						C		
<i>Pycnocentroides</i> species	3.8								C
Number of taxa		9	9	10	11	8	9	9	9
Number of EPT taxa		0	0	0	0	0	1	1	2
MCI-sb score		91	80	50	58	49	52	64	69
SQMCI-sb score		5.3	3.9	2.5	2.8	3.3	3.0	1.9	2.9
Average MCI-sb score		86		54		50		66	
Average SQMCI-sb score		4.6		2.6		3.2		2.4	

Taxonomic diversity is highly variable at Burns Street, with between seven and twenty different taxa (Figure 23). Diversity is similarly low at the three other April 2011 sites. Taxonomic diversity in Owhiro Stream is generally considerably lower than the median of 18 taxa per site found by Scarsbrook *et al.* (2000) in a nation-wide assessment of 66 long-term monitoring sites located throughout New Zealand.

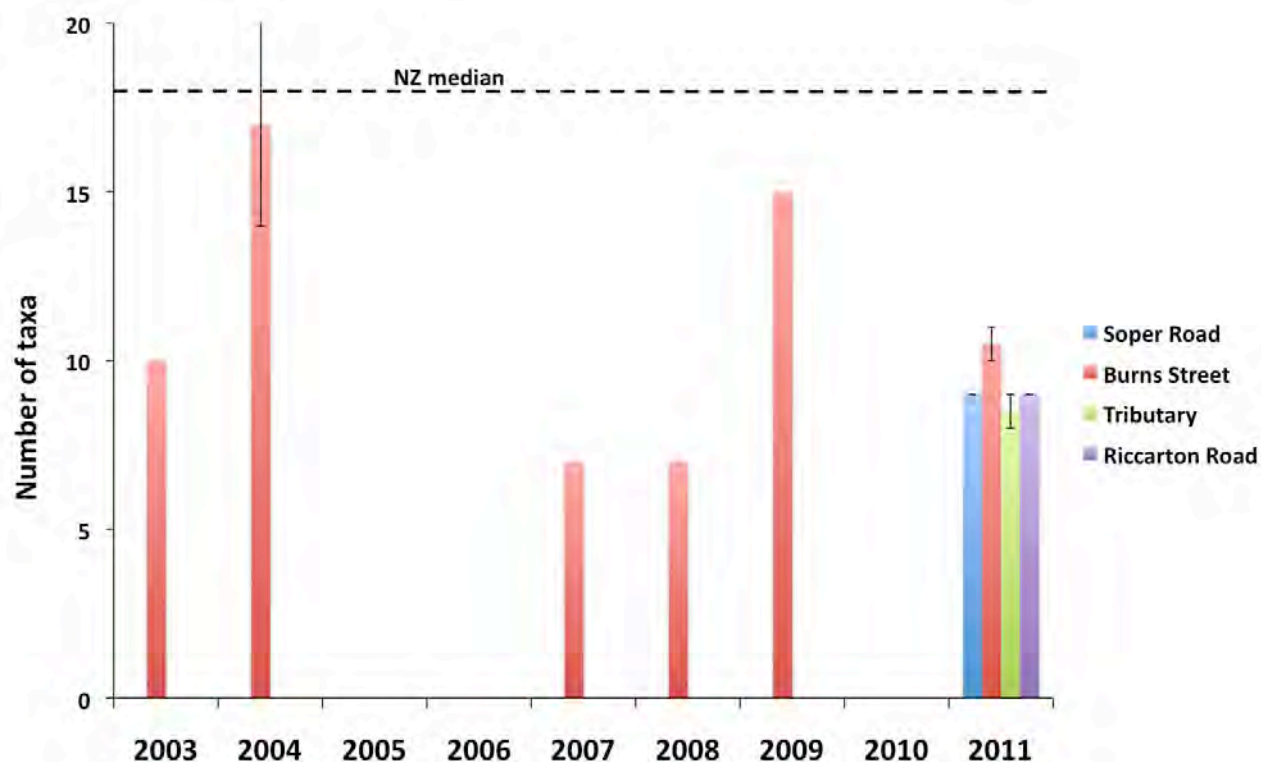


Figure 23 Diversity of the macroinvertebrate community in the Owhiro Stream catchment. Data from ORC SOE monitoring (2003-2009) and Ryder Consulting (2011). The dashed line indicating the New Zealand median of 18 taxa per site is from Scarsbrook et al. (2000). Note that samples were not collected in 2005, 2006 and 2010. Where more than one sample was collected, averages are presented with error bars of +/- one standard error.

The number of EPT taxa (invertebrates typically indicative of higher water quality, e.g., mayflies) is very low, with between zero and two taxa (Figure 24). EPT taxa are typically found in hard-bottomed streams with high water quality, and not in areas dominated by soft sediments, such as in the Owhiro Stream catchment. Diversity of EPT taxa is considerably lower than the median of 8 taxa per site determined by Scarsbrook *et al.* (2000) from their national assessment.

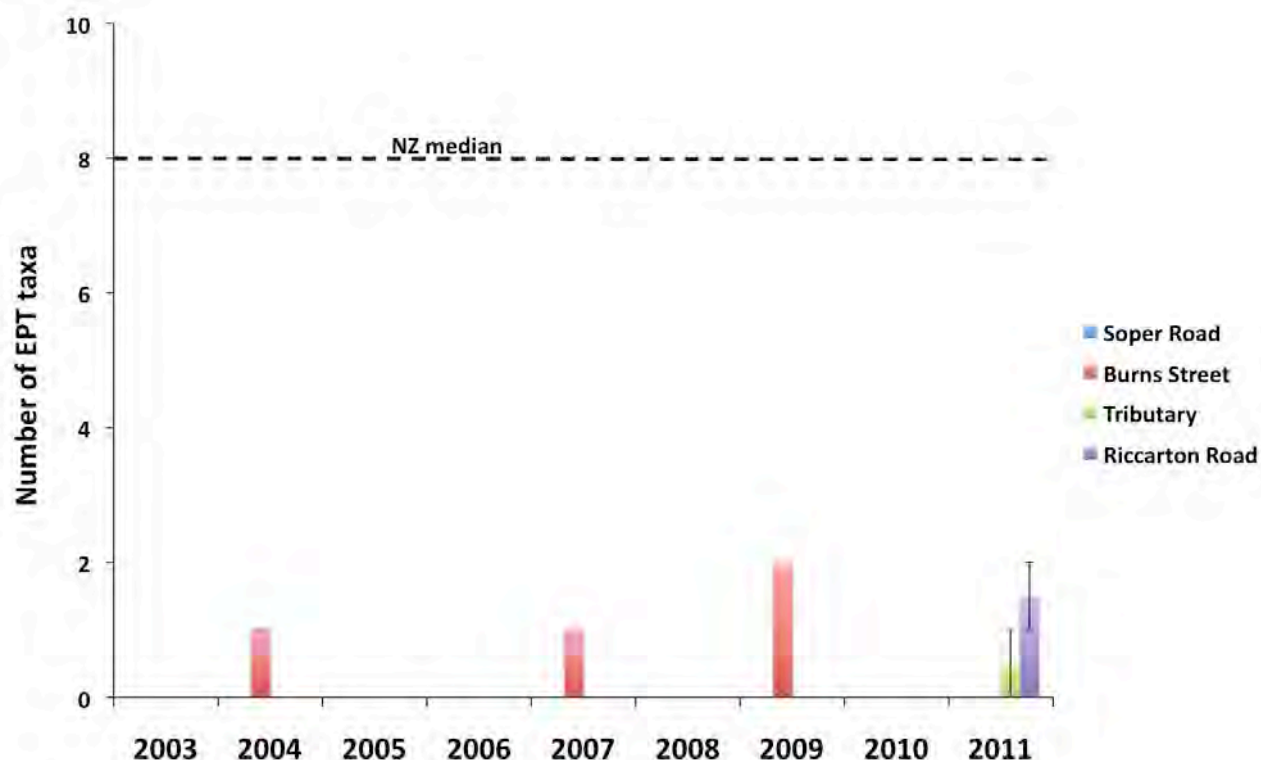


Figure 24 Diversity of EPT taxa in the Owhiro Stream catchment. Data from ORC SOE monitoring (2003-2009) and Ryder Consulting (2011). The dashed line indicating the New Zealand median of 8 EPT taxa per site is from Scarsbrook et al. (2000). Note that samples were not collected in 2005, 2006 and 2010. Where more than one sample was collected, averages are presented with error bars of +/- one standard error.

Macroinvertebrate community health index scores (SQMCI-sb; low scores represent 'probable severe pollution' and high scores represent very 'clean' conditions) are very low. Scores are indicative of 'poor' water quality, except at Soper Road where scores are indicative of 'fair' water quality (Figure 25), using the narrative terminology of Stark and Maxted (2007).

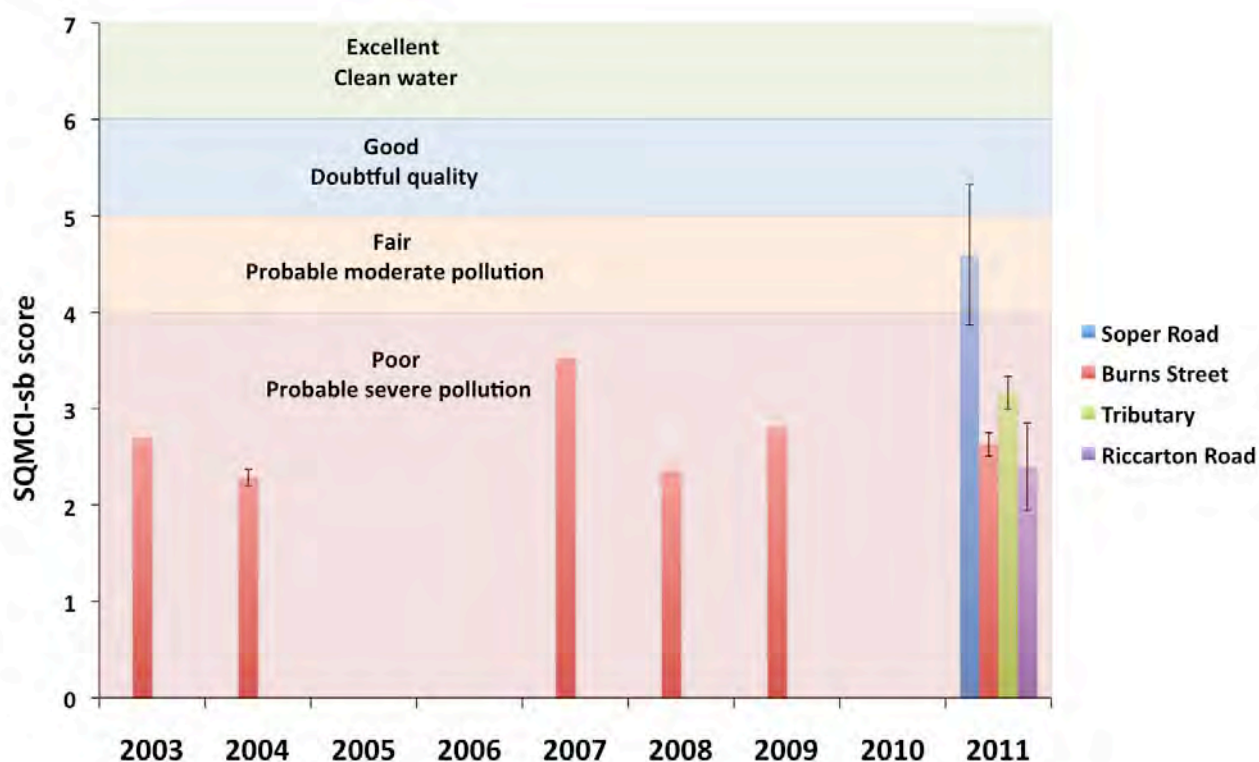


Figure 25 SQMCI-sb scores in the Owhiro Stream catchment. Data from ORC SOE monitoring (2003-2009) and Ryder Consulting (2011). Quality classes from Boothroyd and Stark (2000) and Stark and Maxted (2007). Note that samples were not collected in 2005, 2006 and 2010. Where more than one sample was collected, averages are presented with error bars of +/- one standard error.

5.10 Fish

An examination of the New Zealand Freshwater Fish Database (NZFFD) revealed twelve fish surveys have been undertaken in Owhiro Stream between 1999 and 2007. Additional surveys have been undertaken in 1999 (University of Otago survey, reported in David *et al.* (2002)) and April/May 2011 (Ryder Consulting survey). Four native fish species and two exotic fish species have been found in the stream (Table 27, Figure 26).

Table 27 List of fish species identified as being present in the Owhiro Stream catchment.

Species	Common Name	Native	Migratory
<i>Anguilla dieffenbachii</i>	Longfin eel	Y	Y
<i>Galaxias argenteus</i>	Giant kokopu	Y	Y/N
<i>Galaxias maculatus</i>	Inanga	Y	Y
<i>Gobiomorphus cotidianus</i>	Common bully	Y	Y/N
<i>Perca fluviatilis</i>	European perch	N	N
<i>Salmo trutta</i>	Brown trout	N	Y/N

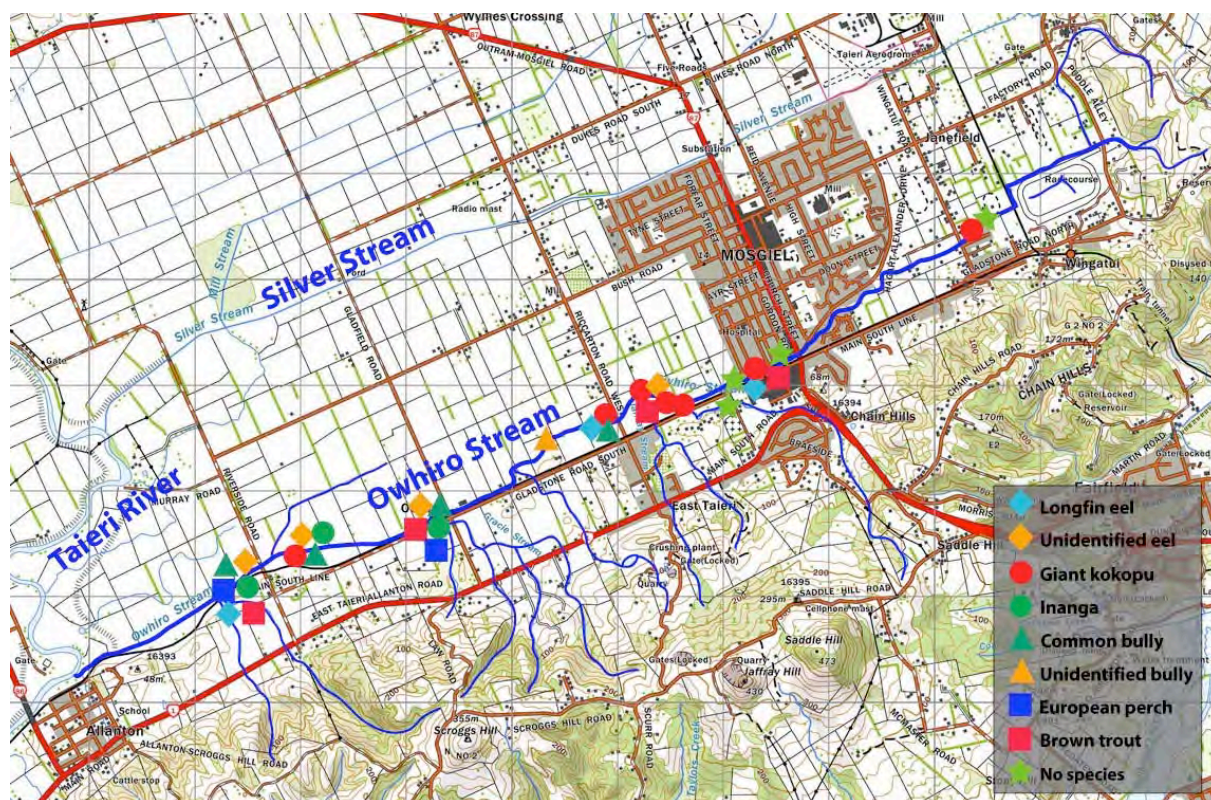


Figure 26 Fish distribution records in the Owhiro Stream catchment. Sourced from NZFFD, David et al. (2002) and Ryder Consulting April/May 2011 survey.

Longfin eels, giant kokopu and brown trout have been found throughout the stream (Figure 26). Common bullies, European perch and inanga have only found in the lower reaches.

The April/May 2011 fish survey found low diversity overall, with the only fish found at Burns Street and Riccarton Road (Table 28). Freshwater crayfish were found throughout the Soper Road area. Giant kokopu, longfin eels and brown trout were found at Burns Street and at Riccarton Road, with common bullies also at Riccarton Road (Table 28, Figure 27). The giant kokopu at Burns Street was heavily gravid (carrying eggs internally) (Figure 27).

Table 28 *Number and length range (mm, in brackets) of native fish caught/observed in Owhiro Stream and tributary, April/May 2011.*

Site	Longfin eel	Giant kokopu	Common bully	Brown trout
Owhiro Stream at Soper Road	–	–	–	–
Owhiro Stream at Burns Street	4 (230--700mm)	1 (262mm)	–	1 (~120mm)
Owhiro Stream tributary	–	–	–	–
Owhiro Stream at Riccarton Road	4 (200-800mm)	1 (258mm)	2 (54-96mm)	–



Figure 27 Fish species caught in Owhiro Stream, April 2011.
Top left: Gravid giant kokopu at Burns Street.
Top right: Common bully at Riccarton Road.
Bottom left: Giant kokopu at Riccarton Road.
Bottom right: Longfin eel at Riccarton Road.

A threat ranking process has recently (June 2009) been applied to New Zealand freshwater fish (Allibone *et al.* 2010). These rankings supersede the rankings conducted under the system of Molloy *et al.* (2002), as listed in Hitchmough (2002) and Hitchmough *et al.* (2007). Under the new ranking system, longfin eel, giant kokopu and inanga are classified as ‘declining’, with the qualifier of ‘partial decline’ for giant kokopu and ‘conservation dependent’ and ‘data poor’ for inanga (Allibone *et al.* 2010).

Electric fishing at Burns Street in 2008 by ORC, as part of the SOE monitoring programme, found only longfin eels.

A University of Otago study used spotlighting to investigate fish communities in eight small streams feeding the lower Taieri and Waipori Rivers (David *et al.* 2002). Owhiro

Stream had one of the least diverse fisheries of the streams surveyed, with only four species found (Table 29). The stream with the highest diversity had eight species (Cullens Creek, a tributary of the Waipori River). Owhiro Stream also had the lowest fish densities with 39.6 fish/km, as compared to Picnic Gully (a tributary of the lower Taieri River) and Lee Creek (a tributary of the Waipori River) with 228.3 fish/km in each (David *et al.* 2002).

Table 29 *Total distance of Owhiro Stream surveyed by spotlight and the estimated abundance fish per km of stream. Data from David et al. (2002). Note eels were unable to be identified to species level.*

	Owhiro Stream
Total distance (m)	3586
<i>Galaxias argenteus</i> (Giant kokopu)	3.6
<i>Anguilla australis</i> and <i>Anguilla dieffenbachii</i> (Eel)	2.5
<i>Gobiomorphus cotidianus</i> (Common bully)	32.3
<i>Galaxias maculatus</i> (Inanga)	1.1
Total fish/km	39.6

An isolated population of giant kokopu was discovered in a short, unchannelised reach upstream of Riccarton Road (Figure 28) (David *et al.* 2002). An individual giant kokopu was also found in the upper reaches of the stream, near Soper Road (Figure 28). Most of the giant kokopu were in the 21-25cm size class, with few less than 11cm long (Figure 29). In the eight streams surveyed, about half of all recorded giant kokopu were larger than 15cm, of which >25% were larger than 20cm (David *et al.* 2002). The giant kokopu population in Owhiro Stream appeared to have poor recruitment and, coupled with the isolated and fragment distribution, may be vulnerable to extirpation (local extinction) in the future (David *et al.* 2002).

Fig. 2 (continued)



Figure 28 Longitudinal distribution of giant kokopu and brown trout in Owhiro Stream. NS = not surveyed. SF = spring fed. Each point along stream represents a record of an individual fish. From David et al. (2002).

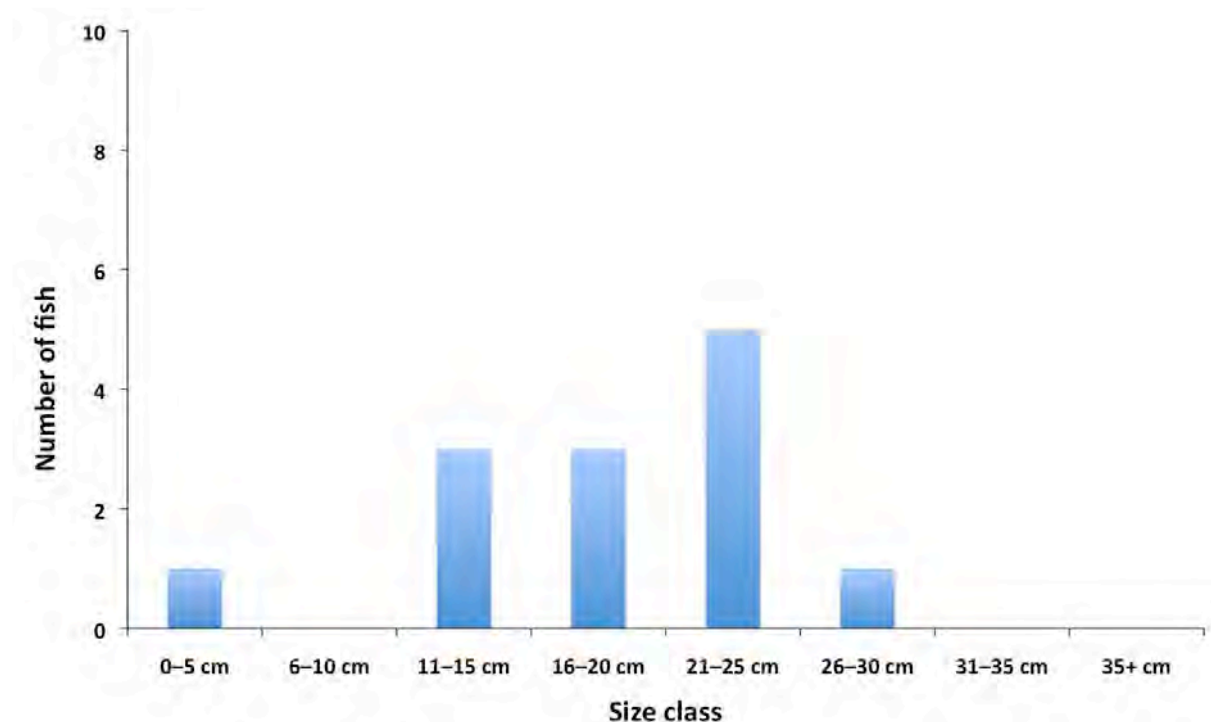


Figure 29 Number of giant kokopu recorded within each size (total length) category in Owhiro Stream. Data from David et al. (2002).

Another University of Otago study, in 2002-2003, used spotlighting and three-pass electrofishing in lower Taieri River tributaries (Silver Stream, Lee Creek and Owhiro Stream) (Hickey and Closs 2006). Owhiro Stream was re-sampled at the same sites as those surveyed in 1999 by David *et al.* (2002). Similar diversity of fish fauna was found.

5.11 Summary of aquatic ecosystems

The Owhiro Stream catchment has pastoral land in both the upper and lower reaches, with the Mosgiel urban area and industrial land dominating the middle reaches. The stream has been straightened, with few naturally sinuous sections, and is incised. Riparian vegetation is generally restricted to pasture and exotic grasses, and consequently shading of the stream is limited. Instream habitat diversity is low, and is dominated by runs; occasional shallow riffles and deeper pool sections are also present. Bed substrate is highly unstable and is dominated by soft sediments, with occasional gravels in riffle sections.

Overall, water quality throughout Owhiro Stream is poor. Dissolved oxygen levels are low, concentrations of suspended sediments are high and nutrient concentrations (nitrogen and phosphorus) are higher than guideline levels. Faecal contaminant levels are also high and often exceed recreational guidelines. During rain events, stormwater discharges contain high faecal contaminant and nutrient levels. These contaminants are sourced from pastoral land runoff. Wastewater discharges would also contribute to the elevated levels. Stormwater discharges also contain very high concentrations of cadmium, copper, lead, and zinc. These contaminants are sourced from industrial land and road runoff.

Aquatic community health is low throughout the catchment. Aquatic plant communities are generally restricted to exotic plants on the stream bed and along the edges. Algal communities are restricted to sparse diatom mats and filamentous algae. The fine and mobile bed substrates throughout Owhiro Stream are generally unsuitable for supporting diverse benthic algal communities. Benthic macroinvertebrate communities are of low quality throughout the stream, and are generally dominated by taxa typically found in streams with poor water quality, or in habitat dominated by soft sediments. Both of these conditions are found in Owhiro Stream. Macroinvertebrate community health is of 'fair' to 'poor' quality. The threatened freshwater crayfish has only been found in the upper reaches of Owhiro Stream.

Owhiro Stream contains a freshwater fish community with very low diversity and densities. Longfin eels and brown trout have been found in the lower reaches to Mosgiel, while European perch, inanga and common bullies have only been found downstream of Mosgiel. No fish have been detected in the Owhiro Stream tributary. Giant kokopu have been found throughout Owhiro Stream, with the largest populations downstream of Mosgiel, and an isolated individual in the upper reaches, near Soper Road. However, the giant kokopu population has a fragmented distribution and appears to have poor recruitment; these factors increase the vulnerability of this native fish to disturbance.

5.12 Issues associated with stormwater and wastewater

5.12.1 Stormwater

General

Physical habitat in Owhiro Stream has historically been significantly modified. Examples include channel straightening, and removal and modification of riparian vegetation. Flood flows occur regularly in Owhiro Stream and are influential in affecting physical habitat: considerable erosion of the Owhiro Stream banks was observed at Riccarton Road. High volumes of stormwater contribute to these floods. During high rainfall events, the volume of stormwater input may be greater than that in the stream at that point. Of particular concern are the pollutants carried by the stormwater and their potential effects on water quality and aquatic communities.

Stormwater inputs to Owhiro Stream are from pastoral, urban and industrial land. The stormwater contains high faecal contaminant and nutrient levels; high BOD, suspended sediments, and turbidity; and very high concentrations of cadmium, copper, lead, and zinc. In addition, litter was observed throughout the stream at Burns Street.

Nutrients

Nutrient concentrations are high in the Owhiro Stream catchment and exceed guideline levels under low flows. Nutrient concentrations are also high in the stormwater. High nutrient levels can contribute to increased growth of algae and macrophytes.

Suspended sediments

Suspended sediment levels in Owhiro Stream are very high. These particles settle out of suspension onto the bed, with larger, heavier particles settling more quickly than smaller, lighter ones. Sedimentation occurs more rapidly in slower flowing reaches. Excessive

sediment loads can affect physical stream characteristics, plants and algae, and invertebrates and fish, as well as human aesthetic, recreational, and spiritual attributes.

Heavy metals

Dissolved metal concentrations are high in the Owhiro Stream catchment during rainfall events. Contaminant concentrations may only be high for short periods during rain events, however this short-term exposure may have adverse effects on aquatic communities. Heavy metals can contribute to decreased diversity of invertebrate communities, with reduced abundance of more 'sensitive' taxa, such as mayflies, and increased abundance of more 'tolerant' taxa, such as worms. Heavy metal contamination can also affect fish growth.

5.12.2 Wastewater

High levels of faecal contaminants and nutrients have been found in Owhiro Stream. These contaminants are likely sourced from runoff from pastoral land, but also from wastewater overflows. Three wastewater pumping stations in the Mosgiel area have emergency overflows which discharge to Owhiro Stream: in a tributary channel near Wingatui Racecourse, at Wingatui Road, and on Gladstone Road North near Irwin Logan Drive.

Water quality in Owhiro Stream downstream of the emergency wastewater discharge points is poor with respect to microbial contamination, even at low flows. However, microbial contamination is worse at high flows, as a result of rainfall events. For example, the maximum *E. coli* level found at Burns Street during ORC water quality monitoring, which is generally undertaken under low flow conditions, is 5700 mpn/100mL. The maximum concentration of faecal coliforms is 5000 cfu/100mL. Water quality sampling during rainfall events found a maximum *E. coli* level in Owhiro Stream just upstream of Gordon Road of 48400 mpn/100mL and the maximum faecal coliform concentration was 47000 cfu/100mL. These very high levels in Owhiro Stream were found upstream of stormwater outfalls, and were thus sourced from higher in the catchment. The presence of three wastewater overflows, which only operate during high rainfall events, may have contributed to these high faecal contaminant levels.

While faecal contamination is high during rainfall events, water in the stream at such times is highly unlikely to be used for either primary or secondary contact recreation. The

high contaminant levels under low flow conditions, which often exceed recreational contact guidelines, also indicate that the stream is not suitable for recreation.

6. Overall summary and catchment comparison

The Silver Stream has a relatively unmodified channel in its upper reaches, but is confined between high, man-made flood banks in the lower reaches. Water quality in the lower reaches is relatively poor, with high faecal contaminant levels but low nutrient levels. Dissolved oxygen levels are high. Rainfall events contribute high contaminant levels via stormwater, however dilution in the stream is high due to high flow rates, and higher quality water from the upper catchment. Macroinvertebrate communities are of high quality in upstream areas, but decline in quality downstream. The fish community is very diverse, with the stream providing important spawning and nursery habitats for brown trout, as well as several migratory native fish, including lamprey.

Overall, water and habitat quality, and the quality of aquatic communities, in Owhiro Stream are more degraded than in the Silver Stream. Owhiro Stream is generally confined within an incised channel that runs through pastoral, urban and industrial land. Water quality is poor, with high contaminant concentrations, especially during high rainfall events. Stormwater and emergency wastewater discharges to Owhiro Stream contribute to high contamination levels. There is less dilution available in Owhiro Stream compared with the Silver Stream, due to Owhiro having a much smaller catchment, and Owhiro catchment is entirely modified for urban and farm land use activities. In contrast, the Silver Stream receives the bulk of its flow from the upper, native forest dominated catchment, which yields far less contaminants.

Stormwater runoff from Mosgiel contributes to rapid changes in the flow of Owhiro Stream during rain events, and this disturbs the local stream bed and banks. Macroinvertebrate communities in Owhiro Stream are of poor quality, and are influenced by the bed substrate composition (predominantly fine sediments) and elevated contaminant concentrations. The Owhiro Stream fish community has very low diversity, with few fish found in the Mosgiel area.

Using a system of 'poor', 'good' and 'excellent', the overall quality of the different habitat features and aquatic ecosystems of the two catchments have been interpreted relative to each other (Table 30). This interpretation is based on information summarised in this report.

Table 30 *Habitat and ecosystem quality in the Owhiro Stream and Silver Stream catchments. Values are ‘poor’, ‘good’ and ‘excellent’.*

	Owhiro Stream	Silver Stream
Riparian vegetation	Poor	Poor
Bank stability	Poor	Good
Flow variability	Poor	Good
Bed substrate	Poor	Good
Instream cover	Poor	Poor
Water quality	Poor	Good
Invertebrates	Poor	Good
Fish	Poor	Excellent

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Appendix One

Invertebrate data summaries and metric calculations

Invertebrate abundance data was converted into coded abundance scores using the codes established by Stark (1998) (Table A1.1).

Table A1.1 *Coded abundance scores used to summarise macroinvertebrate data (after Stark 1998).*

Abundance	Coded Abundance	Weighting factor
1 - 4	Rare (R)	1
5 - 19	Common (C)	5
20 - 99	Abundant (A)	20
100 - 499	Very abundant (VA)	100
> 500	Very very abundant (VVA)	500

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: Reflects health of the community through a measurement of the variety of the taxa present. Taxonomic richness generally increases with increasing water quality, habitat diversity, and habitat stability.

Ephemeroptera, Plecoptera and Trichoptera index (EPT): These insect groups are generally dominated by ‘pollution sensitive’ taxa. In stony bed rivers, this index usually increases with higher water quality and greater habitat diversity.

Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table A1.2), for example, a low site score (e.g., 40) represents ‘probable severe pollution’ and a high score (e.g., 140) represents very ‘clean’ conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Abundance of all taxa is recorded using a five-point scale (i.e., rare = 1-4 animals per sample, common = 5-19, abundant = 20-99, very abundant = 100-499, very very abundant = >500). As for MCI, SQMCI scores can be interpreted in the context of national standards (Table A1.2).

$$\text{SQMCI} = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Macroinvertebrate Community Index for soft-bottomed streams (MCI-sb) and semi-quantitative MCI for soft-bottomed streams (SQMCI-sb) (Stark and Maxted 2007): These biotic indices have recently been developed specifically for use in soft-bottomed streams. The original MCI and SQMCI were developed for use in hard-bottomed streams based on sampling macroinvertebrates from riffle or run habitats, however their use has often been extended through a wide range of habitats including soft-bottomed areas. The soft-bottomed indices use the same principles as the hard-bottomed MCI and SQMCI indices, however new taxon-specific tolerance scores (between 1 and 10) have been derived specifically for soft-bottomed streams (Stark and Maxted 2007).

MCI-sb and SQMCI-sb are calculated using the same formulae as for the hard bottomed indices (see above). As for MCI and SQMCI, MCI-sb and SQMCI-sb scores can be assigned into classes corresponding to different levels of organic pollution (enrichment) (Table A1.2).

Table A1.2 Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).

Quality Class A	Quality Class B	MCI, MCI-sb	SQMCI-sb
Clean water	Excellent	> 120	> 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

Appendix Two

Riparian vegetation data

Note: **Bold** listings indicate abundant taxa. Weed status from Weedbusters (www.weedbusters.org.nz).

Silver Stream at Puddle Alley

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Acer pseudoplatanus</i>	sycamore	Y	Pest plant
<i>Alnus glutinosa</i>	common alder	Y	
<i>Aristotelia serrata</i>	makomako, wineberry		
<i>Coprosma lucida</i>	karamu		
<i>Cytisus scoparius</i>	broom	Y	Pest plant
<i>Fuchsia excorticata</i>	kotukutuku, tree fuchsia		
<i>Leycesteria formosa</i>	Himalayan honeysuckle	Y	Pest plant
<i>Salix fragilis</i>	crack willow	Y	Pest plant
<i>Solanum laciniatum</i>	poroporo		
<i>Ulex europaeus</i>	gorse	Y	Pest plant
Lianes			
<i>Calystegia silvatica</i>	great bindweed	Y	
<i>Hedera helix</i> subsp. <i>helix</i>	ivy	Y	Pest plant
<i>Muehlenbeckia australis</i>	pohuehue, large-leaved muehlenbeckia		
<i>Rubus fruticosus</i>	blackberry	Y	Pest plant
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Astelia fragrans</i>	bush flax		
<i>Dactylis glomerata</i>	cocksfoot	Y	
<i>Glyceria fluitans</i>	floating sweetgrass	Y	
<i>Lolium perenne</i>	perennial rye grass	Y	
<i>Schedonorus arundinaceus</i>	tall fescue	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	
<i>Anagallis arvensis</i>	scarlet pimpernel	Y	
<i>Barbarea intermedia</i>	winter cress	Y	
<i>Bellis perennis</i>	daisy	Y	
<i>Calendula officinalis</i>	marigold	Y	
<i>Cerastium fontanum</i>	mouse ear chickweed	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Cirsium vulgare</i>	Scotch thistle	Y	
<i>Cotula australis</i>	soldiers button		
<i>Crepis capillaris</i>	hawksbeard	Y	
<i>Hypochaeris radicata</i>	catsear	Y	
<i>Jacobaea vulgaris</i>	ragwort	Y	Pest plant
<i>Malva dendromorpha</i>	tree mallow	Y	
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Nasturtium microphyllum</i>	one rowed watercress	Y	
<i>Plantago lanceolata</i>	narrow-leaved plantain	Y	
<i>Plantago major</i>	broad-leaved plantain	Y	
<i>Polygonum arenastrum</i>	small-leaved wireweed	Y	
<i>Rumex acetosella</i>	sheeps sorrel	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Silene dioica</i>	red campion	Y	
<i>Solanum dulcamara</i>	bittersweet	Y	Pest plant
<i>Solanum nigrum</i>	black nightshade	Y	
<i>Taraxacum officinale</i>	dandelion	Y	
<i>Trifolium repens</i>	white clover	Y	
<i>Tropaeolum majus</i>	nasturtium	Y	Pest plant
<i>Verbascum thapsus</i>	woolly mullein	Y	
Ferns			
<i>Asplenium appendiculatum</i> subsp. <i>appendiculatum</i>	ground spleenwort		
<i>Blechnum novae-zelandiae</i>	kiokio		

Silver Stream at Gordon Road

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Alnus glutinosa</i>	common alder	Y	
<i>Coriaria arborea</i>	tutu		
<i>Cytisus scoparius</i>	broom	Y	Pest plant
<i>Salix fragilis</i>	crack willow	Y	Pest plant
<i>Ulex europaeus</i>	gorse	Y	Pest plant
Lianes			
<i>Calystegia silvatica</i>	great bindweed	Y	
<i>Rubus fruticosus</i>	blackberry	Y	Pest plant
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Bromus willdenowii</i>	prairie grass	Y	
<i>Carex geminata</i>	cutty grass, rautahi		
<i>Dactylis glomerata</i>	cocksfoot	Y	
<i>Glyceria fluitans</i>	floating sweetgrass	Y	
<i>Juncus articulatus</i>	jointed rush	Y	
<i>Lolium perenne</i>	perennial rye grass	Y	
<i>Phormium</i> sp.	flax		
<i>Poa annua</i>	annual poa	Y	
<i>Poa pratensis</i>	Kentucky bluegrass	Y	
<i>Schedonorus arundinaceus</i>	tall fescue	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	
<i>Anagallis arvensis</i>	scarlet pimpernel	Y	
<i>Brassica napus</i> var. <i>napus</i>	weed rape	Y	
<i>Cerastium fontanum</i>	mouse ear chickweed	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Crepis capillaris</i>	hawksbeard	Y	
<i>Jacobaea vulgaris</i>	ragwort	Y	Pest plant
<i>Lotus pedunculatus</i>	lotus	Y	
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Nasturtium microphyllum</i>	one rowed watercress	Y	
<i>Ranunculus repens</i>	buttercup	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Solanum dulcamara</i>	bittersweet	Y	Pest plant
<i>Trifolium pratense</i>	red clover	Y	
<i>Trifolium repens</i>	white clover	Y	
Ferns			
<i>Pteridium esculentum</i>	bracken		

Silver Stream at Riccarton Road

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Salix fragilis</i>	crack willow	Y	Pest plant
<i>Ulex europaeus</i>	gorse	Y	Pest plant
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Carex geminata</i>	cutty grass, rautahi		
<i>Cynosurus cristatus</i>	crested dogstail	Y	
<i>Glyceria fluitans</i>	floating sweetgrass	Y	
<i>Juncus articulatus</i>	jointed rush	Y	
<i>Lolium perenne</i>	perennial rye grass	Y	
<i>Schedonorus arundinaceus</i>	tall fescue	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	
<i>Cerastium fontanum</i>	mouse ear chickweed	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Cirsium vulgare</i>	Scotch thistle	Y	
<i>Crepis capillaris</i>	hawksbeard	Y	
<i>Fumaria muralis</i>	scrambling fumitory	Y	
<i>Helianthus annuus</i>	sunflower	Y	
<i>Lotus pedunculatus</i>	lotus	Y	
<i>Mentha spicata</i>	mint	Y	
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Nasturtium microphyllum</i>	one rowed watercress	Y	
<i>Plantago lanceolata</i>	narrow-leaved plantain	Y	
<i>Ranunculus repens</i>	buttercup	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Sisymbrium officinale</i>	hedge mustard	Y	
<i>Solanum dulcamara</i>	bittersweet	Y	Pest plant
<i>Trifolium pratense</i>	red clover	Y	
<i>Trifolium repens</i>	white clover	Y	
<i>Vicia sativa</i>	vetch	Y	

Owhiro Stream at Soper Road

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Cytisus scoparius</i>	broom	Y	Pest plant
<i>Eucalyptus</i> sp.	gum tree	Y	
<i>Ulex europaeus</i>	gorse	Y	Pest plant
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Aira caryophylla</i>	silvery hair grass	Y	
<i>Austroderia richardii</i>	toetoe		
<i>Dactylis glomerata</i>	cocksfoot	Y	
<i>Phleum pratense</i>	timothy	Y	
<i>Poa pratensis</i>	Kentucky bluegrass	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	
<i>Callitriche stagnalis</i>	water starwort	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Crepis capillaris</i>	hawksbeard	Y	
<i>Elodea canadensis</i>	Canadian pondweed	Y	Pest plant
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Plantago major</i>	broad-leaved plantain	Y	
<i>Plantago major</i>	broad-leaved plantain	Y	
<i>Ranunculus repens</i>	buttercup	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Solanum dulcamara</i>	bittersweet	Y	Pest plant
<i>Taraxacum officinale</i>	dandelion	Y	
<i>Trifolium pratense</i>	red clover	Y	
<i>Trifolium repens</i>	white clover	Y	
<i>Tripleurospermum inodorum</i>	scentless mayweed	Y	
<i>Vicia sativa</i>	vetch	Y	
Ferns			
<i>Blechnum novae-zelandiae</i>	kiokio		
<i>Pneumatopteris pennigera</i>	gully fern		
<i>Polystichum vestitum</i>	punui, prickly shield fern		

Owhiro Stream at Burns Street

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Hebe</i> sp.	Hebe		
<i>Hoheria populnea</i>	lacebark, houhere		
<i>Pittosporum eugenioides</i>	lemonwood, tarata		
<i>Ulex europaeus</i>	gorse	Y	Pest plant
Lianes			
<i>Calystegia silvatica</i>	great bindweed	Y	
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Aira caryophylla</i>	silvery hair grass	Y	
<i>Bromus willdenowii</i>	prairie grass	Y	
<i>Dactylis glomerata</i>	cocksfoot	Y	
<i>Schedonorus arundinaceus</i>	tall fescue	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	
<i>Callitriche stagnalis</i>	water starwort	Y	
<i>Cerastium fontanum</i>	mouse ear chickweed	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Cirsium vulgare</i>	Scotch thistle	Y	
<i>Fumaria muralis</i>	scrambling fumitory	Y	
<i>Leontodon taraxacoides</i>	hawkbit	Y	
<i>Linaria purpurea</i>	purple linaria	Y	
<i>Linum bienne</i>	pale flax	Y	
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Plantago lanceolata</i>	narrow-leaved plantain	Y	
<i>Ranunculus repens</i>	buttercup	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Solanum dulcamara</i>	bittersweet	Y	Pest plant
<i>Trifolium pratense</i>	red clover	Y	
<i>Trifolium repens</i>	white clover	Y	
<i>Vicia sativa</i>	vetch	Y	

Owhiro Stream tributary

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Cytisus scoparius</i>	broom	Y	Pest plant
<i>Populus nigra</i> var. <i>italica</i>	Lombardy poplar	Y	
<i>Ulex europaeus</i>	gorse	Y	Pest plant
Lianes			
<i>Calystegia silvatica</i>	great bindweed	Y	
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Aira caryophylla</i>	silvery hair grass	Y	
<i>Carex</i> sp.	Carex		
<i>Dactylis glomerata</i>	cocksfoot	Y	
<i>Glyceria fluitans</i>	floating sweetgrass	Y	
<i>Juncus articulatus</i>	jointed rush	Y	
<i>Juncus edgariae</i>	wiwi, Edgars rush		
<i>Phleum pratense</i>	timothy	Y	
<i>Poa pratensis</i>	Kentucky bluegrass	Y	
<i>Schedonorus arundinaceus</i>	tall fescue	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	
<i>Callitriche stagnalis</i>	water starwort	Y	
<i>Cardamine hirsuta</i>	bitter cress	Y	
<i>Cerastium fontanum</i>	mouse ear chickweed	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Crepis capillaris</i>	hawksbeard	Y	
<i>Galium aparine</i>	cleavers	Y	
<i>Jacobaea vulgaris</i>	ragwort	Y	Pest plant
<i>Linum bienne</i>	pale flax	Y	
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Myosotis laxa</i>	water forget-me-not	Y	
<i>Nasturtium microphyllum</i>	one rowed watercress	Y	
<i>Ranunculus repens</i>	buttercup	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Sisymbrium officinale</i>	hedge mustard	Y	
<i>Solanum nigrum</i>	black nightshade	Y	
<i>Stellaria graminea</i>	stitchwort	Y	
<i>Trifolium pratense</i>	red clover	Y	
<i>Trifolium repens</i>	white clover	Y	
<i>Veronica persica</i>	scrambling speedwell	Y	
<i>Vicia sativa</i>	vetch	Y	
Ferns			
<i>Blechnum fluviatile</i>	kiwikiwi, creek fern		
<i>Polystichum vestitum</i>	punui, prickly shield fern		

Owhiro Stream at Riccarton Road

Species name	Common name	Exotic species	Weed status
Trees and shrubs			
<i>Populus nigra</i> var. <i>nigra</i>	black poplar	Y	Pest plant
<i>Ulex europaeus</i>	gorse	Y	
Grasses			
<i>Agrostis capillaris</i>	browntop	Y	
<i>Aira caryophyllea</i>	silvery hair grass	Y	
<i>Critesion murinum</i>	barley grass	Y	
<i>Cynosurus cristatus</i>	crested dogstail	Y	
<i>Dactylis glomerata</i>	cocksfoot	Y	
<i>Glyceria fluitans</i>	floating sweetgrass	Y	
<i>Juncus articulatus</i>	jointed rush	Y	
<i>Juncus effusus</i>	leafless rush	Y	
<i>Lolium perenne</i>	perennial rye grass	Y	
Herbs			
<i>Achillea millefolium</i>	yarrow	Y	Pest plant
<i>Anagallis arvensis</i>	scarlet pimpernel	Y	
<i>Callitriche stagnalis</i>	water starwort	Y	
<i>Cerastium fontanum</i>	mouse ear chickweed	Y	
<i>Cirsium arvense</i>	Californian thistle	Y	
<i>Cirsium vulgare</i>	Scotch thistle	Y	
<i>Crepis capillaris</i>	hawksbeard	Y	
<i>Malva dendromorpha</i>	tree mallow	Y	
<i>Mimulus guttatus</i>	monkey musk	Y	
<i>Persicaria hydropiper</i>	water pepper	Y	
<i>Ranunculus repens</i>	buttercup	Y	
<i>Rumex obtusifolius</i>	broad-leaved dock	Y	
<i>Solanum dulcamara</i>	bittersweet	Y	
<i>Trifolium pratense</i>	red clover	Y	
<i>Trifolium repens</i>	white clover	Y	
<i>Urtica urens</i>	stinging nettle	Y	

Appendix Three

Habitat assessment data

Note: bold text indicates a dominant habitat feature

Silver Stream catchment

Site name	Silver Stream at Puddle Alley	Site name	Silver Stream at Gordon Road
Easting (NZTM)	1397002	Easting (NZTM)	1393873
Northing (NZTM)	4918632	Northing (NZTM)	4917182
Date	13-4-11	Date	13-4-11
Site length (m)	80	Site length (m)	50
Riparian width (m), true left	3 - 4	Riparian width (m), true left	5
Riparian width (m), true right	10	Riparian width (m), true right	5
Shading	Partial shading / Heavily shaded	Shading	Open
Lower bank height (m), true left	0.1 - 0.5	Lower bank height (m), true left	0.2 - 1.5
Lower bank height (m), true right	0.2 - 2	Lower bank height (m), true right	0.2 - 2
Upper bank height (m), true left	3	Upper bank height (m), true left	4 - 5
Upper bank height (m), true right	>10	Upper bank height (m), true right	4 - 5
Bank stability	Mostly stable	Bank stability	Stable / Mostly stable
Bank undercut	No	Bank undercut	No
Channel shape	Weakly sinuous	Channel shape	Straight / Weakly sinuous
Vegetated bank width (m)	25	Vegetated bank width (m)	20
Wetted channel width (m)	6 - 8	Wetted channel width (m)	4 - 9
Flow conditions	Base flow	Flow conditions	Base flow
Flow types	Riffle, Run	Flow types	Riffle, Run
Water depth (cm)	10 - 50	Water depth (cm)	10 - 30
Stream bed substrate	Silt/sand, Gravel, Cobble	Stream bed substrate	Silt/sand, Gravel , Cobble
Bed stability	Highly stable / Moderately stable	Bed stability	Moderately stable
Macrophytes	Marginal	Macrophytes	Marginal
Periphyton	Sparse	Periphyton	Sparse / Common
Wood	Common	Wood	Absent
Moss	Absent	Moss	Absent
Leaves	Abundant	Leaves	Absent

Site name	Silver Stream at Riccarton Road
Easting (NZTM)	1392152
Northing (NZTM)	4916576
Date	13-4-11
Site length (m)	60
Riparian width (m), true left	5
Riparian width (m), true right	5
Shading	Open
Lower bank height (m), true left	0.2 - 1
Lower bank height (m), true right	0.5 - 1
Upper bank height (m), true left	4 - 5
Upper bank height (m), true right	4 - 5
Bank stability	Stable
Bank undercut	No
Channel shape	Straight / Weakly sinuous
Vegetated bank width (m)	10 - 15
Wetted channel width (m)	3 - 5
Flow conditions	Base flow
Flow types	Riffle, Run
Water depth (cm)	25 - 50
Stream bed substrate	Silt/sand, Gravel , Cobble
Bed stability	Highly stable / Moderately stable
Macrophytes	Marginal
Periphyton	Sparse
Wood	Sparse
Moss	Absent
Leaves	Absent

Owhiro Stream catchment

Site name	Owhiro Stream at Soper Road	Site name	Owhiro Stream at Burns Street
Easting (NZTM)	1396492	Easting (NZTM)	1394367
Northing (NZTM)	4916549	Northing (NZTM)	4915138
Date	13-4-11	Date	13-4-11
Site length (m)	50	Site length (m)	60
Riparian width (m), true left	2 - 3	Riparian width (m), true left	5
Riparian width (m), true right	2 - 4	Riparian width (m), true right	4
Shading	Partial shading	Shading	Open / Partial shading
Lower bank height (m), true left	0.2 - 1	Lower bank height (m), true left	0.2 - 0.3
Lower bank height (m), true right	0.2 - 1.5	Lower bank height (m), true right	0.2 - 1
Upper bank height (m), true left	2	Upper bank height (m), true left	2 - 3
Upper bank height (m), true right	2 - 2.5	Upper bank height (m), true right	2 - 3
Bank stability	Mostly stable	Bank stability	Stable / Mostly stable
Bank undercut	No	Bank undercut	Yes
Channel shape	Straight	Channel shape	Straight
Vegetated bank width (m)	9 - 10	Vegetated bank width (m)	10
Wetted channel width (m)	1 - 2	Wetted channel width (m)	1 - 2
Flow conditions	Base flow	Flow conditions	Base flow
Flow types	Riffle, Run	Flow types	Riffle, Run
Water depth (cm)	5 - 20	Water depth (cm)	5 - 30
Stream bed substrate	Clay/mud, Silt/sand , Gravel	Stream bed substrate	Silt/sand, Gravel, Cobble
Bed stability	Highly unstable	Bed stability	Moderately stable
Macrophytes	Submerged, Marginal	Macrophytes	Marginal
Periphyton	None visible	Periphyton	Common / Abundant
Wood	Sparse	Wood	Sparse
Moss	Absent	Moss	Absent
Leaves	Sparse	Leaves	Sparse

Site name	Owhiro Stream tributary	Site name	Owhiro Stream at Riccarton Road
Easting (NZTM)	1394065	Easting (NZTM)	1392979
Northing (NZTM)	4914858	Northing (NZTM)	4914657
Date	13-4-11	Date	13-4-11
Site length (m)	75	Site length (m)	120
Riparian width (m), true left	3 - 4	Riparian width (m), true left	4 - 10
Riparian width (m), true right	2	Riparian width (m), true right	4 - 10
Shading	Open / Partial shading	Shading	Open
Lower bank height (m), true left	0.6	Lower bank height (m), true left	0.3 - 1
Lower bank height (m), true right	0.6	Lower bank height (m), true right	0.3 - 1
Upper bank height (m), true left	2 - 3	Upper bank height (m), true left	3 - 4
Upper bank height (m), true right	2 - 3	Upper bank height (m), true right	3 - 4
Bank stability	Stable / Mostly stable	Bank stability	Mostly stable / Highly unstable
Bank undercut	Yes	Bank undercut	Yes
Channel shape	Straight	Channel shape	Strongly sinuous
Vegetated bank width (m)	5 - 6	Vegetated bank width (m)	4 - 10
Wetted channel width (m)	0.8 - 1	Wetted channel width (m)	0.5 - 5
Flow conditions	Base flow	Flow conditions	Base flow
Flow types	Riffle, Run	Flow types	Riffle , Run, Pool
Water depth (cm)	20 - 30	Water depth (cm)	10 - 100
Stream bed substrate	Clay/mud, Silt/sand, Gravel	Stream bed substrate	Silt/sand, Gravel , Cobble
Bed stability	Highly unstable	Bed stability	Highly unstable
Macrophytes	Marginal	Macrophytes	Marginal
Periphyton	None visible	Periphyton	None visible / Sparse
Wood	Sparse	Wood	Sparse
Moss	Absent	Moss	Absent
Leaves	Sparse	Leaves	Absent



Appendix E

E1 Mosgiel Predicted Stormwater Flooding

Table E1-1: Mosgiel Predicted Stormwater Flooding (Model Results)

E2 Mosgiel Predicted Wastewater Flooding

Table E2-1: Mosgiel Predicted Wastewater Flooding (Model Results)



E1: Mosgiel Predicted Stormwater Flooding

Table E1-1: Mosgiel Predicted Stormwater Flooding (Model Results)

Location		Description	Min rainfall Event (yr ARI)
CONFIRMED	Gordon Road/Lanark Street	Nuisance flooding in kerb of Gordon road/Lanark Street during 1 in 2 yr ARI events. During 1 in 5 yr, deep flooding (>30 mm) Gordon Road, increased extent nuisance flooding Lanark Street. Verified by workshop discussions and matches deep flooding shown in DCC photographs. Issue may have been resolved following training works – uncertain. Lanark Street main line flowing full. Pipe capacity insufficient to convey flows, manhole overflows result on Gordon road and Lanark Street.	1 in 2
	Kinmont Crescent	Overland flow from Gebbie Street and upper Kinmont Crescent ponds in low point of Kinmont Crescent and adjacent to state highway (rear of Kinmont Crescent) Deep (>300 mm) ponding with risk to habitable floor flooding of 2 properties. Verified by workshop discussions. Corresponding complaints. Pipe capacity insufficient to convey flows, manhole overflows result on Kinmont Crescent and Gebbie Street. Overland flows to low point in Kinmont Crescent. Deep flooding >300 mm/.	1 in 5
	Gow Street/McGlashan Street/Gladstone Road South/Quarry Road	Pipe capacity Gow Street, McGlashan Street and Gladstone Road South insufficient to convey flows, manhole overflows result. Flooding exacerbated by boundary condition of Quarry Creek causing backwater effect on the network. Deep flooding >300 mm.	1 in 10
	Carlyle Road/Mallard Place/Bush Road/Tyne Street	Pipe capacity on Carlyle Road insufficient to convey flows, manhole overflows result. Hydraulic bottleneck on Carlyle Road. Previous deep flooding thought to be due to PS pump failure. Nuisance Flooding / Deep Flooding >300 mm.	1 in 2
	Woodland Avenue	Pipe capacity downstream of intake structure insufficient to convey flows, overtopping of structure results. Stormwater also inundates wastewater PS on Woodland Avenue, wastewater overflows result. Deep flooding >300 mm.	1 in 2
	Reid Avenue	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding / deep flooding . Significant flooding from swale reported 2010. Community reports that swale frequently overtops.	<1 in 10



Location		Description	Min rainfall Event (yr ARI)
	Gladstone Road North	Pipe capacity insufficient to convey flows, manhole overflows result. Deep Flooding >300 mm.	1 in 2
	Ayr Street (Argyl Street/Forfar Street/Hall Street/Irvine Street)	Pipe capacity insufficient to convey flows, manhole overflows result. Flooding due to undersized pipework and backwater effect from stormwater main downstream. Reported flooding in Gordon Road, Ayr, Irvine, Argyle, Hall Street and Forfar Street. Moderate to high confidence for flooding predicted in this area.	1 in 2
	Bruce Street/Inglis Street/McDonald Street/Shaw Street.	Pipe capacity insufficient to convey flows, manhole overflows result. Undersized pipework and backwater effect from stormwater main. A large area of Shaw Street is predicted to flood; this compares well with a report of "severe flooding" in 2005 (it is assumed that this was during the high intensity February event) and another complaint in 2007. Moderate to high confidence for flooding predicted in this area.	1 in 2
	Forfar Street	Pipe capacity insufficient to convey flows, manhole overflows result. Drop in pipe diameter causing hydraulic restriction – drop in diameter may be due to an error in the GIS data. However, this is an area of reported flooding.	1 in 2
	Perth Street (east and west)	Pipe capacity insufficient to convey flows, manhole overflows result. Backwater effect from downstream stormwater main results in high hydraulic grade line which intersects with low point. Blockage reported on Perth Street	1 in 2
	Wickliffe Street/Victoria Street	Pipe capacity insufficient to convey flows, manhole overflows result. Flooding due to DN150 pipe in Wickliffe Street creating a hydraulic bottle neck. The undersized pipe may be a GIS error.	1 in 2
	Braeside and Clyde Street	Pipe capacity insufficient to convey flows, manhole overflows result. Shallow overland flow across both roads predicted, due to overtopping upstream. Flood complaints on both Braeside and Clyde Street. Moderate confidence for this area.	1 in 5
	Lanark Street/Montrose Street/Argyle Street	Pipe capacity insufficient to convey flows, manhole overflows result. Flooding due to undersized pipework and backwater effect from stormwater main downstream. Reported flooding in Argyle and Forfar Street. Moderate to high confidence for flooding predicted in this area.	1 in 2
	Silverstream Drive/Braemar Street/Watt Street	Pipe capacity insufficient to convey flows, manhole overflows result. Shallow flooding due to limited pipe capacity and backwater effect from downstream main. Historic issues on Silverstream Drive, Braemar Street and Watt Street	1 in 5



Mosgiel Integrated Catchment Management Plan

CONTRACT No 3206

Location		Description	Min rainfall Event (yr ARI)
	Edgeware Avenue/Glenleigh Place	Pipe capacity insufficient to convey flows, manhole overflows result. Minor shallow flooding due to undersized pipework. Blockage reported at Glenleigh Place.	1 in 5
	High Street/Doon Street/Arran Street	Pipe capacity insufficient to convey flows, manhole overflows result. Shallow flooding due to intersection of low points in road with hydraulic grade line of downstream main.	1 in 5
	Ross Street, Stirling Crescent, Factory Road	Nuisance flooding predicted during 1 in 2 yr ARI. Some pockets of deep flooding (+ 300 mm) predicted during 1 in 10 yr ARI. Reports of Factory Road flooding in past but workshop discussions indicated no other known issues. Shallow flooding due to insufficient capacity in stormwater main downstream causing backwater effects and manhole overflows in this location.	1 in 2
UNCONFIRMED	Ashton Street	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 2
	Church Street (southern end and northern end).	Pipe capacity on Church Street insufficient to convey flows. Manhole overflows result. Nuisance flooding (<300 mm deep).	1 in 2
	Forth Street	Stormwater main downstream is flowing full causing a backwater effects along Forth Street resulting in manhole overflows. Nuisance flooding (<300 mm deep).	1 in 2
	High Street (southern end), Elmwood Drive, Ash Place, Cornish Lane	Pipe capacity insufficient to convey flows, manhole overflows result. Exacerbated by backwater effect from Owhiro Stream. Nuisance flooding (<300 mm deep).	1 in 2
	Goodall, Esk Place, Duff Place, Eden Street	Pipe capacity insufficient to convey flows, manhole overflows result. Exacerbated by backwater effect from surcharging of stormwater main downstream. Nuisance flooding (<300 mm deep)	1 in 2
	Hartstonge Avenue	Pipe capacity insufficient to convey flows, manhole overflows result. Exacerbated by backwater effect from surcharging of stormwater main downstream. Nuisance flooding (<300 mm deep)	1 in 2
	Spey Street	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 2
	Burns Street	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 2
	Dryden Street, Morrison Street, High Street	Limited pipe capacity exacerbated by backwater effect from stormwater main downstream which results in the hydraulic grade line intersecting low points in the road. Nuisance flooding (<300 mm deep)	1 in 5



Mosgiel Integrated Catchment Management Plan

CONTRACT No 3206

Location		Description	Min rainfall Event (yr ARI)
	Murray Street, Lorne Street, Peat Place	Pipe capacity insufficient to convey flows, manhole overflows result. Exacerbated by backwater effect from surcharging of stormwater main downstream. Nuisance flooding (<300 mm deep)	1 in 2
	Bush Road (eastern end)	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 5
	Doon Street (western end)	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 5
	Irwin Logan Drive	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 5
	Rear of Oak Place	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 5
	Thames Street (eastern and western ends)	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 10
	Windsor Place	Pipe capacity insufficient to convey flows, manhole overflows result. Nuisance flooding (<300 mm deep)	1 in 10



E2: Mosgiel Predicted Wastewater Flooding

Table E2-1: Mosgiel Predicted Wastewater Flooding (Model Results)

Location		Description	Min rainfall Event (yr ARI)
CONFIRMED	Lanark Street	Manhole overflow predicted, corresponding with complaint (details within main text of ICMP).	1 in 10
	Tyne Street/Silverstream Drive	Confirmed manhole overflows (details within main text of ICMP).	1 in 10
	Woodland Avenue Pump Station	Confirmed manhole overflow (details within main text of ICMP).	1 in 5
	Catchment Wide	Confirmed Gully trap / boundary trap overflows (details within main text of ICMP).	unknown
	Tyne Street subdivision	Historic wastewater flooding (details within main text of ICMP).	n/a
	King Street	Flooding in this area is caused by an overflow backing up from the wastewater main line running along Gordon Road. The manhole cover level in question has been set using LiDAR levels, which is lower than original GIS levels. Confidence in the flooding predicted for the area is low to moderate. Reported in customer complaints as “problem other”. However, workshop discussions indicated no known issues from operations personnel.	1 in 10
UNCONFIRMED	Gladstone Road North, Gladstone Road South, Cemetery Road, Henderson Street, Kura Place, Arran Street, High Street, Gordon Road	Unconfirmed manhole overflows – further details within main text of ICMP	1 in 2
	Hagart Alexander Drive	Model indicates flooding in this area is caused by the lack of capacity in the pipeline leading to the Burns Street wastewater PS causing flows to back up the system and exit the overflow located in the area. No complaints have been received from this area in the past. Confidence in the modelled flooding is moderate.	1 in 10



Appendix F

F1 DCC Integrated Decision Making Framework

Table F1-1: Risk Consequence Matrix for Issues Prioritisation

Table F1-2: Likelihood (Frequency) Table

Table F1-3: Consequence (Impact) Table



F1: DCC Integrated Decision Making Framework

Table F1-1: Risk/Consequence Matrix for Issues Prioritisation

RISK LIKELIHOOD	CONSEQUENCE				
	Negligible (1)	Minor (10)	Medium (40)	Major (70)	Extreme (100)
Likely (5)	Low (5) Manage Passively	Moderate (50) Manage Passively	Very High (200) Manage Actively	Extreme (350) Manage Actively	Extreme (500) Manage Actively
Quite Common (4)	Low (4) Manage Passively	Moderate (40) Manage Passively	Very High (160) Manage Actively	Very High (280) Manage Actively	Extreme (400) Manage Actively
Unlikely (3)	Negligible (3) Manage Passively	Moderate (30) Manage Passively	High (120) Manage Actively	Very High (210) Manage Actively	Very High (300) Manage Actively
Unusual (2)	Negligible (2) Accept	Low (20) Manage Passively	High (80) Manage Actively	High (140) Manage Actively	Very High (200) Manage Actively
Rare (1)	Negligible (1) Accept	Low (10) Accept	Moderate (40) Manage Passively	High (70) Manage Actively	High (100) Manage Actively

Note

The Risk Matrix includes an indication of the minimum acceptable treatment strategy. In all cases the option of avoiding the risk should be considered first.



Table F1-2: Likelihood (Frequency) Table

LIKELIHOOD TABLE					
Threat	Consequence Description	Probability	Frequency	Description	Rating
	Likely	>50 %	Greater than every two years	The threat can be expected to occur <u>or</u> a very poor state of knowledge has been established on the threat	5
	Quite Common	20 – 50 %	Once per 2-5 years	The threat will quite commonly occur <u>or</u> a poor state of knowledge has been established on the threat	4
	Unlikely	10 – 20 %	Once per 5-10 years	The threat may occur occasionally <u>or</u> a moderate state of knowledge has been established on the threat	3
	Unusual	2 – 10 %	Once per 10-50 years	The threat could infrequently occur <u>or</u> a good state of knowledge has been established on the threat	2
	Rare	<2 %	Less than once per 50 years	The threat may occur in exceptional circumstances <u>or</u> a very good state of knowledge has been established on the threat	1



Table F1-3: Consequence (Impact) Table

CONSEQUENCE TABLE (Threats only)										
Impact Description		SERVICE DELIVERY	SOCIAL / CULTURAL				ENVIRONMENT	ECONOMIC		Consequence Rating
		Performance Measures (PM)	Health & Safety	Community / Social	Compliance	Reputation / Brand / Image	Environment	Indirect Cost (incl. other DCC)	Direct Cost	
Threat	Extreme	Complete failure to deliver services	Single fatality	Longterm effect on land use	Commission of Inquiry	International media coverage	Permanent widespread ecological damage	>\$25M	>\$5M	100
			Widespread severe illness	Significant damage or disruption to more than 50 properties	Law Suit Resulting in Imprisonment of Management or Council	Statutory control imposed				
				Mass evacuation of more than 100 people						
	Major	Failure to be within 20% of a significant PM target	Permanent disability	Formal complaint by key stakeholder	Ministerial Inquiry	Sustained national media coverage	Heavy ecological damage, costly restoration	\$5M-25M	\$1M-5M	70
		PMs exceeded by 50% - implying overspend	Multiple severe illness	Significant unplanned disruption to essential/significant community services and/or structures	Heavy Prosecution of Management	International media coverage with reasonable defence				
				Significant damage to multiple public properties	Ministerial questions					
				Significant damage or disruption up to 50 properties	Breach of Act or regulation or consent condition with material effect.					
				Mass evacuation up to 100 people						
	Medium	Failure within 20% of a significant PM target	Serious injuries	Simultaneous unplanned disruption to multiple households or commercial premises or community services and/or structures	3rd party investigation	Regional media coverage or short term national coverage	Major but recoverable ecological damage	\$1M-5M	\$200K-1M	40
		PMs exceeded by 40% - implying overspend	Severe illness or illness to multiple individuals	Formal complaint by member of the public or ratepayer	Technical breach of Act, consent condition or regulation but minor material effect	Sustained national media coverage with reasonable defence				
				Significant damage or disruption up to 5 properties	Breach With Modest Legal Rebuke					
				Evacuation up to 10 people						
				Formal complaint by key stakeholder with reasonable defence						
	Minor	Failure within 20% of a minor PM target	Minor injuries	Casual community complaints	Official information request	Adverse Regional media coverage or short term national coverage with reasonable defence	Limited but medium-term negative effect	\$125K-1M	\$25K-200K	10
		PMs exceeded by 30% - implying overspend	Illness to several individuals	Formal complaint by member of the public or ratepayer with reasonable defence	Minor Breach					
	Negligible	PMs exceeded by 20% - implying overspend	Slight injuries	Unplanned disruption to single household or commercial premises or community services and/or structures	Minor complaint	Adverse editorial comment in Regional media.	Short-term damage	\$25K-125K	\$5K-25K	1
			Illness to individual				Debatable damage			



Appendix G

G1 Stormwater QBL Assessment Criteria

Table G1-1: Stormwater Option Assessment Criteria and Scoring System

G2 Wastewater QBL Assessment Criteria

Table G2-1: Wastewater Option Assessment Criteria and Scoring System

G3 Stormwater Flooding- Catchment-Wide

Table G3-1: Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacity

Table G3-2: Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacity

Table G3-3: Stormwater Flooding – Catchment-Wide Option Comparison

G4 Stormwater Flooding – Gordon Road

Table G4-1: Option Mo4: Local Upgrade Gordon Road Table

Table G4-2: Option Mo5: Provide Storage Gordon Road

Table G4-3: Stormwater Flooding – Gordon Road Option Comparison

G5 Stormwater Flooding – Kinmont Crescent

Table G5-1 Option Mo6: Reduce Overland Flows to Kinmont Crescent

Table G5-2 Option Mo7: Intercept Overland Flows at Kinmont Crescent

Table G5-3: Stormwater Flooding – Kinmont Crescent Option Comparison

G6 Stormwater Flooding – Gow Street/McGlashan Street

Table G6-1: Option Mo10: Upsize Local Pipework Gow Street

G7 Stormwater Flooding – Reid Avenue

Table G7-1: Option Mo12: Upsize Main Reid Avenue

Table G7-2: Option Mo13: Increase Volume of Reid Avenue Swale

Table G7-3: Stormwater Flooding – Reid Avenue option Comparison

G8 Stormwater Flooding – Woodland Avenue

Table G8-1: Option Mo14: Upsize Pipework Woodland Avenue

Table G8-2: Option Mo16: Provide Formal Overland Flow Path Woodland Avenue

Table G8-3: Stormwater Flooding – Woodland Avenue Option Comparison

G9 Wastewater Flooding/Overflows

Table G9-1: Option WMoA

Table G9-2: Option WMoB

Table G9-3: Option WMoC

Table G9-4: Option WMoD

Table G9-5: Wastewater Flooding/Overflows Option Comparison



G1: Stormwater QBL Assessment Criteria

Table G1-1: Stormwater Option Assessment Criteria and Scoring System

QBL	Option Assessment Criteria	-10	-5	0	5	10
Environmental (10)	<i>Removal of known wastewater cross connections</i>	Does not remove cross connection	Reduces likelihood of cross connection occurring	Assists in finding unknown cross connections	Removes cross connection for design events (emergency overflow still exists)	Removes cross connection under all events
	<i>Contaminant Reduction</i>	None	5-25 %	25-40 %	50-75 %	75-100 %
	<i>Use of Source Control / LID</i>	No treatment or control	End of pipe treatment (catchment or sub catchment based)	Site based in-line treatment/collection of contaminant	LID with water re/use up to design event	Source control - avoid generation of contaminant of concern
	<i>I/I reduction</i>	No I/I reduction possible			Minor I/I reduction possible without exacerbating stormwater flooding	Major I/I reduction possible without exacerbating stormwater flooding
	<i>Construction effects</i>	Major discharge of contaminants into environment during construction	Minor discharge of contaminants into environment during construction		All contaminants generated contained on site and disposed of appropriately	No effects on environment - no contaminants generated during construction
	<i>Replication of current flow patterns</i>	No volumetric control	Minimal attenuation	Replicates or reduces current flow patterns up to 1 in 2 year event	Replicates or reduces current flow patterns up to 1 in 10 year event	Replicates or reduces current flow patterns up to a 1 in 100 year event



Mosgiel Integrated Catchment Management Plan

CONTRACT No 3206

QBL	Option Assessment Criteria	-10	-5	0	5	10
	<i>Option flexibility</i>	Constrained.	Flexible for short term scenarios but cannot be staged	Will accommodate all scenarios but minimal staging	Flexible for all but extreme scenarios and can be staged	Flexible for all scenarios and can be staged
Social (10)	<i>Interest / support of community / social interest groups</i>	Major opposition from community / special interests groups	Some opposition from community / special interests groups		Some support from community / special interests groups	Major support from community / special interests groups
Cultural (10)	<i>Fit with Māori cultural values</i>	Contradicts Key cultural values	Unlikely to fit with values and preferred approaches	Not specifically identified as preferred approach, but likely to fit	Fits with preferred approach recommended by local iwi.	Involves iwi in development and design of option
Implementation Risk (20)	<i>Risk of operational failure</i>	Likely operational failure. Unproven technology	New technology. Extensive training required	Moderately complicated new technology	Minor modifications to technology already used. Simple new technology	Proven technology, already utilised throughout city
Economic (10)	<i>Estimated Capital Cost - order of magnitude (note does not allow for internal costs)</i>	\$10 m+	\$1-\$10 m	\$500k - \$1 m	<\$500 k	Free
	<i>Risk of cost escalation due to construction unknowns</i>	High - escalation likely as no alternatives and insufficient information	Moderate risk. Low number of alternatives available		Can be managed via alternatives	Low risk. Well known issue and design criteria



QBL	Option Assessment Criteria	-10	-5	0	5	10
	<i>Risk of land availability</i>	Unlikely to secure land	Long process for negotiation, or high cost of land expected	Moderate process/costs anticipated	Unutilised land likely easy to secure.	Land already owned by DCC
	<i>Risk of protracted consent process with authorities</i>	Consent unlikely	High risk of long process	Medium consent process anticipated	Short consent process anticipated	No consent necessary
Effectiveness (Risk Reduction) (30)	<i>Risk Reduction</i>	Extreme risk reduced to very high; Very High reduced to high.	Extreme risk reduced to High	Extreme or Very High risk reduced to Moderate; High risk reduced to Moderate or low.	Extreme or Very High risk reduced to Moderate; High risk reduced to Low or negligible.	Extreme or Very High risk reduced to Low or negligible.
	<i>Deep flooding 1 in 50 year future - current</i>	Increase in number of properties flooding in current scenario	No change in number of properties predicted to flood, current or future	No change in properties flooding currently, reduction in future flooding	Number of properties predicted to flood in future scenario same as predicted for current scenario	Number of properties predicted to flood in future scenario less than predicted for current scenario
	<i>Manholes overflowing 1 in 10 - future-current</i>	Increase in number of manholes overflowing in current scenario	No change in number of manholes overflowing, current or future	No change in number of manholes overflowing currently, reduction in future number of manholes overflowing	Number of manholes overflowing in future scenario same as predicted for current scenario	Number of manholes overflowing in future scenario less than predicted for current scenario
	<i>Improvement in LOS</i>	Significant reduction in perceived LOS Increase in % customer complaints	Perceived LOS likely to decrease, some increase in % customer complaints	No change to perceived LOS or % customer complaints	Minimal improvement to perceived LOS, some reduction in % customer complaints	Significant improvement to perceived LOS, large reduction in % customer complaints



G2: Wastewater QBL Assessment Criteria

Table G2-1: Wastewater Option Assessment Criteria and Scoring System

QBL	Option Assessment Criteria	-10	-5	0	5	10
Environmental (10)	<i>Removal of known wastewater cross connections.</i>	Does not remove cross connection.	Reduces likelihood of cross connection occurring.	Assists in finding unknown cross connections	Removes cross connection for design events (emergency overflow still exists)	Removes cross connection under all events
	<i>I&I reduction</i>	No I&I reduction	-	-	Minor I&I reduction possible without exacerbating stormwater flooding, or, major I&I reduction possible with only minor additional stormwater flooding	Major I&I reduction possible without exacerbating stormwater flooding
	<i>Reduction in Energy Consumption</i>	Large increase in energy consumption	Minimal increase in energy consumption	No increase in energy consumption	Minimal reduction in energy consumption	Significant reduction in energy consumption
	<i>Construction impact</i>	Medium to long term construction impact	Short term construction impact	Construction impact is mitigated	Construction impact on environment is offset	No construction impact
Social (10)	<i>Fit with Māori cultural values</i>	Major opposition from community / special interests groups	Some opposition from community / special interests groups	-	Some support from community / special interests groups	Major support from community / special interests groups



Mosgiel Integrated Catchment Management Plan

CONTRACT No 3206

QBL	Option Assessment Criteria	-10	-5	0	5	10
Cultural (10)	<i>Risk of operational failure</i>	Contradicts Key cultural values	Unlikely to fit with values and preferred approaches	Not specifically identified as preferred approach but likely to fit	Fits with preferred approach recommended by iwi	Involves iwi in development and design of option
Implementation Risk (20)	<i>Risk of failure</i>	Likely operational failure. Unproven technology	New technology. Extensive training required.	Moderately complicated new technology	Minor modifications to technology already used. Simple new technology	Proven technology, already utilised
Economic (10)	<i>Estimated Capital Cost - order of magnitude</i>	>\$15M	\$5M-\$15M	\$1M-\$5M or funding from renewals	\$500k-\$1M	<\$500k
	<i>OPEX cost</i>	Large increase in OPEX	Marginal increase in OPEX	No effect on OPEX	Marginal reduction in OPEX	Large reduction in OPEX
	<i>Risk of cost escalation due to construction unknowns</i>	High - escalation likely as no alternatives and insufficient information	Moderate risk. Low number of alternatives available	-	Can be managed via alternatives	Low risk. Well known issue and design criteria
	<i>Risk of land availability (negotiation breakdowns, land costs)</i>	Unlikely to secure land	Long process for negotiation, or high cost of land expected	Moderate process / costs anticipated	Unutilised land likely easy to secure	Land already owned by DCC or land not required



Mosgiel Integrated Catchment Management Plan

CONTRACT No 3206

QBL	Option Assessment Criteria	-10	-5	0	5	10
	<i>Risk of protracted consent process with authorities</i>	Consent unlikely	High risk of long process	Medium consent process required	Short consent process required	No consent necessary
Effectiveness (Risk Reduction) (30)	<i>Manholes overflowing 1 in 10 yr ARI current before and after upgrades</i>	Increase in number of manholes overflowing after upgrade	-	No change in number of manholes overflowing after upgrade	-	Number of manholes overflowing after upgrade less than predicted for current scenario.
	<i>Improvement in level of service</i>	Significant reduction in perceived level of service Increase in % customer complaints	Perceived level of service likely to decrease, some increase in % customer complaints	No change to perceived level of service or % customer complaints	Minimal improvement to perceived level of service, some reduction in % customer complaints	Significant improvement to perceived level of service, large reduction in % customer complaints
	<i>Meets future growth of city and climate change</i>	Does not allow growth of city	Marginal growth accommodated	-	Meets future growth	Allows for future growth with some headroom / flexibility
	<i>Sensitivity of solution to parameters and assumptions</i>	Very sensitive	-	Moderately sensitive	-	Not sensitive



G3:Stormwater Flooding – Catchment-Wide Option Evaluation

Table G3-1: Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacity

Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacity				
Option Assessment Criteria	Category Weighting	Sub-Weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	5	Due to the simplicity of this option, there are few design options apart from refining pipe sizing but there would be added benefit in staging.
Environment Score (20)			-25.05	
Interest / support of community / social interest groups	10	10	0	Given the flooding is within the local area of the proposed upgrade, it is considered that there will be some support from the community for the flood alleviation although there may be significant disruption to traffic/businesses during works.
Social Score (10)			0	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.
Implementation Risk Score (20)			200	
Estimated Capital Cost - order of magnitude (note	10	2.5	-10	Capital cost greater than \$10 m, but staging of works would allow financial control over



Option Mo1: Catchment Wide Network Upgrade: Improvement of Pipe Capacity				
Option Assessment Criteria	Category Weighting	Sub-Weighting	Score	Comment
does not allow for internal costs)				successive financial years
Risk of cost escalation due to construction unknowns	10	2.5	-5	Moderate to high risk due to scope of works not being currently clearly defined. Risk would be resolved during design process.
Risk of land availability		2.5	10	Works would be in road reserve.
Risk of protracted consent process with authorities		2.5	10	Assumed no consent required for pump station upgrade
Economic Score (10)			12.5	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The design would ensure that the upgraded pipe network would reduce the deep flooding for the future scenario.
Manholes overflowing 1 in 10 - future-current		7.5	10	The design would ensure that the upgraded pipe work is sized to prevent manhole overflows.
Improvement in LOS		7.5	10	As this option potentially reduces overland flow through previously flooded areas, there will be a significant improvement in LOS.
Effectiveness (Risk Reduction) Score (30)			262.5	
TOTAL SCORE: 450				



Table G3-2: Option Mo3: Catchment Wide Retrofit Swales to local Roads

Option Mo3: Catchment-Wide Retrofit Swales to Local Roads				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	5	Provision of swales will provide contaminant reduction. Until design is carried out it is unknown if sufficient retention time would be provided for full contaminant removal.
Use of Source Control / LID		1.67	0	In-line source control or LID is proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	5	It would be anticipated that suitable attenuation will be incorporated as part of the swale designs.
Option flexibility		1.67	5	Due to the simplicity of this option, there are few design options but there would be added benefit in staging.
Environment Score (20)			41.75	
Interest / support of community / social interest groups	10	10	5	Given the flooding is within the local area of the proposed upgrade, it is considered that there will be some support from the community. The works will cause general disruption during construction.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	5	Simple new technology
Implementation Risk Score (20)			100	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-10	Capital cost greater than \$10 m.



Risk of cost escalation due to construction unknowns		2.5	-5	Moderate risk with unknown service connections and retrofitting swales within an established road corridor.
Risk of land availability		2.5	10	The works would be in road reserve.
Risk of protracted consent process with authorities		2.5	0	As there would be an overall water quality enhancement and a generic design used, it would be anticipated that approval based on a standard design would be secured at the outset of the project. Moderate consent process is anticipated.
Economic Score (10)		-12.5		
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The number of overflowing manholes will be reduced.
Improvement in LOS		7.5	0	The perceived LOS may be improved to the flooding, however swales may pond with water following an event, and may collect rubbish if not adequately maintained. This may negate the LOS benefits with the works
Effectiveness (Risk Reduction) Score (30)		187.5		
TOTAL SCORE: 317				



Table G3-3: Stormwater Flooding – Catchment-Wide Option Comparison

Option QBL Assessment Criteria	Option			
	Category Weighting	Sub-weighting	Mo1 Network Upgrade:	Mo3 Retrofit Swales
Removal of known wastewater cross connections.	10	N/A	N/A	N/A
Contaminant Reduction		1.67	-10	5
Use of Source Control / LID		1.67	-10	0
I/I reduction		1.67	5	5
Construction effects		1.67	5	5
Replication of current flow patterns		1.67	-10	5
Option flexibility		1.67	5	5
Environment Score (20)			-25.05	41.75
Interest / support of community / social interest groups	10	10	0	5
Social Score (10)			0	50
Fit with Māori cultural values	10	10	0	0
Cultural Score (10)			0	0
Risk of operational failure	20	20	10	5
Implementation Risk Score (20)			200	100
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-10	-10
Risk of cost escalation due to construction unknowns		2.5	-5	-5
Risk of land availability		2.5	10	10
Risk of protracted consent process with authorities		2.5	10	0
Economic Score (10)			12.5	-12.5
Risk Reduction	30	7.5	5	5
Deep flooding 1 in 50 year future - current		7.5	10	10
Manholes overflowing 1 in 10 - future-current		7.5	10	10
Improvement in LOS		7.5	10	0
Effectiveness (Risk Reduction) Score (30)			262.5	187.5
TOTAL			450	317



G4: Stormwater Flooding – Gordon Road

Table G4-1: Option Mo4: Local Upgrade Gordon Road Table

Option Mo4: Local Upgrade Gordon Road				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	0	Due to the simplicity of this option, there are few design options apart from refining pipe sizing and there would be minimal added benefit in staging.
Environment Score (20)			-33.4	
Interest / support of community / social interest groups	10	10	5	Given the location of the flooding, it is considered that there will be support from the community for the flood alleviation although there may be significant disruption to traffic/businesses during works.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.
Implementation Risk Score (20)			200	



Option Mo4: Local Upgrade Gordon Road

Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-5	Capital cost between \$1 - \$10 m assuming there are no complications constructing in Gordon Road.
Risk of cost escalation due to construction unknowns		2.5	-5	Moderate to high risk due to unknown underground services. Risk would be resolved during design process.
Risk of land availability		2.5	10	Works would be in road reserve.
Risk of protracted consent process with authorities		2.5	10	No consent required
Economic Score (10)			25	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates deep flooding is alleviated.
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates no manholes overflow.
Improvement in LOS		7.5	10	As this option potentially reduces overland flow through previously flooded areas, there will be a significant improvement in LOS.
Effectiveness (Risk Reduction) Score (30)			262.5	
TOTAL SCORE: 454				



Table G4-2: Option Mo5: Provide Storage Gordon Road

Option Mo4: Local Upgrade Gordon Road				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, and this an asset upgrade option.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There will be no attenuation provided with this option.
Option flexibility		1.67	0	Due to the simplicity of this option, there are few design options apart from refining pipe sizing and there would be no added benefit in staging.
Environment Score (20)			-33.4	
Interest / support of community / social interest groups	10	10	5	Given the location of the flooding, it is considered that there will be support from the community for the flood alleviation although there may be significant disruption to traffic/businesses during works.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.
Implementation Risk Score (20)			200	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-5	Capital cost between \$1 - \$10 m.
Risk of cost escalation due to construction unknowns		2.5	-5	Moderate to high risk as further investigation of site levels is required to



Option Mo4: Local Upgrade Gordon Road				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
				confirm option suitability. Risk would be resolved during design process.
Risk of land availability		2.5	10	Proposed to use DCC owned amenity land.
Risk of protracted consent process with authorities		2.5	0	Risk is moderate given the location of the works.
Economic Score (10)			0	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates deep flooding is alleviated.
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates no manholes overflow.
Improvement in LOS		7.5	10	As this option potentially reduces overland flow through previously flooded areas, there will be a significant improvement in LOS.
Effectiveness (Risk Reduction) Score (30)			262.5	
TOTAL SCORE: 429				



Table G4-3: Stormwater Flooding – Gordon Road Option Comparison

Option QBL Assessment Criteria	Option			
	Category Weighting	Sub-weighting	Mo4 Local Upgrade:	Mo5 Provide Storage
Removal of known wastewater cross connections.	10	N/A	N/A	N/A
Contaminant Reduction		1.67	-10	-10
Use of Source Control / LID		1.67	-10	-10
I/I reduction		1.67	5	5
Construction effects		1.67	5	5
Replication of current flow patterns		1.67	-10	-10
Option flexibility		1.67	0	0
Environment Score (20)			-33.4	-33.4
Interest / support of community / social interest groups	10	10	5	5
Social Score (10)			50	50
Fit with Māori cultural values	10	10	0	0
Cultural Score (10)			0	0
Risk of operational failure	20	20	10	10
Implementation Risk Score (20)			200	200
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-5	-5
Risk of cost escalation due to construction unknowns		2.5	-5	-5
Risk of land availability		2.5	10	10
Risk of protracted consent process with authorities		2.5	10	0
Economic Score (10)			25	0
Risk Reduction	30	7.5	5	5
Deep flooding 1 in 50 year future - current		7.5	10	10
Manholes overflowing 1 in 10 - future-current		7.5	10	10
Improvement in LOS		7.5	10	10
Effectiveness (Risk Reduction) Score (30)			262.5	262.5
TOTAL			454	429



G5: Stormwater Flooding – Kinmont Crescent

Table G5-1 Option Mo6: Reduce Overland Flows to Kinmont Crescent

Option Mo6: Reduce Overland Flows to Kinmont Crescent				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the proposal.
Option flexibility		1.67	-5	Due to the simplicity of this option, there are few design options and there would be no added benefit in staging.
Environment Score (20)			-45.75	
Interest / support of community / social interest groups	10	10	0	Current flooding affects only a small number of properties, support would then be limited to those affected parties
Social Score (10)			0	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.
Implementation Risk Score (20)			200	



Option Mo6: Reduce Overland Flows to Kinmont Crescent				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-5	Capital cost \$1.7 – 2.2 million
Risk of cost escalation due to construction unknowns		2.5	0	Moderate risk due to levels unconfirmed level data. Risk would be resolved during design process.
Risk of land availability		2.5	10	Works would be in road reserve.
Risk of protracted consent process with authorities		2.5	10	No consent required
Economic Score (10)			37.5	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	5	The properties currently affected will perceive this as a significant improvement in LOS. However the number of affected properties is minimal for the required expenditure.
Effectiveness (Risk Reduction) Score (30)			225	
TOTAL SCORE: 421				



Table G5-2 Option Mo7: Intercept Overland Flows at Kinmont Crescent

Option Mo7: Intercept Overland Flows at Kinmont Crescent				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	-5	Due to the simplicity of this option, there are few design options and there would be no added benefit in staging.
Environment Score (20)			-41.75	
Interest / support of community / social interest groups	10	10	0	Current flooding affects only a small number of properties, support would then be limited to those affected parties
Social Score (10)			0	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.
Implementation Risk Score (20)			200	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	5	Capital cost less than \$500 k.
Risk of cost escalation due to		2.5	0	Moderate risk due to levels unconfirmed level data. Risk would be resolved



Option Mo7: Intercept Overland Flows at Kinmont Crescent

Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
construction unknowns				during design process.
Risk of land availability		2.5	10	Works would be in road reserve.
Risk of protracted consent process with authorities		2.5	10	No consent required
Economic Score (10)			62.5	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	5	The properties currently affected will perceive this as a significant improvement in LOS. However the number of affected properties is minimal for the required expenditure.
Effectiveness (Risk Reduction) Score (30)			225	
TOTAL SCORE: 446				



Table G5-3: Stormwater Flooding – Kinmont Crescent Option Comparison

Option QBL Assessment Criteria	Option			
	Category Weighting	Sub-Weighting	Mo6 Reduce Overland Flows	Mo7 Intercept Overland Flows
Removal of known wastewater cross connections.	10	N/A	0	0
Contaminant Reduction		1.67	-10	-10
Use of Source Control / LID		1.67	-10	-10
I/I reduction		1.67	5	5
Construction effects		1.67	5	5
Replication of current flow patterns		1.67	-10	-10
Option flexibility		1.67	-5	-5
Environment Score (20)			-41.75	-41.75
Interest / support of community / social interest groups	10	10	0	0
Social Score (10)			0	0
Fit with Māori cultural values	10	10	0	0
Cultural Score (10)			0	0
Risk of operational failure	20	20	10	10
Implementation Risk Score (20)			200	200
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-5	5
Risk of cost escalation due to construction unknowns		2.5	0	0
Risk of land availability		2.5	10	10
Risk of protracted consent process with authorities		2.5	10	10
Economic Score (10)			37.5	62.5
Risk Reduction	30	7.5	5	5
Deep flooding 1 in 50 year future - current		7.5	10	10
Manholes overflowing 1 in 10 - future-current		7.5	10	10
Improvement in LOS		7.5	5	5
Effectiveness (Risk Reduction) Score (30)			225	225
TOTAL			421	466



G6: Stormwater Flooding – Gow Street/McGlashan Street

Table G6-1: Option Mo10: Upsize Local Pipework Gow Street

Option Mo10: Upsize local Pipework Gow Street				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	-5	Due to the simplicity of this option, there are few design options and there would be no added benefit in staging.
Environment Score (20)			-41.75	
Interest / support of community / social interest groups	10	10	0	Current flooding affects only a small number of properties, support would then be limited to those affected parties
Social Score (10)			0	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology
Implementation Risk Score (20)			200	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	0	Capital cost between \$500k - \$1M assuming that there is a free discharge into the Quarry Creek.
Risk of cost escalation due to construction unknowns		2.5	-10	High risk due to unconfirmed Quarry Creek flood level information. The risk would be



Option Mo10: Upsize local Pipework Gow Street				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
				better understood following further investigation.
Risk of land availability		2.5	10	Works would be in road reserve.
Risk of protracted consent process with authorities		2.5	5	Given the issue with the Quarry Creek flooding, it is likely that there with be a long consenting process.
Economic Score (10)		12.5		
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	5	The properties currently affected will perceive this as a significant improvement in LOS. However the number of affected properties is minimal for the required expenditure.
Effectiveness (Risk Reduction) Score (30)		225		
TOTAL SCORE: 396				



G7: Stormwater Flooding – Reid Avenue

Table G7-1: Option Mo12: Upsize Main Reid Avenue

Option Mo12: Upsize Main Reid Avenue				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	0	Due to the simplicity of this option, there are few design options apart from refining pipe sizing and there would be minimal added benefit in staging.
Environment Score (20)			-33.4	
Interest / support of community / social interest groups	10	10	5	As the flooding occurs in a high profile location (adjacent to sports fields), it is considered that there will be major support from the community
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.



Option Mo12: Upsize Main Reid Avenue				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Implementation Risk Score (20)		200		
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	0	Capital cost between \$500k - \$1m assuming there are no complications constructing in St Andrew Street
Risk of cost escalation due to construction unknowns		2.5	-5	Moderate to high risk due to unknown underground services. Risk would be resolved during design process.
Risk of land availability		2.5	10	Works would be in road reserve.
Risk of protracted consent process with authorities		2.5	10	No consent required
Economic Score (10)		37.5		
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	10	As this option potentially reduces overland flow through previously flooded areas, there will be a significant improvement in LOS.
Effectiveness (Risk Reduction) Score (30)		262.5		
TOTAL SCORE: 467				



Table G7-2: Option Mo13: Increase Volume of Reid Avenue Swale

Mo13: Increase Volume of Reid Avenue Swale				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	N/A	N/A
Contaminant Reduction:		1.67	-5	There will be some minor additional contaminant removal with the increased swale volume.
Use of Source Control / LID		1.67	0	There is additional source control provided with the increased swale volume.
I/I reduction		1.67	5	As the proposal is to reduce/remove surface flows of stormwater, this will lower the potential for stormwater to enter the sewer system via manholes, gully traps etc.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-5	There will be some additional attenuation provided with increased swale volume.
Option flexibility		1.67	-10	Due to existing site layout adjacent to the swale, the options are constrained.
Environment Score (20)			-16.7	
Interest / support of community / social interest groups	10	10	5	As the flooding occurs in a high profile location (adjacent to sports fields), it is considered that there will be major support from the community
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit
Cultural Score (10)			0	
Risk of operational failure	20	20	5	Proven technology
Implementation Risk Score (20)			100	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	5	Capital cost less than \$500 k.
Risk of cost escalation due to construction unknowns		2.5	0	Moderate risk due to low number of alternatives. Risk would be resolved



Mo13: Increase Volume of Reid Avenue Swale				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
				during design process.
Risk of land availability		2.5	10	All land is parks and reserves.
Risk of protracted consent process with authorities		2.5	0	As the works involve alteration to a major SW asset that provides treatment and attenuation benefits, the consenting authority may spend more time reviewing the consent.
Economic Score (10)		37.5		
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	10	As this option potentially reduces overland flow through previously flooded areas, there will be a significant improvement in LOS. Note, this LOS improvement may be negated if the swale encroaches on the sports ground area.
Effectiveness (Risk Reduction) Score (30)		262.5		
TOTAL SCORE: 383				



Table G7-3: Stormwater Flooding – Reid Avenue option Comparison

Option QBL Assessment Criteria	Option			
	Category Weighting	Sub-weighting	Mo12 Upsize Main	Mo13 Increase Volume Swale
Removal of known wastewater cross connections.	10	N/A	N/A	N/A
Contaminant Reduction		1.67	-10	-5
Use of Source Control / LID		1.67	-10	0
I/I reduction		1.67	5	5
Construction effects		1.67	5	5
Replication of current flow patterns		1.67	-10	-5
Option flexibility		1.67	0	-10
Environment Score (20)			-33.4	-16.7
Interest / support of community / social interest groups	10	10	5	5
Social Score (10)			50	50
Fit with Māori cultural values	10	10	0	0
Cultural Score (10)			0	0
Risk of operational failure	20	20	10	5
Implementation Risk Score (20)			200	100
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	0	5
Risk of cost escalation due to construction unknowns		2.5	-5	0
Risk of land availability		2.5	10	10
Risk of protracted consent process with authorities		2.5	10	0
Economic Score (10)			37.5	37.5
Risk Reduction	30	7.5	5	5
Deep flooding 1 in 50 year future - current		7.5	10	10
Manholes overflowing 1 in 10 - future-current		7.5	10	10
Improvement in LOS		7.5	10	10
Effectiveness (Risk Reduction) Score (30)			262.5	262.5
TOTAL			467	383



G8: Stormwater Flooding – Woodland Avenue

Table G8-1: Option Mo14: Upsize Pipework Woodland Avenue

Option Mo14: Upsize Pipework Woodland Avenue				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	10	High score as the predicted flooding levels are high enough to inundate the local wastewater pumping station.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	0	Due to the simplicity of this option, there are few design options apart from refining pipe sizing and there would be minimal added benefit in staging.
Environment Score (20)			-25.05	
Interest / support of community / social interest groups	10	10	5	Given the flooding is within the local area of the proposed upgrade, it is considered that there will be some support from the community for the flood alleviation.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	10	Proven technology.
Implementation Risk Score (20)			200	



Option Mo14: Upsize Pipework Woodland Avenue				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	5	Capital cost less than \$500 k.
Risk of cost escalation due to construction unknowns		2.5	0	Moderate risk due to limited options. Risk would be resolved during design process.
Risk of land availability		2.5	0	Part of the works would be in private property. However given the proposal offers a reduction to flood risk, it is anticipated that there would be moderate objection to be resolved.
Risk of protracted consent process with authorities		2.5	10	No consent required
Economic Score (10)			37.5	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	5	The properties currently affected will perceive this as a significant improvement in LOS. However the number of affected properties is minimal for the required expenditure.
Effectiveness (Risk Reduction) Score (30)			225	
TOTAL SCORE: 437				



Table G8-2: Option Mo16: Provide Formal Overland Flow Path Woodland Avenue

Option Mo16: Provide Formal Overland Flow path Woodland Avenue				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	N/A	0	N/A
Contaminant Reduction:		1.67	-10	There will be no additional contaminant removal, this is purely an asset upgrade.
Use of Source Control / LID		1.67	-10	There is no source control or LID proposed as part of this option.
I/I reduction		1.67	10	High score as the predicted flooding levels are high enough to inundate the local wastewater pumping station.
Construction effects		1.67	5	Use of suitable erosion and sediment control measures during construction will minimise the effects of contamination during the construction period.
Replication of current flow patterns		1.67	-10	There is no volumetric control or attenuation associated with the pipe upgrades.
Option flexibility		1.67	0	Due to the simplicity of this option, there are few design options apart from refining pipe sizing and there would be minimal added benefit in staging.
Environment Score (20)			-25.05	
Interest / support of community / social interest groups	10	10	5	Given the flooding is within the local area of the proposed upgrade, it is considered that there will be some support from the community for the flood alleviation.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Unlikely to affect Maori values, and likely to fit
Cultural Score (10)	0			
Risk of operational failure	20	20	10	Proven technology
Implementation Risk Score (20)			200	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	5	Capital cost less than \$500 k.



Option Mo16: Provide Formal Overland Flow path Woodland Avenue				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Risk of cost escalation due to construction unknowns		2.5	0	Moderate risk due to limited options. Risk would be resolved during design process.
Risk of land availability		2.5	-5	Parts of the works are within private property, the rest is with road reserve. Council may need to purchase land for the overland flow path and construct bunding.
Risk of protracted consent process with authorities		2.5	0	There may be a medium length consenting process given the creation of a formal flood route.
Economic Score (10)			0	
Risk Reduction	30	7.5	5	
Deep flooding 1 in 50 year future - current		7.5	10	The modelled option indicates a reduction in deep flooding
Manholes overflowing 1 in 10 - future-current		7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in LOS		7.5	5	The properties currently affected will perceive this as a significant improvement in LOS. However the number of affected properties is minimal for the required expenditure.
Effectiveness (Risk Reduction) Score (30)			225	
TOTAL SCORE: 400				



Table G8-3: Stormwater Flooding – Woodland Avenue option Comparison

Option QBL Assessment Criteria			Option	
	Category Weighting	Sub-weighting	Mo14 Upsize Pipe	Mo16 Overland Flow Path
Removal of known wastewater cross connections.	10	N/A	0	0
Contaminant Reduction		1.67	-10	-10
Use of Source Control / LID		1.67	-10	-10
I/I reduction		1.67	10	10
Construction effects		1.67	5	5
Replication of current flow patterns		1.67	-10	-10
Option flexibility		1.67	0	0
Environment Score (20)			-25.05	-25.05
Interest / support of community / social interest groups	10	10	5	5
Social Score (10)			50	50
Fit with Māori cultural values	10	10	0	0
Cultural Score (10)			0	0
Risk of operational failure	20	20	10	10
Implementation Risk Score (20)			200	200
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	5	5
Risk of cost escalation due to construction unknowns		2.5	0	0
Risk of land availability		2.5	0	-5
Risk of protracted consent process with authorities		2.5	10	0
Economic Score (10)			37.5	0
Risk Reduction	30	7.5	5	5
Deep flooding 1 in 50 year future - current		7.5	10	10
Manholes overflowing 1 in 10 - future-current		7.5	10	10
Improvement in LOS		7.5	5	5
Effectiveness (Risk Reduction) Score (30)			225	225
TOTAL			437	400



G9: Wastewater Flooding/Overflows

Table G9-1: Option WMoA

Option WMoA				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	2.5	5	Removes Silver Stream overflow and Tyne Street manhole overflows in 1 in 10 year event.
I&I reduction		2.5	5	Removes groundwater infiltration from catchment WW6.
Reduction in Energy Consumption		2.5	5	Reduction in energy consumption due to groundwater reduction however this will be offset by removal of overflows which will mean more water in storm events will be pumped to Green Island WWTP.
Construction impact		2.5	0	Minimal construction required.
Environment Score (20)			37.5	
Interest / support of community / social interest groups	10	10	5	Given the overflows is within the local area of the proposed upgrade, it is considered that there will be some support from the community for the upgrades.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Not specifically identified as preferred approach, as no consultation has been undertaken but likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	5	Proven technology however may not achieve desired level of groundwater infiltration reduction
Implementation Risk Score (20)			100	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	5	Capital cost between \$500,000 and \$1,000,000.
Risk of cost escalation due to construction unknowns		2.5	5	Risks can be managed via alternatives.
Risk of land availability		2.5	10	Work in road reserve.
Risk of protracted consent process with authorities		2.5	0	No consents required.



Option WMoA				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Economic Score (10)			50	
Manholes overflowing 1 in 10 yr ARI current before and after upgrades	30	7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in level of service		7.5	5	The removal of Silver Stream overflow is a significant improvement in LOS however there were no customer complaints for this overflow.
Meets future growth of city and climate change		7.5	5	Meets future growth
Sensitivity of solution to parameters and assumptions		7.5	0	Moderately sensitive
Effectiveness (Risk Reduction) Score (30%)			150	
TOTAL SCORE: 388				



Table G9-2: Option WMoB

Option WMoB				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	2.5	5	Removes Silver Stream overflow and Tyne Street manhole overflows in 1 in 10 year event.
I&I reduction		2.5	5	Removes groundwater infiltration from catchment WW6.
Reduction in Energy Consumption		2.5	0	Reduction in energy consumption due to groundwater reduction however this will be offset by removal of overflows which will mean more water in storm events will be pumped to Green Island WWTP. Having an additional PS pumping to Green Island is
Construction impact		2.5	-5	Long rising main to construct which will have a short term impact.
Environment Score (20)			12.5	
Interest / support of community / social interest groups	10	10	5	Given the upgrades will remove overflows to the Silver Stream it is considered that there will be some support from the community for the upgrades.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Not specifically identified as preferred approach, as no consultation has been undertaken but likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	5	Proven technology however may not achieve desired level of groundwater infiltration reduction
Implementation Risk Score (20)			100	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	-5	Capital cost between \$5,000,000 and \$15,000,000.
Risk of cost escalation due to construction unknowns		2.5	5	Risks can be managed via alternatives.
Risk of land availability		2.5	10	Expansion work at Burns Street PS is in Council owned land and new rising main alignment is within road



Option WMoB				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
				reserve.
Risk of protracted consent process with authorities		2.5	0	No consents required.
Economic Score (10)			25	
Manholes overflowing 1 in 10 yr ARI current before and after upgrades	30	7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in level of service		7.5	5	The removal of Silver Stream overflow is a significant improvement in LOS however there were no customer complaints for this overflow.
Meets future growth of city and climate change		7.5	5	Meets future growth
Sensitivity of solution to parameters and assumptions		7.5	5	
Effectiveness (Risk Reduction) Score (30)			187.5	
TOTAL SCORE: 375				



Table G9-3: Option WMoC

Option WMoC				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	2.5	5	Removes Silver Stream overflow and Tyne Street manhole overflows in 1 in 10 year event.
I&I reduction		2.5	5	Removes groundwater infiltration from catchment WW6.
Reduction in Energy Consumption		2.5	0	Reduction in energy consumption due to groundwater reduction however this will be offset by removal of overflows which will mean more water in storm events will be pumped to Green Island WWTP.
Construction impact		2.5	0	
Environment Score (20)			25	
Interest / support of community / social interest groups	10	10	5	Given the upgrades will remove overflows to the Silver Stream it is considered that there will be some support from the community for the upgrades.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Not specifically identified as preferred approach, as no consultation has been undertaken but likely to fit.
Cultural Score (10)			0	
Risk of operational failure	20	20	5	Proven technology as constructing new pipeline and storage.
Implementation Risk Score (20)			100	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	0	Capital cost between \$1,000,000 and \$5,000,000.
Risk of cost escalation due to construction unknowns		2.5	5	Risks can be managed via alternatives.
Risk of land availability		2.5	10	Storage to be constructed at WWTP (Council owned land) and Murray Street pipeline is within road reserve.



Option WMoC				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Risk of protracted consent process with authorities		2.5	0	No consents required.
Economic Score (10)		37.5		
Manholes overflowing 1 in 10 yr ARI current before and after upgrades	30	7.5	10	The modelled option indicates the number of overflowing manholes will be reduced.
Improvement in level of service		7.5	5	The removal of Silver Stream overflow is a significant improvement in LOS however there were no customer complaints for this overflow.
Meets future growth of city and climate change		7.5	5	Meets future growth
Sensitivity of solution to parameters and assumptions		7.5	-10	Amount of storage required is sensitive to soil saturation parameters.
Effectiveness (Risk Reduction) Score (30)		75		
TOTAL SCORE:288				



Table G9-4: Option WMoD

Option WMoD				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
Removal of known wastewater cross connections.	10	2.5	5	Removes Silver Stream overflow and Tyne Street manhole overflows in 1 in 10 year event.
I&I reduction		2.5	-10	No I&I reduction
Reduction in Energy Consumption		2.5	-5	No I&I reduction and removing overflows therefore more flow will have to be pumped to Green Island WWTP
Construction impact		2.5	-5	Storage tank will have large footprint
Environment Score (20)			-37.5	
Interest / support of community / social interest groups	10	10	5	Given the upgrades will remove overflows to the Silver Stream it is considered that there will be some support from the community for the upgrades.
Social Score (10)			50	
Fit with Māori cultural values	10	10	0	Not specifically identified as preferred approach, as no consultation has been undertaken but likely to fit.
Cultural Score (10)			0	
Risk of operational failure			10	Proven technology as constructing new pipeline and storage.
Implementation Risk Score (20)			200	
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	10	2.5	0	Capital cost between \$1,000,000 and \$5,000,000.
Risk of cost escalation due to construction unknowns		2.5	5	Risks can be managed via alternatives.
Risk of land availability		2.5	10	Storage to be constructed at WWTP (Council owned land) and new pipeline is within road reserve.
Risk of protracted consent process with authorities		2.5	0	No consents required.
Economic Score (10)			37.5	
Manholes overflowing 1 in 10 yr ARI current before and after		7.5	10	The modelled option indicates the number of overflowing manholes will be



Option WMoD				
Option Assessment Criteria	Category Weighting	Sub-weighting	Score	Comment
upgrades				reduced.
Improvement in level of service	30	7.5	5	The removal of Silver Stream overflow is a significant improvement in LOS however there were no customer complaints for this overflow.
Meets future growth of city and climate change		7.5	5	Meets future growth
Sensitivity of solution to parameters and assumptions		7.5	-10	Amount of storage required is sensitive to soil saturation parameters.
Effectiveness (Risk Reduction) Score (30)			75	
TOTAL SCORE:325				



Table G9-5: Wastewater Flooding/Overflows Option Comparison

Option QBL Assessment Criteria	Option			
	WmoA	WmoB	WmoC	WmoD
Removal of known wastewater cross connections.	5	5	5	5
I&I reduction	5	5	5	-10
Reduction in Energy Consumption	5	0	0	-5
Construction impact	0	-5	0	-5
Environment Score (20%)	37.5	12.5	25	-37.5
Interest / support of community / social interest groups	5	5	5	5
Social Score (10%)	50	50	50	50
Fit with Māori cultural values	0	0	0	0
Cultural Score (10%)	0	0	0	0
Risk of operational failure	5	5	5	10
Implementation Risk Score (20%)	100	100	100	200
Estimated Capital Cost - order of magnitude (note does not allow for internal costs)	5	-5	0	0
Risk of cost escalation due to construction unknowns	5	5	5	5
Risk of land availability	10	10	10	10
Risk of protracted consent process with authorities	0	0	0	0
Economic Score (10%)	50	25	37.5	37.5
Manholes overflowing 1 in 10 yr ARI current before and after upgrades	10	10	10	10
Improvement in level of service	5	5	5	5
Meets future growth of city and climate change	5	5	5	5
Sensitivity of solution to parameters and assumptions	0	5	-10	-10
Effectiveness (Risk Reduction) Score (30%)	150	187.5	75	75
TOTAL	388	375	288	325