

Willoughby City Council Water Quality Monitoring Report Spring 2022 - Autumn 2023



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Table of Contents

1	Execu	tive summary	1					
2	Glossary and acronyms							
3	Background5							
4	Study Area6							
5	Sites .		8					
6	Metho	d descriptions	9					
6	.1 Mad	croinvertebrates	9					
6	.2 Wa	er Quality1	0					
6	.3 Rap	pid Riparian Assessment	1					
6	.4 Rai	nfall	1					
7	Rainfa	II and Sampling1	2					
8	Swain	es Creek	3					
8	1 Site	Profiles	3					
8	2 Res	sults and Interpretation	3					
Ŭ	8.2.1	Macroinvertebrates	3					
	8.2.2	Water Quality	4					
	8.2.3	Rapid Riparian Assessment	5					
٩	Flat R	nck Creek 1	7					
J Q	1 Site		7					
0 0	2 Ros	ults and Interpretation	י פ					
J	921	Macroinvertebrates	8					
	922	Water Quality	9					
	9.2.3	Rapid Riparian Assessment	0					
40	Caller		0					
10	Sallor	s Bay Creek	2					
1	0.1 3 0.2 E	Ite Profiles	2 ว					
	U.Z	Macroinvortebrates	2 2					
	10.2.1	Water Quality	2					
	10.2.2	Ranid Rinarian Assessment	4					
	10.2.0		T					
11	Scotts	20 Creek	6					
1	1.1 S	20 Second Se	6					
1	1.2 R	22 Meansing at the pretation	7					
	11.2.1	Wacroinvertebrates	1					
	11.2.2	Water Quality	8					



11.2.3 Rapid Riparian Assessment	
2 Sugarloaf Creek	
12.1 Site Profiles	
12.2 Results and Interpretation	
12.2.1 Macroinvertebrates	
12.2.2 Water Quality	
12.2.3 Rapid Riparian Assessment	
3 Blue Gum Creek	
13.1 Site Profiles	
13.2 Results and Interpretation	
13.2.1 Macroinvertebrates	
13.2.2 Water Quality	
13.2.3 Rapid Riparian Assessment	
4 Conclusions	
14.1 Macroinvertebrates	
14.2 Water Quality 42	
14.3 Rapid Riparian Assessment	
5 Recommendations43	





Figure 1 Willoughby City Council Water Quality Management Program Sites Map of sites for chemical and ecological monitoring across six creeks	7
Figure 2 Collecting macroinvertebrates from Swaines Creek	1
Figure 3 Preserved macroinvertebrates	9
Figure 4 Collecting freshwater macroinvertebrates, this water bug is a backswimmer (Notonectidae)	9
Figure 5 Collecting water quality samples and taking field measurements.	. 10
Figure 6 Swaines Creek with riparian vegetation	11
Figure 7 Rainfall and sampling events for Spring 2022 and Autumn 2023	. 12
Figure 8 Swaines Creek	. 13
Figure 9 SIGNAL SF results for Swaines Creek	. 13
Figure 10 Taxa Richness results for Swaines Creek	. 14
Figure 11 Summary of Swaines Creek scorecard rankings	. 16
Figure 12 Flat Rock Creek at Flat Rock Gully	. 17
Figure 13 Water quality sampling point for WCC-FR2	. 17
Figure 14 Flat Rock Creek SIGNAL SF results	. 18
Figure 15 Flat Rock Creek SIGNAL Taxa Richness results	. 18
Figure 16 Summary of Flat Rock Creek at Flat Rock Gully scorecard ranking	. 21
Figure 17 Summary of Flat Rock Creek at Narremburn scorecard rankings	. 21
Figure 18 WCC_SB1 Sailors Bay Creek	. 22
Figure 19 Sailors Bay Creek SIGNAL SF results	. 22
Figure 20 Sailors Bay Creek Taxa Richness results	. 23
Figure 21 Summary of Sailors Bay Creek scorecard rankings	. 25
Figure 22 WCC_SC1 Scotts Creek at North Arm Reserve	. 26
Figure 23 WCC_SC2 Scotts Creek at Willis Park	. 26
Figure 24 WCC_SC3 Scotts Creek 3 at Muston Park	. 26
Figure 25 Scotts Creek SIGNAL SF results	. 27
Figure 26 Scotts Creek Taxa Richness results	. 27
Figure 27 Summary of Scotts Creek at North Arm scorecard rankings	. 31
Figure 28 Summary of Scotts Creek at Willis Park scorecard rankings	. 32
Figure 29 Summary of Scotts Creek at Muston Park scorecard rankings	. 32
Figure 30 WCC_SGL1 Sugarloaf Creek	. 33
Figure 31 WCC_SGL2 Sugarloaf Creek 2 at Butt Park	. 33
Figure 32 Sugarloaf Creek SIGNAL SF results	. 34
Figure 33 Sugarloaf Creek Taxa Richness results	. 34
Figure 34 Summary of Sugarloaf Creek at Sunnyside scorecard rankings	. 37
Figure 35 Summary of Sugarloaf Creek at Butt Park scorecard rankings	. 37
Figure 36 WCC_BG1 Blue Gum Creek	. 38
Figure 37 Blue Gum Creek SIGNAL SF results	. 38
Figure 38 Blue Gum Creek taxa richness results	. 39
Figure 39 Summary of Blue Gum Creek scorecard rankings	. 41





1 Executive summary

This report presents the findings of water quality monitoring and macroinvertebrate sampling carried out in Spring 2022 and Autumn 2023. The six areas surveyed were:

- Swaines Creek
- Flat Rock Creek
- Sailors Bay Creek
- Scotts Creek
- Sugarloaf Creek, and
- Blue Gum Creek catchments.

Sydney Water conducted water quality analysis at ten sites within these six study areas. Samples were collected quarterly and after three wet weather events to monitor physical and chemical attributes.

Biological assessment using macroinvertebrate collections were conducted at each of the study creeks during both Spring and Autumn seasons.

Rapid Riparian Assessments were carried out when macroinvertebrates were collected. For Spring 2022 and Autumn 2023 riparian scores fell into either the *Good* or *Excellent* category, which is consistent for creeks with large riparian buffer zones. Flat Rock Creek at Flat Rock Gully had the highest rapid riparian assessment score falling into the *Excellent* category at 80.2 in Spring 2022. Sailors Bay Creek had the lowest riparian score falling into the *Good* category at 29.1 in Spring 2022. Higher riparian scores generally occur where creeks have larger buffer zones, higher scoring vegetation communities, litter reduction and improved weed management.

Monitoring results for pH, turbidity and conductivity were generally good at all ten sites within the six sample creeks. Scotts Creek in North Arm Reserve had an unusually high conductivity level (2,990 µS/cm) in October 2022.

Similar to previous years, median concentrations of total nitrogen and total phosphorous exceeded guideline levels at all sites for 2022-23, indicating elevated levels of organic pollution across the Willoughby LGA. Sources could include fertiliser run-off from recreational open spaces and residential gardens, raw sewage and commercial cleaning products in stormwater or general run-off. Concentrations of total nitrogen and total phosphorous were consistent with previous sampling periods.

During 2022-23 dry weather faecal coliform and enterococci levels improved at Scotts Creek Muston Park, with the dry weather median level for faecal coliforms falling below the ANZECC (2000) guideline level for the first time in the past six report periods. Inconsistently, the mid and downstream sites of Scotts Creek (at Willis Park and at North Arm Reserve) both showed increases in dry weather median faecal coliform and enterococci levels, with median dry weather levels exceeding the ANZECC (2000) guidelines at both sites for the first time.





Flat Rock Creek at both the Flat Rock Gully and Narremburn sites had dry weather median faecal coliform and enterococci levels above the recommended ANZECC (2000) guideline. Wet weather median levels for both faecal coliforms and enterococci were above the recommended ANZECC (2000) guidelines at the Swaines Creek and Flat Rock Creek at Flat Rock Gully.

Copper results were elevated above hardness modified guideline levels on all four dry weather sampling occasions at Scotts Creek at Willis Park and Scotts Creek at Muston Park in 2022-23. The remaining creeks were above hardness modified guideline levels on one or two occasions. Anthropogenic sources of copper include electrical wiring and electroplating, the production of alloys, copper piping, photography, antifouling paints and pesticide formulations. This may lead to concentrations entering the aquatic environment (either directly via sewage or industrial discharges or through atmospheric deposition).

Zinc levels were elevated above the hardness adjusted recommended guideline (ANZECC 2000) at the three Scotts Creek sites on most occasions. Blue Gum Creek was the only site with no exceedances of the zinc criteria. Scotts Creek at Willis Park and Sugarloaf Creek at Sunnyside Crescent were the only sites that exceeded the hardness adjusted guideline for lead, each with one elevated level in dry weather.

Average taxa richness for sites in 2022-23 ranged between 4 (Blue Gum Creek in Autumn 2023) and 13.5 (Sailors Bay Creek in Autumn 2023). While taxa richness for most sites was consistent with previous years, Blue Gum Creek showed decreases in both Spring 2022 and Autumn 2023.

Signal-SF scores for sites in 2022-23 ranged between 3.79 (Swaines Creek at Ferndale Park in Spring 2022) and 5.01 (Sugarloaf Creek at Sunnyside Crescent in Autumn 2023) and were consistent with habitats experiencing probable moderate organic pollution. This range of scores is comparable to other urbanised streams in the Sydney metropolitan area and macroinvertebrates found in this range have the ability to withstand pollution. Scores recorded in 2022-23 did not change notably from the historical Signal-SF data.





2 Glossary and acronyms

Item	Meaning					
Abundance	The total number of individual specimens; in a sample, community, ecosystem etc.					
Algae	Comparatively simple chlorophyll-bearing plants, most of which are aquatic and microscopic in size.					
Alkalinity	The ability of a solution to neutralise acid (or buffer).					
Ammonia	A colourless gas. In the aquatic environment, it exists in the relatively harmless form ammonium (NH4) and the toxic form ammonia (NH3).					
Analyte	The physical and chemical parameters (indicators) to be measured.					
Anthropogenic	Impacts on an environment that are produced or caused by humans					
ANZECC	Australian and New Zealand Environment and Conservation Council (ANZECC) is a forum for member governments to develop coordinated policies about national and international environment and conservation issues.					
Catchment	The area that is drained by a river, lake or other water body.					
CFU/100mL	Colony Forming Units per 100 mL					
Community	Assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.					
Concentration	The quantifiable amount of a chemical divided by the total volume of a mixture.					
Conductivity	The measure of salt content in soil or water; it refers to the ability of the substance to transfer an electrical charge.					
Dissolved Oxygen	The measurement of the concentration of oxygen that is dissolved in a water body.					
Diversity (Biological)	The measure of the number and/or degree of available organisms in an environment.					
Eutrophication	Enrichment of a water body with nutrients that results in increased aquatic plant growth and low oxygen levels.					
Faecal Coliforms	Bacteria which inhabit the intestines of humans and other vertebrates and are present in faeces. Used as a primary indicator of sewage pollution in the environment.					
Guideline (water quality)	Concentration limit or narrative statement recommended to support and maintain a designated water use.					
Habitat	The place where a population lives and its surroundings, both living and non-living.					



Item	Meaning					
Indicator	A parameter (chemical, biological or geological) that can be used to provide a measure of the quality of water or the condition of an ecosystem.					
Macroinvertebrate (Aquatic)	nimals without backbones that when mature are greater than 1 nillimetre; live in the water column, on the water surface or on the bottom f a waterway.					
mg/L	Milligrams per litre					
Nitrogen (Aquatic)	An element that is essential for plant and animal growth, it occurs in three forms nitrate, nitrite, and ammonium.					
NTU	Nephelometric Turbidity Units					
Nutrients	Compounds required for growth by plants and other organisms. Major plant nutrients are phosphorus and nitrogen.					
рН	A measure of the degree of acidity or alkalinity; expressed on a logarithmic scale of 1 to 14 (1 is most acid, 7 neutral and 14 most alkaline).					
Phosphorus	s an element that is essential for plant and animal growth, excess concentrations can lead to eutrophication.					
Physico-Chemical	The measure and relationship between the physical and chemical identities of a water body.					
Sensitive organism	An organism that's survival is highly susceptible to shifts in environmental conditions.					
Sewage	The wastewater from homes, offices, shops, factories, and other premises discharged to the sewer. Is usually 99% water.					
SIGNAL SF	SIGNAL-SF (Stream Invertebrate Grade Number Average Level-Sydney Family) is a biotic index using aquatic macroinvertebrates to assess stream health.					
Stormwater	Rainwater that runs off the land, frequently carrying various forms of pollution such as litter and detritus, animal droppings and dissolved chemicals. This untreated water is carried in stormwater channels and discharged directly into water bodies.					
Stormwater system	The system of pipes, canals and channels used to carry stormwater to bodies of water, such as rivers or oceans. The system does not usually involve any significant form of treatment.					
Tolerant organism	Is an organism that can survive in highly variable environmental conditions.					
Turbidity	A measure of the amount of suspended solids (usually fine clay or silt particles) in water and thus the degree of scattering or absorption of light in the water.					
μg/L	Micrograms per litre					
μS/cm	Micro-siemens per centimetre (unit of conductivity)					

Willoughby City Council Water Quality Monitoring Report | Spring 2022 - Autumn 2023

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3 Background

Water quality monitoring is carried out by the Willoughby City Council (WCC) to inform environmental management and development decisions. The aims of this report are:

- assess physical and chemical water properties of six major creeks (Scotts Creek, Sugarloaf Creek, Swaines Creek, Blue Gum Creek, Flat Rock Creek, and Sailors Bay Creek), within the Willoughby City Council local government area during dry and wet weather conditions,
- assess diversity and abundance of macroinvertebrate communities at six creeks within the study area,
- analyse environmental and ecosystem health data which will assist in monitoring the impact of future developments, creek restoration, stormwater management, bushland rehabilitation and general anthropogenic activities and incidents within the catchment,
- provide information to assist the direction of future water quality monitoring plans, and
- provide an easy to interpret report for the community.

Biological and chemical monitoring enables the Willoughby City Council to:

- build on baseline data that enables the temporal evaluation and analysis of the health of the catchments of the strategy,
- track new and existing impacts affecting the catchments,
- provide direction and monitor potential infrastructural works within the LGA, such as, instream or riparian rehabilitation and stormwater treatment projects, and
- build on the known taxa list for each catchment and to aid in the identification of key indicator taxa.

This report is a continuation of baseline data collected in surveys which commenced in Spring 2012. Historical data can be found in previous reports and used for comparison. Technical details for methods used, quality procedures, accreditation and journal references are the same as previous years and can also be found in previous reports.



4 Study Area

Willoughby City has an estimated population of approximately 81,196 people, with a population density of 36.2 persons per hectare and a total land area of 23 km² (WCC, 2021). The area forms one of Sydney's major residential, industrial, and commercial districts and includes the major business areas of Northbridge, St Leonards, Artarmon, and Chatswood. It is located approximately 9 km from the Sydney CBD. Willoughby City is predominantly a residential area, but also has substantial industrial and commercial areas. Significant bushland areas are located along the Lane Cove River and foreshore areas of Castle Cove, Castlecrag, Middle Cove, Northbridge, and Lane Cove West.

Historically, low-rise single dwelling houses formed most of the residential land use. With increases in residential populations, construction of high rise residential/commercial developments has increased the pressure placed on the adjacent remnant bushland and natural areas. From Census data, analysis of the types of dwellings in Willoughby City in 2016 showed approximately 55% were medium or high-density housing.

The LGA is divided into two main catchments comprising a total of 12 sub-catchments draining to the east and west. Approximately 83% of the total area located within the middle harbour catchment area drains to the east, including Scotts, Sugarloaf, Sailors Bay, and Flat Rock creeks. The main western catchment area flows into the Lane Cove River and includes Blue Gum and Swaines creeks.

Soil within the LGA is comprised of two broad types. Above 90 m altitude, shale derived clay is the dominant substrate however lower lying Hawkesbury sandstone dominates the more coastal areas to the east.

The average rainfall for the Willoughby LGA is approximately 1140 mm with historically regular rainfall across each month. The lowest rainfall generally falls in spring and the heaviest falls in late summer to early winter.



Figure 1 Willoughby City Council Water Quality Management Program Sites Map of sites for chemical and ecological monitoring across six creeks.





5 Sites

For each catchment, there is one site where macroinvertebrates, riparian vegetation and water quality are assessed. Additional water quality only sites are located at Flat Rock Creek, Scotts Creek, and Sugarloaf Creek (Table 1). In total, there are six macroinvertebrate sites, six riparian sites and ten water quality sites. Three sites, Swaines Creek at Ferndale Park (WCC_SW1), Flat Rock Creek at Flat Rock Gully (WCC_FR1) and Scotts Creek at Muston Park (WCC_S3), have additional water quality samples collected for wet weather monitoring.

Site	Location	Dry Weather Water Quality (Wet weather)	Macroinvertebrates	Rapid Riparian Assessment
WCC_BG1	Blue Gum Creek 1	\checkmark	\checkmark	\checkmark
WCC_SW1	Swaines Creek at Ferndale Park	✓ (✓)	\checkmark	\checkmark
WCC_FR1	C_FR1 Flat Rock Creek at Flat Rock Gully		\checkmark	\checkmark
WCC_FR2	Flat Rock Creek at Narremburn	\checkmark		
WCC_SB1	Sailors Bay Creek off The Palisade	✓	\checkmark	\checkmark
WCC_S1	Scotts Creek at North Arm Reserve	\checkmark		
WCC_S2	Scotts Creek at Willis Park	\checkmark	\checkmark	\checkmark
WCC_S3	Scotts Creek at Muston Park	✓(✓)		
WCC_SGL1	Sugarloaf Creek at Sunnyside Cres	\checkmark	\checkmark	\checkmark
WCC_SGL2	Sugarloaf Creek at Butt Park	\checkmark		

Table 1 Survey sites for monitoring chemical and ecological attributes.

Willoughby City Council Water Quality Monitoring Report | Spring 2022 - Autumn 2023





6 Method descriptions

6.1 Macroinvertebrates



Aquatic macroinvertebrates are small (>1 mm), spineless animals that naturally occur in water bodies. Macroinvertebrates are useful as bioindicators because some are more sensitive to pollution than others. A water pollution problem may be indicated if a stream is found to have a macroinvertebrate community dominated by pollution-tolerant animals and missing the more pollution-sensitive animals.

Macroinvertebrates are collected following a standard method. This involves using a fine mesh net to upwell the water and dislodge the animals (Figure 2). They are picked from the debris and preserved for lab-based identification and enumeration (Figure 3).

Figure 2 Collecting macroinvertebrates from Swaines Creek

SIGNAL SF

SIGNAL SF stands for *Stream Invertebrate Grade Number Average Level - Sydney Family.* It is an index for freshwater macroinvertebrates examined at the family taxonomic level to assess stream health.

This index assigns *sensitivity scores* from 1 (being tolerant to poor stream health) to 10, (being very sensitive to poor stream health), for each individual family.



Figure 3 Preserved macroinvertebrates

Taxa Richness



This is the total number of different types of animals collected. Generally, in healthier ecosystems, there will be higher diversity, which is higher taxa richness (Figure 4).

Figure 4 Collecting freshwater macroinvertebrates, this water bug is a backswimmer (Notonectidae)





6.2 Water Quality

Physical, chemical, and biological conditions of the six main catchments in the Willoughby City Council local government area were assessed following the same methods as previous years. This provides information that can create a snapshot of what was happening in the creek at that point in time.

Routine monitoring of water quality was undertaken on a quarterly basis at all ten sites for the period July 2022 to July 2023. Sampling occurred during dry weather conditions, as determined by rainfall not exceeding 5 mm in the 5 days leading up to sampling.

Wet weather events can cause an influx of pollutants from stormwater and run-off, as well as changing the physical characteristics. Higher dissolved oxygen levels would be common in wet weather events due higher water flow.

Several analyses are conducted in the field and additional water is collected for lab analysis (Figure 5). The lab analysis is performed at the Sydney Water Laboratory located in West Ryde.

The results are then compared back to the Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines. The ANZECC (2000) water quality guidelines outline a framework for assessing water quality in terms of whether the water is suitable for a range of environmental and community values. Exceedances of the ANZECC (2000) guidelines may indicate environmental disturbance.

Table 2 Survey sites for monitoring chemical and ecological attributes

Category	Analytes
Chemical	Total nitrogen, total phosphorous
Microbiological	Faecal coliforms, enterococci
Physical	Temperature, pH, conductivity, dissolved oxygen, suspended solids
Metal	Total copper, total lead, total zinc



Figure 5 Collecting water quality samples and taking field measurements



6.3 Rapid Riparian Assessment



Rapid Riparian Assessments were added to the monitoring program in Spring 2015 to cover areas of data, such as stream features, which are not covered in macroinvertebrate and water quality sampling.

The riparian zone is the area where a body of water or stream, meets the land. Rapid Riparian Assessments provides information on and assessment of the features of the stream and the vegetation community surrounding the stream.

Figure 6 Swaines Creek with riparian vegetation

The main categories assessed are:

- Site features
- Channel features
- Depositional features
- Erosional features
- Riparian vegetation
- Vegetation structure

Each variable within these categories is scored and form an overall score that will fall into an overall riparian health category (Table 3).

Table 3 Rapid Riparian Assessment Categories

Category	Score range	Colour code
Excellent	≥60	\bigcirc
Good	27 to 59.99	\bigcirc
Fair	-6 to 26.99	0
Poor	-39 to -6.01	\bigcirc
Very Poor	-72 to -39.01	

6.4 Rainfall

Rainfall plays a key role in the water quality of streams. The stream flow can be greatly altered during a high rainfall event, which can cause bank erosion, increased turbidity, higher nutrient concentrations, and other pollution.

This can directly impact the macroinvertebrate community through loss of habitat and decreased water quality. The water quality results may also exceed the recommended guidelines because of increased stormwater input.

Seasonal rainfall, particularly extended low levels of rain can benefit both macroinvertebrates and water quality. Flowing water will flush out the stream and provide the conditions to avoid algae build up and oxygen depletion.

The rainfall data used is from the Sydney Water rain gauge located at West Ryde.





7 Rainfall and Sampling

Daily rainfall for the sampling period is presented below (Figure 7). Rainfall was generally low and sporadic throughout the sampling period. The highest daily rainfall for the period was 77.5 mm on 2 July 2022. Other daily rainfall events over 50 mm were recorded on 3 July 2022 (60.0 mm), 4 July 2022 (60 mm), and 2 April 2023 (58.0 mm). The cumulative rainfall between 1 July 2022 and 1 August 2023 was 1,162 mm.

Dry weather water quality sampling occurred at all ten sites on 29 July 2022, 31 October 2022, 2 March 2023, and 5 May 2023. Three wet weather water quality sampling events were sampled at Scotts Creek 3, Flat Rock Creek 1, and Swaines Creek 1 on 17 November 2022, 15 December 2022, and 6 April 2023.

Spring 2022 sampling of macroinvertebrates and rapid riparian assessments occurred in the last week of November 2022. Autumn 2023 sampling for macroinvertebrates and rapid riparian assessments occurred in early May 2023.



Figure 7 Rainfall and sampling events for Spring 2022 and Autumn 2023

8 Swaines Creek

8.1 Site Profiles

WCC_SW1: Swaines Creek 1 at Ferndale Park (Water quality and macroinvertebrates)



Figure 8 Swaines Creek

WCC_SW1 is the sole site on Swaines Creek, located midstream within the catchment. It is located in a narrow section of creek and has a moderate amount of native riparian vegetation. During dry weather, the site experiences low to moderate flows and its substrate comprises mainly bedrock, boulders, and cobbles, with moderate algal cover (Figure 8). A sewer overflow point is present immediately upstream of the sampling area.

8.2 Results and Interpretation

8.2.1 Macroinvertebrates

SIGNAL SF

The SIGNAL SF score for Spring 2022 was lower than previous years and was the lowest SIGNAL SF score for the current reporting period. The SIGNAL SF score for Autumn 2023 was within the range of historical results.



Figure 9 SIGNAL SF results for Swaines Creek







Taxa Richness

Average taxa richness for Spring 2022 was higher than the low Spring 2021 result for this site. The average taxa richness for Autumn 2023 was slightly higher than the low Autumn 2022 result but remained lower than Autumn 2021 and Autumn 2020.

Figure 10 Taxa Richness results for Swaines Creek

Macroinvertebrates summary

SIGNAL SF for Spring 2022 was lower than previous years, and the lowest score for the current reporting period

Taxa Richness in both Spring 2022 and Autumn 2023 increased compared to respective seasons in 2021 and 2022

8.2.2 Water Quality

- Faecal coliform results for dry weather ranged from 320 to 23,000 CFU/100mL. Despite the one very high result, the dry weather faecal coliform median for 2022-23 remained below the recommended ANZECC (2000) guideline value.
- Enterococci results for dry weather ranged from 67 to 14,000 CFU/100mL. Despite the one very high result, the dry weather enterococci median for 2022-23 remained below the recommended ANZECC (2000) guideline value.
- All total nitrogen results were above the relevant ANZECC (2000) guideline, with the dry weather median level similar to previous years.
- Three of the four dry weather total phosphorous results were below the relevant ANZECC (2000) guideline. The dry weather median was lower than previous years, falling below the relevant ANZECC (2000) guideline.
- Dissolved oxygen (DO) saturation levels, turbidity, pH, and conductivity levels were all within the recommended ANZECC (2000) guidelines for Swaines Creek on all sampling occasions.
- Total calcium and total magnesium results were comparable to the historical median concentrations.
- Zinc, lead, and copper results were similar to historical median concentrations



Table 4 Water quality results summary for Swaines Creek - dry weather medians 2016 - 2023 (ANZECC 2000 exceedances in bold)

Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	420	480	2150	1795	1240	920	1105
Enterococci	CFU/100mL	190	160	1490	330	325	480	430
Total nitrogen	µg/L	850	815	890	795	880	740	920
Total phosphorous	µg/L	24	50	48	42.5	48.5	44	43
Dissolved Oxygen	%sat	92.4	88.8	88.2	86.7	88.9	88.9	81.8
рН	pH Units	7.35	7.44	7.44	7.46	7.61	7.50	7.71
Conductivity	µS/cm	515	493	566	546	468	371	348
Suspended solids	mg/L	2.0	1.0	3.0	1.0	2.0	2.0	2.5
Turbidity	NTU	4.75	2.4	1.2	2.8	1.9	1.8	2.1
Zinc	µg/L	13	12.5	11.5	11.0	12.5	8.0	13.0
Lead	µg/L	0.45	0.6	0.4	0.5	0.4	0.6	0.7
Copper	µg/L	2.45	3.2	3.4	3.2	3.4	3.2	4.0

Water quality summary

Faecal coliform median result was lower than previous years

Total nitrogen and total phosphorous median levels were elevated, but typical for Swaines Creek

Other water quality measures were consistent with previous years

8.2.3 Rapid Riparian Assessment

The overall riparian health scores for Swaines Creek were *Excellent* for Spring 2022 at 74 and *Good* for Autumn 2023 at 59. A higher proportion of weeds were recorded in Autumn 2023, accounting for the lower score compared to Spring 2022. Bushland with a large riparian buffer zone, the absence of weeds and good vegetation structures contribute to a high rapid riparian assessment score.





The chemical ranking improved to a D in 2022-23 compared to F in 2021-22, while the metals ranking fell from A in 2021-22 to B in 2022-23. This was reflected by a slight increase in the overall scorecard ranking (Figure 11).



Swaines Creek at Ferndale

Figure 11 Summary of Swaines Creek scorecard rankings

9 Flat Rock Creek

9.1 Site Profile

Flat Rock Creek has two water quality sites and one macroinvertebrate site.

WCC_FR1: Flat Rock Creek 1 at Flat Rock Gully (Water quality and macroinvertebrates)



Figure 12 Flat Rock Creek at Flat Rock Gully

WCC_FR1 is on Flat Rock Creek, located in the lower section of the catchment. This site lies at the base of a relatively steep catchment and is characterised by several deep pools which exhibit low to moderate flow during dry weather. The substrate consists primarily of bedrock and boulders, and the riparian vegetation of both native and exotic species (Figure 12).

WCC_FR2: Flat Rock Creek 2 at Narremburn (Water quality only)

WCC-FR2 is sampled on Flat Rock Creek, upstream from WCC_FR1, located midstream within the catchment. WCC_FR2 is situated upstream of a gross pollutant trap located underneath the Gore Hill Freeway. This section of creek consists of a fully concreted canal system (Figure 13) with low flows during dry weather. Domestic rubbish and algae were recorded at this site.



Figure 13 Water quality sampling point for WCC-FR2







9.2 Results and Interpretation

9.2.1 Macroinvertebrates

SIGNAL SF

The SIGNAL SF values for Spring 2022 and Autumn 2023 were consistent with the historical values for Flat Rock Creek (Figure 14), indicating that there has been no major change to stream health and habitat conditions.

Figure 14 Flat Rock Creek SIGNAL SF results



Taxa Richness

Taxa Richness for Spring 2022 was similar to Spring 2021 and remained notably lower than the higher than unusually high Spring 2020 result. The taxa richness for Autumn 2023 was slightly higher than Autumn 2022 (Figure 15).

Figure 15 Flat Rock Creek SIGNAL Taxa Richness results



Macroinvertebrates summary

SIGNAL SF values for Spring 2022 and Autumn 2023 were consistent with the historical values

Taxa Richness for Spring 2022 and Autumn 2023 was slightly higher than the respective previous seasons





9.2.2 Water Quality

- Faecal coliform results exceeded the ANZECC (2000) guideline on three dry weather sampling and two wet weather events at the Flat Rock Gully site. The dry weather median value was higher than those of the last six years
- Faecal coliform results exceeded the ANZECC (2000) guideline on three of the four dry weather sampling events at the Narremburn site
- Enterococci results exceeded the ANZECC (2000) guidelines on all dry weather sampling occasions at Flat Rock Gully, and on all sampling occasions at the Narremburn site. The median dry weather level at Flat Rock Gully was similar to 2021-22, but much higher than the five years prior
- Total nitrogen and total phosphorous concentrations exceeded the respective guidelines at both sites on all sampling occasions
- The dissolved oxygen saturation levels were below the ANZECC (2000) guidelines on two of the four dry weather and two of the three wet weather sampling occasions at the Flat Rock Gully site, and within the ANZECC (2000) guideline range on all four occasions at Narremburn
- Turbidity, pH, and conductivity levels complied with the respective ANZECC (2000) guidelines on all sampling occasions at both sites
- Median dry weather results for total magnesium, calcium, and hardness were within the overall range of historical results
- Total copper, zinc and lead concentrations were within the range of historical results

Table 5 Water quality results summary for Flat Rock Creek at Flat Rock Gully dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	6550	850	345	580	4070	2500	1180
Enterococci	CFU/100mL	1265	1240	176	315	405	570	228
Total nitrogen	µg/L	4705	5295	5475	3615	2650	3550	3425
Total phosphorous	µg/L	68	34.0	26.5	31.5	39.5	50	34
Dissolved Oxygen	%sat	87.6	86.6	92.0	89.6	91.8	91.3	88.5
рН	pH Units	7.62	7.60	7.77	7.80	7.84	7.95	7.81
Conductivity	µS/cm	531	505	510	419	437	465	430
Suspended solids	mg/L	4.5	1.5	1.0	2.5	2.0	2.0	2.0
Turbidity	NTU	11.3	4.6	4.6	7.8	3.2	2.3	6.0
Zinc	µg/L	26.0	26.0	14.0	18.5	19.3	18.0	24.0
Lead	µg/L	0.65	0.5	0.3	0.6	0.5	1.0	0.6
Copper	µg/L	6.7	6.2	3.6	4.0	4.9	5.1	4.7



Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	3500	525	3000	3600	8000	580	125500
Enterococci	CFU/100mL	600	875	680	410	1300	320	22600
Total nitrogen	µg/L	5660	1825	4630	2590	2570	3585	3500
Total phosphorous	µg/L	43	48	52	32	75	35	79
Dissolved Oxygen	%sat	83.5	96.4	79.8	97.7	96.8	85.9	86.8
рН	pH Units	7.78	7.55	7.67	7.89	7.90	7.65	7.76
Conductivity	µS/cm	506	367	557	405	450	430	500
Suspended solids	mg/L	3.0	3.5	2.0	5.0	12.0	2.0	2.0
Turbidity	NTU	7.2	7.8	6.6	2.7	3.3	2.9	5.8
Zinc	µg/L	15.0	21.0	25.0	23.0	28.0	25.0	42.5
Lead	µg/L	0.5	1.0	0.3	0.5	3.4	2.8	4.1
Copper	µg/L	3.5	3.8	3.8	3.5	6.4	4.1	4.6

Table 6 Water quality results summary for Flat Rock Creek at Flat Rock Gully wet weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Water quality summary

Median dry weather faecal coliform level for 2022-23 was higher than the 2021-22 period but consistent with the prior years

The median dry weather total nitrogen level was higher than previous years

9.2.3 Rapid Riparian Assessment

Flat Rock Creek riparian health scores were *Excellent* for both sampling seasons, 80.2 (Spring 2022) and 63.2 (Autumn 2023). Both these results were slightly higher than last year where scores from both seasons were in the *Excellent* category.







Flat Rock Creek at Flat Rock Gully



Figure 16 Summary of Flat Rock Creek at Flat Rock Gully scorecard ranking

Microbiological results were poorer than the previous sampling periods for Flat Rock Creek at Flat Rock Gully falling to a rank of F (Figure 16). Flat Rock Creek at Narremburn also showed a fall in the microbiological category from a C rank to F (Figure 17). Chemical rank fell from E to F at Flat Rock Gully, while metals increased a rank from C to B. Overall, water quality fell at both sites on Flat Rock Creek in 2022-23.







10 Sailors Bay Creek

10.1 Site Profiles

Sailors Bay Creek has one macroinvertebrate site and one water quality site.

WCC_SB1: Sailors Bay Creek (Water quality and macroinvertebrates)

WCC_SB1 is the sole site on Sailors Bay Creek, located midstream within the catchment. It has low flow during dry weather and the substrate consists primarily of bedrock and boulders. The sampling site is situated close to residential housing buffered with moderate levels of riparian vegetation including both native and exotic species. The presence of algae and domestic rubbish is regularly observed at this site.



10.2 Results and Interpretation

10.2.1 Macroinvertebrates



Figure 18 WCC_SB1 Sailors Bay Creek

SIGNAL SF

No major changes to stream health and habitat conditions were indicated, with the SIGNAL SF scores for both Spring 2022 and Autumn 2023 consistent with the historical results for Sailors Bay Creek (Figure 19).

Figure 19 Sailors Bay Creek SIGNAL SF results





Taxa Richness

Taxa richness in Sailors Bay Creek has historically been quite variable, however both Spring 2022 and Autumn 2023 results were consistent was the previous 2021-22 results.

Figure 20 Sailors Bay Creek Taxa Richness results

Macroinvertebrates summary

SIGNAL SF results for Spring 2022 and Autumn 2023 were consistent with historical results Taxa Richness results for Spring 2022 and Autumn 2023 were similar to the respective previous seasons

10.2.2 Water Quality

- Faecal coliform results exceeded the respective ANZECC (2000) guideline on one of the four sampling occasions
- Enterococci exceeded the respective ANZECC (2000) guideline on two occasions. The dry weather median was also above the guideline
- All total nitrogen and total phosphorous results exceeded the respective ANZECC (2000) guidelines
- Dissolved oxygen saturation levels were within the ANZECC (2000) guideline range on all four sampling occasions
- Turbidity, pH and conductivity levels were all within the recommended guidelines
- Total calcium, magnesium and hardness results were in the overall range of past results
- Total copper, zinc and lead results were slightly higher than the previous three years



Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	268	78	580	627	200	990	840
Enterococci	CFU/100mL	1050	85	135	380	130	380	440
Total nitrogen	µg/L	710	725	750	730	600	580	870
Total phosphorous	µg/L	34.5	29	28.5	27.0	26.5	30	34
Dissolved Oxygen	%sat	96.2	90.5	94.8	89.95	83.8	77.1	85.45
рН	pH Units	7.36	7.54	7.65	7.64	7.46	7.47	7.65
Conductivity	μS/cm	401	361	418	394	536	633	429
Suspended solids	mg/L	5.0	1.5	1.0	1.0	2.0	2.0	2.0
Turbidity	NTU	7.3	2.1	2.4	3.2	3.2	1.2	3.4
Zinc	µg/L	19.0	11.5	16.5	14.0	22.5	26.0	16.5
Lead	µg/L	1.4	0.6	0.8	0.9	1.2	0.5	0.9
Copper	µg/L	4.4	3.0	3.2	3.0	4.2	3.2	5.2

Table 7 Water quality results summary for Sailors Bay Creek dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Water quality summary

The median enterococci level for Sailors Bay was above the ANZECC (2000) guideline All nutrient results exceeded the respective ANZECC (2000) guidelines

10.2.3 Rapid Riparian Assessment

Sailors Bay Creek fell into the *Good* category for Spring 2022 and Autumn 2023 with results of 29.1 and 38.1 respectively.





The microbiology category fell two ranks to a C in 2022-23. Combined with falls in the chemical and riparian categories, the overall scorecard ranking for Sailors Bay Creek at Keep Reserve decreased (Figure 21).



Sailors Bay Creek at Keep Reserve

Figure 21 Summary of Sailors Bay Creek scorecard rankings

11 Scotts Creek

11.1 Site Profiles

Scotts Creek catchment has three water quality sites and one macroinvertebrate site.



Figure 22 WCC_SC1 Scotts Creek at North Arm Reserve

WCC_SC1: Scotts Creek 1 at North Arm Reserve (Water quality only)

WCC_SC1 is one of three sites on Scotts Creek, located downstream within the catchment, close to the entry into Castle Cove. Riparian vegetation consisted of mostly exotic flora (Figure 22). The presence of domestic rubbish and algae were frequently recorded at this site.

WCC_SC2: Scotts Creek 2 at Willis Park (Water quality and macroinvertebrates)

WCC_SC2 is the second site on Scotts Creek, located midstream within the catchment. It primarily consists of bedrock substrate surrounded by a thick mix of exotic and native riparian flora (Figure 23). It is located immediately upstream of a small waterfall and exhibits low to moderate flows in dry weather. A sewer overflow is located upstream, adjacent to a nearby tributary which flows directly into Scotts Creek. The presence of domestic rubbish and algae is frequently recorded at this site.

Figure 23 WCC_SC2 Scotts Creek at Willis Park

WCC_SC3: Scotts Creek 3 at Muston Park (Water quality only)

WCC_SC3 is the third site on Scotts Creek, located upstream within the catchment area. It is located within Muston Park, surrounded by medium density residential houses, and features a man-made sandstone bank edge (Figure 24). Domestic rubbish has been reported at the site on several occasions and a surface scum was reported for the dry weather sampling in February 2018.



Figure 24 WCC_SC3 Scotts Creek 3 at Muston Park







11.2 Results and interpretation

11.2.1 Macroinvertebrates



SIGNAL SF

The SIGNAL SF result for Spring 2022 was lower than Spring 2021 but remained higher than the low result of Spring 2020. The Autumn 2023 result was consistent with the historical results for Scotts Creek at Willis Park.

Figure 25 Scotts Creek SIGNAL SF results



Taxa Richness

Taxa Richness in Spring 2022 was similar to Spring 2021 and remains higher than the low result of Spring 2020. Taxa Richness for Autumn 2023 was consistent with the previous Autumn seasons.

Figure 26 Scotts Creek Taxa Richness results

Macroinvertebrates summary

SIGNAL SF score in Spring 2022 was slightly lower than Spring 2021, while the Autumn 2023 score was consistent with historical Autumn data

Taxa Richness for Spring continues to rise after the lower level of Spring 2020. Autumn 2023 was consistent with previous years





11.2.2 Water Quality

- Faecal coliform results for the mid catchment and downstream sites at Willis Park (WCC_SC2) and North Arm (WCC_SC1) each exceeded the ANZECC (2000) guideline on two occasions. For the first time at both these sites the dry weather median level for faecal coliforms was above the ANZECC (2000) guideline
- Enterococci results exceeded the ANZECC (2000) guideline on two occasions at the midstream site (WCC_SC2) and on one occasion from the downstream site (WCC_SC1). The dry weather median for Willis Park (WCC_SC2) exceeded the ANZECC (2000) guideline
- Typically, total nitrogen and total phosphorous results for the mid catchment and downstream sites (WCC_SC2; WCC_SC1) were generally at or above the respective ANZECC (2000) guidelines
- Uncharacteristically for the upstream site at Muston Park (WCC_SC3), the dry weather median faecal coliform median was below the ANZECC (2000) guideline, with exceedances on two of the four sampling occasions
- Wet weather median results for faecal coliform and enterococci levels at the Muston Park site (WCC_SC3) were also lower than previous years, with that for faecal coliforms below the ANZECC (2000) guideline recommendation, and that for enterococci only slightly above the ANZECC (2000) guideline recommendation
- All total nitrogen and phosphorous results at the Muston Park site (WCC_SC3) exceeded the recommended guidelines at levels typical for this site
- Dissolved oxygen saturation levels were within the ANZECC (2000) guideline range at the three sites on all but one sampling occasion (WCC_MSC3 on 5 May 2023)
- Turbidity results were below the ANZECC (2000) guideline on all dry weather sampling occasions, but exceeded on wet weather event (WCC_MSC3 on 5 December 2022)
- pH levels were all within the recommended ANZECC (2000) guidelines at the three sites on all sampling occasions
- Median total copper, zinc and lead levels were within the range of historical results



Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	1039	46	74	66	226	38	340
Enterococci	CFU/100mL	86	30	58	68	51	36	119
Total nitrogen	µg/L	1195	1010	985	735	900	490	725
Total phosphorous	µg/L	46	29	40	70.5	63.5	71	51
Dissolved Oxygen	%sat	98.8	98.7	98.0	94.7	96.5	102	90.8
рН	pH Units	7.56	7.66	7.74	7.72	7.82	7.97	7.57
Conductivity	μS/cm	421	1578	876	743	778	480	411
Suspended solids	mg/L	2.0	1.5	4.5	3.0	2.0	2.0	2.0
Turbidity	NTU	3.3	2.4	2.6	1.4	2.0	1.0	2.0
Zinc	µg/L	27.5	45.0	39.0	31.0	43.0	20.0	34.5
Lead	µg/L	0.55	0.4	0.7	1.1	0.6	0.4	0.6
Copper	µg/L	5.35	5.6	6.2	7.6	6.5	5.7	5.7

Table 8 Water quality results summary for Scotts Creek (WCC_SC1) dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Table 9 Water quality results summary for Scotts Creek (WCC_SC2) dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	1365	147	395	605	445	110	450
Enterococci	CFU/100mL	420	98	150	124	57	55	63
Total nitrogen	μg/L	1235	1265	1540	995	835	1050	830
Total phosphorous	µg/L	78	44	41	57	87.5	99	58.5
Dissolved Oxygen	%sat	96.1	91.6	94.2	89.6	92.55	87	79.65
рН	pH Units	7.46	7.36	7.54	7.58	7.57	7.54	7.40
Conductivity	μS/cm	408	1541	1396	814	829	502	384
Suspended solids	mg/L	2.0	2.0	1.0	1.0	2.0	2.0	2.0
Turbidity	NTU	4.55	2.0	1.4	1.0	2.1	1.3	2.0
Zinc	µg/L	36.5	46	43	37.5	43.0	33.0	37.0
Lead	µg/L	0.65	0.4	0.4	0.5	0.4	0.9	0.5
Copper	µg/L	7.5	6.8	6.6	7.8	6.3	7.7	7.9



Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	690	10000	2700	24000	55500	10000	13700
Enterococci	CFU/100mL	308	6950	970	790	825	650	370
Total nitrogen	µg/L	1605	2260	2650	1670	1925	1420	1490
Total phosphorous	µg/L	42	118	80	69	143	166	129.5
Dissolved Oxygen	%sat	93.4	88.0	80.2	92.6	79.8	74.5	83.4
рН	pH Units	7.52	7.35	7.41	7.8	7.59	7.58	7.82
Conductivity	μS/cm	417	1032	2462	1066	649	508	455
Suspended solids	mg/L	2.0	4.5	2.5	5.0	6.5	2.0	3.5
Turbidity	NTU	2.0	2.4	2.8	3.2	4.0	4.0	6.0
Zinc	µg/L	25.0	55.0	64.0	57.0	48.5	56.0	39.0
Lead	µg/L	0.2	0.8	0.5	0.4	0.5	0.5	0.5
Copper	µg/L	9.0	17.4	11.9	8.5	9.6	23.6	13.2

Table 10 Water quality results summary for Scotts Creek (WCC_SC3) dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Table 11 Water quality results summary for Scotts Creek (WCC_SC3) wet weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	160	6450	8000	32000	40000	64500	619000
Enterococci	CFU/100mL	94	1350	1900	1900	10000	1550	5100
Total nitrogen	µg/L	1420	2130	2590	1970	2160	1710	2165
Total phosphorous	µg/L	65	62	82	305	100	206	172
Dissolved Oxygen	%sat	99.4	97.8	90	100.0	97.3	79.2	86.2
рН	pH Units	7.65	7.68	7.46	7.75	7.63	7.50	7.79
Conductivity	μS/cm	276	835	1028	1752	460	480	440
Suspended solids	mg/L	6.0	1.5	2	5.0	9.0	2.5	8.0
Turbidity	NTU	14.0	2.6	2.9	3.0	14.0	5.8	11.8
Zinc	µg/L	73	39	44	64	66.0	61.0	49.0
Lead	µg/L	2.8	0.4	0.5	0.4	1.8	0.7	3.8
Copper	µg/L	16.1	9.0	10.1	14.3	30.3	16.7	17.8

0





Water quality summary

Overall water quality at the upstream site Scotts Creek site at Muston Park (WCC_SC3) has shown considerable improvement compared to previous years, with much lower microbiological and nutrient concentrations

The mid catchment and downstream sites at Willis Park (WCC_SC2) and North Arm (WCC_SC1) have shown a decline in microbiological quality

11.2.3 Rapid Riparian Assessment

Scotts Creek recorded results well within the *Good* range in Spring 2022 and Autumn 2023 with scores of 43.9 and 44.0 respectively. Even with the presence of weeds and introduced varieties of plants, this site has a large buffer zone and nestled within bushland.



Scotts Creek at the North Arm site saw an overall scorecard ranking drop slightly to below C, due to a fall in the microbiological category (Figure 27). At the Willis Park site, while the microbiological ranking fell one grade to a C, the physical category ranking increased one rank to an A, resulting in the overall scorecard ranking remaining unchanged for 2022-23 (Figure 28). At the Muston Park site the overall scorecard category increased, mainly due to improvement in microbiological category from an F to a C (Figure 29).







Scotts Creek at Willis Park

Figure 28 Summary of Scotts Creek at Willis Park scorecard rankings



Scotts Creek at Muston Park

Figure 29 Summary of Scotts Creek at Muston Park scorecard rankings

12 Sugarloaf Creek

12.1 Site Profiles

There is one macroinvertebrate site and two water quality sites within the Sugarloaf Creek Catchment.

WCC_SGL1: Sugarloaf Creek 1 at Sunnyside Cres. (Water quality and macroinvertebrates)

WCC_SGL1 is located downstream within the catchment. It is situated at the mouth of a steep catchment, below a waterfall, close to the entry into Sugarloaf Bay, Castlecrag. The substrate consists of boulders, cobbles and sand (Figure 30). Riparian vegetation consists of both native and exotic species, including heavy sections of Lantana. In Spring 2017, it was observed vegetation had been cleared along tracks, making access easier. Rubbish remains frequently sighted. Macroinvertebrates are sampled at both edge and riffle habitats.



Figure 30 WCC_SGL1 Sugarloaf Creek

WCC_SGL2: Sugarloaf Creek 2 at Butt Park (Water quality only)

WCC_SGL2 is the second water quality site on Sugarloaf Creek, located midstream within the catchment. It is located downstream of medium density residential housing, a gross pollutant trap and small waterfall (Figure 31). Domestic rubbish was recorded on several occasions. In the past, this site has experienced low flow during dry weather and emitted occasional foul odours.



Figure 31 WCC_SGL2 Sugarloaf Creek 2 at Butt Park







12.2 Results and Interpretation

12.2.1 Macroinvertebrates



SIGNAL SF

Both Spring 2022 and Autumn 2023 Signal SF scores were slightly higher than previous results and consistent with the historical averages for Sugarloaf Creek.

Figure 32 Sugarloaf Creek SIGNAL SF results



Taxa Richness

Both Spring 2022 and Autumn 2023 Taxa Richness results were similar to previous years.

Figure 33 Sugarloaf Creek Taxa Richness results

Macroinvertebrates summary

SIGNAL SF scores for both Spring 2022 and Autumn 2023 were consistent with the historical averages, indicating stable stream health

Taxa Richness for both Spring 2022 and Autumn 2023 were consistent with the previous year, but remaining lower than Spring 2020 and Autumn 2021



12.2.2 Water Quality

- Faecal coliform and enterococci results exceeded the respective ANZECC (2000) guideline recommendations at both sites on Sugarloaf Creek on the 2 March 2023. The Butt Park site (WCC_SGL2) had an additional exceedance for enterococci on the 29 July 2022
- Total nitrogen results exceeded the ANZECC (2000) guideline on all sampling occasions at both sites
- Total phosphorous results exceeded the respective ANZECC (2000) guidelines on two of the four sampling occasions at each site
- Dissolved oxygen saturation levels were within the ANZECC (2000) guideline range at both sites on all sampling occasions
- pH, conductivity and turbidity results were within the respective ANZECC (2000) guidelines on all sampling occasions
- Suspended solids and turbidity results were highest for both sites were on 2 March 2023
- · Zinc, lead, and copper results were within the range of historical levels
- Total magnesium, calcium and hardness results were within the range of historical levels

Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	155	36	52	198	164	59	220
Enterococci	CFU/100mL	130	82	89	130	109	220	60
Total nitrogen	µg/L	1955	1770	2220	1325	1110	870	1240
Total phosphorous	µg/L	28.5	29.5	36	45	45	95	45
Dissolved Oxygen	%sat	99.8	98.8	98.4	98.2	97.3	92.1	92
рН	pH Units	7.47	7.55	7.64	7.69	7.75	7.54	7.69
Conductivity	µS/cm	279	288	328	340	325	285	252
Suspended solids	mg/L	2.0	1.0	3.5	1.0	2.0	2.0	2.0
Turbidity	NTU	2.1	1.0	1.0	1.2	1.6	0.9	1.5
Zinc	µg/L	16.0	15.5	18.5	18.0	24.0	16.0	18.0
Lead	µg/L	0.6	0.4	0.75	0.4	1.9	1.1	0.6
Copper	µg/L	1.8	2.2	2.75	2.4	6.5	3.4	2.1

Table 12 Water quality results summary for Sugarloaf Creek at Sunnyside (WCC_SGL1) dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)





Table 13 Water quality results summary for Sugarloaf Creek at Butt Park (WCC_SGL2) dry weather medians 2016-2023 (ANZECC 2000 exceedances in bold)

Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	735	2055	405	755	1030	370	800
Enterococci	CFU/100mL	1220	2870	295	245	441	97	238
Total nitrogen	µg/L	2315	2495	3200	3060	2720	1990	2715
Total phosphorous	µg/L	35.5	46	46	83.5	89.5	232	108
Dissolved Oxygen	%sat	90.0	89.9	88.4	85.4	77.7	75.2	58.8
рН	pH Units	7.0	6.89	6.98	7.05	6.95	7.09	6.95
Conductivity	µS/cm	264	269	288	310	292	264	262
Suspended solids	mg/L	2.5	1.0	2.5	3.0	4.5	3.0	3.5
Turbidity	NTU	2.8	2.6	1.4	3.7	2.8	2.4	4.3
Zinc	µg/L	18.5	20.5	18.5	21.0	27.5	20.0	26.0
Lead	µg/L	0.8	0.5	0.6	1.1	1.3	0.7	0.8
Copper	µg/L	2.7	1.8	1.9	3.0	3.4	2.4	4.8

Water quality summary

Water quality was generally better at the Sunnyside Park site than the Butt Park site

Poor water quality was experienced at both sites on 2 March 2023

12.2.3 Rapid Riparian Assessment

Sugarloaf Creek scored in the *Excellent* range for Spring 2022 (61.0) and *Good* for Autumn 2023 (57.0). This bushland site has a large riparian buffer zone with good vegetation structures.







Sugarloaf Creek at Sunnyside



Figure 34 Summary of Sugarloaf Creek at Sunnyside scorecard rankings

At Sugarloaf Creek at Sunnyside Park, scorecard rankings for the microbiology fell one rank to a B and the chemical rank increased from an F to an E. The overall scorecard ranking remained unchanged (Figure 34). The overall scorecard ranking at Sugarloaf Creek at Butt Park also remained unchanged (Figure 35).



Figure 35 Summary of Sugarloaf Creek at Butt Park scorecard rankings

13 Blue Gum Creek

13.1 Site Profiles

Blue Gum Creek catchment has one water quality site and one macroinvertebrate site.

WCC_BG1: Blue Gum Creek 1 at Blue Gum Reserve (Water quality and macroinvertebrates)

WCC_BG1 on Blue Gum Creek is the furthest site downstream of the catchment area. The sampling site is surrounded by dense riparian vegetation trailing into the creek itself. The vegetation adjacent to the sampling site is composed predominantly of exotic species, particularly *Tradescantia fluminensis.* Erosion of the creek bed has led to the substrate being composed primarily of sand and silt banks.



Figure 36 WCC_BG1 Blue Gum Creek



13.2 Results and Interpretation

13.2.1 Macroinvertebrates

SIGNAL SF

Spring 2022 and Autumn 2023 had SIGNAL SF scores that were consistent with previous results, indicating stable stream health for Blue Gum Creek

Figure 37 Blue Gum Creek SIGNAL SF results







Taxa Richness



Spring 2022 taxa richness decreased considerably compared to the previous two Spring seasons. Autumn 2023 taxa richness was also considerably lower than that of Autumn 2022. Taxa richness for Blue Gum Creek was the lowest of the five sites in both Spring 2022 and Autumn 2023

Figure 38 Blue Gum Creek taxa richness results

Macroinvertebrates summary

While **taxa richness** was considerably lower than previous results in both Spring 2022 and Autumn 2023, **SIGANL SF** scores remained consistent with previous results, indicating stable stream health for Blue Gum Creek

13.2.2 Water Quality

- Faecal coliform results exceeded the ANZECC (2000) guideline on one occasion
- Enterococci results exceeded the ANZECC (2000) guideline on two occasions
- Total nitrogen concentrations exceeded the ANZECC (2000) guidelines on all sampling occasions
- Total phosphorous concentrations exceeded the ANZECC (2000) guidelines on one occasion
- Dissolved oxygen saturation levels within the ANZECC (2000) guideline range on all four sampling occasions
- pH, turbidity and conductivity levels were within the respective ANZECC (2000) guidelines on all sampling occasions
- Total zinc, copper and lead concentrations were within the range of historical results
- Total magnesium, calcium and hardness results were within the overall range of past results



Analyte	Unit	2022-23	2021-22	2020-21	2019-20	2018-19	2017-18	2016-17
Faecal coliforms	CFU/100mL	205	225	792	68	450	94	430
Enterococci	CFU/100mL	150	172	168	178	205	965	179
Total nitrogen	µg/L	390	630	2115	540	595	775	525
Total phosphorous	µg/L	16.5	70.5	61	31	69	71.5	29.5
Dissolved Oxygen	%sat	93.8	84.8	80.3	81.5	57.65	63.3	68.5
рН	pH Units	7.15	6.90	7.12	7.10	6.95	7.16	7.43
Conductivity	µS/cm	476	498	496	504	503	481	333
Suspended solids	mg/L	5.0	15.5	15.0	5.5	14.5	2.0	5.0
Turbidity	NTU	6.2	13.0	5.6	6.3	10.5	1.8	3.4
Zinc	µg/L	12.5	16.5	13.0	12.5	12.0	15.5	9.0
Lead	µg/L	0.5	0.6	0.9	1.3	0.9	1.3	0.7
Copper	µg/L	2.2	2.7	3.2	2.6	1.4	2.4	1.5

Table 14 Water quality results summary for Blue Gum Creek 2016-23 (ANZECC 2000 exceedances in bold)

Water quality summary

Water quality results for Blue Gum Creek were generally good, with the exception of 2 March 2023 when most results were higher than usual

Total nitrogen was the only median level to exceed the respective ANZECC (2000) guideline

13.2.3 Rapid Riparian Assessment

Blue Gum Creek fell into the *Excellent* category for Spring 2022 and Autumn 2023 with scores of 66.2 and 60.0 respectively. Weed management has helped reduce the coverage of noxious weeds but continues to remain a challenging task.







Blue Gum Creek



Figure 39 Summary of Blue Gum Creek scorecard rankings

At Blue Gum Creek the chemical, physical, metals and riparian rankings all increased compared to 2021-22. Accordingly, the overall scorecard ranking also increased (Figure 39).



14 Conclusions

14.1 Macroinvertebrates

There has been a historical trend of seasonal variability with macroinvertebrate results. This is based on the environmental and biological factors that result in different diversity and abundance in spring compared to autumn.

During rainfall events, there will be changes in hydrology, organic matter, and pollutant level. This can impact on the diversity and abundance of aquatic animals including fish and macroinvertebrates.

The study creeks are regularly exposed to a combination of significant anthropogenic and environmental impacts due to industrial, commercial, and urban development and the resultant storm water after rainfall events. Rainfall was generally low and sporadic throughout the sampling period with the highest daily rainfall for the period was 77.5 mm in July 2022

Signal-SF scores for sites in 2022-23 ranged between 3.79 (Swaines Creek at Ferndale Park in Spring 2022) and 5.01 (Sugarloaf Creek at Sunnyside Crescent in Autumn 2023) and were consistent with habitats experiencing probable moderate organic pollution.

Average taxa richness for sites in 2022-23 ranged between 4 (Blue Gum Creek in Autumn 2023) and 13.5 (Sailors Bay Creek in Autumn 2023). While taxa richness for most sites was consistent with previous years, Blue Gum Creek showed decreases in both Spring 2022 and Autumn 2023.

14.2 Water Quality

Water quality is highly dependent on both natural and anthropogenic factors. The creeks sampled under the Willoughby City Council monitoring program are categorised as highly disturbed systems as they flow through urbanised systems that receive substantial road and stormwater runoff (ANZECC 2000).

In urban areas, there are more pollution sources and impervious surfaces, which can magnify the effects on water quality. Where there are areas of high impervious surfaces, such as roads, footpaths, and buildings, it increases the volume and speed of the rainwater. These impervious surfaces are often a source of pollutants, such as oils, metals, and nutrients, which are then deposited in streams.

The water quality results for 2022-23 are largely reflective of the historical data collected. Of particular note is the improvement in water quality for the upper catchment site on Scotts Creek (WCC_SC3; Muston Park) which generally has the poorest water quality of all sites. Unfortunately, water quality for the mid and lower sites on Scotts Creek (North Arm and Willis Park) showed increased medians for faecal coliforms, enterococci, and nutrients.

Total nitrogen and phosphorous were elevated across all sites, with only very few results below the respective ANZECC (2000) guideline.

Although the streams monitored in this program are highly altered, they each still retain ecological and conservation values. A realistic objective would be to maintain present water quality to retain a functional, albeit modified, ecosystem that would support the management goals assigned to it.





14.3 Rapid Riparian Assessment

The aim of bringing in Rapid Riparian Assessments into the monitoring program was to collect baseline information about the physical stream features and surrounding area. This type of information was not covered in the traditional macroinvertebrate and water quality analysis.

For Spring 2022 and Autumn 2023 riparian scores fell into either the Good or Excellent category, which is consistent for creeks with large riparian buffer zones. Flat Rock Creek at Flat Rock Gully had the highest rapid riparian assessment score falling into the *Excellent* category (80.2) and Sailors Bay Creek had the lowest riparian score falling into the *Good* category (29.1). These results are consistent with urban catchments and indicate that the systems are not overly degraded.

Creeks with wide vegetation buffer zones, have the potential to be in the excellent category when weeds and litter are cleared at these sites.

The areas of the assessment that have the highest impact on the overall scores of catchments are:

- Land use
- Sewer lines
- Litter present
- Stream confinement
- Vegetation community composition
- Weed infestation

Some of these high scoring categories such as sewer lines, and stream confinement are difficult to change. However, removal of weeds, litter, and improving types of riparian vegetation can improve scores and change category gradings.

15 Recommendations

Continue monitoring of macroinvertebrates, riparian reaches, and water quality at current sites.

Continue weed maintenance and rubbish removal as currently conducted to help maintain and improve Rapid Riparian Assessment results.

Consider collecting pre-and post-work macroinvertebrate and water quality data on any council projects that aim to improve water quality or are likely to impact catchment water quality.