Targeted Wet Weather Monitoring Plans for the Lower Ōpāwaho/Heathcote River, and Te Tauawa-a-Maka /Nottingham Stream

Prepared for

Christchurch City Council

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Limitations:

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Executive Summary

Christchurch City Council (CCC) undertakes monitoring of water quality in Christchurch and Banks Peninsula. This is a requirement of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC231955) and the associated Environmental Monitoring Programme (EMP). Targeted Wet Weather Monitoring (TWWM) of surface water must be undertaken as part of this monitoring to determine sources of stormwater contaminants.

Pattle Delamore Partners Limited (PDP) has been engaged by CCC to prepare a targeted wet weather monitoring plan for the lower Ōpāwaho/Heathcote River and Te Tauawa-a-Maka/Nottingham Stream. PDP has provided a lower- and upper-bound option for each of the catchments, where:

- Option 1 is summarised in Table 1. It is based on having sufficient sampling locations to characterise the wider catchment where stormwater contaminants may be contributed from, then the sampling locations are progressively moved to focus on the source(s) of elevated contaminants found within a catchment. This option:
  - Includes monitoring for Priority 1 and 2 sites both catchments, excluding Priority 3 sites to reduce costs and target key areas only.
  - Uses fewer samplers and requires less laboratory analysis.
  - Risks elevated contaminants being diluted by other inflows.
  - Risks inaccurate flow monitoring leading to misunderstandings around contaminant loads.
- Option 2 is summarised in Table 2. It narrows down the source of contaminants more quickly due to greater coverage before moving sampler locations. This option:
  - Consists of monitoring Priority 1, 2 & 3 sites for both catchments.
  - Has the risk of sampling a greater number of sites that are not contributing elevated contaminant loads.
  - Higher cost involved in purchasing additional samplers and laboratory analysis.
  - Higher cost involved in purchasing Doppler flow meter’s and stream gauging.

An overview of Options 1 and 2 are displayed in Table 1 and Table 2, respectively. Plans showing the proposed sampling locations are provided in Appendices A and B.

Table 1: Option 1 - Targeted Wet Weather Monitoring Plan Overview

Catchment	Analysis	Events	Method
Priority 1 & 2 locations in both Te Tauawa-a-Maka/Nottingham Catchment and the lower Ōpāwaho/ Heathcote Catchment	Samples shall be analysed by the CCC IANZ-accredited lab for total and dissolved metals, turbidity, suspended solids, E.coli, DOC, pH, turbidity, BOD_5 and nutrients.	Ten storm events must be sampled using Autosamplers. Events require > 3 mm of rain, preceded by at least three antecedent dry days.	One event mean composite (EMC) sample per site, per storm event, that has been flow-weighted. Samples shall be generated using autosamplers. Flow monitoring will require eleven Bubbler Flow Modules and surveyed cross-sections

Table 2: Option 2 - Targeted Wet Weather Monitoring Plan Overview

Catchment	Analysis	Events	Method
Priority 1, 2 & 3 locations in both Te Tauawa-a-Maka/Nottingham Catchment and the lower Ōpāwaho/ Heathcote Catchment	Samples shall be analysed by the CCC IANZ-accredited lab for total and dissolved metals, turbidity, suspended solids, E.coli, DOC, pH, turbidity, BOD_5 and nutrients.	Ten storm events must be sampled using Autosamplers. Events require > 3 mm of rain, preceded by at least three antecedent dry days.	One event mean composite (EMC) sample per site, per storm event, that has been flow-weighted. Samples shall be generated using autosamplers. Flow monitoring is recommended to incorporate Doppler flow meters and/or stream gauging for increased accuracy

PDP recommends that at least ten storm events with varying durations, intensities, and antecedent dry periods are sampled at each targeted wet weather monitoring site to establish statistical trends.

The following information is required from CCC prior to beginning the monitoring programme:

- Access information regarding sites mentioned in Section 7.1.1.

Physical surveys of each stream cross-section for the proposed monitoring sitesPrior to implementing the TWWMP, PDP recommends that conductivity and water level loggers are deployed at proposed locations in the lower Ōpāwaho/Heathcote Catchment to ensure the sites are not tidally influenced and are not impacted by contaminants from the estuary. Without further catchment analysis, it also cannot be confirmed that Bubbler Flow Modules will trigger correctly during rainfall events due to tidal fluctuations, so this should also be assessed prior to deploying the samplers.

PDP also recommends that sediment sampling of the Ōpāwaho/Heathcote River and estuary is undertaken to rule-out leaching of contaminants from bed sediments. PDP also recommends sampling is undertaken in the pond at Westlake Reserve in the Nottingham Catchment, to rule out groundwater/source contamination before moving into more targeted monitoring. However, PDP recognise this monitoring is outside of scope and may not occur prior to the implementation of the targeted wet weather monitoring plans.

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1.0 Introduction

The Christchurch City Council (CCC) undertakes monitoring of water quality in Christchurch and Banks Peninsula. Primarily, this is done to meet the requirements of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC231955) and the associated Environmental Monitoring Programme (EMP). Annual reporting on this monitoring has identified sites where water quality does not meet the targets set out in the CSNDC. These sites have been selected for Targeted Wet Weather Monitoring (TWWM) of surface water in accordance with Schedule 3 (k) of the consent:

> *"Carry out targeted wet weather monitoring of surface water in selected receiving environments, to improve knowledge of the state of the receiving environment, contaminant inputs and treatment efficiency, and to inform mitigation options under the SMPs. Selected areas may include new stormwater developments and retrofits and known existing hotspots of contaminants. Sampling shall focus on detailed methods to characterise inputs. Such as the use of auto-sampling, rather than grab sampling."*

Pattle Delamore Partners (PDP) has been engaged by CCC to prepare a targeted wet weather monitoring plan for the lower Ōpāwaho/Heathcote River near Ferrymead and Te Tauawa-a-Maka/Nottingham Stream in Halswell and a targeted dry weather monitoring plan for Addington Brook. This report contains the targeted wet weather monitoring plans for the lower Ōpāwaho/Heathcote River near Ferrymead and Te Tauawa-a-Maka/Nottingham Stream in Halswell. A separate report has been prepared for the targeted dry weather monitoring plan.

1.1 Objective

This report aims to present a monitoring plan that will aid in identifying sources of stormwater contaminants within Te Tauawa-a-Maka/Nottingham Stream and the lower Ōpāwaho/Heathcote River.

The monitoring plan and contaminant source identification are required to address Condition 59 of the CSNDC and the recommendations in the 'Condition 59 responses to monitoring report 2022 - surface water' (Margetts, et al., 2022).

1.2 Scope of Works

This deliverable consists of a concise monitoring report covering wet weather monitoring. It includes:

- consideration of industrial/commercial/high traffic areas, roofing sources, the Condition 59 high-risk sites assessment, contaminant load modelling, and tidal effects where applicable (AECOM, 2023);

- the sites to be sampled and sampling equipment to be used.
- the recommended water level/flow monitoring methodology for each site;
- the methodology for monitoring of weather conditions to ensure sampling adheres to the EMP storm criteria (minimum of three dry days and a rainfall depth of 3 mm before sampling begins, and sampling within 1-2 hours of the desired rainfall being achieved);
- an outline of the intended protocol for the compositing of samples from the wet weather autosampler samples;
- the constituents to be analysed in wet weather water samples relevant to meeting the objectives of the project, and recommendations made by CCC and AECOM (2022; 2023); and
- the intended protocols for installation, maintenance and quality assurance of the wet weather monitoring instruments.

2.0 Background

The catchments addressed by this targeted wet weather monitoring plan are as follows:

- Lower Ōpāwaho/Heathcote Catchment
- Te Tauawa-a-Maka/Nottingham Catchment

These catchments suffer from “urban stream syndrome”. This syndrome describes the consistent ecological degradation of streams in urbanised catchments. As outlined by Walsh et al. (2023), key symptoms of urban stream syndrome include:

- hydrographs that quickly respond to rainfall;
- elevated/increased contaminant concentrations;
- altered channel morphology; and
- reduced ecological diversity.

This monitoring plan aims to identify sites contributing to elevated contaminant concentrations. Specifically, this report seeks to identify sites discharging stormwater at concentrations that could cumulatively or directly detrimentally impact the environment and human health.

Due to the limited existing water quality data available for the catchments, PDP has advised that catchment scale sampling should be undertaken before site-specific sampling is considered. Once sampling results are obtained, the monitoring locations should be adapted to target sub-catchments with higher contaminant contributions. Therefore, this monitoring plan is the first step in delineating the catchment to identify specific locations contributing to elevated contaminant concentrations. Two approaches have been considered, one involving a comprehensive spread of sampling sites can be used to allow for a faster delineation, or alternatively, an approach involving fewer sites can be used to ensure resources are conserved. Options for both approaches are provided in this report for CCC to select their preferred approach.

AECOM (2023) has provided a high-level desktop assessment of high-risk sites within the lower Ōpāwaho/Heathcote, Curletts, Addington and Te Tauawa-a-Maka/Nottingham Catchments. A 'high risk' site was defined as "A site that has the potential to discharge contaminants to stormwater at concentrations that could exceed Attribute Target Levels (ATLs)". There was a specific focus on sites that could contribute copper and/or zinc – as these contaminants exceeded the ATLs (AECOM, 2023). The number of high-risk sites found in the relevant catchments were:

- Lower Ōpāwaho/Heathcote Catchment – 18 sites; and
- Te Tauawa-a-Maka/Nottingham Catchment – 1 site.

While these sites were considered in the selection of water sampling locations, ultimately, the key decision factors included existing water quality data, proximity to industrial/commercial/high traffic areas and roofing sources, and the ability to delineate sections of the stormwater network to aid in further investigations.

2.1 Lower Ōpāwaho/Heathcote Catchment

The lower Ōpāwaho/Heathcote River is a spring-fed stream that meanders through several Christchurch suburbs before discharging into the Avon/Heathcote Estuary in Ferrymead. This stormwater monitoring plan covers the lower Ōpāwaho/Heathcote Catchment, from the intersection of SH 74 and Ferry Road, and the Ferrymead Bridge. The catchment is shown in Appendix A.

2.1.1 Water Quality

Previous sampling from the lower Ōpāwaho/Heathcote River, near the Ferry Road bridge, showed elevated levels of zinc and copper (dissolved). While this is similar for all the upstream sampling points, a statistically significant increase in dissolved zinc of 10% since 2007 has made this segment of the river a key focus area (Margetts, et al., 2022). This increasing trend in zinc can likely be attributed to:

- Cumulative inputs down the catchment, which culminate at this site; or
- Sources of zinc located between Tunnel Road and Ferry Bridge that discharge into the Ōpāwaho/Heathcote River.

All waterways could transport potential source contaminants into the lower Ōpāwaho/Heathcote Catchment (Margetts, et al., 2022).

The waterways that discharge into this reach of the river include:

- Ferry Esplanade Reserve Drain No 1
- Settlers Reserve Drain
- Avoca Valley Stream
- Truscott's Stream Branch
- Matuku Waterway
- The Steamwharf Stream

Additional potential sources of contaminants include:

- Dredging of an upstream reach of the lower Ōpāwaho/Heathcote River;
- Estuary contaminants entering the Lower Ōpāwaho/Heathcote River during high tide;
- Leachable heavy metals contained within stream bed sediment.

Dredging is unlikely to be a source of the increasing zinc contamination, as the timings of past dredging operations do not align with the increase in zinc concentration. While tidal impacts may be the source of contaminants at the Ferry Bridge site, catchment contributions were estimated to be more likely (Margetts, et al., 2022). However, to rule out these alternate sources PDP proposes the following:

- Sampling of estuary water to be analysed for metals;
- Stormwater samples taken at high tide being sampled separately from low tide samples; and
- Sediment samples being collected in the lower Ōpāwaho/Heathcote River and estuary and analysed for leachability.

2.2 Te Tauawa-a-Maka/Nottingham Catchment

Te Tauawa-a-Maka/Nottingham Stream begins at Westlake and flows through Oaklands and Halswell before its confluence with Knights Stream to become the Halswell River. Te Tauawa-a-Maka/Nottingham Stream is narrow and has incised banks. The catchment is mainly suburban, with some commercial premises located in the middle reaches.

In this monitoring plan, Te Tauawa-a-Maka/Nottingham Stream refers to the stream segment situated between the headwaters at Westlake Drive, and Candys Road. Te Tauawa-a-Maka/Nottingham Catchment refers to the catchment associated with this stream segment. The catchment is shown in Appendix B.

Te Tauawa-a-Maka/Nottingham Stream was a part of CCC's stream enhancement projects during the 1990s, with a focus on enhancing its ecological function (Suren, Graynoth, Biggs, Barker, & McMurtie, 2002). Stream enhancements involved:

- Diversifying stream depth and velocity;
- Replacing bare concrete and sand/gravel bed with a mix of cobbles and gravels; and
- Riparian planting.

In 2021, stream bed repairs were undertaken to infill holes and remove sediment in areas where it has built up. The impact this work has had on water quality is unclear.

2.2.1 Water Quality

CCC began monitoring Te Tauawa-a-Maka/Nottingham Stream at Candys Road in 2011. A statistically significant increase in zinc of 6% has occurred since monitoring began in 2011, and larger contaminant spikes have occurred since 2016 (Margetts, et al., 2022), leading to an increase in average/baseline contaminant levels.

The majority of copper and zinc samples collected during the 2020 monitoring year met the ATL. There was one dry weather zinc exceedance, whilst most other exceedances occurred during wet weather sampling. Previous contaminants of concern identified for the site include copper, zinc, dissolved reactive phosphorus (DRP) and *Escherichia coli* (E. coli).

3.0 Monitoring Sites

As outlined above, the Targeted Wet Weather Monitoring project shall incorporate sampling in the following catchments:

- Lower Ōpāwaho/Heathcote Catchment; and
- Te Tauawa-a-Maka/Nottingham Catchment.

Sampling in these catchments shall be undertaken by autosamplers to ensure capture of the varying concentrations across a rainfall event. This includes the first flush of contaminants, which is often missed using other methods such as grab sampling.

PDP has identified a total of 11 sampling sites, including seven in the lower Ōpāwaho/Heathcote Catchment, and four in the Te Tauawa-a-Maka/Nottingham Catchment. Details of the selected sites are outlined in the following sections.

A priority of 1, 2, or 3 has been assigned to each site, 1 being high priority and 3 being low priority.

- Priority 1 sites are locations of high importance that cover a significant spatial variability and take precedence over other sites. In PDP's opinion, they must be sampled;
- Priority 2 sites are locations of importance that provide additional spatial variability. It is highly recommended they are sampled; and
- Priority 3 sites are non-essential but should be sampled where possible and provide land use variability.

On NIWA's recommendation, PDP has added six additional sites within the Te Tauawa-a-Maka/Nottingham Catchment. These are designated as Priority 3. These sites allow for further catchment delineation and can be included if that is CCC's preference.

PDP recommend autosamplers for all sites where possible. Where this is not possible due to cost or availability of equipment, PDP recommends that low-priority sites are left for future sampling.

The sites selected for monitoring in this sampling plan were selected based on the following criteria:

- Existing knowledge of issues in the catchment, as outlined in Section 2.0
- Catchment land uses and building/roading infrastructure density
- High-risk sites, as identified by AECOM (AECOM, 2023)
- Findings of the PDP site walkovers, including but not limited to:
  - accessibility issues
  - safety issues
  - verification of network layout
- Key network sub-catchments and tributaries
- Existing CCC monthly monitoring locations (Margetts, et al., 2022)
- Tidal influences, as described in Section 4.1

Proposed sampling locations for the lower Ōpāwaho/Heathcote Catchment and Nottingham Catchment are outlined in Table 3, and Table 4, respectively. Sampling locations OH6 and OH7 are situated within manholes whilst the remaining sampling sites are situated in waterways. Figures showing these potential locations are appended in Appendix A and Appendix B, respectively.

3.1 Lower Ōpāwaho/Heathcote Catchment

Table 3: Lower Ōpāwaho/Heathcote lower catchment sampling locations

Site ID	Description	Reasoning	Sampling Method	Water Level Monitoring	Priority
OH1	Avoca Valley Diversion (In-stream)	Will capture discharges from the western industrial area, indicated as high-risk	Autosampler	Bubbler Flow Module/Stream Gauging	1
OH2	Horotane Valley Drain (In-stream)	Will capture discharges from Horotane Valley, indicated as high risk	Autosampler	Bubbler Flow Module/Stream Gauging	1
OH3	Butts Valley Drain (In-stream)	To represent discharges from high-risk areas in Butts Valley	Autosampler	Bubbler Flow Module/Stream Gauging	1
OH4	Matuku Waterway (In-stream)	To represent discharges from the eastern section of the catchment	Autosampler	Bubbler Flow Module/Stream Gauging	2
OH5	Bridle Path Waterway (In-stream)	To represent contaminants from the large southern catchment	Autosampler	Bubbler Flow Module/Stream Gauging	3
OH6	Settlers Crescent Drain Outlet (Manhole)	To represent northern industrial/commercial area	Autosampler	Bubbler Flow Module/Stream Gauging	2
OH7	Northwest Drain (Manhole)	Drains a high-risk site	Autosampler	Bubbler Flow Module/Stream Gauging	3

3.2 Te Tauawa-a-Maka/Nottingham Catchment

Table 4: Te Tauawa-a-Maka/Nottingham Stream Sampling locations

Site ID	Description	Reasoning	Sampling Method	Water Level Monitoring	Priority
NS1	Nottingham Stream upstream of Candys Road crossing (In-stream)	Existing CCC monthly monitoring site; end of catchment water quality	Autosampler	Bubbler Flow Module/Stream Gauging	1
NS2	Nottingham Stream upstream of Halswell Junction Road (In-stream)	Investigate any change caused by residential and road areas downstream	Autosampler	Bubbler Flow Module/Stream Gauging	2
NS3	Nottingham Stream upstream of Nichols Road (In-stream)	Delineate predominately residential area with commercial carpark discharge	Autosampler	Bubbler Flow Module/Stream Gauging	2
NS4	Nottingham Stream at Ridder Reserve (In-stream)	Capture water quality information for the top of the catchment to determine increase across catchment	Autosampler	Bubbler Flow Module/Stream Gauging	1
NS5	Nottingham Stream downstream of Ohalloran Drive	Characterise change in Nottingham stream contamination levels from the residential area downstream of NS2, and the grassed open area upstream of NS1	Autosampler	Bubbler Flow Module/Stream Gauging	3

Table 4: Te Tauawa-a-Maka/Nottingham Stream Sampling locations

Site ID	Description	Reasoning	Sampling Method	Water Level Monitoring	Priority
NS6	Nottingham Stormwater Network at 19B Halswell Junction Road	Characterize residential area runoff for the area upstream of the sampling point	Autosampler	Bubbler Flow Module/Doppler Flow Meter	3
NS7	Nottingham Stream at Riddlers Reserve	Investigate any change caused by residential and park areas upstream and downstream	Autosampler	Bubbler Flow Module/Stream Gauging	3
NS8	Nottingham Stream downstream of Nottingham Stream Avenue	Investigate water quality at the headwaters of Nottingham Stream	Autosampler	Bubbler Flow Module/Stream Gauging	3
NS9	Nottingham Stormwater Network Westlake Reserve	Characterize residential area runoff for the area upstream of the sampling point	Autosampler	Bubbler Flow Module/Doppler Flow Meter	2
NS10	Nottingham Stream upstream of Westlake	Characterize stormwater quality upstream of Westlake	Autosampler	Bubbler Flow Module/Stream Gauging	3
NS11	Nottingham Stormwater Network at Thorlea Place	Characterize residential area runoff for the area upstream of the sampling point	Autosampler	Bubbler Flow Module/Doppler Flow Meter	3

3.3 Monitoring Site Options

PDP has produced two options for recommended sites to be monitored based on the tables and priorities above.

- Option 1 is based on having sufficient sampling locations to characterise sub-catchments, before sampling locations are moved to focus on the source(s) of elevated contaminants found within those wider sub-catchments. It includes monitoring for Priority 1 and 2 sites both catchments, excluding Priority 3 sites to reduce costs and target key areas only. Key risks and considerations include:
  - Uses fewer samplers and requires less laboratory analysis.
  - Risks elevated contaminants being diluted by other inflows.
  - Risks inaccurate flow monitoring leading to misunderstandings around contaminant loads.
- Option 2 uses a wider network of autosamplers to narrow down the source of contaminants, delineating the catchments more quickly. Option 2 consists of monitoring Priority 1, 2 & 3 sites for both catchments. Key risks and considerations include:
  - Has the risk of sampling a larger number of sites that are not contributing elevated contaminant loads.
  - Higher cost involved in purchasing additional samplers and laboratory analysis.
  - Higher cost involved in purchasing Doppler flow meter’s and stream gauging.

4.0 Flow Monitoring Methodology

Flow monitoring is recommended at all sampling locations, as this allows contaminant loads to be calculated. However, the lower Ōpāwaho/Heathcote Catchment is highly tidal. Flow monitoring results may therefore be affected by incoming tides, making them unreliable.

There are five different potential options for flow monitoring:

- Rating Structures;
- Acoustic Doppler velocity devices;
- 730 series Bubbler Flow Modules (Bubbler Flow Module);
- Water level measurements and stream gauging; and/or
- Foregoing flow monitoring.

PDP have investigated the applicability of these options in the following sections.

4.1 Tidal Influence

PDP utilized an assumed area of tidal influence to assist in the selection of seven sampling locations within the lower Ōpāwaho/Heathcote Catchment. This area was based on the 1-year Annual Exceedance Probability (AEP) high tide of 10.699 m RL (Christchurch Drainage Datum) at Ferrymead Bridge from CCC's tidal statistics report (GHD & HKV, 2021), overlain on the 1 m LiDAR DEM flown in 2020. This does not consider the effect of tidal gates. The area of tidal influence has not been confirmed. PDP has proposed that tidal effects are investigated prior to monitoring, using conductivity probes, as discussed in Section 5.5.

4.2 Rating Structures

According to ECan's publicly available data, there are numerous existing rating structures situated within the lower Ōpāwaho/Heathcote catchment, and a site visit to Te Tauawa-a-Maka/Nottingham Catchment confirmed the existence of a staff gauge at Candys Road.

The existing staff gauge at Candys Road indicates that there is a cross-section available; however, the reliability of this gauge is uncertain. Therefore, it is recommended an alternative flow monitoring method is adopted for Te Tauawa-a-Maka/Nottingham Catchment.

ECan's data shows stormwater instrumentation at the confluence of the Matuku waterway and the lower Ōpāwaho/Heathcote River. However, the type of instrumentation is not shown. We request this information from CCC. These existing flow monitoring locations are shown in Figure 1.

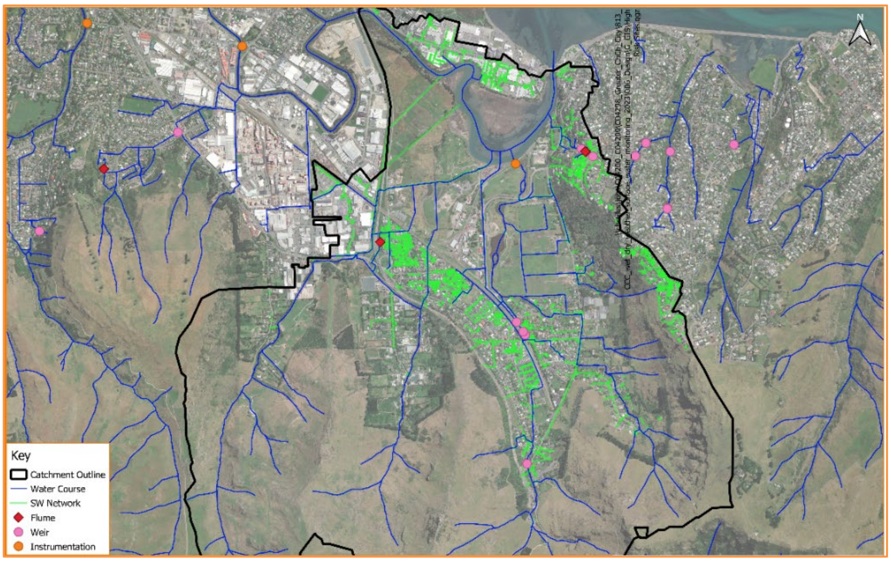

Figure 1. Rating structures in the lower Ōpāwaho/Heathcote Catchment

The locations of existing rating structures in the lower Ōpāwaho/Heathcote Catchment do not align with the proposed sampling locations. The use of new rating structures is not advisable, due to the tidal conditions of the site, high costs, and fish passage issues.

4.3 Bubbler Flow Module

ISCO autosamplers with 700 series modules can estimate the flow in any location with a known level-flow relationship (Teledyne Isco, 2013). Stage-flow relationships (rating curves) can be estimated from stream gauging, rating structures, or by using surveyed cross-sections (upstream, downstream, and at the proposed monitoring site so that bed slope can be calculated) and an estimated Manning's roughness coefficient.

This monitoring methodology will have more uncertainty and cannot be applied in areas that are tidally affected or have backwater conditions. Therefore, to apply this methodology in the lower Ōpāwaho Catchment, monitoring must be implemented above 10.699 m RL (Christchurch Drainage Datum).

4.4 Acoustic Doppler Devices

Acoustic Doppler Current Profilers (ADCP) can measure velocity and depth in streams where current meter/gauging instruments are difficult/costly to apply, like the tidally affected areas of the lower Ōpawaho/Heathcote River (USGS, 2009). The ADCP can be deployed to log the velocity profile of the stream, over the duration of the sampling event. These profiles could then be used to find the average velocity. Generally, this is found at 0.4 times the depth of the flow, from the bed of the channel (Pradhan, Khatua, & Dash, 2015). In addition to the ADCP, a stream survey would be required, to calculate flow from velocity. Quotes for ADCP devices were obtained and are displayed in Table 5. Due to the high prices related to ADCP flow monitoring and the uncertainty surrounding applicability, this methodology is not recommended.

Doppler flow meters use an ultrasonic beam to determine the velocity and depth, which are used to compute the flow rate of a liquid given a known cross-sectional area. However, this device is ill-suited to rivers and streams as it requires a known cross-sectional area to calculate flow from water depth and velocity, and will therefore be affected by the variable nature of the cross-sections in natural waterbodies. Additionally, it is unclear whether this would accurately represent the velocity of the stream in tidally influenced areas. This methodology would be applicable to areas outside of the tidal influence and for sampling points within the stormwater pipe network. Quotes were obtained from Instruments Direct (2024) and are displayed in Table 5.

Table 5: Acoustic Doppler Device Pricing

Device	Description	Cost per unit (ex.Tax)
ADCP – Boat Mounted	RS5 portable ADCP	NZD 53,9801
ADCP – Bottom Mounted	Argonaut-XR	NZD 30,5531
Open Channel Flow Meter (Doppler flow meter)	Greyline AVFM 6.1 Area Velocity Flow Meter	NZD 6,857[2,3]
Portable Open Channel Flow Meter (Doppler flow meter)	Greyline MantaRay Portable Area Velocity Flow Meter	NZD 10,518[2,3]

Notes:

1. *The quote is valid until 06/05/2023 and was supplied by ENVCO.*
2. *Quote was obtained from Instruments Direct* (Instruments Direct, 2024)
3. *Converted to NZD from USD using exchange rate of 1:1.68 dated 2/04/2024*

4.5 Stream Gauging

Water level measurements and stream gauging may also be undertaken, to create rating curves for flow estimates. If this option were to be pursued, the water level measurements and level monitoring equipment must be installed upstream of the high tide mark in the lower Ōpāwaho/Heathcote Catchment. This also includes the locations with tide gates, as the water level during a rainfall event will back up during high tide. These same considerations will have to be applied to sampling locations.

This methodology would be applicable for flow monitoring at any of the Te Tauawa-a-Maka/Nottingham Catchment sampling locations.

4.6 Summary

In summary, PDP recommends that the following flow monitoring devices should be utilised for the monitoring plan:

- Bubbler Flow Module;
- Stream Gauging; and/or
- Doppler flow metre devices.

If implemented in the Ōpāwaho/Heathcote Catchment, these monitoring methodologies will only provide reliable data if situated outside the area of tidal influence. If monitoring/sampling is to be undertaken within the area of tidal influence, an ADCP device could be deployed, or flow monitoring could be foregone. ACDP devices are not economically viable, and therefore are not recommended. A lack of flow data would prevent contaminant load concentrations from being calculated, making sampling results less comparable.

Rating structures are the best practice methodology for flow monitoring, and calculating event mean concentrations. However, the existing rating structures will not be utilised for this monitoring as their locations are ill-suited to the monitoring plan. PDP does not recommend installing new rating structures as they are not cost-efficient and could pose a barrier to fish passage.

4.7 Recommendations

PDP recommend that for flow monitoring in the Te Tauawa-a-Maka Catchment and Ōpāwaho/Heathcote Catchment, autosamplers with Bubbler Flow Modules are utilised in conjunction with a stream/pipe survey to obtain all variables required for the Manning's Equation. This will enable flow to be calculated through the application of Manning's Equation. When using Manning's Equation, PDP recommends that roughness values are obtained from the CCC's '*Wetlands, Waterways, and Drainage Guide'* (2012), or other similar guidance documents such as Hicks & Masons '*Roughness Characteristics of New Zealand Rivers'*, as is good practice (Hicks & Mason, 1998). Stream gauging and Doppler flow meter devices would also be applicable at these sites and would provide a greater deal of reliability. However, these options would be more time-consuming and costly.

PDP recommend that in the Ōpāwaho/Heathcote Catchment, monitoring is undertaken outside of the area of tidal influence. However, this means a large area of the catchment will be excluded from the assessment. If monitoring were to be undertaken within this tidal area the results would be highly impacted by the tide, and by backflow. Additionally, only concentration data could be supplied, making water quality information hard to assess and compare.

To select the seven sampling sites shown in Table 3, PDP utilized an assumed area of tidal influence, as described in Section 4.1. It is recommended that this area of tidal influence is confirmed prior to sampling through fieldwork and/or modelling.

5.0 Sampling Methodology

Wet weather sampling shall be carried out in Te Tauawa-a-Maka/Nottingham Catchment and the lower Ōpāwaho/Heathcote Catchment.

A minimum of 12 different storm events were recommended for sampling in NIWA's TWWM report for Curlett and Hayton Streams (Borne & Gadd, Targeted wet weather monitoring of Curlett and Haytons Streams 2021, 2022). PDP recommend that a minimum of ten storm events should be sampled. If more are possible, they should be carried out. These events should be reported on, in compliance with the CSNDC.

5.1 Storm Criteria

Wet weather samples shall be collected when the following criteria are met, as per the CSNDC EMP:

- Minimum three-day dry period prior to sampling;
- Minimum of 3 mm total rainfall depth; and
- Capturing the first flush (15 – 25 mm), by sampling within 1 – 2 hrs of the rainfall depth being achieved.

5.2 Sampling Methods

Autosamplers will be installed at each of the sites listed in Table 3 and Table 4. It is suggested that for the Te Tauawa-a-Maka/Nottingham and lower Ōpāwaho/Heathcote catchments, autosamplers are fitted with Bubbler Flow Modules rather than 1640 Liquid Level Sampler Actuators (actuators), as actuators have historically been unreliable trigger mechanisms.

At this stage of the TWWMP, it has not been confirmed whether any sampling locations are impacted by backflow conditions and high tides; however, the sample sites have been chosen to avoid the area of tidal influence. If backflow conditions are observed at a sampling site during flow monitoring, it is recommended that the site be relocated further upstream.

Autosamplers will be programmed to trigger when the conditions outlined in Section 5.1 are met, and water levels begin to rise. As outlined by Borne (2023), setting flow-based pacing for sample collection will require rainfall vs runoff volume relationships. These relationships can be developed using 3 – 5 storm events with variable depths (3 – 50 mm) and durations. Rainfall data from the nearest rain gauges will be utilized to develop these relationships.

Discrete flow-based samples will be collected throughout the storm hydrograph. Up to 24 one-litre samples will be collected throughout the storm event (Borne, 2023). The time-step will be calculated based on the storm duration, and rainfall-runoff volume relationships. Data will be logged on the ISCO samplers, not via telemetry. This data can be downloaded to a laptop provided the ISCO USB Communication Cable and Flowlink Software are also purchased. These samples should be delivered to a CCC laboratory within 24 hours of the end of the storm event where possible.

As recommended by Borne (2023), polypropylene (PP) sampling bottles will be utilized for sample collection. These bottles will be acid-washed prior to being deployed in the automatic samplers.

5.3 Sample Compositing

Samples should be transported to the CCC laboratories for flow-weighted compositing. As samples will be collected on a flow-proportional basis (where possible), even volumes from each of the 24 sample bottles should be mixed into a churn splitter to generate one composite sample, as recommended by Borne (2023).

In the event of equipment failure or insufficient water for sample collection, the hydrograph will be used to back-calculate the required portion from each successfully collected sample bottle. This will ensure the analysed sample is still flow-weighted.

5.4 Sample Analysis

A wide range of contaminants will be assessed in collected samples. Autosampler sites will be sampled for the following contaminants, as requested by CCC:

- Total suspended solids (TSS)
- Turbidity
- pH
- Total Copper, Lead, and Zinc
- Dissolved copper, Lead, and Zinc
- Total Ammoniacal-N
- Biochemical Oxygen Demand (BOD_5)
- Total Nitrogen
- Nitrate-N + Nitrite-N
- Dissolved Reactive Phosphorus (DRP)
- Total Phosphorus
- Dissolved Organic Carbon (DOC)
- *E.coli*
- Total Hardness

Heavy metals and DRP have been recommended due to historic ATL exceedances, as discussed in Section 2.2.1. TotalHardness has been added as it effects the toxicity of metals. Nutrient analysis is recommended due to the number of nurseries and farms situated within the catchment.

E. coli results may not be reliable as it is unclear if samples can be collected and analysed within the required 24-hr window, due to storm event variability, rainfall timing, and timeliness of sample collection.

Samples should be transported to the Christchurch City Council IANZ accredited laboratory within 24 hrs of the completion of the storm event to perform sample analysis.

5.5 Quality Assurance

Stormwater monitoring is a uniquely challenging data collection exercise, due to the variability in stormwater flow, intensity, and duration. Storm events often occur with little to no warning and can be few and far between. To ensure high-quality samples are obtained, PDP recommends the following processes should be implemented:

- Composite volume-based sampling has been utilized to generate samples that show the event mean concentration (McCarthy & Harmel, 2014).
- Where possible, a field replicate will be collected at each site, for at least one sampling event as manual compositing generates a higher error (McCarthy & Harmel, 2014; Zhang, 2014);
- Chain of custody forms shall be completed for all samples (McCarthy & Harmel, 2014; Zhang, 2014);
- Samples should be sent to the lab within 24 hrs of the end of the storm event (Borne, 2023);
- At least ten different storm events will be sampled, to capture variability (Borne & Gadd, 2022); and
- Samples shall be analysed by IANZ-accredited labs.

McCarthy & Harmel (2014) suggested additional quality assurance processes such as:

- Refrigeration of samples stored in autosamplers;
- Collection and analysis within 24 hrs;
- Rinsate/equipment blanks; and
- Composite samples in each bottle;
- Locating sites at existing hydraulic control structures;

However, these additional processes were not viewed as practicable, due to timeliness, complexity, and cost.

6.0 Risks and Limitations

PDP has not confirmed that the proposed monitoring sites within the Ōpāwaho/Heathcote Catchment are outside the area of tidal influence. Prior to sampling, PDP recommends that conductivity and water level loggers are deployed at proposed locations in the lower Ōpāwaho/Heathcote Catchment. This data can be used to check the sites are not tidally influenced.

PDP advises that any *E. coli* results obtained must be interpreted with caution. Results may not be reliable as it is unclear if samples can be collected and analysed within the required 24-hr window, due to storm event variability, rainfall timing, and timeliness of sample collection.

Using the Bubbler Flow Modules in conjunction with Manning's Equation will add uncertainty to the EMC calculations, and is a less reliable flow monitoring methodology than Doppler Flow meters and Stream Gauging. To limit this risk, a sensitivity assessment could be undertaken to assess uncertainties. A suggested approach for this is measuring/testing all samples collected and then calculating an EMC from the flow data, then calculating the EMC using flows derived from a different Manning's roughness and assessing the uncertainty (Gadd, 2023)).

Without further catchment analysis, it cannot be confirmed that Bubbler Flow Modules will trigger correctly during rainfall events. Additionally, it cannot be confirmed that samples are not contaminated by estuarine water. To limit these risks conductivity probes could be deployed alongside Autosamplers.

The assumed area of tidal influence described in Section 4.1 encompasses:

- Ferrymead Heritage Park;
- Ferrymead Railway;
- Farmland in the central areas of the catchment;
- Tramway Historical Society; and
- Ferrymead Events Centre.

Contaminants discharged by these higher-risk areas have not been included in this assessment due to tidal complications. In a future stage, this risk could be mitigated by grab sampling in and around these catchments. Additionally, if no unusual contaminant loading is identified in the proposed sampling locations, autosamplers could be moved downstream into the tidally affected area. However, the reliability and comparability of samples taken in this area will be detrimentally impacted.

7.0 Installation & Maintenance

7.1 Installation

Autosamplers should be situated above flood levels on concrete plinths, in lockable cabinets. Concrete plinths are recommended due to wind loading on cabinets and should be installed if/where possible. This should prevent damage from flooding, weather, and interference from the public. If the cabinet is installed near residential properties, the cabinet shall be noise-lined with polystyrene or similar. Cabinets should be installed by qualified contractors. Autosamplers should be installed separately by a suitably qualified person.

As per Niwa guidance (2014), the following requirements must be met for the installation of Autosamplers:

- The intake shall be positioned within a well-mixed section of flowing water;
- The nozzle intake shall be orientated parallel to the flow;
- The intake shall be situated slightly above the bed of a pipe, or stream;
- The height of the sampler should not be situated excessively above the sample point; and
- The length of tubing should not cause pump and purging times greater than 5 mins per sample.

In open channels, this will be achieved by attaching the intake to a waratah, to ensure it remains in an appropriate location. For intakes situated in stormwater drains, the intake will be secured in place, e.g., to an access structure, pipe, or weir. Installation details will be confirmed at a later date, after consultation with the contractors tasked with installation.

7.1.1 Private Land Access Requirements

Location OH5 will all require stakeholder engagement and access requests prior to installation. OH5 is located on rating lot 143353, next to a public access path, as pictured in Figure 2.

Figure 2. Sampling location OH5, situated on private property.

Location OH1 appears to be situated on KiwiRail land. The waterway is owned by CCC. This site will require stakeholder engagement prior to sampling. PDP recommend the autosampler is situated within the Tunnel Road corridor if possible.

7.2 Maintenance

To ensure samplers and in-situ instruments are adequately maintained prior to sampling, the following routine maintenance checks should be undertaken:

- Carry out routine, inspections prior to undertaking each auto-sampling round;
- Where possible, carry out inspection of autosamplers at the beginning of rainfall events, to ensure they have triggered correctly.
- Ensure autosamplers are fully charged prior to deployment.
- Ensure autosampler pumps are calibrated between each sampling round.
- Ensure there is adequate spare autosampler tubing.

8.0 Reporting

PDP recommend that after three storm events have been sampled, collected data should be reviewed to ensure the objectives of the project are being met. It is recommended that on completion of this review, autosamplers are relocated as required (e.g. if backflow or tidal influence is observed).

Once ten storm events have been sampled, results should be analysed and reported on. PDP recommend that the following analysis is undertaken:

- Rainfall profiles of all sampled events should be analysed and presented.
- Contaminant load calculations should be undertaken for samples collected during the wet weather monitoring, using contaminant concentrations and flow estimates.

This information can be used to inform future monitoring plans.

9.0 Information Required

PDP requires the following information from CCC:

- The type and status of the stormwater instrumentation at the confluence of the Matuku waterway and the lower Ōpāwaho/Heathcote River;
- Access information regarding sites mentioned in Section 7.1.1.
- Any existing relevant stream cross-sections near the proposed monitoring sites.

10.0 Conclusion and Recommendations

PDP has completed the TWWMP for the lower Ōpāwaho/Heathcote Catchment, and Nottingham Catchment. These monitoring plans include details on:

- Previous catchment monitoring, and existing catchment information, including limitations and complicating factors;
- Monitoring locations, with assigned priority levels;
- Sampling protocols including:
  - Sampling event criteria;
  - Installation method;
  - Sampling collection and compositing method; and
  - Flow monitoring;

For this monitoring plan, are 18 sampling locations prioritized from 1-3 recommended across two catchments. PDP has produced two options for recommended sites to be monitored. These options are described below:

- Option 1 consists of Priority 1 and 2 sites at both catchments, excluding Priority 3 sites to reduce costs and target key areas only. Flow will be monitored using 730 series Flow Bubbler modules. This information is summarised below in Table 6.
- Option 2 consists of monitoring Priority 1, 2 & 3 sites for both catchments. Flow will be monitored using rating structures where possible, and stream gauging where rating structures are not appropriate. For this option, Doppler flow meters shall be deployed in the piped sections of the network. This information is summarised below in Table 7.

The selected sampling locations have been assigned a priority level, to give CCC flexibility in the number of sampling/monitoring devices they wish to obtain. At a maximum, this work will require the use of 18 Autosamplers.

The key differences between Option 1 and Option 2 is the additional monitoring locations and the higher accuracy flow monitoring methodology. This information is summarised below in Table 6 and Table 7.

Table 6: Option 1 - Targeted Wet Weather Monitoring Plan Overview

Catchment	Analysis	Events	Method
Priority 1 & 2 locations in Te Tauawa-a-Maka/Nottingham Catchment and in the lower Ōpāwaho/ Heathcote Catchment	Samples shall be analysed by the CCC IANZ-accredited lab for total and dissolved metals, turbidity, suspended solids, E.coli, DOC, pH, turbidity, BOD_5 and nutrients.	Ten storm events must be sampled using Autosamplers. Events require > 3 mm of rain, preceded by at least three antecedent dry days.	One event mean composite (EMC) sample per site, per storm event, that has been flow-weighted. Samples shall be generated using autosamplers. Flow monitoring will require eleven Bubbler Flow Modules and surveyed cross-sections

Table 7: Option 2 - Targeted Wet Weather Monitoring Plan Overview

Catchment	Analysis	Events	Method
Priority 1, 2 & 3 locations in Te Tauawa-a-Maka/Nottingham Catchment and in the lower Ōpāwaho/ Heathcote Catchment	Samples shall be analysed by the CCC IANZ-accredited lab for total and dissolved metals, turbidity, suspended solids, E.coli, DOC, pH, turbidity, BOD_5 and nutrients.	Ten storm events must be sampled using Autosamplers. Events require > 3 mm of rain, preceded by at least three antecedent dry days.	One event mean composite (EMC) sample per site, per storm event, that has been flow-weighted. Samples shall be generated using autosamplers. Flow monitoring is recommended to incorporate Doppler flow meters and/or stream gauging for increased accuracy

10.1 Additional Monitoring

Catchments selected for surface water sampling showed elevated contaminant levels and surface water sampling locations have been recommended to assist in identifying the potential source of these contaminants. However, discharges to the stormwater network and/or surface water may not be the source of elevated contaminant levels.

Prior to implementing the TWWMP, PDP recommends that conductivity and water level loggers are deployed at proposed locations in the lower Ōpāwaho/Heathcote Catchment. This will aid in ensuring the proposed sites are not tidally influenced. Without further catchment analysis, it cannot be confirmed that Bubbler Flow Modules will trigger correctly during rainfall events. Additionally, it cannot be confirmed that samples are not contaminated by estuarine water. PDP also recommends sampling is undertaken in the pond at Westlake Reserve in the Nottingham Catchment, to rule out groundwater/source contamination before moving into more targeted monitoring.

PDP recommends that alternate contaminant sources are investigated, however PDP recognise this is outside of scope and is unlikely to occur prior to the implementation of the targeted wet weather monitoring plans. Alternate sources of contamination could be investigated by implementing the following sampling for the Lower Ōpāwaho/Heathcote Catchment:

- Samples of water from the Avon-Heathcote Estuary could be taken and analysed for metals to investigate whether tidal influence may be contributing to the increase in contaminant concentrations, rather than runoff from the Heathcote Catchment;
- Stormwater samples taken at high tide could be processed separately from low tide samples to develop an understanding of the driving factors behind increasing contaminant concentrations in this reach (this could be implemented in the CCC monthly monitoring); and
- Sediment samples could be collected at a variety of locations and analysed for leachability, to investigate whether the increase in contaminants is related to legacy sediment issues.

The Nottingham Catchment may also benefit from a round of sediment sampling with leachability testing; however, this would have lower priority than the recommended sampling above.

11.0 References

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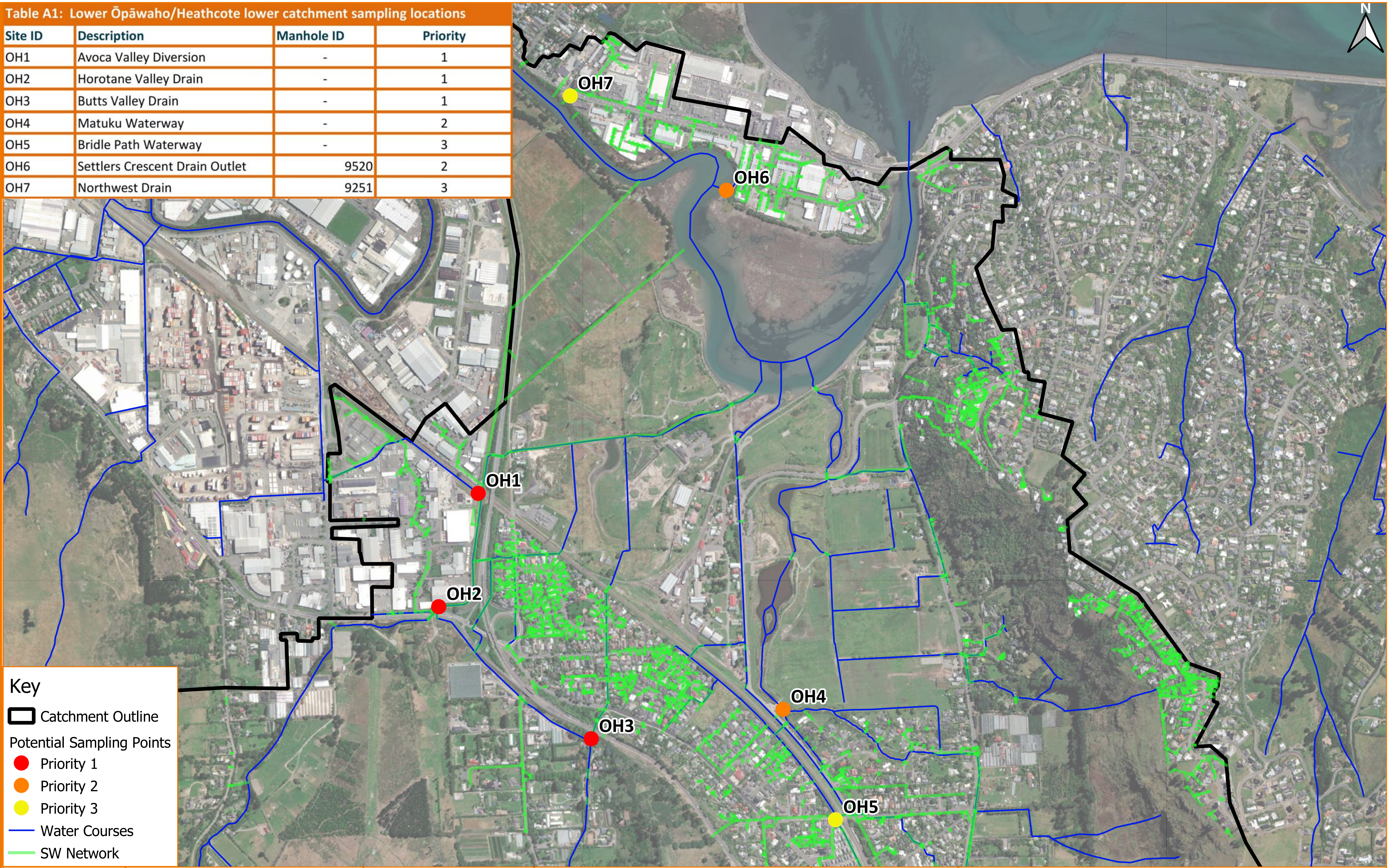
Appendix A: Lower Ōpāwaho/Heathcote Catchment Sampling Map

Table A1: Lower Ōpāwaho/Heathcote lower catchment sampling locations

Site ID	Description	Manhole ID	Priority
OH1	Avoca Valley Diversion	-	1
OH2	Horotane Valley Drain	-	1
OH3	Butts Valley Drain	-	1
OH4	Matuku Waterway	-	2
OH5	Bridle Path Waterway	-	3
OH6	Settlers Crescent Drain Outlet	9520	2
OH7	Northwest Drain	9251	3



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REVISION: 3
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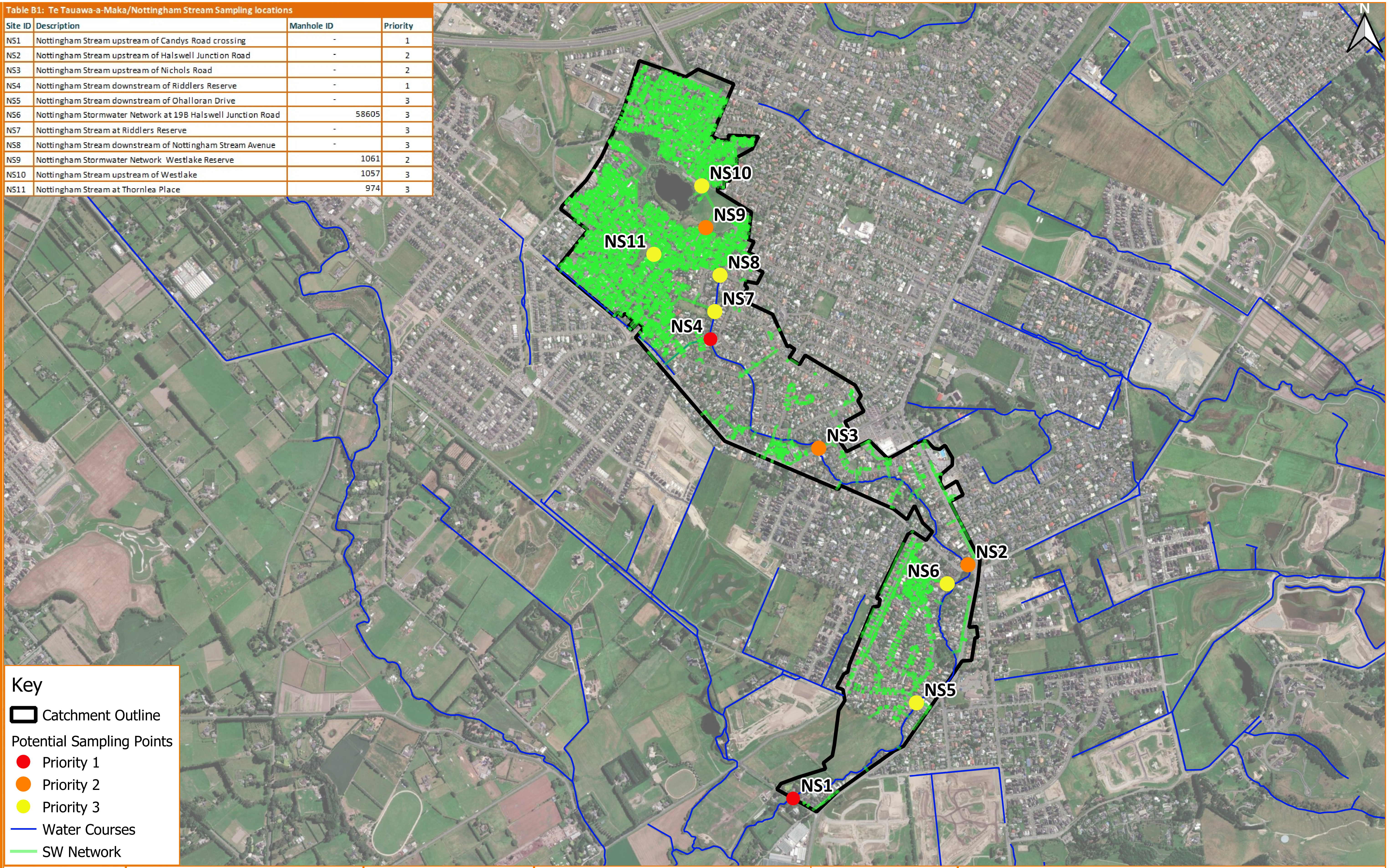
Lower Heathcote Catchment: Proposed Water Quality Sampling Locations

Targeted wet weather monitoring plan

Appendix B: Te Tauawa-a-Maka/ Nottingham Catchment Sampling Map

Table B1: Te Tauawa-a-Maka/Nottingham Stream Sampling locations

Site ID	Description	Manhole ID	Priority
NS1	Nottingham Stream upstream of Candys Road crossing	-	1
NS2	Nottingham Stream upstream of Halswell Junction Road	-	2
NS3	Nottingham Stream upstream of Nichols Road	-	2
NS4	Nottingham Stream downstream of Riddlers Reserve	-	1
NS5	Nottingham Stream downstream of Ohalloran Drive	-	3
NS6	Nottingham Stormwater Network at 19B Halswell Junction Road	58605	3
NS7	Nottingham Stream at Riddlers Reserve	-	3
NS8	Nottingham Stream downstream of Nottingham Stream Avenue	-	3
NS9	Nottingham Stormwater Network Westlake Reserve	1061	2
NS10	Nottingham Stream upstream of Westlake	1057	3
NS11	Nottingham Stream at Thornlea Place	974	3



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Nottingham Catchment: Proposed Water Quality Sampling Locations

Targeted wet weather monitoring plan