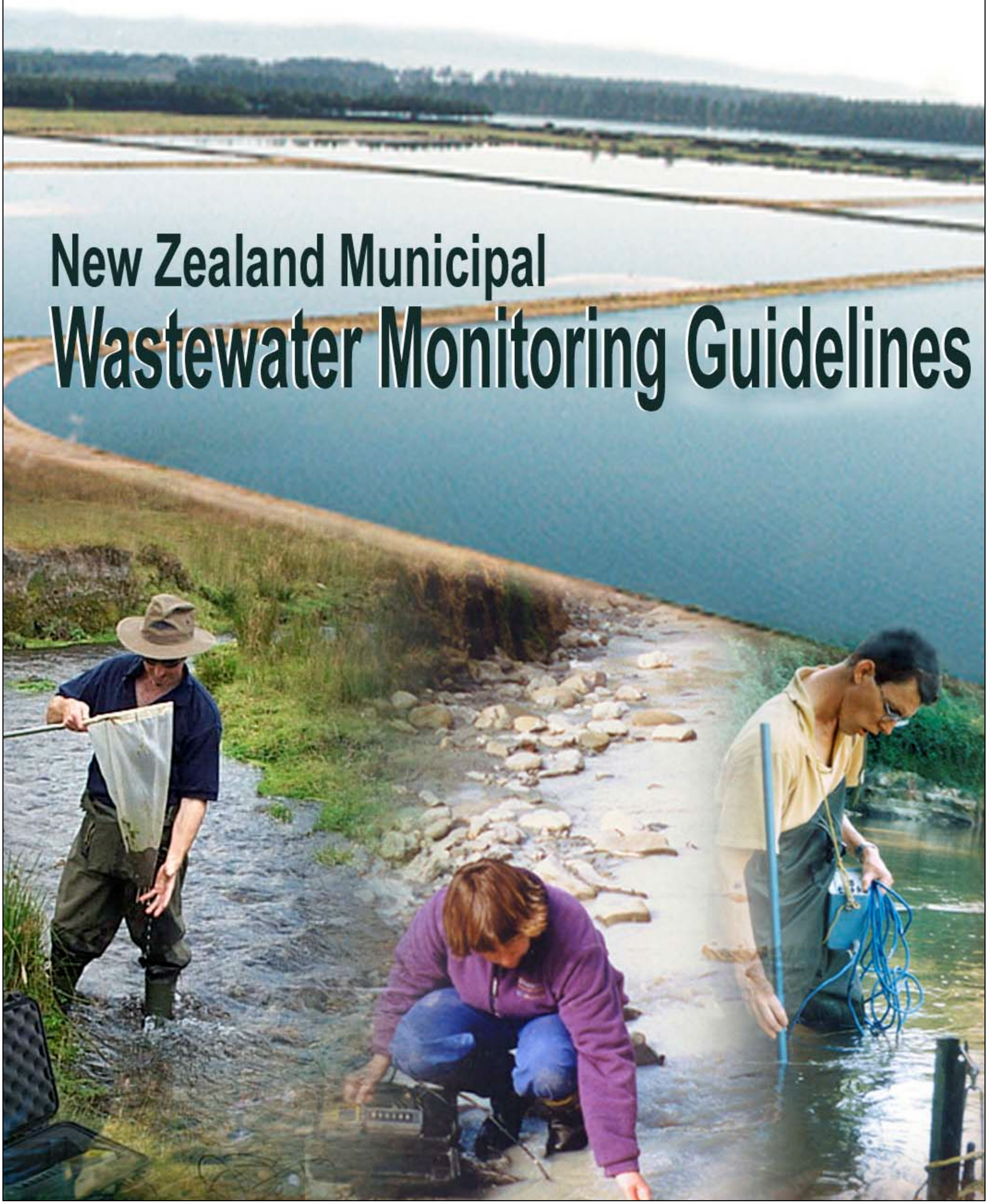
NZWERF

New Zealand Water Environment Research Foundation

Ministry for the Environment
Manatū Mō Te Taiao
Sustainable Management Fund

New Zealand Municipal Wastewater Monitoring Guidelines



New Zealand Municipal
Wastewater Monitoring Guidelines

NZ Water Environment Research Foundation

Edited by David Ray (NIWA)

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FOREWORD

Discharges from wastewater treatment plants have a significant impact on the environment. Effective monitoring is vital to ensure that discharges from wastewater treatment plants are not resulting in adverse environmental or health effects.

Designing wastewater monitoring programmes can be complex. Wastewater treatment plants discharge into a range of receiving environments, including into rivers, estuaries, streams, lakes, and on to land. And the discharges vary in nature depending on the level of industrial input and the type of treatment process.

The purpose of the Ministry for the Environment's Sustainable Management Fund is to support the community, industry, iwi, and local government in a wide range of practical environmental management initiatives. I am pleased that the fund has been able to support the development of these guidelines to assist in the development of monitoring programmes for municipal wastewater discharges.

The core principle of these guidelines is that the higher the potential risks of the discharge to the receiving environment, the greater the level of monitoring that will be required. This approach works best if the experience of the treatment plant operator, regulator and local knowledge and values are incorporated into the design of the monitoring programme.

These guidelines provide a framework for councils and their communities to work collectively through a risk-based process, prior to a resource consent renewal or review, to develop an appropriate environmental monitoring programme.

Hon Marian L Hobbs

Minister for the Environment

PREFACE

The Wastewater Monitoring Guidelines were developed under a Ministry for the Environment initiative, in response to the demand from local authorities and consultants for a consistent approach to setting wastewater monitoring requirements under resource consent conditions. The development of the scope of the Guidelines involved extensive consultation with interested parties, including four workshops around New Zealand.

During the consultation process there was considerable debate about the scope and content of the Guidelines. Like many resource management issues, the setting of monitoring programmes can be contentious. These Guidelines will not prevent debate during the development of a monitoring programme, but they should provide a coherent framework within which that debate takes place.

These Guidelines should be regarded as a ‘living document’, subject to continual revision and improvement. Readers are encouraged to submit their comments to the NZ Water Environment Research Foundation. It is hoped that future versions will address more fully the monitoring requirements for wastewater discharges onto land. More detailed comment on air and biosolids discharges should also be considered. Detailed reference to these topics was not possible in this version of the Guidelines.

David Ray
Editor

ACKNOWLEDGEMENTS

The Steering Group for the consultation phase of the Wastewater Monitoring Guidelines project comprised the following people:

Lisa Sheppard (Ministry for the Environment)
James Holloway (Southland Regional Council)
Ken Becker (Auckland Regional Council)
Martin King (Tasman District Council)
Simon Matthews (Watercare Service Ltd)
Urlwyn Trebilco (Environment Waikato)
Brian Turner (Dunedin City Council)
John Goldsmith (Hutt City Council)
Bob McWilliams (Hastings District Council)
Paul Prendergast (Ministry of Health)
Tim Charleson (Rotorua District Council)

The Steering Group membership was altered slightly for the Guidelines preparation phase of the project, and comprised the following people:

Glenn Wigley (Ministry for the Environment)
Bob McWilliams (Hastings District Council)
Urlwyn Trebilco (Environment Waikato)
Eric Pyle (Forest and Bird Society)
Brian Turner (Dunedin City Council)
Martin King (Tasman District Council)
William Kapea (Te Hao o Ngati Whatua)

The Steering Group members played a pivotal role in the development of the Guidelines, and donated many hours to the project.

The Guidelines have been co-authored and reviewed by a number of people from several organisations. Their names are cited at the beginning of their respective chapters. Other people who contributed to reviewing the document (apart from the preparation phase Steering Group) included Juliet Milne (Otago Regional Council) and Andrew Ball (ESR). A number of people also made valuable submissions on the draft Guidelines (released in June 2002).

The Guidelines were funded principally through the Minister for the Environment's Sustainable Management Fund, administered by the Ministry for the Environment. However, funds for the project were boosted substantially by individual contributions from the following local authorities with the assistance of New Zealand Water and Wastes Association. These contributions enabled the scope and content of the Guidelines to be significantly expanded.

Buller District Council
Environment Canterbury
Far North District Council
Gisborne District Council
Hutt City Council
Manukau City Council
Masterton District Council
Napier District Council
Ruapehu District Council
South Taranaki District Council
Taupo District Council
Waimate District Council
Western Bay of Plenty District Council
Clutha District Council
Environment Waikato
Franklin District Council
Hauraki District Council
Kapiti Coast District Council
Marlborough District Council
Matamata Piako District Council
Rodney District Council
Selwyn District Council
Tasman District Council
Timaru District Council
Wanganui District Council
Westland District Council

EXECUTIVE SUMMARY

David Ray (NIWA)

This document provides guidance to developing monitoring programmes for municipal wastewater discharges. The Guidelines use a risk-based approach. The guiding principle is that the higher the risk to the environment from the discharge, the greater the required scale of monitoring.

Although the principles of these Guidelines can be applied to many types of monitoring programmes (e.g., investigative monitoring for consent applications), the primary focus is monitoring required for resource consent conditions.

Preliminary (Part One)

The Guidelines are divided into four Parts. Part One provides an introduction to the scope and structure of the Guidelines (Chapter 1), the statutory requirements for wastewater monitoring (Chapter 2), and links to other relevant guidelines (Chapter 3).

Risk analysis (Part Two)

The process of developing the monitoring programme is shown in Figure 1 (note that Figure 1 is also included in a laminated sheet contained in the rear pocket of the Guidelines). The first phase is to identify the hazards and analyse the risks of the discharge to the receiving environment, including people (Chapter 4). This phase is termed the HIAMP process (Hazard Identification, Analysis, and Monitoring Plan – refer to Figure 2). The steps to completing the HIAMP process are set out in Sections 4.3.2 to 4.3.4, and summarised in Section 4.3.5 (included on the laminated sheet in the rear pocket).

Firstly, the characteristics of the discharge are identified by characterising the untreated wastewater and the performance of the wastewater treatment system (Chapter 5). This characterisation process is documented in Table 5.5 (page 47). Secondly, the characteristics of the receiving environment are assessed (Chapter 6) and documented in Table 6.2 (page 54). This takes into account the sensitivity and assimilative capacity of the receiving environment in relation to the discharge. Thirdly, the values of the community (including the Tangata Whenua, the 'host' community, and the wider affected community) need to be taken into account (Chapter 7). This ensures that the risk analysis is not a purely technical assessment, but also recognises the effects of the discharge on the community's values.

Once this characterisation is completed, the risks of the discharge are analysed (Chapter 4). This is done in a detailed manner, addressing each constituent of the wastewater (e.g., suspended solids, nutrients, pathogens). The different types of impact (public health, ecological, social, economic, aesthetics and odour) are identified for each constituent. For each of these impact types, the level of impact is assessed. The level of impact takes into account the characteristics of the discharge and receiving environment and the community values in an integrated manner. The likelihood of each of these impacts is then assessed. Finally, the level of impact and the likelihood of that impact are combined to identify the appropriate level of monitoring resources for each constituent of the wastewater. This 'appropriate resources' designation is ranked on a scale from 1 to 3, plus a further option of 'none' (i.e., no monitoring required for the constituent).

The risk analysis process is documented on two Worksheets (Appendix 3). The first, Worksheet A, addresses the 'normal' situation – i.e., that which is normally expected to occur. Note that this includes normally expected variations in wastewater characteristics and environmental conditions – for example, it might include the 5-year low flow in a receiving river. The second, Worksheet B, addresses 'abnormal' situations – i.e., those that are not normally expected to occur, but are considered possible. Examples are major treatment plant failures and extreme environmental conditions (e.g., extreme low flows in rivers).

Design of monitoring programme (Part Three)

Designing the monitoring programme begins with developing a conceptual plan (Chapter 8). This involves defining the objectives of the programme and its intended end uses, and then considering the appropriate mix of monitoring options, based on the outcomes of the risk analysis process from Part Two. The development of the conceptual plan is an iterative process, as indicated in Figure 1. Once an initial concept programme is prepared, the monitoring options are considered in detail (Chapters 9 to 12), and the concept plan revised if necessary. These monitoring options are divided into four general types; sewerage network and treatment plant monitoring (Chapter 9), discharge monitoring (Chapter 10), receiving environment monitoring (Chapter 11), and monitoring effects on community values (Chapter 12).

There is considerable debate as to whether sewerage network and/or treatment plant monitoring should be required in resource consent conditions. It is beyond the scope of these Guidelines to provide guidance on this issue. However, an understanding of the characteristics of the wastewater within the sewerage network and wastewater treatment plant can help with diagnosing problems with the effluent discharge quality, as well as providing valuable information on treatment plant management. Therefore an overview of such monitoring is provided in Chapter 9.

Chapter 10 addresses discharge monitoring options. Guidance is provided on what to monitor (Table 10.1 on page 86) and how often (Table 10.4 on page 96), based on the 'appropriate resources' designations in Worksheets A and B. Details on each monitoring parameter are provided, as well as integrated monitoring options such as whole effluent toxicity testing.

Chapter 11 addresses receiving environment monitoring options. It is more difficult to provide a direct link to the risk analysis process for this chapter, because of the complex nature of receiving environment monitoring. However, the 'appropriate resources' designations should be used to help judge the appropriate scale of monitoring, and Table 11.1 (page 104) presents a guide to choosing the wastewater characteristics to be monitored. Chapter 11 also provides detailed information on receiving environment monitoring methods.

The community can be involved in effects monitoring in a variety of ways, although this is still somewhat of an emerging practice (Chapter 12). Community involvement options include evaluation by the community of technical monitoring results, involvement of community representatives in monitoring activities, and monitoring effects on people's values, usually by surveys (e.g., impacts from odour, noise, litter, etc.).

Once the conceptual monitoring programme has been refined and the appropriate mix of monitoring options determined, the details of the monitoring programme should be confirmed (Chapter 13). Issues to be addressed include: spatial and temporal scale of monitoring; location of sampling sites; monitoring frequency and timing; how data is interpreted (statistical design criteria); how compliance consent conditions are written; and what actions are taken on the basis of the results.

Detailed sampling and analytical methods are addressed in Chapter 14. Finally, Chapter 15 deals with the review procedures for the monitoring programme.

Case Studies (Part Four)

In addition to the numerous brief examples that are given in Chapters 4 to 15, three hypothetical case studies are provided in Part Four, based on the Martinborough (Wairarapa), Cooks Beach (Coromandel), and Green Island (Dunedin) wastewater discharges.

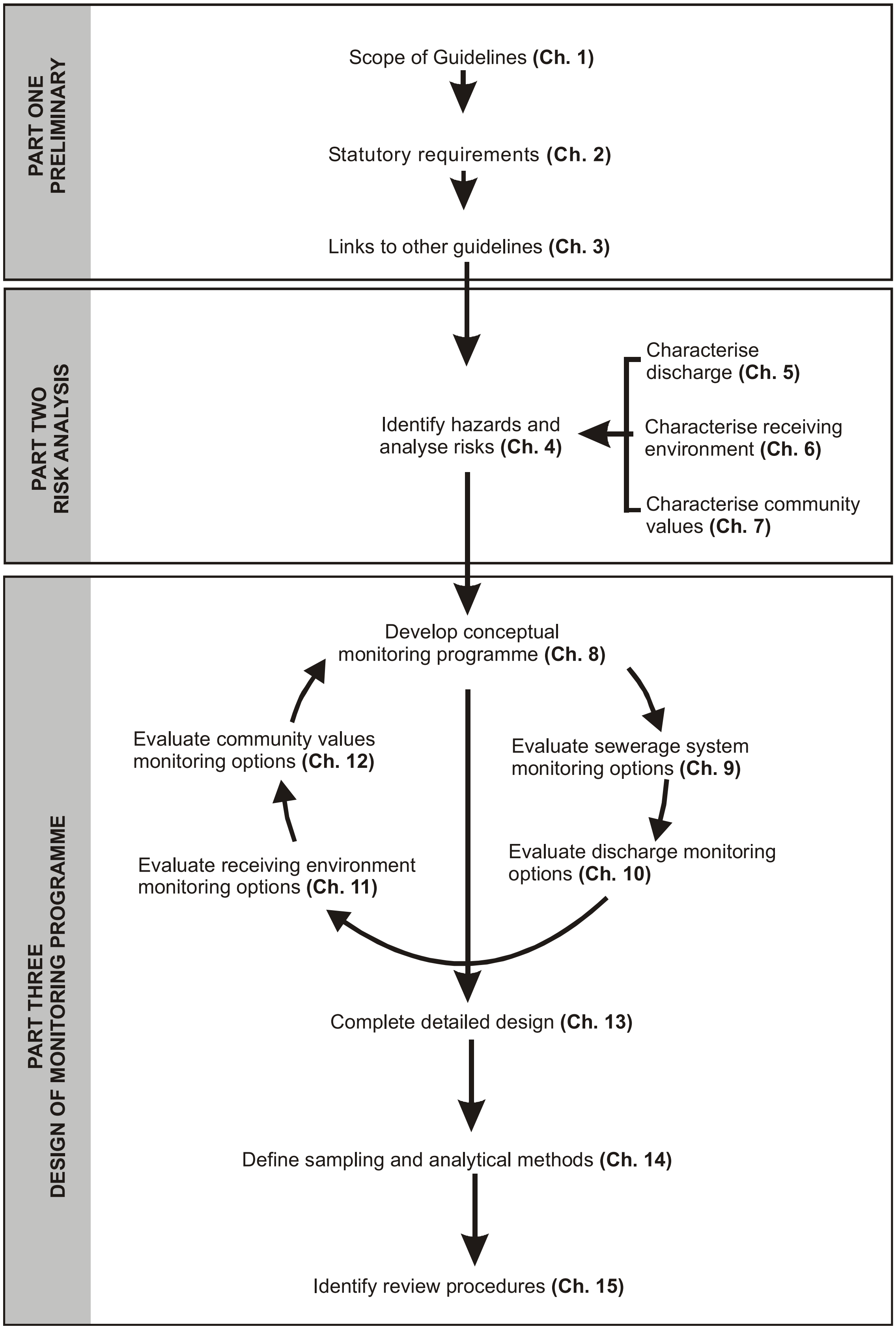


Figure 1: The process of designing the wastewater monitoring programme

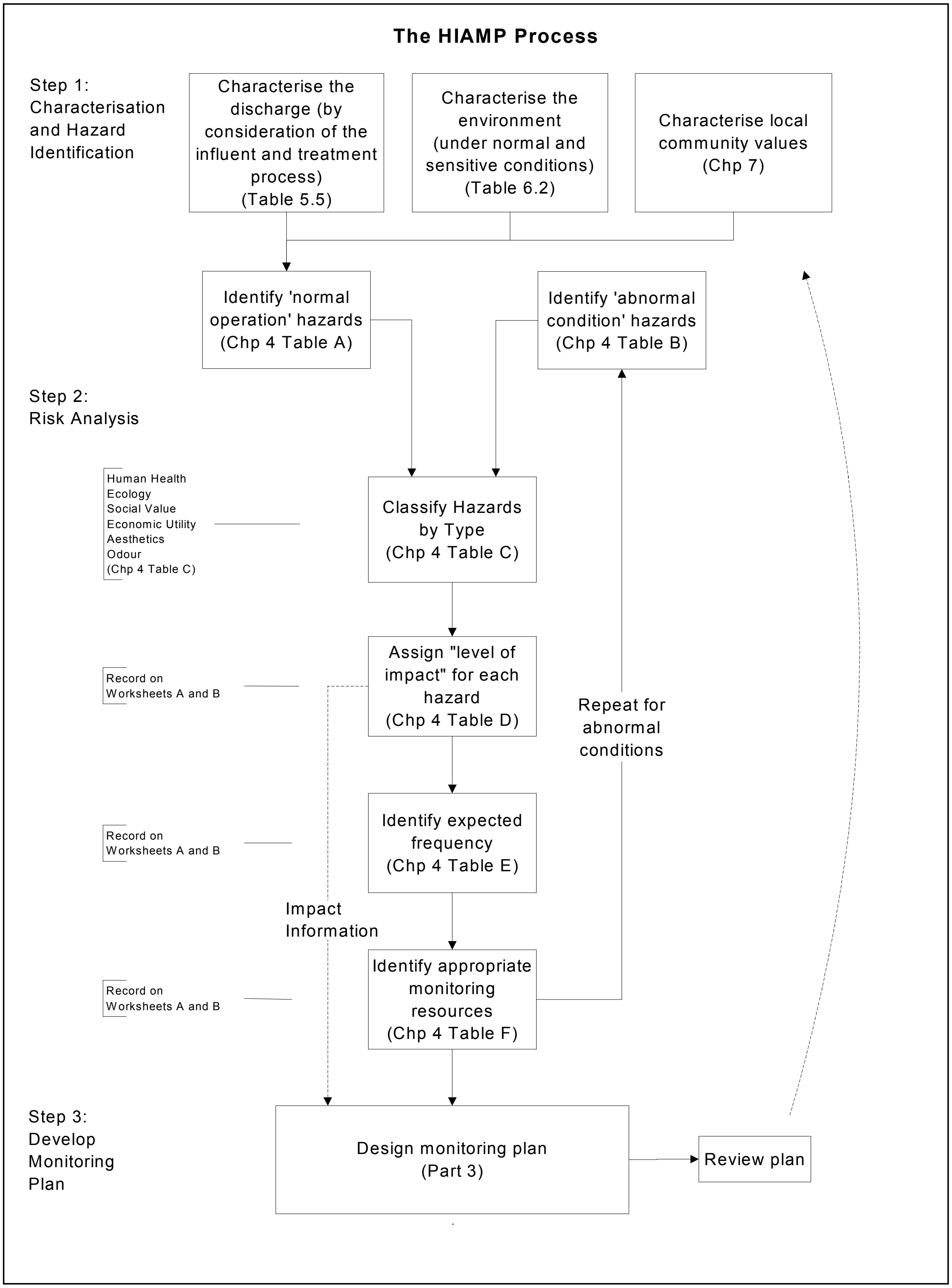


Figure 2: The HIAMP process (flow diagram by Geraint Bermingham, URS).

Contents

PART ONE: PRELIMINARY

CHAPTER 1
INTRODUCTION

David Ray (NIWA)

1.1 Why monitor?

The main reason for monitoring wastewater discharges and their effects on the environment is to help us manage our activities and water resources in an effective and sustainable manner. Like many areas of resource management, "we cannot manage what we do not measure". Monitoring is also required explicitly under the Resource Management Act 1991, as discussed in Chapter 2 of these Guidelines.

However, monitoring can be expensive, and there must be a sound rationale supporting any monitoring programme. Above all, the scale of monitoring should be appropriate to the potential for, and severity of, adverse effects on the environment. For this reason, these Guidelines follow a 'risk-based' approach. The risk-based approach takes into account the characteristics of the discharge (e.g., its volume and contaminant concentrations) and the sensitivity of the receiving environment. The details of this risk-based approach are described in detail in Chapter 4, but the guiding principle is that, the higher the potential risk of the discharge to the receiving environment, the greater the scale of monitoring.

1.2 Development of the Guidelines

The Ministry for the Environment (MfE) has been aware for some years of the difficulties that have been faced by territorial and regulatory authorities in setting wastewater monitoring programmes that are consistent and appropriate. In 2000 the Ministry commissioned a consultation process with affected parties (including local authorities, Tangata Whenua and consultants) to confirm whether Wastewater Monitoring Guidelines were required, what the scope and content of the Guidelines should be, and whether a risk-based approach was appropriate. This consultation process was overseen by a Steering Group comprising representatives from MfE, territorial authorities, regional councils, and the Ministry of Health. Four workshops were held around the country, and questionnaires were sent to all members of the New Zealand Water and Wastes Association (NZWWA). The consultation process demonstrated strong support for development of the Guidelines, as well as adopting a risk-based approach, provided that this approach was not overly complex. The scope and content of these Guidelines follows closely that agreed to through the consultation process.

The writing of the Guidelines was carried out by a team of specialists from several different organisations, overseen by a Steering Group comprising representatives from MfE and local government, plus two people bringing Maori and environmental non-government organisation perspectives, respectively.

1.3 Objectives

The objectives of these guidelines are:

'To assist with determining monitoring requirements for municipal wastewater discharges, that are appropriate to the environmental and public health risks presented by the discharge.'

1.4 Scope

These Guidelines address monitoring requirements for municipal wastewater discharges, including discharges with trade waste inputs. Stand-alone industrial wastewater discharges and stormwater discharges are not specifically included. However, the framework and approach of the Guidelines should be applicable to these other discharges.

The Guidelines do not provide guidance on how to set compliance limits in resource consent conditions; they are purely aimed at designing a monitoring programme.

Monitoring of sewer overflows is not addressed in these Guidelines. This does not imply that sewer overflows are of less concern than discharges from wastewater treatment plants; on the contrary, overflows can result in much more serious (albeit infrequent) impacts than those from treatment plant discharges. However, monitoring requirements for sewer overflows are very site-specific, since overflows occur intermittently and with little warning. The description of some of the receiving environment monitoring methods in Chapter 11 may be useful if monitoring the effects of sewer overflows is being considered.

Liquid, solid (including biosolids) and gaseous discharges are covered, but, to keep the Guidelines manageable, the focus is mainly on liquid discharges. Monitoring requirements for biosolids are to be addressed in the New Zealand Water Environment Research Foundation (NZWERF) Biosolids guidelines. Discharges to water, land and air will be addressed, but only discharges to surface waters are covered in detail. Monitoring requirements for discharges to land are addressed in the NZ Guidelines for Utilisation of Sewage Effluent on Land (NZLTC 2000). If there is a demand for more detail on solid and gaseous discharges, and discharges onto land or into the air, extra detail may be added in subsequent versions of the Guidelines.

These Guidelines are deliberately aimed at small to medium sized discharges, since this is where there is the greatest need for guidance. Large discharges (e.g., the Watercare Services Wastewater Treatment Plant at Mangere and the Christchurch Wastewater Treatment Plant) will involve one-off, specialised approaches to developing monitoring programmes. However, these Guidelines should provide some assistance even with these large discharges.

The Guidelines address even the smallest reticulated wastewater systems, but are not intended for single dwellings served by an on-site system. Reference should be made to the 'On-site domestic wastewater management' guidelines, AS/NZS 1547 2000 (Standards NZ 2000).

It is important to note that these Guidelines will not provide an exact 'answer' for a particular wastewater discharge situation. The intention is to provide a framework for designing monitoring programmes, and to provide some robust and easy-to-follow guidance on what monitoring is appropriate for different situations.

Types of monitoring programmes

These Guidelines are pertinent to four generic types of monitoring programmes.

- Baseline monitoring - measuring the state of the receiving environment before commencement of discharge. This is often carried out as part of an Assessment of Effects on the Environment (AEE), and is usually more detailed than monitoring required under the resource consent conditions.
- Compliance monitoring - checking compliance with numeric limits in resource consent conditions (usually discharge monitoring and/or receiving environment monitoring).
- Trend monitoring - documenting general trends over time in the characteristics of the receiving environment. This is usually not associated with resource consent compliance limits.
- Investigative monitoring - facilitating investigative monitoring that is activated on defined trigger-levels being exceeded, or when non-compliance occurs, to determine more precisely the nature and cause of the problem.

The main focus of the Guidelines is on the second and third types of monitoring programme, but the framework should also assist with the other types of monitoring.

1.5 Structure of the Guidelines

The Guidelines are divided into four parts. The first three of these Parts, which describe the process of developing the monitoring programme, are shown in the flowchart in Figure 1.1. The fourth Part comprises case studies.

Part One – Preliminary

Part One provides an introduction to the development of a monitoring programme. Chapter 1 sets the scope and structure of the Guidelines. Chapter 2 briefly describes the statutory requirements for monitoring. Chapter 3 explains the relevance of other guidelines and standards to these Guidelines.

Part Two – Risk Analysis

Part Two sets out the risk analysis process. At the end of Part Two, the user will have developed a 'risk profile' for the discharge, which will provide clear guidance on what level of monitoring is appropriate, and which components of the discharge and receiving environment have the highest priority for monitoring. As with any 'new' approach, the risk-based approach may appear somewhat daunting at first. However, the reader is urged to persevere with the process, as there are significant benefits to be gained, and the procedure should lead to a common basis for defining monitoring requirements.

Chapter 4 sets out the principles of the risk analysis process. It then sets out a step-by-step process for analysing the risks, using a series of ‘look-up’ tables and a worksheet to document the risk analysis. A worked example is also provided, to assist the reader with understanding the process.

The risk analysis is based on the characteristics of the discharge and the receiving environment. Chapter 5 provides a system of characterising the discharge, firstly by characterising the untreated wastewater, then characterising the effectiveness of the wastewater treatment plant (WWTP). Chapter 6 describes the characterisation of the receiving environment, addressing in particular the sensitivity of the receiving environment to the discharge.

Chapter 7 discusses the consideration of community values in the risk analysis process.

The intention with Part Two is that the reader will not follow the Part in a purely sequential manner. Instead, an iterative process between Chapter 4 and the following three chapters will be required (refer to Figure 1.1).

Part Three – Design of the Monitoring Programme

Part Three describes the design of the monitoring programme, based on the risk analysis completed in Part Two. Again, the process is an iterative one, rather than purely sequential (refer to Figure 1.1).

Chapter 8 sets out the conceptual design of the monitoring programme. Central to this is the setting of the programme’s objectives and defining the proposed end uses of the monitoring results. This leads to a concept plan for the programme, considering the appropriate mix of monitoring options.

Chapters 9 to 12 describe the monitoring options in detail. Chapter 9 describes briefly the options for monitoring of the sewage network system and in-plant monitoring. This is aimed mainly at operational-type monitoring.

Chapter 10 describes options for effluent discharge monitoring, which will be the central ‘plank’ for most monitoring programmes. Chapter 11 sets out options for receiving environment effects monitoring, focusing on surface water receiving environments.

Chapter 12 discusses the emerging options for monitoring the effects of wastewater discharges on community values. Three main themes are addressed – evaluation by the community of technical monitoring results, involvement of community representatives in monitoring activities, and ways of monitoring effects on people’s values (e.g. impacts from odour, noise, litter, etc.).

Chapter 13 describes the detailed design of the monitoring programme, once the skeleton of the monitoring programme has been confirmed. Considerable attention is paid to how monitoring programmes must be essentially statistical in nature, given the very tiny fraction of the waste stream or receiving environment that is being monitored.

Chapter 14 addresses methods to be used for sampling and analytical procedures, as well as quality control measures. Finally, Chapter 15 considers briefly the review procedures for monitoring programmes, including in particular the selection of the duration of the programme.

Part Four – Case Studies

Prior to finalisation, these Guidelines were trialed under three 'real-life' situations. Wastewater discharges at Cooks Beach (a land disposal system on the Coromandel Peninsula), Martinborough (an oxidation pond discharge into the Ruamahanga River in the Wairarapa) and Green Island (a relatively large ocean outfall at Dunedin) were chosen for the trial. District and regional council staff and one consultant used the draft Guidelines to develop a monitoring programme, and to provide the authors with feedback on the draft Guidelines. The trials were written up as Case Studies, with the intention of providing the reader with examples of how the Guidelines can be applied.

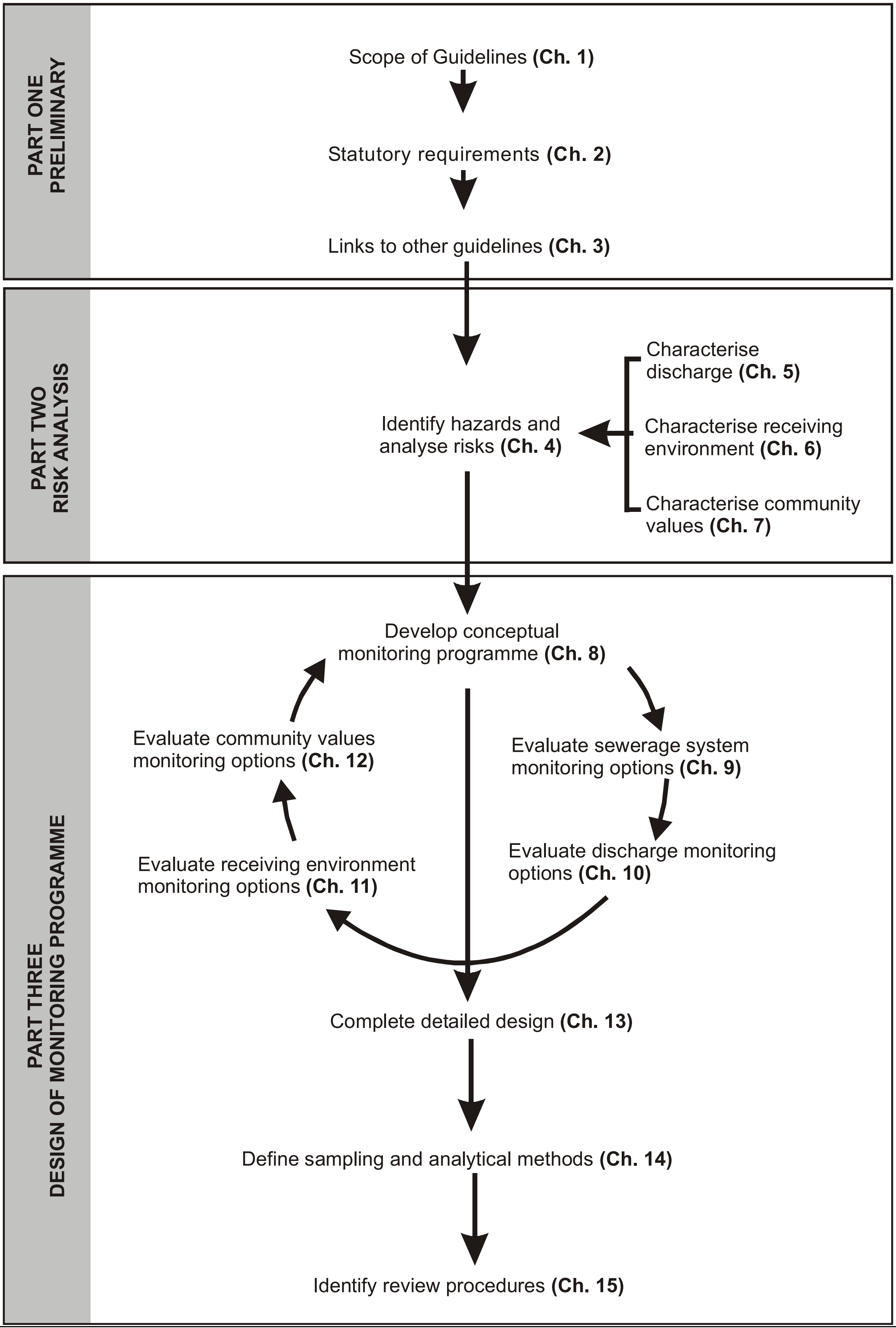
1.6 Statutory Status of the Guidelines

These Guidelines have no statutory status, and are therefore not legally binding on any party. They are intended purely as a guide for consent applicants, regulatory authorities, and interested parties. Furthermore, these Guidelines should in no way override the resource consent process defined by the RMA.

1.7 Management of the Guidelines

These Guidelines are intended to be a 'living document', administered by NZWERF under a contract to MfE. One of NZWERF's responsibilities is to manage any updates to the Guidelines. Recommendations for minor amendments to the Guidelines should be made to the NZWERF Chief Executive, PO Box 1301, Wellington. Amendments are to be made only with the approval of the NZWERF Board and the MfE.

A complete review of the Guidelines is to be conducted in 2007. This will be initiated by NZWERF, and will involve consultation with affected parties.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Complete detailed design (Ch. 13)
Define sampling and analytical methods (Ch. 14)
Identify review procedures (Ch. 15)

Figure 1.1 The process of developing a monitoring programme using these Guidelines.

CHAPTER 2
STATUTORY REQUIREMENTS

Laurence Dolan (URS (New Zealand) Ltd)

2.1 Introduction

This section describes the legislative requirements relating to wastewater treatment plants, specific to monitoring. It addresses the requirements of the Resource Management Act 1991.

2.2 Resource Management Act 1991

The Resource Management Act 1991 (RMA) is the legislation controlling the use of natural resources in New Zealand. Part II of the RMA sets out the purpose and principles. The purpose of the Act is:

"To promote the sustainable management of natural and physical resources".

The RMA provides a definition of 'sustainable management' in section 5. Essentially, the term means communities managing resources to provide for their social, economic, and cultural well being and for their health and safety while meeting certain environmental imperatives. The potential of natural and physical resources to meet the reasonably foreseeable needs of future generations must be sustained, the life-supporting capacity of resources must be safeguarded and adverse effects of activities on the environment must be avoided, remedied or mitigated. This last focus upon the effects of activities is a key feature of the Act.

MfE (1999) provides useful guidance to the Act.

2.3 Regional Plans

Section 64 of the RMA requires regional councils to prepare a regional coastal plan. Section 63 allows regional councils to prepare plans in respect of other resources or activities. All regional plans must be prepared in the manner set out in the First Schedule.

Individual regional coastal plans and regional plans may contain requirements with respect to the quality of discharges and/or receiving environments and associated monitoring. Consent applicants need to consult the relevant regional plans in detail when preparing a monitoring programme. In many cases, the requirements of the regional plan will have more bearing on the monitoring programme than the RMA.

2.4 Resource consents

The owners of wastewater treatment plants are required to obtain resource consents under the RMA for discharges to the environment, unless these discharges are expressly allowed in a regional plan or proposed regional plan. In general a wastewater treatment plant would require the following consents:

- Discharge permit for contaminant discharges to water, for the discharge of effluent to a water body (section 15(1)(a)).
- Discharge permit for contaminants onto or into land in circumstances where it may result in a contaminant entering water, eg for disposal of biosolids onto land, irrigation of effluent to land, or for discharges through the base of oxidation ponds (section 15(1)(b)).
- Discharge permit for contaminants into air for odour or aerosol discharges (section 15(1)(c)).

An application for a resource consent requires the preparation of an assessment of effects on the environment, in accordance with section 88 and the Fourth Schedule. The Fourth Schedule sets out matters that should be included in an assessment of effects on the environment, including clause 1(i):

> *"Where the scale or significance of the activity's effect are such that monitoring is required, a description of how, once the proposal is approved, effects will be monitored and by whom."*

Section 108 of the RMA authorises the imposition of conditions on a resource consent. In accordance with sections 108(3) and (4), conditions may require the consent holder to collect, at its own expense, information relating to the exercise of the resource consent, and relevant to the effects of the activity, and provide it to the consent authority, including:

- The making and recording of measurements.
- The taking and supplying of samples.
- Carrying out analyses, surveys, investigations, inspections, or other specified tests.
- Carrying out and analysing measurements, samples, analyses, surveys, investigations, inspections, or other specified tests in a specified manner;
- Provision of information to the consent authority at a specified time, or times.
- Provision of information to the consent authority in a specified manner.
- Compliance with the condition at the consent holder's expense.

CHAPTER 3
LINKS TO OTHER GUIDELINES

Laurence Dolan (URS (New Zealand) Ltd)

3.1 Introduction

These monitoring Guidelines are not intended to be a stand-alone document. There are a range of other guidelines that have direct relevance to the development of wastewater monitoring programmes. Each of these needs to be considered in conjunction with the Wastewater Monitoring Guidelines. The following is a list of other relevant guidelines:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000a).
- Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC 2000b).
- Guidelines for the Application of Biosolids to Land in New Zealand (due for completion late in 2002).
- New Zealand Guidelines for Utilisation of Sewage Effluent on Land (NZLTC 2000).
- Manual for Wastewater Odour Management, Second Edition (NZWWA 2000).
- NZS 9201 Model General Bylaws, Part 23 - Trade Waste.
- Drinking Water Standards for New Zealand (MoH 2000).
- Guidelines for Drinking Water Quality Management for New Zealand (MoH 1995).
- Microbiological Water Quality Guidelines (MfE 2002a).
- USEPA NPDES Permit Writers' Manual (USEPA 1996).
- The New Zealand Waste Strategy (MfE 2002b).

The scope of each of these guidelines is discussed briefly below.

3.2 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

These guidelines are an update of the 1992 Australian Water Quality Guidelines for Fresh and Marine Waters. They provide quality management guidelines to protect and manage the environmental values related to the following fresh and marine water resources:

- Aquatic ecosystems.
- Primary industries.
- Recreation and aesthetics.

- Drinking water.
- Industrial water.

The guidelines are not mandatory standards that set maximum limits for contaminants, but rather are intended to be used to trigger action.

3.3 Australian Guidelines for Water Quality Monitoring and Reporting

These guidelines are related to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000a). They provide the guidance necessary for designing monitoring programmes with which to assess receiving water quality in freshwater, marine waters and groundwaters. There is some overlap between the Wastewater Monitoring Guidelines and the ANZECC Monitoring Guidelines. The ANZECC Guidelines are more detailed in some of the issues they address with respect to receiving environment monitoring. The user of Part Three of this document is strongly advised to consult Australian Guidelines for Water Quality Monitoring and Reporting.

3.4 Guidelines for the Application of Biosolids to Land in New Zealand

The NZWERF Biosolids Guidelines (currently in draft form) will address monitoring of biosolids and the receiving environment.

3.5 New Zealand Guidelines for Utilisation of Sewage Effluent on Land

These are guidelines for the land treatment of municipal and domestic effluents. They consist of two documents. Part 1 provides a guide to the overall process involved in designing a system, gaining resource consents and setting up management systems. Part 2 provides supporting information on key issues relating to designing, operating and monitoring land treatment systems. Part 2 is most relevant to wastewater monitoring.

3.6 Manual for Wastewater Odour Management

This Manual contains information on procedures and processes for the management of odour from wastewater facilities. It addresses the regulatory and legislative issues, methods of quantifying odour, dispersion modelling and standards, and techniques for assessing the potential for odour problems to occur.

Methods of odour control, such as prevention, use of buffer zones, chemical scrubbers and biofilters, are outlined.

In addition, case studies and process guidelines offer examples for practical application to real situations.

3.7 Model General Bylaw - Trade Waste

This model general bylaw addresses, among other things, acceptable discharge characteristics for discharges of trade waste into sewerage systems. It provides guideline values for maximum concentrations of general chemical characteristics, heavy metals and organic compounds and pesticides. Note that many local bodies have their own trade waste bylaws; not all of these follow the Model General Bylaw.

3.8 Drinking Water Standards for New Zealand

The drinking water standards list the maximum acceptable values (MAVs) for concentrations of chemical, radiological and microbiological contaminants for public health in drinking water for community water supplies. Also specified are sampling frequencies and testing procedures that must be used to demonstrate that the water complies with the standards.

3.9 Guidelines for Drinking Water Quality Management for New Zealand

These guidelines form a companion volume to the Drinking Water Standards for New Zealand. They explain the principles the standards were based on, how the MAVs were derived and the part aesthetic quality plays in producing a safe, wholesome and acceptable community drinking water.

3.10 Microbiological Water Quality Guidelines

These guidelines cover three categories of water use:

- Marine bathing and other contact recreation activities.
- Fresh water bathing and other contact recreation activities.
- Recreational shellfish gathering.

Note that the MfE (2002a) microbiological guidelines are interim, and will be revised in 2003.

Note also that these guidelines should not be directly used to determine water quality criteria for wastewater discharges, because there is the potential for the relationship between indicators and pathogens to be altered by the treatment process (refer to Section 10.6). The guidelines should also not be directly applied to assess the microbiological quality of water that is impacted by a nearby point source discharge of treated effluent (particularly disinfected effluent and including waste stabilisation pond effluent) without first confirming that they are appropriate (refer to Section 11.8).

3.11 USEPA NPDES Permit Writers' Manual

This document provides detailed guidance to discharge monitoring. It is available on the web at http://www.epa.gov/owm/sectper.htm.

The USEPA has many other relevant guidelines too numerous to describe in this document. These can be accessed via USEPA's website at http://www.epa.gov/clariton/.

3.12 The New Zealand Waste Strategy

This document sets out New Zealand's strategy for waste minimisation and management, and as such is an overarching strategy for management of wastewater discharges. It is available on the web at http://www.mfe.govt.nz/.

PART TWO:
RISK ANALYSIS

CHAPTER 4
THE RISK ANALYSIS PROCESS

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4.1 Introduction

As discussed in Chapter 1, these Guidelines use a risk-based approach as a basis for developing monitoring programmes. This chapter describes how to carry out the risk analysis process.

Although in many cases the risk analysis process will be co-ordinated by one person, it is strongly recommended that the analysis is carried out by a team with between them the knowledge of the receiving environment, the waste stream and the waste process. This team might include the plant operator, the asset manager, wastewater treatment specialist(s), specialists in assessing environmental impacts, and representatives of the community.

Section 4.2 summarises the principles of the risk-based approach. Section 4.3 sets out the risk analysis process in a step-by-step manner. It is necessary to refer to Chapters 5, 6 and 7 whilst carrying out the risk analysis; this is explained fully in Section 4.3.

Those users new to risk-based analysis may initially find the process complex. However, the risk process instructions are set out in a straightforward way, and provide users with a clear, step-by-step methodology. First time users should refer to the example provided in Appendix 4 to assist with the understanding of the risk analysis process.

4.2 The risk-based approach

4.2.1 The concept of risk and risk-based management

Risk-based management offers the ability to systematically manage unplanned or unintended future events and the associated uncertainties. The process used for the risk-based development of a monitoring programme in these Guidelines is termed the ‘HIAMP’ process (Hazard Identification, Analysis, and Monitoring Plan).

4.2.2 Aim of the risk-based approach

The aim of the risk-based approach adopted by these Guidelines is to ensure that a monitoring programme devised for any given situation:

- Reflects the true risks faced by the receiving environment.
- Is efficient in terms of resources expended.
- Aids the control of the risks.

The risk analysis process is designed to identify the level of risk associated with each individual hazard posed by the wastewater discharge. This in turn provides clear guidance on which constituents represent the highest priority for monitoring.

4.2.3 Terminology

Risk

The term 'risk' as used in these Guidelines is defined as a function of both the likelihood and impact of an untoward event. This definition is consistent with the relevant New Zealand Standard on Risk Management, AS/NZS4360.

Hazard

The term 'hazard' as used in these Guidelines is defined as a source of potential harm. This definition is consistent with the relevant New Zealand Standard on Risk Management, AS/NZS4360.

Impact

The term 'impact' as used within the HIAMP process is defined as an adverse effect on the environment (including the human environment).

4.3 The HIAMP risk analysis process

4.3.1 Overview of the HIAMP risk model

The HIAMP process is summarised in Figure 4.1. The process is designed as a series of discrete steps, as follows (full details in Section 4.3.2):

Step 1: Characterisation and Hazard Identification

This step enables an understanding of the main factors that influence the risks associated with discharge to the local environment to be developed. It involves the characterisation of the discharge (the untreated waste stream and treatment process) and the receiving environment, as well as the associated community values.

Each source of risk (hazard) associated with the waste stream, the treatment process and the receiving environment is then identified.

Step 2: Risk Analysis

The impacts resulting from each source of risk are assessed against a 'consequence scale'. The anticipated likelihood of occurrence is also recorded. This information is then used to establish the appropriate level of monitoring resources.

Step 3: Monitoring Plan Development

Using the results of Step 2, a monitoring plan is developed that reflects the risk profile and uses the appropriate level of resources in a targeted and efficient way. This step is covered in Part Three of the Guidelines.

The HIAMP process comprises:

- A set of User Instructions (detailed instructions in Sections 4.3.2 to 4.3.4, summarised in Section 4.3.5),
- Look-Up Tables A – F (Section 4.4), and
- A combined Worksheet and Risk Register (Worksheets A and B, Appendix 3). The Worksheets are used to record the hazards and risk analysis data as it is developed during the HIAMP process. An example that demonstrates use of the Worksheets is provided in Appendix 4. [Because these worksheets are referred to frequently in the Guidelines, it is suggested that the user photocopies the worksheets.]

4.3.2 Step 1: Characterisation and Hazard Identification

This first step comprises a formal characterisation of the waste stream, the treatment process and the receiving environment, the taking into account community values and a formal hazard identification step involving the use of key-word prompts.

Step 1.1: Characterise the discharge

Refer to Chapter 5 to characterise the waste stream and treatment process, and hence the wastewater discharge. Table 5.5 in Chapter 5 (page 47) provides the user with a system of documenting the characteristics of the discharge.

Step 1.2: Characterise the environment

To characterise the receiving environment, refer to Chapter 6. Table 6.2 in Chapter 6 (page 54) provides the user with a system of documenting the characteristics of the receiving environment.

Step 1.3: Characterise community values

The values of the local community – in particular, those people who live close to the treatment plant – must be taken into account when assessing the risk. This is addressed in Chapter 7. It is suggested that the user compiles a series of notes that summarise the assessment of community values, as the tabular approach used in Chapters 5 and 6 is unlikely to be appropriate for Chapter 7.

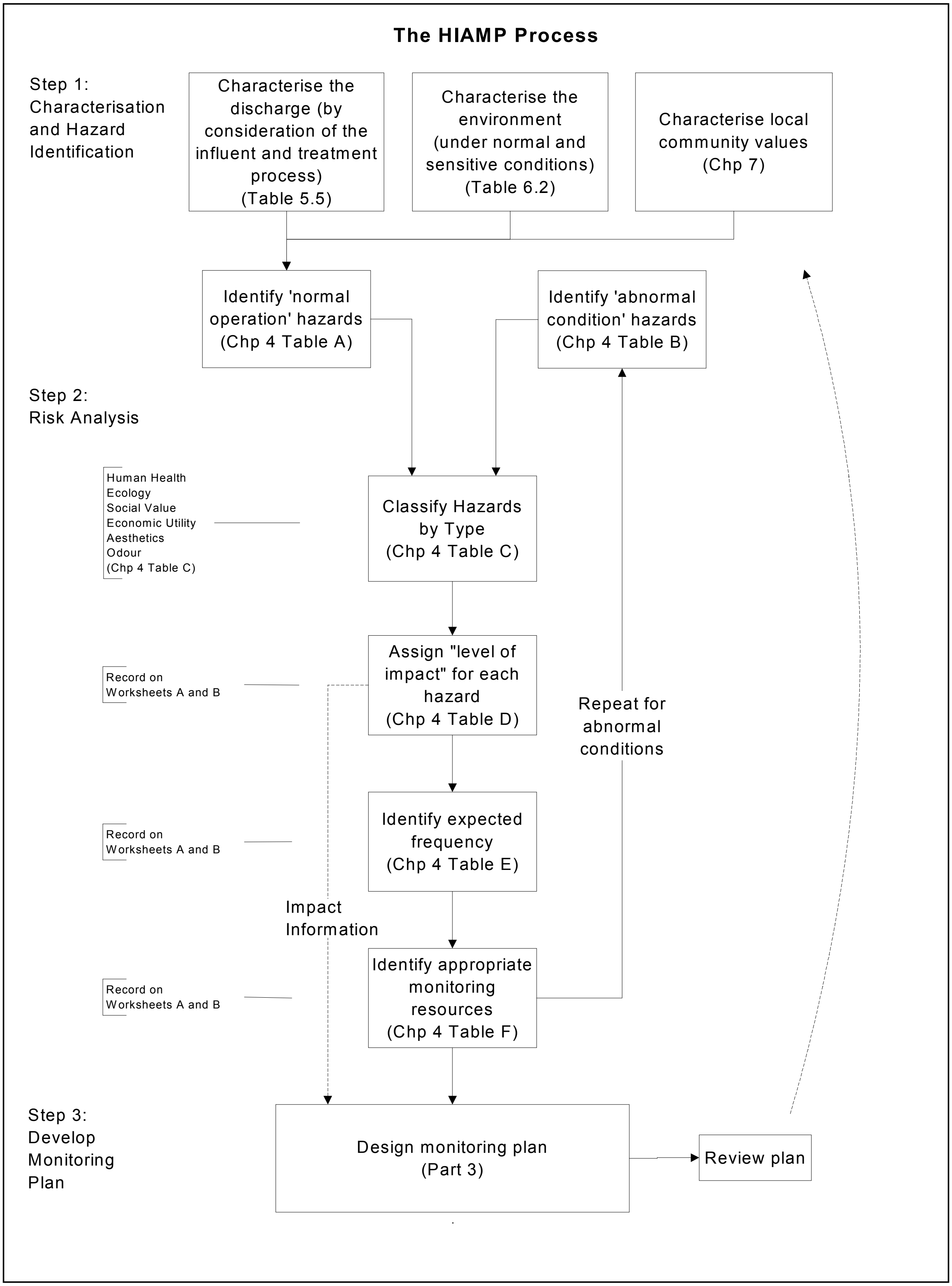

Figure 4.1: The HIAMP process.

Step 1.4: Hazard Identification

Ideally, a group working within a workshop environment will carry out the hazard identification process. This will ensure that all required knowledge is available to identify all risks. Alternatively, the process can be carried out by a series of people with between them the knowledge of the receiving environment, the waste stream and the waste process.

When characterising the wastewater discharge and receiving environment, the user needs to consider risks associated with both 'normal' conditions and 'abnormal' conditions. These are described as follows.

Risk related to 'normal' conditions

This refers to the sources of risk associated with the waste stream, the plant and the receiving environment during 'normal' conditions. Normal conditions are those that are *expected* to occur. Table A in Section 4.4 provides a list of key-words that are designed to prompt the user to identify the 'normal' hazards. Note that natural fluctuations in contaminant concentrations, wastewater flow rate and environmental conditions are part of the normal condition. For example, the 5-year low flow in a receiving river would be considered part of the 'normal' conditions. Tables 5.5 and 6.2 should document the characteristics of the discharge and receiving environment under normal conditions.

Risks related to 'abnormal' conditions and gross uncertainty

This refers to hazards associated with the waste stream, the plant and the receiving environment that arise due to gross uncertainty and abnormal conditions. Abnormal conditions refer to those events that result from faults, failures and untoward events that are not normally expected or repeating, but are considered possible and credible as well as unusually sensitive environmental conditions. Examples include major plant failures, process upsets and toxic shock incidents, and unusual long-term weather conditions (e.g., a 50-year drought). Gross uncertainty may be present in cases where there is some uncertainty regarding the capability or suitability of a given process, or the dynamics of the environment in response to the discharge inflows. This type of gross uncertainty is over and above the normal levels expected when predicting discharge impacts.

Table B (Section 4.4) provides a list of key-words that are designed to prompt the user to identify 'abnormal' sources of risk.

Users may find that the same hazard will be identified more than once by the use of key-word prompts. Where this occurs, the duplication is simply removed before the 'Analysis' step (see Step 2 below).

At completion of Steps 1.1 to 1.4, the user should have completed:

- ***Tables 5.5 and 6.2 (discharge and receiving environment characteristics under normal conditions).***
- ***Notes on abnormal conditions for the influent wastewater, treatment plant and receiving environment.***
- ***Notes on community values relevant to the discharge and receiving environment.***

4.3.3 Step 2: Risk Analysis

Step 2 involves analysing the impact and likelihood of each of the hazards identified in Step 1. Use Worksheets A and B in Appendix 3 to document this analysis.

Step 2.1: Identifying the Type of Impact

Use the information gathered in Step 1 to provide a brief description of the nature of the impacts under normal conditions in the first empty column in Worksheet A. Refer to the example worksheet in Appendix 4 for guidance.

Identified risks need to be assigned to a given type, or types, of impact to enable the level of impact to be ascribed. Six distinct types of impact are used:

- Human health and safety.
- Ecology.
- Community Values.
- Economic Utility.
- Aesthetics.
- Odour.

A description of each of these impact types is given in Table C (Section 4.4). 'Odour' and 'aesthetics' have been ascribed separate impact types to 'community values', in the view of the prominence these two issues have with wastewater discharge issues.

Step 2.2: Rating the Level of Impact

This step involves identifying the anticipated level of impact. The general description of the impact scale is given in Table 4.1 below. Each step on the scale is intended to represent an 'order of magnitude' increase in impact. The detailed impact scales for each type of impact (i.e., human health and safety, ecology, etc) is described in Tables D1 to D6 (Section 4.4).

Each impact scale is based upon a 6 step scale denoted 'A' to 'F', with a consistent descriptor term used for all types of risk. The scale for each type of impact ranges from an 'F' rating that denotes 'insignificant impact', to a level commensurate with the maximum potential impact. As human health is considered to carry most importance by society, the highest level for human health (only) is rated 'A'. Other types of impact have different maximum ratings (for example, Aesthetics scale ranges from D to F only).

When assessing the level of impact, it is clearly necessary to account for the relative volume of the discharge (i.e. the flow rate) to the characteristics of the receiving environment (e.g., degree of dilution), as these will have a significant bearing on the level of impact.

Use the first column of the paired columns in Worksheet A to document the assessed level of impact (refer to example in Appendix 4 for guidance). Reasonable assumptions are to be made when identifying the anticipated level of impact. Use separate lines where there is clearly more than one type of event of discrete level of impact resulting from one 'prompt'. Normal levels of uncertainty regarding discharge constituents and anticipated sensitivity of the receiving environment should be considered, and a reasonably precautionary approach taken.

Table 4.1: Impact Designations (see Tables D1 - 6 for specific descriptions for each separate 'type' of impact – Section 4.4).

Term	General Description and Notes	Designation
Highly Injurious	Most serious consequence. Public illness or injury that could involve death. This level only applies to 'Human Health and Safety' type of impact	A
Critical	Very serious impact involving permanent or long-term damage	B
Major	Partial or temporary but significant damage	C
Moderate	Clear stress noted and intervention expected to be required to limit impacts	D
Slight	Measurable or notable impact but intervention unlikely to be called for	E
Insignificant	Impact expected but may not be measurable or of concern	F

Step 2.3: Identifying the Likelihood

For each hazardous event identified, a judgement must be made as to the frequency or likelihood of it occurring. The frequency or likelihood scale used is described qualitatively using a 5-step scale. This is given in Table E in Section 4.4.

Note that the first three terms in Table E relate to essentially routine or normal events, whilst the last two describe unexpected or abnormal conditions.

The appropriate likelihood is recorded on the worksheet for each identified hazardous event.

It may be that for any one type of hazardous event there are a number of possible likelihoods for different impacts. For example, the likelihood of 'slight' odour may be 'frequent', while the likelihood of 'moderate' odour might be 'occasional' (refer also to the example in Appendix 4). It is normal to describe similar combinations of impact and likelihood as one event with representative values, using reasonable assumptions (i.e. using highest realistic likelihood). However, it is sometimes necessary to describe two or possibly more events to cover all important scenarios.

Step 2.4: Assigning the Appropriate Level of Monitoring Resources

The final step in the analysis process is to identify the level of resources appropriate for monitoring. This is accomplished by using Table F, which draws on the worst-case combinations of the scale of impact with the likelihood.

Step 2.5: Risk Analysis for abnormal risks

Repeat steps 2.1 to 2.4 for abnormal condition risks. Fill in Worksheet B at each step.

At the completion of Steps 2.1 to 2.5, the user should have completed Worksheets A and B. The user should then proceed to Chapter 8 to complete Step 3.

4.3.4 Step 3: Developing the monitoring plan

The output of the HIAMP process is used to develop an appropriate monitoring programme. Guidance for the development of the monitoring programme is given in Part Three, starting at Chapter 8.

4.3.5 Summary of instructions

The instructions for the HIAMP process are summarised below. Note that this list of instructions is also contained on the laminated sheet contained in the pocket at the rear of the Guidelines. As each step is completed, fill in Worksheets A and B in Appendix 3 (refer to the example worksheets in Appendix 4 for assistance).

- **Step 1:** **Characterisation and Hazard Identification**
- **Step 1.1:** Characterise the effluent discharge (by consideration of the influent stream and treatment plant process) under 'normal' and 'abnormal' conditions, using Chapter 5 for guidance. Fill in Table 5.5 in Chapter 5 (page 47).
- **Step 1.2:** Characterise the environment under 'normal' and 'sensitive' conditions using Chapter 6 for guidance. Fill in Table 6.2 in Chapter 6 (page 54).
- **Step 1.3** Take into account community values, using Chapter 7 for guidance.
- **Step 1.4** Use key-word prompts in Tables A and B (pages 25 and 26) to identify the hazards associated with 'normal' and 'abnormal' conditions as well as gross uncertainty.
- **Step 2:** **Risk Analysis**
- **Step 2.1:** For each hazard previously identified under 'normal' conditions, describe the events and impacts and identity all impacts by 'type' as per Table C (page 27). Use Worksheet A in Appendix 3 (at rear of Guidelines) to document the analysis.
- **Step 2.2:** For each impact, identify the 'level of impact' using Table D (pages 28 to 30).
- **Step 2.3:** For each event, identify the 'likelihood' using Table E (page 31).
- **Step 2.4:** Identify appropriate level of resources from Table F (page 32).
- **Step 2.5:** Repeat Steps 2.1 to 2.4 for abnormal conditions, and complete Worksheet B in Appendix 3.

- **Step 3: Monitoring Programme**

  Using results of risk analysis, develop monitoring programme – refer to Part 3 of Guidelines, beginning at Chapter 8.

4.4 Look-Up tables

Table A: Sources of Risk (Normal Conditions)

Key Word	Comment	Reference
Normal Constituents	Consider the risks created by the constituents expected to be in the waste stream (most probably chronic impacts)	Chapter 5 Section 5.2 Table 5.2
Volume Slug	Is the nature of the catchment such that sudden wastewater volume changes can occur?	Chapter 5 Section 5.2.1
Contaminant or Waste Slug	Is the nature of the catchment such that contaminant or waste slugs can or do occur?	Chapter 5 Table 5.3
Odour	Does the treatment process create odour that could be detected at or beyond the plant boundary?	Chapter 5 Table 5.3
Trade Waste (normal constituents)	Are there potential sources of trade waste that routinely discharge contaminants that will pass through the treatment process and cause chronic impacts of any kind?	Chapter 5 Table 5.2
Solids Disposal	Are there any issues or risks associated with sludge or other process-generated solids disposal?	Chapter 5 Section 5.3
Other Sources of Risk	Any other sources of risk under normal conditions	Chapter 5 Tables 5.2, 5.3

Table B: Sources of Risk (Abnormal Conditions and Gross Uncertainty)

Key Word	Comment	Reference
Process fault or upset conditions	Is the process potentially unreliable or could it become unstable? If so what would be the effect of changes to the effluent composition?	Chapter 5 Section 5.3 Table 5.4
Extreme weather related upset of process	Could the process be upset by extreme weather conditions? If so what would be the effect of changes to the effluent composition as well as the weather-related sensitivities of the receiving environment?	Chapter 5 Table 5.4
Trade Waste (abnormal constituents)	Are there any potential sources of trade waste that could lead to unintended contaminants passing through treatment process from time to time and cause acute impacts of any kind?	Chapter 5 Tables 5.2, 5.4
Toxic Shock/Slug (constituents that could cause an upset within process)	Are there industries or any other potential sources of waste that could lead to unintended contaminant load that could de-stabilise the treatment process? (acute impacts)	Chapter 5 Tables 5.2, 5.4
Is there a characteristic of the environment that may result in unusual sensitivity under specific unusual conditions	Some conditions or events not related to the discharge stream may result in unusual environmental sensitivity at times – e.g., low flows in streams.	Chapter 6 Section 6.4
Contaminant composition uncertainty	Is there materially significant uncertainty regarding the composition of the influent waste stream?	Chapter 5 Section 5.2
Uncertainty (volume)	Normal volume and seasonal profile not fully quantified	Chapter 5
Lack of environmental knowledge (uncertainty)	Is there significant uncertainty regarding the environmental impact from the discharge?	Chapter 6
Uncertainty (ecosystem dynamics)	Is there any uncertainty regarding the ecosystem dynamics?	Chapter 6
Other sources of risk	Any other sources of process related risk (see chapter text for identification methodology)?	Chapters 5, 6, 7

Table C: Type of Impact

Type of Impact	Example	Reference
Human Health and Safety	Pathogens or other health-affecting agent in zone of influence where people swim, undertake water sports, fish or collect shellfish, or where water is abstracted for drinking water. Reduced water clarity or slime build up on rocks that presents a potential hazard to bathers.	Chapter 6 Section 6.4
Ecology	Any species, communities, or ecosystems adversely affected by the waste stream.	Chapter 6
Community Value	Any cultural or social aspect impacted directly or indirectly by the waste stream.	Chapter 7
Economic Utility	Any current or anticipated economic use of the environment that is adversely impacted by the waste – e.g., downstream abstractions for water supply; commercial fishing	Chapter 7
Aesthetics	Any aesthetic impact caused by the waste or the physical effects of the waste stream.	Chapter 6 Section 6.4 Chapter 7
Odour	Any impact caused by unpleasant odour events outside the waste facility boundaries.	Chapter 5 Chapter 7

Table D1: Level of Impact (Human Health and Safety)

Level of Impact	Example	Designation
Highly Injurious	Illness anticipated in large numbers of people, some serious	A
Critical	Illness anticipated in the community	B
Major	Isolated illnesses anticipated; significant hazard to bathers from poor water clarity or slimes on substrates	C
Moderate	Precautions in place to protect the public (e.g., beach closures); possibility of hazard to bathers from poor water clarity or slimes on substrates	D
Slight	Concern leading to call for increased monitoring; compromised water clarity and/or evidence of slime build up on substrates	E
Insignificant	No measurable decrease in community well-being or effects on water clarity or slimes	F

Table D2: Level of Impact (Ecology)

Level of Impact	Example	Designation
Highly Injurious	Not applicable	X
Critical	Severe impact over wide area; medium to long term effects	B
Major	Severe impact over small area <u>or</u> moderate impact over large area; medium to long term effects	C
Moderate	Moderate impact over small area <u>or</u> minor impact over wide area; short term effects	D
Slight	Minor short term impact over small area	E
Insignificant	No discernible impact on any ecosystem or species	F

Table D3: Level of Impact (Community Value)

Level of Impact	Example	Designation
Highly Injurious	Not applicable	X
Critical	Concern at regional or national level.	B
Major	Intense concern from local community; some district-wide concern.	C
Moderate	Widespread local community/tangata whenua concern.	D
Slight	Minor concern from tangata whenua or special interest groups (e.g. Fish & Game)	E
Insignificant	Minor concern expressed by a few individuals only	F

Table D4: Level of Impact (Economic Utility)

Level of Impact	Example	Designation
Highly Injurious	Not applicable	X
Critical	Existing local uses of environment prevented for extended time periods	B
Major	Existing local uses of environment prevented for short periods	C
Moderate	Restrictions on local activities of environment	D
Slight	Advice issued of potential impact	E
Insignificant	No noticeable effect	F

Table D5: Level of Impact (Aesthetics)

Level of Impact	Example	Designation
Highly Injurious	Not applicable	X
Critical	Not applicable	X
Major	Obvious effect to large number of people	C
Moderate	Effect visible to casual observer; visible from public areas	D
Slight	Effect visible only when observed closely from a stationary position, or visible effect from little visited areas	E
Insignificant	Very limited visual effect	F

Table D6: Level of Impact (Odour)

Level of Impact	Example	Designation
Highly Injurious	Not applicable	X
Critical	Not applicable	X
Major	Offensive, objectionable odour in local community areas. Many complaints expected.	C
Moderate	Objectionable odour noticeable by community. Complaints expected from ‘reasonable’ people	D
Slight	Inoffensive odour in public areas. A few complaints possible	E
Insignificant	No odour beyond boundaries. No odour complaints would be expected	F

Table E: Likelihood Categories

Likelihood	Typical Frequency	Designation	Note
Continuous	Is expected to be the normal condition or diurnal in nature	I	Represent typically normal conditions
Frequent	Although not the normal condition – can be expected to be seen every few days or weeks	II	
Seasonal	Can be expect more than once per year	III	
Occasional	Expected to occur in some years	IV	Typically abnormal conditions
Possible	Conceivable during the life of the plant	V	

Table F: Appropriate Resources (applies to each type of impact).

Level of impact (refer Tables D1-6)	Likelihood (refer Table E)				
	I	**II**	**III**	**IV**	**V**
A	1	1	1	1	1
B	1	1	1	1	3
C	2	2	2	2	None
D	2	2	2	3	None
E	3	3	3	3	None
F	3	3	3	None	None
	Typically normal conditions			Typically abnormal conditions	

Key: 1 = Detailed management plan and employment of dedicated resources

2 = Standard monitoring regime appropriate to the type of hazard, within capacity of normal level of resources

3 = Incidental, implied from other monitored constituents or indicators

None = Monitoring not appropriate

CHAPTER 5
RISK ANALYSIS: CHARACTERISING THE DISCHARGE

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5.1 Introduction

This chapter assists the reader in characterising the wastewater discharge, as required in Step 1.1 in the HIAMP process (refer to Section 4.3). The discharge characterisation process is as follows:

- The untreated wastewater is characterised using Section 5.2 and Table 5.2.
- The efficiency and effectiveness of the wastewater treatment process is characterised, using Section 5.3 and Tables 5.3 and 5.4.
- By integrating the first two steps, the wastewater discharge to the receiving environment is characterised. This information is then used in Section 4.3 to assess the risk presented by the discharge.

The key points in the text are summarised at the rear of the chapter in the following:

Table 5.2 - untreated wastewater characteristics;

Table 5.3 - wastewater treatment plant performance – normal conditions; and

Table 5.4 - treatment plant performance – vulnerability to 'upset'.

The reader may choose to refer to these tables in the first instance, then refer to the chapter text for more detail.

The output from this chapter for use in Step 1.1 in the HIAMP process is the completion of Table 5.5 (page 47, at the end of the chapter). Table 5.5 helps the reader to build up and document the profile of the influent wastewater, the treatment process, and finally the effluent discharge. An example of how to fill in Table 5.5 is provided in Table 5.6.

5.2 Influent wastewater characterisation

5.2.1 Flow volume

Flow volume is an important factor in discharge characterisation. Generally, a large discharge has a higher risk of adverse environmental effects than a smaller discharge with the same contaminant concentrations into the same receiving environment. If available, good historic flow records should be used and be taken into account with the risk assessment. If flow records are not available, the following can be used as a guide for assessing flows.

Flow varies between communities, and is influenced by many factors. Flow volume varies over a typical day, and throughout any year depending on the type of dwelling, its occupants and their habits, and the influence of any industrial trade waste contributions. Several measures are important:

- Average dry weather flow (ADWF) which is the wastewater flow taken after three consecutive days without rainfall, or with rainfall less than one millimetre.
- Peaking factors are applied to the ADWF to obtain the peak daily flow (PDF).
- Peak wet weather flow (PWWF) – includes additional flow from stormwater cross-connections and groundwater infiltration.

Typical New Zealand values for ADWF are as follows:

140 - 180 L/person/day	-	on-site systems
270	-	community systems
150	-	summer holiday house
360	-	luxury home with modern conveniences

Peaks in daily flow occur mid to late morning and early evening. Peaking factors can be calculated by analysing community flow data. If there is no data, published values can be used (based on ADWF and connected population, ranging from 2 - 6).

Infiltration can occur even in new reticulation systems and can vary, depending on the season and local groundwater levels. Infiltration calculations are usually based on community area, with New Zealand values in the range 0.05 - 0.07 L/s/ha. Stormwater inflow depends on the number of connections from roof downpipes, manhole covers, yard drains and pipe cross connections. New Zealand values are generally in the range 0.15 - 0.19 L/s/ha, with 30% allowance for extreme conditions. Some older wastewater treatment plants (WWTPs) were designed for flows up to six times ADWF to accommodate large inflows from groundwater and stormwater.

The trade waste component of any wastewater will have a significant impact on the flow rate and volume depending on the type of industry and its size in relationship to the size of the community.

Certain trade wastes can produce high loadings of various constituents in wastewater, for example, industrial processes are responsible for 30 - 85% of metals in New Zealand municipal wastewaters (NZLTC, 2000). So the proportion of the wastewater that comes from trade and industrial sources (known as *trade waste*) is a significant factor when assessing and characterising any wastewater discharge.

5.2.2 Temperature

The temperature of wastewater in domestic sewage is slightly higher than the incoming water supply due to the addition of warm water. Depending on location, the mean annual temperature of wastewater varies from about 10 to 21^{o} C, with 15.6 ^{o}C taken as a representative value. The variation is greater in areas with high trade waste inputs due to hot inputs from cleaning and cooking and chilled water being added with some food processing industries.

5.2.3 pH

This is the concentration of hydrogen ions (H^+) in the wastewater, and measures how acidic or alkaline the wastewater is. If extreme pH is not adjusted prior to discharge, toxic effects can result such as salt precipitation or some compounds becoming more toxic (e.g. ammonia).

The average pH of New Zealand untreated wastewater pH is 7.5, depending on the contributing flows.

5.2.4 Suspended solids

High suspended solids (SS) levels can result in overloading of some treatment processes, and can also impact on receiving environments. Typical influent SS levels in New Zealand are in the range 50-800 g m^{-3} with an average of 300 g m^{-3}.

5.2.5 Biochemical oxygen demand (BOD)

This measures the oxygen required by micro-organisms to degrade organic matter, usually over five days (BOD_5). It is the most common measure of organic pollution.

BOD can be critical as it can cause organic enrichment, bacterial growths on aquatic surfaces and dissolved oxygen depletion. BOD is the preferred organic strength measurement in New Zealand. Typical influent BOD concentrations in New Zealand domestic wastewater range between 150 - 450 g m^{-3}, with an average value of 250 g m^{-3} (Hauber, 1995).

5.2.6 Fats, oils and greases

Fats and oils are contributed to domestic wastewater in butter, lard, margarine and vegetable oils and fats. Fats are also found in meats, parts of cereals, seeds, nuts, milk and certain fruits. Kerosene, lubricating and road oils also reach the sewers from garages, shops and car sale yards. Trade wastes with high levels are animal and dairy processing wastes. Fats, oil and grease are similar chemically. They are relatively stable compounds and are not easily decomposed by bacteria. Fats and greases can cause problems in both sewers and at the treatment plant. Trade wastes usually have stringent limits so that these are removed prior to the sewer.

5.2.7 Nutrients and ammonia

The main nutrients of interest in wastewater are nitrogen and phosphorus.

Nitrogen

Nitrogen is found in untreated wastewater mainly in two forms – ammoniacal (NH_4 and NH_3) (about 60%) and organic (about 40%) forms. High nitrogen levels in receiving surface waters can result in micro and macro-scale plant growth (algal blooms, excessive aquatic weed growth) and toxic effects on aquatic organisms.

Typical New Zealand untreated wastewater total nitrogen concentrations are in the range 7 - 60 g m^{-3}, with an average concentration of 35 g m^{-3} (Hauber, 1995).

Ammoniacal nitrogen is an important nitrogen compound. It exists in two forms, ionised (NH_4^+) and unionised (NH_3). The unionised form is toxic to aquatic organisms, in both fresh and marine waters. Receiving water pH and temperature both influence ammonia toxicity.

Phosphorus

Phosphorus (P) in wastewater comes from sources such as detergents and organic matter breakdown. It is found in inorganic and organic forms.

Elevated phosphorus in wastewater discharges can cause excessive plant growth in surface waters. Typical untreated wastewater total phosphorus (TP) concentrations in New Zealand are between 3.3 - 13 g m^{-3}, with an average concentration (across the WWTPs surveyed) of 7 g m^{-3} (Hauber 1995).

5.2.8 Cations and anions

Cations and anions found in wastewater include sodium, potassium, calcium and chloride. In general, these are not routinely monitored in New Zealand domestic wastewater, since they do not usually result in adverse environmental effects. In some cases, they may be monitored for specific reasons (e.g., ion build up in soils used for land disposal).

5.2.9 Pathogens

Many different micro-organisms are found in untreated wastewater, including bacteria, viruses, helminths and protozoa. Many of these are relied on in WWTPs for biological wastewater treatment. Disease causing micro-organisms are called pathogens.

Pathogenic bacteria found in wastewater include *Yersinia*, *Shigella* (bacterial dysentery), *Vibrio* (cholera), *Salmonella* (typhoid) and *Escherichia*. Most enteric bacteria die off quickly outside the gut, but some can persist in water or soil.

Viruses found in wastewater include enteroviruses, rotaviruses and hepatitis. Most viruses do not survive well outside their host and numbers decrease rapidly, depending on the treatment method used.

Helminths include threadworms, nematodes (roundworms, hookworms), cestodes (tapeworms) and trematodes (flukes). These organisms are parasitic, and can be easily passed on through wastewater. Eggs and larvae are stable in soil environments and can be viable for a long time. Helminths from wastewater discharges are not normally a risk to receiving environments in New Zealand.

Protozoa found in wastewater include *Giardia* and *Cryptosporidium*, which can cause disease. These organisms are difficult to remove from wastewater, as their reproductive cysts and oocysts are able to pass through most treatment processes, although recent developments in ultra violet light treatment are addressing this problem. Protozoa are able to persist on vegetation (via applied wastewater) for a short period and can survive for days in soil. Some protozoa can survive for several months in water, particularly intermediate stages (like *Giardia* cysts).

Human infection potential determines the required treatment level for pathogen removal. If a wastewater with a high pathogen level is discharged, health effects can occur in people contacting with the discharge, either water-borne (swimming, drinking, eating shellfish or plants growing in the water) or land (direct contact with wet surfaces, aerosols from irrigation being ingested).

Bacterial indicators that are usually used for wastewater in New Zealand are *E. coli*, faecal coliforms and enterococci. Values in untreated wastewater for the selected organisms are shown in Table 5.1.

Table 5.1: Typical range for selected micro-organisms in untreated wastewater (number/100 mL). From Metcalfe and Eddy (1991).

Organism	Faecal Coliforms	Enterococci	*Giardia* cysts	*Cryptosporidium* oocysts	Helminth ova	Enteric Viruses
Range of Values	10^6-10^7	10^4-10^5	10^1-10^5	10^1-10^3	1-10^3	10^3-10^4

5.2.10 Heavy metals

High levels of heavy metals can be toxic to biota and people. There are also several metalloid compounds (like aluminium, boron and arsenic) which have similar properties and effects. Metal solubility is generally low and is influenced by pH (as pH increases, solubility decreases).

Industrial trade waste sources contribute a large proportion of metals and metalloids in New Zealand wastewater. Industry-specific metals and metalloids include chromium (tanning), arsenic, copper, zinc/ nickel (metal plating), aluminium (metal smelting) and boron.

Metals contributed from domestic sources come from water treatment, detergents, soap, cosmetics, household dust, medicines, toilet paper and pipework (copper). Metal concentrations from domestic sources are usually low compared to industrial sources and generally do not pose significant environmental effects. However, in some systems (such as low flows and older pipes), household sources cannot be completely ruled out as contaminant mass loading is concentration and flow dependent.

5.2.11 Persistent organic pollutants (POPs)

Persistent organic pollutants (POPs) are defined as organic substances that are persistent and possess toxic characteristics. There is a wide range of compounds that fall into this category, including phenols, chlorinated hydrocarbons (DDT, PCP, PCBs), pesticides and herbicides (2,4,5T; 2,4D), PAHs (polycyclic aromatic hydrocarbons), large organic molecules and BTEX (benzene, toluene, ethylbenzene, xylenes). Concentrations should be below levels of concern unless there is a significant point-source discharge into the sewerage system, e.g., from a primary industry such as a woolscour.

5.2.12 Characterising the influent wastewater

Table 5.2 provides a comparative guide to the levels of common constituents in New Zealand wastewater, for domestic and typical industrial wastewater components. An indicative assessment of the relevant characteristics of a wastewater can be made using this table, taking into account both domestic and industrial components.

More specific information is difficult to provide, given the wide variability of New Zealand wastewaters. Where possible, monitoring records should be used to assess the potential hazard for the wastewater constituents. Alternatively, screening sample analyses should be carried out to better assess the influent wastewater characteristics, the results of which can be compared to the values in Section 5.2.

At this stage, the reader should be able to fill in the first two columns in Table 5.5. An example of how to use Table 5.5 is provided in Table 5.6.

The reader should also make notes on the possible large changes to the wastewater characteristics under 'abnormal' conditions. For example, certain industrial practices might lead to occasional peaks in toxic elements being discharged to the sewer. Obviously this requires a degree of judgement, based on past experience. Further examples of abnormal conditions are given in Table B in Chapter 4.

5.3 Treatment processes

The treatment processes described below are divided into primary, secondary and tertiary treatment components for convenience. There can be debate over whether a treatment process should be considered secondary or tertiary, or a combination of the two. The divisions used below are not definitive.

5.3.1 Primary treatment

These are physical unit operations to remove large solids and floatable material. Typical unit processes include:

- Screening and grit removal - usually the first process at a WWTP. Removing large particles will prevent blockages downstream.
- Sedimentation – used to remove further larger particles as settled sludge. Sedimentation can also remove some heavy metals and POPs (persistent organic pollutants) which adsorb onto the settled particulate matter and are removed with the sludge.
- Further improvements include using chemical additives to improve solids removal and to precipitate out heavy metals (the Advanced Primary Treatment system).

5.3.2 Secondary treatment

There are two types of secondary processes: aerobic and anaerobic. Within each category, there are suspended growth and attached growth processes. In New Zealand, aerobic processes used are:

- Suspended growth: activated sludge (AS), high-rate activated sludge (HRAS), pond systems (aerated and passive), sequencing batch reactors (SBRs), and advanced integrated pond systems.
- Fixed growth: trickling filters, rotating biological contactors, packed bed reactors.

In New Zealand, anaerobic processes in use are:

- Suspended growth: pond systems, sludge digestion, upflow anaerobic sludge blanket reactors.
- Fixed growth: anaerobic filters, expanded bed reactors.

For specific details on how each of the treatment processes operate, refer to relevant literature (e.g., Metcalf and Eddy (1990); NZLTC (2000)).

Common suspended growth aerobic systems

Activated sludge (AS)

Bacteria are kept in suspension in wastewater via aeration for a set time inside a tank. Excess cells are settled out in a separate clarifier unit.

BOD and SS removal rates are good, but limited nutrient removal occurs. Pathogen removal is poor. Heavy metal removal is moderate, through adsorption and settling as per primary treatment. POPs and hydrocarbons removal is low to moderate by bio-oxidation, air stripping and floc adsorption (providing the concentration of POPs is not lethal to the treating microbes).

AS systems can have problems handling volume slug loads, due to insufficient freeboard or volume available. Toxic slugs can cause biomass die off within the activated sludge tank, with a consequent large sludge volume increase and possible overloading of the clarifier unit. Toxic slugs can also result in excess growth of filamentous organisms, causing ‘bulking’ of the reactor contents and reducing settle ability in the clarifier.

There are several variations of AS possible. High Rate Activated Sludge (HRAS) involves higher loadings with a shorter retention time and some solids recycle. Extended Aeration (EA) uses a longer retention time, with high levels of oxygen being diffused into the wastewater.

Another variation is the Sequencing Batch Reactor (SBR). This variant of AS involves the same processes, but they occur sequentially within the same tank. All SBRs have a five step operating sequence, and sludge wasting occurs to improve performance. Well designed and operated SBRs can substantially reduce nitrogen and phosphorus concentrations.

Pond systems

These use the action of bacteria, algae and climate (sun, wind) to reduce organic and pathogenic loading. Ponds can be aerobic (shallow, oxygenated) or facultative (medium depth, areas of high and low oxygenation).

Pond systems usually have multiple ponds in series or parallel, to improve treatment. Ponds (especially two pond systems) are a very common wastewater treatment process.

BOD and SS removal rates are reasonable, but limited nutrient and ammonia removal occurs. Pathogen removal in conventional pond systems is relatively good, due to microbial predation and the action of UV light (in sunlight). Ponds provide flow buffering, which means their response to sudden volume slugs is good. Toxic slugs may result in the killing of pond microbial populations which will reduce treatment and disinfection performance. Adding internal rock filters and baffles can improve performance by removing suspended solids and promoting better mixing. Additional aeration can be provided via mechanical aerators to increase dissolved oxygen.

Heavy metal removal is moderate, primarily through adsorption and settling. POPs and hydrocarbons removal will be low.

A recent development has been the Advanced Integrated Ponds (AIPS) concept. It uses several ponds, the first being an advanced facultative pond which reduces the organic loading of the wastewater. The next pond is a ‘high rate’ algal pond, which is shallow and paddlewheel-mixed. It promotes algal cell growth to take up nutrients. An algal settling pond is then used, to harvest algal cells (and hence nutrients). Final maturation ponds are used to disinfect the wastewater before discharge. BOD, SS, pathogen and nutrient removal (particularly nitrogen) are good for this system.

Common fixed growth aerobic systems

Trickling filter

This system consists of a tank filled with media (covered in a microbial biofilm), over which the wastewater trickles. The biofilm takes up nutrients and organic matter from the passing wastewater flow. Collected percolate flows into a clarifier to settle out sloughed biofilm before being discharged.

Trickling filters are good at removing BOD and SS. Nutrient removal is poor to moderate, with limited ability to remove ammoniacal nitrogen and phosphorus. Pathogen removal is generally not high. Trickling filters deal poorly with toxic slugs, which can kill micro-organisms in the biofilm layer and cause excessive sloughing (heavily loading the clarifier unit). Volume slugs can be dealt with reasonably well, but high shear velocities can also result in biofilm sloughing and overloading of the clarifier unit.

Heavy metal removal is low to moderate, primarily through adsorption and settling. POPs and hydrocarbons removal will be low.

Performance can be improved by recycling some of the sloughed biofilm into the inflow (*solids contact* process), which improves organics and nutrient removal.

5.3.3 Tertiary treatment

These processes involve wastewater polishing and/or disinfection from secondary treatment processes.

Wetlands

Constructed wetlands can be used as secondary or tertiary treatment units. They are an established treatment technology in New Zealand. There are two types:

Surface flow (SF)

Semi-aquatic/aquatic plants grow in a soil or gravel media base with the wastewater passing through in a free manner, with open water areas. The plants filter out solids and remove nutrients. Biofilms growing on the media and the plants also remove organic compounds and nutrients.

SF wetlands remove BOD and SS well, but have limited ability to remove nitrogen. Pathogen removal is moderate to good (due to the action of UV in sunlight, and predation). Toxic slug handling is not good, with possible plant and microbial death occurring. Heavy metal removal is low to moderate, primarily through adsorption and filtering/settling. POPs and hydrocarbons removal will be low.

Sub-surface flow (SSF)

Semi-aquatic plants grow in a gravel media base and the wastewater flows through the media and plant roots without reaching the surface.

BOD and SS removal in SSF wetlands is good. Nitrogen removal is average. Phosphorus removal depends on the media's adsorption properties, which can decrease over time. Volume slugs are handled moderately, as excess flow may break through and pond on the media surface. Toxic slug handling is not good, as the microbial population in the media and the plants can be killed, reducing treatment levels. Influent SS needs to be low to avoid clogging the media bed. Heavy metal removal is moderate through adsorption and filtering/settling.

The performance of both SF and SSF wetlands is dependent on the level of pre-treatment prior to discharge into the wetlands. Wetlands generally perform well when located downstream from a well designed and maintained oxidation pond system.

Overland flow (OLF)

Pre-treated wastewater is distributed across the upper portions of graded, vegetated slopes and allowed to flow over the surface to collection drains at the slope bottom.

BOD and SS removal is relatively good. Pathogen removal is good, primarily due to the action of UV light in sunlight. Nutrient removal is good, due to uptake by vegetation and absorption by the soil, although performance can reduce over time. Volume slugs are poorly handled, as excess flow will move quickly downslope, and will result in reduced removal of contaminants, particularly SS. Some shearing of slope material can also occur. Toxic slugs will also be poorly handled, as die-off of vegetation can occur.

Heavy metal removal is good through adsorption and filtration in the soil.

The performance of overland flow systems is highly dependent on good design and operation/maintenance. If there is insufficient contact time with the soil surface, wastewater treatment can be negligible.

Slow rate land treatment systems

Pre-treated wastewater is applied via sprinklers or drip irrigation onto land, which is vegetated. The applied wastewater either percolates through the soil or is taken up via plants. Treatment occurs as the wastewater passes through the soil.

BOD and SS removals are good. Nutrient removal is generally good, due to soil absorption and plant uptake, but can vary depending on soil type and whether the plant crop is harvested to remove nutrients from the site. Pathogen removal is relatively good, as most pathogens are retained and die off within the soil profile, depending on the soil type. Volume slugs are handled poorly, as the sprinklers can only deliver a set amount, resulting in backing up through the system. Toxic slugs are also handled poorly as this may cause vegetation die-off and microbial die-off within the soil in the disposal area. Heavy metal removal is good, through adsorption and filtration in the soil.

Rapid infiltration land treatment systems (RI)

Pre-treated wastewater is applied intermittently, at high volume loadings, to shallow basins. Applied wastewater percolates through the soil profile where treatment occurs.

BOD and SS removal is generally good. Pathogen removal can be good if pathogens are retained within the soil profile, but this depends on the soil type, loading rate and depth of unsaturated soil (i.e., distance to the water table). Nutrient removal will generally be moderate, due to soil absorption and microbial action, but can vary depending on soil type. Nutrient (especially phosphorus) removal generally reduces over time. Volume slugs can be handled depending on freeboard available in the basins. Toxic loadings may cause microbial populations present in the soil profile to be killed, reducing treatment effectiveness.

Heavy metal removal is moderate to good, through adsorption and filtration in the soil, but this can decrease over time. POPs and hydrocarbons removal will generally be low through bio-oxidation (providing the concentration of POPs is not fatal for the treating microbes).

RI system treatment is generally less effective than that of slow rate systems.

Disinfection

Chlorination

Chlorine compounds have good kill rates for some micro-organisms during and after application (due to a chlorine residual forming). It is effective against most bacteria, but is less effective against viruses and protozoa.

Chlorine-based compounds can interact with organic material present in the wastewater to form trihalomethanes (THMs) and other organic chlorines, which are toxic.

Ultraviolet light (UV)

UV light is used to disinfect wastewater, by exposing wastewater to UV light from an array of quartz light tubes. The UV light penetrates the bacterial cell wall and kills the cell or disrupts its DNA. Newer UV systems are effective against all pathogens, including viruses and protozoa, but older systems are less effective against viruses and protozoa. It has no residual effect, and some bacteria can repair the UV-induced damage, although newer systems are becoming more effective in avoiding this problem. A high clarity wastewater is required, although the UV is effective in lower clarity wastewater when the suspended solids are mainly algal cells (e.g., pond discharges). Significant advances have been made with UV in recent years, and UV is becoming an accepted wastewater disinfection method in New Zealand.

Ozone

Ozone gas is passed through the wastewater inside a tall contact tank. The bacteria are killed by cell wall disintegration. Ozone can produce toxic residuals but these are very short-lived, dissipating rapidly. Ozone is effective against bacteria, protozoa and viruses. Ozone is not commonly used in New Zealand.

5.3.4 Characterising the treatment system

Tables 5.3 and 5.4 summarise process unit removals for typical constituents and performance of process units under abnormal conditions. A general characterisation of the overall treatment plant can be made from the information contained in the two tables.

When characterising the performance of a treatment system, the operation of the treatment units in combination must be considered. For example, a well designed UV disinfection system will still produce an effluent with high pathogen levels if there is not sufficient pre-treatment to reduce SS concentrations to acceptable levels.

At this stage, the reader should be able to fill in the columns in Table 5.5 that relate to the treatment process units. An example of how to use these tables is provided in Table 5.6. The reader should also make notes on the vulnerability of the plant to 'upset' conditions, i.e., under abnormal conditions. These notes can be drawn on in the HIAMP process in Chapter 4.

5.4 Characterising the discharge

To characterise the discharge, the outcomes of Sections 5.2 (untreated wastewater characterisation) and 5.3 (treatment plant characterisation) need to be integrated. This can be done by completing Table 5.5. This will result in a 'low', 'medium' or 'high' potential hazard rating for each of the constituents in the discharge. An example of how to complete the table is provided in Table 5.6.

Table 5.5 should be seen as a guide only. It may be necessary to modify the table, depending on the situation. In particular, it may be necessary to add further wastewater constituents to the table – for example, if POPs or hydrogen sulphide are considered to be important wastewater constituents.

Note that if monitoring records are available for the effluent discharge, these should be used to assist with the discharge characterisation. Care will be required in the interpretation of these records if modifications to the treatment plant are planned.

Once Table 5.5 is completed (complete with the notes made on abnormal conditions – refer to Sections 5.2.12 and 5.3.4), Step 1.1 in the risk analysis process in Chapter 4 is completed.

Table 5.2: Typical influent concentrations or values in wastewater (guide only – use monitoring data if possible)

Constituent	Wastewater Source						
		Additional Industrial					
	Domestic (without significant trade wastes)	**Food Production/ Processing**	**Meat Processing**	**Tanning/Hide Processing**	**Metalworking**	**Dairy Processing**	**Animal By-Products Processing**
Temperature	L	L-H	L-M	M-H	L-H	L-M	M-H
pH	M	L-H(process dependent)	M	M	L-H	M-H (process dependent)	L-M (process dependent)
BOD	M	H	H	M-H	L	H	H
Suspended Solids	M	H	H	M-H	L	H	H
Fats, Oil and Grease, floatables	M	M-H	H	M	L-M	H	H
Nutrients -nitrogen -phosphorus	 M M	 M-H M	 H M-H	 L-M L-M	 L L	 M-H L-M	 M-H M-H
Ammonia	M	M	H	L-H	L	M	M-H
Pathogens	H	L-M	H	L	L	L-M	M-H
Heavy metals	L (depends on industry in catchment)	L	L	L-H	H	L	L
Specific compounds of note	Pathogens	BOD, SS, pH	BOD, SS, Fats Oil and Grease	Chromium	Cyanide, nickel, zinc, copper, chromium	Fats, Oil and Grease, BOD, SS	BOD, SS, Fats, Oil and Grease

Note: H = High concentration or hazard potential; M = Medium concentration or hazard potential; L = Low concentration or hazard potential

Table 5.3: Process unit performance – normal operation (guide only – apply relevant experience where possible)

Constituent to be removed	Primary Treatment		Secondary Treatment						Tertiary Treatment			Disinfection		
	Screen	Sediment	AS	HRAS	TF	Ponds	AIPS	SBR	Wetlands	OLF/SR	RI	UV	Cl	Ozone
Temperature balancing	-	P-A	P	P	A	A-G	A-G	P	A-G	A-G	A-G	-	-	-
pH balancing	-	P	P	P	A	A-G	A-G	P	A-G	A-G	A-G	-	-	-
BOD	P	A	G	G	A	A	G	A	G	A-G	A	-	-	-
SS	P	A	G	A	A	A	G	A	G	A-G	A	-	-	-
F, O & G	P	P-A	A	A	A	P-A	A	A	A-G	A-G	G	-	-	-
Nutrients														
- Nitrogen	P	P	P	P	P-A	P-A	A	A	A	A	P	-	-	-
- Phosphorus	P	P	P	P	P	P-A	A	A	P-A	A	P	-	-	-
Ammonia	P	P	P	P	P	P-A	A	A	P-A	A	P	-	-	-
Pathogens	P	P-A	P	A	A	A-G	A-G	A	A	A-G	A	A-G*	A*	A-G*
Heavy metals	P	A	A	A	P-A	A	A	A	A	A	A-G	-	-	-
Odour generation	Y	Y	N – when well maintained	N – when well maintained	Y – unless covered + extracted	Y	N – when well maintained	N – when well maintained	Y	N – when well maintained	N – when well maintained	-	-	-

Abbreviations

Screen	**Screening**	**Sediment**	**Sedimentation**
AS	Activated sludge	HRAS	High rate activated sludge
TF	Trickling filter	AIPS	Advanced integrated pond systems
SBR	Sequencing batch reactor	OLF	Overland flow
SR	Slow rate system	RI	Rapid infiltration
UV	Ultraviolet disinfection	Cl	Chlorine

Removal Rating (Performance):

G	Good removal	A	Average removal
P	Poor removal		

Odour Generation Rating:

Y	Yes	N	No

* Disinfection capability dependent on removal capability of treatment units prior to disinfection process.

Table 5.4: Process unit performance – vulnerability to 'upset' conditions (guide only – apply relevant experience where possible)

Condition	Primary Treatment		Secondary Treatment						Tertiary Treatment			Disinfection		
	Screen	**Sediment**	**AS**	**HRAS**	**TF**	**Ponds**	**AIPS**	**SBR**	**Wetlands**	**OLF/SR**	**RI**	**UV**	**Cl**	**Ozone**
Handles process upset change?	A	A	P-A	P-A	P	A	P-A	A	P-A	A	A	-	-	-
Handles sudden volume changes?	A	A	A	A	A	A*	A	P	A*	A	A*	-	-	-
Handles toxic shock/slug?	A	A	P-A	P-A	P	P-A	P-A	P	P-A	P-A	A	-	-	-
Reliability	A	A	P-A	A	A	A	A	A	A	A	A	A	A	A
Ease of operation?	G	A-G	A	A	A	G	A	A	A	A	A	A	A	A

Abbreviations:

Screen	**Screening**	**Sediment**	**Sedimentation**
AS	Activated sludge	HRAS	High rate activated sludge
TF	Trickling filter	AIPS	Advanced integrated pond systems
SBR	Sequencing batch reactor	OLF	Overland flow
SR	Slow rate system	RI	Rapid infiltration
UV	Ultraviolet disinfection	Cl	Chlorine

Performance Rating (reliability and/or 'robustness')

G	Good	A	Average
P	Poor		

* Dependent on the amount of freeboard available within the treatment unit(s).

Table 5.5: Discharge characterisation sheet. Fill this sheet in for Step 1.1 in risk analysis in Chapter 4. See also example in Table 5.6. Add other constituents and make other adaptions to this table if required.

Wastewater sources: ……………………………………………………………

Flow (best estimate): **ADWF:**……………………………… **PWWF:**………………………………..

Constituent	**Influent characteristics**		**Treatment plant process unit performance, normal operation (give rating of P, A or G for each unit for each constituent, from Tables 5.3 & 5.4)**					**Known data on w/w effluent (Note 1)**	**Assessed hazard potential of discharge constituent (give rating of L, M or H) (Note 2)**
	Known data on influent w/w (Note 1)	**Influent characteristic rating (L, M or H – from Table 5.2)**							
Temperature									
pH									
BOD, COD									
Suspended solids									
Fats, oil & grease, floatables									
Nutrients -nitrogen -phosphorus									
Ammonia									
Pathogens (indicators)									
Heavy metals									
Odour									

Note 1: Enter any known data, e.g., mean and 95 %ile concentrations, daily loads, etc. Refer to another sheet if necessary.

Note 2: Assess the characteristics of the discharge (final column) by combining the influent characteristic rating with the treatment process unit ratings. The L, M & H ratings in the final column should represent the assessed potential hazard rating of each discharge constituent. Known data on the effluent discharge (penultimate column) should be taken into account if this is available. L = low potential hazard, M = medium potential hazard, H = high potential hazard (refer to Tables 5.2 to 5.4).

Table 5.6: Discharge characterisation sheet (EXAMPLE. Note that more detail than shown below would be desirable.)

Wastewater sources: **Smallville (population 5,000). Light industry, including electroplating shop.**

Flow (best estimate): **ADWF:……………………………… PWWF:………………………………..**

Constituent	**Influent characteristics**		**Treatment plant process unit performance, normal operation (give rating of P, A or G for each unit for each constituent)**					**Known data on w/w effluent (Note 1)**	**Assessed hazard potential of discharge constituent (give rating of L, M or H)**
	Known data on influent w/w (Note 1)	**Influent characteristic rating (L, M or H)**	**Two-stage oxidation pond**	**Surface flow wetland**					
Temperature		L	A	A					L
pH		M	A	A					L
BOD, COD		M	A	A					L
Suspended solids		M	A	G					L
Fats, oil & grease, floatables		M	A	A					L
Nutrients									
-nitrogen		M	P	A					L
-phosphorus		M	P	P					M
Ammonia		M	P	P					M
Pathogens (indicators)		G	A	A					L-M (variable)
Heavy metals									M (considerable

(mainly zinc)		G	A	A					uncertainty)
Odour		M	Y	Y					M

CHAPTER 6
RISK ANALYSIS: CHARACTERISING THE RECEIVING ENVIRONMENT

Paul Barter, Barry Robertson (Cawthron Institute)

6.1 Introduction

The purpose of this chapter is to assist the reader with characterising the receiving environment, as required in Step 1.2 in the risk analysis process (refer to Section 4.3.1). The key points are summarised in Table 6.2 (page 54), with a worked example in Table 6.3.

Classification of the receiving environment is a fundamental step in the HIAMP process. Since the receiving environment represents the final step in any wastewater treatment and discharge process, the way in which an effluent is incorporated into the receiving environment is of critical importance in determining the extent and degree of adverse effects to that environment. Receiving environment classification can take many forms and can be very complex or very general, depending on the desired outcome. For example, physical factors such as climate, geography and biology are often used to 'ecotype' an environment, but social and cultural values are also important and might be incorporated under certain circumstances. In general, characterisation of the receiving environment allows for the creation of groups, or types of environments, which will react in a different fashion when exposed to a wastewater discharge. For the purposes of these Guidelines, receiving environment classification will focus solely on physical, chemical and biological factors and will not try to fully incorporate social and cultural aspects, as these are covered separately in Chapter 7.

Receiving environment characterisation has been divided into two primary categories: (i) type of environment (*e.g.,* lake, estuary etc.) and (ii) characteristics within each environment that affect the extent to which wastewater components will be assimilated (called 'assimilative capacity'). The types of environment have been deliberately modelled after the ecosystem classifications used in the recent ANZECC guidelines (ANZECC 2000a) and reflect the broad categories of different receiving environments (i.e., Water, Soil, Air). Within each of these broad categories are additional divisions (e.g., lakes, rivers, estuaries), which reflect easily discernible differences in the individual category.

The characteristics of each of these receiving environment types (e.g*.,* substrate, ecology etc.) are used to derive which constituents of the wastewater (e.g., pH, nutrients, etc.) are most important for consideration in the risk assessment (HIAMP) process in Chapter 4, and during the design of the monitoring programme.

In this chapter, the broad categories that make up each of the types of receiving environments will be discussed first with some guidance on how the categories are defined.

From this, the wastewater and receiving environment components that may present a hazard (e.g., nutrients, odour, flow etc) are outlined in a matrix against the types of environments to help the reader short-list which factors have the highest priority (see section 6.4.1). From this, the applicable constituents can be compared against the primary factors affecting assimilative capacity and sensitivity for the particular receiving environment. The output from this table can then be used to generate a list for inclusion in the HIAMP model.

6.2 Types of receiving environments

6.2.1 Water

Surface waters are the primary receiving environment for almost all wastewater discharges in New Zealand (Table 6.1). As such, the focus of the guidelines and particularly this chapter will be on surface waters, with far less emphasis placed on air and soil discharges, although these will be addressed.

Table 6.1: Summary of wastewater plants and flow into different receiving environments in New Zealand (from Macdonald et al. 2001).

Receiving Environment	Number of Wastewater Plants		Average Daily Flow	
	Count	(%)	Sum	(%)
Freshwater				
<50% of stream/river flow	133	47.00	159,198	21.26
>50% of stream/river flow	14	4.95	12,787	1.71
Lake	4	1.41	2,868	0.38
Marine				
Estuarine	7	2.47	146,487	19.57
Harbour	13	4.59	10,314	1.38
Shoreline	6	2.12	8,587	1.15
Off-shore outfall	29	10.25	325,289	43.45
Land & other				
Total flow to land	59	20.85	46,716	6.24
Land, excess flow to surface water	17	6.01	35,553	4.75
Piped to another plant	1	0.35	888	0.12
Total	283	100	748,687	100

Table 6.1 shows that almost two-thirds (65.5%) of the average daily volume of wastewater in New Zealand is discharged to a marine receiving environment. The majority of the remainder is discharged to a freshwater environment (23.4%), while only 6% is discharged entirely to land.

However, when comparing numbers of wastewater plants producing these volumes, the proportions are very different, with roughly half (53%) of the total WWTPs discharging to a freshwater environment while roughly 20% of the WWTPs discharge to a marine environment. This distribution demonstrates that the freshwater discharges tend to be from smaller plants, while the marine discharges are from much larger facilities. This ratio is not unexpected, given that most of the major urban centres are situated on the coast.

Freshwater

The freshwater receiving environments have been divided into four main categories (refer to Figure 6.1):

(i) Lakes & Reservoirs.

(ii) Rivers/streams where wastewater input is <50% of normal base flow.

(iii) Rivers/streams where wastewater input is >50% of normal base flow.

(iv) Groundwater.

These categories are fairly self-explanatory and will not be discussed in detail. There are numerous references that cover the hydrology of New Zealand (e.g., Mosley 1992, Viner 1987 etc.) for those interested in obtaining more detail. There is also a reasonable summary of New Zealand's freshwater environments in Appendix 2, Volume 2 of the ANZECC (2000a) guidelines.

The majority of existing discharges to freshwater in New Zealand are to rivers or streams where the wastewater input represents less than 50% of the normal base flow (Table 6.1).

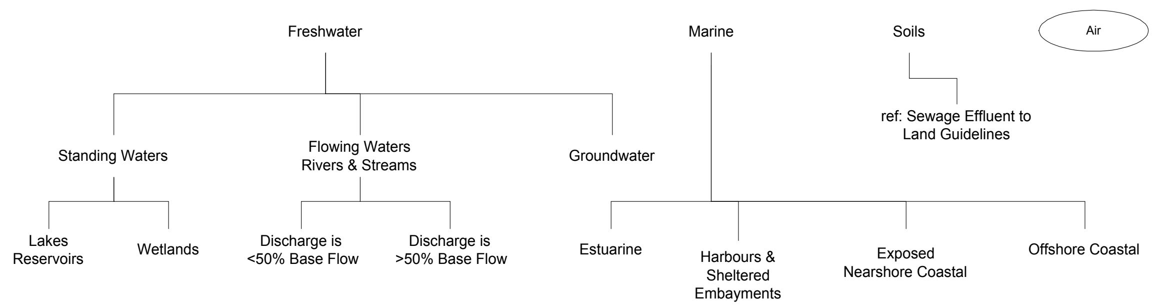

Figure 6.1: Receiving Environment Categories.

Marine waters

The marine receiving environments have been divided into four main categories:

(i) Estuarine.

(ii) Harbours and Sheltered enclosed embayments.

(ii) Exposed Nearshore Coastal (shoreline).

(iii) Exposed Offshore coastal.

As was the case with freshwater, these categories are self-explanatory and will not be discussed in detail. Unlike the freshwater environments in New Zealand, general texts on the coastal waters are not readily available and tend to be more specific to individual disciplines. For example, physical oceanography (Heath 1985), ecology (Morton & Miller 1968; Jones 1983), fish life (Francis 1988; Doak 1984), botany (Adams 1994), etc. There is also a cursory summary of the New Zealand coastal environment in Appendix 2 (Volume 2) of the new ANZECC guidelines.

Many people view ports and harbours as analogous to nearshore coastal. However, ports and harbours differ from coastal environments in that they are generally subject to a lesser amount of mixing and dispersion, which is a fundamental component of receiving environment characterisation.

6.2.2 Soil

Like water, the soil environment that receives wastewater discharges can be divided into various categories based on such parameters as soil type, existing land uses, proximity to ground and surface waters, size of site, slope and various physical and chemical parameters. Although this chapter includes soil as a receiving environment, the primary purpose is to offer guidance on discharges to surface waters, since the guidelines for disposal of sewage onto land (NZLTC 2000) address the soil receiving environment. The land disposal guidelines include sections on wastewater characteristics, site selection, soil treatment processes, environmental effects, application methods, and crop selection. If soil disposal is a primary component of the wastewater discharge scenario being evaluated, it is recommended that these other guidelines be used in conjunction with these wastewater monitoring guidelines.

6.2.3 Air

In a similar vein to water and soil, the air environment receiving secondary emissions from a wastewater plant can be divided into categories based on such parameters as land use, meteorology and topography. However, because air emission problems (particularly odours) can arise in most, if not all, of the different air environments (e.g., low or high wind velocities) air is considered as a single category in this chapter. In many areas air emissions are a major concern for environmental assessment, particularly in relation to odour. Pathogens contained in discharged aerosols can also be of concern. Generally, however, the isolation from most public activity and the short distances travelled by most aerosols makes all but odour issues insignificant.

6.3 Receiving environment hazard identification

In order to develop the list of hazards needed for the HIAMP framework, the following section uses a two-part approach to narrow down the possible wastewater constituents that are of concern. The process is set out in Table 6.2, with an example provided in Table 6.3. The process for filling in Table 6.2 is as follows:

1. From the first part of the table, select the relevant receiving environment and tick the shaded boxes for this receiving environment.

2. For each characteristic (i.e., Dilution, Substrate etc) in the second half of the Table, cross out the descriptions that don't apply (i.e., if Dilution is poor, cross out 'moderate' and 'excellent').

3. For each characteristic (i.e., Dilution, Substrate etc) tick the shaded boxes relating to the description not crossed out.

4. Bring the ticks down to the row titled 'Include in HIAMP' to identify which issues should be identified in the worksheet in Appendix 3.

By selecting a particular receiving environment in the first half of Table 6.2, the list of constituents will be shortened (see estuary example, Table 6.3). For example, pH will never be an issue for a wastewater discharge into the marine environment. This shortened list is then transferred to the second part of the table where each of these constituents is compared against the assimilative characteristics and sensitivity for that particular environment. From this second table, the list of hazards for the HIAMP model may be further reduced. However, any hazard checked in the bottom half of the table should be added to the HIAMP worksheet.

On completion, this process will result in a list of general wastewater constituents that may be of concern for the given receiving environment and will therefore need to be considered in the development of a monitoring programme. These general categories of constituents will, in many cases, need to be refined to fit a targeted monitoring programme. For example, the wastewater characterisation (Chapter 5) may identify specific toxic compounds or nutrients to address. If a complete list of target metals is identified when the discharge is characterised, this list should be used in place of the more generic 'Toxic compounds' when filling in the HIAMP worksheet(s). On the other hand, if pH is highlighted as a factor in the discharge characterisation in Chapter 5, but the receiving environment is a marine outfall, there is no rationale for including it in the HIAMP worksheet as an ecosystem risk.

Table 6.2: Receiving environments, constituents of concern, and assimilative capacity. Shaded boxes = potentially of concern. Refer to Section 6.4 for explanation of assimilative capacity terms.

Receiving Environment	Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Lake/Reservoir		-	-							
River/ Stream (>50% base flow)										
River/ Stream (<50% base flow)			-	-						
Estuary	-		-							
Harbours & Sheltered Embayments	-		-							
Nearshore Marine (shoreline)	-	-	-		-					
Offshore Marine	-	-	-		-					
Groundwater	-			-						
Air	-	-	-	-		-	-	-	-	
Soils		-		-		-	-			

Assimilative Capacity/Sensitivity Of		Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Dilution	Poor										
	Moderate	-	-	-							
	Excellent	-	-	-	-	-	-	-	-	-	-
Substrate (s)	Mud	-		-		-	-	-			
	Sand	-	-	-		-	-	-			-
	Rock	-	-	-		-	-	-	-	-	-
Enrichment status	Unenriched	-		-			-	-		-	-
	Mod Enrichment	-		-			-	-		-	-
	Enriched	-	-	-	-	-	-	-		-	-
Sensitivity of Ecological Values	High					-	-	-			-
	Moderate	-				-	-	-			-
	Low	-	-	-	-	-	-	-	-	-	-
Significant other Inputs	Yes										
	No	-	-	-	-	-	-	-	-	-	-
Aesthetics	Important	-	-	-					-	-	-
	Not so Important	-	-	-	-	-	-	-	-	-	-
Contact Recreation	Yes	-	-	-					-	-	
	No	-	-	-	-	-	-	-	-	-	-
Water Supply (Economic Utility)	Drinking	-	-		-						
	Irrigation	-	-		-		-				
	Industrial	-	-		-			-	-		
Food gathering	Yes	-	-	-		-	-	-	-	-	

	No	-	-	-	-	-	-	-	-	-	-
Include in HIAMP	Yes										
	No										

Table 6.3: Worked example of estuary receiving environment.

Transfer Down

Receiving Environment	Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Lake/Reservoir		-	-							
River/ Stream (>50% base flow)										
River/ Stream (<50% base flow)			-	-						
Estuary	-	✓	-	✓	✓	✓	✓	✓	✓	✓
Harbours & Sheltered Embayments			-							
Nearshore Marine (shoreline)	-	-	-		-					
Offshore Marine	-	-	-		-					
Groundwater	-			-						
Air	-	-	-	-		-	-	-	-	
Soils				-		-	-			

Assimilative Capacity/Sensitivity Of		Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Estuary			✓		✓	✓	✓	✓	✓	✓	✓
Dilution	~~Poor~~										
	Moderate	-	-	-	✓	✓	✓	✓	✓	✓	✓
	~~Excellent~~	-	-	-	-	-	-	-	-		-
Substrate (s)	~~Mud~~	-		-		-	-	-			-
	Sand	-	-	-	✓	-	-	-	✓	✓	-
	~~Rock~~	-	-	-		-	-	-	-	-	-
Enrichment status	**Unenriched**	-	✓	-	✓	✓	-	-	✓	-	-
	~~Mod Enrichment~~	-		-			-	-		-	-
	~~Enriched~~	-	-	-	-	-	-	-	-	-	-
Sensitivity of Ecological Values	~~Low~~					-	-	-			-
	Moderate	-	✓		✓	-	-	-	✓	✓	-
	~~High~~	-	-	-	-	-	-	-	-		-
Significant other Inputs	~~Yes~~										
	No	-	-	-	-	-	-	-	-	-	-
Aesthetics	~~Important~~	-	-	-					-	-	-
	Not so Important	-	-	-	-	-	-	-	-	-	-
Contact Recreation	**Yes**	-	-	-	✓	✓	✓	✓	-	-	✓
	~~No~~	-	-	-	-	-	-	-	-	-	-
Water Supply (Economic Utility)	~~Drinking~~	-	-		-						
	~~Irrigation~~	-	-		-		-				

	~~Industrial~~	-	-		-			-	-		
Food gathering	**Yes**	-	-	-	✓	-	-	-	-	-	✓
	~~No~~	-	-	-	-	-	-	-	-	-	-
Include in HIAMP	Yes		✓		✓	✓	✓	✓	✓	✓	✓
	No	✓		✓							

6.4 Characteristics of receiving environment

The remainder of this chapter defines the various categories of assimilative capacity and sensitivity listed in Table 6.2. It should be noted that these are not absolute measures and are only intended to help provide a relative scale to prioritise the constituents in the wastewater for inclusion in the HIAMP model. If in doubt about which option within a category to use, it would be prudent to choose the more conservative value. For example, choose moderate dilution over excellent dilution.

Dilution

Although fully understanding all the parameters that influence dilution and dispersion can be quite complicated, for the purposes of this chapter they have been simplified into the primary factors driving wastewater dilution. Namely, the configuration of the outfall (e.g., diffuser vs. end of pipe), relative volumes of wastewater versus receiving water, and velocity of the receiving water. By looking at these three factors, the relative dilution (i.e. poor, moderate, excellent) can be determined. As guidance, each of these three scenarios is discussed briefly.

Poor dilution (generally less than 50 fold dilution at 100m from outfall)

Poor dilution usually occurs when an effluent is piped directly onto the surface of a slow moving receiving water. This category is characterised by a conspicuous and persistent plume in the receiving water under all discharge flows and receiving environment conditions. This is most pronounced when effluents are discharged to an estuarine or coastal environment where the lighter, freshwater effluent sits atop the heavier saline receiving water or in lakes or rivers where available dilution is low. Although poor dilution is most obvious for poorly treated effluents, the level of treatment has little effect on dilution.

Moderate dilution (generally between 50 & 250 fold dilution at 100m from outfall)

Most wastewater outfalls in New Zealand currently fall under this category. This category is characterised by a noticeable, but perhaps intermittent plume in the vicinity of the discharge that may or may not dissipate fairly quickly. This plume might show up as a discolouration in the receiving water or just as likely as a ‘boil’ or ‘slick’ representing a change in the surface tension of the receiving water. Moderate dilution can cover a wide range of scenarios. For example, a low volume discharge into a fast moving, large river might achieve moderate dilution regardless of whether the effluent is diffused or not. Similarly, a large volume discharge into a slow moving coastal environment might also achieve moderate dilution if the effluent is sufficiently diffused and submerged.

Excellent dilution (generally >250 fold dilution at 100m from the outfall)

Very few wastewater outfalls in New Zealand have excellent dilution. This category is characterised by an absence of a visible plume under all operating and receiving environment conditions. It also applies almost exclusively to multiport, submerged diffusers into fast moving or large volume receiving waters.

Substrate

Substrate has been broken into three categories: Mud, Sand and Rock. It is loosely defined as the bottom type in the vicinity of the outfall that is likely to be impacted by the discharge. A variety of substrates can exist, so multiple selections can be made. Substrate is an important factor for determining receiving environment sensitivity, particularly with regard to nutrient enrichment and sedimentation/smothering.

Enrichment status

The trophic state of an aquatic receiving environment refers to the nutritional level of that waterbody and is generally determined by measuring the nutrients or organic primary productivity of that body. Commonly, there are three trophic states (unenriched, moderately enriched, and enriched) for marine and fresh waterbodies. Their general characteristics are described in Table 6.4 but it must be borne in mind that additional baseline data may be required to define appropriate categories.

Table 6.4: Categories of trophic status and the likely response of various waterbodies.

Trophic Category	**Lake or Reservoir (see Cooke et al. 1986)**	**Rivers and Streams (see Biggs 2000)**	**Coastal and Estuarine**
Unenriched Low in nutrients and organic production.	Usually deep with nutrient-poor sediments, few macrophytes and high dissolved oxygen in the deepest water (e.g. Lake Manapouri). Diversity of phytoplankton can be high.	Usually few macrophytes or periphyton growth.	Low production and abundance of fast-growing algae, such as phytoplankton, attached algae and short-lived macroalgae (*e.g.* sea lettuce).
Moderately enriched Moderate nutrients and organic production	Moderate nutrient levels in sediments, some macrophytes and moderate dissolved oxygen in deepest water(e.g., Lake Tarawera)	Moderate macrophyte and periphyton growth.	Moderate production and abundance of fast-growing algae, such as phytoplankton, attached algae and short-lived macroalgae (*e.g.* sea lettuce). Many New Zealand estuaries fit this category.
Enriched High nutrients and organic production.	Often shallow to moderately deep, nutrient-rich sediments, low oxygen in deepest water (e.g. Lake Hayes. Lake Rotorua). Water is often coloured and phytoplankton populations are nearly monospecific.	High periphyton, and macrophyte growth. Sometimes, low dissolved oxygen particularly in early morning.	High production and abundance of fast-growing algae, such as phytoplankton, attached algae and short-lived macroalgae (*e.g.* sea lettuce). Shading by these plants reduces the abundance of slow-growing benthic macrophytes such as seagrasses and kelps. Sometimes low dissolved

	oxygen in poorly flushed waters.

Sensitivity of ecological values

Impacts of wastewater on marine and freshwater ecology is a complex issue but is most frequently addressed by considering effects at the community level. Such impacts include:

- Loss of rare or sensitive species.
- Quantitative changes (e.g., in age structure) of longer-lived species.
- Decreased species diversity.
- Dominance of opportunistic species.

Although impacts can occur to most members of an aquatic community, the effect on the benthic (bottom-dwelling) community, in particular, is often used as an indicator of the likely worst case overall ecological impact of a particular discharge. This is because various contaminants, including nutrients, organic matter, metals, synthetic organic toxicants and pathogens, accumulate in marine and freshwater sediments at greater concentrations than the overlying water. As such, aquatic sediments serve as 'sinks' for contaminants, with the potential to affect benthic communities and overlying water quality. In addition, compared with overlying water, which exhibits large short term fluctuations in physical, chemical and biological characteristics, the benthic environment is much more stable as it effectively 'integrates' these fluctuations over time.

Given that the benthic community is likely to be a good indicator of wastewater impacts, the sensitivity of that community (plus any other more sensitive individuals or communities) can be categorised into low, moderate and high sensitivity groupings as follows:

High sensitivity: This category implies that there are communities, habitats or species in the vicinity of the outfall that are especially sensitive to wastewater contaminants. As a consequence, avoiding adverse effects to these groups is of paramount importance. Examples include the presence of rare, threatened or endangered species; direct proximity to reserve areas; or the presence of species that are particularly sensitive to wastewater discharge related effects (e.g*.,* smothering, enrichment etc.) It also includes communities or species that are very slow to recover from a disturbance. An example of this category would be a lake that is completely contained within an unmodified catchment.

Low sensitivity: This category is characterised by a relative lack of biota or an environment that is impoverished, homogeneous, or ubiquitous. Ubiquitous communities/species, although not without ecological merit, can be considered of lower ecological sensitivity for small scale disturbance if they are common enough on local, regional, national scales. An example of this type of community would be a coastal environment dominated by high energy, mobile coarse sediments where physical disturbance is the dominating force.

Moderate Sensitivity: This category, as the name implies, falls somewhere in between the two extremes of low and high sensitivity, and under most circumstances will be value judgement based. It includes areas where loss of, or adverse effects to, a part of the community might be an issue, but not to such an extent that it should be completely avoided. It includes areas that might already be slightly compromised, from either other inputs or periodic natural disturbance.

Significant other inputs to the environment

Other inputs (e.g., wastewater sources, septic runoff, industrial discharges, stormwater, solid waste disposal, aquaculture, and dredge disposal) can have a dramatic effect on the assimilative capacity of a receiving environment. If these other inputs are not taken into account, it might erroneously be assumed that the assimilative capacity is much higher than it actually is because the bulk of the capacity has already been expended.

Ideally, the condition of any given receiving environment will be the result of the combination of inputs it already receives. As such, the effects of other inputs on the assimilation of wastewater constituents will already be adequately accounted for by the other categories, e.g., enrichment status, contact recreation etc. However, for the sake of ensuring a more holistic assessment, the category of 'other inputs' has been included in the hazard identification procedure. The category has been divided into two groupings, significant other inputs and no significant other inputs.

Whether any of these other inputs represents a significant contribution is again a judgement-based decision, but generally if the activity requires a resource consent it should be considered a significant input. Additionally, significant inputs of contaminants may be entering a receiving environment via non-point sources that do not require a consent (e.g., during flooding in a river, agricultural runoff and construction site runoff).

Aesthetics

This is a somewhat subjective category, but in general, more pristine areas are considered of higher aesthetic value than areas that are subject to a high degree of development or modification. There are numerous items to consider when assessing the aesthetic nature of a receiving environment. These include but are by no means limited to: proximity to parks & reserves, amount of tourist activity, level of industrial development, colour of the receiving water (deep blue waters are inherently more aesthetically valued than brown or green waters), adjoining beaches etc. Again, if in doubt, choose the more conservative value of 'high importance'.

Human health and safety via contact recreation

There are at least two aspects to consider with contact recreation: firstly, the potential for infection from pathogens; and secondly, physical hazards caused by poor water clarity and/or build up of slimes on substrate (refer to MfE 1994a and MfE 1992, respectively).

At one time contact recreation activities were primarily restricted to swimming and bathing but that is no longer the case. Therefore, when interpreting this category, it is important to consider not just whether the given receiving environment is as suitable swimming/bathing area but the myriad other activities that could be taking place e.g., surfing, boardsailing, kayaking, personal watercraft (e.g., Jet ski), snorkelling, SCUBA diving, etc. If it is suspected that any of these activities are conducted on a regular basis, then the contact recreation 'Yes' box should be selected.

Water supply

Some receiving waters may be taken for community water supplies, irrigation and industrial purposes. These are classified under 'economic utility' in the HIAMP process. If so, there will be a need to ensure that any risk of contamination to these supplies is adequately taken into account and appropriate monitoring undertaken. The quality of water required for water supply will vary depending on the type of supply. The ANZECC (2000b) water quality guidelines provide direction on the appropriate parameters to monitor for various types of water supply, and the NZ Drinking Water Standards (MOH 2000) set compliance limits for the protection of human health.

Food gathering

This category can include either community-based (community value) or commercial activities (economic utility). Given the potential human risks associated with all but the most stringent wastewater treatment processes, any amount of food gathering should be considered significant, even if the food source is not commonly thought to retain contaminants. This includes everything from small amounts of plants collected for cultural or spiritual reasons, up to large commercial fishing activities. Common examples include collection of watercress, shellfish (e.g., mussels, pipis, cockles, scallops, koura, etc.), fishing, whitebaiting etc.

Cultural or spiritual value

Under the Third Schedule to the RMA, waters may be managed for Cultural Purposes and waters may be classified for such purposes where cultural or spiritual values are specified for that area. Such values, including burial sites and traditional food gathering areas, are of particular significance to Maori, but other groups may also consider an area to have cultural or spiritual values. This aspect is covered in greater detail in Chapter 7, but is also included here as it has bearing on the receiving environment sensitivity in a similar manner to aesthetic values.

CHAPTER 7
RECOGNISING COMMUNITY VALUES

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7.1 Why recognise community values?

Community values are an important driver for establishing priorities under a risk-based approach to setting priorities for wastewater monitoring. Ideally, consistent with the Australian and New Zealand Risk Management Standard (AS/NZS 4360), adopting a risk management framework should involve explicit consideration of both review and monitoring, and communication and consultation with affected parties. In addition, while risk is a function of likelihood and magnitude of effect, the context of the activity is an important component of any risk analysis.

Monitoring programmes for wastewater discharges are instituted in conjunction with setting conditions for resource consents (both new consents and renewals). At the present time very few consents include requirements for recognising community values, though this may be becoming more common. However, there can be significant benefits gained by recognising and taking account of community values.

These include:

- A broader understanding of the effects of discharge on the receiving environment and the host communities (i.e., those communities affected by the wastewater system) by capturing well established bodies of knowledge that might reflect local knowledge, but also more general social and cultural information.
- Understanding of the factors that influence community priorities, thus providing a way of determining where emphasis should be placed.
- A process for engaging the community and gaining their understanding and support.
- A process for meeting legislative requirements.

The effects of wastewater treatment processes have both physical and value components. Thus there are a number of community-based factors that influence both the level of risk, and the available (acceptable) processes for reducing those risks. These physical and social factors, which include perceptions of risk, affect the priorities resulting from adopting a risk-based approach.

7.2 Which values?

7.2.1 What do we mean by values?

Values are basic principles, which are reflected in our cultures and help us in a variety of ways; to understand and give meaning and significance to our world, and to say what is important. Specifically, they assist us to -

- Understand our place in the world (e.g., "we should treat other species with the same level of respect we treat people", or "people are more important than other species").
- Identify desirable goals and situations, and choose among alternatives (e.g., "protecting water quality for human consumption is important", or "taking the long-term view is important", or "using resources sustainably is essential").
- Develop a basis for relating to the environment (physical, social and spiritual environment) to maximise the achievement of desirable goals (e.g., "rivers can no longer be treated as convenient dumping grounds for waste", or "discharge of wastewater into rivers is acceptable provided that certain environmental standards are met").
- Set social norms and determine appropriate behaviours (e.g., "respect for others is important", or "wastefulness should be discouraged").

From the Maori perspective this can be portrayed by a proverb: -

Toi tu te marae o Tane

Toi tu te marae o Tangaroa

Toi tu te iwi …

If the marae of Tane (Deity of the Forest) survives

If the marae of Tangaroa (Deity of the Sea) survives

The people live on …

Whilst some values can be very closely linked to the survival of communities and cultures, they are not easily scientifically testable propositions; they reflect fundamental beliefs.

Values are basic principles that are usually shared widely in common with others but not necessarily universally by everyone in the community. Not everyone will express similar values in the same way or hold the same attitudes to everything. Therefore, the concept of values encompasses both the idea of community norms and the idea that there will be differences in values held by different groups within a community, or different individuals within a group.

Maori values do not differ essentially from Pakeha values when looking at our natural environment and the effects of wastewater discharges.

Values are expressed in attitudes and the way people behave to other people, and to the environment. However, even if values remain fairly constant over time, the interpretation of those values in determining appropriate behaviour (*tikanga*) can change over time in new and evolving social and technological contexts. This means that certain cultural values do not necessarily prescribe the same behaviours for all time. For example, the values of *tapu* and *noa* are still important to preserving both spiritual and physical well being in the Maori community. The relationship of Maori communities with their *taonga* and their *waahi tapu* is still important. What has changed is the way these values are implemented, the modern-day *tikanga*. *Tikanga* may change over time. It is not necessarily applicable everywhere in the country. It is important to remember that iwi in different areas have their own tikanga for dealing with these matters.

Technical understanding and good information can influence how values are re-interpreted into behaviour. For example, the repugnance for Maori to the discharge of sewage into water can be resolved using the belief that materials can be cleansed by recycling them through *whenua*, the land. Knowledge of the cleansing effects of passage through the soil has enabled modern arrangements for sewage effluent to be designed to take advantage of this without causing offence to Maori in the modern world (e.g., effluent irrigation to land).

7.2.2 Community values

Values are diverse; they may relate to many different aspects of people's lives. The phrase 'community values' is intended to describe the mix of social, community and spiritual values; to be inclusive of the diversity of values which people in the community hold.

It is likely that certain values will generally be applicable to thinking about the operation of wastewater treatment plants, such as, for example -

1. The discharge of effluent containing significant residues of human wastes to water will always be offensive to local communities.

2. Protecting water quality in neighbouring water bodies is important.

3. The ability of neighbours to live in healthy conditions or neighbouring businesses to maintain the health of the natural environment should not be compromised by the operations of a WWTP.

4. The operations of a WWTP should not create significant offence to other parties, beyond the boundary of the plant.

This cluster of value statements describes various things which communities value - a healthy environment (2), healthy people (3), opportunities for people to enjoy natural environmental amenities (4) - all linked to a basic moral position (1).

However, the expression of values may differ for different interest groups in the community, or for communities in different geographical locations. For example, if a WWTP is located in a totally rural community, with predominantly productive agricultural business neighbours, these neighbours are likely to place considerable importance on controlling risks from aerosols, preventing contamination of surface water by sewage effluent or bio-solids, or ensuring that weeds are well controlled on land within the plant boundary so that they cannot pose a threat to neighbouring farmers. In contrast, if the locality has a significant rural-residential lifestyle presence, neighbours are likely to put greater emphasis on the possibility of off-site odour, visual and noise effects.

As a result, what is important may vary from group to group or place to place. This has implications for how to go about 'recognising community values' in monitoring activities. Ideally, the approach to working out what is appropriate should involve face-to-face discussion - *kanohi ki kanohi.*

7.2.3 Recognising well-established bodies of knowledge and value bases

Because of the multi-cultural make-up of New Zealand's population, we have a diversity of values. There are two dominant, well-established bodies of knowledge and understanding - the values and knowledge of Maori as long-standing indigenous people of the land, and the values and knowledge of Pakeha as the more recent arrivals, with more techno-centric approaches. These two cultural strands display some values that are very similar and some that are contrasting.

There are undoubtedly comparable and parallel ideas between the two dominant strands, even if the 'point of entry' into a discussion may appear conflicting. For example, asking Pakeha about a proposal for sewage effluent discharge into a river is most likely to evoke a response which discusses water quality in terms of faecal contamination, nutrient and turbidity levels, and the potential effects on recreational use of the water or on abstraction for commercial use. In contrast, asking Maori the same question is most likely to evoke a response which challenges the whole idea of discharge to the river, raises issues of *waahi tapu, kaitiakitanga* and *whakapapa* and then examines potential effects on customary rights to gather food nearby. Different values means that different issues may take on greater importance. But are the sets of underlying values really so different?

In fact, the two responses differ most in their initial 'point of entry' to the discussion and range of issues. Maori and Pakeha may not be so different in some of the important underlying values. However, they may choose to express them in different ways, or not to articulate some values at all. Furthermore, there are many very similar concepts that are relevant to managing and monitoring the effects of waste water treatment plants:

kaitiakitanga	responsibility to look after the land, the water and the people in their *rohe*, that is, the environment and the people who live in that environment
rangatiratanga	the right to make rules governing the use of resources
whakapapa	interconnectedness; linking people to nature by tracing back to *Ranginui* and *Papatuanuku*

Maori classify water according to a number of different states, including:

- *Waiora* which is the purest form of water and has the potential to give life, to sustain well being and to counteract evil. Waiora is used in sacred rituals to purify and sanctify.
- *Waikino* is water that is polluted, debased and spoilt. Water in this polluted form has the potential to cause harm to all life forms including humans.
- *Waimate* is water that is so polluted that its life-force has expired. The mauri has left the water. Waimate has lost its power to regenerate itself and other living things.

Practical implications of water management associated with these categories link to the notion of sustainability. The brief descriptions of some Maori concepts provided above are not comprehensive. They are provided for the reader as examples of different but comparable forms of expression. Details may vary in different parts of the country, and the reader should engage local iwi representatives in a dialogue to achieve better mutual understanding.

Many Maori are increasingly comfortable with the concept of sustainability, interpreted in the sense of 'managed use' of resources. Sustainability has undoubtedly gained widespread currency in pakeha discussions on resource management.

It makes sense to recognise both Maori and Pakeha values and knowledge not only because of what can be learnt from being open to various sources of knowledge in our communities. In this particular instance it is reinforced by the partnership obligations flowing from the Treaty of Waitangi, now required under the RMA and several other recent pieces of legislation.

The significance of this discussion, in the context of a risk-based approach to monitoring wastewater treatment plants, can be summed up as follows:

- Recognising community values is important to implementing a risk-based approach to monitoring.
- Since communities are not homogenous in the values they subscribe to, it is necessary to draw on the well-established value bases and bodies of knowledge.
- Acceptance of this has practical implications for the way local authorities approach the need for community input into monitoring programmes - whom to work with in establishing community priorities, and deciding what to monitor.

7.2.4 Examples of community values relevant to wastewater discharge monitoring

The community values as presented in Section 7.3.2 point to a range of possible issues and effects which help to explain why monitoring is important, and also indicate what to monitor for. These include:

- Risk to spiritual well-being or aesthetics from inappropriate discharge practices.
- Risk of causing undesirable changes in natural systems (e.g., loss of fish species, algal blooms, etc.) from bio-chemical contaminants in the discharge.

- Risks to human health from bio-chemical contaminants in the discharge.
- Risks of reducing or losing natural environmental amenities from intrusive odours, aerosols, noise or water contamination.
- Derived risks to property values in the neighbourhood.

If monitoring is not effective in avoiding these risks, or in maintaining them at levels acceptable to the community, then monitoring and management has failed.

7.3 The impact of community values on risk perceptions

Values inform perceptions. Perceived risk is a judgement or valuation by individuals or groups of people. Whether estimates of risk are made by technical experts or by the general public, they cannot avoid containing elements of perception. This derives from the way in which people design models or experiments, the weighting that they give to social importance, the way in which they select or derive data and even in the risks they choose to study.

However, perceived risk estimates differ from technical assessments because they take into account a wider range of factors or attributes of the risk and general context of the situation. Risk perceptions are often more to do with the acceptability of the risk than the level of the risk, and typically factors such as the type of harm, the number of people affected, whether exposure to the risk is voluntary, and how much is known about the risk dominate the way risks are perceived. Thus risk perceptions are founded on value systems.

There is no general method for dealing with the differences between perceptions and technological judgements. Sometimes communities estimate risk as being lower than technical experts and sometimes they estimate it as being higher. Society's inputs are perceptions, deriving from values, and to adequately include these in decision processes ways of measuring (or at least eliciting) community values are needed. Community perceptions of risk are informed by local knowledge, written and verbal history, and social and cultural customs, and evaluation of the magnitude of effect component of risk requires consideration of human values and emotions.

Interaction between technical experts and communities is a useful way of developing mutual understanding and respect. The term ‘risk communication’ is used in a technical sense to mean the development of communication channels that are used to transmit information between different parties such as council staff and communities. It is essential that all the parties involved in communicating risk recognise that they should listen, ask questions, provide responses and be prepared to acknowledge uncertainty. Effective risk communication depends on trust and credibility and two-way communication.

An important aspect of risk communication is deciding who should be involved. This requires identifying a community of interest that might not necessarily be defined solely on geographical factors. Individuals and groups from outside the local area may have links with the area that mean that they also need to be considered. In many cases the local community will be able to advise as to who might need to be consulted.

Another aspect of risk communication is ensuring that all parties have a common understanding of the language being used. While technical experts should avoid ‘talking down’ to individuals and community groups, they should at the same time make sure that the terms they use are simple, clear and consistent.

7.4 Using qualitative risk assessment to help include values

Qualitative risk assessment can be used to prioritise risks where quantitative information is not available. It uses words to describe the probability or likelihood of the effect occurring and the magnitude of that effect, and then combines these to form a qualitative estimate of the level of risk. The benefit of using qualitative risk assessment to elicit community estimates of risk levels is that the descriptors used to describe likelihood and magnitude (see below) can incorporate values.

Qualitative analysis requires three sets of word scales that should be constructed individually for each situation. The first of these is the likelihood of the event occurring. This is described in Table E in Chapter 4. The second word scale is the magnitude of the event. This is described in Table D3 in Chapter 4 (aesthetics and odour and also described in Tables D5 and D6, respectively). The likelihood and magnitude tables can be combined in a matrix that is used to develop a ‘level of risk’ designation that is used to group and rank risks (see Table F in Chapter 4).

Recognising community values in risk assessment (i.e. in the process of determining the likelihood and magnitude components as above) can be done through a range of ways of allowing community input to monitoring and evaluation of WWTP performance, all of which depend on effective risk communication. Some particular ways of doing this are described in Chapter 13. It is the process of community assessment and judgment that enables communities to express their values in relation to managing the effects of WWTPs.

Therefore, critical questions to think about are:

- Who/which groups should you try to involve (who are the affected parties and interested parties).
- How often.
- How should this be done (this may differ from group to group).
- What are the prior information needs of the community and what are the feedback requirements for the operators.

7.5 Putting these ideas into practice

Community values can be recognised explicitly through the consultation processes surrounding the applications for resource consents. However, even if consents have been granted for long periods (e.g., 35 years), it should not be assumed that it might be several decades before such an opportunity arises again. Other opportunities will arise from time to time during periodic reviews of monitoring results by the consent authority. These are usually stipulated in consent conditions. The consent authority may review monitoring reports for reasons that may include community concerns, as a reflection of their values.

PART THREE: DESIGN

CHAPTER 8
CONCEPTUAL DESIGN OF THE MONITORING PROGRAMME

Rob Bell, David Ray, Chris Hickey, Graham McBride (NIWA)

8.1 Introduction

8.1.1 Design of the monitoring programme - overview

The risk analysis completed in Part Two (summarised on Worksheets A and B in Appendix 3) provides the starting point for the design of the monitoring programme. The final column in Worksheets A and B identifies the level of resources appropriate for monitoring of each of the identified risks in the discharge.

The final output from Part Three of the Guidelines should be a detailed monitoring programme. The process of arriving at this monitoring programme is summarised as follows:

1. Define the objectives and end uses of the monitoring programme, and design the conceptual form of the monitoring programme (Chapter 8).

2. Review the monitoring options in Chapters 9 to 12 to determine which options are most relevant in terms of the risks identified in Part Two and the objectives and end uses defined in Chapter 8.

3. For each monitoring option chosen in step 2 above, use Chapters 13 (detailed design) and 14 (sampling and analytical methods) to determine the details of the monitoring programme.

4. Determine the review procedures for the monitoring programme (Chapter 15).

This process is shown diagrammatically in Figure 1.1 (Chapter 1 – also presented on the laminated sheet at the rear of the document).

8.1.2 Conceptual design

Developing a conceptual design for a monitoring programme is not a simple step-by-step process; rather, it is an iterative process, as shown in Figure 1.1. An initial concept is developed based on the knowledge gained in Part Two, and then the concept is refined once the range of different monitoring options in Chapters 9 to 12 is considered in more detail.

One of the key elements in developing the conceptual programme is clearly identifying its objectives. If the purpose of the monitoring programme is not clarified and agreed to by all relevant parties, it is unlikely to be effective or cost-efficient. As part of this process, the end uses of the programme must be identified and clearly stated.

By the end of Chapters 8 to 12, the user should have prepared a conceptual monitoring programme that identifies the objectives and proposed end uses of the programme, the key constituents in the effluent that need to be addressed by the monitoring programme, and the appropriate mix of sewerage network, discharge, receiving environment, and community effects monitoring. The exact constituents to be monitored and the frequency and location of sampling will not be finalised; this is completed in Chapter 13.

8.2 Setting monitoring objectives

8.2.1 Identifying end-use expectations

One of the key considerations when setting the objectives for a monitoring programme is the proposed end use of the monitoring results. Is the intended use of the results to test and report on consent compliance? Or is it for trigger-level monitoring using indicators to detect symptomatic plant performance? Is a widely-disseminated report or Web page to stakeholders and the local community required? After the monitoring programme has been running for some time, regulatory authorities and the public are likely to ask questions such as "are we achieving the water quality objectives for this receiving environment?" If a monitoring programme has not been specifically designed to answer such questions, then it is unlikely that a satisfactory answer can be given. Also, by identifying the type of information that can be produced, it is less likely that stakeholders will place unrealistic expectations on a monitoring programme (Ward et al. 1990). Information types can be classified as:

- Narrative information—that *describes* the result e.g., "the water surface was free from visible discoloration and slicks".
- Numerical information—numerical presentation of monitoring observations. This should not simply comprise a compilation of tables of numbers, with the readers left to draw their own conclusions. If the expectation is for a trend assessment over time, then the monitoring data needs to be appropriate for use in a trend analysis software package.
- Graphical Information—visual presentation of results, which can be a useful approach to conveying information.
- Statistical information—this is an important consideration, especially where a small number of samples are being used to represent the entire 'population' of the waste stream. Statistical summaries can provide an understanding of the average, changing and extreme water quality conditions. This issue is addressed in more detail in Chapter 13.
- Indices—producing an index that combines information from several variables into a single number. This is mainly used for environmental effects monitoring, and sometimes in local community surveys of the effects on people.

If the HIAMP process in Part Two highlights areas where there is uncertainty or a major public issue, one of the objectives may relate to allaying public concerns through monitoring for a defined period, in which case that objective should be written with a duration clause at an early stage.

8.2.2 Generic approach to setting objectives

The process of setting objectives is summarised in Figure 8.1. The output from the HIAMP process should underpin the formulation of monitoring objectives.

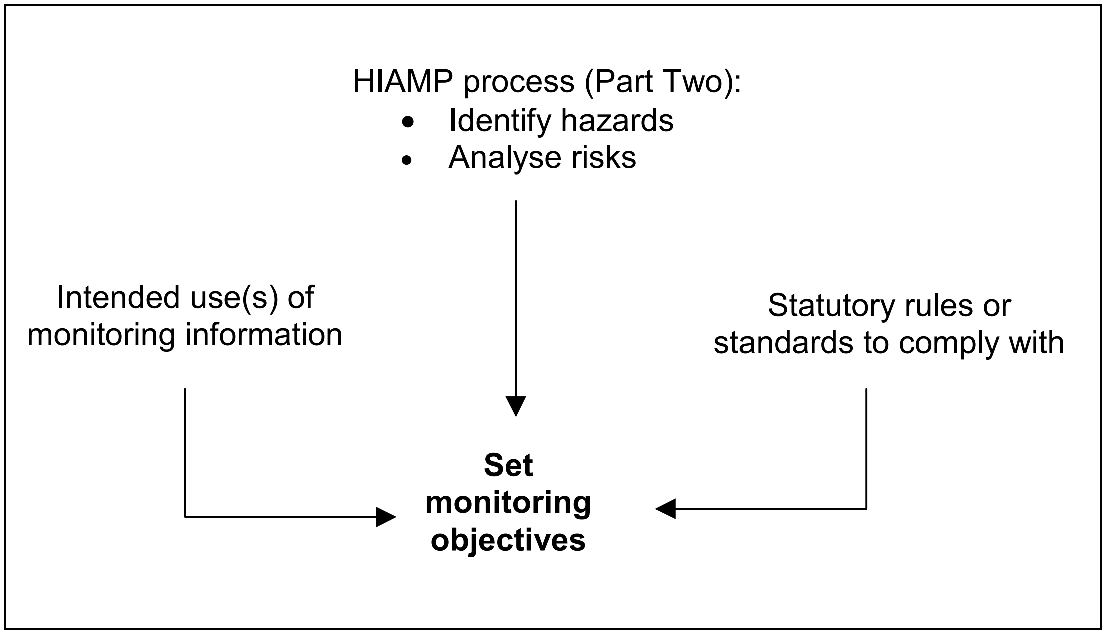


Figure 8.1: Process leading up to setting monitoring programme objectives.

The two 'side inputs' in Figure 8.1 are important contributors to the process of setting objectives. The importance of considering the intended use of the results has already been addressed in Section 8.2.1. In addition, statutory rules (e.g., in regional plans) can require specific elements in the monitoring programme. For example, there might be narrative or numeric water quality standards or rules that are required to be met for the particular receiving environment. This is separate from the HIAMP process, being an imposed condition where the discharge may have special restrictions under statutory Coastal or Regional Plans, or any future changes to a National Policy Statement, the NZ Coastal Policy Statement, or the Hazardous Substances and New Organisms (HSNO) Act. Monitoring requirements may also need to be revised following the release of statutory environmental standards through the RMA or HSNO Act.

Generic objectives for monitoring

General objectives for a monitoring programme might include:

- Provide assurance that compliance with numeric limits in resource consent conditions is being achieved (*compliance monitoring*);

- Measure the state of the receiving environment before and after commencement of discharge (*baseline monitoring*);
- Document general trends over time in the quality of the waters, sediments, biota or air in the receiving environment (*trend assessment*);
- Assess the overall loads of material discharged to the environment e.g., nutrients, toxicants (*contaminant loads*);
- Alleviate uncertainty over an initial review period that a specific constituent of public concern is posing a low risk to the environment — also for a new plant, or where monitoring data is not available;
- Develop an understanding of how the environmental system functions and responds to impacts, by measuring processes and their responses. Mostly used for scientific studies, but may be appropriate for AEE-type investigations;
- Facilitate investigative monitoring that is activated on defined trigger-levels being exceeded, or when non-compliance occurs, to determine more precisely the nature and cause of the problem, e.g., repeat sampling with replicates, or analysing other bacterial or viral indicator groups to clarify an anomalous faecal indicator result (*investigative monitoring*).

Given the expense of routine monitoring, programmes should comprise components that are directly targeted at the most important of the above objectives, rather than try to accomplish a mix of several objectives. Guidance with more specific objectives for the various types of monitoring programme is provided in Section 8.2.3.

8.2.3 Setting objectives for specific types of monitoring

Baseline or AEE monitoring

In most situations, monitoring data should be gathered prior to a resource consent application, for the following reasons:

- The presence or absence, or relative importance of a pollutant can be more clearly established or refuted.
- Effluent variability can be more clearly defined.
- To assess the state of the receiving environment, as defined by a variety of environmental variables or indicators.

Effluent discharge monitoring

Effluent monitoring usually has the objective of checking compliance with a set of resource consent conditions. However, a secondary objective is to collect sufficient data as supporting information to help interpret measurements of the selected effluent constituents e.g., water temperature, effluent flow, winds (for odour monitoring). Some constituents may also be measured to check the plant operation from an operator's viewpoint, but may not necessarily be required for compliance, e.g., BOD and DO, which are not normally required for coastal and open harbour discharges.

Important issues to address when setting objectives for discharges into surface waters are the dilution and dispersion of the discharge, and the characteristics of the mixing zone. These issues are covered in Sections 11.3 and 11.10.

Environmental effects monitoring

Guidance is given in Chapter 2 of the ANZECC (2000b) guidelines for setting objectives for monitoring different types of aquatic environment effects. For land disposal of wastewater, the purpose and objectives for monitoring and management programmes are discussed in Chapter 7 of the Guidelines for Utilisation of Sewage Effluent on Land (NZLTC 2000). Some background guidance for developing objectives to monitor discharges to air is provided in the Manual for Wastewater Odour Management (NZWWA 2000).

There are special issues to consider when setting objectives for effects monitoring. Natural environmental variability and multiple diffuse sources of pollutants from the catchment throw up confounding processes that can severely limit the resolving power of environmental monitoring programmes. The ability of a monitoring programme to clearly identify the effects of a discharge becomes increasingly difficult with distance from the discharge point. This monitoring conundrum is exacerbated by the modern trend towards higher effluent quality and increased public expectations to demonstrate *no* environmentally significant effect on ecosystems or public health. Consequently, over the last few years there has been a trend towards testing the compliance of discharges by tightly monitoring the effluent. However, an effluent monitoring plan for a significant discharge is usually supported by a less frequent environmental monitoring programme, with the objective of 'trend assessment' or checking environment loading. Even then, it is difficult to isolate the effects of a discharge into a large receiving environment unless sufficient monitoring effort is applied to determine effects over and above natural variability and the confounding effects of other discharges.

Careful attention is therefore required to set very specific objectives for an environmental effects monitoring programme. Environmental monitoring is generally more expensive than effluent monitoring, which means the scope and frequency of sampling must be modest. This raises the question about how well trends can be assessed with only one or two samples per year. Monitoring that is able to integrate effects over time should be the prime focus, e.g., sediment quality, or sentinel shellfish. This is discussed further in Chapter 11.

For discharges into streams and small rivers the receiving environment is less complex. For example, upstream control sites can provide a more robust comparison of effects in an environmental monitoring plan.

There are a number of other aspects that could be considered in developing specific objectives to monitor aquatic environments (refer also to Chapter 11):

- Upstream 'control' sites vs. downstream comparisons (only for uni-directional river systems–not estuaries, lakes or coastal waters); 'reference' sites with comparable physical habitats are required for other environments.

- The RMA requires that water quality standards be met after ‘reasonable mixing’. This zone around a discharge, often called a mixing zone or non-compliance zone, needs to be considered when setting monitoring objectives. For example, the objectives could be to sample at the edge of the zone, or to monitor the discharge and calculate the diluted contaminant concentration beyond the mixing zone dilution (or possibly a combination of the two methods). Refer also to Section 11.10 and Chapter 13.
- Detecting any environmental-effect ‘gradient’ (including within the mixing zone) with distance from the discharge.
- Key species or sensitive species that can be monitored as an indicator of ecosystem functioning and health.
- The important role fine sediments play in the functioning of benthic ecosystems, and their role in transporting contaminants. The ability of sediments to integrate effects means that infrequent sediment quality monitoring can sometimes be used for effects monitoring. Refer also to Sections 11.5 and 11.6.

8.2.4 Integrated approach to monitoring

Increasingly, an integrated, multi-pronged approach to monitoring is being used for significant discharges. Traditionally, monitoring only involved the measurement of several individual effluent components or environmental variables. Judgements were then made on ecological or environmental effects by comparing the sample concentrations against established guideline values. For significant discharges, it is now more common to use a combination of the following four approaches:

Specific physico-chemical and microbiological controls

Determine what individual effluent constituents or receiving environment variables need to be controlled and hence monitored:

- Physico-chemical constituents (e.g., pH, temperature, suspended sediments, DO, BOD_5, nutrients, metals, POPs).
- Microbiological indicators for public health (e.g., faecal coliforms, *E. coli*, enterococci, possibly even viruses and protozoa for large discharges).

Community monitoring and surveys

Examples include odour monitoring (e.g., surveys or diaries), effects on other resource users, and aesthetics (e.g., visual observations of a plume by the public). Refer also to Chapter 12.

Toxicological approach

Protects the environment from the aggregated toxic effect of the mixture of pollutants in the effluent by checking the response of organisms to exposure to the whole effluent. This is often referred to as Whole Effluent Toxicity (WET) testing. Refer also to Section 10.8.

Biomonitoring approach

Use of biological indicators or an ecosystem condition index, where appropriate species are monitored directly for stress e.g., use of caged mussels. Alternatively, monitor an index of ecosystem structure e.g., abundance or presence/absence of a key species in the receiving environment. Guidance documents are available for toxics bio-indicators (e.g., MfE 1998) and community biomonitoring e.g., Section 3.2, Vol. 4, ANZECC(2000a). Refer also to Chapter 11.

This suite of monitoring is then drawn together to provide a 'weight of evidence' assessment of the effects of the discharge on the environment. However, for lower risk, smaller discharges, the first of these approaches is still likely to be adequate (e.g., monitoring effluent characteristics only). Guidance is given in Chapters 9 to 12 on the merits of each approach to monitoring, and when a combination of approaches might be used.

8.2.5 Writing objectives

A set of monitoring objectives must be specific, measurable, result-orientated, realistic and attainable. The key questions to address when writing monitoring objectives are:

- Do the objectives specify what is to be achieved, and indicate when each stage is complete?
- Are the monitoring objectives clear and concisely defined?

Two examples of monitoring objectives are provided below:

1. To determine if a sewage discharge is causing contaminant concentrations in a river to exceed water quality guidelines beyond the initial mixing zone, under base flow conditions.

2. To determine whether the annual load of phosphorus and nitrogen from the discharge exceeds a pre-determined level (where the HIAMP process, public concerns and a synthesis of the environmental effects has highlighted the potential for nuisance algal growths).

Note that the objectives do not specify details of sampling frequency, compliance period, how the samples are measured, where to sample, or how big the mixing zone is, and how the consent conditions are written. These matters are decided during the detailed design phase, discussed in Chapters 9 to 13.

8.3 Scale of monitoring

Having set the monitoring objectives, the next step is mapping out the scale of a monitoring programme. This involves determining the geographic spread and length of time over which a system is monitored. These issues are addressed in Chapters 10 and 11, but are introduced briefly below.

Geographic spread and time scales to 'capture' information

For an effluent discharge, monitoring must occur as close to the discharge point as possible to include any post-treatment changes in the composition of the effluent, e.g., faecal contamination by water fowl or photo-reactivation of faecal indicator bacteria by sunlight-induced processes. For example, the discharge permit for Project Manukau requires measurement at the point of discharge, even though the final effluent is stored in a holding pond until the next high tide.

In addition to direct wastewater monitoring, the effects of a discharge to water or air may also be monitored at the edge of that discharge's mixing or non-compliance zone, after allowing for reasonable mixing. The size of the non-compliance zone should be determined from desk-top studies of the receiving environment or field studies on mixing behaviour. Guidance on mixing zones can be found in Rutherford et al. (1994).

For environmental effects monitoring, the appropriate geographical spread, resolution of sampling effort and deciding what time scales to 'capture' becomes more difficult, depending on how simple or complex the monitoring objectives are. For instance, if seasonal variability in the discharge (e.g., summer holiday influx) and the associated environmental response is a key issue, then sampling twice per year will not be adequate to detect a seasonal signal. Guidance is given on establishing spatial spread and appropriate time scales in Chapter 3 of ANZECC (2000b). For a preliminary assessment of the required geographical spread, number of sites and time scales, the following questions should be asked:

- How much will the monitoring cost to cover the selected geographical and time scales?
- Is the level of resolution (time and space) of the monitoring programme fine enough to satisfy the programme objectives?

Duration of monitoring

Usually monitoring is required regularly throughout the fixed term of a resource consent, set by the regulatory authority. However, there are situations where other monitoring durations should be considered, such as AEE investigations, community surveys, and any interim monitoring of the influent, effluent, or receiving environment that is done to reduce uncertainty in the public's mind. Selecting the duration of the compliance or reporting period is described in Chapter 13.

CHAPTER 9
SEWERAGE NETWORK AND TREATMENT PLANT MONITORING

Paul Kennedy, Jennifer Gadd (Kingett Mitchell Ltd)

9.1 Introduction

The need to monitor wastewater treatment plant effluent quality is influenced by both the nature of the influent to the treatment plant and the effectiveness of the treatment process. Having an understanding of the nature of the sewerage catchment and the quality of the influent provides valuable information on treatment plant management. It can also assist with issues that might arise in relation to sludge quality and discharge and receiving environment monitoring (discussed in Chapters 10 and 11).

There is considerable debate as to whether sewerage network and/or treatment plant monitoring should be required in resource consent conditions. It is beyond the scope of these Guidelines to provide guidance on this issue. However, some guidance is provided in this chapter on how to go about such monitoring if it is deemed to be of benefit.

Contaminants are derived from a wide variety of sources in the reticulation system (refer to Chapter 5). In addition to wastes derived from larger identifiable industries (tanneries, meat works, food processors, metal finishers, wool scourers), there are contributions from smaller industrial and commercial contributors (e.g., photographic developers, restaurants, butchers, dentists) and household sources (e.g., discarded paints and solvents, general household cleaning products, cosmetics).

9.2 Monitoring within the sewerage system

Monitoring within the sewerage system typically takes two forms:

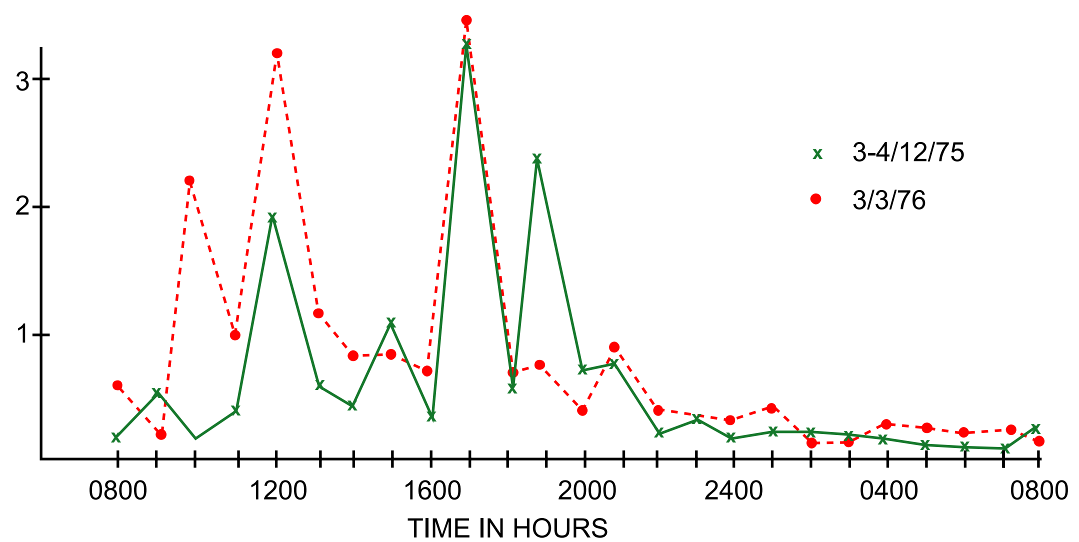
1. Monitoring of wastewater influent quality to the treatment plant. This provides information on influent quality, but also allows assessments of plant treatment efficiency through the treatment plant and of the overall plant efficiency.

2. Monitoring of wastewater quality within the sewerage system network.

Monitoring of wastewater influent quality can be carried out using manually collected grab samples or automated sampling equipment (to collect composite samples or systematic point in time samples). AS/NZS 5667/10 provides guidance on sampling of waste waters. Refer also to Chapter 14.

Both methods of sampling have disadvantages and no one single sampling method is always ideal. Grab sampling for influent quality has one significant drawback - the influent quality to treatment plants is highly variable and diurnally variable. The within-day variation arises mainly from the timing of different activities associated with sources delivering to the reticulation. As such, single grab samples taken at the same time of day may result in misleading information on influent quality (the inset box shows the variation during the day of the quality of wastewater entering the treatment plant). Such variation means that the calculation of constituent loads (e.g., BOD, suspended solids, phosphorus) based on grab samples of influent can be quite erroneous.

Example – Diurnal variation in zinc in wastewater discharged from the historic Moa Point wastewater outfall (zinc concentration in g m^{-3}).



Treatment plants typically compare measured influent quality with expected quality and loads based on standard equivalent person loads. If the measured load significantly exceeds the estimated loads then evaluation of known contributor loads may be required. Montgomery Watson (1999) reported that wastewater treatment plant operators at larger plants have found that influent loads often exceeded predictions. This is not surprising, as unknown additions will result in increases in loadings. If there are uncertainties in influent quality, or differences between estimated and measured loads are significant, it may be necessary to actively assess wastewater quality within the reticulation system. As is the case with influent quality assessment, different sampling may be required to answer different questions.

Sampling of average wastewater quality at key points in the network (e.g., branches) will provide information on sub-catchment contributions, which may narrow down the location of unidentified contributors. Grab sampling (or sequential auto-sampling) will assist in identifying intermittent contributors (e.g., of metals such as chromium, nickel and zinc). Investigations of network and influent quality assist in ensuring that the contributors to the treatment plant are well understood.

As identified above, the examination of influent composition is dependent upon the objectives of the monitoring. For the purposes of assessing treatment efficiency in relation to discharge quality, the monitored constituents should match those monitored in the discharge.

For the assessment of contributions from particular industries, some knowledge of the key constituents contributed by the particular industry is required.

Examination of the types of waste streams derived from commercial and industrial activities in the sewerage catchment provides the first means of assessing unusual contributions to the treatment plant. A range of waste streams have the potential to contain potentially hazardous constituents. Examples include:

- Inks, dyes, pigments, paints, lacquers and varnishes from a variety of commercial and industrial processes.
- Oil and oil-water mixes and emulsions, vegetable oils from garages, recycling depots and food manufacturers.
- Resins, latex, adhesives and glues from a variety of manufacturers.
- Photographic chemicals.
- Solvents used in a variety of industrial and commercial activities and processes.
- Animal and vegetable fats and waxes from animal and vegetable processing.
- A wide range of contaminants from industrial processes involving cleaning of tanks, traps, factory equipment and floors.

Table 9.1 provides a summary of the types of constituents that could be included in any influent or network monitoring programme involving particular industry/trade sectors or industries. A good source of information regarding what is in various waste streams entering treatment plants is the Ministry for the Environments "What's in your waste" web-site. The web site can be found at http://www.mfe.govt.nz. The site provides considerable information on likely contaminants in a wide range of industries classified by ANSIC categories.

Table 9.1: Examples of key influent monitoring parameters by contributing industry sector (for more detail refer to "What's in my waste" – www.mfe.govt.nz).

Industry	General	Organic	Nutrients	Metal	Other	Organic compounds
Meat works, rendering etc.,	SS	BOD,	N, P		NH_4-N, sulphides	
Dairy factories	pH	BOD	N, P		Biocides	
Vegetable processors	SS	BOD				
Food industry	pH	BOD			surfactants	
Brewers	pH					
Tanneries	SS, pH		Ammonia	Mn, Cr	Boron, sulphide	Solvents, various compounds
Metal finishing, electroplaters	pH			Cd, Cr, Ni, Zn	CN	
Dry cleaners					detergents	solvents
Photographers				Ag	Various inorganic compounds, CN	Various
Paint, printers etc.,		BOD		Various		Solvents
Battery manufacture	pH			Pb, Sb		
Textile	SS	BOD			Surfactants Sulphites, peroxides, chlorites, grease	Dyes, organic acids
Laundries					surfactants	

9.3 Trade waste management and trade waste by-laws

Most territorial authorities operating wastewater treatment plants in New Zealand receive some type of trade waste into their treatment plant. Accepting and removing hazardous constituents from wastewater entering a treatment plant has several implications to the Council or operator of the treatment plant. These are:

- Risk to the functioning of the treatment plant.
- Risk in terms of discharge of unknown hazardous constituents.
- Risk in terms of the quality of biosolids produced at the treatment plant.

Trade waste by-laws are the key mechanism that is used to manage the entry of trade wastes into wastewater treatment plants in New Zealand. Tonkin & Taylor (1998) identified that a survey of larger wastewater treatment plants in New Zealand (>20,000 m^3/day) showed that all operated under a trade waste by-law and that 55% of those had updated their trade waste by-law in relation to the 1995 model by-law. Montgomery Watson (1999) noted that it appeared that at that time about 20% of territorial authorities did not operate under trade waste by-laws.

Montgomery Watson (1999) noted that "*Proper management of WWTFs requires owners/operators to have a thorough knowledge of trade waste discharges to sewers and the issuing of trade waste permits by territorial local authorities is currently the only means of controlling the toxicant load arriving at the WWTF*".

9.4 Monitoring within the treatment plant

Monitoring within treatment plants is a treatment plant-specific matter (i.e., dependent upon treatment plant process, treatment components etc). Monitoring is typically carried out to provide information on within-plant treatment processes and the efficiency of treatment associated with different components at different points in the plant. These might include:

- Performance of clarifiers.
- Performance of an ultraviolet disinfection system.
- Performance of a maturation section within an oxidation pond.

This type of monitoring should be designed around specific objectives and must meet specific constituent/sampling requirements by a suitably trained person. Constituents, number of samples and method of sampling are the key considerations. Monitoring typically involves one or more of the following key groups of constituents shown in Table 9.2.

Table 9.2: Examples of key within-plant performance monitoring.

Constituent	Treatment Plant component
Microbiological removal	• Effectiveness of Ultraviolet or other disinfection units • Effectiveness of oxidation/maturation ponds
Suspended solids	• Operation of clarifiers, sand filters
Biological oxygen demand	• Effectiveness of digesters.
Dissolved reactive and total phosphorus	• Operation of biological nutrient removal (BNR) components of plant.
Ammoniacal-nitrogen	• Operation of oxidation ponds • Operation of BNR components of plant

CHAPTER 10
DISCHARGE MONITORING

Paul Kennedy, Jennifer Gadd (Kingett Mitchell Ltd)

10.1 Introduction

This chapter addresses the monitoring of discharges from the WWTP. The main focus is on selecting the 'traditional' characteristics to be monitored in the wastewater discharge. Some guidance is also given on choosing the monitoring frequency for each of these characteristics, although this is site-specific, and is addressed in more detail in Section 13.3.3.

Other discharge monitoring issues addressed include toxicity testing, mixing zones, sludge 'discharge', and air discharges.

Design of discharge monitoring must not be made in isolation of other monitoring (e.g., receiving environment monitoring). Before embarking on this chapter, reference must first be made to Chapter 8, regarding the conceptual design of the monitoring programme.

Further detailed guidance to discharge monitoring can also be found in the USEPA 'Permit Writers' Manual' (USEPA 1996), available on the web at www.epa.gov/owm/sectper.htm.

Structure of chapter

Section 10.2 provides a guide to selecting the discharge characteristics to be monitored, based on the outcomes of the risk analysis in Chapter 4.

Sections 10.3 to 10.6 address monitoring options for the traditional characteristics of the wastewater discharge, namely:

- Flow
- Physical characteristics
- Chemical characteristics
- Microbiological characteristics

Note that further details on these wastewater characteristics can be found in Section 5.2.

Section 10.7 provides guidance on determining the frequency of monitoring for the parameters described in Sections 10.3 to 10.6.

Sections 10.8 and 10.9 address toxicity testing and mixing zones, respectively.

Sections 10.10 and 10.11 briefly address monitoring of sewage sludge and air discharges, respectively.

A summary of the relevance of the range of constituents that can be monitored in a discharge is provided in Tables 10.A to 10.H, contained in Appendix 2.

10.2 What should be monitored in the wastewater discharge?

The parameters to be monitored in the wastewater discharge should be determined by the outcomes of the risk analysis process in Chapter 4. A ‘designation’ for appropriate resources will have been assigned to each characteristic of the wastewater in Worksheets A and B (Appendix 3). This designation provides a guide as to whether or not each of the wastewater characteristics requires monitoring, as set out in Table 10.1. Note that Table 10.1 relates to monitoring required under resource consent conditions. A larger range of monitoring parameters might be appropriate for investigative monitoring for a resource consent application, for example.

Table 10.1: Guide to choice of monitoring parameters in wastewater discharge, using risk analysis results from Chapter 4. Apply this guide to each of the wastewater characteristics listed in Worksheets A & B (Appendix 3).

Appropriate resources designation (from last column in Worksheets A & B)	Description of appropriate resources (as defined in Table F, Section 4.4)	Requirements for discharge monitoring for relevant characteristic
1	‘Detailed management plan and employment of dedicated resources’	Monitoring of characteristic definitely required, unless monitoring an alternative indicator will achieve same level of information.
2	‘Standard monitoring regime appropriate to the type of hazard, within capacity of normal level of resources’	Monitoring of characteristic probably required, but an indicator could be used if appropriate.
3	‘Incidental, implied from other monitored constituents or indicators’	Monitoring of characteristic probably not required, but monitoring an appropriate indicator should be considered.
None	Monitoring not appropriate	Monitoring of the characteristic not required.

Table 10.1 makes frequent reference to the use of indicators as options to monitoring a particular characteristic. The purpose of indicators is to provide a lower cost for routine monitoring that can be used instead of the actual characteristic of interest. Should a threshold be reached, the programme then defaults to a wider range of pre-defined constituents or a greater frequency, depending upon the programme. The most common example of an indicator is the use of indicator bacteria such as faecal coliforms or *E. coli* to

indicate the overall microbiological quality of the wastewater (i.e., the likelihood of the wastewater sample containing pathogens).

There are few widely recognised indicators used for routine wastewater discharge monitoring. However, it is possible to use one parameter to monitor for others if there is a relationship between their presence. For example:

- Suspended solids or turbidity to represent all particulate emissions (rather than both and/or volatile solids).
- Zinc to represent all metals in situations where only household sources of waste are involved (instead of copper, zinc, cadmium and lead).

Common sense needs to be used in the final selection of the monitoring parameters. For example, there are few monitoring programmes that would not require some form of indicator bacteria monitoring, in view of the universal concerns regarding public health issues for wastewater discharges.

Sections 10.3 to 10.7 provide details on each of the characteristics that can be monitored, and should be used to help confirm which characteristics to monitor. Further details are also contained in Section 5.2.

10.3 Flow monitoring

10.3.1 Why measure flow?

Flow is one of the most important parts of discharge monitoring. Flow needs to be measured to ensure that consent conditions on flow rate, volume and contaminant loadings are complied with. Flow and volume measurements are also used in combination with discharge quality data to calculate the loads of contaminants discharged into a waterbody. Consent authorities may specify limits as loads rather than concentrations. This is particularly the case for nutrients and persistent contaminants such as heavy metals, where the total amount discharged is more important environmentally than the concentration.

Dilution and dispersion calculations also require accurate discharge flows. Flow data can be used with discharge quality data to predict contaminant concentrations in the receiving environment.

Finally, flow monitoring data can be used to detect leaks from and inflows into the wastewater treatment system, when the inflow from the sewerage system is also measured. When discharge flows are less than the inflows, and cannot be accounted for by evaporation, there may be some loss to the ground (and potentially groundwater) or other leaks in the system. If discharge flows are consistently greater than flows in, this indicates further inputs such as rainwater or groundwater infiltration.

Daily flow should be measured for most wastewater discharges, as a minimum.

10.3.2 What do consent conditions typically require?

Resource consents almost always specify a maximum volume that can be discharged. For example:

At a rate of up to 18,600 m^3/day, seven days a week, 52 weeks a year.

The maximum discharge rate of treated effluent shall be 6m^3/s.

There is no standardised approach to identifying flow limitations within consent conditions granted by Regional Councils. Typically, the consent requires that daily records of flow through the treatment plant are maintained and that these are made available to the Regional Council that granted the consent, for the purposes of verifying that flow consent conditions are met.

10.3.3 How is flow measured?

Flow measurement of discharge at treatment plants may be required in open channels and within pipes. In open channels, flow is often measured by assessing flow through flumes or weirs and measuring the water level. Closed pipe measurements can be undertaken using a variety of methods. These include mechanical methods, magnetic flow meters, ultrasonic flow meters and acoustic meters. The inset box below provides some examples of the types of flow measurements devices used at some treatment plants in New Zealand.

Examples of flow measurement at treatment plants around New Zealand

Treatment Plant	Operating Council	Flow Measurement
Rosedale	North Shore City	Magflow, continuous recorder
Warkworth	Rodney District	Magflow, continuous recorder
Wellsford	Rodney District	Ultrasonic meter at the inflow
Omaha	Rodney District	Propeller flow meter, counter on top
Ngaruawahia	Waikato District	Magflow, continuous recorder
Hamilton	Hamilton City	Was a Wesmar flow meter Now Magflow, continuous recorder, between 1° and 2° plants.

10.4 Physical characteristics

To avoid repetition, the reader is referred to the description of the various wastewater characteristics in Chapter 5. The comments below relate more to the relevance of these characteristics to discharge monitoring.

10.4.1 Temperature

Increases in temperature can have a range of effects in receiving waters, as discussed in Chapter 11. Temperature is easily measured in situ with a thermometer or thermistor, sometimes combined with meters that measure oxygen or conductivity. Because of its ease of measurement, temperature monitoring is commonly monitored in discharges, particularly where there are significant trade waste inputs. However, in most treatment plants the discharge has a temperature similar to the receiving environment and as such it is not a critical monitoring parameter. Temperature influences mixing properties when wastewater discharges to coastal waters.

10.4.2 pH

pH is an important characteristic, as it affects chemical reactions and toxicity of ammonia, sulphide and most metals. As such it is a key monitoring parameter.

10.4.3 Particulates (suspended solids, turbidity)

Particulates can be measured directly by weight of particulate matter in water, or indirectly as turbidity or clarity. Suspended solids is a relatively inexpensive test that provides a useful indication of overall wastewater quality, and hence should be included in most monitoring programmes.

10.4.4 Colour and clarity

MfE (1994a) provides information on the optical characteristics of wastewaters. Colour is rarely measured for treatment plant discharges, although guidance is given in MfE (1994a) on predicting the likely impacts on receiving waters, e.g., by measuring light absorbance of the effluent using a spectrophotometer.

Clarity can be assessed indirectly through measurement of suspended solids or turbidity (Section 10.4.3). The effects of the discharge on receiving water clarity can also be predicted by measuring the clarity of diluted effluent (refer to MfE 1994a). Measurement of both colour and clarity is discussed in more detail in Section 11.4.2 (page 114).

10.4.4 Electrical conductivity

Electrical conductivity indicates the amount of dissolved ions in a water sample. It can be used as a very general (and inexpensive) indicator of water quality, as it reflects the combined effects of dissolved constituents. However, conductivity is not a critical measurement in terms of environmental effects.

10.4.5 Alkalinity and hardness

Alkalinity is the acid-neutralising capacity of a water sample. It is typically reported as the concentration of $CaCO_3$. Hardness refers to the amount of calcium and magnesium in the water. Hardness information of discharges to freshwaters may be required if toxicity of dissolved metals in the discharge is being assessed.

10.5 Chemical characteristics

There is a wide range of chemical constituents present in wastewater, as discussed in Chapter 5. However, monitoring all constituents in wastewater is rarely necessary, as many parameters are not environmentally relevant. This section identifies chemical parameters that can be monitored in wastewater discharges and why they would be included in a monitoring programme.

10.5.1 Oxygen demand (BOD and COD)

Five day biochemical oxygen demand (BOD_5) is a common monitoring requirement for consent conditions, although this should depend on the type of receiving environment. BOD_5 is an empirical test that measures the oxygen utilised during a specific incubation period for the biochemical degradation of organic material and the oxygen consumed by the oxidation of reduced inorganic constituents in the wastewater such as sulphides and ferrous iron.

Oxygen demand is also exerted by reduced forms of nitrogen in the wastewater when mediated by micro organisms. Many biological treatment plants contain these types of nitrifying organisms and they can oxidise nitrogenous compounds in a wastewater sample collected in the plant or downstream. This increases the BOD. Adding an inhibitory chemical can inhibit this interference and the BOD measured is reported as carbonaceous BOD, or $cBOD_5$.

Chemical oxygen demand (COD) is another measure of oxygen demand. COD represents the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. COD can be related to BOD or other constituents such as total organic carbon in a particular discharge through analysis of paired samples.

Typically BOD is measured as a gauge of potential oxygen demand in wastewater discharges. In some situations it may also be important to measure the soluble BOD to determine the proportion of BOD attributable to particulate matter in the wastewater. High particulate BOD has the potential to increase benthic oxygen demand in streams or coastal sediments where it is deposited (leading to anaerobic conditions in sediments and in smaller waterways). BOD monitoring typically becomes more important in discharges to smaller freshwater streams and rivers.

10.5.2 Fats, oils and greases

Fats, oils and greases discharged in large quantities with the final effluent can result in surface slicks that are obvious to the public. Aquatic biota can also be adversely affected. Where primary processing industries such as abattoirs or fellmongeries discharge to the sewer, these compounds should normally be monitored in the discharge.

10.5.3 Nutrients and ammonia

Nitrogen is mainly found in two forms in wastewater discharges; as ammoniacal nitrogen (NH_4-N) and as organic nitrogen, in the form of amino acids and within particulate matter. In most situations it is best to measure both forms, by measuring TKN (total kjeldahl nitrogen – a measure of organic nitrogen plus NH_4-N) and NH_4-N. If cost is an important issue, consideration could be given to measuring NH_4-N only. Nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N) should also be monitored if these forms are likely to be present in high concentrations in the discharge (most analytical methods measure nitrate plus nitrite simultaneously).

Phosphorus is present in wastewaters as phosphate (PO_4^{3-}); either dissolved (dissolved reactive phosphorus, DRP) or within particulate matter (total phosphorus, TP). It is best to measure both forms if possible. DRP is the best indicator for short term effects on receiving waters, while TP gives a better indication of long term loads on the environment.

Identification of the need to monitor particular forms of nitrogen and phosphorus will depend upon the nutrient sensitivity of the receiving environment.

10.5.4 Cations and anions

There are a range of general cations and anions that are present in treated wastewater. Table 10.2 provides a summary of the key anions and cations. Many are insignificant, as they are either environmentally benign and present at low concentrations in the wastewater (e.g., K^+) or are present in high concentration in the receiving water (e.g., B, Na^+ and Cl^- in coastal waters).

Table 10.2: Summary of cations and anions commonly found in wastewater, and their relevance for monitoring.

	Significance of Environmental effects/ environmental relevance	Measure in wastewater discharging to:	
		Freshwater receiving environment	Marine receiving environment
Anions			
Fluoride (F^-)	Insignificant	No	No
Chloride (Cl^-)	Insignificant	No	No
Bromide (Br^-)	Insignificant	No	No
Sulphate (SO_4^{2-})	Moderate	Possibly	No
Carbonate (CO_3^{2-})	Moderate	Rarely	No
Bicarbonate (HCO^{3-})	Moderate	Rarely	No
Cations			
Sodium (Na^+)	Insignificant[1]	No	No
Potassium (K^+)	Insignificant	No	No
Magnesium	Moderate	Rarely	No

(Mg^{2+})			
Calcium (Ca^{2+})	Moderate	Rarely	No

[1]except for land disposal

10.5.5 Metal contaminants

Metals (e.g., lead, copper) and semi-metallic elements (e.g., arsenic) are present in wastewaters from domestic and industrial sources. In fact, there are suggestions that the domestic sources of some elements (e.g., copper) are more important than the industrial sources, and so even small WWTPs treating small communities may have significant amounts of metals in the wastewater effluent. During wastewater treatment, a proportion of the metals will settle into the sludge. However, some will remain in the liquid effluent, depending on the treatment processes and the characteristics of the individual elements.

Many of the metals found in wastewater effluents are toxic to aquatic organisms, depending on the concentration. ANZECC (2000a) and USEPA (1999b) provide guideline concentrations for toxicity of individual metals in aquatic environments. Table 10.3 provides a summary of metals in wastewater and their significance in fresh and coastal waters.

Although a number of the metals listed in Table 10.3 are likely to be present in toxic concentrations in the discharge (copper, lead, zinc and nickel), this does not mean that these metals always need to be monitored. Whether monitoring is required (and whether dissolved or total metal concentrations are measured) will often depend on the nature of the receiving environment, and in particular the level of dilution.

Table 10.3: Summary of metals found in wastewater and their relevance for monitoring.

Metal or metalloid	Likelihood of presence in wastewater at toxic concentrations[1]	Measure in wastewater discharging to:	
		Freshwater receiving environment	Marine receiving environment
Aluminium	Possibly	Rarely	Rarely
Antimony	Unlikely	No	No
Arsenic	Unlikely	Rarely	Rarely
Beryllium	Extremely Unlikely	No	No
Bismuth	Extremely Unlikely	No	No
Boron	Possibly	Rarely	No
Cadmium	Possibly	Possibly	Possibly
Caesium	Extremely Unlikely	No	No
Chromium	Possibly	Possibly	Possibly
Cobalt	Unlikely	No	No
Copper	Likely	Probably	Probably
Gold	Extremely Unlikely	No	No
Iron	Unlikely	Rarely	No
Lanthanum	Extremely Unlikely	No	No
Lead	Likely	Possibly	Possibly
Lithium	Extremely Unlikely	No	No
Manganese	Unlikely	Rarely	No
Mercury	Possibly	Possibly	Possibly
Molybdenum	Extremely Unlikely	No	No
Nickel	Likely	Possibly	Possibly
Rubidium	Extremely Unlikely	No	No
Selenium	Unlikely	No	No
Strontium	Extremely Unlikely	No	No
Thallium	Extremely Unlikely	No	No
Tin	Unlikely	Rarely	Rarely
Uranium	Extremely Unlikely	No	No
Vanadium	Unlikely	No	No
Zinc	Likely	Probably	Probably

[1]The likelihood of these elements is obviously dependent on the types of trade waste inputs to the wastewater stream.

10.5.6 Persistent organic pollutants (POPs)

POPs (refer to description in Section 5.2.11) are currently not routinely monitored in wastewaters in New Zealand, but there may be situations where occasional screening tests should be performed where the risk analysis process has identified potential sources (e.g., industry).

The inset box on the following page provides further information on the complex nature of trace organics in wastewater, and in particular provides comments on endocrine disrupters.

Trace organic compounds in wastewater

Our society uses a vast array of materials and chemical compounds in its everyday life. Many of these end up in the wastewater system through use by industry, use in the home through cleaning and by being washed off our bodies during bathing and showering. In recent years there has been increasing focus on one specific group of substances which are referred to as 'endocrine disrupting substances' (EDS). The USEPA has identified a wide range of organic compounds (e.g., polychlorinated biphenyls, organochlorine insecticides, polyaromatic hydrocarbons and others) as priority pollutants. Stubin et al. (1996) provided a summary of the detection of organic priority pollutants in New York wastewater up to 1993. This list of chemicals has not changed substantially over the last decade but our awareness of the significance of persistent organic pollutants (POPs) has. This is evident by the extensive work undertaken on organochlorine chemicals in the New Zealand environment by the Ministry for the Environment (see http://www.mfe.govt.nz/issues/waste/organochlorines/organo.htm)

EDS are "exogenous substances that cause adverse health effects in an intact organism, or its progeny, consequent to changes in endocrine function". A potential EDS is "a substance that possesses properties that might lead to endocrine disruption in an intact organism" (EUR 1996 in Olsson et al. 1998). Persistent organic pollutants have been identified as potential EDS for many years. Their key effect lies in their interaction with hormone receptors, transport proteins, have toxic effects on gonads, the hypothalamus, the pituitary or endocrine glands (Olsson et al. 1998). Olsson et al. (1998) describe a wide range of global EDS effects. The authors also provide background information on a number of key groups of organic chemicals that are implicated as EDS. These include the range of organochlorine compounds, polybrominated diphenyl ethers, polychlorinated diphenyl ethers, chlorinated paraffins, halogenated phenols, polychlorinated naphthalene's, alkyl phenols, phthalates, bisphenol A, tetrabromobisphenol A amongst others.

EDS are not sourced just from industrial sources. Boronti et al. (2000) examined the presence of a number of EDS in Italian wastewater treatment plants. Treatment plants where the contribution was predominantly domestic in origin were identified as contributors of EDS. Ternes et al. (1999) and Johnson & Sumpter (2001) reviewed the effectiveness of treatment works at removing EDS. Field data indicates that the activated sludge treatment process consistently removes over 85% of compounds such as estradiol, estriol and ethinylestradiol. Compounds such as alkylphenol accumulate in sludge because of its hydrophobicity. Some EDS are removed through the action of micro-organims in the treatment process. The estrogenic alkylphenols and steroid estrogens in treated wastewater are the incomplete breakdown products of their parent compounds.

Surfactants are an important group of compounds entering treatment plants. Alkylphenol polyethoxylates (APE) are important non-ionic surfactants. Activated sludge plants effectively remove it from the waste stream. However during the treatment process incomplete biodegradation releases products into the wastewater that are released to the environment in the discharge. The breakdown products include compounds such as nonylphenol and short chained ethoxylates. These compounds are hydrophobic and tend to increase in concentration through the treatment plant to discharge.

There have been a number of studies undertaken to show the significant range of human-derived compounds in the wastewater entering treatment plants. These include early work by authors including Shiraishi et al. (1985) who examined organic compounds in wastewater from a Japanese treatment plant. That study identified a range of halogenated organic compounds and alkylphenyl compounds amongst others. Paxeus (1996), Paxeus & Schroder (1996) and Hirsch et al. (1999) reported on organic compounds and antibiotics in municipal wastewater in Europe. The former authors identified over 50 organic compounds in influent and effluent (alcohols, ethers, acids and esters, dioxanes and dioxolanes, odorants (e.g., citronellol, terpinolene), nitrogen and phosphorus containing compounds, phenols and ketones. The fate of the compounds identified differed significantly depending upon their properties (e.g., volatilisation, octonol/carbon partition coefficient etc,.,). Compounds such as perfume additives (including polycyclic musks used in household fragrances, cleaners etc. - refer Verbruggen et al. 1999), washing powders, cleaning agents and solvents are significantly removed through volatilisation; partial removal of less volatile compounds occurs (e.g., benzothiazole, dimethyl-quinine etc.). Overviews of the processes involved/contributing to the fate of organic compounds in treatment plants can be found in references such as WPCF (1990).

The complexity of the nature of organic chemicals in treatment plant wastewaters is illustrated well through the presence of a large range of man-made drugs/pharmaceuticals in wastewater (used for both humans and animals). Klummerer.(2001) provides a review of drugs, antibiotics (e.g., ibruprofen – see also Stumpf et al. 1999), anaesthetics, disinfectants, x-ray contrast chemicals and also the trace elements such platinum, gadolinium and osmium etc., which are used in a variety of medical procedures. Further information can be found in EU (2001)

10.6 Microbiological characteristics

Public health protection is one of the key reasons that wastewater discharges are monitored. There are a wide variety of potentially disease-causing organisms (i.e., pathogens) in wastewater. These pathogens fall into three major groups: bacterial (*e.g., Campylobacter*, *Salmonella*, *Yersinia*, enteropathogenic *E. coli)*, viral (e.g., poliovirus, hepatitis A, coxsachievirus, echovirus, human calicivirus, reovirus, adenovirus), and protozoan (e.g., *Giardia*, *Cryptosporidium*). The actual organisms present is dependent upon the prevalence or the incidence of disease within the community.

Most resource consents for wastewater discharges specify conditions that limit the concentration of indicator bacteria in the final effluent. Most consents also require the final effluent to be monitored for the indicator bacteria.

10.6.1 Indicator bacteria

Indicator bacteria have been used for many years as a relatively inexpensive means of assessing human health risks for recreational waters. Indicator bacteria themselves are generally not disease-causing, but they are found in large numbers in the gut of warm-blooded animals, including people; hence their usefulness as indicators of faecal pollution. If indicator bacteria are used, the appropriate types to use are as follows:

- *Escherichia coli* (*E. coli*)for fresh waters.
- Enterococci for contact recreation in marine waters (including estuaries).
- Faecal coliforms for marine shellfish-gathering waters.

Although a useful monitoring tool, it must be recognised that indicator bacteria have some significant weaknesses as indicators of risk to human health. In some circumstances indicator organisms may not reflect the risk from pathogens, e.g.:

- If the treatment system removes indicator bacteria in preference to viruses and protozoa (e.g., chlorination). The relationship between indicator bacteria and pathogens should be established for the effluent discharge if possible.
- If there is an outbreak of disease in the community (e.g. virus) the increased concentration of viruses may not be reflected by an increased concentration of the indicator bacteria, which generally occur at fairly consistent concentrations.
- Where the water quality of the receiving water is greatly influenced by faecal point source.

Under these circumstances pathogens should be considered (Section 10.6.2).

10.6.2 Pathogens

Testing can be carried out for a range of pathogenic organisms, depending upon the specific need of the testing programme. Three groups of organisms may be included in monitoring. These are:

- Protozoans such as *Giardia* and *Cryptosporidium*.
- Viruses such as human enteric viruses.
- Bacterial pathogens such as *Salmonella* and *Campylobacter*.

However, there are a number of problems with monitoring such pathogens, especially for small community WWTPs. For example, the pathogens may only be present in the wastewater when there is a disease outbreak in the community – thus a non-detect result might not provide a true indication of the potential risk to the receiving environment. Also there are considerable costs involved in analysing for pathogens. Before embarking on monitoring pathogens, specialist site-specific advice should be sought (often this is available from laboratories specialising in pathogen analyses). It is usually worthwhile monitoring indicator bacteria in conjunction with any pathogen monitoring.

10.7 Monitoring frequency

Table 10.4 provides guidance on the appropriate monitoring frequency for the characteristics discussed in Sections 10.3 to 10.6. However, required monitoring frequency varies on a case-by-case basis, and depends on a number of factors, not all of which are obvious. Monitoring frequency should not be confirmed until after consulting Section 13.3.3, ‘Selection of sampling sites and sampling frequency’.

Table 10.4: Guide to monitoring frequency for various discharge characteristics. Refer also to Section 13.3.3. Note that characteristics to be monitored should be determined *before* consulting this table.

Parameter	Appropriate resources designation (from Worksheets A & B)		
	3	**2**	**1**
Temperature	Nil – weekly	Weekly - daily	Daily – continuously
pH	Nil – monthly	Weekly – daily	Daily – continuously
Total suspended solids	Monthly – fortnightly	Fortnightly – weekly	Daily
Turbidity	Monthly	Fortnightly – weekly	Daily
Volatile suspended solids	–	Nil to Annually	Quarterly
Biochemical Oxygen Demand	Monthly	Fortnightly – weekly	Weekly – daily
Chemical Oxygen Demand	Nil – monthly	Monthly – weekly	Weekly – daily
Foam & Scum	Daily checks	Daily checks	Daily checks
Fats, oils and greases	Nil – monthly	Monthly – weekly	Weekly – daily
Total Nitrogen or TKN	Quarterly	Monthly	Weekly
Ammoniacal–N	Quarterly – monthly	Monthly – weekly	Weekly – daily
Nitrate–N & Nitrite–N	Nil – quarterly	Quarterly – monthly	Weekly
Total Phosphorus	Quarterly	Monthly	Weekly
Dissolved Reactive Phosphorus	Nil – quarterly	Quarterly – monthly	Weekly
E. coli, enterococci, &/or faecal coliforms	Monthly	Weekly	Daily
Pathogens	–	Quarterly	Monthly - weekly
Cd, Cu, Ni, Pb, Zn	Nil – annually	Annually – quarterly	Quarterly - monthly
Hg, As, Ag, Cr	–	Annually	Quarterly
Hardness or Alkalinity	–	Annually	Quarterly
POPs	–	Annually	Quarterly

– = Non-routine monitoring. However, monitoring may be required during extreme events such as low flows in receiving environments, accidental overflows or for resource consent applications etc.

10.8 Toxicity monitoring

10.8.1 Why carry out toxicity testing?

Comparison of contaminant concentrations in discharged wastewater with receiving environment guidelines (after mixing) does not always provide a clear indication of the potential for adverse effects. Toxicity to biota in the receiving environment may arise due to a *combination* of contaminants in discharged wastewater. Toxicity testing of wastewater provides a means of looking at the combined effects of the wastewater on biota. A number of councils (e.g., Hastings District Council) undertake toxicity testing as a requirement of current discharge consents. Toxicity testing can comprise Whole Effluent Toxicity (WET) testing or Direct Toxicity Assessment (DTA). WET testing is now fairly commonplace in New Zealand, but DTA is much less common at present.

10.8.2 Whole Effluent Toxicity (WET) Testing

WET testing has been used in New Zealand since the mid 1980's, initially using species imported from overseas or using New Zealand species with protocols developed for similar species overseas (Hickey 1995). A WET test measures the response of a test organism to the wastewater, or dilutions of it, under controlled laboratory conditions. The response of the organism in the test is measured using a defined 'endpoint'. The endpoints typically involve effects on reproduction, growth and survival.

WET tests can be carried out using dilution series to assess the response, using a range of statistical measures. Examples include the no observable effects concentration (NOEC), the lowest observed effect concentration (LOEC), the EC_{50} (the concentration affecting 50% of the test organisms) and the LC_{50} (the concentration causing mortality to 50% of the test organisms).

Most tests undertaken are acute tests because they are short term (48 or 96 hour). Chronic tests are typically longer, as they measure well-being in terms of factors such as reproductive success. Chronic tests form the toxicity basis for water quality guidelines derived in the ANZECC (2000a) water quality guidelines.

Testing used in New Zealand follows procedures based upon international standards (e.g., those of ASTM, APHA and USEPA). Tests may be undertaken using internationally recognised benchmark species or native species for which test protocols have been developed. ANZECC (2000a) recommends running tests using an invertebrate, vertebrate and a plant to identify the most sensitive species for developing WET permit limits or testing requirements.

For effective use of WET testing as conditions on resource consents, it is important to have available a set of standardised protocols with native species that can be used throughout New Zealand for routine testing. Reference should be made to 'Standard Methods for Whole Effluent Toxicity Testing: Development and Application' (Hall and Golding 1998).

A tiered approach is recommended for implementation of effluent toxicity monitoring programmes (Table 10.5). The type of assessment regime follows a risk-based approach that is influenced by the nature of the discharge and the risk level in the receiving environment. Factors that influence the risk level include: available effluent dilution, diversity of valued native species and the presence of culturally sensitive species. Together, these factors will dictate both the type and frequency of testing undertaken.

Table 10.5: Selection of toxicity test types and applications (after Martin et al. 1998).

Type of assessment	Species Selection	Applications/risk level
Effluent Screening	• 1-3 'benchmark' species • acute endpoints • 1 sample • toxicity present/absent	• Preliminary investigations
Definitive Testing	• 3 species • acute and chronic tests • possibly native species • 1 or more samples	• Consent applications • Consent monitoring • Process efficiency • Effluent characterisation • Low risk environment • Large dilution factor and mixing zone • Includes some chemical analysis
Site-specific Investigations	• Multiple species • Native species • Acute and chronic tests • Multiple sampling dates	• Consent applications • High risk fragile environment • Low dilution and small mixing zones • Extensive concurrent chemical analyses • Biological monitoring of receiving site (s)

To carry out effective toxicity testing of wastewater, it is recommended that multiple indicator species be used (USEPA 1991, ANZECC 2000a). A first priority is to test diverse types of organisms, using a battery of standardized methods and associated organisms (e.g., microbes, plants, terrestrial and/or aquatic invertebrates, and fish). Beyond that, suitable local species might be used if site-specific information is required, but parallel tests with a standard species should also be done. The standard species used in routine toxicity assessment programmes are limited in number, but now represent a broad spectrum of types of organisms, including native species (Hall and Golding 1998; Hickey 2000). Studies with reference toxicants (e.g., ammonia, zinc) have enabled the sensitivity of native species to be established and compared with international species used for guideline derivation (Hickey 2000).

Standard test species should be chosen for their adaptability to laboratory conditions, and also as representatives of sensitive species in the environment. More methods are becoming available for smaller organisms with short life cycles, allowing tests of reproductive performance within a reasonable time.

Information on the likely chemical nature of the effluent may be useful in choosing the test species. For example, while cladocerans are sensitive to metals, they have low sensitivity to ammonia. Amphipods may be more suitable species for detection of ammonia toxicity.

Freshwater toxicity testing is typically carried out using organisms such as water fleas (*Daphnia carinata* and *D. magna*), which are common in lakes and ponds, and the green alga *Selenastrum capricornutum*. These species are sensitive to many toxicants and are used internationally in toxicity tests. Daphnia are commonly used for chronic tests in which reproductive success is measured (the number of young produced).

Marine toxicity testing in New Zealand typically involves testing with species such as micro-organisms (bacteria and alga) and invertebrates such as amphipods (*Chaetocorophium* sp.), sand dollar embryos, and Pacific oyster larvae.

Once the toxicity of the discharge has been established using a suite of WET tests, any future monitoring programmes could revert to testing using fewer species based on measured sensitivity. For this role, a sufficiently sensitive standard species might be used as a surrogate for protection of the local community. For example, rainbow trout might be used as a surrogate for the protection of native New Zealand fish species, since they are generally more sensitive to toxicants.

> Example: Hastings District Council undertake toxicity assessment at a 1:200 dilution (the compliance receiving water dilution at the Hastings outfall) using alga, Microtox™, and sand dollar embryo. Compliance is assessed by determining the threshold effects concentration (TEC) value for each of the test species used. The TEC is the geometric mean of the no observed effect concentration (NOEC) and the lowest observed effects concentration (LOEC).

Toxicity testing can be followed up if required with toxicity identification evaluation (TIE) to try to identify the cause of the observed toxicity.

10.8.3 Direct toxicity assessment

Direct toxicity assessment (DTA) involves measuring the toxicity of receiving water samples, or testing in the receiving environment itself, as opposed to testing in dilutions of the wastewater. This approach is described in ANZECC (2000a).

10.8.4 Conditions modifying toxicity

Ambient conditions and biotic factors can modify the effects of toxicants in nature. These modifiers must be taken into account when extrapolating results of toxicity tests to the field.

The major physicochemical factors influencing toxicity in aquatic environments are temperature, pH, light, hardness, and dissolved and suspended organic matter. pH is probably the most important physicochemical modifier, especially for metals, but also for ammonia, hydrogen sulphide and other ionisable substances for which the undissociated form is more toxic. Higher temperature often increases toxicity, but this is not universal. Light can degrade toxicants or, for some PAHs, stimulate higher potency.

Oxidation-reduction potential is important in sediments, where toxic forms of substances often prevail under reduced conditions (anoxia). Hard water decreases the toxicity of most metals. Organic matter can adsorb and reduce the toxicity of some substances, whether the organic matter is dissolved, suspended, or a component of sediment or soil.

Important biotic modifiers include organism behaviour, life cycles, body size, nutrition, adaptation, interactions between species and the possibility of multiple stressors. Behaviour of toxicant-exposed organisms can be important, especially avoidance reactions. Early life stages in plants and animals generally include the most sensitive stages, which is the main reason they are used in toxicity tests. Aside from that, body size has a variable role in tolerance of toxicants. Poor-quality nutrition can increase toxic effects. Adaptation to toxicants generally increases tolerance two- or three-fold.

Multiple sources of stress can combine in the organism to make it more sensitive. Stressors could include adverse natural conditions such as high temperature, human activities such as dredging, or the presence of toxic substances.

10.9 Mixing zone characterisation

When discharges to receiving environments occur, the nature of the receiving environment determines the fate of the wastewater discharged and therefore the effects that might arise from the discharge. Understanding the physical properties of the treatment plant discharge (the structure and manner of discharge) and the nature of the initial mixing zone provides valuable information for determining whether the discharge has potential to have effects. To assist in determining what monitoring should be undertaken on the discharge, two key approaches to understanding the discharge environment are noted briefly below. These are described more fully in Chapter 11 (receiving environment monitoring). See also Rutherford et al. (1992).

Modelling

Initial dilution from discharges can be predicted using computer models (see Williams 1985). Hydrodynamic models such as the USEPA model CORMIX version 3.0 (Cornell Mixing Zone Expert System, Jerka et al. 1996) can be used to examine and predict the fate of pollutants discharged into water bodies such as rivers, lakes and the sea. The main focus of the model is on the nature of the initial mixing zone around the discharge point. Output from the model in relation to initial mixing can be used to assist in justifying the need for particular parameters within the discharge monitoring programme where water column chemistry, toxicity or other issues are at question. It should be noted that if other concerns exist (e.g., benthic bioaccumulation, total loading conditions on consent), then there may still be a need for discharge monitoring of a particular constituent.

Use of field measurements to assess dispersion and dilution

Information can be obtained from field studies of the environment around the discharge point. Basic physical information can assist in assessing the nature of the likely dispersion and dilution of discharged wastewater. Information can also be collected on water column physical and chemical properties and quality that also provides information on the nature of dispersion and dilution. Techniques include measurement of conductivity (salinity), temperature, water depth, and current velocity.

Use of dye to assess dilution

Dye can be injected into discharge outfalls (e.g., at the final pump station) at a known rate. A field fluorometer is used to detect the concentration of dye and the dilution calculated for the sampling point. With multiple measurement, the dispersion of the dye can be examined.

10.10 Monitoring of sewage sludge quality (biosolids)

Monitoring requirements for biosolids are addressed in the NZWERF Biosolids guidelines, so are only covered briefly in this section. Reference should be made to the Biosolids guidelines for monitoring requirements.

The main reason that biosolids should be monitored is to safeguard public and environmental health. If biosolids are being removed from the WWTP to a disposal site, or for beneficial use, the biosolids have the potential to come into contact with people, plants and animals. As biosolids contain pathogens, there is potential for this contact to result in disease or illness.

Biosolids can also contain inorganic contaminants such as heavy metals and toxic organic compounds. Typically 50-95% of the metals in sewage are removed during treatment and are deposited with the biosolids. The chemical and biological characteristics of biosolids depend on the composition of the wastewater entering the WWTP and the treatment processes. Elevated concentrations of metals or toxic organics in sludge may have implications for its use and disposal. Some sludges from WWTPs treating large amounts of industrial waste may be classed as hazardous waste, whereas other sludges have beneficial uses.

10.11 Monitoring of discharges to air (odour, aerosols)

10.11.1 Why monitor air quality?

Wastewater treatment facilities commonly discharge to air in the form of odour and aerosols. WWTPs with oxidation ponds and aeration lagoons can be particularly odorous if poorly managed. Odour can be obnoxious to WWTP neighbours. Any process at WWTPs involving aeration facilities have the potential to generate aerosols that can be distributed within the site (requiring consideration of worker health and safety) and beyond the site boundary.

10.11.2 Monitoring of pathogens

Assessment of airborne pathogens requires collection of air samples for testing. This is carried out by obtaining samples of a known volume of air in a downwind direction from the source under scrutiny (e.g., oxidation pond, aeration lagoon) and testing for indicator bacteria (usually faecal coliforms) to see whether bacteria are being transported with water droplets derived from the activity on-site.

Monitoring of airborne pathogens is a specialist field, and is beyond the scope of these Guidelines.

10.11.3 Assessment of odour

Odour emissions from WWTPs are complex in nature. Odour is derived from a variety of sources within treatment plants. These include inlet chambers, open transport channels, weirs and drop structures, trickling filters, aerated lagoon and other aerated ponds, non-aerated ponds and sludge stockpiles and ponds.

Due to the sensitivities of the human olfactory system, odour associated with many compounds is detectable at very low concentrations. Assessment of odour generated at WWTPs is a complex subject due primarily to the variation in sensitivity to odours of different people (Van Harreveld 2001, Sucker et al. 2001).

MfE (1994b) and NZWWA (2000) discuss the measurement and management of odours at WWTPs. Typically, odour in WWTP resource consents is limited in terms of its potential effects on a geographical basis. Usually this is achieved through the inclusion in the treatment plant's discharge to air permit of a condition requiring "no odour beyond the boundary of the treatment plant". An example of such a condition is:

"There shall be no discharges to air from any facility at the wastewater treatment plant that are noxious, dangerous or offensive or objectionable at or beyond the boundary of that land owned by the permit holder."

The identification and confirmation of a breach in this consent condition is often achieved through the opinion of an officer of the Regional Council.

However, apart from the identification of off-site odours it is often necessary to monitor components of the treatment plant that contribute to the overall odour generated. On-site odour monitoring can be carried out in three main ways. The first is the use of human olfactory assessment (using individuals such as Council staff to make observations as to the nature of odour or using human panels and olfactometers). The second is using chemical compound specific monitoring/measuring devices, and the third is through the use of electrochemical measures of odour.

Jiang (2001) reviewed sampling methods for odour, including sampling of point sources (using isokinetic sampling) and sampling of area sources using isolation chambers (flux hoods – these were used to determine odour from point sources at the Mangere treatment plant), and portable wind tunnels. Both methods are used in Australia for collecting samples for measuring odour emission rates from area sources (Jiang 2001).

Nimmermark (2001) reviewed the use of 'electronic noses' for the detection of odour. Electronic noses are capable of detecting some compounds at concentrations in air lower than human noses are able. However, a number of compounds that are offensive to the human nose are not detected. Nimmermark (2001) summarises the available equipment on the market as at March 2001.

CHAPTER 11
MONITORING RECEIVING ENVIRONMENT EFFECTS

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11.1 Introduction

11.1.1 Why monitor the receiving environment?

The purpose of this chapter is to describe a range of options commonly used in monitoring wastewater effects on the receiving environment so that those involved in setting consent monitoring conditions, or designing receiving environment surveys, can avoid some of the common pitfalls. Monitoring receiving environment effects will usually be carried out to fulfil conditions stipulated in a resource consent, or less commonly, in response to triggers such as a significant deterioration in effluent or receiving water quality. Resource consent monitoring conditions are usually imposed where there are concerns about actual or perceived impacts, for example effects on ecological values or human health. These concerns may arise because:

- Adverse impacts have already been documented, and it is necessary to check that receiving environment quality doesn't deteriorate.
- There is uncertainty regarding the nature and severity of impacts – for example, in the case of a new discharge.
- Existing monitoring data indicates water and/or sediment quality criteria have been exceeded.
- There is recognition that the level of impact may change over time, because of changes in the nature of the discharge or the characteristics of the receiving environment. For example, a river may experience an extended and unprecedented low flow period, making it more vulnerable to discharge impacts.

Not all discharges will require receiving environment monitoring. The extent of routine monitoring required for a discharge consent is often not as comprehensive as that of an Assessment of Environmental Effects (AEE), and where it has been convincingly demonstrated that actual and potential receiving environment effects are negligible, it is often appropriate not to impose any receiving environment monitoring conditions.

Cumulative environmental change is another issue often addressed by effects monitoring. This could be a cumulative temporal effect, for example a build-up of wastewater contaminants in sediments around an outfall following many years of discharge; or cumulative spatial effects, where ambient environmental quality deteriorates because of the occurrence of other diffuse or point source discharges that affect the same receiving environment.

11.1.2 How is the HIAMP process used?

It is more difficult to provide a direct link between the risk analysis process in Chapter 4 and receiving environment monitoring, because of the complex nature of receiving environment monitoring. However, the outputs of the risk analysis process in Chapter 4 (i.e., the 'appropriate resources' designations summarised in Worksheets A and B) should be used to help judge the appropriate scale of receiving environment monitoring. Table 11.1 provides a guide as to whether or not the various wastewater characteristics require monitoring in the receiving environment.

Table 11.1: Guide to choice of monitoring parameters in the receiving environment, using risk analysis results from Chapter 4. Apply this guide to each of the wastewater characteristics listed in Worksheets A & B (Appendix 3).

Appropriate resources designation (from last column in Worksheets A & B)	Description of appropriate resources (as defined in Table F, Section 4.4)	Requirements for receiving environment monitoring for relevant characteristic
1	'Detailed management plan and employment of dedicated resources'	Monitoring of characteristic probably required.
2	'Standard monitoring regime appropriate to the type of hazard, within capacity of normal level of resources'	Monitoring of characteristic should be considered. Use an indicator if appropriate.
3	'Incidental, implied from other monitored constituents or indicators'	Monitoring of characteristic not required unless unusual circumstances prevail.
None	Monitoring not appropriate	Monitoring of the characteristic not required.

This chapter builds on previous chapters, specifically Chapter 6 (characterising the receiving environment) and Chapter 10 (discharge monitoring). The discussion focuses almost exclusively on discharges to aquatic environments, which represent the vast majority of wastewater discharges in New Zealand (MacDonald et al. 2001), but considerations for discharge to air and land are also addressed briefly at the end of this Chapter.

The general hazard categories listed in the HIAMP worksheet(s) and their relationship to the section(s) within this Chapter are listed in Table 11.2. Reference should also be made to Chapter 8, regarding the conceptual design of the monitoring programme.

Table 11.2: HIAMP hazard categories with section references within this chapter for both freshwater and marine receiving environments.

HIAMP Hazard Category	Freshwater	Marine
BOD, COD	11.4.5; 11.6	11.4.5; 11.5
Suspended Solids, Turbidity, Colour	11.4.2	11.4.2
pH	11.4.5	11.4.5
Temperature	11.4.5	11.4.5
Fats, oils and greases	11.4.3	11.4.3
Ammonia	11.4.6	11.4.6
Nitrogen	11.4.6; 11.6	11.4.6; 11.5
Phosphorus	11.4.6; 11.6	11.4.6; 11.5
Pathogens	11.8	11.8
Odour	11.11	11.11
Heavy metals	11.6; 11.7	11.5; 11.7
POPs	11.6; 11.9.2	11.5; 11.9.2
Sulphides	11.4.6; 11.6	11.4.6; 11.5

11.2 Key considerations for receiving environment effects monitoring

Defining requirements for monitoring receiving environment effects needs to take a number of factors into account, but primarily:

- the characteristics of the effluent;
- the discharge regime;
- dispersion and dilution processes after discharge; and
- the characteristics of the receiving environment.

Where little detailed information on the receiving environment is available, even basic information on these factors can greatly assist in identifying some key design elements of a monitoring programme and the key areas where further investigation is required. For example, any information on effluent characteristics, such as the volume of the discharge, and the suite of contaminants present and their concentration, will allow the key constituents relevant to effects monitoring to be identified. This topic was covered in Chapter 10. Similarly, the scale of the discharge in relation to the nature and sensitivity of the receiving environment will provide a useful initial insight into how significant any effects are likely to be. In turn, such information will provide guidance as to the nature (e.g., scale and frequency) of monitoring required.

In any monitoring programme, it will usually be desirable to at least identify the direction and characteristics of effluent dispersion after discharge, since this will assist with the selection of receiving environment monitoring sites and sampling methods. In some circumstances it may also be necessary to quantify effluent dilution, for example where it is necessary to assess potential water quality impacts on human health. When assessing what, where, and how to monitor effects, it is useful to recognise the water column and the substratum as the two main components of the receiving environment in all aquatic systems. The substratum may be the bed of river, lake or coastal area, and may consist of both hard (e.g., rock, cobble etc.) and soft-sediment (e.g., mud, sand) types. The water column and substratum have markedly different intrinsic characteristics, and are also subject to different influences from wastewater discharges, as described below.

11.2.1 Water column

The water column is subject primarily to dissolved contaminants and, to a lesser extent, particulates from the wastewater discharge. Background environmental conditions tend to be highly transient. Background water quality, for example, changes diurnally, seasonally, and inter-annually, as well as in relation to climatic events like storms. Such changes could reflect both external and intrinsic processes. For example, external forces such as changing states of the tide may bring about diurnal changes in a coastal or estuarine system (e.g., increased freshwater influence in an estuary during the ebb tide). In a freshwater system, diurnal changes may be the result of intrinsic factors such as the activity of plant life, which produce oxygen in the day-time via photosynthesis and deplete it during night-time respiration (MfE 1992). Furthermore, water quality effects from wastewater discharges may also be transient, for example where discharges are intermittent. Similarly, the biological components of the water column – plant plankton (phytoplankton), animal plankton (zooplankton), and fish - are also relatively transient. When effects monitoring programmes are being designed, it is particularly important to recognise and account for variability in background water quality and wastewater discharge effects in terms of when and where to monitor, and how often (see Chapter 8 – Concept design; and Chapter 14 – Methods).

Basic questions and answers for receiving environment effects monitoring:

Q: *Is receiving environment monitoring warranted?*
A: The HIAMP output will help to answer this based on treatment level, receiving environment characterisation, and what's in the discharge, to name a few. In some circumstances a good discharge-monitoring programme can be used in lieu of receiving environment effects monitoring.

Q: *Is dilution and dispersion of the effluent well understood?*
A: If it isn't, then running a simple computer model (*e.g.* Cormix) and/or conducting dilution/dispersion studies (*e.g.* dye dispersion and/or drogue tracking) should be considered as a first step. If you don't know where your effluent is going and at what concentrations, it is difficult to conduct meaningful effects monitoring. Dilution and dispersion monitoring generally only needs to be conducted once, and can save both time and effort on subsequent effects monitoring.

Q: *What are the substrate(s) in the vicinity of the outfall?*
A: Fine muddy sediments are susceptible to nutrient enrichment and contaminant loading, causing adverse biological effects to benthic macrofauna. If the discharge is likely to contribute to such parameters, monitoring may be necessary. Coarse, mobile sandy sediments or rocky substrates, may be less susceptible to nutrient enrichment or contaminant loading, but may be highly sensitive to sediment accumulation.

Q: *Is there a visible plume under most discharge scenarios?*
A: If so, then receiving environment water quality monitoring (for clarity, temperature, dissolved oxygen, floatables *etc.*) should be seriously considered. If there is no visible plume then there might be strong justification for conducting only discharge monitoring, or focusing on sediments.

Q: *To what extent is contact recreation or shellfish gathering/food gathering taking place in the receiving environment?*
A: If either of these activities takes place on a regular basis then monitoring for human health indicators may be warranted. The simplest of these is the collection of water samples for indicator bacteria; however, collection of indigenous biota known to bioconcentrate indicator bacteria (*e.g.* shellfish) or transplanted biota (*e.g.* caged eels or bivalves) could also be considered.

11.2.2 Substratum

In contrast to the water column, the substratum is a relatively stable medium in which to assess receiving environment effects. The physical, chemical and biological characteristics of the substratum may integrate transient changes of a wastewater outfall from both dissolved contaminants in the water column and deposited organic-rich or contaminated particulate material (e.g., sewage solids). While substratum characteristics (e.g., sediment contaminants, ecological communities) will change over scales of months (e.g., seasonally) and years, they remain relatively stable over smaller time scales, and provide a good way of detecting impacts. For example, elevated, variable nutrient inputs may be determined from the proliferation of stream periphyton communities. However, care must be taken as the substratum can be sensitive to short duration, event-related change such as storms or floods (e.g., hydraulic effects from high stream flows removing periphyton). Biggs (2000) recommends at least three weeks of low flow prior to conducting bio-assessments of periphyton communities.

The influence of dissolved or deposited contaminants on the substratum will depend on the discharge configuration and the characteristics of the receiving environment. Shallow freshwater streams may experience both water column and depositional effects where there is complete vertical mixing of the effluent and the receiving water. At submarine outfalls, the substratum in the immediate vicinity will primarily be exposed to depositional impacts rather than water column effects. In coastal and estuarine situations, wastewater effluents generally form buoyant surface plumes, limiting depositional effects. The main exceptions are for intertidal discharges or where the plume from a subtidal discharge impinges on the intertidal zone.

The episodic nature of water column effects compared to the more stable, cumulative nature of substratum effects mean that water column monitoring may need to be repeated many times in order to obtain representative information about the effects of a discharge. In contrast the substratum may be reliably characterised with fewer surveys. In fact, substratum impacts can often be adequately assessed by a one-off ‘snap shot’ survey; an approach that would probably be highly misleading in the case of water column monitoring. A further important difference between the water column and substratum monitoring is the spatial scale over which impacts may occur. While it is typical to measure a gradient of decreasing effects from the point of discharge in both cases, measurable effects on water quality may extend much further than substratum effects. Barter & Forrest (1999a), for example, describe water quality and potential human health effects from a subtidal coastal wastewater discharge extending for hundreds of metres to kilometres from the outfall, in the absence of any discernible effects on the substratum.

11.2.3 Standard approach

In this Chapter we propose a standardised framework to wastewater discharge effects monitoring, based on the following key elements:

- An assessment of effluent dispersion characteristics and, where necessary, effluent dilution.

- Water column sampling for: key physical parameters (temperature, clarity, and floatables); key chemical constituents (pH, dissolved oxygen, nutrients); and key indicators of potential risks to human health (indicator bacteria).
- Substratum investigations to assess effects from the deposition of sewage-derived particulates in terms of: trace contaminants and sediment enrichment (where fine-grained soft-sediments are present); and effects on ecological communities.

These basic elements will apply to many wastewater discharge scenarios. While there will be some instances where only a low level of monitoring effort is appropriate for any one of these components, we would generally advocate that receiving environment impacts from a wastewater discharge are assessed using a range of complementary approaches. This recognises the many examples, especially in coastal and estuarine systems, where the receiving environment is highly complex, and cause-effect links between a wastewater discharge and a degraded environment may not be clear. In such situations, the extent of adverse effects from a wastewater discharge usually needs to be assessed using a 'weight of evidence' approach, in which a range of different measures are used to paint a picture of the 'true' extent of effects, within the framework of a well-designed survey (see Chapter 13).

Clearly, a 'recipe' approach will not apply to every situation, and the approach taken needs to be tailored to fit specific circumstances. Hence, a degree of caution should be exercised when using these Guidelines. Note that this Chapter provides only a cursory overview of approaches to receiving environment monitoring, in order to highlight key aspects of the recommended approach. Other reference material is referred to, since there is a wealth of information on receiving environment monitoring, from collection and sampling methods, to quality assurance quality control objectives. Some of the most frequently referenced materials currently available and relevant to New Zealand are listed in Table 11.3.

Table 11.3: Commonly used effects monitoring guidelines.

Reference	Title	Notes
ANZECC (2000a)	Australian and New Zealand Guidelines for Fresh and Marine Water Quality	General water quality guidance
ANZECC (2000b)	Australian Guidelines for Water Quality Monitoring and Reporting	Water quality monitoring
MFE (1992)	Guidelines for the control of Undesirable biological growths in Water	Covers freshwater biological growths.
MFE (1994a)	Guidelines for the Management of Water Colour and Clarity	
Biggs (2000)	New Zealand Periphyton Guidelines – Detecting Monitoring and Managing Enrichment of Streams	Very applicable to nutrient-rich wastewater discharges
AS/NZS 5667	Water quality sampling guidance on the design of sampling programmes, sampling techniques and the preservation and handling of samples.	Basic water quality sampling techniques. Similar to ISO-5667
MoH (2000)	Drinking Water Standards for New Zealand	Sets drinking water criteria for pathogens and contaminants for protection of human health
Stark et al. (2001)	Protocols for sampling macroinvertebrates in wadeable streams	Collection and analysis methods for freshwater macroinvertebrates
Kingsford & Battershill (1998)	Studying Temperate Marine environments: A handbook for ecologists.	Basic study designs and examples. Covers equipment, methods and design.
PSEP (1997)	Recommended Protocols for Measuring Selected Environmental variables in Puget Sound	Field collection methods for marine biota and sediments

11.3 Effluent dilution and dispersion

Effluent dispersion and dilution are not technically effects monitoring components, nor are they discharge monitoring components, but instead fall somewhere in between. However, since any effects will be determined, in part, by the direction and strength of the effluent plume, they require consideration prior to initiating a monitoring programme. Without knowledge about where the effluent is likely to end up, it is meaningless to try to select monitoring sites and/or sampling and analysis methods. For new discharges, these components will almost certainly be considered as part of an AEE. However, many existing discharges either preceded the standard compilation of this information, or the information is no longer available and requires re-collecting.

As mentioned previously, determination of effluent dispersion and/or dilution is generally only required once, unless there are changes in either the discharge (e.g*.,* quality, quantity, location, diffuser type) or the receiving environment (e.g*.,* changes in flow direction and/or volume). Dispersion and dilution can be assessed as a desktop exercise through the use of computer models (e.g., Cormix) and/or using a variety of different field methods (e.g., drogues, dye, current meters). These two different approaches are often used in conjunction, especially where field data like current measurements are required to validate computer models.

11.3.1 Computer models

The use of hydrodynamic computer models for determining dilution and dispersion has grown appreciably over the last decade due to the rise in computing power and development of affordable 'off-the-shelf' packages. Previously this type of evaluation was limited to municipalities with large outfalls and even larger budgets, whereas the use of this technology is now within the reach of the majority of dischargers. While evaluation of the data still requires some basic understanding of hydrodynamic processes, there are numerous organisations within New Zealand qualified to offer assistance or conduct this type of study.

The number of different commercially available computer models and the continuous development of new products precludes the description of all but a few selected examples. The examples listed have been chosen because they have a proven track record in New Zealand, and are directly applicable to wastewater discharges. This list is by no means comprehensive and direct endorsement of these particular products should not be inferred.

Examples of wastewater computer models:

- **US EPA's CORMIX**: a hydrodynamic mixing zone model for discharges into riverine, lake and marine receiving waters including subsurface single- and multi-port diffusers as well as buoyant surface discharges. A full description of the CORMIX model and its underlying assumptions is given in the users manual (Jerka, et al. 1996). Although the primary use of the model is for pre-construction design purposes under varying flow and discharge configurations, it can also be used to verify field data and extrapolate near-field mixing under varying flow regimes for existing outfalls.

Danish Hydraulic Institute's Mike series: Mike 21 is an example of the range of different modelling packages produced by the DHI. It is a 2D engineering modelling tool for rivers, estuaries and coastal waters. MIKE 21 consists of more than twenty modules covering areas including, coastal hydrodynamics, environmental hydraulics, sediment processes, and wave processes. This group also produces 3D hydrodynamic models and models for treatment plants and reticulation systems including wastewater and stormwater. In general, the DHI models are much more expensive than the Cormix model and require a better understanding of hydrodynamics, but also are much more flexible than the Cormix system.

Puffin: A locally developed model for evaluating far-field dispersion of effluent plumes based on *in situ* current meter data. Puffin is a simpler version of many 2D and 3D models and requires less field verification. Puffin has been used recently to evaluate the upgraded Green Island outfall in Dunedin (Papps 1998) and is currently being used for other proposed outfall extensions.

11.3.2 Drogue studies

A drogue is a device that drifts along with water currents without being influenced by surface winds, and thus provides a measure of the direction and speed of water movement (hence effluent plume movement) in the vicinity of a discharge. Tracking of drogues is usually accomplished by taking position readings (e.g., GPS fixes) at regular intervals. One common drogue configuration is the holey-sock drogue, consisting of a cylindrical nylon tube reinforced with stainless steel rings (Figure 11.1). The holey-sock drogue is preferred over the window-shade style outlined in the New Zealand Water and Soil Conservation Authority's Ocean Outfall Handbook (Williams 1985). Studies have shown that current flow around a window-shade drogue may cause lift, similar to air flow for a sail boat, and that cylindrical drogue designs that enclose a parcel of water (like the holey-sock) have been found to more accurately follow the ambient current patterns (Sombardier & Niiler 1994).

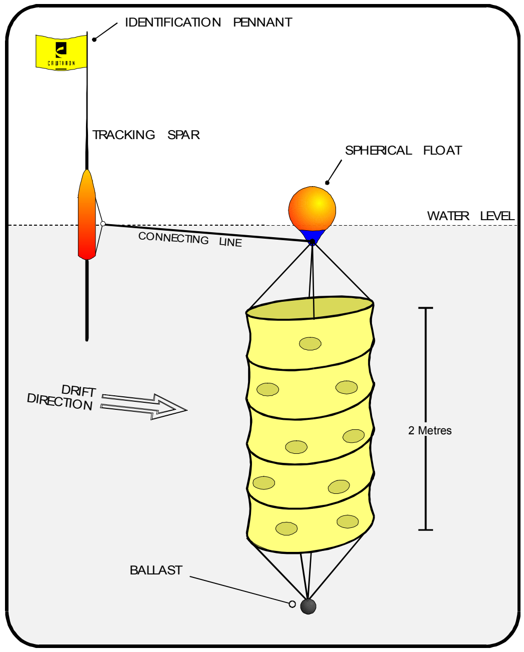


Figure 11.1: Holey sock drogue

Drogues do not necessarily have to be complicated, however, and tracking a surface plume in low wind situations can be accomplished using very cost-effective means. For example, oranges have been used in many situations to serve as inexpensive (and biodegradable) drogues.

11.3.3 Dye studies

Fluorescent dyes are often used to track effluent plumes either visually or quantitatively using a field fluorometer. The two most frequently used dyes are Rhodamine WT and Fluoroscein. Rhodamine is a red dye while Fluoroscein is green. Both readily disperse in water and can easily be injected into an effluent discharge to track the plume as it disperses in the receiving environment. Rhodamine is the preferred dye for wastewater studies for several reasons: it disperses readily in receiving waters, is easily detected (visible to the naked eye to 1 g m^{-3} and by fluorometer to as low as 0.01 mg m^{-3}), is very stable, and is non-toxic. Although Fluoroscein shares some of these attributes, it is less stable and tends to break down under UV light more quickly than Rhodamine. It also tends to adhere to particulate matter more readily than Rhodamine. For batch releases where the dye will be tracked visually, Fluoroscein is sometimes preferred as many people see green as a less offensive colour than red. Use of dye often requires a resource consent (which is normally granted very quickly by the regulatory authority, provided that affected parties are notified of the planned use of the dye).

Dye studies fall into two categories, (i) Qualitative: where a large slug of dye is tracked visually; and (ii) Quantitative: where the dye is injected at a known rate and tracked below the visible range using a field fluorometer. Qualitative studies tend to involve less equipment and are used to get an idea of the large scale dispersion of the surface effluent plume but will not generally yield dilution ratios. Visual tracking of the plume can be accomplished either from shore surface observations or through the use of aerial photography.

Quantitative studies involve more equipment, but provide dilution estimates. The equipment includes a metering pump that can inject the dye at a constant rate and a field fluorometer calibrated to measure the specific dye being used. Grab samples of the receiving water can be analysed individually, or alternatively the fluorometer can be run in flow-through mode or towed *in-situ* where continuous readings are collected. A modification of this approach is to link a field fluorometer with a datalogger and GPS to collect real-time concentrations as well as positions to map the effluent plume.

11.3.4 Current meters

Current meters are used to measure the current velocity and direction that can be used to extrapolate dispersion and dilution in the vicinity of a discharge. These measurements are typically used to feed into or validate the computer models mentioned previously. There is a huge range of instrumentation available from older mechanical meters to modern profiling meters that can collect simultaneous readings from various depths (or bins) within the water column. The most widely used meters calculate velocity and direction using either electromagnetic (e.g. InterOcean S4 meter) or Doppler sound shift technology (e.g., RD Instruments ADCP, Sontek ADCP, Falmouth Scientific ACM, Marsh McBirney Doppler meter etc.) Meters can be moored in a single position for an extended period, used to collect *in situ* velocity measurements in rivers/streams, or vessel mounted for collection of data from multiple positions. A good basic summary of marine current meters is presented in Kingsford & Battershill (1998).

11.4 Monitoring water column effects

11.4.1 Background

In most situations, the water column should only require monitoring for a subset of the key discharge constituents identified in Chapter 10, along with some basic receiving environment constituents. These include:

- Most of the key physical parameters, especially temperature, clarity, and aesthetic parameters (i.e. floatables).
- Only a few chemical constituents, especially pH, dissolved oxygen, and nutrients.
- Human health constituents (usually indicator bacteria).

The rationale for these choices lies primarily in the 'best bang for the buck' approach. While it is perfectly feasible to sample the water column for trace contaminants such as heavy metals, such constituents are closely associated with particulate matter. Since particulate material tends to settle out of the water column, trace contaminants in the receiving environment are usually more of an issue in sediments than in the water column itself. Additionally, while measuring contaminants in the water column only gives a 'snap shot' at one particular instance, measuring these constituents in the sediments can show historic or chronic inputs. An exception to this approach is fast flowing rivers/streams where stony habitats predominate. In these areas alternative approaches are often required (see section 11.6.2).

In most wastewater discharge situations, grab samples taken at the water surface will be sufficient for receiving environment monitoring, since buoyant effluent plumes will usually mix with surface waters. An important exception can occur in stratified freshwater-dominated estuarine systems, where subtidal effluent discharges can be trapped beneath surface freshwater layers (e.g., Sherwin, et al 1997, Roberts 1998) and water column profiles need to be established for key parameters. Water column profiling may also be undertaken as a component of effluent plume studies, for example to validate dispersion and dilution models (see section 11.3.1).

Similarly, water column effects monitoring would not normally involve an assessment of phytoplankton, zooplankton or fish. Since these groups are usually transient, cause and effect relationships are difficult to ascertain without undertaking extensive research. Some of the potential effects on water column biology can be addressed theoretically, however. For example, potential enrichment effects on phytoplankton (e.g*.,* the potential for bloom formation) can be dealt with via nutrient mass load approaches. Similarly, a number of studies have described the sensitivity or avoidance behaviour of fish in relation to effluent plumes, especially for heat and ammonia (e.g*.,* Beitinger and Freeman 1983).

A further rationale for the selection of water column constituents is that many are specified in the various water quality classes in the Third Schedule of the RMA, hence compliance with such classes in relation to mixing zone characteristics can be determined (see section 11.10). For example, temperature, pH and dissolved oxygen have specific numerical limits for 5 of the 11 RMA water quality classes. Additionally, some of the key constituents (e.g*.,* colour/clarity, floatables) are given narrative limits in Sections 70 and 107 of the RMA, and compliance with these limits is often incorporated into discharge permits. Further information on receiving environment effects monitoring using these key water column constituents is given below. Note that monitoring of public health constituents (pathogens and indicator bacteria) is addressed in Section 11.8.

11.4.2 Colour and clarity

Optical measurements of a receiving water are carried out as changes in colour and/or clarity can reduce photosynthesis, alter predator/prey dynamics, cause hazards to bathers (from lack of visibility of swimming hazards), and/or reduce aesthetic values. There is a wealth of background information on colour and clarity measurements in both the ANZECC water quality guidelines (ANZECC 2000a) and the MfE colour and clarity guidelines (MfE 1994a), which will not be repeated here. The latter of these guidelines was developed to help address the narrative limits in sections 70 and 107 of the RMA, namely, "*there shall be no conspicuous change in colour or visual clarity"*. These same narrative standards for colour and clarity are usually either included verbatim in individual discharge consents or are inferred by their inclusion in the RMA. As such it is expected that a majority of wastewater monitoring programmes will include some sort of colour and/or clarity component. Although numerous methods exist for measuring colour and clarity, only those most frequently employed for addressing these narrative standards in wastewater programmes are discussed.

Before going into the individual methods, however, some background information on assessing these narrative standards is worth considering. Firstly, the bulk of the underlying scientific data used to support the MfE (1994a) guidelines was conducted in freshwater environments, and therefore the approach is more focused toward freshwater rather than marine or estuarine waters. This is not to imply that the guidelines are inappropriate for marine environments, merely that careful site-specific consideration should be used when trying to apply the guidelines to either marine or estuarine environments. Secondly, although colour and clarity are both specified in the limits, colour is rarely assessed and clarity measures are usually solely used (rightly or wrongly) to assess the standards. This is most likely due to the relative ease of conducting clarity measures compared with colour measures. Finally, while there are no 'hard and fast' rules on which methods to use, there are some general tips that may help to make a decision as listed in the following text box:

General tips on deciding which colour/clarity methods to use:

- Black disk is suited to all water types, although it can be difficult to use from a small boat.
- Secchi disk is generally suitable only for lakes, estuarine and marine waters.
- Turbidity (NTU) lacks a direct relationship to other clarity measures, and has inter-instrument variability, but can still be used for relative measures both spatially and temporally.
- Transmissivity has a better relationship to other clarity measures but is not as widely used as turbidity, most likely due to cost factors and historical precedent.
- Transparency tubes (e.g., SHMAK tube) work only for very turbid waters, where visibility is less than the tube length.

Colour (Munsell scale)

The Munsell Scale is basically a set of colour patches that are used to match the colour of the receiving water against a set of standards. The patches are very similar in style to the sheets of paint colours available from paint shops. Without going into detail on how the scale is used, its primary advantage is that a quantitative difference in colour can be ascertained, which can subsequently be used for regulatory purposes. The Munsell scale can be likened to a 100 point compass rosette, which is divided equally by the colours Red, Yellow, Green, Blue, and Purple (see Figure 11.2). The MfE colour and clarity guidelines (MfE 1994a) recommend no greater than a 5 to 10 point change in Munsell colour, depending on water quality class as a suitable limit. At the time of writing, charts cost approximately $100 USD and are available through the Munsell Color Company Incorporated.

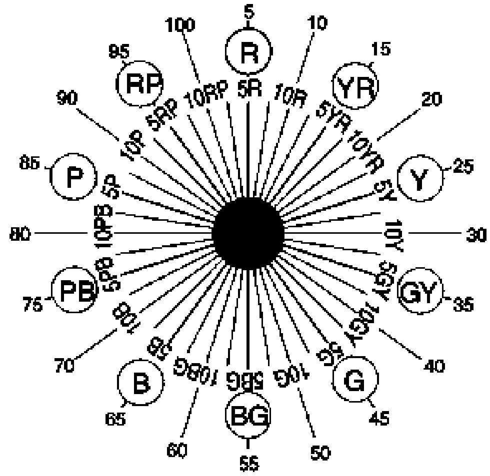


Figure 11.2: Munsell scale

> ***Munsell Scale advantages and disadvantages:***
>
> ***Pros:*** One of the only reliable field measurements for hue
>
> ***Cons:*** Can only be used for receiving environments and not on effluents
> Not in wide use and not readily available

Turbidity (nephelometer, turbidimeter)

Turbidimeters or nephelometers measure the relative clarity of a water sample based on the 90 degree sidescatter of a beam of light. The instrument is calibrated using either a formazin standard or a secondary standard, which is equivalent to formazin. Formazin is a compound that appears cloudy white in solution and can be mixed in discreet concentrations, allowing for the preparation of quantifiable standards. Readings are then based on the relative clarity of a sample compared against the standard and are expressed as nephelometric turbidity units or NTU, where higher NTUs represent more turbid waters. Although nephelometry is a widely used measure of clarity, the readings themselves are not directly comparable with other clarity measures such as transmissivity. That is, NTUs cannot be converted to percent transmittance, suspended solids concentrations, secchi depth or black disk distance without deriving the relationship on the given receiving water or effluent through the collection of site specific measurements (Davies-Colley & Smith 2001). Another pitfall to these turbidity measurements is that different instruments from various manufacturers may yield different readings. Hence, turbidity results from monitoring programmes using different instruments may not be directly comparable. However, a series of readings using the same instrument will allow for assessing turbidity changes over time or relative differences between different locations. Even with these problems, however, turbidity is still widely used for both discharge and receiving environment monitoring programmes because of a number of factors including ease of use, small sample sizes, and very low cost. If nephelometry is adopted as a monitoring parameter, the make and model of the instrument used must be reported along with any results.

Turbidity advantages and disadvantages:

Pros: Small sample size
Easy to use, very low cost
Large range
Can be used on both effluent and receiving waters
Cons: Comparability between instrument types may be poor
Lack of relationship with other clarity measures.

Secchi disk, black disk, and transparency tubes

Secchi disk, black disk, and transparency tubes are all measures of water clarity, which use the same basic principal. A disk or target is moved away from the observer or viewer until it has disappeared from sight. Readings are expressed as the distance at which the disk disappears, such that clear waters have high readings and turbid waters have low readings.

The difference in the three methods can be attributed in large part to the different environments in which they are primarily used. The Secchi disk has historically been used for marine and lake studies where clarity is measured vertically. The Secchi disk itself is simply a weighted white or black-and-white disk that is lowered on a graduated line until the disk is no longer visible. The black disk, on the other hand, is used primarily in river and stream monitoring where clarity is measured horizontally, since clarity distance often exceeds depth to the bottom. The black disk measurement is fairly self-explanatory and is merely a small black disk (usually 200 mm diameter) that is viewed through the water via a small reverse periscope. The distance at which the black disk is no longer visible equates to the clarity of the water. Another reason black-disk is used preferentially in freshwater environments is that in marine environments the black-disk distance may exceed boat length, making measurement impossible. Finally, transparency tubes are clear (usually perspex) tubes that either have the target painted on the bottom or have a magnetic target that can be moved along the length of the tube (e.g., SHMAK tube). These tubes are generally limited to waters with higher turbidities, as their length is restricted. One advantage to these devices, however, is that readings do not have to be taken *in situ* and samples can be collected for analysis. This is advantageous when conditions would make *in situ* readings dangerous or when samples such as effluents are measured.

	Secchi Disk	**Black Disk**	**Tube**
Pros:			
Low cost	X	X	X
Easy to use	X	X	X
True measure of clarity	X	X	

Lots of historic data	X	X[a]	
Can be used on effluents		X[b]	X
Cons:			
Receiving water only	X		
Limited range			X

[a] Very little historic marine data

[b] Only with modified trough

Transmissivity

The final clarity measure discussed is transmissometry. A transmissometer is akin to a nephelometer in that it measures the attenuation of a beam of light passed through a sample but with some fundamental differences. Firstly, a transmissometer, unlike a nephelometer, measures the amount of light passing directly through the sample and not the amount deflected at 90 degrees. As such, these instruments are measuring clarity in the same fashion as Secchi disks or black disks, only on a much smaller scale. Readings are presented as percent transmittance over a given path length (e.g., 25 cm) and can therefore be adjusted to a standardised length (e.g., % transmittance m^{-1}), regardless of the instrument. This also makes them directly comparable to other clarity readings like Secchi disk or black disk. However, transmissometers tend to be more expensive than nephelometers, which is probably why they are not more widely used for effects monitoring.

Transmissivity advantages and disadvantages:

Pros: Can measure the direct transmittance of light and can be compared with Secchi disk or black disk
Can be used on effluent samples
Easy to use and interpret

Cons: Expensive compared with other clarity measures

11.4.3 Floatables (scums, films, other floatables)

For the purposes of these guidelines, the term ‘floatables’ refers to scums, slicks, films, foam, floating particulate matter or any other floating debris (e.g., plastics) associated with a wastewater discharge. For domestic wastewater, slicks and films are typically caused by the discharge of oil and grease in the form of salts and esters of fatty acids (Williams 1985), while foams are caused by methyl blue active substances (e.g., detergents) or proteins. Depending on the level of treatment, particulates in the form of paper, plastics and other solids can also form conspicuous amounts of floatable material.

The primary reason for including floatables as part of a receiving environment monitoring programme is because they are included in sections 70 and 107 of the RMA. These sections state that, after reasonable mixing, a wastewater discharge should not give rise to: “*The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials”*. However, unlike the colour and clarity limits that are listed in the same sections of the RMA, there are no existing guidelines for interpreting what would constitute a conspicuous discharge.

Monitoring for floatables is perhaps the most subjective measure included in water quality effects monitoring, as it relies solely on personal observation. While it can be assessed narratively, comparisons over time are difficult using this method and some sort of quantitative approach is often required. One approach is to assign a relative scale of the conspicuousness of the visual effect so that comparison between sites and/or surveys can be performed. An example of this type of relative scale, from Forrest and Brown (1996), is presented in Table 11.4. This scale was accompanied by criteria for assessing how the observations were made (e.g., from a passing vessel at a certain speed).

Table 11.4: Scales used for assessment of the conspicuousness of visual effects

Rank	Description
0	Visual effect absent
1	Effect visible only when observed closely from a stationary position.
2	Effect visible to a passer-by or casual observer but effect not grossly visible.
3	Effect grossly visible or 'eye-catching' to a passer-by or casual observer

Floatables observations advantages and disadvantages:

Pros: Simple low cost method
Does not require training

Cons: Subjective to individual making observation
Relative scale needs to be adopted for quantitative measurement

11.4.4 Electrical conductivity

Conductivity is the capacity of a substance (the receiving water) to conduct an electrical current, and is usually expressed in micro-siemens per centimetre ($\mu S\ cm^{-1}$). In simple terms, the more ions present in the water, the higher the conductivity. As such, marine and estuarine waters have much higher conductivities than freshwaters. For example, freshwaters rarely exceed 500 $\mu S\ cm^{-1}$ while coastal seawater (with a salinity of 33) would have a conductivity of roughly 27,500 $\mu S\ cm^{-1}$. Conductivity and salinity are often used interchangeably, and even though this is not technically correct it is beyond the scope of these Guidelines to delve into the differences. Readers are directed to ANZECC (2000a) or other basic water quality texts for clarification. Since freshwater conductivities can vary widely (i.e., 20 - 2000 $\mu S\ cm^{-1}$) depending on the receiving environment, it is imperative that levels and variation of the receiving environment be determined if conductivity is included in a monitoring programme. If, however, the conductivity of the receiving environment is known along with the conductivity of the effluent, and the two are disparate enough, this measure can be a simple and inexpensive way of tracking effluent presence in a receiving environment.

In marine situations, conductivity measurements are often made through the water column to determine if a density layer exists of lighter less saline waters over heavier more saline waters (a halocline). Determination of this halocline is important, because distinct density boundaries can trap a submerged discharge and prevent it from rising to the surface. It is also important to identify this type of stratification if any receiving water column monitoring is being conducted. Otherwise, sampling may not be taking place in the effluent plume, but rather in a water layer overlying the trapped plume. Trapped layers are often subject to far less efficient dilution and dispersion, and evaluation of this reduced mixing is important. A similar, and more common, density gradient occurs when two distinct temperature regimes exist, a warmer lighter layer on top of a colder denser layer (thermocline).

Conductivity advantages and disadvantages:

Pros: Low cost *in-situ* method which can sometimes be used to track effluent plumes.
Can be used to document stratified water bodies (*i.e*. haloclines).

Cons: Freshwater conductivities have high natural variability and site specific information is crucial.
Often confused with salinity.

11.4.5 Temperature, pH, dissolved oxygen

Temperature, pH and dissolved oxygen (DO) have been included together since they are all essentially physical characteristics of the water column that directly affect aquatic life, and all three are specified in the various water quality classes in the Third schedule of the RMA. By having RMA-stipulated limits for the various water quality classes, compliance with such classes in relation to mixing zone characteristics can be determined. For example, temperature, pH and dissolved oxygen have specific numerical limits for 5 of the 11 RMA water quality classes (see Table 11.5).

Temperature criteria are generally limited to not more than a 3° C temperature change away from ambient conditions. Changes in temperature can have direct impacts on thermally sensitive organisms or indirect impacts through decreased oxygen saturation. Temperature is also important in that it can cause water column stratification (see above). Temperature readings are easy and very inexpensive and are therefore included in many monitoring programmes. Similarly, pH changes can have both direct and indirect effects on receiving water biota, and the most frequent criteria is a range of between 6 and 9. Direct effects occur, as most biota can only tolerate a specific pH range, and indirect effects involve the increased toxicity of some metals (e.g., aluminium) and ammonia at different pH ranges. Given the buffering capacity of seawater, pH is not a parameter that is likely to be an issue in either marine or estuarine monitoring programmes. However, it is often included since it is inexpensive and easy to measure *in-situ*.

Note: It is worth remembering that pH is a logarithmic scale from 0 to 14, with values less than 7 being acidic and greater than 7 being basic, or alkaline. As such, monitoring programmes should report minima, maxima and median values rather than mean or averaged values, as arithmetic means of logarithmic values are incorrect and misleading.

Dissolved oxygen criteria for various water quality classes are generally greater than 80% saturation, as values below this percentage can have direct effects on respiration of aquatic biota, among other factors. Wastewater discharges are often high in biochemical oxygen demand (BOD), which directly reduces oxygen concentrations in receiving waters. The 80% saturation criteria should, however, be used carefully, as many natural systems undergo wide changes in DO levels on a diurnal basis. If DO is considered as a constituent for effects monitoring, sufficient readings must be collected to determine any natural variation in receiving environment concentrations before attempting comparison with DO criteria. In most circumstances reduction in DO is not an issue for wastewater discharged to marine environments and does not require inclusion in a monitoring programme. However, the relative ease of measuring DO, coupled with the receiving water criteria, often leads to the inclusion of this parameter regardless.

Table 11.5: Water quality classes and criteria from Third Schedule of RMA.

<table>
<tr><th>RMA Water Quality Class</th><th>Temperature</th><th>pH</th><th>DO</th><th>Other</th></tr>
<tr><td>Aquatic Ecosystems (AE)</td><td>± 3 °C Change</td><td>No change causing adverse effect on aquatic life</td><td>> 80% saturation</td><td>• No adverse effect on aquatic life from:
• Contaminant discharge
• Depositional matter</td></tr>
<tr><td>Fishery (F)</td><td>± 3 °C Change
< 25°C</td><td></td><td>> 80% saturation</td><td>• No tainting of fish for human consumption</td></tr>
<tr><td>Fish Spawning (FS)</td><td>± 3 °C Change</td><td></td><td>> 80% saturation</td><td>• No undesirable biological growths</td></tr>
<tr><td>Shellfish Gathering (SG)</td><td>± 3 °C Change</td><td></td><td>> 80% saturation</td><td>• Aquatic organisms shall not be rendered unsuitable for human consumption by the presence of contaminants.</td></tr>
<tr><td>Water Supply (WS)</td><td></td><td>6.0 - 9.0</td><td>> 5g m^{-3}</td><td>• The water shall not be rendered unsuitable for treatment for human consumption.
• The water shall not be tainted or contaminated so as to make it unpalatable or unsuitable for consumption by humans after treatment or unsuitable for irrigation.
• No undesirable biological growths</td></tr>
<tr><td>Contact Recreation (CR)</td><td colspan="4">• Water should not be rendered unsuitable for bathing from:
• Reduction in visual clarity
• Presence of contaminants
• No undesirable biological growths</td></tr>
<tr><td>Irrigation (I)</td><td colspan="4">• The water shall not be tainted or contaminated so as to make it unsuitable for the irrigation of crops growing or likely to be grown in the area to be irrigated.
• No undesirable biological growths</td></tr>
<tr><td>Industrial Abstraction (IA)</td><td colspan="4">• The quality of the water shall not be altered in those characteristics which have a direct bearing upon its suitability for the specified industrial abstraction.
• No undesirable biological growths</td></tr>
<tr><td>Natural State (NS)</td><td colspan="4">• The natural quality of the water shall not be altered.</td></tr>
<tr><td>Aesthetics (A)</td><td colspan="4">• The quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified aesthetic values.</td></tr>
<tr><td>Cultural (C)</td><td colspan="4">• The quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified cultural or spiritual values.</td></tr>
</table>

11.4.6 Nutrients

Nutrients are an important component of receiving environment monitoring, especially in situations where the ratio of discharge volume to receiving environment volume is high (e.g., small streams/rivers), or where the receiving environment is sensitive to increased nutrient inputs (e.g., spring-fed stream with relatively stable flows). High concentrations of nutrients in the water can result in excessive growth of aquatic plants such as phytoplankton, cyanobacteria, macrophytes, seagrasses, and filamentous and attached algae.

Key nutrients in wastewater discharges are nitrogen and phosphorus, which come in many different chemical forms. Nitrogen is generally regarded as a limiting nutrient in estuarine and marine systems, hence can promote adverse effects through the stimulation of excessive algal growth. The forms of nitrogen that are most readily available (i.e., bioavailable) are nitrate, nitrite and ammonia, which are collectively referred to as dissolved inorganic nitrogen (DIN). Total nitrogen (TN) is the sum of organic nitrogen plus DIN and, as the name implies, provides a measures of the total pool of nitrogen in the system, recognising that organic nitrogen can be converted to the more bioavailable forms by sediment microbial processes. TN should not be confused with total Kjeldahl nitrogen (TKN), which is the sum of organic N and ammonia. For effects monitoring purposes it is usually sufficient to have a measure of the bioavailable nitrogen pool (DIN) and the total pool (TN).

Like nitrogen in marine systems, phosphorus is often the limiting nutrient in freshwater systems or the upper reaches of estuaries. It can exist in the water in organic phosphate, orthophosphate (inorganic, dissolved phosphorus), total phosphorous (dissolved and particulate), and polyphosphate (from detergents) forms. Phosphorous is constantly cycled from one biogeochemical form to another within an ecosystem, but not all are available for nuisance plant growth (i.e., bioavailable). The most bioavailable form of phosphorous is considered to be orthophosphate (PO_4^{3-}). Bioavailable phosphorous is comprised of soluble reactive phosphorous (SRP – equivalent to dissolved reactive phosphorus, DRP) and bioavailable particulate phosphorus (BPP). For effects monitoring purposes it is usually sufficient to have a measure of the bioavailable phosphorous (SRP/DRP) and the total pool (TP).

Measuring each of the nutrient species (both N and P) in receiving water is generally recommended even though it is only one of the species that is likely to be limiting to plant growth. In most situations limiting the analysis to nitrate, ammonia and SRP/DRP is sufficient, however discharge considerations may warrant analysing additional parameters (see Section 10.4). It is also important to remember that natural variations are likely to take place and multiple samples over an extended time frame (e.g., monthly samples over the course of a year) may be required to ascertain natural temporal variation in a receiving water. Understanding the extent of this natural variation is critical prior to attempting to draw any relationship between discharge and ambient receiving water concentrations. Further information regarding freshwater nutrients and their capacity to promote eutrophication are presented in the MfE water quality guidelines No. 1 (MfE 1992) and the periphyton guidelines (Biggs 2000). The latter of these also contains recommended nutrient concentrations for freshwater environments along with some of the important caveats to consider when attempting to apply the limits specified.

Summary of N and P Nutrient Species:

- **DIN (Dissolved Inorganic Nitrogen)** = Combination of Nitrate, Nitrite, and Ammonia. These represent the most readily bioavailable forms of nitrogen.
- **TN (Total Nitrogen)** = Organic nitrogen plus inorganic nitrogen (DIN).
- **TKN (Total Kjeldahl nitrogen)** = Organic nitrogen plus ammonia.
- **DRP (Dissolved Reactive Phosphorus)** = Also called soluble reactive phosphorus (SRP). One bioavailable form of Phosphorus (see BPP). Most commonly measured form.
- **BPP (Bioavailable Particulate Phosphorus)** = Second bioavailable form of phosphorus. BPP + SRP makes up total bioavailable phosphorus.
- **TP (Total Phosphorus)** = Combination of both bioavailable and other forms of phosphorus.

11.4.7 Phytoplankton, zooplankton and fish

As mentioned previously in section 11.4.1 an assessment of phytoplankton, zooplankton or fish is not normally included in water column effects monitoring. This is because these groups are primarily mobile or transient, and cause and effect relationships are difficult to ascertain without undertaking extensive research. Generally the potential effects on water column biology can be addressed theoretically. For example, potential enrichment effects on phytoplankton (e.g*.,* the potential for bloom formation) can be dealt with via nutrient mass load approaches. The potential effects on fish populations can vary widely depending on the quality of the effluent and are not as easily addressed in a theoretical sense. For example, Beitinger & Freeman (1983) have shown fish avoidance behaviour from wastewater effluent while in other cases (e.g*.,* Barter & Forrest 1999b) nutrient rich effluent appears to support fish aggregation.

Due to the cost of conducting and analysing this type of data in conjunction with the lack of direct cause and effect relationship, inclusion of phytoplankton and or zooplankton monitoring should only be considered if certain conditions apply. These are listed in the following text box.

Only consider conducting phytoplankton or zooplankton monitoring if:

- Nutrient levels are very high in the discharge
- Dilution and dispersion are low enough that nutrient rich waters persist in the vicinity of the discharge.
- Blooms have been documented or observed previously.

Likewise, monitoring bioaccumulation, histopathology (presence of disease/lesions), habitat modification, or behavioural changes in fish can be an expensive exercise, which may or may not yield meaningful results. Again, this approach should only be considered in special circumstances like those listed in the text box.

Only consider conducting bioaccumulation monitoring if:

- There is a contaminant in the discharge (e.g*.,* mercury) which is known to have high bioaccumulation or bioconcentration factors in fish
- The discharge is into a high profile trout fishing river/stream.

- There is commercial or recreational fishing activity in the immediate vicinity of the discharge, and there are human health implications.

Sampling methods for these parameters are covered in detail in either the Puget Sound Monitoring Protocols (PSEP 1997) or studying temperate marine environments (Kingsford & Battershill 1998).

11.5 Effects on sediments and biology: marine environment

For various reasons, effects monitoring requirements for marine and freshwater environments have been presented separately, although cross-referencing is used where there are similarities between the two. In this section, the requirements for the marine environment are discussed.

The data of MacDonald et al. (2001) indicate that, by volume, about 66% of New Zealand's present-day wastewater discharges are into the marine environment. Many of these discharges are into areas characterised by soft-sediment habitats. It is logical, therefore, that a discussion of effects monitoring requirements for marine systems should focus mainly on such areas. While effects monitoring in rocky habitats is referred to at times, more comprehensive discussions can be found elsewhere (e.g., Kingsford and Battershill 1998).

11.5.1 Assessing effects on sediment quality

Except where buoyant effluent plumes affect intertidal areas, the substratum in marine systems will primarily be exposed to the impacts of sewage-derived solids that are deposited in the vicinity of the outfall. Enhanced deposition of organic-rich solids can result in a range of effects in marine systems.

As a measure of depositional impacts, it is important to assess the severity and extent of organic enrichment of the seabed in the case of all wastewater discharges. For discharges where toxic contaminants have been identified, it will also be important to assess sediment-associated contaminant levels and their implications.

11.5.2 Enrichment

There are a number of key indicators of changes in sediment quality under different levels of enrichment that are reasonably easy to measure. These are outlined below.

Sediment organic content: this can be measured either as percent ash free dry weight (% AFDW) or percent total organic carbon (% TOC). These are relatively inexpensive lab-based analyses of sediment samples that provide a direct measure of sediment organic content. They are not identical measures, however, but can be roughly related by using the formula from Craft, et al. (1991) where $TOC\% = 0.4(AFDW) + 0.0025(AFDW)^2$.

***Sediment nutrient content*:** as discussed in section 11.4.6, nitrogen is the key nutrient that limits algal growth in estuarine and marine systems. Sediments can be measured for DIN as an indication of the bioavailable forms and TN as an indication of the total nitrogen pool.

Sediment redox status: whereas unenriched sediments are typically grey/brown, excessively enriched and anoxic (oxygen-depleted) sediments can be black. As the level of enrichment increases, and the sediment becomes increasingly anoxic, the black zone moves closer towards the sediment surface. While this change can be quantified by measuring redox potential in sediment cores, the technique is difficult and results are often equivocal (e.g., Pearson & Stanley 1979). A somewhat crude yet widely used alternative is to measure the depth of transition between 'clean' surface sediments and the anoxic 'black zone'. This approach has limitations in the case of muddy estuarine sediments where sediments may be naturally anoxic in all but the very surface of a core profile.

Sediment odour: unenriched sediments are typically relatively odourless or 'muddy'-smelling, whereas excessively enriched and anoxic sediments have a strong 'rotten egg' smell of hydrogen sulphide. While this is a highly subjective 'measure' it can nonetheless add to the overall weight of evidence regarding the severity of impacts. As above, this approach has limitations in the case of muddy estuarine sediments that are naturally anoxic.

11.5.3 Contaminants

The term 'contaminant' as used in this Chapter, refers to all of the toxic wastewater constituents listed in Chapter 10, such as metals and metalloids (e.g., copper, mercury, zinc, and arsenic), as well as organic compounds (e.g., PAHs, PCBs and pesticides). There may be significant differences between each contaminant in their nature and effect. For example, some contaminants will be more toxic than others or have a relatively greater capacity for bioaccumulation and biomagnification through the food chain (e.g., mercury). Despite such differences, effects monitoring requirements for contaminants can be discussed collectively since: (i) all of them are primarily sediment-associated; (ii) all are usually measured via core sampling of surficial sediments; and (iii) their environmental significance can usually be evaluated against sediment quality guidelines or the state of the biological community.

When making a decision on whether or not to conduct sediment contaminant analyses, at least two important factors need consideration:

- Which contaminants should be tested for?
- Are the sediments likely to accumulate contaminants?

Contaminant analyses can be very expensive. Given the usual complexity of receiving environment sampling (e.g., multiple sampling sites or replicate samples), only those contaminants identified as problematic in the discharge monitoring (Chapter 10) should be considered for effects monitoring.

Furthermore, coarse sediments like gravel and sand are not likely to accumulate particulate-bound contaminants nearly as readily as fine muddy sediments. Also, sediments subject to regular disturbance and redistribution or resuspension are less likely to accumulate contaminants. In such situations, the analysis of multiple sediment samples for a suite of contaminants may be expensive, yet reveal nothing about wastewater-related effects.

There are a couple of approaches that can be taken where there is doubt about the likely extent of sediment contamination. One is to have only a few samples analysed, to see whether there is an obvious impact that needs more detailed evaluation. The other is to initially have samples analysed for a subset of the contaminants, before deciding whether analysis of all contaminants of concern is required. One strategy commonly employed is to first analyse selected samples for key trace metal contaminants, since the cost per analysis is considerably less than for organic contaminants like pesticides.

Sediment grain size analyses should also be considered for assessing wastewater impacts on soft-sediment communities. A full break down by standard grain size classes is generally not necessary, but analyses should at least differentiate between mud (silt/clay particles < 63 µm), sand (> 63 µm – 2 mm) and larger size classes. This requirement is a reflection of two key influences of sediment grain size characteristics.

Note:

Sediment grain size and organic content are both important factors when assessing contaminant levels in sediments.
Grain Size: At a minimum analysis should include gravel, sand and mud:

Grain size class		Particle size range	
		mm	Phi units
Gravel		2.0 - 4096	-1.0 to -12
Sand		0.0625 (63 µm) – 2.0	4.0 to -1.0
Mud	Silt	0.0039 – 0.0625	8.0 to 4.0
	Clay	< 0.0039	14.0 to 8.0

Organic content: Use either ash free dry weight (AFDW) or percent total organic carbon (TOC).
$TOC\% = 0.4(AFDW) + 0.0025(AFDW)^2$ [Craft 1991]

First, chemical contaminants are associated mainly with the fine muddy sediment fraction. A valid comparison of contaminant levels at different sites (e.g., control vs impact sites) will need to recognise any major differences in sediment grain size characteristics. Where these differ greatly, it may be necessary to normalise the contaminant data (e.g., express contaminant concentrations per gram of mud) or analyse the data in such a way that grain size differences are taken into account. Second, sediment grain size characteristics can greatly influence the ecological community present. As was the case for contaminants, biological differences between samples or sites will need to recognise any differences in sediment grain size.

Interpretation of the potential ecological implications of sediment contaminant results is usually done on an individual constituent basis, where a single parameter is tested against a sediment quality guideline level. Sediment quality guidelines aim to predict ‘acceptable’ levels of contaminants in sediment, based on ecological effects criteria. New Zealand has recently published national guidelines for sediment quality (ANZECC 2000a) based on international guidelines (e.g., PSDDA & U.S. Army Corps of Engineers 1989, Long & Morgan 1991). The ANZECC (2000a) guidelines specify, for individual contaminants, a lower threshold (ISQC-Low) that indicates a *possible* biological effect, and an upper threshold (ISQC-High) that indicates a *probable* biological effect.

It should be recognised that because the guidelines are limited to individual analytes, they do not take into account the synergistic, antagonistic or additive effects of combined contaminants within a sediment, nor the extent to which the contaminants are bioavailable. Experience has shown such guidelines are usually conservative in that values for a range of constituents may be exceeded in the absence of discernible ecological effects.

Sampling

For an assessment of contaminant levels, and for direct measures of the level of enrichment (e.g., % TOC), sampling of surficial sediments will be adequate for most wastewater monitoring studies. Furthermore, since sediment-dwelling fauna (see section 11.5.4) generally inhabit surficial sediments (e.g., the surface 50-100 mm of a muddy sediment), it is most relevant in ecological terms to target surface sediments during sampling. In this way, relationships between contaminant/enrichment levels and biological effects can be examined.

Collection of surficial sediments can be accomplished using a variety of methods. The most common of these, however, are manual collection with hand corers or remote sampling from the water surface using a grab or coring device. The small volume of material generally required for most analyses means that simple gravity cores can often be used for this type of remote sampling.

Contaminant analysis advantages and disadvantages:

Pros: Gives direct measure of concentrations in the receiving environment
Can be easily checked against guideline levels to determine potential effects
May not require lots of replication and multiple samples to elucidate trends

Cons: Does not apply to all sediments. Not much value for coarse sandy and/or mobile sediments.
Can be expensive, especially organic analyses
Concentrations might not be bioavailable and may give a misleading picture of potential effects

11.5.4 Assessing ecological effects

Background

Monitoring ecological effects on the seabed is perhaps one of the most important components of an effects monitoring programme in a marine system. Although other components (e.g., contaminant monitoring) provide a picture of the potential to cause effects, ecological monitoring allows for direct assessment.

There are a number of studies from New Zealand (e.g*.,* Roper 1990, Barter and Forrest 1999b) and overseas (e.g*.,* Chapman, et al 1995, Koop & Hutchings 1996, Smith 1996, Underwood & Chapman 1996) that describe large subtidal wastewater discharges that have had little discernible ecological impact on soft sediment or rocky habitats. Koop & Hutchings (1996), for example, note that most of the studies of impacts from Sydney's deepwater outfall have been unable to detect environmental impacts. The study of ecological effects from Tauranga's wastewater discharge by Roper (1990) indicates that even in an estuarine environment with adequate flushing, seabed impacts can be limited to within tens of metres from the outfall.

In contrast, a number of other studies in New Zealand (e.g.*,* Roper et al*.* 1989, Anderlini & Wear 1992) and overseas (e.g., Chapman et al*.* 1995) have revealed sediment contamination and ecological impacts over scales of hundreds of metres, even in relatively exposed coastal areas. The more significant effects are described for discharges which are large, receive minimal treatment, or consist of industrial as well as domestic wastewater. As a general trend, the effect of discharges to intertidal areas, which would be exposed to buoyant effluent plumes, appear far greater than for the subtidal (Fairweather 1990, Smith 1996, May 1985). Clearly, the impacts of wastewater discharges can be variable and depend on a combination of wastewater treatment, contaminant loading, and a range of site-specific environmental factors.

A discussion of effects monitoring requirements needs to recognise two main ecological components of the seabed environment: (i) infauna, which is the assemblage of animals (often microscopic) that live buried or partially buried with the sediment matrix (e.g., worms, bivalve shellfish); and (ii) epibiota, which refers to the animals and plants (e.g., sea stars, urchins, seaweeds) that inhabit the surface of the seabed. Epibiotic assemblages may be a significant feature of both rocky and soft-sediment habitats, although epibiota can be relatively impoverished in both. Infaunal assemblages, on the other hand, are a unique feature of soft-sediment habitats.

Effects on sediment-dwelling infauna

Many wastewater monitoring studies target the infaunal assemblage. This in part reflects the fact that a large proportion of wastewater outfalls are situated on soft muddy sediments. An advantage of infaunal sampling in such situations is that results can be interpreted in light of any sediment quality data from the same sampling stations.

In addition, infauna, and especially macrofauna (by definition infaunal animals that are retained on a 0.5 mm mesh screen), have been used for several decades as sensitive indicators of the effects of wastewater discharges, and are suitable for quantitative studies. For example, the composition of the macrofaunal community, the number of different species, and the number of individuals of a given species, all provide a valuable indication of the quality of soft-sediment habitats.

The enrichment effects from wastewater and other organic-rich discharges are particularly well documented and understood. A generalised model for the effects of organic enrichment is provided in Table 11.6. This model shows that significant organic enrichment is typically accompanied by a proliferation of one or a few macrofaunal species, and a decrease in species richness (the number of different species present).

Table 11.6. Generalised model of the effects of organic enrichment. (adapted from Pearson & Rosenberg 1978).

Level of enrichment	Macrofaunal Response
Unenriched	Moderate species richness with a moderate abundance distributed evenly among species
Low	Transition zone: abundance and species richness may be higher than 'normal'
Moderate	Moderate-low species richness with a few 'opportunist' species occurring in high abundance
High	Low species richness consisting of one or a few opportunist species which reach very high abundance levels. [*e.g.* Very high capitellid levels are defined as > 1,000/m^2 (ANZECC 2000a)]
Extreme	Anoxic, sulphide-rich conditions either devoid of macrofauna or having very few species in very low abundance

Seabed macrofauna can be collected through a variety of methods, however, the two most common are manual methods (large hand cores) or grab sampling methods. Sample volume should be consistent between sites and surveys to allow cross comparison. As a rule of thumb, samples should be at least 10 cm depth and have a minimum surface area of at least 125 square centimetres. Because macrofaunal communities may be variable or patchy, it is standard practice to take replicate samples from any one site in order to provide an average picture of species richness and abundance, and provide a representative sample of the species present. The identification and enumeration of seabed macrofauna is usually performed on preserved samples in the laboratory with the aid of a binocular microscope, and requires specialist expertise.

Sediment infauna monitoring advantages and disadvantages:

Pros: Lots of historical data for comparative purposes
Good relationship between enrichment level and effects on biota.
Cons: Analysis and taxonomic identification requires specialised expertise
Not as valuable in sandy coarse sediments.
Can be expensive, particularly since replicates and multiple samples are required.

Effects on epibiota

The wastewater impact studies that have described effects on epibiota tend to be those conducted in environments where rocky habitats were dominant (e.g., May 1985, Chapman et al. 1995, Smith 1996, Underwood & Chapman 1996). Generally, however, less attention has been paid to sampling epibiota in either rocky or soft-sediment communities, than the infaunal community. This reflects a number of factors as follows:

- The sensitivity of most epibiotic assemblages to wastewater-related impacts is poorly understood.
- Sampling methods (especially quantitative sampling) for epibiota tend be more labour intensive than for infauna.
- Epibiota can be highly variable spatially and over time, meaning that it can be relatively difficult to separate background variation from wastewater impacts.
- The taxonomy of epibiota, especially in rocky habitats, is generally less well understood than for infaunal assemblages.

Hence, it is suggested that wastewater effects monitoring programmes should target sediment quality and infaunal sampling where possible. Nevertheless, in soft-sediment habitats where epibiota are a conspicuous feature (but not dominant), it is desirable to document any major effects if they are present. A reasonable approach in such situations would be to undertake a quantitative programme to sample infauna and sediment quality, supported by semi-quantitative sampling of epibiota. This could involve, for example, recording the conspicuous species present and whether they were rare, common, or abundant according to defined density categories; or making percent cover estimates of sessile (attached or encrusting) species (e.g., seaweeds). In exclusively soft-sediment areas, dredging may also be a useful tool, since it provides a broad-scale semi-quantitative sample of epibiota and shallow infauna that are large, sparse, or patchy, and that cannot easily be sampled by other methods.

Where epibiota are dominant, and especially if rocky habitat is dominant, it may be necessary to undertake quantitative sampling. Most of the common quantitative methods are non-destructive and involve sampling along transects or within quadrats. A transect is usually a straight line of a few metres to tens of metres long and perhaps 1-2 m wide, and is suited to the sampling of large, sparsely populated, or patchy epibiota. A quadrat is a small rectangular or square frame (usually 1 m^2 or less) that is suited to sampling small and common epibiota.

Sampling in transects or quadrats will usually require making counts of target species, or obtaining percent cover estimates of target species or entire assemblages. Percent cover estimates can be derived from the 'point count' method conducted *in situ*, or using photoquadrats. A photoquadrat consists of a camera and frame designed to take a photo of a small quadrat area. Photoquadrats are often used for deeper subtidal outfalls where time constraints placed on divers do not allow for *in situ* sampling. In addition to sampling the species present, such methods can also be used to quantify the nature of the substratum. In a rocky habitat subject to wastewater discharge effects, for example, it may be of interest to know whether depositional impacts have resulted in an increase in bare rock substratum, or an increase in sediment cover, relative to control areas or baseline conditions. A comprehensive account of appropriate methods for sampling epibiota is provided in Kingsford and Battershill (1998), and is not further discussed here.

11.6 Effects on sediments and biology: freshwater environment

11.6.1 Overview

While the marine environment receives approximately two thirds of New Zealand's wastewater discharges by volume, the greatest number of discharges (~ 53 %) are into freshwater environments, primarily rivers and streams (MacDonald et al. 2000). Since discharges to lakes are insignificant in the New Zealand context both in terms of volume (< 1 %) and number of discharges (< 2%), it is only effects monitoring requirements for rivers and streams that are considered here.

The evolution and general approach to ecological effects monitoring in rivers and streams provides an interesting contrast with the marine environment. Whereas ecological assessment studies in marine systems have focussed primarily on soft-sediment habitats, the focus in rivers and streams has primarily been on monitoring wadeable hard-bottomed habitats, in particular faster-flowing 'riffle' areas. Such areas are readily accessible and have macrofaunal communities that include the most pollution-sensitive of the stream invertebrates. A knowledge of pollution effects on this community has lead to the development of a number of community-based environmental health indices, including the well known macroinvertebrate community index (MCI) and its derivatives (Stark 1993, Boothroyd & Stark 2000).

In contrast, the soft-sediment habitats characteristic of relatively slow-flowing streams and rivers are less well understood, and less favoured in environmental assessment studies. In part this reflects the fact that it may be relatively difficult to obtain 'representative' samples from such habitats. It also recognises that the macrofaunal communities of soft-sediment areas are relatively impoverished and species-poor, do not contain the pollution-sensitive species characteristic of riffle areas, and are less amenable to comparative quantitative sampling than riffles (Stark, et al 2001).

This contrast between hard-bottomed and soft-sediment habitats creates an interesting dilemma for wastewater monitoring. On the one hand, ecologically sensitive riffles are the logical habitats in which to assess ecological effects, while soft-sediment habitats, are an obvious focal point for targeting sediment-associated contaminants. Since these two habitat types may not coincide in terms of proximity to the wastewater discharge, drawing links between environmental quality and ecological effects can be more difficult than in marine sediments. Hence it is useful to consider approaches to effects monitoring in hard-bottomed vs soft-sediment habitats separately.

11.6.2 Ecological effects in hard-bottomed riffle habitats

Since muddy sediments may be difficult to find in fast-flowing streams, sampling for sediment-associated contaminants is not often carried out in wastewater monitoring studies in these systems. Instead, inference about environmental effects often relies heavily on riffle sampling of macroinvertebrates and biological growths (e.g., Harding 2000). Stark et al. (2001) recommend two sampling protocols for macroinvertebrates in such habitats and they are not further discussed here. Biological growths include autotrophic growths like periphyton, whose proliferation may indicate nutrient enrichment. Visual scales for assessing periphyton are provided in Biggs (2000). Other potentially nuisance biological growths are heterotrophic slimes collectively referred to as sewage fungus, discussed in MfE (1992). The occurrence of such growths has been described for untreated wastewater discharges, but now generally appears uncommon with the move to improved effluent treatment.

Where potentially toxic contaminants or high nutrient concentrations have been identified as an environmental concern, but cannot be sampled in sediments, some assessment of risk to downstream ecological communities is still desirable. While direct sampling and analysis of receiving waters can be carried out, the limitations of 'snap-shot' water quality sampling described in Section 11.4.1 need to be recognised. Furthermore, it is usually desirable to consider potential ecological effects under a 'worst-case' scenario. This is usually assumed to be where a high (e.g., 95th percentile) concentration of each contaminant is discharged at maximum effluent flow during low-flow conditions in the receiving environment. In the most simplistic approach, where complete mixing of the effluent and receiving water is assumed, the downstream concentration of a contaminant can be calculated as follows:

$$\text{Concentration}_{ds} = [\text{Concentration}_{eff} \text{ x } P_{eff}] + [(\text{Concentration}_{us} \text{ x } (1\text{-}P_{eff})].$$

where ds = downstream, us = upstream, eff = effluent, P_{eff} = effluent volume as a proportion of downstream flow.

The predicted downstream concentration can then be compared to appropriate water quality guidelines (e.g. ANZECC 2000a) to provide some indication of potential effects.

Riffle Habitat monitoring advantages and disadvantages:

Pros:
Lots of historical data for comparative purposes
Well developed indices for evaluating effects (e.g. MCI, SQMCI)

Cons:
Direct relationship to sediment contaminant/enrichment level and biota does not exist like in marine situations due to spatial separation of the two environments
Analysis and taxonomic identification of macrofauna requires specialised expertise

11.6.3 Ecological effects in soft-sediment habitats

The general approach to sampling freshwater soft-sediments, and interpretation of results, is largely the same as for marine sediments (section 11.5.1). While assessment of effects on the ecological communities of soft-sediment habitats provides the opportunity for exploring relationships between contaminant concentrations and ecological effects, the lack of pollution-sensitive macroinvertebrates in freshwater soft-sediments means that it can be difficult to detect effects, or that only gross effects may be detected.

Unlike riffle habitats, therefore, ecological communities in soft-sediment habitats may provide a poor basis for assessing the ecological effects of wastewater discharges. This is not always the case, however, since many of the community-based ecological changes described for marine sediments are similar for freshwater sediments. For example, while enrichment in marine sediments may lead to a proliferation of polycheate or nematode worms, enrichment in freshwater soft-sediments may lead to a proliferation of oligochaete worms and chironomid larvae (Biggs 2000).

Rather than focus macroinvertebrate sampling on soft-sediments alone, Stark et al. (2001) suggest that sampling in soft-bottomed streams should comprise a semi-quantitative 'multi-habitat' approach that targets, for example, bank margins, aquatic macrophytes, and woody debris. The latter can be an important substrate for pollution sensitive groups of macroinvertebrates. The need for a semi-quantitative rather than quantitative approach stems from the fact that there may be inter-site variability due to differing proportions of the habitats sampled. However, they also provide a quantitative protocol for sampling the macroinvertebrates communities of macrophytes alone. Such an approach would conceivably be useful for assessing the effects of dissolved contaminants or nutrients (and their effects) in the water column, rather than sediment-associated contaminants.

Soft sediment monitoring advantages and disadvantages:

Pros: Direct relationship to sediment contaminant/enrichment level and biota is possible

Cons: Often requires multi-habitat approach
Soft muddy substratum for sampling not as prevalent as in marine situations.
Relative lack of macrofauna compared to other environments.

11.7 Bioaccumulation and transplanted biota

11.7.1 Bioaccumulation

Bioaccumulation is, as the name implies, the build-up or increase of contaminants within a living organism due to the presence of that contaminant in the environment. Bioaccumulation studies generally involve the collection and analysis of native populations of organisms (usually sedentary) which are utilised as bioindicators of chemical or bacteriological contamination. The most widely used organisms for these types of studies are bivalves. Bivalves such as the blue mussel (*Mytilus edulis galloprovincialis*) or green-lip mussel (*Perna canaliculus*), filter large volumes of water, and numerous studies have shown that they can accumulate contaminants to a level several orders of magnitude above the water column concentrations. They are also very simple physiologically and do not tend to metabolise. The preferential use of permanently attached biota (e.g., mussels, oysters) rather than motile biota (e.g., fish, snails) is due to the fact that mobile biota can selectively avoid unfavourable environmental conditions. Mobile biota can also confound analysis if they accumulate a body burden from elsewhere prior to moving into the selected study area.

Potential problems with conducting this type of analysis involve selective uptake rates by different species and even variously sized individuals of the same species. Further, because mussels depurate or eliminate fat loving (lipophilic) contaminants from their body tissues, both in response to cleaner conditions and through the release of gametes during spawning, one-off sampling does not always give a clear indication of actual concentrations. When attempting to use other biota such as fish or eels, there is a much higher probability that certain contaminants, particularly PAHs, will be metabolised and body burdens will not be representative of environmental conditions.

With this said, however, bioaccumulation can be an effective means of evaluating ambient receiving environment concentrations. The relative ease and low cost of collecting indigenous organisms, along with the direct relationship to both human health and environmental factors makes them ideally suited to certain situations. The use of a bioaccumulation monitoring should only be considered under certain circumstances like those listed in the text box. Otherwise, direct measurement of either water column or substrate variables is generally a preferable approach.

Consider conducting bioaccumulation monitoring only if the following conditions apply:

Resident biota are present in sufficient numbers to sample on multiple occasions

The discharge contains either contaminants or biological pathogens

Measuring water or sediment levels directly is not sufficient

Biota are collected for human consumption (*e.g.* mussels, watercress)

Bioaccumulation monitoring advantages and disadvantages:

Pros: Relatively inexpensive
Sedentary organisms
Can biomagnify contaminant concentrations well above background water levels
Can be used to assess both bacteriological and toxic parameters

Cons: Can release or depurate themselves of contaminant loads.
Different species accumulate and release contaminants at different rates.

11.7.2 Transplanted biota

The most common uses of transplanted biota are caged bivalves in the marine environment and freshwater mussels and caged eels in the freshwater environment. Transplanted biota involves collecting resident biota (ideally from a clean source) and transplanting them in an area where they are subject to effluent exposure in the receiving environment. The same general considerations that applied to resident bioaccumulation hold true for transplanted biota. For example, selective uptake rates, depuration, and metabolism of contaminants.

One real advantage to transplanted biota over resident bioaccumulation studies is that transplanted organisms can be positioned exactly where they are wanted and not where they happen to reside. The downside to this is that artificial structures like moorings are usually required to suspend the biota within the water column at the proper level. Other problems often arise in that the transplanted organisms cannot survive in the new environment or are stressed to different degrees depending on the contaminant gradient and thereby filter or feed selectively which varies uptake rates. In addition finding a resident population in a pristine environment is not always possible. It is often necessary to either transplant the biota to a clean environment, so they can depurate any existing body burdens prior to initiating the study, or have a control population in a clean environment during the course of the study for comparative purposes. As was the case with resident biota, the same general considerations need to be addressed prior to choosing this method as a monitoring approach.

Transplanted biota monitoring advantages and disadvantages:

Pros: Can be used when resident organisms are not present
Can be placed in exact locations
Can be used to determine exposure rates and not just body burdens

Cons: High cost
Usually requires mooring or other attachment device for deployment

11.8 Monitoring human health issues

Since domestic wastewater can contain high concentrations of disease-causing pathogens, the potential for adverse human health effects resulting from wastewater discharges needs addressing. Health risks associated with activities in sewage-contaminated waters arise primarily from water ingestion during contact recreation (e.g., swimming, surfing) and from eating filter-feeding shellfish (e.g., oysters & mussels) which have accumulated bacteria and other pathogens in their bodies. However, contact through inhalation or direct contact with ears, nasal passages, and cuts or abrasions are also potential entry points for pathogens.

Monitoring of receiving waters for human health risks can be done by monitoring either or both of indicator bacteria or pathogens. The advantages and disadvantages of these methods is described in Section 10.6. It should be noted that, in most circumstances, it will be very difficult to find evidence of pathogens at any distance from the wastewater outfall, unless there are large numbers of such pathogens in the discharge. On the other hand, if indicator bacteria are to be used in receiving environment monitoring, the relationship between indicator bacteria and pathogens should be established for the effluent discharge if possible.

The Ministry of Health (MoH) and MfE released guideline values for indicator bacteria concentrations for contact recreation and shellfish harvesting waters in August 2002 (MfE 2002a). However, these guidelines should not be directly applied to assess the microbiological quality of water that is impacted by a nearby discharge of treated effluent (particularly disinfected effluent and including waste stabilisation pond effluent) without first confirming that they are appropriate. While it is correct to infer that water exceeding the guideline values poses an unacceptable health risk, the converse is not necessarily true; water containing less than the guideline indicator bacteria values does not necessarily correspond to an acceptable health risk. This is because effluent may be treated to a level where the indicator bacteria concentrations are very low, but pathogens such as viruses and protozoa may still be present at substantial concentrations, effectively changing the indicator/pathogen ratio.

11.9 Other monitoring tools

11.9.1 Stable isotopes as tracers

In simple terms an isotope is one of two or more elements, of which the individual atoms have the same atomic number but different atomic weights based on the number of neutrons in the nucleus. For example ^{13}C and ^{14}C are both isotopes of Carbon, each with 6 protons but with 7 and 8 neutrons respectively. The latter of these, carbon-14 is very well known because it is a radioactive isotope of carbon that decays at a known rate and has been used extensively in geology and archaeology to date artefacts. On the other hand, carbon-13 is not radioactive and is therefore referred to as a stable isotope of carbon.

Analysis of the stable isotopes of carbon and nitrogen (^{13}C and ^{15}N) for tracking terrestrial inputs of particulate organic matter (POM) into marine systems is an emerging science in New Zealand. Although the use of these isotopes for tracking wastewater inputs into marine systems has been well understood for more than twenty years (Rau, et al 1981, Sweeney, et al 1980), recent advancements in analytical instrumentation have brought down the cost of conducting these tests to the point where they can be considered for routine effects monitoring and not merely as an interesting research topic.

In simple terms, the analysis involves comparing the ratio of the stable isotopes of carbon and nitrogen (^{13}C and ^{15}N) against the parent forms of each atom (^{12}C and ^{14}N). Marine organisms and sediments tend to have different sources of carbon of nitrogen than their terrestrial counterparts and therefore have been shown to have markedly different isotopic signatures. However, marine organisms and sediments in the vicinity of wastewater outfalls are subjected to terrestrial sources of carbon and nitrogen and show an isotopic shift towards this terrestrial signature.

The use of this technique for helping to elucidate any outfall-derived organic enrichment has been used recently on several studies (e.g., Rogers 1999, Barter 2000) and is showing promise as routine monitoring tool.

Stable isotope analysis advantages and disadvantages:

Pros: Can show a direct link between enrichment and wastewater outfall
Low cost (about the same price as other nutrient methods).
Analytical results include total organic carbon (TOC) and total organic nitrogen (TON).

Cons: Not yet widely used in New Zealand
Lack of historical data for comparison

11.9.2 Semi permeable membrane devices (SPMDs)

Semi-permeable polymeric membrane devices (SPMDs) are relatively new monitoring tools that are being developed to act as bioaccumulation surrogates. They consist of low-density, semi-permeable polyethylene tubing containing lipid material that concentrates organics such as PAHs. The SPMD method provides a potential alternative to bioaccumulation, or to

SPMD monitoring advantages and disadvantages:

Pros: Can be used when resident organisms are not present
Can be used in environments that might otherwise kill transplanted biota

Cons: High cost
Specific to organic contaminants, not bacteria or metals
Requires mooring or other attachment device for deployment

water quality programs. Although the SPMD approach has been used both internationally and in New Zealand, (e.g*.,* Peven, et al. 1997, Hofelt & Shea 1997, Miller 1999), its use in wastewater monitoring programmes is not widely documented. This is likely because the levels of contaminants in wastewater are generally low compared to other studies where SPMDs have been used (*e.g.* oil spill research, commercial ports & harbours) and the monitoring costs are usually high. Use of SPMDs for effects monitoring would only be justified if the discharge had high concentrations of organic contaminants (*e.g.* pesticides, PAHs) and other options like bioaccumulation were not feasible.

11.9.3 Fluorescent whitening agents (FWAs)

Fluorescent whitening agents are a group of compounds (*e.g.* Hiltamine Arctic White, tinopal CBS-X) that are routinely added to commercial washing powders to brighten fabrics. They adsorb to fabrics and fluoresce when exposed to UV radiation in daylight. Because of their ubiquitous use and presence in domestic wastewaters, they have been targeted as a potential faecal source indicator (Sinton et al. 1998). FWAs, along with other washing powder components (i.e.sodium tripolyphosphate), are rarely used for routine monitoring of treated wastewaters and instead have been more frequently used for tracking septic tank contamination of potable water wells and recreational waters.

FWA monitoring advantages and disadvantages:

Pros: FWAs are a common component of domestic wastewater
Detectable at low levels
Cons: Not routinely used for treated wastewaters
Natural fluorescence can interfere with detection

11.9.4 Sterols

Sterols is a generic term used to describe a host of different 27 to 29 carbon, cholestane-based sterols present in faecal material including: cholesterol, coprostanol, sitosterol, sitostanol, and campestanol. Of these, coprostanol is the main human faecal sterol and has been used as a faecal source indicator since it is exclusively produced in the intestinal tracts of humans and some higher mammals. In contrast, other sterols like cholesterol are present in myriad different animal products (e.g. eggs, milk etc) and are not good indicators. As a

Sterol monitoring advantages and disadvantages:

Pros: Robust indicator which can withstand treatment processes (e.g. chlorination)
Persistent in receiving environment
Detectable at low levels
Cons: Expensive

biological indicator sterols are very robust and generally have a much longer environmental fate than other routine indicators such as coliform bacteria. However, even though the use of sterols as a wastewater monitoring tool has been well documented (Brown & Wade 1984, Dureth et al. 1986) they are not routinely used. This is primarily due to cost since determination of sterols requires gas chromatography/mass spectrometry methods, which are inherently more expensive than other analytical techniques used for alternative indicators.

11.10 Mixing zones

The RMA requires that any standards imposed through classification or section 107 is met after '*reasonable mixing*'. Zones of reasonable mixing are areas of transition within which classifications do not apply. They are effectively zones of non-compliance. From a practical viewpoint standards can only apply after reasonable mixing of any contaminant or water with the receiving water, disregarding the effect of any natural perturbation. The area within which this mixing occurs is called a 'zone of reasonable mixing'. This 'zone of reasonable mixing' provides for the mixing of discharges with receiving waters. Some further mixing could still occur outside of the zone as long as the effects in section 107(1) of the RMA do not occur and the relevant water quality classification standards are met.

In general, it is not intended that the size of a zone of reasonable mixing be tailored to the volume and nature of a discharge, but rather that the volume and nature of a discharge fit the standards and criteria in accordance with regulatory framework (e.g., Regional Council's Coastal Plan). The zone of reasonable mixing depends on:

- The rate of discharge and concentrations.
- The physical configuration of the outfall or structure from which the discharge is emitted.
- The depth, current velocity and direction, and the rate of turbulent mixing of the receiving water.
- Ambient concentrations in the receiving water.

The general requirements for the zone of reasonable mixing are outlined in *"Resource Management Ideas No 10 – A discussion on reasonable mixing in water quality management."* (Rutherford, et al. 1994) as follows:

- The size of the zone of reasonable mixing should be minimised.
- Any adverse effects should be confined to within the zone of reasonable mixing.
- Any adverse effects within the zone of reasonable mixing should be no more than minor.

It is anticipated that a discharger, altering the extent to which contaminants or water are discharged into the receiving environment, can control the size of the zone of reasonable mixing. For example, lowering the volume or improving the level of treatment or mixing characteristics, even by a small degree, can produce marked changes in mixing zone specification.

It is also important to appreciate that a single discharge may have more than one zone of reasonable mixing. For example, a coastal outfall may have one zone of reasonable mixing for seabed impacts and another for water column impacts. The location of the zone of reasonable mixing should also take into account the nature and degree of uses in that area. Data from other areas can help clarify a likely zone of reasonable mixing.

11.11 Air and land discharges

11.11.1 Air

As mentioned previously, discharges to air from wastewater plants are of a secondary nature. This is because the overwhelming majority of the emissions from a plant are either in the form of biosolids or liquid effluent, with any discharges to air being either incidental release of spray or aerosols or through the treatment process. They are also being treated as a secondary concern given the focus of these guidelines, which concentrate on discharge to aquatic environments.

With these caveats in mind, discharges to air can be divided into three main categories: (i) aerosols, (ii) odour, and (iii) treatment related contaminants. The latter of these is a very broad term that is used to describe all other discharges to air and can include sludge incineration stack gases, anaerobic digestion gas exhaust, and sludge drier emissions to name a few. While these processes have the potential to emit considerable amounts of methane, nitrogen oxides, sulphur oxides, and particulates to the air; it is not within the scope of these guidelines to address these issues. These issues are generally specific to individual treatment plants and mitigative action to reduce emissions is almost always employed to the point where odour, and to a much lesser degree, aerosols become the primary air emission concerns.

Aerosols

Aerosols are small air-bound particles of water. These particles are only visible to the naked eye in high concentration and large volumes. For example, the haze that is often observed along the surf zone of beaches is made up of aerosols. The diminutive size of individual aerosols, however, does not mean that they cannot act as vectors for the microscopic pathogens that are present in wastewater effluent. Wastewater aerosols have the potential of containing not only pathogenic micro-organisms but also minute organic and inorganic particulates. In almost all circumstances, though, the isolation from most public activity surrounding wastewater facilities and the short distances travelled by high concentrations of aerosols makes all but odour issues insignificant.

If it is expected that exposure to aerosols might be an issue there are several good references available, although specialist advice will probably be required. A general discussion of the types of pathogens present in wastewater is covered in section 11.8 and more detailed discussions are available in most wastewater engineering texts. In addition, the recent sewage effluent to land guidelines (NZLTC 2000) discusses the emission rates, exposure routes and mitigative measures for controlling aerosols from irrigation equipment.

Odour

Without question, public perception places odours as the most significant air related discharge from wastewater plants. Reactions to odour are as variable as the people that encounter them, and range from ambivalence to physical effects like nausea. Generally, the reaction to wastewater odours is a negative one, but it is not within the scope of these guidelines to discuss odour assessment methods. Odour effects monitoring and assessment methods are covered in the sewage effluent to land guidelines (NZ Land Treatment Collective 2000).

11.11.2 Land

Discharge of wastewater directly to land constituents a small percentage (roughly 6%) of the total daily effluent volumes in New Zealand (Macdonald, et al 2001). This, coupled with the recent release of guidelines specifically designed to address the discharge of wastewater to land (NZLTC 2000), are the two main reasons why discharge to land is not being covered in detail in this Chapter.

The recent land disposal guidelines include sections on wastewater characteristics, site selection, soil treatment processes, environmental effects, application methods, and crop selection. With respect to effects monitoring the land disposal guidelines outline approaches for monitoring:

- Soil, surface and ground waters.
- Soil quality.
- Climate and air quality.
- Vegetation.

CHAPTER 12
MONITORING EFFECTS ON COMMUNITY VALUES

James Baines, Janet Gough (Taylor Baines Associates)
Donald Couch (Lincoln University)

12.1 Levels of community involvement

The community can be involved in the effects monitoring process in a variety of ways. At differing levels of community involvement, they include -

1. Evaluation by the community of technical monitoring results.
2. Involvement of community representatives in monitoring activities, including data gathering.
3. Monitoring effects on people's values (e.g., impacts from odour, noise, litter, etc.).

12.1.1 Evaluation by the community of technical monitoring results

This is common practice with many Councils, and occurs when small groups of community representatives are sent periodically the results of technical monitoring activities (e.g., water quality test results) and invited to review and comment on the results. The approach, which serves as a mechanism for communicating information on certain aspects of the WWTP's performance to interested community participants, requires the existence of appropriate community groups or groups of representatives and tends to be targeted at groups with a statutory basis (e.g., Runanga or Community Boards) or groups which are part of a larger organisational network (e.g., Fish & Game Council). Providing this information increases the communities' knowledge and understanding and typically the information is fed back to the larger community as well as other community groups, and friends and neighbours.

At this level of involvement, the community is unlikely to have had any input to setting priorities for monitoring; they simply receive information deemed important by technical experts.

12.1.2 Involvement of community representatives in monitoring activities

This is when small groups of community representatives commit themselves to gathering information in a systematic and agreed way (e.g., water samples at bathing beaches), delivering the samples for analysis and then meeting to review and interpret the results. Such an arrangement implies a focus on a particular type of risk factor (e.g., the risk of water contamination). Because of the greater level of community participation, it is likely that the community representatives have had an opportunity to discuss and negotiate priorities for such monitoring with the WWTP operators and administrators.

Another example might be the establishment of a community liaison group with neighbours of the WWTP as a mechanism for channelling and reviewing observations and complaints about the effects of the WWTP's operations that come to the attention of people nearby. This would usually go hand in hand with an agreed response procedure. While such an arrangement might involve regular review meetings, the intervening activities may be anything but regular. The purpose of such a community liaison group is to support a mechanism for anyone in the neighbouring community to relay observations or complaints directly to the plant's operators. Depending on the performance of the plant, such observations may be very rare or very frequent.

These arrangements provide good examples of risk communication mechanisms – channels of communication between the community and the plant operators are maintained on an 'as required' basis.

12.1.3 Social monitoring activities (impact monitoring)

Social monitoring occurs when neighbours of the WWTP are systematically surveyed about their experience of the plant's operations over the preceding time period. It is likely to occur at time intervals related to any formal review of consent conditions and plant performance (say every 3-5 years). The focus is on assessing the impacts that the WWTP's operations have had on its neighbours. An assessment of impacts enables individuals to relate any effects they might experience to the environmental qualities they value. Effects are thus related to values.

If motivation and effective participation are considered important, then it is likely that modes of involvement which allow community members to make input to setting priorities as well as evaluating results will be favoured (i.e., the second and third categories above).

12.2 Why monitor effects on community values?

Monitoring activities allow, at the very least, for information on the performance of WWTPs to be made available to members of the community. With higher levels of involvement, community members have greater knowledge and understanding of the significance of the information. Over a period of time, this allows the community to learn more about the operation of the plant. Community members may then be in a position to re-assess the risks, the need for particular monitoring, the level of monitoring effort that is appropriate, and the priorities for monitoring effort.

If a risk-based monitoring regime changes over time, then the community should be provided with the opportunity to review its priorities.

Consent conditions embody protection for neighbours and other parties who have a stake in the quality of the environment. Community involvement in monitoring effects can provide input to the review processes for consent conditions. Social monitoring may identify issues and effects not previously considered in the setting of consent conditions and the design of monitoring regimes. It can also provide a channel for community input to future consent conditions, complementary to the input of technical experts.

12.3 Approaches to monitoring effects on community values

12.3.1 Choosing how to incorporate monitoring of effects on community values

The approach chosen will reflect the scale of the system, and the size and sensitivity of local communities. There will be costs involved with monitoring community values (as for monitoring technical aspects) and these costs will fall on the community involved. Therefore, before deciding on what form of community involvement there should be in the monitoring programme, the community should be consulted so that members of the community are aware of what has been proposed, understand the costs involved and who will have to pay, and know the expected benefits. These costs and benefits include costs in terms of people's valuable time. Such contributions will in most cases reduce the dollar cost of administering consents (see 12.3.3).

The remainder of this section contains examples of each level of community involvement in monitoring.

12.3.2 Evaluation by the community of technical monitoring results

This involves use of established community representative groups (e.g., Runanga, Community Boards or Ratepayer Associations in urban centres, or established residents groups) or the formation of groups representing neighbours interests and the interests of other immediate stakeholders in the locality (e.g., user groups of a river being used to receive effluent discharge - 'Friends of the ......River').

Several questions to think about here are:

- Which groups should be sent the monitoring results and invited to comment?
- What criteria are used in identifying such groups?
- Are any of the existing groups actually well placed in order to make sensible evaluation of the results? In other words, do members of the group have first-hand experience - residential occupancy, workplace or recreational location - which enables them to make sense of the results?
- (How) will groups be able to ask questions about the monitoring activities? Of whom?

12.3.3 Two examples of involvement

A formalised monitoring group - the Lyttelton Harbour Basin Issues Group

The Lyttelton Harbour Basin Issues Group was established by Environment Canterbury and the Banks Peninsula District Council as a means of establishing a communication channel between the councils and the communities of the harbour basin. Representatives of each community attend regular meetings every six weeks and report back to their communities.

A key activity of this group has been to design and implement a water-monitoring programme. Members of the group collect water samples on a weekly basis from eight local bathing beaches, and these samples are analysed by Environment Canterbury. Initially eighteen months of continuous sampling was undertaken to obtain baseline data. This has now been replaced by monitoring over the summer months only (November to April). In addition, Rapaki has been taking shellfish samples from six sites around the harbour for analysis on a monthly basis.

The group has designed a notice that is placed at each site being monitored, explaining the programme. If the sample for a particular beach reaches the bathing water trigger level, then a 'don't swim' sign can be placed while additional sampling is undertaken.

The water monitoring programme has been designed by the group with expert assistance provided by the two councils, Health Authorities, and other invited experts. An important aspect is that the group retains ownership and drives the process. Results to date have demonstrated that the highest enterococci readings occur after heavy rain, and the group is considering how to establish a monitoring programme for peak flows on some of the main streams entering the harbour.

Another important aspect is that while the initial focus has been on water quality, the group's mandate is not limited to water monitoring. Currently the Lyttelton group is concerned about issues relating to multiple use of the harbour. Some aspects of this impinge on water quality, but other aspects are related to community integrity and amenity values.

Resources to support the activities of this group have come from various sources and individuals on the group have given their time for free, both in attending meetings, and undertaking the monitoring programme. Environment Canterbury has funded the laboratory analyses of water samples. They have a statutory obligation to monitor and the free sample collection means that they are able to monitor a larger number of areas than they would otherwise. Rapaki and Crown Public Health have paid for shell fish testing at various times. Several community organisations have made contributions in kind - meeting venues, collection and delivery of samples.

For further information, contact John Porter at the Banks Peninsula District Council.

A formalised neighbours liaison group - Redvale Landfill Community Liaison Committee

[Note: while this example is associated with a solid waste facility, the rationale for its establishment is consistent with the focus of these guidelines for WWTPs. Other groups exist for WWTPs as in the case of Moa Point, in Wellington]

The Redvale Landfill Community Liaison Committee was established as a condition of the resource consents for operating the landfill. It comprises twelve members and meets quarterly. Membership of the committee is predominantly (more than half) from those within the immediate host community of Dairy Flat, while the Auckland Regional Council, the Rodney District Council and the facility's technical Peer Review Committee are each represented and the facility's manager is a member (as well as being a neighbour).

The Committee's role is to allow issues and concerns relating to the operation of the landfill to be debated and negotiated. At least one local resident is designated Resident Liaison

Officer, a neighbour to whom complaints can be lodged. However, neighbours are actively encouraged to report any off-site effects directly to the facility manager. A recording and response procedure is in place. The Community Liaison Committee supports this mechanism for direct communication between operator and neighbours by regular reviews of the complaints register, evaluating patterns of effects and assessing whether the operator's responses have been reasonable and effective. Through the Liaison Committee, complaints can be de-personalised, and legitimate community interests advocated.

Such Liaison Committees can instigate 'open days' or tours of the facility, so that neighbours can be informed about the operations and understand likely sources of risk. With a mechanism such as this, it is more likely that priorities for attention and discussion will be set by members of the community rather than technical experts.

For further information, contact the Manager, Redvale Landfill, Dairy Flat.

Some such groups are set up with independent facilitators, although with goodwill and good intentions by all parties, this should not be a requirement.

12.3.4 Social monitoring activities (impact monitoring)

The emphasis in social monitoring should be on making a realistic assessment of the community's experience, from the community's point of view. In the specific context of odour monitoring, Lincoln Ventures (1997) distinguish between an 'indicative survey', the main focus of which is to improve management of the plant for odour effects, and a 'definitive survey' where the immediate objective is to provide information for legal proceedings (e.g., consent hearings, enforcement orders, abatement notices).

The nature of monitoring is that it is a systematic and repeated activity. Therefore, to be useful, social monitoring needs to be as practical and affordable as possible, in terms of time, financial and human resources. One approach to this is the recent case study survey work carried out for eight case studies as part of a research programme commissioned by the Foundation for Research, Science & Technology (Taylor Baines & Associates, 2001).

Key aspects of this survey approach involve:

- Purposive sampling of neighbours, in terms of proximity, topography and wind pattern;
- Sampling for representative coverage rather than statistical analysis;
- Use of unprompted and prompted questions, to allow respondent experience and priorities to determine emphasis;
- Systematic assessment of respondent experience, to elicit overall patterns and trends in effects and impacts;
- A risk-based approach to assessment (i.e., covering both frequency of effect and severity of impact, and the use of word scales);
- Supplementing individual survey interviews (i.e., precisely replicated structure) with semi-structured key informant interviews to incorporate the experience of organised

community groups as appropriate, and to access secondary data sets that assist in the overall assessment;

- Providing feedback to those who have been surveyed, prior to finalising the survey results - for validation.

This method of surveying may be applied in a completely open-ended way, covering all potential aspects of community experience of the plant's operations, or in a more targeted way, where the focus is on one specific type of effect.

CHAPTER 13
DETAILED DESIGN OF MONITORING PROGRAMME

Rob Bell, Graham McBride, David Ray, Chris Hickey (NIWA)

13.1 Introduction

Having developed a conceptual monitoring programme from the HIAMP process (Chapters 4 and 8) and chosen which monitoring options to adopt (Chapters 9 to 12), the details of the monitoring programme need to be determined. Certain fundamental questions need to be answered when considering the detailed design of a monitoring programme and how compliance is to be tested. For example:

- What are the objectives of the monitoring programme? (Chapter 8)
- What scale (duration and extent) is appropriate?
- What variables or components should be measured? (see Chapters 9 to 12)
- What sampling site(s) should be used?
- What are the practical consequences of various sampling frequencies, compliance periods, sampling time (time of day or week)?
- Should grab samples be used, or bulking methods to obtain a composite sample?
- How should data problems be handled, e.g., ‘outliers’, ‘less-than’ or ‘greater-than’ values, ‘non-detect’ results, missing data?
- How should compliance consent conditions be written?
- What decisions and actions should be made on the evidence of the sample results?
- Will the monitoring programme be cost-effective and is it affordable?

The detailed design of the various components of a monitoring programme is summarised in Figure 13.1.

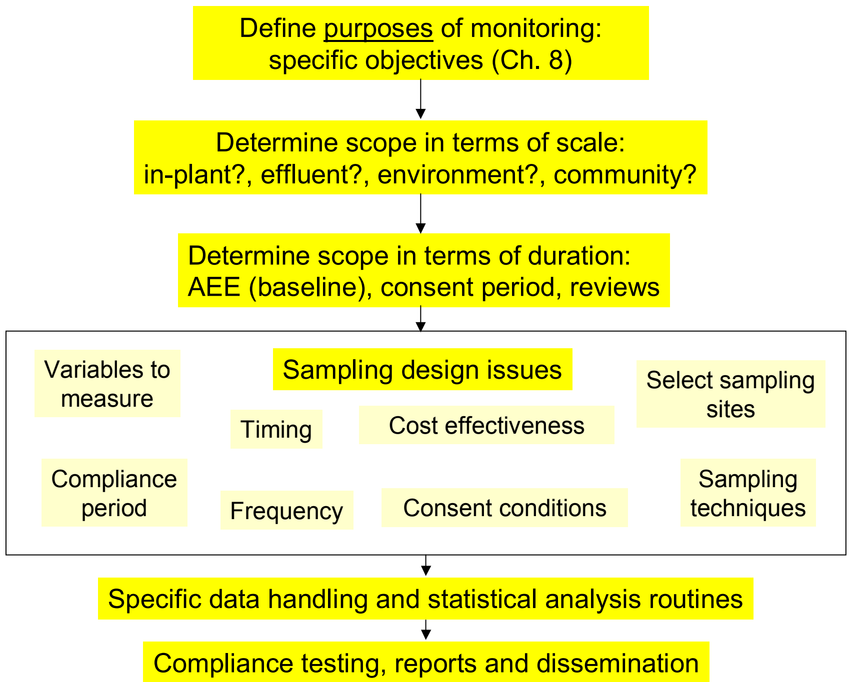


Figure 13.1: Framework for the detailed design of a monitoring programme

13.2 Key requirements

A useful checklist of key questions to ask before finally deciding on monitoring measurements is provided in Table 13.1 (adapted from ANZECC 2000b).

Table 13.1: Checklist for the selection of monitoring options

Relevance	Does the measured variable reflect directly on the main risks and issues of concern?
Validity	Does the measured variable respond to changes in the discharge or environment and have some explanatory power?
Diagnostic value	The measured variable must be able to detect changes and trends in conditions or discharge characteristics for the specified monitoring duration or compliance period. Can the amount of change be assessed quantitatively or qualitatively?
Responsiveness	Does the measured variable detect changes early enough to allow a management response, and will it reflect changes due to the intervention by management?
Reliability	The measured variable must be measurable in a reliable, reproducible and cost-effective way.

For most situations where the wastewater comprises sewage, effects on public health (e.g., water-contact recreation and shellfish gathering) will invariably be identified as one of the main public and cultural issues. Consequently, monitoring an appropriate faecal indicator in the effluent will usually be required as a minimum, and possibly at some receiving environment sites where recreational activities might be compromised.

The other critical physical variables to measure are the discharge flow rate (to gain an estimate of environmental loadings) and temperature (for interpretation purposes).

13.3 Statistical sampling design criteria

13.3.1 Representing wastewater in the presence of variability

Monitoring can only hope to sample a very tiny fraction of a waste stream or a snapshot of the receiving environment quality. For example, if 6 one-litre grab samples are taken per annum from an average effluent flow of 10 L s^{-1}, these samples will represent only 0.000002% of the total effluent volume over a year. Yet we are hoping to use these tiny samples to represent the wastewater. Furthermore, intensive monitoring of wastewater streams has demonstrated that there can be substantial variability of its components. For example, it is not uncommon for faecal indicators to vary over orders of magnitude. Some of this variability is 'natural'–all natural processes exhibit *some* variability, after all. But some may be a pattern, e.g., caused by plant overloading or equipment malfunctioning. An analysis of monitoring results seeks to separate such pattern from inherent randomness, and that is the fundamental task of statistics.

The ecological community's response to effluent loadings may also be variable. For example, the input of inorganic nitrogen to an estuary may stimulate the growth of phytoplankton during warm periods only when conditions are optimal.

Environmental and effluent variability, both with time and space, is the most important aspect to be considered in the detailed design of monitoring programmes. Consequently, monitoring design and interpretation is essentially statistical in nature, to move beyond a few sample results through to inferring knowledge about the total 'population' or quality of a continuous waste stream or receiving environment.

In those situations where high variability exists together with financial constraints on the extent of monitoring, it is vital that monitoring targets the key issues and risks. Otherwise the all too common scenario occurs where a monitoring dataset is too variable to reveal any impact or trend, or adequately describe the discharge.

13.3.2 Have potential sources of variability been identified?

If possible, the variability in the treatment plant performance or in the receiving environment should be gleaned from pilot studies, AEE studies, consulting other plant operators or from the literature. An example is oxidation pond effluent, where the DO varies diurnally (i.e., throughout a day/night cycle). Knowing this variability will help with deciding when the sample of the effluent should be taken or when a river reach is most stressed on a daily basis. For example, dissolved oxygen is often lowest in a river in the early morning.

Variability may also be important at seasonal timescales. For example, suspended sediment concentrations and chlorophyll *a* from oxidation pond systems tends to peak over late spring and summer.

Disruptive processes that might occur in the effluent treatment system or receiving environment should also be considered – refer to the risk-assessment process for ‘abnormal’ conditions in Chapter 4.

13.3.3 Selection of sampling sites and sampling frequency

How many sites should be sampled? How many samples are needed for measuring each effluent constituent or environmental variable at each site? How many samples can be afforded? Answers to these questions depend on the outcomes of the HIAMP risk analysis in Chapter 4, anticipated variability, the ability to compute robust sample statistics (e.g., median, 90%ile, 95%ile) to compare with consent conditions, and the costs of sampling.

Sampling Locations (effluent and influent monitoring)

Specifying the appropriate monitoring location for effluent compliance may seem obvious, but is critical to producing valid compliance data. Some considerations are:

- The wastewater or odour flow should be measurable at the monitoring location.
- The location should be easily and safely accessible.
- The sample must be representative of the discharge during the time period it is monitored.

Expanding on the last point, the discharge must be as well-mixed as possible, where the flow has experienced hydraulic turbulence. Logically, the monitoring location should be just prior to discharge or at the entry point to an outfall pipe. This will also ensure measurements of faecal indicator bacteria include the effects of water-fowl contamination in oxidation ponds, chlorine-residual effects (if chlorine is used for disinfection), and any photo-reactivation of faecal-indicator bacteria that might have taken place after treatment with UV-disinfection.

In some instances, a monitoring location may be required well before the discharge point. Such circumstances can include compliance of multiple waste streams from different treatment plants and industries in an area that are served by a common outfall, or where the detection of a pollutant is required in the influent before treatment and dilution occurs within the plant, e.g., if a certain percentage or log-order removal is specified in a consent.

Sampling a waste stream at a weir is not recommended, as solids settle behind a weir and floating oil and grease tend to accumulate immediately downstream of a weir.

Sampling locations (receiving-environment monitoring)

Specifying locations for environmental-effects monitoring is more complex, and specialist advice should be sought. Some guidance is provided in Chapter 3 of the ANZECC (2000b) guidelines. The three approaches to sample site selection are:

- Random sampling–randomly selected sites. This may not be the most cost-efficient pattern because of variation within the site.
- Stratified random sampling–system is divided into parts (strata) in each of which the variable of interest is as uniform as possible, either in space (one or more samples per strata) or with time (e.g., may sample more often in a season that shows more variability). This is more efficient than using simple random sample sites.
- Systematic sampling–samples are collected at regular intervals in space (or time), but care is needed to avoid bias, e.g., discharge impact may be routinely lower in the morning than afternoon, and tides are not synchronous with a 24-hour solar day.

Selected sites must be accurately defined and fixed to ensure they can be sampled repeatedly. Archiving site photographs can be an important feature, to guide future samplers to collect from the defined site. Such care with fixing sampling locations is highlighted when compliance is required by way of sampling around the edge of a mixing zone. GPS can be a useful tool for this, but the accuracy of the instrument should be checked carefully.

Finally, sampling sites must be accessible and safe under most conditions, especially if located in lakes, large rivers, estuaries, harbours or open coastal waters.

Sampling frequency (effluent and influent monitoring)

Specifying the frequency of sampling for discharge monitoring is an interactive process that includes the duration over which compliance is to be tested or results reported, and the sample statistics that will be used, as determined by the planning for the end-use of the monitoring information (Chapter 8). For instance, calculating a 95-percentile sample statistic requires between 10 and 19 samples, depending on the method used to calculate it (see Section 13.4.5), so if a 3-month compliance or report period were deemed necessary, the sampling frequency would have to be approximately weekly to extract a 95%ile. If cost factors and the level of risk meant that monthly sampling was sufficient, then the compliance period would need to be annually if a 95%ile was one of the consent conditions imposed.

For variables that are associated with a lower concern or risk, the sampling frequency is often set much lower than high-risk variables. But cognisance must be given to seasonal variability (e.g., summer vs winter), rather than simply measuring it once a year, which provides very limited explanatory power.

Sampling frequency (receiving environment monitoring)

Specifying sampling frequency for receiving environments is much more difficult. The reader is once again referred to Chapter 3 of the ANZECC (2000b) guidelines. Consideration of all the key timescales that naturally occur in environmental systems is required to ensure the sampling frequency is sufficient to capture natural 'cycles'. The Nyquist fundamental frequency states that to resolve any time cycle Δt, you need to sample at least more frequently than $\Delta t/2$. For example, to resolve an annual cycle, you would need to sample at least at 6-monthly intervals, and preferably 3- to 4-month intervals for better resolution. To resolve a cycle over a single season, at least monthly sampling is required.

Other timescales to consider are:

- Impact of episodic events, such as storms or river floods, on natural disturbance to the receiving environment or contamination by catchment run-off (e.g., faecal indicator bacteria from farmland). Equally, summer low-flows or droughts can induce highly variable natural impacts on a freshwater system.
- Tidal cycles for lowland rivers, estuaries and coastal waters. Tides occur at regular cycles of 12.4 hours, which means the following high water on the next day is approximately one hour later. Salinity and current velocity change dramatically during a tide cycle, so monitoring of intra-tidal effects means several samples may be required during a tide cycle. Low-frequency monitoring also needs to allow for tides to ensure there is no bias e.g., six-monthly sampling should be done at the same tide state (high, mid-ebb, low water, or mid flood) and tide range (spring, mean or neap).
- Interannual cycles of 2 to 5 years, generated by the El Niño–Southern Oscillation system, can produce high variability in rainfall, river run-off, water temperatures, and winds, which need to be taken into account in selecting a sampling frequency and duration when embarking on trend-type monitoring objectives.

13.3.4 Selection of compliance period and sampling numbers

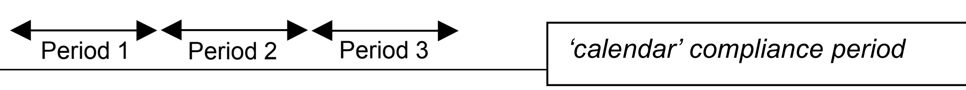
Setting a compliance or reporting period is a crucial decision, as it determines the overall number of samples (*n*) used to test compliance against a numeric standard for a selected sampling frequency. Settling on a compliance period needs to take into account: medium to long-term variability; minimum number of samples needed for calculating percentile limits; and public expectations or activities that dictate the duration of a compliance period, e.g., summer bathing season.

Situations have occurred where the compliance period was set without due cognisance of monthly and seasonal (annual) cycles in the discharge. For example, a typical oxidation pond discharge has higher concentrations of suspended solids over summer months than at other times during the year. These solids are largely algal cells from summer blooms rather than sewage-derived particles. If a 3-month compliance period is required, then this type of variability needs to be taken into account, with perhaps setting a different summer median and say 90%ile, than those that would apply for the rest of the year (or by adopting a different variable, e.g., filtered BOD_5).

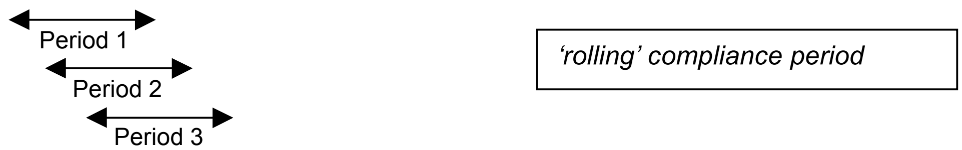
Calendar vs rolling period

The other issue to resolve is whether the compliance period is based on consecutive calendar (fixed) periods or a rolling period.

A ‘calendar’ or fixed compliance period simply uses the *n* samples collected over a defined calendar period (e.g., a 6-month or 12-month period) to test compliance. In the following calendar period, a completely new batch of *n* samples is analysed. Only one report on compliance determination is required for each elapsed calendar period.



A 'rolling' compliance period also uses *n* successive samples to test compliance. But the rollover is accomplished by dropping the *x* oldest sample(s), and introducing the same number (*x*) of the latest sample(s) taken, to make up a new batch of *n* samples to test compliance. Effectively, this is a sliding or overlapping window of *n* samples. For a given elapsed calendar period, *n*/*x* compliance reports will be required.



Consider a discharge for which compliance with certain limits is required over a six-month period, based on weekly sampling, and that the discharge impacts upon recreational waters. The question then is: should compliance be assessed on a rolling six-month basis or on a fixed (calendar) six-month basis?

In the former case, compliance could be assessed each week, by dropping off the datum for the oldest week and adding in the latest value, and then re-assessing compliance. That is, 26 times per six-month period. In the latter case, compliance would be assessed and reported just once every six months.

A problem with the former is that the applicant can be found to be in breach of a compliance rule on many occasions, with each occasion being the result of the same data or event! For example, imagine that there have been 4 exceedances of a 95%ile enterococci concentration limit in a 26-week period from October to March (encompassing most of the bathing season). In this case the 95%ile standard for that period has been breached (because the consent only allows 3 exceedances in a six-month period). Now also imagine the (quite plausible) scenario that all of these 4 exceedances occurred in the weeks of March. Then under a rolling compliance assessment basis, there would be 22 weekly compliance assessments in which the effluent would be declared to be in breach of its standard. These 22 'fail' assessments would include all the new data from weeks in April to August (inclusive). But all of these declarations would be attributable to data from the same 'event', being the exceedances of enterococci in March. Consequently, the same reasons for a given breach of the standard will have to be re-iterated to the regulatory authority many times over and probably explained to the public. The process of operating a 'rolling' compliance period is also more difficult to explain.

Note that it usually will not be necessary to wait until the end of the compliance period to determine that there has been non-compliance for the 'calendar' compliance approach. In the example used above, if the compliance period had been January to June (inclusive), non-compliance would have been determined at the end of March – there would be no need to wait until the end of June.

Accordingly, it seems sensible in most cases to use calendar (fixed-period) compliance assessments rather than rolling assessments.

13.3.5 Statistical approaches for designing compliance rules

Sampling error

The heterogeneous nature of the sampled wastewater means that small and infrequent samples of the discharge will exhibit variability. Statisticians call this 'sampling error' – but that does not mean that an error has been made in sampling! If an error is made in the sampling or in analysing the sample's contents this is known as 'measurement error'.

Percentile standards or maximum limits?

In setting a discharge monitoring standard one is interested in some critical concentration of a contaminant (e.g., nitrogen, suspended solids, a bacterial indicator) derived from toxicity, ecological or epidemiological studies. These critical values are never known precisely – their derivation always calls for an element of value-judgement, and recognition that the scientific studies upon which they are based are not absolute in their findings. Because of this, there is increasing use of percentile standards, in which concentrations may exceed the critical value for some proportion of the time (typically 5%, in which case we have a 95%ile standard, and/or 50% for a median standard). The case for percentile standards, rather than maximum standards, is made stronger when one recognises two mechanisms that may give rise to results that are too high (rather than too low):

- The occasional presence of sample contamination or laboratory error.
- The at-times heterogeneous nature of effluent treatment processes and therefore effluent quality (e.g., some parcels of an effluent stream may not have been as effectively sterilised by UV lamps, and so are rather higher in their concentration of a bacterial indicator than is the bulk of the fluid).

When we consider the statistical 'sampling error' along with percentile standards we *must* consider 'burden-of-proof' issues. For example, see Figure 13.2, showing a hypothetical situation in which we actually know the true 95%ile concentration (i.e., 60 units – we never do know it of course, but the Figure will be instructive). Figure 13.2a shows a situation where the *sample* 95%ile (63.5 concentration units), calculated using some standard formula (see Appendix 1) is greater than this true value of the continuous discharge. But for another determination as shown in Figure 13.2b the *sample* 95%ile (58.2 concentration units) is lower than the true value. Either situation can occur. And because in practice we do not ever know the true value, we always are uncertain about whether the true value is above or below our sample-statistic value. This is where the burden-of-proof issue arises, in which either the 'producer's' risk (i.e., discharger's risk) or the 'consumer's' risk (i.e., environment's risk) may be kept small. They *cannot* both be made small. These two approaches are characterised as the 'benefit-of-doubt' and 'fail-safe' approaches respectively (Ellis 1989; McBride 2000a; McBride et al. 2000).

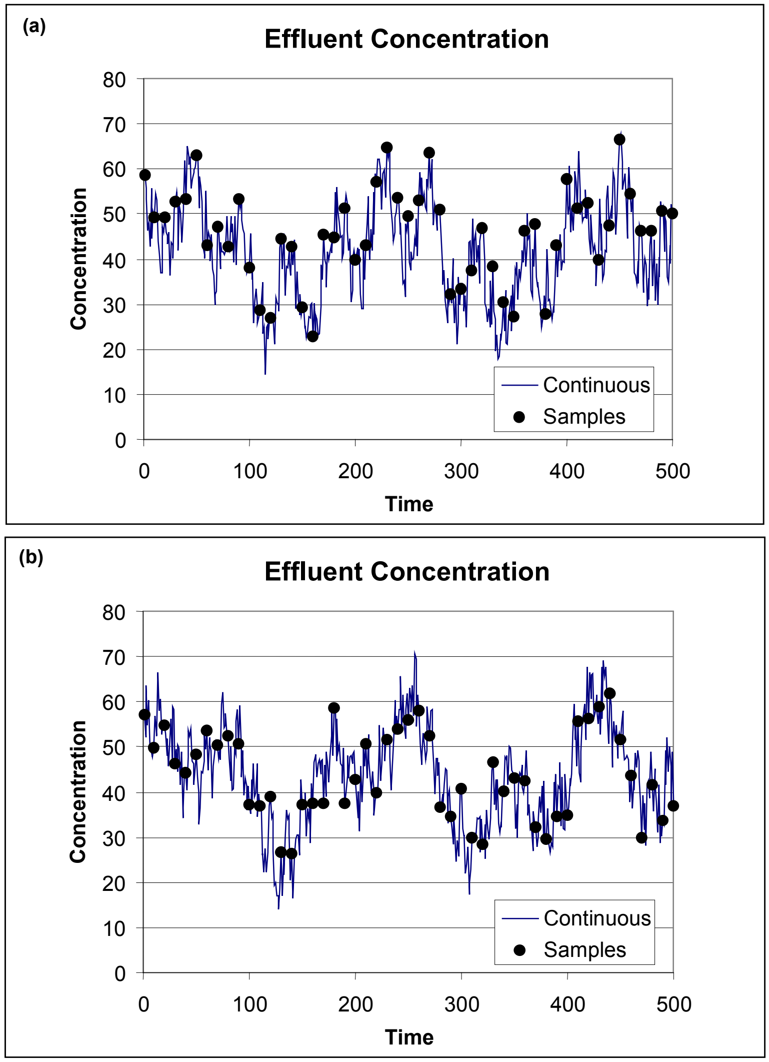


Figure 13.2: Two scenarios of a 'continuous' time series of a discharge concentration with a true 95-percentile concentration of 60 units, but have then been grab-sampled at a time spacing of 10 time units, where: (a) the 95-percentile of sample concentrations is >60 (i.e., 63.5); and (b) the 95-percentile of sample concentrations is <60 (i.e., 58.2). (from McBride et al. 2000).

If one or the other risk is desired to be kept small – where the discharger or the environment is given the benefit-of-doubt – some calculation procedures are available. These may be somewhat complicated and require certain assumptions to be made about the statistical distribution of the effluent quality, posing further difficulties – especially when little previous monitoring data is available. A third approach is to ignore 'sampling error' and assume the samples measured completely represent the characteristics of the continuous waste stream. Sometimes the sample statistic will be below the true value and sometimes it will be above the true value (as in Figure 13.2). This is called the 'even-handed' approach, because it treats both risks equally. It leads to discharge monitoring compliance conditions couched in terms of sample percentiles. For example:

Based on no fewer than 20 samples on separate days over 3 months, the median concentration of faecal coliform bacteria of the samples shall not exceed 2000 MPN per 100 mL, and no more than 10% of samples shall exceed 8000 MPN per 100 mL.

Proportional compliance conditions

A simpler approach to operate with is to consider instead the permissible proportion of exceedances of a percentile limit in a batch of samples. This is much more easily understood by all parties (public included), as it lends itself to simple tabulation. There are two further advantages:

1. No assumptions about the distribution of the effluent quality data are needed (because the probability of pass or fail in a fixed number of random samples always follows the binomial distribution i.e., a 'heads or tails' situation discussed in most elementary statistics texts);

2. It is immediately obvious when the standard has been breached (i.e., more than the permissible number of exceedances have occurred); there is no need to wait until the end of the compliance assessment period to make that decision and to seek to mitigate the problem.

Often, discharge monitoring conditions are based on a mixture of a 50%ile concentration limit (i.e., median) and an upper-percentile limit (80%ile, 90%ile, or 95%ile). Look-up tables (such as Table 13.2) allow one to determine the permissible number of sample exceedances (*e*) in a compliance period comprising *n* samples, based on keeping the discharger's risk[1] at no more than 10%. For calculation of other values of the number of samples (*n*) or the discharger's risk, refer to McBride et al. (2000) and McBride & Ellis (2001).

1 This is the risk that at some future time the discharger will in breach of the consent conditions, by way of the measured samples, when in fact the true 'continuous' effluent concentration is below the percentile limit.

Table 13.2: Number of exceedances (e) out of n samples permitted to meet percentile discharge compliance standards based on a discharger's risk of no more than 10%.

Number of samples taken in monitoring period (*n*)	**Number of permitted exceedances (*e*) for a 10% discharger's risk to meet the performance standards listed.**			
	Median (50%ile)	**80%ile**	**90%ile**	**95%ile**
5	4	2	1	1
6	5	2	2	1
7	5	3	2	1
8	6	3	2	1
9	6	3	2	1
10	7	4	2	1
11	8	4	2	2
12	8	4	3	2
13	9	4	3	2
14	9	5	3	2
15	10	5	3	2
16	11	5	3	2
17	11	6	3	2
18	12	6	3	2
19	12	6	4	2
20	13	6	4	2
21	13	7	4	2
22	14	7	4	2
23	15	7	4	3
24	15	7	4	3
25	16	8	4	3
26	16	8	5	3
27	17	8	5	3
28	17	8	5	3
29	18	9	5	3
30	19	9	5	3
31	19	9	5	3
32	20	9	5	3
33	20	10	6	3
34	21	10	6	3
35	21	10	6	3
36	22	10	6	4
40	24	11	6	4
50	30	14	8	5
100	56	25	14	8

Note: These numbers are in fact pessimistic because their calculation is based on the assumption that the effluent is in fact always borderline for compliance. Such an assumption is necessary using standard statistical methods. But in general this assumption is *not true* An alternative (Bayesian) approach to the calculations does not make this assumption and so results in smaller numbers of samples being required (McBride & Ellis 2001). Note that this alternative approach has already been used in the compliance rules in new drinking-water standards (MoH 2000), and will be explained in some detail in the Ministry of Health's forthcoming Guidelines for Drinking-Water Management.

A few examples of 'proportional' consent conditions are listed in Table 13.3 that were adopted for the North Shore wastewater treatment plant discharge consent, based on a discharger's risk of 10%.

Table 13.3: Examples of the 'proportional' discharge compliance standards for the North Shore WWTP, based on a discharger's risk of 10%. The first two components are based on a median limit over a 1-year compliance period, while the indicator bacteria are based on a median and 95%ile over a 3-month (13-week) compliance period.

Constituent	Units	Sample type	Sample frequency	Standard(*)
Total BOD_5	g m^{-3} O	grab	fortnightly	over 1 year, no more than 16 exceedances above 20
Total Nitrogen	g m^{-3} N	grab	monthly	over 1 year, no more than 8 exceedances above 30
Faecal coliforms	cfu/100 mL	grab	3 per week	for any 3-month(1) period, no more than 23 exceedances above 1000 and no more than 4 exceedances above 10000
Enterococci	cfu/100 mL	grab	3 per week	for any 3-month(1) period, no more than 23 exceedances above 100 and no more than 4 exceedances above 1000

(*) Standards for Total BOD_5, TN use 50%ile limits only, the other constituents use both 50%ile and 95%ile limits.

(1) Calendar 3-month period of 13 weeks

13.4 Sampling techniques and times

Composites versus grab samples

For many analytical procedures, the sample collection method is not specified, therefore it needs to be specified in the resource consent conditions or an associated monitoring/management plan.

Composite sampling provides a way of obtaining a representative measure of a continuous effluent stream with a minimum of analytical effort. By bulking multiple sub-samples, individual concentrations are lost, and so the analytical results refer to average concentrations (or loads if sampling is volume-based rather than time-based). In contrast, grab sampling sets out to measure the instantaneous characteristics of the effluent at that particular time and place.

The type of sampling used depends very much on the objectives of monitoring and also the constituent being measured. Where extremes in quality are of concern (as with judging compliance with upper percentile), grab sampling should be used. If, on the other hand, the main interest is in means, trends or overall 'loads' on the environment, there are circumstances where composite sampling will provide superior precision to that from grab sampling. One example may be to smooth out the diurnal (daily) fluctuations in flow and/or concentration.

Caveats on the usefulness and validity of composite sampling are:

- That the effluent constituent being measured must be stable and the only change in concentration occurs by physical dilution processes rather than by biochemical/chemical decay (e.g., the need for filtration for total ammonia or dissolved reactive phosphorus before storage) or microbiological processes (e.g., changes in the numbers of culturable bacteria with time). Other constituents that should only be taken with grab samples are: temperature, residual chlorine, oil and grease, sulphides, phenols, cyanides, pH, and volatiles (USEPA, 1996).
- A single composite analysis will always be less precise than the mean of a number of grab sample analyses taken over the same period.
- There is no way of knowing just how much variability has been smoothed out; therefore the degree of representativeness of any one composite remains unknown (unless prior information exists regarding the temporal variability in the discharge quality).

Grab samples can measure maximum effects only when the sample is collected during flows likely to contain the maximum concentration of pollutants.

For composite sampling to give a useful improvement over grab sampling for a given amount of effort, that part of the variation ('within-composite') that is averaged out by each composite sampling, must be substantial compared with the longer-term ('between-composite') variation from one composite sample to the next.

Large diurnal variations in effluent quality are unlikely for an effluent from larger oxidation ponds apart from dissolved oxygen and temperature. Consequently composite sampling is not generally recommended for such discharges. However in the case of the Moa Point WWTP, consent conditions required that composite samples be taken for effluent constituents, including faecal indicator bacteria. This created a conundrum where extensive testing of composite versus grab samples for indicator bacteria revealed pronounced differences in meeting levels set in the consent conditions, and discussion on the relevance of storing bacteria samples for 24 hours. Most indicator bacteria analyses should commence within 6 hours (ideally 2 to 3 hours), which mostly precludes any compositing method of sample collection.

Programmed sampling equipment is available to automatically take composite samples that are either based on a flow-weighted basis or a time–weighted basis.

Time of sampling

The time of day when monitoring samples are taken needs to be determined in the design of the programme. Considerations are:

- Variation in discharge rate over a 24-hour (diurnal) cycle. When does the peak discharge occur, and when is it a minimum?

- Variation in concentrations over a 24-hour (diurnal) cycle. Is there a daily peak for any constituents being monitored? For example with oxidation ponds, dissolved oxygen will be minimum around sunrise, while faecal indicator bacteria may be lowest towards mid-afternoon after a decent dose of solar radiation.
- Variation in discharge rate and concentrations during a typical week (e.g., week day discharge versus weekend).

13.5 Design of data processing steps

While often forgotten, it is essential that the data handling protocols right through to the production of the final report are designed beforehand and included in the monitoring budget. Some steps along the way should include:

- Pre-processing procedures for adjusting measurements (if not already done by the laboratory) e.g., adjusting ammoniacal nitrogen or %DO saturation for temperature, pH or salinity.
- Plotting software package and procedures to view and plot monitoring data.
- Develop checks for outliers, missing data, non-detects, ‘greater-than’ or ‘less-than’ data and process according to preset protocols. (See section on special data handling techniques).
- Specify the methods to be used for calculating required sample statistics e.g., median, 90-percentile, range, number of exceedances (*e*) of a specified concentration. (See section on methods to compute percentiles).
- Set up milestones when a statistical analysis of environmental and community monitoring data is to be carried out, against a hypothesis or objective such as: there is no significant change or trend with time, or there is no significant difference between upstream and downstream of the discharge (see Chapter 11).
- Design a clear and concise presentation layout for results.
- Protocols for dissemination to the Regional Council, stakeholders, and the public, including any Web page display.
- Design archive and back-up system for the monitoring data.

Special data handling problems

One should always be seeking to interpret data into information. In doing so, water-quality data can pose some special problems:

- ‘Non-detects’, or ‘less-thans’, where the result is less than a detection limit.
- Skewness, where very high values may occasionally be present (especially for microbiological analyses).
- ‘Outliers’, where the data seem inexplicably large or small.

- ‘Greater-thans’, where the test's upper detection limit is less than the actual concentration (for example, this would be reported for *E. coli* if all wells in a Colilert tray were positive for presence of that organism).

The first two problems are easily handled using standard statistical analyses. Thus means and standard deviations would be calculated, maybe adopting the non-detect limit as the numeric value (or half of its value) or using logarithms to remove the skewness in the data. The last two problems are much more problematical using such standard (i.e., ‘parametric’) techniques. However, if we use methods that use only the ranks of the data (i.e., ‘non-parametric’ techniques), rather than the actual data values, most of the last two issues are resolved. One does not need to consider whether the outlier is an artefact or is real, it merely becomes a datum with high rank, as does a ‘greater than’.

Note: common use of Microsoft EXCEL® often results in the ‘<‘ or ‘>‘ qualifiers on monitoring data becoming divorced from the numerical value. It is important they are stored with the value.

Calculating percentiles from sample data

It is often a surprise to people that there are several methods that can be used to calculate percentiles (e.g., medians, 95%iles) from sample data, and they produce *different results*. While it is often thought that there is always *one* ‘statistically correct’ way to proceed, often there are several – calculation of percentiles being a case in point. Consequently, the design of the data analysis routines needs to specify a method to consistently calculate sample percentiles. The most common methods are Weibull, Hazen and the procedure embedded in Microsoft Excel® (and also in the statistics package S-Plus). This is no trivial matter: results for 95%iles of bathing beach enterococci data using Weibull and the Excel method can produce results that differ four-fold in value (McBride 2000b). The same may well be true for effluent microbiological variables.

The Hazen method is generally preferred, as it provides an answer about half-way between the other two methods. Also the Weibull convention, although used widely in the UK water industry (Ellis 1989), requires 19 samples before a 95%ile can be calculated, whereas only 10 are required for the Hazen procedure. Microsoft Excel® produces an answer for any number of samples (even just 1!), which is very misleading for small sample sizes. Formulae are given in Appendix 1. Note however that while the Excel method does pose some conceptual difficulties (in particular, in being able to calculate any percentile given just one datum), at least it is ubiquitous, whereas special procedures need to be available for computation of the Hazen method (which can be done as a macro in Excel).

13.6 Cost

Now that the monitoring programme has been designed, it should be fully costed, including sample collection (labour and capital items), sample preparation, delivery to laboratory, laboratory analyses, processing monitoring data and disseminating reports to regulatory agencies and the public. Any additional monitoring that might be required when trigger levels are exceeded should also be estimated.

If the total ongoing cost cannot be afforded, then further iterations of the monitoring programme design will be required e.g., reducing sampling frequency, increasing compliance or reporting period, reducing the scale of any environmental-effects monitoring, or investigating a different mix of monitoring approaches. For the latter, a few toxicity tests per year for a lower-risk discharge may be more cost-effective than measuring several discharge constituents more frequently.

If further cost reductions are required, there is the option of reducing the number of constituents, tests or variables measured. However, this would necessitate returning to Chapter 8 and redefining the objectives of the monitoring programme, in the context of the HIAMP process.

13.7 Monitoring management plan

The preparation of a monitoring management plan is becoming a commonplace procedure, and is frequently required as a requirement of a resource consent condition. The main advantage of such a plan is that it can be picked up and implemented by a person who is new to the monitoring programme. This is particularly useful when monitoring personnel have not been involved in the development of the programme, or when there is a change in personnel. Another advantage is that the plan can include minor items that are not deemed necessary to be included as a consent condition, and hence can be changed more readily, provided there is agreement between the regulatory authority and the consent holder.

The monitoring plan will often form a part of a wastewater management plan for the WWTP. Issues that might be covered include:

- Maps showing sampling locations.
- Sampling methods (timing, frequency, volumes, sampling equipment, preservation).
- Laboratory delivery details, analytical procedures (see Chapter 14).
- Description of other monitoring procedures, e.g., surveys of biota, community surveys.
- QA procedures (see Chapter 14).
- Data interpretation protocols, including statistical analyses.
- Response procedures in the event of non-compliance or treatment plant breakdown.
- Reporting and information dissemination protocols.
- Names and contact details of key personnel (consent holder, WWTP personnel, regional council staff, Medical Officer of Health, key interest groups, local residents).
- Copy of the resource consent conditions.

CHAPTER 14
SAMPLING AND ANALYTICAL METHODS

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14.1 Methods for sampling and sample handling

14.1.1 Introduction

Obtaining representative samples and maintaining their integrity are critical parts of any monitoring programme. Analytical methods have been standardised but the results are only as good as the sample collection and preservation methods.

In sampling, the objective is to collect a small portion of an environment that is representative of the whole body. Once the sample is taken the constituents of the sample must stay in the same condition as when collected.

The US Environmental Protection agency (EPA) has estimated that 95% of the total variability in environmental measurements is due to sample collection and handling and that only 5% is due to variability during laboratory analysis. The 95% can be further broken down into 85% of variability from sample collection and 10% from sub-sampling in the laboratory (Rosecrance & Adolfo 1996). This gives some indication as to the importance of using correct sampling procedure at all times.

Analytical laboratory personnel are usually a valuable source of knowledge for sampling and sample handling methods. The reader is strongly advised to consult laboratory personnel before embarking on a sampling programme.

14.1.2 Composite sampling methods

The advantages and disadvantages of using composite versus grab sampling are described in Section 13.4. If composite sampling is to be used, there are four methods to be considered. Smoley (1993) describes these as follows:

a) **Constant time – constant volume**: Samples of equal volume are taken at equal increments of time and composited to make an average sample.

b) **Constant time – volume proportional to flow increment**: Samples are taken at equal increments of time and are composited proportional to the volume of the flow since the last sample was taken.

c) **Constant time – volume proportional to flow rate:** Samples are taken at equal increments of time and are composited proportional to the flow rate at the time each sample was taken.

d) **Constant volume – time proportional to flow volume increment:** Samples of equal volume are taken at equal increments of flow volume and composited.

The most common form of composite collected by automatic sampler is d), whereby the sampler is triggered to take an incremental constant volume sample each time a given volume of flow has passed through the measuring point. A flow meter is not required for composite sample type a). Note that a flow proportional composite can be manually prepared from individual grab samples if flow data is available. Samples b) and c) are also usually collected and composited manually.

Guidance to the most appropriate type of composite method to use can be found in ISO 5667/10 5.3.1.2.

It is also possible to take composite samples manually, but the volume of the bucket, ladle or bottle should be well defined and known to a precision of ±5%.

Discrete samples that make up a composite sample can be stored in individual containers and then mixed proportionally when the sampling period is complete. However, it is more common for the discrete samples to be collected in one sample container, so that no further mixing is required.

14.1.3 Sample collection equipment

Manual sampling

A grab sample can be taken manually using a scoop, pump, vacuum or other suitable device that will collect a sample from the intended location. Samples of influent wastewater or from within the process are often taken from flow channels. The simplest sampler is a pole with a clamp for a sample container to dip into the channel. Many WWTPs use a 'Mighty Gripper', a stainless steel spring loaded clamp which securely fastens around the sample container. Sample volumes are typically about one litre.

The collection of environmental samples from the receiving waters requires a diverse range equipment, depending on the parameters being monitored. Grab samples from surface water can be effectively carried out with a 'sample container on a pole' technique, either from the shore or from a boat. If subsurface samples are required, submersible pumps can be used or specialised water column samplers are available.

Automatic Samplers

Automatic samplers allow the collection of multiple samples or composite samples over extended periods. They are most applicable to sewer and treatment plant sampling and are available in widely varying levels of sophistication, performance, mechanical reliability and cost. Samplers are available with inputs for triggering from a flow meter to enable automatic flow compositing. Bottle samplers (usually 24 bottles) are available to collect individual samples on a time or flow basis

Auto samplers are not usually considered appropriate for microbiological sampling as the sample tube is not sterilised between samples and therefore contamination of subsequent samples could occur. Other constituents can also change in concentration with time – for example, ammonia can be converted to nitrate. If in doubt, consult with the analytical laboratory prior to sampling.

14.1.4 Sample containers

ISO 5667 – 10:1992 lists the following factors to be considered when choosing a sample container:

- High resistance to breakage.
- Good sealing efficiency.
- Ease of reopening.
- Good resistance to temperature extremes.
- Practicable size, shape and mass.
- Good potential for cleaning and re-use.
- Availability and cost.

Sample containers are generally made out of glass or plastic. The type of determinand the sample is to be analysed for often controls the type of material the container is made from, as some containers will react with the determinands and give false results when the sample is analysed. If you require a sample to be analysed for more than one determinand, it is possible that you may have to use more than one type of sample container.

Plastic containers are commonly used for sampling wastewater, although glass containers **must** be used if the sample is to be analysed for oils and grease, hydrocarbons, detergents and pesticides. If you are not sure which type of container you require, the laboratory that is carrying out the analysis will be able to advise you.

Containers must be cleaned before sampling commences in order to reduce the risk of the sample being contaminated. Containers must be thoroughly rinsed with water after cleaning to minimise risk of the sample being contaminated. This is particularly important if the sample taken is to be analysed for detergents.

Please note that sampling lines should also be considered as containers, and therefore the method of selection of materials for containers should also apply to sampling lines.

14.1.5 Sample preservation

If a sample is to remain representative of the water sampled when it is analysed, it is usually necessary to preserve the sample to prevent changes taking place. This is particularly important with regard to composite samples, which could be collected over a period of a day or more.

The most common way of preserving wastewater samples is with ice, to cool the sample to between 0 ºC and 4 ºC. If the sample is being collected over an extended period of time the preservation of the sample should form an integral part of the collection procedure. Keeping the samples in the dark can enhance preservation further.

There are other limited methods of chemical preservation that are applicable to specific types of samples. For example, sulphuric acid (H_2SO_4) can be added to ammonia samples to lower the pH if the sample is not to be analysed immediately. Sodium thiosulphate is added to water samples for bacteriological analysis to nullify the disinfecting effect of chlorine. If you are unsure as to how to preserve your samples, contact the laboratory that will analyse them for advice. A summary table of sample preservation and minimum sample size is given in APHA Standard Methods 20th Ed. (Table 1060-I) (APHA 1998).

14.1.6 Microbiological samples

Special attention must be given to microbiological samples, because they are very susceptible to being contaminated by poor sampling technique. When taking a microbiological sample, keep the following issues in mind:

- Automatic composite samplers used for general wastewater sample collection are inappropriate for microbiological sample collection due to sample tube contamination. Specialist microbiological samplers are available but are rarely used in the field due to cost and availability. Microbiological samples are usually taken by means of grab samples.
- Bottles for collecting microbiological samples will have been sterilised before use. The lids may have a seal over them, which has to be broken before you take the sample. If this seal is damaged in any way, do not use this bottle to take the sample, as it may not be sterile.
- Never rinse out the bottle that the sample is to be collected in. Bottles for final effluent microbiological samples may contain the sodium thiosulphate, which inactivates any chlorine disinfectant present, and therefore reduces the risks of all the micro-organisms in the water dying before analysis takes place.
- The bottle may have a 'use by' date on it. If it has and the date is in the past, do not use this bottle to collect samples, as it may not be sterile.
- When taking the sample do not touch the neck of the bottle, or the inside of the lid. The lid must not be put down on any surfaces as this can contaminate the sample. If sampling in channels use a dip bottle holder to prevent accidental contamination of the sample.
- When transporting bacteriological samples, keep them separate from other non-sterile samples and cool with ice. The freezer blocks used in chilly bins are most suitable for this purpose, as they will not leak when they melt. If regular ice has to be used take care not to let melted ice come into contact with the bottle lids (this is best achieved by keeping the ice inside a plastic bag, separate from the sample bottles). If melted ice does come into contact with the bottles the samples may have to be thrown away.
- Remember that even if the outside of the bottle is dirty, whilst it may not directly affect your sample it could contaminate the laboratory. Samples must not be exposed to direct sunlight and must reach the laboratory within the specified time limit at the appropriate temperature (not frozen).

If you have to take samples for microbiological analysis and you are unfamiliar with aseptic technique, you must contact the laboratory for advice before collecting any samples.

14.1.7 Chemical samples

Special attention may need to be given to samples that are taken for the following types of analyses:

- Low level metals/trace organics.
- Dissolved metals.
- Dissolved gases.

These types of parameters can be affected by physical changes that occur after the sample has been taken, such as the loss of gases from the sample or change in pH, which has the effect of altering the result to one that is not representative of the water being sampled. Samples that are being analysed for metals/organics that may be present in very low quantities may also be adversely affected by very low levels of contamination introduced at the time of sampling as the result of poor collection technique.

14.2 Analytical methods

14.2.1 Standard analytical texts

The most widely utilised text of standardised analytical procedures for wastewater and environmental samples is *Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998. APHA, AWWA, WEF Washington, DC*. This text covers a wide range of parameters applicable to the majority of wastewater monitoring programmes.

The USEPA has developed a large number of standard analytical procedures, many of which parallel the APHA Standard Methods. USEPA have a large number of standard methods for environmental monitoring. The list of standard USEPA methodologies can be found on the website: http://www.epa.gov/epahome/index/

Additional test methods can be found in:

Official Methods of Analysis of the Association of Official Analytical Chemists. 1990. 15th Ed. Volumes 1-2 & Supplement, published by the Association of Official Analytical Chemists (AOAC);

Annual Book of ASTM Standards. 1997. Volumes 11.01-11.04 (Water Methods, Atmospheric Analysis, Hazardous Substances), published by the American Society for Testing and Materials (ASTM).

International and country specific standards (ISO, NZS etc.) are also available which cover procedures and methods for sample collection and analysis for many of the parameters identified in this chapter.

14.2.2 Categories of analytical methods

Constituents of wastewater can be divided broadly into three categories; chemical, physical and biological. However, in order to make this chapter more usable in the field, the constituents of wastewater that are commonly investigated have been associated with different points in the wastewater treatment and disposal cycle.

14.2.3 Sewerage network

Samples may be taken in the sewerage network for a number of reasons:

- Trade effluent monitoring
- Monitoring discharges from Combined Sewer Overflows
- Monitor infiltration
- Characterise sewage before treatment

Determinant	Analysis Reference	Comments
Total Suspended Solids (TSS)	APHA 2540D	
Biochemical Oxygen Demand (BOD)	APHA 5210B	
Chemical Oxygen Demand (COD)	APHA 5220C,D	
Total Kjeldahl Nitrogen (TKN)	APHA 4500-N_{org}	
Ammonia (NH3)	APHA 4500-NH_3	
Conductivity	APHA 2510	
Fats, Oil & grease	APHA 5520	
Temperature	APHA 2550	
pH	APHA 4500-H^+	
Sulphide	APHA 4500-S^{2-}	
Chloride	APHA 4500-Cl^-	
Trade waste specific constituents		Tests specific to particular trade waste discharges, could include heavy metals, organics, solvents

14.2.4 Influent

Samples may be taken of wastewater influent for the following reasons:

- Characterise the influent to determine treatment required
- To calculate load to the plant for operational control

- Consent requirements
- Contractual requirements

In addition to the above analyses, it is often useful to further characterise the influent fractions in terms of soluble and particulate fractions. This information is necessary if a wastewater treatment simulation model is to be used for design or performance optimisation. The data is obtained by filtering the wastewater sample and determining the appropriate parameters on the filtrate. A satisfactory filtered sample is produced by using a GF/C grade filter. The parameters generally required are soluble COD, BOD, TKN and phosphorus.

Determinant	Analysis Reference	Comments
Temperature	APHA 2550	
pH	APHA 4500-H^+	
Total Suspended Solids (TSS)	APHA 2540D	
Biochemical Oxygen Demand (BOD)	APHA 5210B	
Chemical Oxygen Demand (COD)	APHA 5220C,D	
Total Kjeldahl Nitrogen (TKN)	APHA 4500-N_{org}	
Ammonia (NH3)	APHA 4500-NH_3	
Total Phosphorus	APHA 4500-P	
Microbiological	APHA Part 9000	Includes faecal indicator bacteria (E. coli, enterococci, faecal coliforms), virus, protozoa
Fats/Grease/Oils	APHA 5520	
Total Organic Carbon (TOC)	APHA 5310	
Volatile Organic Compounds (VOC)	APHA 6200	
Alkalinity	APHA 2320	
Chloride	APHA 4500-Cl^-	

14.2.5 Within the plant

Samples may be taken at various locations around a wastewater treatment plant for a number of reasons (refer also to Chapter 9):

- To assess performance of a particular process.
- To compare performance of different processes.
- To characterise return effluent streams within the plant.
- Process control.

Determinant	Analysis Reference	Comments
Biochemical Oxygen Demand (BOD)	APHA 5210B	If nitrification is known to occur across the plant carbonaceous BOD should be measured, rather than BOD_5.
Chemical Oxygen Demand (COD)	APHA 5220C,D	
Total Suspended Solids (TSS)	APHA 2540D	MLSS for activated sludge plants
Total Kjeldahl Nitrogen (TKN)	APHA 4500-N_{org}	
Ammonia (NH3)	APHA 4500-NH_3	
Microbiological	APHA Part 9000	Includes faecal indicator bacteria (E. coli, enterococci), virus, protozoa
Nitrate, nitrite NO_3, NO_2	APHA 4500 – $NO_{2/3}$	For BNR plant control
Soluble phosphorus	APHA 4500 -P	
Alkalinity	APHA 2320	For BNR plant control
pH	APHA 4500-H^+	
Dissolved oxygen	APHA 4500-O	Aeration tanks in activated sludge plants, oxidation ponds
Odour	Dynamic olfactometry	Specialist odour lab required for quantification of odours
Algal analysis, chlorophyll A	APHA Part 1000	Oxidation ponds

14.2.6 Effluent

The effluent may be sampled for a number of different reasons as follows:

- Consent compliance.
- To calculate load to the receiving water.
- To determine efficiency of the plant.

Determinant	Analysis Reference	Comments
Biochemical Oxygen Demand (BOD)	APHA 5210B	If nitrification is known to occur across the plant, carbonaceous BOD should be measured, rather than BOD_5.
Chemical Oxygen Demand (COD)	APHA 5220C,D	
Total Suspended Solids (TSS)	APHA 2540D	
Ammonia (NH3)	APHA 4500-NH_3	

Determinant	Analysis Reference	Comments
Microbiological	APHA Part 9000	Faecal indicator bacteria (E. coli, enterococci), virus, protozoa
pH	APHA 4500-H^+	
Metals	APHA Part 3000	Analyse for total metals.
Pesticides/Herbicides/Insecticides	APHA 6610, 6630, 6640, 6651. USEPA methods	Specialist laboratory requirements – consult laboratory for sampling containers etc.
Nutrients	APHA	Will include nitrogen and phosphorus
Organic Compounds	APHA Part 6000	Could include wide range of organic compounds dependent on receiving environment – VOC, extractable base/neutrals and acids, PAH
Temperature	APHA 2550	
Surfactants	APHA 5540	
Halogenated Compounds		Could be required if effluent is chlorinated
Sulphide	APHA 4500 – S^{2-}	

14.2.7 Receiving environment

The environment that receives the effluent discharge may be sampled for a number of reasons as follows:

- To determine the impact of an effluent discharge.
- To create a state of the environment baseline prior to a new discharge being created.
- Consent compliance.
- To determine sources of pollution.

Water receiving environments can be freshwater, estuarine or marine. The range of appropriate analyses will depend on the specific discharge location and the nature of the receiving water. Some guidance as to where sampling should take place is provided in Chapters 12 and 14. It is not possible to give a definitive list of determinants in this Guideline, however the following may be typical of the parameters required:

Determinant	Comments
Physical and Chemical	
Dissolved Oxygen Temperature pH	Physical and chemical parameters of receiving environments often show short term variability related to the variability of the effluent quality and the degree of dilution of the discharge. Sampling is often in the vicinity of the discharge and at some point remote from the discharge to determine the significance of the discharge impact.

Determinant	Comments
Turbidity	
Nitrogen	
Phosphorus	
Heavy Metals (dissolved)	
Organics	
Microbiological	
Faecal bacteria	Microbiological parameters are usually sampled for public health reasons. Sampling could relate to recreational water contact or food gathering and consumption
Viruses	
Protozoa	
Biology	
Plankton:	Biological monitoring can be directed at acute and chronic impacts. Time frames for monitoring can extend over several years.
Phytoplankton = plants	
Zooplankton = animals	Results are often evaluated in terms of comparative responses observed in the discharge area and in a control area remote from the discharge.
Algae	
Fish	Biological monitoring is usually a multi-disciplinary approach covering a number of scientific fields. Expert advice on monitoring programmes should be sought
Amphibians/Birds/Reptiles/ Mammals	
Benthic Macroinvertebrates	
Periphyton cover	

Detailed advice on sampling and analytical approaches, particularly for biota samples, is provided in the ANZECC (2000b) water quality monitoring guidelines.

14.2.8 Emerging issues

WET testing

Until recently, effluent monitoring programmes for the control of toxic substances have been based largely on effluent limitations for individual chemicals. Data on the toxicity of substances to aquatic organisms, however, are available for only a limited number of compounds. Effluent limitations on specific compounds, therefore, do not necessarily provide adequate protection for aquatic life when the toxicity of all effluent components is not known. Whole Effluent Toxicity (WET) testing is a biological procedure whereby the aggregate toxicity of an effluent is measured as a pollutant parameter. Test methods have been developed to measure the toxicity of effluents to freshwater and marine organisms.

In the WET procedure test organisms are exposed to five effluent concentrations and a control water. The tests determine the effluent concentration, expressed as a volume, that causes death in 50% of the organisms (LC50) within the prescribed test period, or whether survival in a given effluent concentration is significantly different than the controls. The effluent toxicity data are then used to predict potential acute and chronic toxicity of the effluent in receiving water, based on the LC50 and appropriate dilution.

The selection of the appropriate test organisms is important as they have to be representative of the flora and fauna of the discharge environment. It is recommended that specialist advice from a laboratory with WET test experience be engaged to carry out the testing or to provide advice. NIWA has developed expertise in this test with New Zealand organisms.

Pathogen monitoring

Improved analytical techniques for the detection and enumeration of pathogens and a growing focus on issues of human health associated with wastewater discharges into the environment has seen an increased requirement for pathogen monitoring in treatment plant effluent consents. The three main groups of pathogens of concern are bacteria (e.g., *Campylobacter*, *Salmonella*, pathogenic *E. coli*), viruses (e.g., enteroviruses, hepatitis A virus and Norwalk-like viruses) and protozoa (e.g., *Giardia* and *Cryptosporidium*). Pathogen analysis involves specialised sampling and laboratory procedures and it is recommended that expert advice is obtained from the laboratory before a sampling programme is commenced.

Endocrine disrupters

Endocrine disrupters are synthetic chemicals that mimic hormones that regulate the endocrine system in humans and animals. The endocrine system regulates an organisms growth, development and behaviour, and so impairment of this by endocrine disrupters can have serious ramifications. Feminisation of fish downstream of sewage discharges is just one of the phenomena that have been linked with the presence of endocrine disrupters in wastewater. Currently the technology to analyses wastewater discharges for the presence of such chemicals is in its infancy. However, operators of wastewater treatment plants should be aware that the debate over endocrine disrupters is increasing and it is likely that this will become a bigger issue in the future.

14.2.9 Precision versus accuracy

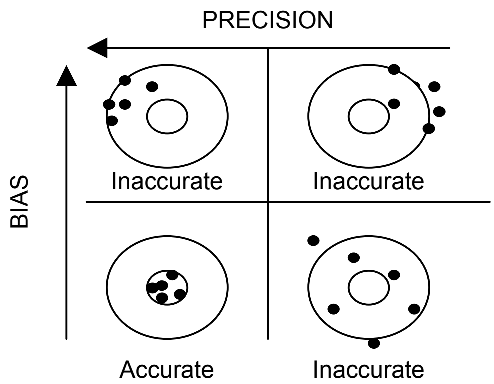
A common mistake many people make is to assume that sample results are 100% accurate and base their interpretation of the data on this premise. It is extremely unlikely that this is ever true, even if the sampling programme has been conducted in the most thorough manner. In particular the heterogeneous nature of wastewater means that sample results will be variable, even if sampling technique is perfect.

Accuracy is a function of high precision and low bias. Sample results with a high precision (i.e. the results are all close to one another), should not be assumed to be accurate, as they may be subject to high bias. For sample results to be accurate the measured value must be close to the true value, and this is achieved by a combination of high precision coupled with low bias. The diagram over best represents this relationship between bias and precision.

In the context of these Guidelines, accuracy and precision are defined as follows:

Accuracy: how close a measurement is to the ‘true’ value. In practice the ‘true’ value is never known, so accuracy of measurement is determined by laboratories using spiked samples and/or interlabarotory comparisons.

Precision: how repeatable a measurement is.



14.2.10 Analysis costs

The costs for sample analysis will generally fall into two broad classes; the standard laboratory charges for routine and high volume analyses and the more expensive charges associated with technically specialised tests or analysis at lower concentrations.

The range of costs for routine influent/effluent tests, such as TSS, BOD, COD, nitrogen, phosphorus etc., is typically \$20 - \$50 per determinand, depending on the nature of the sample. Charges for microbiological samples are typically <\$50 for bacterial analyses but can extent to around \$500 per sample for pathogen testing (virus, protozoa).

Monitoring of the receiving environment generally involves a more diverse range of determinands and analysis at concentrations several orders of magnitude less than may be found in typical effluents. Analytical costs are therefore proportionately higher. It is beyond the scope of this document to identify these costs.

14.2.11 Dealing with data

Units and definitions

The key to dealing with data successfully is to get the units of measurement right and to ensure that the numbers to be manipulated are in compatible units of measure.

Some useful equivalents to common units of measurement are tabulated over.

Unit in Words	Abbreviation	Equivalent
Megalitre	ML	1000 m^3
Litre	L	1000 mL
Gram	g	
Milligram	mg	10^{-3} x g
Microgram	µg	10^{-6} x g
Grams per litre	g L^{-1}	
Grams per metre cubed	g m^{-3}	1 part per million (ppm); mg L^{-1}
Milligrams per meter cubed	mg m^{-3}	1 part per billion (ppb); µg L^{-1}
Metre	m	
Cubic metre	m^3	1000 L
Most probable number	MPN/100 mL	Bacterial count per 100 mL
Colony-forming units	cfu/100 mL	Bacterial count per 100 mL
Plaque-forming units	pfu/L	Virus count per litre
Cubic metres per second	m^3 s^{-1}	Cumec

Expression of results

This Guideline uses the standard negative exponent system for representing units of measurement. For example, using this system, milligrams per litre are represented as g m^{-3} rather than g/m^3.

Figures should only be reported to the accuracy of the equipment or method used to determine them. For example, if the method is only accurate to one decimal place, second and third decimal places should not be reported. Similarly, the appropriate number of significant figures only should be reported.

If a sample has not been collected or analysed for whatever reason, a result of zero should not be shown when the results are tabulated, as this is very misleading.

Data handling

There are many different ways of handling data collected from a sampling programme. Spreadsheet programs can be used to handle large amounts of data and can produce useful charts and provide some statistical analysis.

Statistical analysis is useful as it can simplify data with the detection and definition of trends and relationships. However, there are many different types of statistical analysis available and unless you understand the inputs and outputs of the statistical method chosen it can be very difficult to interpret a data set meaningfully. It is also necessary to understand why the data is being analysed. If you are unsure as to how to analyse a data set specialist statistical advice should be sought. (Refer also to Chapter 13).

14.3 Quality control and assurance

14.3.1 Prior to sampling

There are a number of activities that should be carried out prior to the commencement of a sampling programme in order to ensure that the results obtained are as accurate as possible. It should be recognised that the aim of these activities is to reduce the amount of error caused in the field. A well documented, but badly executed sample programme is just as ineffective as a poorly documented one.

The following activities should be completed before any samples are taken:

- Engage a laboratory to analyse the samples and inform them when to expect the samples and what sort of analysis is required. The limit of detection required and the type of sample that is to be tested may influence the selection of the analytical method. It is important therefore to make sure the laboratory is aware of what type of water the sample is from (i.e. untreated wastewater, treated wastewater, river water etc), and what limit of detection is required for each parameter.
- Arrange transport for the samples from the field to the laboratory.
- Determine how many samples need to be taken and document reasons why this number was selected if setting up a new sampling programme. It is wise to discuss the project with a statistician before undertaking any sampling.
- Make sure personnel taking the samples have been thoroughly trained in using the relevant equipment for both taking samples and undertaking any on-site analysis.
- Select the sample point/s and label clearly. It is also advisable to create a map identifying the location of each sample site.
- Create any documentation that is required, such as chain of custody sheets, sample analysis request sheets etc.

Document all standard operating procedures for collecting samples and make sure all relevant personnel have copies.

14.3.2 During sampling

A carefully written, fully documented sampling programme can be ruined if the method of sample collection is poor. The wrong type of bottle, incorrect storage, dirty equipment, poorly labelled sampling points, unrepresentative sampling points, badly labelled samples etc. can all contribute to sample results that are not representative of the wastewater stream being investigated.

Blank samples

A blank sample is a sample that is taken in exactly the same way as the other samples, except deionised water is used instead. The blank sample is the analysed for the same determinands as the actual samples. Blank samples are used as a method of determining if the sample is being contaminated at specific points in the sampling procedure. Blank samples are of particular importance when the determinands of interest in the actual samples are present in trace quantities. ISO 5667-1 identifies the following types of blanks that can be taken:

- **Transport blank** – This blank is used to estimate the amount of contamination introduced during the transport and storage of samples from the time of sampling, until the time of analysis. Ideally at least one transport blank should be allowed per group of samples.
- **Field blank** – This blank is used to estimate contamination of a sample during the collection procedure. Ideally at least one field blank should be taken per sampling team, per trip, per collection apparatus. Once knowledge of the homogeneity of sampling collections is established, it may be possible to reduce the collection of field blanks.
- **Container blank** – Container blanks should be carried out on all new batches of containers.

Consult ISO 5667-1 5.2.2 for instructions on how to prepare blank samples.

On-site analysis

Certain parameters such as pH, temperature and dissolved oxygen have to be monitored on-site. This is because they can deteriorate quickly and if they were analysed in a laboratory several hours after sampling the results are unlikely to be representative of the true values seen in the field. Personnel taking these type of samples need to be adequately trained in the use of the equipment in the field in order to minimise 'measurement error'. As measurement equipment used in the field is often moved around and stored in different places it is much more prone to damage than equipment that remains in a fixed position in the laboratory. This can also contribute to measurement error. Anybody using measurement equipment in the field should not only follow the manufacturers instructions with regard to usage, but should pay particular attention to storage and cleaning requirements as well as frequency of equipment calibration.

Whilst not an actual analysis procedure, it may also be necessary to filter a sample in the field before sending it to a laboratory for analysis. This is an unusual requirement for wastewater samples, but may be necessary if investigating dissolved metals or nutrients in the receiving environment. The laboratory analysing the samples should advise you if this type of procedure is necessary. Field filtering should only be carried out by a suitably qualified person, as it is easy to contaminate the sample.

14.3.3 Post-sampling

Transportation

Samples should be transported to the laboratory as soon as possible after they have been taken. This is because the characteristics of the sample may start to alter after collection, making the sample unrepresentative of the wastewater being investigated.

All samples should be transported to the laboratory within 24 hours of being taken, although the shorter the time elapsed between collection and analysis the more reliable the result. Preservation of the sample also applies during transportation and every effort should be made to keep the sample cool and dark.

Microbiological samples should arrive at the laboratory within 6 hours of being taken, as the likelihood of the microorganisms dying off after this time greatly increases. Samples that cannot be tested within 24 hours of sampling are invalid samples and must not be tested.

Containers that the samples are transported in should be clean to further reduce risk of contamination of the samples.

Laboratory accreditation

In New Zealand the primary accreditation agency for laboratories associated with water and wastewater testing is International Accreditation New Zealand (IANZ). This agency was formerly known as TELARC, and is governed by an act of parliament. Generally laboratories with IANZ accreditation should be selected for analysis of samples because these laboratories will have quality assurance programmes in place to maintain analytical performance. Effluent resource consents may specify the tests are to be carried out by an IANZ accredited laboratory. However you should note that IANZ accreditation is test specific and therefore not all IANZ laboratories may be accredited for the particular test you wish to use. Confirm the status of test (i.e. analyte *and* method) accreditation with the laboratory.

There may be tests, particularly some environmental or biological tests, where no laboratory has the specific accreditation. In this case you should choose a competent laboratory and discuss the selection of an appropriate standard test method. In these circumstances it is wise to take a few split samples that can be analysed independently and/or spike some samples with a known amount of the material being tested.

14.3.4 Auditing

It is advisable to audit any sample programme, no matter how well prepared in order to ensure that samples are being collected, transported and analysed correctly. If any problems are identified they should be resolved immediately to reduce the amount of error introduced in the field.

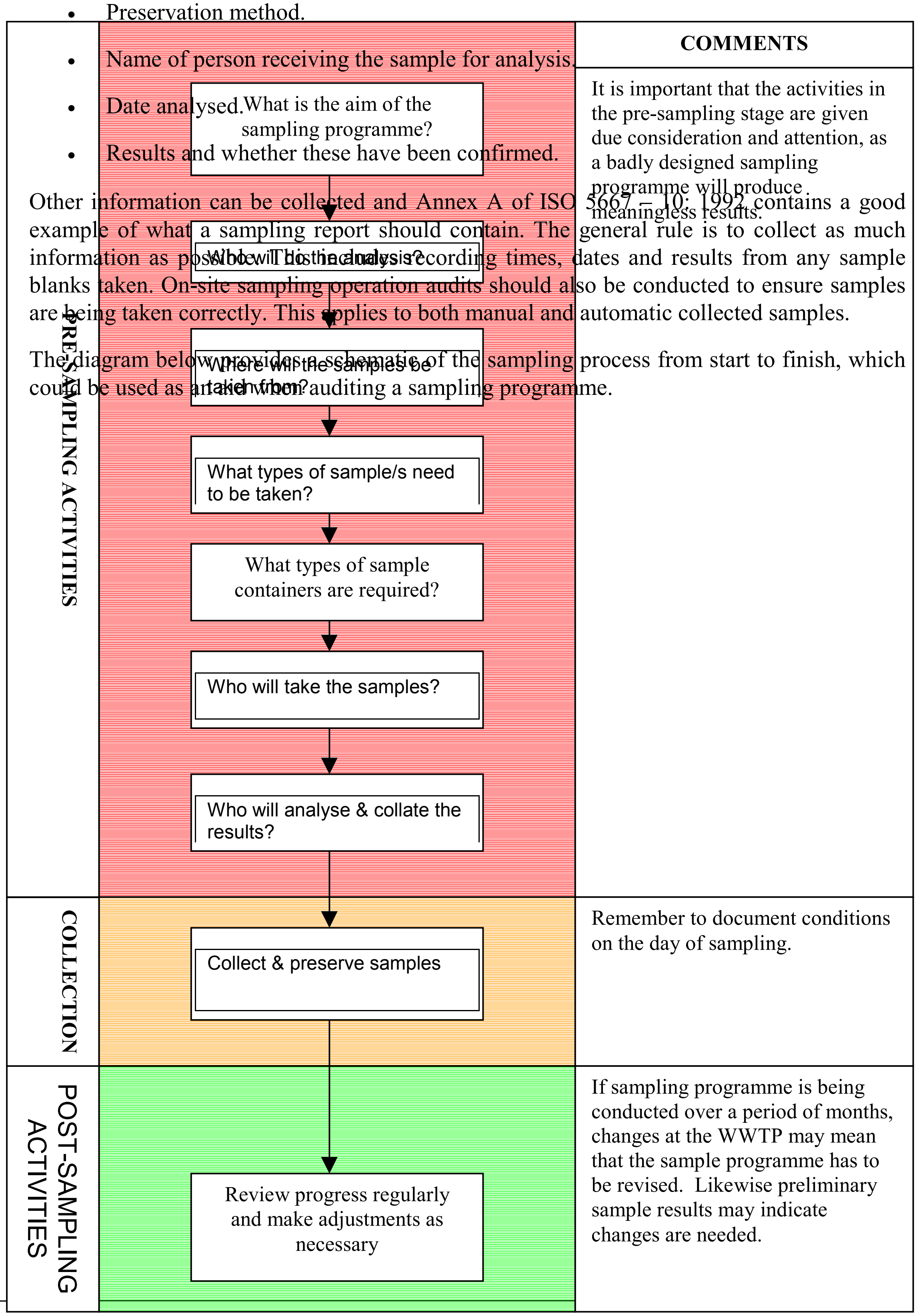
So that it is possible to audit sampling procedure a chain of custody form should be used throughout the sampling process. This should record the following information:

- Name and signature of person collecting sample.
- Date and time sample collected.
- Purpose of the sample.
- Analysis required.

- Location of sample point and unique reference number if one has been assigned.
- Sampling method (i.e. spot, composite).
- Preservation method.
- Name of person receiving the sample for analysis.
- Date analysed.
- Results and whether these have been confirmed.

Other information can be collected and Annex A of ISO 5667 – 10: 1992 contains a good example of what a sampling report should contain. The general rule is to collect as much information as possible. This includes recording times, dates and results from any sample blanks taken. On-site sampling operation audits should also be conducted to ensure samples are being taken correctly. This applies to both manual and automatic collected samples.

The diagram below provides a schematic of the sampling process from start to finish, which could be used as an aid when auditing a sampling programme.



CHAPTER 15
REVIEW OF MONITORING PROGRAMME

Rob Bell (NIWA)

15.1 Introduction

Reviews and audits of monitoring programmes should be planned and undertaken for a variety of reasons, such as: checking compliance; peer-review of results and analysis; periodic investigations and possible redesign of the scope and scale of the monitoring; statutory consented reviews; and revisiting the cost-effectiveness of the monitoring approach.

It is generally recognised that, as time passes, it may be necessary for a consent holder or consent authority to revisit a previously granted consent and review any conditions attached to it. Provisions in the RMA provide this mechanism, to ensure that monitoring conditions do not become outdated, irrelevant or inadequate, while still allowing long-term consents to be granted.

Review mechanisms should be planned into a monitoring plan right from the conceptual design and setting of objectives (Chapter 8). Then the how, when, by whom and the cost of reviews need to be factored into the detailed design of the programme at pre-determined milestones (Chapter 13). This Chapter briefly describes some of the reasons and mechanisms for reviews of monitoring programmes.

15.2 Review/audit objectives

Objectives should be set for the review or audits of various components of a monitoring programme. For example:

- Interim monitoring could be put in place with a dated review clause to cover uncertainties in the level of discharge impacts or to establish treatment plant performance after commissioning.
- Establishing milestones for an overall review of monitoring plan objectives and how well they are being met; asking questions such as "are some variables or constituents borderline or conversely very low, requiring changes to say the monitoring frequency?"
- Periodic technical reviews analysing trends and variability in monitoring data or upstream versus downstream differences – the methodologies are described in Appendix 5 of the ANZECC Water Quality Monitoring Guidelines (ANZECC 2000b), Ellis (1989), Ward et al. (1990), Gilbert (1987), and Zar (1984).
- Occasional reviews of data analysis techniques, software and reporting format, bearing in mind that any mid-course change in statistical techniques or software will

mean previous results may be different (e.g., calculation of percentiles – Chapter 13). Consequently, the entire dataset to the present should be re-analysed.

- Community surveys on best methods and media for dissemination and assimilation of monitoring information, which can be combined with some public awareness of the level of impacts.

15.3 Review mechanisms

For reviews of statutory consent conditions, the two main questions are "when?" and "how?".

The key is to design flexible consent conditions (and supporting monitoring plans – see Chapter 13) at the outset, with review clauses built in at pre-determined milestones. For example, a review after the first one or two years of monitoring can be done in the light of the results to date since commissioning, and then perhaps another review after 5 to 10 years. The discharger then has an opportunity to decrease the monitoring intensity as uncertainty of particular impacts improves to the satisfaction of the community, or where environmental or wastewater quality stabilises to low-risk levels. Conversely, a higher monitoring frequency may be required if the results are borderline or demonstrate adverse impacts.

For example, an extensive monitoring programme might be set up initially if there is public concern and technical uncertainty regarding the effectiveness of an upgrade to a treatment plant or where a new discharge commences into a sensitive environment. If a monitoring review demonstrates that the plant is consistently achieving the predicted level of treatment, or better, it may be appropriate to reduce the extent of monitoring.

Section 127 of the RMA provides a mechanism for the consent holder to apply to cancel or change permit conditions, which can include modification of any monitoring requirement. The procedure for the review is similar to an application for a resource consent [S. 127(3)]. Commonly, much of the detailed design and operation of the agreed monitoring programmes are contained in separate Management or Monitoring Plans that are then referred to in the resource consent.

Sections 128 to 133 of the RMA prescribe the mechanisms whereby the consenting authority can review a resource consent, especially if adverse effects occur on the receiving environment. They may then require the discharger to adopt the best practicable option to remove or reduce any adverse effect. However many permits also provide a clause for the alteration or 'fine-tuning' of monitoring requirements, including further monitoring, or increasing or reducing the frequency of monitoring. A further reason why the consenting authority may require a review is to implement rules of any relevant regional plan that is proposed or becomes operative, or the release of any national guidelines or regulations. Again the procedure is similar to an application for a resource consent.

PART FOUR:
CASE STUDIES

CASE STUDY 1:
MARTINBOROUGH SEWAGE TREATMENT POND

Stephen Yeats (Wellington Regional Council)

Editor's note

The following is a case study where the Wastewater Monitoring Guidelines were used to help develop a monitoring programme for the Martinborough wastewater treatment plant discharge. Note that this case study is the author's interpretation of the use of the Guidelines. Other interpretations are possible.

Description

Martinborough is a small town in the Wairarapa with a growing reputation for producing fine wine. It is about an hour's drive from the Wellington urban area. The population of the town swells during weekends as Wellingtonians travel over to spend time in their holiday homes or casual accommodation.

The Martinborough sewage oxidation pond is located approximately 1 km southwest of the township, and was constructed in 1975. Raw, unscreened sewage is pumped to this pond. Two mechanical aerators were installed in August 1998. The pond is approximately 23 000 m^3 in volume, with a surface area of approximately 16 300 m^2. The average daily flow, based on data from the AEE is 440 m^3/ day, giving a residence time within the pond of 52 days. The peak flow is 1460 m^3/ day.

The discharge was operating under a resource consent granted in 1986 (WAR860077 01). This consent allowed a discharge of up to 1464 m^3/day. There are five conditions attached to the consent, all of which have been complied with.

The treated effluent is discharged from the pond by gravity feeding through a weir and baffle arrangement to a single 300 mm diameter pipeline which terminates immediately beside the Ruamahanga river. The terminal end of the pipe is set in a concrete structure above the normal river water level. Effluent flows from the pipe, down the river bank and into the edge of the river.

The pond treats the effluent from a 2001 census night population of 1356 "*usual residents*". Projections provided in the AEE estimate a population of 1592 by the year 2011. The applicant has based the figures provided in the AEE on a projected estimate of 6% growth rate. The census figures do not reflect higher population during weekends and other holidays. The Council estimates a 20% increase in weekends.

The Ruamahanga river at Waihenga bridge, 2.2 km upstream of the discharge, has a mean annual low flow of 9152 litres a second. Based on the dry weather **influent** flow of 340 m^3 /day

(3.93 L/s), if the effluent being discharged was equal to the influent flow, it would be diluted 2329 times in the river during low flow conditions. Similarly, based on the average daily **influent** flow stated in the AEE of 440 m^3 / day, the effluent would be diluted 1797 times in summer.

The river downstream of the discharge is widely used for recreational, commercial and agricultural purposes. There are 11 resource consents totalling 850 L/s to take water from the river for irrigation below the pond. Wellington Regional Council monitored the Bentleys Beach site for contact recreation in the mid-nineties, and dropped this site after a survey found little recreational use.

Monitoring of the effluent from the pond has been undertaken for a considerable number of years. There are currently two effluent monitoring programmes in place – the WRC sewage programme and the SWDC's own monitoring. Both of these programmes sample the effluent once a month – one within the pond and one at the outfall.

Monitoring of the receiving river was started in 1994. Both the effluent and the river (upstream and downstream) have been monitored by WRC on a monthly basis for a varied suite of parameters since 1994. There is also a biological assessment using a macroinvertebrate community index score once per year both up and downstream.

WRC monitors the water quality at Waihenga bridge once per month as part of the ambient water monitoring study. Monitoring at an ambient site at Tuhitarata was discontinued because little change in water quality was found downstream of Waihenga. The Regional Council also monitors bacteria levels at Waihenga bridge once per week during the swimming season.

The Consent Renewal Process

South Wairarapa District Council applied to the Wellington Regional Council to renew a resource consent to continue discharging sewage to the Ruamahanga river. The previous consent was granted in 1986, and expired in 1997. A final application to renew the consent was made in January 2002.

Thirty four submissions were received. Almost all of them were from landowners downstream of the discharge, and 32 out of the 34 opposed the application. Two were neutral and none supported the application.

In the application, the District Council proposed to continue the discharge as usual until some point in the future, when unspecified improvements would be made to the plant.

In an unorthodox move, the Hearings Committee adjourned the Hearing and instructed all parties to attempt to reach agreement on a satisfactory programme of upgrading the plant. Through further negotiation, agreement was reached to upgrade the plant over a two- stage process within 7 years of commencement of the consent.

The conditions on the granted consent set effluent limits on *E. Coli*, BOD, SS, Oil and Grease, TN, Ammonia N, TP, pH. There are no limits set on the receiving water.

The monitoring condition on the consent states *The consent holder shall, in consultation with the Wellington Regional Council, submit a monitoring programme for the sewage treatment, discharge and receiving water. The monitoring programme is to be confirmed to the satisfaction of the Manager, Planning and Resources, Wellington Regional Council and implemented within two months of the commencement of this consent.*

As a result, staff from both the District Council and the Regional Council have been working together using a draft of the guidelines to agree on a suitable monitoring programme. The worked examples to date are included:

Table 5.5: Discharge characterisation sheet. Fill this sheet in for Step 1.1 in risk analysis in Chapter 4. See also example in Table 5.6. Add other constituents and make other adaptions to this table if required.

Wastewater sources: Martinborough Urban, Permanent Population 1200……………………………………………….

Flow (best estimate): **ADWF:340 m^3 / day……………** **PWWF:………………………………..**

Constituent	Influent characteristics		Treatment plant process unit performance, normal operation (give rating of L, M or H of each unit for each constituent)					Known data on w/w effluent (Note 1)	Assessed characteristics of discharge (give rating of L, M or H) (Note 2)
	Known data on influent w/w (Note 1)	Influent characteristic rating (L, M or H)	Single Pond						
Temperature		L	M					15 degrees	L
PH		M	M					8	L
BOD, COD		M	M					BOD 41 g/m^3	L
Suspended solids		H	M					73	M
Fats, oil & grease, floatables								Not measured	
Nutrients -nitrogen -phosphorus		 M-H M	 L L					TN 21,864 mg/m^3 TPP 8419 mg/m^3	 M M
Ammonia		M	L					10,517 mg/m^3	M
Pathogens (indicators)		M-H	M					FC's 22400 E. Coli 11000 Enterococci	M

								7000	
Heavy metals		**L**	M					Not measured	L

Characterisation of the Environment

Table 6.2: Receiving environments, constituents of concern, and assimilative capacity. Shaded boxes = of concern. Refer to Section 6.4 for explanation of assimilative capacity terms.

Receiving Environment	Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
River/ Stream (<50% base flow)	x	x	-	-	x	x	x	x	x	x

Assimilative Capacity/Sensitivity Of		Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
River		x	x			x	x	x	x	x	x
Dilution	~~Poor~~										
	~~Moderate~~	-	-	-							
	Excellent	-	-	-	-	-	-	-	-	-	-
Substrate (s)	Mud	-	x	-		-	-	-	x	x	x
	Sand	-	-	-		-	-	-	x	x	-
	~~Rock~~	-	-	-		-	-	-	-	-	-
Enrichment status	~~Unenriched~~	-		-			-	-		-	-
	Mod Enrichment	-	x	-		x	-	-	x	-	-
	~~Enriched~~	-	-	-	-	-	-	-		-	-
Sensitivity of Ecological Values	~~High~~					-	-	-			-
	Moderate	-	x	-		-	-	-	x	x	-
	~~Low~~	-	-	-	-	-	-	-	-	-	-
Significant other Inputs	Yes	x	x			x	x	x	x	x	x
	~~No~~	-	-	-	-	-	-	-	-	-	-
Aesthetics	Important	-	-	-		x	x	x	-	-	-
	~~Not so Important~~	-	-	-	-	-	-	-	-	-	-
Contact Recreation	Yes	-	-	-		x	x	x	-	-	x
	~~No~~	-	-	-	-	-	-	-	-	-	-
Water Supply (Economic Utility)	~~Drinking~~	-	-		-						
	Irrigation	-	-		-	x	-	x	x	x	-
	Industrial	-	-		-	x	x	-	-	x	-
Food gathering	Yes	-	-	-		-	-	-	-	-	x
	~~No~~	-	-	-	-	-	-	-	-	-	-
Include in HIAMP	Yes	x	x			x	x	x	x	x	x
	No			x	x						

Community Values

Through the consent process, 34 submitters provided a reasonable overview of the values they wished to be taken into account:

- Use of the receiving river for recreation
- The importance of the river for tourism
- The use of the river for agricultural. Specifically irrigation and water supply.
- Issues of specific relevance to tangata whenua.
- The principle that the rural sector is withdrawing effluent discharges to water, but not the urban centres.

[Editors note: consultation with the community would normally be undertaken prior to lodging the consent application, and this would provide information for the hazard assessment in addition to submissions on the application.]

WORKSHEET A – Normal Conditions															
Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General	Local concern from downstream residents, for various reasons. Iwi object to the principle of discharging to river. Community value, aesthetics, ecology and human health all potentially affected.					C-D	I	D-E	I					2
	Temperature	No anticipated effect													
	pH	No anticipated actual effect													
	SS/turbidity, colour	Seasonal impact on river possible, although likely to be a localised effect.			D	III	E	III							2
	BOD, COD	Seasonal impact possible on ecosystem			E	III									3
	Fats, oils and greases	No anticipated actual effect													
	Ammonia	Ecological effects possible, the frequency of non-compliance with guidelines has increased.			D	III									2
	Nitrogen	Ecology, aesthetics and community values could all potentially be affected in adverse conditions, but monitoring to date shows no major effect.			E	III									3
	Phosphorus	May cause periphyton algal blooms			C	III	E	III			E	III			2
	Pathogens	Widely used for recreation. Human health may be affected	D	III											2
	Heavy metals	No anticipated effect													
	POPs	No anticipated effect													
	Sulphides	No anticipated effect													
	Odour	Some events possible.													
Peak flows		10-20% increase in weekend volumes	D	III	D	III									2
Contaminant or Waste Slug		10-20% increase in volume every weekend	D	III	D	III									2
Odour generation from plant		Only considered to occur during abnormal conditions.													
Solids disposal		Taken off site.													
Other sources of risk (list below)															

WORKSHEET B – Abnormal Conditions and effect of gross uncertainty															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions		Possibility of pond turning anaerobic during certain weather patterns. Result – odour, high SS, BOD, discolouration											D	V	2
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)		Possibility of trade waste chemical emergency. Risk too slight to consider													
Upset of plant related to extreme weather		Possibility of pond turning anaerobic, extreme low flow conditions in the receiving water	C	V	C	V	C	V	C	V	C	V	C	V	2
Abnormal constituents in trade wastes		Trade waste well understood, not considered a significant risk													
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?		Low flows in river	C	V	C	V	C	V	C	V	C	V	C	V	2
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)		Pond very simple, reasonably well understood													
Contaminant composition uncertainty		Very uniform waste stream													
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)		Well understood receiving environment													
Other causes of risk (list below)															

The Objectives of Monitoring

Compliance monitoring for the resource consents is considered important for the following reasons;

- To provide assurance to the community that the treatment plant is producing a reasonable quality effluent
- To demonstrate the level of impact on the receiving waters
- To detect or identify any trends in water quality in the discharge and/or receiving waters.
- To measure the effects of improvements from the proposed upgrading of the plant.
- To demonstrate that the pond is being maintained in an aerobic state, and is not causing nuisance conditions.

The Agreed Monitoring of the Effluent

Three staff from the District Council and the Regional Council met and went through the relevant sections of the guidelines. Agreement was reached on the monitoring of the effluent.

Parameter	Appropriate resources (from Worksheet A)	Monitoring Frequency
BOD	3	Monthly
SS	2	Monthly
Ammonia	2	Fortnightly
Total Nitrogen	3	Monthly
Phosphorus	2	Monthly
E. coli	2	3 times per month
Volume	2	Continuous

The monitoring of the receiving water is still being negotiated at the time of writing. The Regional Council experienced considerable difficulty in establishing the zone of reasonable mixing. Improved guidance on this matter would be desirable.

CASE STUDY 2:
COOKS BEACH SEWAGE TREATMENT PLANT

Chris Stumbles and Rob Docherty (Pattle Delamore Partners)

Editor's note

The following is a case study that uses the Wastewater Monitoring Guidelines to develop a hypothetical monitoring programme for the Cooks Beach wastewater treatment plant discharge. Note that this case study is the authors' interpretation of the use of the Guidelines. Other interpretations are possible. Note also that the following does not necessarily reflect the views of the Thames-Coromandel District Council (who are responsible for the Cooks Beach WWTP).

Description

The Cooks Beach WWTP has been designed to serve the greater Cooks Beach community. Cooks Beach is a small coastal settlement on the Coromandel Peninsula popular with holiday makers. It has a population that varies between 300 in winter and 6,000 during the summer peaks, with the peak summer population projected to increase to around 8,500 at some stage in the future. There is currently 3 km of reticulation with 2 sewage pumpstations and this network is currently being expanded to serve the greater Cooks Beach area. The sewerage network will increase to approximately 10 km of reticulation with 8 sewage pumpstations by 2003.

The WWTP and disposal area are situated on a 40 ha site approximately 1 km south of Cooks Beach with the nearest habitable building located approximately 500 m from the site. There is a small stream with two of its tributaries crossing the site and these could potentially be susceptible to contamination. The stream flows into Cook Stream which discharges into Cooks Bay.

The sewage reticulation catchment contributing to the Cooks Beach WWTP is residential and there is no industry in the area and no trade wastes discharge into the sewerage system, so the plant only treats sewage of a domestic origin apart from about 10 commercial properties including restaurants, dairies and a fast food outlet.

The treatment system consists of a single step screen followed by two Aerated Lagoons which operate in series. Treated effluent is stored in a 35,000 m3 storage pond and applied to 24 ha of forest by means of slow rate spray irrigation (SRI) when conditions are suitable. The system has an ultimate treatment capacity of approximately 1,200 m3/d. There is no disinfection of the effluent before irrigation and the land that is used for irrigation is relatively steep and consists mainly of clay or silty clay soils. Relatively low application rates (35 mm/wk summer and 24 mm/wk winter) have been consented based on detailed hydraulic modelling of the irrigation site.

The treated effluent is applied to land (soil), but there is a possibility of contamination reaching the groundwater after an extended period of application to the land, and also a possibility of contamination of the stream due to overland flow caused by extreme rainfall events, pipe bursts or poor operation of the irrigation system. A resource consent has been granted (20 year term, expiry in 30 June 2019) which requires, inter alia, that soil, groundwater and stream water quality are all monitored on a periodic basis. The system is operated in accordance with a detailed Operation and Maintenance manual.

The HIAMP Evaluation:

Step 1.1: Characterisation of the Effluent Discharge

Refer to completed Table 5.5 below.

Step 1.2: Characterisation of the Environment

This was undertaken for all three receiving environments at Cooks Beach (i.e. Soils, Groundwater and the Stream) using Table 6.2, as they are all potentially affected.

Step 1.3: Community Values

- The following community values were identified and have been considered:
- Maori Issues - protecting the spiritual well being of the streams etc.
- Aesthetic Values - are there any aesthetic problems caused by the WWTP.
- Odour Problems - how are the community affected by odours from the WWTP.
- Food Gathering - are any areas at risk, or perceived to be at risk.
- Property Values - how are these affected by the existence or proximity to the WWTP.
- Use of Amenities - how are the use of amenities eg. stream & beach affected.
- Restricted Access - loss of access to the irrigation area etc.
- Perceived health risks - the perceived health risk is often far greater than the actual risk.
- Community participation - in the current consent there is only a requirement to keep a complaints register at the plant, no other community input into the monitoring of the plant is required.

Step 1.4: Hazard Identification

Items identified in Table 6.2 were transferred to Worksheets A & B. Once again a separate worksheet was prepared for each of the three receiving environments. (i.e. Soils, Groundwater and the Stream)

Step 2: Risk Analysis

The risk analysis steps 2.1 to 2.5 were carried out using Worksheets A & B for each of the receiving environments.

Step 3: Monitoring Programme

A table has been prepared comparing the proposed monitoring requirements, as obtained using the appropriate resource designation (Worksheets A & B) and suggested monitoring frequency (Table 10.4), and the current resource consent monitoring requirements. We have also commented on what we regard as the appropriate level of monitoring.

Table 5.5: Discharge characterisation sheet. Fill this sheet in for Step 1.1 in risk analysis in Chapter 4. See also example in Table 5.6. Add other constituents and make other adaptations to this table if required.

Wastewater sources: … Cooks Beach Residential Area (Population 300 – 6,000)……………………………Flow (best estimate): ADWF:……Summer - 840 m^3/d……………… PWWF:………………………………..

Constituent	Influent characteristics		Treatment plant process unit performance, normal operation (give rating of L, M or H of each unit for each constituent)					Known data on w/w effluent (Note 1)	Assessed characteristics of discharge (give rating of L, M or H) (Note 2)
	Known data on influent w/w (Note 1)	Influent characteristic rating (L, M or H)	Primary Screen	Twin Aerated Lagoons	Slow Rate Irrigation (SRI)				
Temperature	14°C	L	-	H	H			12°C	L
pH	7.2	M	-	H	H				L
BOD, COD	BOD 250 g/m^3	M	L	M	H			BOD 13 g/m^3	L
Suspended solids	TSS 250 g/m^3	M	L	M	H			46 g/m^3	L
Fats, oil & grease, floatables		M	M	H	H				L
Nutrients -nitrogen -phosphorus	 TN 50 g/m^3 TP 10 g/m^3	 M M	 L L	 M L	 H H			 3 g/m^3 0.98 g/m^3	 L L
Ammonia	45 g/m^3	M	L	M	M			0.02 g/m^3	L
Pathogens (indicators)	Ecoli 10^6 cfu/100mL	M	L	M	H			Faecal Coliforms 70 cfu/100 mL	M-L
Heavy metals		L	L	M	H				L
Odour			Y	Y	N				M

Note 1: Enter any known data, e.g., mean and 95 %ile concentrations, daily loads, etc. Refer to another sheet if necessary.

Note 2: Assess the characteristics of the discharge (final column) by combining the influent characteristic rating with the treatment process unit ratings. Known data on the effluent discharge (column 4) should be taken into account if this is available.

L = low, M = medium, H = high **Notes :** Effluent sampled before SRI, Flows extremely variable due to large population fluctuations.

Table 6.2: Receiving environments, constituents of concern, and assimilative capacity. (Groundwater)

Receiving Environment	Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Lake/Reservoir		-	-							
River/ Stream (>50% base flow)										
River/ Stream (<50% base flow)			-	-						
Estuary	-		-							
Harbours & Sheltered Embayments	-		-							
Nearshore Marine (shoreline)	-	-	-		-					
Offshore Marine	-	-	-		-					
Groundwater	-	X	X	-	X	X	X	X	X	X
Air	-	-	-	-		-	-	-	-	
Soils		-		-		-	-			

Assimilative Capacity/Sensitivity Of Groundwater		Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
			X	X		X	X	X	X	X	X
Dilution	~~Poor~~										
	~~Moderate~~	-	-	-							
	Excellent	-	-	-	-	-	-	-	-		-
Substrate (s)	~~Mud~~	-		-		-	-	-			-
	~~Sand~~	-	-	-		-	-	-			-
	Rock	-	-	-		-	-	-	-	-	-
Enrichment status	Unenriched	-	X	-		X	-	-	X	-	-
	~~Mod Enrichment~~	-		-			-	-		-	-
	~~Enriched~~	-	-	-	-	-	-	-	-	-	-
Sensitivity of Ecological Values	~~High~~					-	-	-			-
	Moderate	-	X	X		-	-	-	X	X	-
	~~Low~~	-	-	-	-	-	-	-	-		-
Significant other Inputs	~~Yes~~										
	No	-	-	-	-	-	-	-	-	-	-
Aesthetics	~~Important~~	-	-	-					-	-	-
	Not so Important	-	-	-	-	-	-	-	-	-	-
Contact Recreation	~~Yes~~	-	-	-					-	-	
	No	-	-	-	-	-	-	-	-	-	-
Water Supply (Economic Utility)	Drinking	-	-	X	-	X	X	X	X	X	X
	~~Irrigation~~	-	-		-		-				-
	~~Industrial~~	-	-		-			-	-		-
Food gathering	~~Yes~~	-	-	-		-	-	-	-	-	
	No	-	-	-	-	-	-	-	-	-	-

Include in HIAMP	Yes		X	X		X	X	X	X	X	X

	No	**X**			**X**						

Table 6.2: Receiving environments, constituents of concern, and assimilative capacity. (Stream)

Receiving Environment	Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Lake/Reservoir		-	-							
River/ Stream (>50% base flow)										
River/ Stream (<50% base flow)	X	X	-	-	X	X	X	X	X	X
Estuary	-		-							
Harbours & Sheltered Embayments	-		-							
Nearshore Marine (shoreline)	-	-	-		-					
Offshore Marine	-	-	-		-					
Groundwater	-			-						
Air	-	-	-	-		-	-	-	-	
Soils		-		-		-	-			

Assimilative Capacity/Sensitivity Of		Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Stream		X	X			X	X	X	X	X	X
Dilution	~~Poor~~										
	~~Moderate~~	-	-	-							
	Excellent	-	-	-	-	-	-	-	-		-
Substrate (s)	Mud	-	X	-		-	-	-	X	X	-
	~~Sand~~	-	-	-		-	-	-			-
	~~Rock~~	-	-	-		-	-	-	-	-	-
Enrichment status	~~Unenriched~~	-		-			-	-		-	-
	Mod Enrichment	-	X	-		X	-	-	X	-	-
	~~Enriched~~	-	-	-	-	-	-	-	-	-	-
Sensitivity of Ecological Values	~~High~~					-	-	-			-
	Moderate	-	X			-	-	-	X	X	-
	~~Low~~	-	-	-	-	-	-	-	-		-
Significant other Inputs	~~Yes~~										
	No	-	-	-	-	-	-	-	-	-	-
Aesthetics	Important	-	-	-		X	X	X	-	-	-
	~~Not so Important~~	-	-	-	-	-	-	-	-	-	-
Contact Recreation	Yes	-	-	-		X	X	X	-	-	X
	~~No~~	-	-	-	-	-	-	-	-	-	-
Water Supply (Economic Utility)	~~Drinking~~	-	-		-						
	~~Irrigation~~	-	-		-		-				-
	~~Industrial~~	-	-		-			-	-		-
Food gathering	Yes	-	-	-		-	-	-	-	-	X
	~~No~~	-	-	-	-	-	-	-	-	-	-
Include in HIAMP	Yes		X			X	X	X	X	X	X

	No	X		X	X						

WORKSHEET A – Normal Conditions – SOILS															
Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly inj urious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General	Large fluctuations in flow & load experienced over weekends and holiday periods	F	II	F	II	F	II	F	II	F	II	F	II	3
	~~Temperature~~	Not Required in HIAMP													-
	pH	Long term application could modify soil characteritics			B	V									3
	~~SS/turbidity, colour~~	Not Required in HIAMP													-
	~~BOD, COD~~	Not Required in HIAMP													-
	~~Fats, oils and greases~~	Not Required in HIAMP													-
	Ammonia	Seasonal fluctuations – Possible damage to soil biota if not managed correctly			B	V									3
	Nitrogen	Seasonal fluctuations – Possible overloading of soils if not managed correctly			B	V									3
	Phosphorus	Seasonal fluctuations – Possible overloading of soils if not managed correctly			B	V									3
	~~Pathogens~~	Not Required in HIAMP													-
	Heavy metals	No industry therefore Heavy metals not expected to be a problem													None
	POPs	No industry therefore POP's not expected to be a problem													None
	Sulphides	Low levels of sulphides possible but these are not expected to cause any significant impact													None
	Odour	Limited odour possible at WWTP but not expected to have any significant impact													None
Peak flows		High flows likely during peak periods. These are of short duration and are not likely to have any long term effect.	F	V	D	V	F	V	F	V	F	V	E	V	None
Contaminant or Waste Slug		WWTP is resilient to waste slugs and has large storage capacity													None
Odour generation from plant		Odour possible during desludging process											D	V	None
Solids disposal		No procedure derived yet.													
Other sources of risk (list below)															

WORKSHEET B – Abnormal Conditions and effect of gross uncertainty – SOILS															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions		Large volumes of storage available and plant process very robust. No measurable													None
		impact on soils likely													
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)		Process fairly resilient to shock effects & contributing catchment very unlikely to produce													None
		a toxic shock. No measurable impact on soils likely													
Upset of plant related to extreme weather		Extreme rainfall could result in flushing of the ponds. This is however not expected to have any measurable impact on the soils													None
Abnormal constituents in trade wastes		No trade wastes from catchment.													None
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?		No known sensitivity													None
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)		The process is well understood													None
Contaminant composition uncertainty		The likely contaminants are well known													None
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)		The impact of discharging effluent to soils is fairly well understood													None
Other causes of risk (list below)															

WORKSHEET A – Normal Conditions – GROUNDWATER															
Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General	Large fluctuations in flow & load experienced over weekends and holiday periods	F	II	F	II	F	II	F	II	F	II	F	II	3
	~~Temperature~~	Not Required in HIAMP													-
	pH	Long term application could alter groundwater pH	E	V	B	V			E	V					3
	SS/turbidity, colour	No effect on groundwater expected													None
	BOD, COD	Possible contamination of groundwater after extended application	E	V	F	II			B	V					3
	Fats, oils and greases	No anticipated measurable effect													None
	Ammonia	Possible contamination of groundwater after extended application	B	V	B	V	C	V	B	V					3
	Nitrogen	Possible contamination of groundwater after extended application			B	V	C	V	B	V					3
	Phosphorus	Possible contamination of groundwater after extended application			B	V	C	V	B	V					3
	Pathogens	Possible contamination of groundwater after extended application	B	V			C	V	B	V					3
	Heavy metals	No industry therefore Heavy metals not expected to be a problem													None
	POPs	No industry therefore POP's not expected to be a problem													None
	Sulphides	Low levels of sulphides possible but these are not expected to cause any significant impact													None
	Odour	Limited odour possible at WWTP but not expected to have any significant impact													None
Peak flows		Not likely to have any impact on groundwater													None
Contaminant or Waste Slug		WWTP resilient to waste slugs													None
Odour generation from plant		Odour possible during desludging process													
Solids disposal		No procedure derived yet – On-site disposal could contaminate groundwater													
Other sources of risk (list below)															

WORKSHEET B – Abnormal Conditions and effect of gross uncertainty – GROUNDWATER															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions		Large volumes of storage available and plant process very robust. No measurable													None
		Impact on groundwater likely													
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)		Process fairly resilient to shock effects & contributing catchemnt very unlikely to produce													None
		A toxic shock. No measurable impact on groundwater likely													
Upset of plant related to extreme weather		Extreme rainfall could result in flushing of the ponds. This is however not expected to have any measureble impact on the groundwater													None
Abnormal constituents in trade wastes		No trade wastes from the catchment													None
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?		No known sensitivity													None
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)		Rate of infiltration of contaminants into groundwater not well understood													
Contaminant composition uncertainty		The likely contaminants are well known													None
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)		Ecosystem reasonably well understood													None
Other causes of risk (list below)															

WORKSHEET A – Normal Conditions – STREAM															
Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General	Large fluctuations in flow & load experienced over weekends and holiday periods, but this is not expected to have any impact on the stream													None
	~~Temperature~~	Not Required in HIAMP													-
	~~pH~~	Not Required in HIAMP													-
	SS/turbidity, colour	Failure to operate the irrigation system correctly could result in overland flow into the stream which flows through Cooks Beach and out near the bathing beach			E	V									None
	BOD, COD	Failure to operate the irrigation system correctly could result in overland flow into the stream which flows through Cooks Beach and out near the bathing beach			D	V									None
	Fats, oils and greases	No impact on stream likely													None
	Ammonia	Failure to operate the irrigation system correctly could result in overland flow into the stream which could affect certain orgenisms			B	V	D	V	D	V	E	V			3
	Nitrogen	Failure to operate the irrigation system correctly could result in overland flow into the stream resulting in increased plant growth			B	V	D	V	D	V	E	V			3
	Phosphorus	Failure to operate the irrigation system correctly could result in overland flow into the stream resulting in increased plant growth			B	V	D	V	D	V	E	V			3
	Pathogens	Failure to operate the irrigation system correctly could result in overland flow into the stream which flows through Cooks Beach and out near the bathing beach	B	V			D	V	D	V					3
	Heavy metals	No industry therefore Heavy metals not expected to be a problem													None
	POPs	No industry therefore POP's not expected to be a problem													None
	Sulphides	Low levels of sulphides possible but these are not expected to cause any significant impact													None
	Odour	Increased BOD & nutrient levels in stream caused by failure of the irrigation system could result in odours from the stream					E	V	E	V			E	V	None
Peak flows		High flows likely during peak periods or during extreme rainfall events could result in overland flow of contaminants into watercourses or flooding of sewage pumpstations resulting in contamination of the stream	B	V	D	V	D	V	D	V	E	V	E	V	3
Contaminant or Waste Slug		WWTP resilient to waste slugs													
Odour generation from plant		Odour possible during desludging											D	V	None
Solids disposal		No procedure derived yet. On-site disposal could lead to contamination of the stream.													
Other sources of risk (list below)															

WORKSHEET B – Abnormal Conditions and effect of gross uncertainty – STREAM															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious , B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions	SS	Overland flows into stream could result from pipe bursts/blockages			D	V	E	V			E	V			None
	Path	Overland flows into stream could result from pipe bursts/blockages	B	V			C	V	D	V					3
	NH_4^+	Overland flows into stream could result from pipe bursts/blockages	D	V	D	V									None
	BOD	Overland flows into stream could result from pipe bursts/blockages			D	V							E	V	None
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)		Process fairly resilient to shock effects & contributing catchemnt very unlikely to produce													None
		A toxic shock. No measurable impact on groundwater likely													
Upset of plant related to extreme weather		Extreme rainfall could result in flushing of the pond as well as runoff of irrigated effluent into the streams, or flooding of sewage pumpstations	B	V	D	V	C	V	D	V	E	V	E	V	3
Abnormal constituents in trade wastes		No trade wastes from the catchment													None
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?		No known sensitivity													None
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)		Process well understood													None
Contaminant composition uncertainty		The likely contaminants are well known													None
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)		Ecosystem reasonably well understood													None
Other causes of risk (list below)															

TABLE OF MONITORING REQUIREMENTS

Parameter[4]	Effluent			Groundwater			Stream			Soils[5]		
	Guidelines[1]	Consent[2]	Comments[3]	Guidelines[1]	Consent[2]	Comments[3]	Guidelines[1]	Consent[2]	Comments[3]	Guidelines[1]	Consent[2]	Comments[3]
Flow	Daily Volume	Weekly	Daily Summer	None		N/A	None		N/A	Daily Volume		N/A
Temperature	None	Weekly	Quarterly	-		N/A	None		Quarterly	-		N/A
pH	Quarterly		Quarterly	Quarterly		Quarterly	None		Quarterly	Yearly	Yearly	Yearly
Total Suspended Solids (TSS)	None	Quarterly	Quarterly	None	Yearly	Quarterly	None		Quarterly	-		N/A
Turbidity	N/A		N/A	None		N/A	None		N/A	-		N/A
Volatile Suspended Solids (VSS)	N/A		N/A	-		N/A	-		N/A	-		N/A
Colour	None		N/A	None		N/A	None		N/A	-		N/A
BOD	Quarterly	Quarterly	Quarterly	Quarterly		Quarterly	None	Quarterly	Quarterly	-		N/A
COD	None		N/A	None		N/A	None		N/A	-		N/A
TOC	None		N/A						N/A		Yearly	Yearly
Foam & Scum	None		N/A	None		N/A	None		N/A	-		N/A
Fats, oils and greases	None		N/A	None			None			-		
Total N	Quarterly	Quarterly	Quarterly	Quarterly	Yearly	Quarterly	Quarterly		Quarterly	Quarterly	Yearly	Yearly
TKN	Quarterly		Quarterly	Quarterly			Quarterly		Quarterly	Quarterly		
Ammoniacal-N	Quarterly		Quarterly	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly		N/A
NO_2			Quarterly	Quarterly			Quarterly		Quarterly	Quarterly		
NO_3^-			Quarterly	Quarterly	Quarterly	Quarterly	Quarterly		Quarterly	Quarterly	Yearly	Yearly
Total P	Quarterly	Quarterly	Quarterly	Quarterly			Quarterly		Quarterly	Quarterly	Yearly	Yearly
DRP	Quarterly		Quarterly	Quarterly		Quarterly	Quarterly	Quarterly	Quarterly	Quarterly		
Olsen P												Yearly
E. coli, Enterococci,												
Faecal coliforms	Monthly	Quarterly	Quarterly	Monthly	Quarterly	Quarterly	Monthly	Quarterly	Quarterly	-		
HEVs, Pathogens			N/A	-		N/A	-		N/A	-		
Metals (Cd, Cu, Ni, Pb, Zn)			N/A	None		N/A	None		N/A	None		
Metals (Hg, As, Ag, Cr)				-			-			-		
Hardness or Alkalinity/Conductivity*			N/A	-	Quarterly	Quarterly	-	Quarterly	Quarterly	-		
POP's			N/A	-		N/A	-		N/A	-		
Water Level				Quarterly	Quarterly	Quarterly						

Notes:

* *Conductivity has been added.*

1. *Monitoring as required by Guidelines.*
2. *Monitoring required by existing Cooks Beach consent.*
3. *Monitoring considered desirable (but not altogether necessary) by R. Docherty of Pattle Delamore Partners Limited.*
4. *Consent also requires the following monitoring*

Summer Daily	***Winter Weekly***
Wind	*Wind*
Rainfall	*Rainfall*
Frost	*Frost*
Water level	*Water level*
DO/A/L health	*DO/A/L health*
Aerator hours	*Aerator hours*
Odours	*Odours*

Additional inspection are also carried out by the Operator as detailed in the Cooks Beach O&M manual

5. *The consent requires that soils are monitored at 5 sites and 2 depths at each site for the parameters noted.*

Discussion on decisions made for monitoring

Cooks Beach has four situations that require monitoring. There is the effluent stream and three receiving environments that could be affected by the disposal of effluent from the WWTP (excluding the future disposal of sludge, as the receiving environment has not yet been determined at this stage). The table above compares the current monitoring requirements with those determined using the Guidelines. Some monitoring of the influent and the conditions in the ponds should also be carried out for operational reasons. The reason for each decision is discussed below.

Flow

The volume of effluent applied to the irrigation area (soils) needs to be monitored as well as the rainfall on the site to ensure the soils do not become saturated. In addition to this the groundwater level needs to be monitored to determine what impact the application of effluent to the irrigation area is having on the groundwater table (not identified by the Guidelines). Monitoring of flow into the plant would be useful from an operational point of view.

Temperature

Temperature of the effluent is unlikely to impact on any of the receiving environments, but ambient temperature and wind will affect the rate of evaporation/evapotranspiration from the irrigation area. However, the temperature of the water in the ponds will affect the quality of effluent produced by the plant. Temperature is required to be monitored by the consent, but was not identified by the Guidelines, and in our opinion should only be monitored as an operational requirement.

pH

The current consent only requires monitoring of the pH in the soils on an annual basis. However the Guidelines require the monitoring of pH in the groundwater as well. In our opinion, both soil & groundwater pH require monitoring.

Suspended Solids

Following the Guidelines did not identify the need for any monitoring of Suspended Solids. The current consent however requires the monitoring of TSS in the effluent on a quarterly basis, and the groundwater on an annual basis.

Carbon

The Guidelines suggest monitoring of BOD_5/COD in the groundwater because of the possibility of it being used for potable purposes, but does not identify the stream as requiring monitoring. The current consent on the other hand requires monitoring of the stream but not the groundwater. One area that the Guidelines did not identify, is the possible build up of carbon in the soils. The existing consent requires monitoring of Organic Carbon in the soil on an annual basis. We believe that both the effluent & soils require monitoring.

Floatables

Floatables (foam, scum, fats, oils & greases) should not reach or affect any of the receiving environments as the treatment process should capture all of them, and therefore floatables do not require monitoring. Some monitoring of the build up of floatables on the ponds is required on the operational side.

Nitrogen

Nitrogen in its various forms is one of the most important elements that requires monitoring on this site. Monitoring is required for all three receiving environments. Only Total N, TKN and Ammoniacal-N require monitoring, as the other N species can be derived from these monitoring results.

Phosphorus

The current consent only requires monitoring of Total P in the effluent on a quarterly basis and the soil on an annual basis, while the Guidelines suggest monitoring of both Total P & DRP on a quarterly basis. We believe all 3 receiving environments should be monitored and that soils should also be monitored for Olsen Phosphorus.

Pathogens

The consent requires the monitoring of faecal coliforms on a quarterly basis in the effluent, stream and groundwater. The Guidelines on the other hand require monitoring on a monthly basis. We believe that monitoring should take place on a quarterly basis to coincide with other monitoring frequency.

Metals

Because of the nature of the catchment, it is very unlikely that metals will be a problem, and this has been confirmed by both the Guidelines and the current consent. Some monitoring of the effluent should probably take place every 5 years or so to confirm that this is still the case.

Sampling Frequency

We suggest that sampling of effluent, groundwater and stream water be carried out quarterly, and soil samples be taken on an annual basis. Measurement of flow on the other hand needs to be recorded daily. Although the Guidelines suggest monthly monitoring of BOD_5 and Faecal coliforms, we recommend that this only be monitored quarterly to fit in with the other sampling.

Note that with all the above sampling, if a problem is detected then additional sampling should be undertaken if considered necessary to check the previous result.

CASE STUDY 3
GREEN ISLAND (DUNEDIN) EFFLUENT OUTFALL

Brian Turner (Dunedin City Council)

Editor's note

The following is a case study where the Wastewater Monitoring Guidelines were used to help develop a monitoring programme for the Green Island wastewater outfall. Note that this case study is the author's interpretation of the use of the Guidelines. Other interpretations are possible.

Description

The Green Island wastewater treatment plant is situated adjacent to the Kaikorai Estuary within the boundary of Dunedin City. The treatment plant services a catchment of some 11,000 population for full treatment and the Mosgiel catchment of 10,000 for disinfection only as well as a significant industrial load from Green Island and Mosgiel. The plant is fed by wastewater pumped into the Green Island plant through 4 separate pumping systems (all about 11kms. long) and a gravity sewerage system from Green Island and Burnside.

The catchment includes the Green Island and Concord domestic suburbs and the Burnside industrial area, Brighton and Waldronville domestic sewage from ribbon coastal development, waste from Mosgiel's Wingatui area and the suburbs of Fairfield and Abbotsford, DAF (dissolved air flotation) treated and disinfected industrial primary wastewater and secondary treated wastewater from the Mosgiel trickling filter plant. The Mosgiel treated wastewater is UV disinfected at the Green Island plant.

Once the wastewater has been treated and disinfected it normally gravitates (but can be pumped) some 3kms. to the offshore marine outfall at Waldronville. The outfall is 850m long.

The wastewater treatment plant consists of 1mm rotary screens, a high rate activated sludge plant (HRAS) with ultraviolet (UV) disinfection of the treated wastewater. The sludge process includes thermophilic/mesophilic anaerobic digesters whilst final dewatering is carried out using centrifuges. The sludge, at this stage, is disposed of into the adjacent Green Island landfill.

There is approximately 4 hours storage (a second balancing clarifier) within the plant and a further 12 hours emergency storage in a pond area to prevent any discharge to the Kaikorai Estuary.

Site odour control is achieved by full covering of the plant and venting through biofilters.

A diesel generator will produce sufficient power to operate the majority of the plant during a power outage. The plant operating control system is protected from power surges by lightning conductors and a UPS (uninterruptible power supply) of appropriate capacity.

All chemical and diesel storage and sludge processing areas are bunded or controlled to prevent such materials from entering the Kaikorai Estuary. The site stormwater flows through a large oil/solids separator prior to discharge to drain.

The site is fully sealed to assist with keeping the plant and site clean. The surrounding site buffer land is planted out in pine, eucalypts and native trees and shrubs.

The various plant flows are indicated on Table 5.5.

The HIAMP Evaluation

Step 1.1: Characterisation of the Treated Wastewater Discharge

Refer to the completed Table 5.5 attached.

Step 1.2: Characterisation of the Environment

Refer to the completed Table 6.2 attached.

Step 1.3: Community Values

The following community values were identified and considered:

- Cultural and Social Issues – a Working Party was set up consisting of Iwi, potential neighbours, industry, user groups e.g. Fishing Co-operative, Surf Lifesaving, special interest groups, government departments e.g. DOC, MoF, environmental health e.g. Public Health South and Dunedin Ratepayers.

- Aesthetic Issues – improve the appearance of plant by extensive tree planting, low profile buildings, building colours to blend into the landscape.

- Odour Issues – undertake extensive odour control works, reply immediately to odour complaints and rectify.

- Food Gathering /Spiritual well being of Water Issues – address by involving Iwi in the process right from the beginning.

- Property Value Issues – work with neighbours with respect to odour issues and plant visibility. Plant screening belts early if possible.

- Perceived Health Risk Issues – fully explain treatment processes to the various Health Authorities and Health Professionals.

Step 1.4: Hazard Identification

Items identified in Table 6.2 were transferred to Worksheets A and B.

Step 2: Risk Analysis

The risk analysis steps 2.1 to 2.5 were carried out using Worksheets A and B.

Step 3: Monitoring Programme

A table has been prepared from the resource designations on Worksheets A and B and the suggested monitoring frequencies in Table 10.4. Some comments have been made on the recommended monitoring requirements including a fairly extensive effects-based ecological monitoring programme.

Discussion on Monitoring Decisions

The Green Island High Rate Activated Sludge plant ‘in-season’ is very much an industrial plant with minimal dilution from domestic sources. The ‘Monitoring Requirements’ table relates mostly to monitoring of discharges to the environment. Some of this monitoring is also used for process control. However there is as much monitoring carried out for process control as for the actual discharge monitoring. This is particularly so during the primary processing peak season. Monitoring industrial trade waste discharges is often carried out daily at this stage.

As the treated wastewater is discharged to an offshore marine environment the dilution is considerable. Certain parameters e.g. ammonia relate to the ZIFID (zone of inner field initial dilution – acute toxicity conditions), others relate to the ZID (chronic toxicity conditions) whilst micro-organisms relate to the far-field dilution. The dilutions relate to certain conditions e.g. flow, current speed and the probability of the occurrence – Green Island uses a 90%ile base case.

Environmental monitoring of the ‘ecosystem’ is also used extensively as a tool to ensure that on a long term sustainable basis the ‘ecosystem’ is not degenerating. The ‘ecosystem’ we monitor is some 60kms along the coastline and includes control sites at either end. The Green Island treated wastewater (secondary with disinfection) discharges into the monitored ‘ecosystem’ as does the larger Tahuna treated wastewater (primary).

A discussion of the parameters is given below:

Flow

Flow is measured daily for a number of operational reasons including trade waste charging, calculating plant performance, plant capacity and mass of contaminants into and out of the treatment system. Flow meters should be appropriately calibrated at least annually.

Temperature

Largely monitored for operational reasons. It has little impact on the marine environment from the HRAS plant.

pH

This is probably our most critical monitoring parameter with respect to plant operation. The level of pH is related to the plant operation and the quality of the incoming industrial effluent. The pH is monitored continuously with alarms at high and low set-points both on and off the site. If the pH falls outside the limits we can divert flow to a holding clarifier for later bleed back. If the pH is not within our operational limits the plant becomes unstable.

Suspended Solids

We can readily meet consent levels for SS. However we operate the plant to a UVT (ultra violet % transmission) of >8% to achieve the microbiological indicator consent levels required. The SS is a quick indicator of what the UVT could be.

Carbon

The BOD is not critical to an offshore marine discharge and hence is used for plant operations only and does give a good indication of how effective the HRAS process is at reducing BOD.

Floatables

This parameter is really included in the O&G and is not an issue of note with the HRAS process on the resultant discharge.

Ammonia

We currently exceed our consent. Any effect on the environment does not appear to be an issue although we clearly exceed USEPA acute toxicity guidelines. The level of ammonia is industry sourced and is being reduced by industry using different process chemicals not including ammonia.

Pathogens

We monitor for indicator species at the plant discharge, close proximity beaches to the outfall (weekly in the swimming season and monthly outside this time) and bioaccumulation in shellfish along 60kms of the coastline. Enterovirus testing is also carried out on mussels on a 6monthly basis (this is not a consent condition at this stage). The Guidelines indicate monthly plant testing for indicator organisms. However the Consent requires weekly testing – in future the in-plant testing may match the weekly and monthly beach testing.

Nutrients

Nitrogen and phosphorous are unlikely to be an issue with an offshore marine outfall in a high energy coastal area. We review the nutrient data annually and can ascertain that the nutrients are unlikely to affect any nuisance phytoplankton dynamics in the area. This is one area where we will seek to reduce the testing with the consenting authority.

Metals

Industry in the catchment is mostly primary industry. The metals are very low and could well be tested annually especially if we test 6 monthly for the bioaccumulation of metals in mussels. The metals in the mussels are also low.

Ecological Monitoring

The RMA is effects based. Thus extensive ecological monitoring is carried out as follows (as also indicated above in some sections):

- WET (Whole Effluent Toxicity) testing on 3 species carried out annually – this is not a consent requirement at this frequency.
- Faecal coliforms in mussels and the adjacent water column. Tested quarterly at some 13 sites over 60kms of coastline including control sites.
- Enteroviruses and metals in mussels are tested 6 monthly at sites adjacent to the marine outfalls (Green Island and Tahuna) as well as the two control sites.
- Mussels tested weekly over a 6 week period (January to March) at the closest mussel bed site to the Green Island outfall.
- Rocky shoreline ecological monitoring at the appropriate locations over the 60kms of coastline – this is carried out annually and compares the biodiversity and health of ecological communities at the control sites with the sites adjacent to the outfalls.

Sampling Frequency and Monitoring Parameters

By formalising 'Monitoring Requirements' a sound basis can be developed so that meaningful discussions can be undertaken with 'interested parties' and the consenting authority. Different answers can be arrived at but agreement will be more readily and understandably achieved by carrying out the HIAMP discipline.

Table 5.5: Discharge characterisation sheet.

Wastewater sources: Final treated wastewater: Industrial & Domestic Green Island; Secondary Treated Domestic with some Industry, Mosgiel; DAF treated primary industry Mosgiel.

Flow (best estimate): ADWF: 7,000m^3/day Green Island, Mosgiel 5,000m^3/day, Primary industry 1,000m^3/day = Total 13,000m^3/day PWWF: 22,000m^3/day

Constituent	Influent characteristics		Treatment plant process unit performance, normal operation (give rating of L, M or H of each unit for each constituent)				Known data on w/w effluent (Note 1)	Assessed characteristics of discharge (give rating of L, M or H) (Note 2)
	Known data on influent w/w (Note 1)	Influent characteristic rating (L, M or H)	Fine Screens (1mm)	HRAS High Rate Activated Sludge	Disinfection UV	Sludge Treatment		
Temperature	16°C	L	-	L	-	-	17°C	L
pH	7.8	M(4)	-	L	-	-	8.2	M
BOD, ~~COD~~	770	H	L	H	-	-	125	M
Suspended solids	590	H	L	M	-	-	74	M
Fats, oil & grease, floatables	180	M	M	H	-	-	11	M
Nutrients -nitrogen -phosphorus	-	H	L	L	-	-	TN 81 TP 6	H
Ammonia	Monitor Industry	H	L	L	-	-	78	H
Pathogens (indicators)	10^6	M	L	M	M	-	As enterococci 2.7E+03	M
Heavy metals	-	L	L	M	-	-	Pb – 0.02 Cu – 0.03 Zn – 0.06	L
Odour	Y-N	-	N	N	-	Y	-	Y-N

Note 3: Units g/m^3 unless otherwise stated.
Note 4: Process can be considerably affected by very low/high pH from industry. Trade Waste Consent range 5.8 to 8.5.
Note 5: Effluent data is reported as a median and over the seasonal peak (Jan to June). For the out of season period (July to Dec) BOD(38), SS (29), O&G (7), Ammonia (45), Enterococci (0.65E+03).

Table 6.2: Receiving environments, constituents of concern, and assimilative capacity. Shaded boxes = of concern.

Receiving Environment	Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens
Lake/Reservoir		-	-							
River/ Stream (>50% base flow)										
River/ Stream (<50% base flow)			-	-						
Estuary	-		-							
Harbours & Sheltered Embayments	-		-							
Nearshore Marine (shoreline)	-	-	-		-					
Offshore Marine	-	-	-	X	-	X	X	X	X	X
Groundwater	-			-						
Air	-	-	-	-		-	-	-	-	
Soils		-		-		-	-			

Assimilative Capacity/Sensitivity Of		Temperature	Oxygen/BOD	pH	Sedimentation/smothering (SS)	Odour/Tainting	Floatables/ scums	Colour / clarity (SS)	Nutrients/ enrichment	Toxic compounds	Pathogens	
Offshore marine environment					X		X	X	X	X	X	
Dilution	~~Poor~~											
	Moderate	-	-	-	X		X	X	X	X	X	At ZID
	~~Excellent~~	-	-	-	-	-	-	-	-		-	
Substrate (s)	~~Mud~~	-		-		-	-	-			-	
	Sand	-	-	-	X	-	-	-	X	X	-	
	~~Rock~~	-	-	-		-	-	-	-	-	-	
Enrichment status	Unenriched	-		-	X		-	-	X	-	-	
	~~Mod Enrichment~~	-		-			-	-		-	-	
	~~Enriched~~	-	-	-	-	-	-	-	-	-	-	
Sensitivity of Ecological Values	~~High~~					-	-	-			-	
	Moderate	-			X	-	-	-	X	X	-	
	~~Low~~	-	-	-	-	-	-	-	-		-	
Significant other Inputs	~~Yes~~											
	No	-	-	-	-	-	-	-	-	-	-	
Aesthetics	~~Important~~	-	-	-					-	-	-	
	Not so Important	-	-	-	-	-	-	-	-	-	-	
Contact Recreation	Yes	-	-	-	X		x	x	-	-	X	
	~~No~~	-	-	-	-	-	-	-	-	-	-	
Water Supply (Economic Utility)	~~Drinking~~	-	-		-							
	~~Irrigation~~	-	-		-		-				-	
	~~Industrial~~	-	-		-			-	-		-	
Food gathering	Yes	-	-	-	X	-	-	-	-	-	X	
	~~No~~	-	-	-	-	-	-	-	-	-	-	
Include in HIAMP	Yes				X		X	X	X	X	X	
	No	X	X	X		X						

Location: Green Island (Dunedin City Council) Offshore Marine Outfall: 850m long, 860mm ID. Dilution Zones, ZIFID 17:1, ZID 170:1, Farfield 1000:1

WORKSHEET A – Normal Conditions – Offshore Marine Discharge: Green Island															
Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1) – on the offshore marine receiving environment.	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General	Small domestic load compared to industry. Primary industry seasonal. Large inustrial loading October to June.													None
	~~Temperature~~	Not required in HIAMP[(2)] - process control.													2 – Process Monitoring
	~~pH~~	Not required in HIAMP - process control.													1 – Process & Industry Monitoring.
	SS/turbidity, colour	Discharge < consent, but the higher the SS (up to say 80g/m^3) the lower the UVT[(1)]. Aim for UVT >8%.			F	V			F	V	F	V			1 - Process Monitoring
	~~BOD, COD~~	Not required in HIAMP - process control.													None – Process Monitoring.
	Fats, oils and greases	Not normally an issue, control industry through Trade Waste By laws.			E	V			F	V	F	V			None – Process Monitoring.
	Ammonia	Upstream industrial processes using ammonium chloride for delimming. Breaking down of primary industry protein.			D	II	F	II	E	II	F	II			2 - Process & Industry Monitoring
	Nitrogen	TN mostly relates to ammonia.			F	II	F	II	F	II	F	II			3
	~~Phosphorus~~	Not required in HIAMP													None
	Pathogens	Operation of appropiate UV disinfection relates to UVT & SS.	E	V			E	V	F	V	F	V			None – Process Monitoring.
	Heavy metals	Low levels - mainly primary industry in catchments.			F	V									None
	POPs	Minimal levels in catchments.			F	V									None
	Sulphides	If upstream industrial processes fail high levels of S enter plant. The treatment plant acts as a filter so minimal effect on environment.			E	V									2 - Process Monitoring
	Odour	Not required in HIAMP – some limited monitoring.													None
Peak flows		Tends to dilute incomming wastewater.	F	V			E	V	F	V					None
Contaminant or Waste Slug		Waste slug will damage HRAS but process resilient. Process effected. Environment protected to a considerable degree. Atmospheric odour release as H_2S.											D	III	2 – Industry Monitoring
Odour generation from plant		Some odour if waste slug enters plant from industry that cannot be 'absorbed' by process.											E	III	3
Solids disposal		Can be some odour particularly following waste slug event.											D	III	2
Other sources of risk (list below)															

Note 1 : UVT – Ultra violet % transmission at 254nm relates to effectiveness of UV inactivation of micro- organisms.

Note 2 : Where a parameter is ‘not required in HIAMP’ – see table 6.2 & discharge to the environment.

WORKSHEET B – Abnormal Conditions and effect of gross uncertainty – Offshore Marine Discharge at Green Island															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1) – on the offshore marine receiving environment.	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3)												Appropriate Resources? Use Table F (Step 2.4)
			Human health		Ecology		Community Values		Economic Utility		Aesthetics		Odour		
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions		Process generally reliable and stable.													
	SS	Aeration tanks, loss of air, high SS resulting in low UVT, decreased disinfection and less inactivation of micro-organisms in the wastewater discharge.	E	V			E	V							3 –Maintenance MP2
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)	pH	High or low pH will inactivate aerobic/anaerobic process bacteria. This in turn leads to high SS & low UVT	E	II			E	II	F	II	F	II			3 – Industry Monitoring
	S	At lower level encourage filamentous bacerial growth(thiothrix), at higher levels will inactivate aerobic/anaerobic process bacteria.	E	II	F	II	E	II	F	II					3 – Industry Monitoring
Upset of plant related to extreme weather		Plant could 'washout' under high flow conditions but designed to partially save bio-mass.	F	V			E	V	F	V					None
Abnormal constituents in trade wastes	Ammonia	Use of ammonium chloride in industry. Changing to alternatives for deliming.			D	I									2 - Industry Monitoring
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?		No known sensitivity. The treated wastewater discharge is located in a high energy offshore marine area.													
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)		Process reasonably well understood.													
Contaminant composition uncertainty		Contaminants well known – the timing is not, due to industrial human, process and plant failure within industry.													
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)		Ecosystem reasonably well understood. The environmental monitoring is extensive. The bio-accumulation of indicator organisms & metals in mussels is used to determine the long term effects of the treated wastewaer discharge as well as contamination from non-point source contamination.													
Other causes of risk (list below)															

TABLE OF MONITORING REQUIREMENTS - Green Island: HRAS Activated Sludge :UV Disinifection : Thermophilic / Mesophilic Sludge Digestion.

Parameter	**Effluent**		
	Guidelines(2)	**Consent(3)**	**Comments**
Flow	Daily Volume	Daily	
Temperature	Daily	-	Process Control
pH	Daily	-	Process & Industry Control, continuous record.
UV % Transmission	Daily	Nil	Process Control
Total Suspended Solids (TSS)	Daily	Weekly	Process Control, continuous record.
Turbidity	-	-	
Volatile Suspended Solids (VSS)	-	-	
Colour	-	-	
BOD	Nil	Weekly	Process Control
COD	-	-	
TOC	-	-	
Foam & Scum	-	-	
Fats, oils and greases	Nil	Weekly	
Sulphide	Weekly	Weekly	
Total N	Quarterly	Monthly	
TKN	-	Monthly	
Ammoniacal-N	Weekly	Monthly	
NO_2	Nil	Monthly	
NO_3^-	Nil	Monthly	
Total P	Nil	Monthly	
DRP	Nil	Monthly	
Olsen P	-	-	
Enterococci	Monthly	Weekly	Consent considers ‘swimming season’.
Faecal coliforms		Weekly	
HEVs, Pathogens	Nil	-	
Metals (Cd, Cu, Ni, Pb, Zn)	Annually	Monthly	
Metals (Hg, As, Ag, Cr)	Annually	Monthly	
Hardness or Alkalinity/Conductivity*	-	-	
POP’s	Nil	-	
Ecological Monitoring	Quarterly	Quarterly	Mussel enterovirus & metal testing is carried out 6 monthly.

***Notes**:*

- The Guideline Monitoring parameters are determined from Table 10.4 & Worksheets A&B
- Monitoring as developed from the Guidelines.
- Monitoring as per existing consent.

ABBREVIATIONS

%ile	Percentile
AEE	Assessment of Effects on the Environment (as required under Part Four of the Resource Management Act 1991)
ANZECC	Australian and New Zealand Environment and Conservation Council
BOD	Biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
cBOD	**carbonaceous BOD**
COD	Chemical oxygen demand
DIN	Dissolved inorganic nitrogen (NH_4 + NO_2 + NO_3)
DO	Dissolved oxygen
DRP	Dissolved reactive phosphorus
DTA	Direct toxicity assessment
HIAMP	Hazard Identification, Analysis, and Monitoring Plan (refer to Chapter 4)
ISO	International Standards Authority
MfE	Ministry for the Environment
MoH	Ministry of Health
N	Nitrogen
NH_3	Free ammonia gas
NH_4-N	Ammoniacal nitrogen
NO_2-N	Nitrite nitrogen
NO_3-N	Nitrate nitrogen
NTU	Nephelometric turbidity units
NZCPS	New Zealand Coastal Policy Statement
NZWWA	New Zealand Water and Wastes Association
NZWERF	New Zealand Water Environment Research Foundation
P	Phosphorus
POP	Persistent organic pollutant
ppb	1 part per billion = 1 mg m^{-3} = 1 µg L^{-1}.
ppm	1 part per million = 1 g m^{-3} = 1 mg L^{-1}.
QA	Quality assurance
QC	Quality control
RMA	Resource Management Act 1991
SS	Suspended solids
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
TPH	Total petroleum hydrocarbons
USEPA	United States Environmental Protection Agency
UV	Ultra-violet (light)
VOC	Volatile aromatic compounds (e.g., benzene, toluene, xylene)
WETT	Whole effluent toxicity testing
WWTP	Wastewater treatment plant
ZID	Zone of initial dilution

GLOSSARY

Accuracy The extent to which a measurement approaches the true value of the measured quantity. See also precision.

Acute Occurring over a short period of time; used to describe brief exposures and effects that appear promptly after exposure.

Acute toxicity Rapid adverse effect (e.g., death) caused by a substance in a living organism. Can be used to define either the exposure or the response to an exposure (effect).

Aerobic A condition in which 'free' (atmospheric) or dissolved oxygen is present in the water.

Algae A large group of mainly aquatic one-celled or multi-celled plants, lacking true stems, roots and leaves.

Algal bloom Sudden, massive growths of microscopic and macroscopic plant life, such as green or blue-green algae, which develop in lakes and reservoirs.

Alkalinity The total measurable bases (OH, HCO_3, CO_3) in a volume of water; a measure of a material's capacity to neutralise acids; pH 7.0.

Ammonia Unionised ammonia gas (NH_3). Toxic to many aquatic animals. Also referred to as free ammonia. (This term should not be used to describe ammoniacal nitrogen – see below).

Ammoniacal nitrogen The sum of unionised ammonia gas (NH_3) and ionised ammonia (NH_4).

Ammonium Ionised ammonium (NH_4). Does not include ammonia gas (NH_3).

Anaerobic A condition in which 'free' (atmospheric) or dissolved oxygen is not present in water or sediment.

Aseptic technique Method of collecting samples for microbiological analysis free from unwanted microbial contamination

Assimilative capacity The capacity of a natural system to assimilate contaminants without adverse effects on biota.

Baseline monitoring Refers to a monitoring programme that sets a baseline measurement of environmental conditions, from which future measurements can be compared to assess changes.

Benthic Associated with the river bed, sea bed or lake bed

Bioaccumulation A process by which substances are ingested and retained by organisms, either from the environment directly or through the consumption of food containing the chemicals.

Bioavailable Elements or compounds that can be taken up in their present form by biota. For example, dissolved metals are generally bioavailable, while metals bound to particulates (e.g., sediment) are usually not bioavailable until they are dissociated from the particulate matter. There is a wide range of methods for measuring bioavailability of contaminants, and specialist advice should be sought.

Biochemical Oxygen demand An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed by biological processes breaking down organic waste. See also BOD_5.

Biomass The total weight of live organisms in a sampled population or community.

Biosolids Sewage sludge; semi-solid organic residuals remaining after domestic sewage treatment. Often (but not always) refers to sewage sludge that has had some degree of treatment, most often dewatering.

Biota All living organisms in a given area.

Blank Sample Quality control method used to determine if a sample is being contaminated at specific points in the sampling procedure

BOD_5 Five day biochemical oxygen demand. A common measure of the organic strength of a water sample. The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter, and hence an indication of the demand put on dissolved oxygen in a water sample.

Catch Sample See grab sample.

cBOD Oxygen demand resulting from decomposition of carbonaceous organic matter in a sample (excludes any effect from nitrification). Achieved by including a nitrification inhibitor in the test.

Chain of Custody Quality control method of tracing a sample from its time of collection through to final analysis and reporting of results.

Chemical oxygen demand A measure of the oxygen required to oxidise all compounds, both organic and inorganic, in water. Note that BOD is a subset of COD.

Chlorinated Pesticides A class of persistent, broad-spectrum insecticides that linger in the environment and accumulate in the food chain. Among them are DDT, aldrin, dieldrin, heptachlor, chlordane, lindane.

Chlorinated hydrocarbons A series of chemical groups consisting of organic compounds (i.e., compounds containing carbon) with one or more chlorine atoms bonded to them. Usually persistent and toxic in the environment. Includes chlorinated pesticides, PCBs and TCE, used as an industrial solvent.

Chronic toxicity The capacity of a substance to cause long-term health effects. (See 'acute toxicity'.)

Chronic Characterised by a time period that represents a substantial portion of the life span of an organism (e.g., chronic toxicity is the characteristic of a chemical to produce a toxic response when an organism is exposed over a long period of time).

Community values The mix of social, community and spiritual values held by a community.

Compliance Monitoring Monitoring that checks compliance with resource consent conditions (usually contaminant concentration or load limits).

Composite Sample A mixture of a number of grab samples taken over a period of time from the same location.

Compositing Physically mixing several samples into one larger sample, called a composite sample.

Denitrification The anaerobic biological reduction of nitrate to nitrogen gas.

Detection limit The level below which concentration measurements cannot be reliably determined.

Determinant Parameter being analysed.

Diffuser	Structure designed to enhance the dispersion of the effluent as it is discharged into the receiving environment.
Discharge monitoring	Monitoring of the effluent as it is discharged into the receiving environment.
Disinfection	Inactivation of micro-organisms by addition of a chemical (such as chlorine), boiling, or irradiation with ultra-violet light.
Dissolved oxygen	Oxygen gas that is freely available in water to sustain the lives of fish and other aquatic organisms.
Dissolved inorganic nitrogen	The sum of ammoniacal nitrogen, nitrate and nitrite. The portion of total nitrogen that is readily available as nutrients to aquatic plants.
Dissolved metal	Metals in a water sample that pass a 0.45 micron filter. Often used as a measure of the portion of total metals that are bioavailable (and hence toxic to biota).
Dissolved reactive phosphorus	Phosphorus in a water sample that passes a 0.45 micron filter. Used as a measure of the phosphorus that is readily available as nutrients to aquatic plants.
Diurnal	24-hour or daily cycle.
Domestic sewage	Sewage containing only household wastewater, i.e., no commercial or industrial wastewater.
Duplicate samples	Two samples taken from and representative of the same population and carried through all steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variance of the total method, including sampling and analysis.
E. coli	*Escherichia coli.* A subgroup of faecal coliforms that are used as indicator for the presence of pathogens in fresh water.
Effects monitoring	Monitoring that assesses the effects of an activity (in this case a wastewater discharge) on the receiving environment.
Enriched	Generally refers to an aquatic environment that has an abundance of nutrients. Often implies a eutrophic status.
Enterococci	A subgroup of faecal streptococci that are used as indicator for the presence of pathogens in marine waters and estuaries.
Enteroviruses	A sub-group of viruses that are derived from human sources (e.g. sewage effluent). Human enteroviruses are indicators of the presence of domestic sewage in water, but can vary markedly depending on the disease burden in the community.
Estuaries	Areas where fresh water meets and mixes with salt water. For example, mouths of rivers, salt marshes, and lagoons. Estuaries serve as nurseries, spawning and feeding grounds for a large group of marine life and provide shelter and food for birds and wildlife.
Eutrophic	Abundant in nutrients and having high rates of productivity, frequently resulting in algal blooms and oxygen depletion below the surface layer of a waterbody. In general, an undesirable state for natural water bodies.
Faecal coliforms	Thermo-tolerant bacteria from the coliform group found in the intestinal tracts of mammals (including humans). Used as indicator for the possible presence of pathogens in wastewater, receiving waters, and shellfish.

Far-field The area that is not in the close vicinity of the discharge being considered.

Flocculation The process by which suspended colloidal or very fine particles coalesce and agglomerate into well-defined flocs of sufficient size to settle rapidly.

Grab Sample A sample collected in one go at a particular point in space and time. Also known as a spot or catch sample.

Heavy metals High atomic weight metals, including copper, lead, zinc, chromium, cadmium, mercury. Toxic to biota at high concentrations.

Heterogeneous Being composed of diverse elements

Homogenous Having a uniform consistency

Indicator organisms A group of micro-organisms that are used to indicate the risk of pathogens occurring in a wastewater or receiving water sample. The most common examples are faecal coliforms, *E. coli*, and enterococci.

Influent Wastewater flowing into a treatment plant.

Inorganic nitrogen Non-organic nitrogen (i.e., NH_4-N, NO_3-N and NO_2-N).

Integrated Sample A mixture of a number of grab samples taken at the same time, but from different locations.

Macrophyte Aquatic plant, individually visible to the naked eye.

Mesotrophic Mildly nutrient enriched.

Mixing zone Zone in which mixing of the effluent discharge takes place in the receiving environment. An allowance for reasonable mixing is made in the RMA (1991) (S 69,70, Schedule 3) before water quality standards are required to be met. The extent of the mixing zone will vary on a case-by-case basis. Refer to Rutherford et al. (1994).

Non-compliance zone A zone around a discharge where water quality standards or guidelines are not likely to be met.

NTU A standard unit of turbidity measurement. Relates to the side-scatterance (usually 90°) of light by particles in the water.

Nutrient Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements such as potassium.

Oligotrophic Waters with a low supply of nutrients. Usually indicates high quality lakes and streams.

Organic nitrogen Nitrogen bound with organic compounds; generally not readily available to plants. Can be mineralised to NH_4-N.

Pathogens Disease-causing organisms. Include viruses, bacteria, protozoa and helminths (worms).

Percentile (%ile) The value of a variable that is not exceeded for a stated percentage of an assessment period.

Periphyton Plants, usually algae, which grow on stones, logs and other plants.

Persistent organic pollutants A general term for all organic compounds (referred to as POPs) that are resistant to degradation in the environment, and are potentially toxic to biota. Includes phenols, chlorinated hydrocarbons (DDT, PCP, PCBs), pesticides and herbicides (2,4,5 T; 2,4D).

pH	A measure of the acidity or alkalinity of a solution (defined as the negative logarithm, to base 10, of the hydrogen ion).
Phenols	A class of aromatic organic compounds contain one or more hydroxyl groups attached directly to a benzene ring. Toxic to aquatic biota.
Phytoplankton	Small, free-floating usually microscopic plants (such as algae), found in rivers lakes and the sea. They include diatoms, desmids, and dinoflagellates.
Precision	Precision refers to the degree to which repeated measurements are similar to one another. It measures the agreement (reproducibility) among individual measurements, obtained under prescribed similar conditions. To use an analogy, precise archers have all of their arrows land very close together. However, the arrows of a precise archer may or may not land on (or even near) the bull's-eye. See also accuracy.
Protozoa	Single-celled parasites that produce cysts that are able to survive outside their hosts under adverse environmental conditions. Examples are Giardia and Cryptosporidium.
Reasonable mixing	The term used in Sections 69, 70, 107 and Schedule 3 of the RMA (1991) to define the area beyond which a range of minimum standards must be met. The boundaries of the area of ‘reasonable mixing’ will vary on a case-by-case basis, and is not synonymous with the ‘mixing zone’. Refer to Rutherford et al. (1994).
Salinity	The degree of saltiness in seawater as measured by conductivity at a given temperature e.g. offshore seawater has a salinity of ~35.
Sewage	Wastewater that contains a component of human faeces and urine, as well as other household wastewater (e.g., from showers, sinks and washing machines). Often also contains a proportion of commercial and industrial wastewater (see trade wastes).
Sewer	A pipe or conduit that carries wastewater to a treatment plant or receiving waters. ‘Sanitary’ sewers carry household, industrial, and commercial waste. ‘Storm’ sewers carry runoff from rain.
Sewerage system	Network of pipes, pumps and channels conveying sewage.
Soluble	Fraction of material that passes though a filter (international convention uses a 0.45 micron membrane filter).
Split Sample	A sample that is divided into 2 or more portions after collection, with each portion being analysed separately either in the same laboratory or different laboratories.
Spot Sample	See grab sample.
Standard	For water quality, a limit that must be complied with under law.
Stormwater	Flow of water from urban surface areas after rainfall.
Stratification	Horizontal layering of a water body, caused by layers of water with differing densities (due to vertical changes in temperature and/or salinity).
Suspended solids	Solid particles suspended in water. Some of these particles may settle out in quiescent conditions, but a fraction of the (smaller) suspended solids will always remain in suspension.
Temporal	Varying over time.

TKN See total Kjeldahl nitrogen.

Total ammonia See ammoniacal nitrogen (the preferred term).

Total Kjeldahl nitrogen (TKN) An analytical method that provides a measure of the sum of all nitrogen forms except nitrate and nitrite (i.e., includes organic N and ammoniacal N).

Total metal The concentration of a metal in an unfiltered sample. Note that only a portion of the total metal is usually bioavailable (and hence toxic) to biota. Measurement typically involves sample digestion in a strong acid (usually nitric acid).

Total nitrogen The sum of all forms of nitrogen in a sample, i.e., organic N + ammoniacal N + nitrate N + nitrite N, expressed in mass of nitrogen.

Total phosphorus The sum of all forms of phosphorus in a sample, i.e., dissolved reactive phosphorus + particulate phosphorus, expressed in mass of phosphorus.

Toxic substance A material able to cause adverse effects in living organisms.

Toxicity The inherent potential or capacity of a material to cause adverse effects in living organisms.

Trade waste Definition in NZS 9201:1999 Model General Bylaws Part 23 - Trade Waste is: 'any liquid, with or without matter in suspension or solution, that is or may be discharged from a trade premises in the course of any trade or industrial process or operation, or in the course of any activity or operation of a like nature; but does not include condensing or cooling waters; storm water, or domestic sewage.'

Trend monitoring Monitoring designed to assess trends, or changes, in wastewater or the receiving environment over time. Refer also to baseline monitoring.

Trophic state or level In the context of receiving waters, refers to the nutrient status of the water body. Eutrophic, mesotrophic and oligotrophic are typical examples of trophic levels, ranging from nutrient-enriched (i.e., degraded water quality) to low nutrient (i.e., high water quality), respectively.

Turbidity A measure of water clarity - the cloudiness in a fluid caused by the presence of finely divided, suspended material. Usually measured using a turbidity meter. Turbidity is related (but not directly proportional) to the amount of suspended solids in the water.

Volatile Readily vaporisable at a relatively low temperature.

Wastewater Treatment Plant Facility where contaminants in water or wastewater are substantially removed.

Zone of initial Dilution Zone in which the initial dilution of the wastewater effluent discharge takes place. Should not be confused with the area in which 'reasonable mixing' occurs. The extent of the zone of initial dilution will vary on a case-by-case basis. Refer to Rutherford et al. (1994).

Zooplankton Microscopic animals in aquatic systems. Unlike phytoplankton, zooplankton cannot produce their own food, and so are consumers.

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APPENDIX 1: Calculating sample percentiles

A sample percentile, denoted as '*P*%ile', of a set of sample data is the value that is exceeded by (1–*P*)% of the sample values. For example, a sample median (which is a 50%ile), is the estimated value exceeded exactly as often as not. A sample 95%ile is the estimated value exceeded by 5% of the samples.

There is no one 'statistically-correct' way to calculate sample percentiles.

Three percentile calculators

To illustrate procedures, let's examine the simplest and most commonly used percentile, i.e., the median. For example, it is often quoted in the news media in respect of house prices. Half the data are above the median value and half are below it. Now consider the following small set of nine numbers: 8, 4, 12, 10, 34, 5, 47, 7, 9. The median of these data is in fact the last value in this list, i.e., 9. This is obtained by first sorting ('ranking') the data in ascending order (i.e., 4, 5, 7, 8, 9, 10, 12, 34, 47) and picking out the middle value, that is the fifth value '9' – there are four numbers below this value and four numbers above it. If there were an even number of numbers in this list, we would have to take the arithmetic average of the middle two number as the median. This average 'collapses' the list into an odd number of numbers, and so the middle value (the average of the middle two) will have the same number of values above it as lie below it.

In principle, this ordering concept is easily generalised to other percentiles. For example, an 80 percentile has 80% of data below its value, and therefore 20% above it. But this poses a problem as 20% of 9 samples is not a whole number. This difficulty is avoided by using a formula[2] to calculate a non-integer value of the rank of the percentile data and then interpolating between the adjacent ranked data. An example appears below, but first we will define three formulae for the percentile's rank (r).

Weibull: $r = p(n+1)$

Hazen: $r = ½ + pn$

Excel:[3] $r = 1 + p(n-1)$

wherein $p = P/100$ (so for an 80%ile $p = 0.8$) and n is the number of samples available.

In the simple example in the previous paragraph the Weibull equation happens to give an integer value for r, i.e., $r = 8$. Accordingly the 80%ile of the 9 samples, as calculated by the Weibull formula, is the 8th ranked value, i.e., '34'. But the Hazen formula gives $r = 7.7$. So we must interpolate between the 7th and 8th ranked data to get the 80%ile by the Hazen method, i.e., between '12' and '34'. Using linear

[2] Note: most software packages don't tell you how they calculate percentiles.
[3] This formula is not defined in Excel's Help files or manuals, but it may be simply adduced.

interpolation (as is usual) we get the 80%ile of the 9 samples, as calculated by the Hazen formula as 27.4. The Excel formula gives $r = 7.4$ and so the 80%ile of the 9 samples, as calculated by the Excel formula is 20.8. In summary, the three methods give an 80%ile of 34, 27.4 and 20.8 respectively.

This simple example shows that if the numbers surrounding the computed rank are very different (i.e., 12 and 34 in the above example), then the computed percentiles will be very different also. It also demonstrates the general result that the three formula span the range of results that may be obtained using other formulae,[4] with the Excel estimator always giving the lowest value.

Now note that a certain minimum number of samples ($n_{\min}$) is needed before these formulae can be used, which is important to realise when setting compliance periods and percentile limits. These minimum numbers for a percentile ratio p are:

Weibull: $$n_{\min} \geq \frac{p}{1-p} \text{ if } p \geq 0.5, \text{ otherwise } n_{\min} \geq \frac{1-p}{p}$$

Hazen: $$n_{\min} \geq \frac{1}{2(1-p)} \text{ if } p \geq 0.5, \text{ otherwise } n_{\min} \geq \frac{1}{2p}$$

Excel:[5] $$n_{\min} \geq 1 \text{ for all } p$$

In the case of the increasingly used 95%iles (p= 0.95) the Weibull formula requires 19 (not 20) samples to be at hand before a 95%ile can be calculated, whereas only 10 are required for the Hazen formula. Microsoft Excel® only ever requires one sample, and there is a conceptual difficulty with that property.

Formalising the interpolation

Put sample data $\{X_j\,; j = 1, n\}$ into ascending order. Call this dataset $\{Y_j\,; j = 1, n\}$. Using one of the equations given above calculate r, then break it down to its integer and decimal parts:

$$r = r_{\text{int}} + r_{\text{rem}}$$

Then the P^{th} percentile is calculated from the ascending-ordered data as

$$X_P = (1 - r_{\text{rem}})(Y_{r_{\text{int}}}) + r_{\text{rem}}(Y_{r_{\text{int}}+1})$$

As a further example, say that we want to calculate the 95%ile from a dataset X_j ($j = 1,\ldots, 50$). We therefore have $n = 50$ samples and $P = 95$, so that $p = 0.95$. Say the four largest sample values for suspended solids are 59, 63, 67 and 75 g m^{-3}.

From the ordering of the data we know that $Y_{47} = 59$, $Y_{48} = 63$, $Y_{49} = 67$, $Y_{50} = 75$. So to calculate the 95%ile from the Weibull formula we have $r = 0.95 \times 51 = 48.45$, so $r_{\text{int}} = 48$ and $r_{\text{rem}} = 0.45$. Then using the above equation we obtain $X_{95} = 0.55 \times 63 + 0.45 \times 67 = 64.8$.

To calculate the 95%ile from the Hazen formula we have $r = 0.5 + 0.95 \times 50 = 48.0$, so $r_{\text{int}} = 48$ and $r_{\text{rem}} = 0.0$. Then using we obtain $X_{95} = 1.0 \times 63 + 0.0 \times 67 = 63$.

[4] For example the Tukey and Blom estimators given in Ellis 1989.
[5] This formula is not defined in Excel's Help files or manuals, but it may be simply adduced.

Using the Excel estimator we have $r = 1 + 0.95 \times 49 = 47.55$, so $r_{int} = 47$ and $r_{rem} = 0.55$. Then we obtain $X_{95} = 0.45 \times 59 + 0.55 \times 63 = 61.2$.

APPENDIX 2: Monitoring parameters for discharge monitoring

(Refer to Chapter 10).

Table 10.A: Monitoring parameters - physico-chemical.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Temperature	Wastewater temperature, measured in degrees Celsius	Direct impacts on aquatic life which have a temperature tolerance range. Indirect impacts as high water temperatures reduce the amount of dissolved gases, increase rate of chemical reactions and increase growth rates, increasing the risk of algal blooms.	Yes	Yes
pH	pH is a measure of the waters acidity or alkalinity.	Aquatic life have a tolerance range for pH (usually pH 6 - 9). pH can have indirect impacts on aquatic life by affecting the speciation and toxicity of metals and ammonia.	Yes	No
Electrical Conductivity (EC)	EC is a measure of the ability of water to conduct an electrical current. It provides an indication of the amount of dissolved ions in the water.	Conductivity can be used to indicate ionic pollution but is not typically an environmental issue.	Yes	No
Colour	Colour can be described in reference to Munsell standards or by absorption of light at a particular wavelength.	Colour affects the aesthetics of a waterbody. Some colours can reduce light penetration.	Yes	Typically No
Clarity	Clarity is the limit of visibility in water.	Poor clarity reduces aesthetic values, light penetration and photosynthesis. Poor clarity can also affect the predator/prey activities of aquatic biota.	Yes	Yes

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Turbidity	Turbidity is the scattering of light by particles in the water.	High turbidity affects light penetration and can reduce photosynthesis for algae and macrophytes.	Yes	Yes
Suspended Solids	Suspended solids are particulate matter that can be removed by filtration with a 0.45 □m filter. It includes clay, silt, fine particles of organic and inorganic matter and microscopic and small organisms.	Suspended solids affect light penetration and aesthetics. There can be direct effects on aquatic biota. High suspended solids can lead to sedimentation in deposition areas.	Yes	Yes
Odour	Odour is any apparent odour, caused by the presence of volatile compounds in the air.	Odour has the potential to reduce the aesthetics of a water body.	Yes	Yes
Hardness	The hardness of water depends on the calcium and magnesium content. It is usually measured as carbonate hardness (as $CaCO_3$).	The hardness of a water body affects the toxicity of some metals.	Yes	No
Alkalinity	Alkalinity is capacity of a water body to neutralise acid and is generally reported as g m^{-3} of $CaCO_3$.	Alkalinity affects hardness and toxicity of some metals.	Yes	No

Table 10.B: Monitoring parameters - common ions.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Sodium	Sodium is a common cation and the major cation in seawater (from salt), found as Na^+.	Sodium is naturally high in sea water and in estuaries.	No	No
Potassium	Potassium is a common cation, which is readily soluble in water and found as K^+.	Potassium is an essential nutritional element for aquatic biota.	No	No
Magnesium	Magnesium is a common cation found as Mg^{2+} and is released into freshwater from the weathering of rocks.	Magnesium is a major source of water hardness.	Yes	No
Calcium	Calcium is present in all waters as Ca^{2+}. Calcium is readily dissolved from rocks such as limestone.	Calcium is an essential element for aquatic vertebrates and invertebrates. Calcium is a major source of water hardness and is present in both freshwater and seawater.	Yes	No
Fluoride	Fluoride is a common anion, present as F^-.		Yes	No
Chloride	Chloride is the dominant anion found in seawater and is present as Cl^- in both freshwater and seawater.	Chloride is high in sea water and in estuaries.	No	No
Sulphate	Sulphate is naturally present in surface waters as the anion SO_4^{2-}. Sulphate can be reduced under anaerobic conditions to hydrogen sulphide (H_2S, HS^-).	Hydrogen sulphide is the source of 'rotten egg' odours.	Yes	Yes
Carbonate and Bicarbonate	Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) influence the alkalinity of water.	Carbonate and bicarbonate can form complexes with metals, removing	Yes	No

them from the water column and lowering toxicity

Table 10.C: Monitoring parameters - nutrients.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Dissolved Reactive Phosphorus (DRP)	DRP is the soluble form of inorganic phosphorus found in water (as PO_4-P). It is sometimes known as soluble reactive phosphorus (SRP).	DRP is a plant nutrient. This form of phosphorus is the most bioavailable to plants and is found at low concentrations (<0.001 g/m^3) in pristine freshwater.	Yes	Yes
Total Phosphorus	Total phosphorus includes both DRP, organic phosphorus and phosphorus attached to suspended solids and in organic matter.	Total phosphorus is less bioavailable than DRP. TP can be stored in bottom sediment and act as a future source of nutrients.	Yes	Yes
Nitrate-nitrogen (NO_3-N)	The most common form of inorganic nitrogen in water. Nitrate-nitrogen is the most oxidised form of nitrogen.	A plant nutrient, essential for growth. Nitrate-N is also the most readily available form of nitrogen for plants	Yes	Yes
Nitrite-nitrogen (NO_2-N)	A form of inorganic nitrogen found under reducing conditions. Nitrite-N is rapidly oxidised to nitrate-N in the presence of oxygen.	Nitrite-N is not typically present at detectable concentrations in freshwater. Its presence can indicate an input of industrial or domestic wastewater effluent.	Yes	Yes
Ammoniacal-nitrogen (NH_3-N)	Ammoniacal-nitrogen includes both dissolved ammonia gas (NH_3), and soluble ammonium ions (NH_4^+). The two forms are in an equilibrium which depends on pH and temperature.	Ammoniacal-nitrogen occurs naturally in water bodies from the breakdown of nitrogen containing organic matter (from animals and plants), excretion of biota and reduction of nitrogen gas by micro-organisms. Ammonia	Yes	Yes

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
		gas is toxic at high concentrations (and at certain pH). Ammoniacal-N is oxidised to nitrite-N and nitrate-N.		
Total Kjeldahl Nitrogen (TKN)	TKN includes organic nitrogen, both dissolved and particulate, and ammoniacal-nitrogen.	TKN includes living forms of nitrogen such as algae, that may be in the water.	Yes	Yes
Organic nitrogen (total organic nitrogen)	Nitrogen in the form of protein or transformation products, both dissolved and particulate.	Organic nitrogen comes from plant and animal matter and their degradation products. Nitrogen within algae is also included in organic nitrogen measurements	Yes	Yes
Total Nitrogen	Total nitrogen includes all of the above forms of nitrogen, organic and inorganic, dissolved and particulate.	Some of these forms of nitrogen are not readily bioavailable as plant nutrients.	Yes	Yes

Table 10.D: Monitoring parameters - USEPA Priority Pollutants (trace elements).

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Antimony	Antimony has similar chemical properties to arsenic. It can be found as Sb(III) and Sb(V). Sb(V) dominates in the aquatic environment, particularly as SbO_4^-.	Antimony is acutely toxic to aquatic biota.	Yes	Yes
Arsenic	Arsenic can be found as As(0), As(III) and As(V). As(V) dominates in the aquatic environment, particularly as $H_2AsO_4^-$ and $HAsO_4^{2-}$.	Arsenic is acutely toxic to aquatic biota and can accumulate in plants..	Yes	Yes
Beryllium	Beryllium is an alkaline earth metal that is used in construction of missiles and satellites and has useful nuclear properties.	Beryllium is toxic, but is not commonly used in New Zealand.	No	No
Cadmium	Cadmium is a trace element found as an impurity in zinc and naturally occurring with zinc sulphides. It is found as Cd(0) or Cd(II), with Cd(II) dominating in aquatic systems.	Cadmium is toxic at high concentrations and can bioaccumulate in some aquatic organisms.	Yes	Yes
Chromium	Chromium has two forms in the aquatic environment: Cr(III) and Cr(VI). Cr(VI) dominates under oxidising conditions as CrO_4^{2-} and CrO_7^{2-} It is an important industrial chemical.	Cr(III) is toxic at high concentrations and can accumulate in sediments, particularly anaerobic sediments.	Yes	Yes
Copper	Copper exists mainly as Cu(II) in freshwaters, either as free ions, hydroxides, carbonates or associated with humic matter. Copper is a very common metal with a range of industrial uses.	Copper is an important trace element for aquatic organisms, but is toxic at high concentrations.	Yes	Yes

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Lead	Lead is found in two oxidation states, Pb(II) and Pb(IV). In natural waters ,Pb(II) dominates, mainly as organic complexes. Lead is a dense metal with a wide range of uses, commonly used in industry and for pipes.	Lead is toxic to aquatic organisms at high concentrations.	Yes	Yes
Mercury	Mercury has three oxidation states, Hg(0), Hg(I) and Hg(II). Mercury metal is liquid at room temperature.	All forms of mercury are highly toxic to aquatic organisms. An organic form (methyl mercury) is also bioaccumulative.	Yes	Yes
Nickel	Nickel is a hard metal used in alloys, electrical goods and nickel-cadmium batteries. Nickel is present as free Ni(II) and carbonate complexes in aquatic environments.	Nickel is an essential trace element for plants and animals but is toxic at high concentrations.	Yes	Yes
Selenium	Selenium is semi-metallic and its uses include paints, electronics and photoelectric cells.	Selenium is essential at trace concentrations for animals, but at high concentrations it is toxic.	No	No
Silver	Silver is a hard metal with decorative and industrial uses. Silver halides are used in photography.	Silver is acutely toxic to aquatic biota (hardness dependent).	Yes	Yes
Thallium	Thallium is a metallic element used in lead alloys, photocells and glass manufacture.	Thallium is not required as a nutrient for plants or animals.	No	No
Zinc	Zinc metal is commonly used for a wide range of industrial and domestic uses. Zinc is found as Zn(II) in aquatic environments, as free ions in	Zinc is an important trace element for aquatic plants and animals, but is toxic at high concentrations	Yes	Yes

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
	freshwater and as $ZnCl_2$ in seawater.	(hardness dependent).		

Notes : No – Elements that are not known to be present in significant concentrations or used by industry in New Zealand.

Table 10.E: Monitoring parameters - Other elements.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Aluminium	Aluminium is commonly found as Al(III) oxides and hydroxides and attached to solids in the aquatic environment.	Aluminium is an important trace element for aquatic organisms, but is toxic at high concentrations.	Yes	Yes
Boron	Boron is a non-metal which is present in geothermal waters and associated with coal deposits.	Boron concentrations are naturally high in seawater.	Yes	No
Iron	Iron is typically found as species of Fe(III), (ferric oxides and hydroxides) in the aquatic environment. The reduced form, Fe(II), is present in reducing conditions.	Iron is an important trace element for aquatic organisms. Very high concentrations of iron can cause the formation of iron floc (iron oxides and hydroxides) in streams.	Yes	No
Manganese	Manganese is a metal resembling iron and often used with iron. Permanganate (MnO_4^-) is sometimes used as a mild disinfectant.	Manganese is a vital element for aquatic organisms at trace concentrations.	Yes	No
Tin	Tin is a common metal used in solder alloys and corrosion-resistant coatings.	Tin is toxic to aquatic organisms at high concentrations.	Yes	Yes

Table 10.F: Monitoring parameters - Other Parameters.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Chlorine (FAC)	Free available chlorine (FAC) includes chlorine and hypochlorite from wastewater treatment.	Residual chlorine, if present in wastewaters, can be toxic to aquatic organisms.	Yes	Yes
Biochemical oxygen demand	BOD is the quantity of oxygen required by micro-organisms to stabilise decomposable organic matter under aerobic conditions. This is usually tested as the 5 day BOD (BOD_5).	Wastes with high oxygen demand can deplete the concentration of dissolved oxygen in a water body.	Yes	Yes
COD	Chemical oxygen demand is the amount of a chemical oxidant (potassium chromate) required to oxidise the organic carbon in a sample.	COD can be used as a substitute for BOD analysis for predicting depletion of dissolved oxygen in a water body.	Yes	Yes
Cyanide	Cyanide (CN^-) is used in the mining industry.	Cyanide is toxic to aquatic organisms.	Yes	Yes
Fats, Oil and Grease	Fats, oil and grease includes animal and vegetable oils and petroleum hydrocarbons.	Oil and grease can form surface layers across a waterbody, reducing aesthetics and affecting diffusion of gases into and out of the water.	Yes	Yes

Table 10.G: Monitoring parameters - Organic compounds.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
Surfactants	Surfactants include any soaps and detergents.	Surfactants can result in visible foaming which affects both aesthetics and aquatic biota.	Yes	Yes
Polycyclic aromatic hydrocarbons (PAHs)	PAHs are found as by-products of combustion, some petroleum products and industrial waste.	Some PAHs are carcinogenic and bioaccumulative in aquatic biota. PAHs also accumulate in sediment.	Yes	Yes
Polychlorinated biphenyls (PCBs)	PCBs are chlorinated compounds with low flammability. They were once used in electrical transformers and other industrial uses.	PCBs are highly bioaccumulative and can have adverse effects on aquatic biota.	Yes	Yes
Pesticides	Pesticides include herbicides and insecticides. This includes organochlorine, organophosphate and Organo-nitrogen pesticides.	Many pesticides are toxic to aquatic organisms. Organochlorine pesticides also bioaccumulate in aquatic biota.	Yes	Yes
Phthalates	Phthalates are plasticisers which can be found in industrial discharges and can slowly leach from plastic products.	Some phthalates can be toxic and bioaccumulative. There is some evidence that they may be endocrine disruptors.	Yes	Yes

Table 10.H: Monitoring parameters - Bacteria and pathogens.

Parameter	Description and uses	Environmental Relevance	Freshwater Receiving Environment	Coastal Receiving Environment
E. Coli	*E. Coli* is a strain of faecal bacteria, found in gastrointestinal tracts of mammals.	*E. Coli* is the indicator for fresh water used for contact recreation in the MfE (2002) microbiological guidelines.	Yes	No
Faecal Coliforms	Faecal coliforms are bacteria found in high numbers in human and animal faeces.	Faecal coliforms are the indicator for marine water used for shellfish gathering in the MfE (2002) microbiological guidelines.	No	Yes
Enterococci	Enterococci are a strain of faecal bacteria, found in gastrointestinal tracts of mammals.	Enterococci are the indicator for marine water used for contact recreation in the MfE (2002) microbiological guidelines.	No	Yes
Campylobacter	*Campylobacter* are pathogenic bacteria.	*Campylobacter* were found at more than half the sites in a recent, extensive study of recreational freshwater sites in NZ (Till et al. 2002).	Yes	Yes
Protozoa	Protozoa are single-cell animals and include *Giardia* and *Cryptosporidium*.	Some protozoa are pathogenic and can cause gastro-intestinal diseases	Yes	Yes
Viruses	Viruses are parasitic organisms containing DNA or RNA inside a protein coating.	Common waterborne viruses can cause hepatitis and gastroenteritis.	Yes	Yes

APPENDIX 3: Worksheets for Chapter 4 (use to document HIAMP process)

WORKSHEET A – Normal Conditions															
Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health and safety		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General														
	Temperature														
	pH														
	SS/turbidity, colour														
	BOD, COD														
	Fats, oils and greases														
	Ammonia														
	Nitrogen														
	Phosphorus														
	Pathogens														
	Heavy metals														
	POPs														
	Sulphides														
	Odour														
Peak flows															
Contaminant or Waste Slug															
Odour generation from plant															
Solids disposal															
Other sources of risk (list below)															

WORKSHEET B – Abnormal Conditions and effect of gross uncertainty															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health and safety		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate (see Table F)
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions															
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)															
Upset of plant related to extreme weather															
Abnormal constituents in trade wastes															
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?															
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)															
Contaminant composition uncertainty															
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)															
Other causes of risk (list below)															

APPENDIX 4: Example of use of Worksheets for Chapter 4

The following is an example using the HIAMP process. Refer also to example Worksheets A and B on following pages.

The example uses the following scenario:

- Plant serves small township of a population of approximately 5000
- Light industry including a plate shop is sited nearby. The associated trade waste is well controlled but some chemicals that could be spilt would be expected to cause problems.
- The plant uses established technology
- A small local community is sited near to the plant boundary
- The short outfall discharges into a local marine bay
- There is a small swimming beach on the bay and shellfish and other recreational fishing takes place some distance from the outfall.
- The bay exhibits moderately good flushing

The risk analysis (see worksheets on following pages) demonstrates that standard monitoring regimes are deemed appropriate except for pathogens and metals from local trade processes, where a detailed management plan and dedicated resources should be considered.

WORKSHEET A – Normal Conditions – EXAMPLE

Steps 1.1 to 1.4 Identify risks (hazards)		Step 2 Analyse normal risks													
Use Table A		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health and safety		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Characteristics of wastewater discharge	General	Some local concerns regarding waste discharge to the sea due to strong cultural identity with bay. Concerns may also affect possible use of bay for fish farming					C	I	D	I					2
	Temperature	No anticipated measurable adverse impact			F	I									3
	pH	No anticipated measurable adverse impact			F	I									3
	SS/turbidity, colour	Possible localised impact causing visible colour change									E	IV			3
	BOD, COD	Possible seasonal impact but likely to be minor			D	IV	D	IV							2
	Fats, oils and greases	No anticipated measurable adverse impact			F	I									3
	Ammonia														
	Nitrogen														
	Phosphorus														
	Pathogens	Swimming beach is not expected to be affected. However, shellfish collection takes place near to discharge. Some fishing takes place in bay.	B	III					D	III					1
	Heavy metals	Limited localised odour possible at discharge location			C	IV									2
	POPs														
	Sulphides														
	Odour	Limited localised odour possible at discharge location											E	II	3
Peak flows		Some scouring of mud channel expected during high rain events due to stormwater ingress to sewage system			E	IV									3
Contaminant or Waste Slug		Local plate shop flushes vats every few months – Not toxic to process but higher than normal metals levels expected at times. This could accumulate in shell fish	B	III	D	III	C	III	B	III					1
Odour generation from plant		Process known to cause odour if not operating at optimum condition											C	IV	2
Solids disposal		Solids will be trucked away via main road through local community to new landfill. Some uncertainty regarding ground water under landfill. Community expressed wish for composting. Some odour, seagulls and restricted use of surrounding land.			F	I	D	I	D	I	D	I	E	I	2

Other sources of risk (list below)		None identified													

WORKSHEET B – Abnormal Conditions – EXAMPLE															
Steps 1.1 to 1.4 Identify hazards		Step 2.5 Analyse abnormal risks (repeat steps 2.1 to 2.4 for abnormal risks)													
Use Table B		Describe nature of impacts or event (Step 2.1)	Assess impact level & likelihood for each impact type – use Tables D & E (Steps 2.2 & 2.3) Impact level: A = highly injurious, B = critical, C = major, D = moderate, E = slight, F = insignificant (see Tables D1 to D6) Frequency: I = continuous, II = frequent, III = seasonal, IV = occasional, V = possible (see Table E)												Appropriate Resources? Use Table F (Step 2.4)
			Human health and safety		Ecology		Community Values		Economic Utility		Aesthetics		Odour		1 = detailed management plan 2 = standard approaches 3 = incidental none = monitoring not appropriate
			level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	level	likeli-hood	
Constituents of concern for treatment plant fault conditions	SS	Faults in this type of process known to cause SS levels to rise. Raised levels for extended periods could lead to smothering of sediment dwelling animals, visual impacts, silting of channel.			C	IV	D	IV			E	IV			2
	Path	Faults in this type of process known to allow pathogens to pass through. Raised levels could reach swimming beach and shell fish beds	A	V			C	V	C	V					1
Constituents of concern for treatment plant upset condition (e.g., from toxic shocks)		Process known to be robust to toxic shock but possibility of process upset remains in very unusual circumstances. Extended process upset would result.			C	IV	C	IV	C	IV			C	IV	2
Upset of plant related to extreme weather	Odour	Extreme hot weather known to cause odour problems with this type of process					D	IV					C	IV	2
Abnormal constituents in trade wastes		Trade waste well understood but possible for other metals from local industry.			C or D	IV	C	IV	C	IV					2
Is there a characteristic of the environment that may result in particular sensitivity under specific unusual conditions?		None known													
Process uncertainty (is there a significant aspect of the process behaviour that is uncertain?)		Process well understood													
Contaminant composition uncertainty		Contaminant loads well understood													
Significant lack of knowledge of environmental behaviour (uncertainty regarding ecosystem dynamics etc)		Ecosystem reasonably well understood													
Other causes of risk (list below)		None identified													